Hood River Basin
Water Conservation Strategy

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1 Introduction

The Hood River Water Conservation Strategy stems from the collaboration and perseverance of a group of local partners called the Water Planning Group (WPG). This group includes local residents and representatives from Hood River County, the Hood River Watershed Group, the Confederated Tribes of the Warm Springs (CTWS), Farmers Irrigation District (FID), Middle Fork Irrigation District (MFID), East Fork Irrigation District (EFID), Oregon Water Resources Department (OWRD), Oregon Department of Fish & Wildlife (ODFW), Oregon Department of Environmental Quality (ODEQ), and the National Marine Fisheries Service (NMFS). The proposed strategies and actions in this document are based on findings from the Hood River Basin Study (Basin Study), a compilation of several assessments, technical reports, and models completed by Watershed Professionals Network (WPN 2013 a, b), the Bureau of Reclamation (2014 a, b, c & d, 2015), and Normandeau and Associates (2014). The Water Conservation Strategy is also based on the experience and ideas generated by WPG members. This document is intended to guide and inspire continued collaboration, innovation, and efforts to protect and manage water, the most limited and vital natural resource in the Basin.

1.1 Basin Study

In response to a changing climate and watershed conditions, Hood River County initiated the Hood River Basin Study to evaluate the future of its water supply. Funding and technical support for the study were provided by the Bureau of Reclamation (Reclamation) and OWRD. The study included assessments of current water use, water conservation potential, and prospective new storage sites (WPN 2013 a & b, Hood River County 2013). In addition, a fish habitat model was created to identify optimal streamflows for salmon and steelhead at different life stages and locations (Normandeau 2014). A groundwater model was built to evaluate the effects of potential increased groundwater use (Bureau of Reclamation 2014c). Finally, climate and surface water models were developed to predict future stream flows and habitat conditions under alternative water management scenarios (Bureau of Reclamation 2015). These assessments, models, and reports are outlined in **Figure 1**.

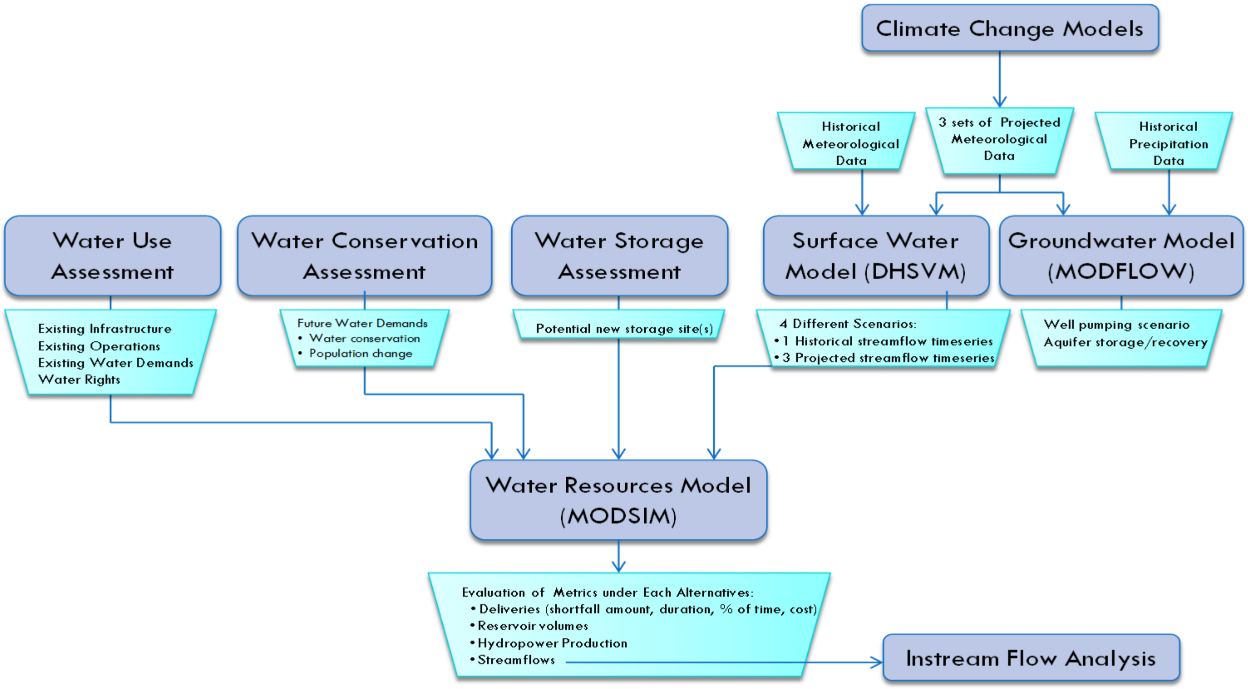

Figure 1. Schematic of components of the Hood River Basin Study.

2 Watershed & Community Context

There are three primary forks to the mainstem Hood River (**Figure 2**). The West Fork Hood River subbasin accounts for 30 percent of total Basin area, but due largely to the orographic effects of the Cascade Mountain range, contributes greater than 40 percent of natural flow through the mainstem Hood River. The Middle Fork and East Fork combine to form the East Fork Hood River drainage, which accounts for approximately 45 percent of the total basin area and natural flow through the mainstem Hood River. The headwaters of Middle Fork and East Fork drainages are fed in part by the glaciers along the north and east sides of Mount Hood. The mainstem Hood River, located downstream of the confluences of the three forks, makes up the remaining 25 percent of the basin.

There are two major reservoir systems in the basin. Laurance Lake is located on a tributary to the Middle Fork Hood River (Clear Branch), and Upper and Lower Kingsley reservoirs on Ditch Creek drain into the mainstem Hood River. The Kingsley Reservoir system is primarily fed by water diverted from tributaries to the West Fork Hood River. These reservoir systems primarily support agriculture and recreation. Laurance Lake also supplies water for three hydropower facilities operated by MFID. FID operates two hydropower plants near the mouth of the Hood River utilizing live flow.

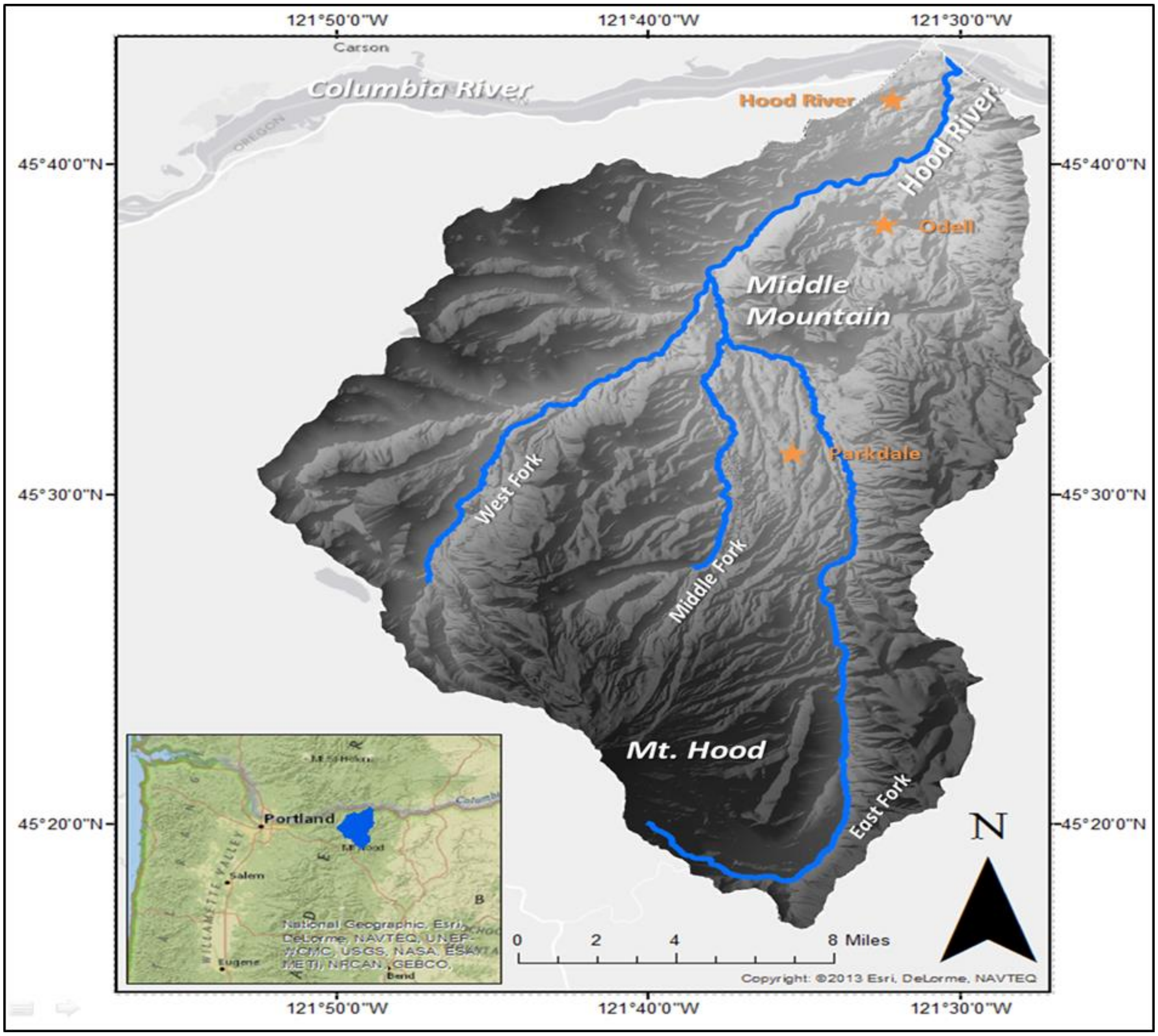

Figure 2. Shaded relief map of the Hood River basin study area

2.1 Fish Populations

The Hood River Watershed has one of the most diverse assemblages of anadromous and resident fish in the state of Oregon. This includes spring and fall Chinook salmon, summer and winter steelhead, coho, Pacific lamprey, bull trout, sea-run and resident cutthroat trout, and rainbow trout. All of the anadromous populations of salmon and steelhead, as well as bull trout, are listed as threatened under the federal Endangered Species Act. The high fish-species diversity in the Hood River Basin is due to the watershed's geography. It is within the transition zone between the west and east side of the Cascade Range, with the Columbia River as a conduit. Ecologically, this is reflected by the presence of both winter and summer steelhead, and fall and spring Chinook salmon. Its glacier-fed streams provide very cold water, which supports two populations of bull trout.

The Hood River is an essential basin within Oregon for recovery of the Lower Columbia Salmon and Steelhead ESU. This is due to the unique genetics and life history diversity of its populations. For example, the basin contains the only population of summer steelhead in the Lower Columbia ESU. With the exception of winter steelhead, the current extinction risks of salmon and steelhead populations within the Hood are very high (ODFW 2010). Tribal, state, and federal fisheries agencies estimate that recovery of Hood River winter steelhead and spring Chinook populations is likely with appropriate restoration and conservation actions. However, they have concerns about recovery of fall Chinook, summer steelhead, and coho.

Bull trout in the Hood River basin are thought to exist as two reproductively independent local populations (USFWS 2002, Rieman and McIntyre 1995). The "Clear Branch" population was isolated from the rest of the basin by the construction of Clear Branch Dam in 1968. Bull trout in this population inhabit Laurance Lake reservoir and two tributaries that flow into it. The "Hood River" population is distributed in the mainstem Hood River, Middle Fork Hood River, and a few Middle Fork tributaries. Fluvial migrants from the Hood River basin forage and winter in the Columbia River. The status of both local populations is tenuous (Starcevich & Jacobs 2010).

Pacific lamprey are re-colonizing the basin after the 2010 removal of Powerdale Dam, which was located at river mile 4 of the mainstem Hood River. CTWS has been documenting this re-colonization and have found adults and ammocoetes up to river mile 1 of the East Fork Hood River.[1] In addition to benefiting and expanding the range of this depleted species, lamprey will provide a valuable forage base to native fish.

Stream Flow has been identified as a primary limiting factor to the recovery of listed salmon and steelhead in the Basin. The primary threats to summer streamflow are withdrawals for agriculture and off-channel hydropower production, as well as predicted reduction in summer streamflow from climate change. In the winter, bankfull flows are important for cleaning silt from gravel beds, scouring out pools, and depositing new streambed material and wood. Winter withdrawals for hydropower production could interfere with these channel-maintaining processes.

2.2 Ceded Lands

The Hood River Watershed is part of the ceded lands of the Confederated Tribes of the Warm Springs Reservation. Tribal members harvest salmon and steelhead from the Hood River for subsistence and ceremonial purposes. Tribal fishing opportunity has become severely restricted because of low fish populations and the need to protect weak or threatened stocks. Hood River anadromous fish populations are co-managed by CTWS and ODFW.

2.3 Economy

The economy of Hood River County is heavily dependent upon irrigated agriculture, with one-third of personal incomes in the County coming from the fruit industry (Radtke *et al*. 2000). Approximately 80% of cropland is in tree fruit production, which generates high economic value

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[1] Andrew Wildbill, CTWS, personal communication

per acre. In 2012, gross agricultural commodity sales in Hood River County were $112,094,000[2]. The estimated value added as the crop moves through the first handler level is two times the gross sales, resulting in a total economic impact of $336 million in 2012 (Burt & Brewer 2007).

Another economic consideration relating to the watershed and restoration efforts is hydropower production. MFID and FID have hydropower projects within their irrigation delivery systems. This enables them to capture energy from their diverted irrigation water during the summer. They also have separate water rights to generate hydropower in the winter. Since construction of the power plants in the mid-1980s, they have generated nearly $90 million. This has helped fund extensive delivery system upgrades (e.g., over 100 miles of open canals and distribution lines converted to pressurized pipeline), on-farm irrigation efficiency upgrades, fish-screening projects, and removal of fish passage barriers within MFID and FID. The canal to pipeline conversion projects in these districts have saved approximately 25 cfs. A portion of this conserved water has been left instream and the remainder is returned downstream of the power plants (Perkins 2013).

The delivery system upgrades also enabled FID to eliminate 1,450 individual pumps, which has conserved 1.45 million kilowatt hours annually. At the same time, the FID and MFID plants together are generating roughly 47.5 million kilowatt hours annually, which is enough to power over 4,100 homes a year with 'zero carbon emission' energy (Perkins 2013).

Fish populations and the local economy are inextricably linked in the Hood River Basin. From an ecological standpoint, if instream flows are insufficient, Hood River salmon and steelhead will not recover to self-sustaining levels. From an economic standpoint, a certain amount of water is required to sustain existing agricultural and energy production. Furthermore, healthy fish runs benefit the local economy through sport fishing revenues and preventing costly conflicts over water allocations. Identifying and building local support for effective solutions that keep both fish and people on a productive trajectory is the essential goal of this Water Conservation Strategy.

3 Conservation Strategies

Figure 3 shows monthly average irrigation and potable water use, as well as stream flow on the Hood River at Tucker Bridge. The figure illustrates that, during the summer, irrigation water use is 10-20 times potable water use, and on average diverts one third of the total streamflow in the Hood River. Therefore, most of the conservation strategies in this document focus on agriculture. The six strategies listed in **Table 1** and discussed below provide the primary known opportunities for improving water availability for multiple needs in the future. Several other strategies, including modifying points of diversion, groundwater recharge, voluntary fallowing of annual crops, metering with tiered pricing, and changes to forest management may also be good options but need further investigation. These strategies are described and discussed in Sections 4 and 7.

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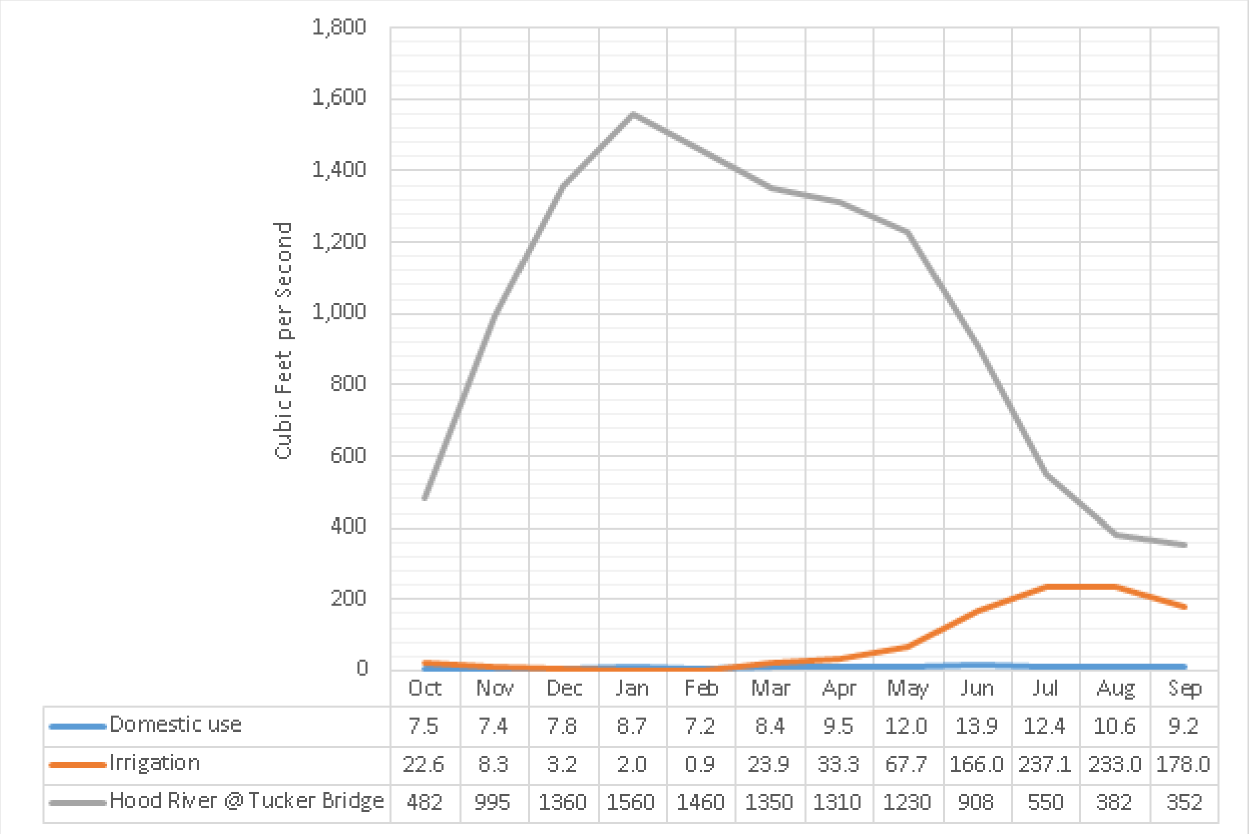
[2] http://oain.oregonstate.edu/



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Domestic use	7.5	7.4	7.8	8.7	7.2	8.4	9.5	12.0	13.9	12.4	10.6	9.2
Irrigation	22.6	8.3	3.2	2.0	0.9	23.9	33.3	67.7	166.0	237.1	233.0	178.0
Hood River @ Tucker Bridge	482	995	1360	1560	1460	1350	1310	1230	908	550	382	352

Figure 3. Mean monthly water use for irrigation and domestic uses, and mean monthly stream flow for the Hood River at Tucker Bridge.

Table 1. Primary opportunities for water conservation (summer months).

Actions	Total Potential Savings	Most Likely in next 20 yrs.
On-farm irrigation water management	32 cfs	26 cfs
Conveyance system upgrades	27 cfs	27 cfs
Expanded water storage in existing reservoirs	4 cfs	4 cfs
New storage site	22 cfs	
Hydropower rebalancing	13 cfs (varies)	13 cfs
Voluntary fallowing of annual crops/pastures	Up to 17 cfs	8 cfs
	115 cfs	**76 cfs**

3.1 On-farm Irrigation Water Management

Efficient on-farm irrigation water management (IWM) requires the use of *both* efficient irrigation equipment and irrigation scheduling. Efficient equipment allows an irrigator to apply water at an appropriate rate for their soils and slopes, while irrigation scheduling optimizes the total amount and frequency of irrigation based on actual crop need. If an irrigator uses efficient irrigation equipment, but increases the duration and/or frequency of irrigation (because they are not monitoring crop need), little to no water may be saved. Conversely, inefficient irrigation equipment may not be able to apply water at a low enough rate to make irrigation scheduling effective.

Older, traditional irrigation systems typically consist of hand or wheel lines with impact sprinklers that, on average, apply 2.4 – 3 feet/irrigation season (HRSWCD 2013, Irrinet 2007, Pers. comm. Craig DeHart, Jer Camarata, & John Buckley 2012). Depending on the crop, this can lead to the application of more water than is necessary and result in wasted labor, fertilizer, and water (via surface runoff or deep percolation). New, more efficient systems typically consist of fixed poly-tubing with micro or rotator sprinklers. Recent studies in the Hood River Basin found that, on average, orchards with micro-sprinklers applied 1.53 feet (19")/year (HRSWCD 2013, Irrinet 2007). Pear trees, which make up 62% of the Valley's agricultural land, typically need 1.6 feet of irrigation water in an average summer (**Figure 4**).[3] Thus they are well suited for irrigation with micro-sprinklers. Other crops, like alfalfa, have higher water demands (e.g., 2.25 ft./yr.) and require mobile irrigation equipment such as wheel lines. Although alfalfa and pasture can be converted from wheel line to more efficient center pivots, the economic return on alfalfa and pasture usually makes this conversion cost-prohibitive to a grower. Overall, alfalfa and pasture make up roughly 13% of the Valley's cropland.

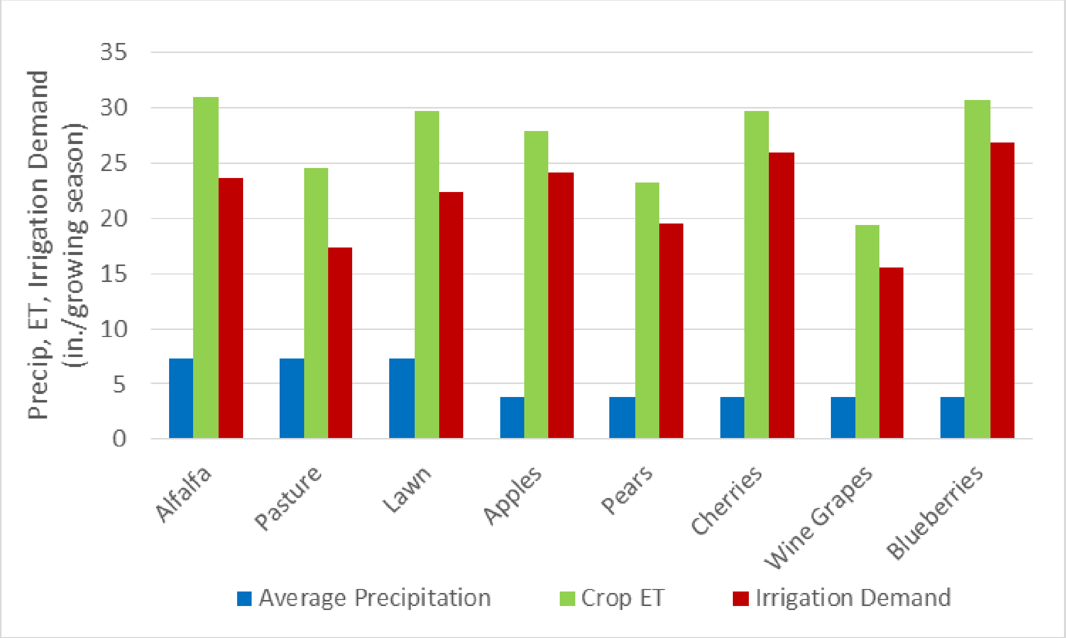


Figure 4. Irrigation demand for major crops in the Hood River Basin. Irrigation demand is derived from evapotranspiration (ET) less precipitation during the growing season.

Irrigation scheduling is based on site conditions, soil moisture data, and evapotranspiration estimates (i.e., crop demand). Soil moisture monitoring is done on site by either the farmer or a

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[3] www.usbr.gov/pn/agrimet/

contractor. Evapotranspiration estimates, which are derived from local weather data and crop-specific water needs, are available via the web.[4] Combining the information, either in a tracking sheet (i.e., check-book style) or on-line irrigation scheduler[5], allows growers to know how much and when they need to water to meet their crop's demand.

Costs to install soil moisture sensor networks varies based on size of the orchard block that is being contiguously managed. Estimates to install networks range from $2,500 to $5,000 per block. Orchard block size varies depending on crop, variety, and the configuration of the farm, but is generally between 2 to 50 acres. Based on these assumptions the cost to install soil moisture networks ranges from $50 to $2,500 per acre.

One potential way of reducing or sharing costs amongst growers would be to have the irrigation district maintain a network of soil moisture sensors and then disseminate that information for use. Growers could potentially subscribe to the service and pay an annual fee or it could be funded by outside sources. For the districts that have hydropower, it may be that the cost of the program would be offset by additional hydropower revenue.

Table 2 summarizes potential on-farm water reduction from sprinkler conversion and use of irrigation scheduling for each irrigation district (WPN 2013a). The average cost of upgrading from hand lines with impact sprinklers to polytubes with micro-sprinklers is $1,200 to $1,400 (Irrinet 2007).[6] The projected water savings and costs in **Table 2** assume that 100% of the remaining 11,192 acres of hand line/solid set systems are converted to rotator/micro systems. This would yield a total savings of 31.6 cfs. Average estimated monthly savings are shown in **Figure 5**.

Table 2. On-farm Water Savings from Sprinkler Conversion & Irrigation Scheduling by Irrigation District

	DID	EID	FID	MFID	MHID
Total Acreage (ac)	870	9,149	5,868	6,396	1,111
Acres Converted (ac)	370	5,408	731	4,294	389
Calculated Existing Use (ft/yr)	1.88	2.09	1.96	2.16	2.2
Calculated Projected Use (ft/yr)	1.51	1.58	1.86	1.58	1.9
Water Savings (%)	19.50%	24.40%	5.00%	26.80%	13.70%
Water Savings (ac-ft/yr)	318	4,675	572	3,689	334
Water Savings (cfs)	1	15.4	1.9	12.2	1.1
Cost ($)	$444,000	$6,489,600	$877,200	$5,152,800	$466,800

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[4] www.usbr.gov/pn/agrimet/or_charts.html

[5] http://weather.wsu.edu/is/

[6] Hood River Soil & Water Conservation District, unpublished data.

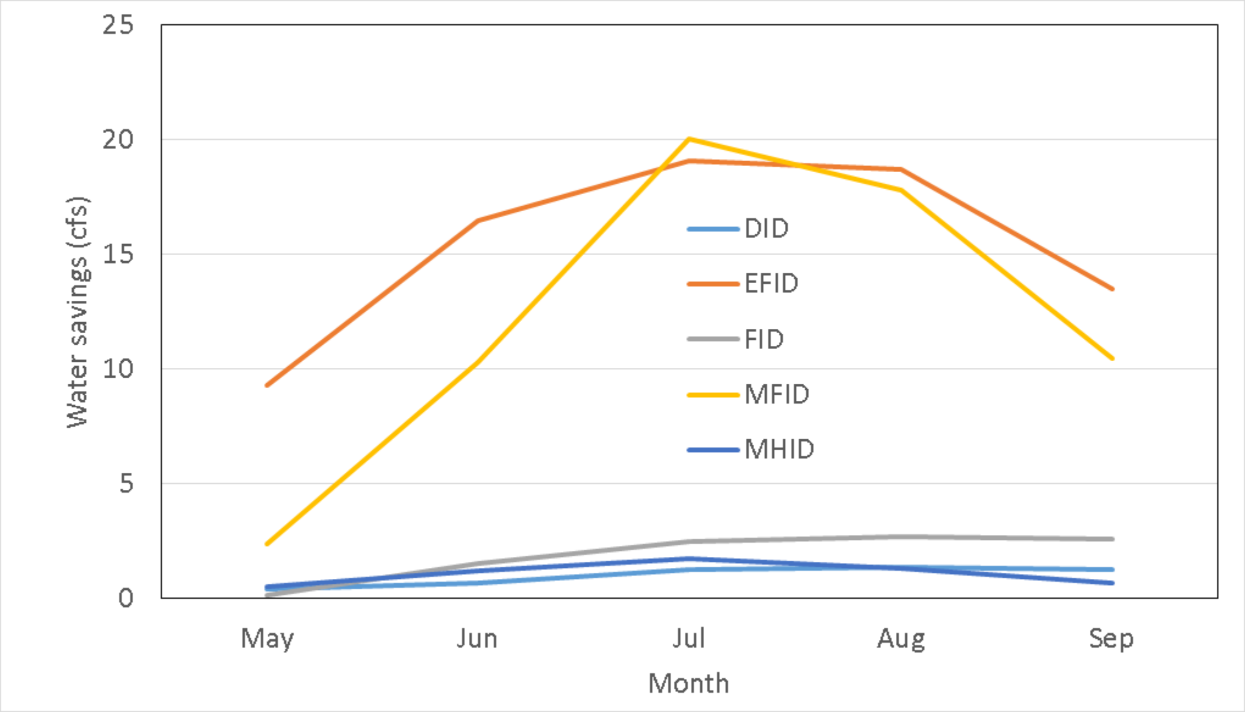


Figure 5. Monthly water savings by irrigation district. These values assume 100% conversion of hand line/solid set systems to rotator/micro systems and that water savings are proportional to monthly use yields.

3.2 Conveyance System Upgrades

Eliminating losses in irrigation water conveyance systems would reduce irrigation use by 27 cfs. The biggest losses occur through end-spills and canal seepage within EFID. Although eliminating all open conveyance (i.e., canals) is the ideal solution, operational changes could also be implemented that would have a smaller impact, but would come at a fraction of the price. Operational changes can include a wide range of activities, the most common being some form of a regulating reservoir (also known as “surge ponds”) or telemetry. Several options exist for improving conveyance, which are discussed in Section 4.

3.3 New / Expanded Storage

Increasing reservoir storage volume in the Basin would allow a portion of winter and spring runoff to be captured and released in the summer when natural streamflow is the lowest and water use is the greatest. The Hood River Water Conservation Assessment (WPN 2013a) determined that the most cost-effective (i.e., cost/acre-foot) new or expanded storage in the Basin is as follows:

- MFID: Expansion of Laurance Lake by a 3’ raise in dam height for an additional 370 acre-feet
- FID: Expansion of Upper Green Point Reservoir by 8’ raise in dam for an additional 561 acre-feet
- EFID (MHID): New site on West Fork Neal Creek for a possible 2,557 acre-feet of new storage.
- DID: No storage recommended due to small demand relative to live streamflow.

3.4 Voluntary Fallowing of Annual Crops/Pasture

The cost to install and establish fruit trees is $5,000 - $12,000/acre, and they can sustain long-term damage if they are not watered sufficiently each summer. This precludes fallowing these perennial crops during dry years. This not the case for annual crops like alfalfa and pasture, hence, one practical option for water savings during dry years would be to~~,~~ compensate willing landowners to fallow their hay fields. Hay and forage crops are served predominantly by wheel line, which use approximately 36" of irrigation water per year according to a recent SWCD study (HRSWCD 2013). Based on this water use, approximately 175 acres of alfalfa would need to be fallowed to realize a one cfs average increase in streamflow over the April – September growing period. This would represent 5.8% of the 3,000 acres in the Hood River basin that irrigation districts identified as "Hay and forage" (WPN 2013a). If funds were available and landowners were willing, up to 17 cfs could be saved if all hay and forage acres were fallowed during a dry year.

3.5 Modifying Points of Diversion (PODs)

Diverting streamflow close to the place of use allows water to stay in the stream as long as possible. Both FID and MFID do this through the use of multiple diversion points, however EFID diverts 100% of its demand from a single point located above the entire district. This diverts water out of the stream for longer than may be necessary and also causes a higher percentage of streamflow to be diverted than could otherwise be achieved. For example, during summer of 2015 EFID diverted approximately 85% of the streamflow at its diversion point (105 cfs diverted from live flow of 125 cfs). Developing a secondary diversion point further downstream could significantly improve streamflow below EFID's diversion. A range of options exist for modifying EFID's POD, two of which are further discussed in section 5.3 below.

3.6 Metering with Tiered Pricing

Charging customers based on the amount of water used, as opposed to a fixed cost, can lead to significant reductions in water use. Without additional study, it is not possible to quantify the water conservation that would be achieved under a use-based rate structure, but economic theory suggests that, if water were priced high enough, usage would be near actual crop demands. Undertaking the sprinkler conversion and soil moisture monitoring (discussed above) and using a 100 percent conversion rate, potential Basin-wide water reduction would be near 32 cfs. This value should be seen as the upper bound for on-farm conservation because it is unlikely that district customers would accept water rates that are high enough to discourage all unessential watering.

Implementing a use-based rate structure would require installing flow meters for each customer, replacing worn meters, and reading meters at least once per year. The cost of a flow meter is dependent on the diameter of pipe. At the time of this writing, a flow meter for ¾-inch pipe costs approximately $300; for a 2-inch pipe, the cost is approximately $1,000. Because of the high sediment load in the Hood River, it is likely that meters would need to be replaced roughly every 5 years. Installing meters would take approximately one hour per meter. Although meters could be read only at the end of each season, customers would probably feel more comfortable with meters also being read at the start of each season.

Estimated costs to implement a use-based rate program are based on: 1) an average cost of $450 per flow meter, 2) $50 to install each meter, 3) replacing one-fifth of the meters each year, and 4) $25 to read each meter (twice) each year. The costs shown in **Table 3** are specific to implementing a use-based rate structure. To achieve the water reduction values shown in Table 3, all acreage must also be using micro sprinklers with soil moisture sensors. The cost of upgrading any acreage not currently using micro sprinklers (11,354 acres, not including wheel lines) would cost an additional $13,430,000, based on $1,200 per acre.

Table 3. Capital cost, annual cost, and potential water reductions available through implementing use-based rate structure.

District	Accounts	Costs			Reduction in Water Use[4]	
		Capital[1]	Annual Meter Replacement[2]	Semi-Annual Meter Reading[3]	CFS	%
DID	65	$32,500	$6,500	$1,625	1.0	18.3
EFID	1,117	$558,500	$111,700	$27,925	15.5	24.4
FID	1851	$925,500	$185,100	$46,275	1.9	5.1
MFID	406	$203,000	$40,600	$10,150	12.2	26.8
MHID	167	$83,500	$16,700	$4,175	1.1	13.7
Total	3,606	$1,803,000	$360,600	$90,150	31.7	17.7 (avg)

[1] *Capital costs based on an average cost of $450 per meter and $50 to install.*

[2] *Annual meter replacement equal to cost of replacing 1/5 of all meters.*

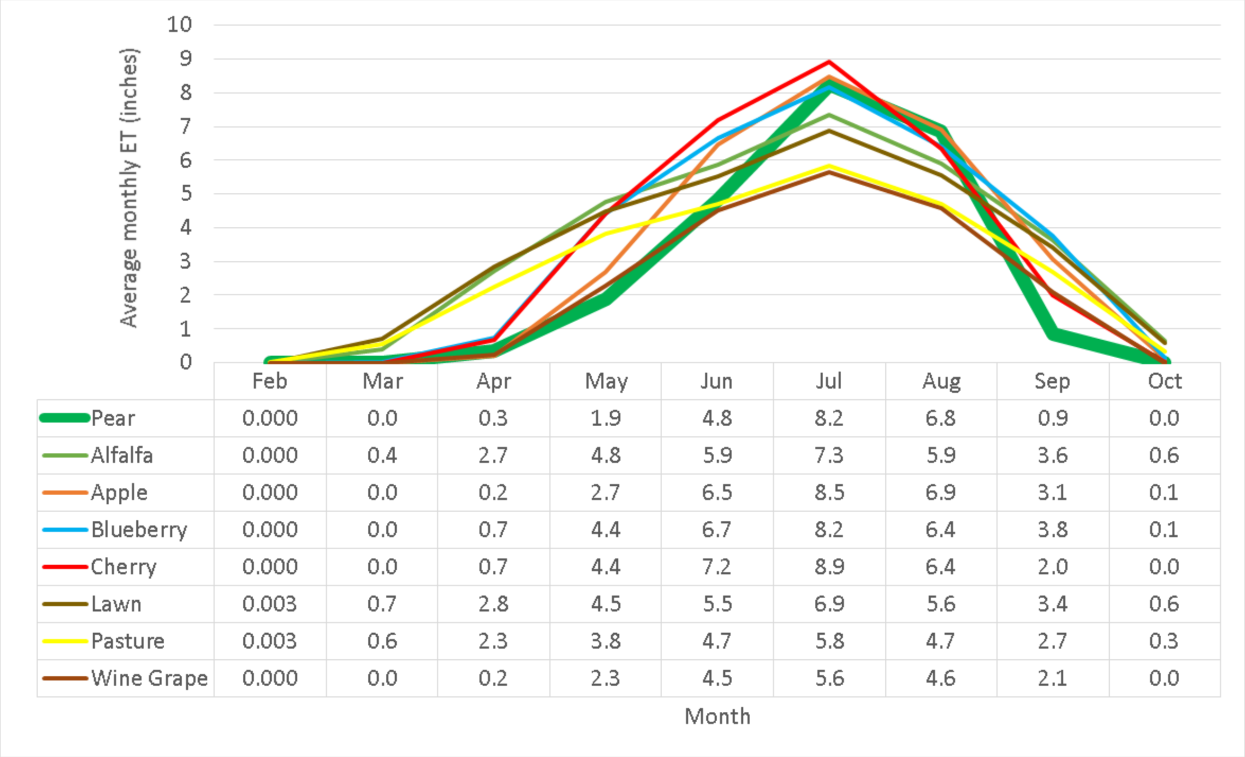
[3] *Semi-annual meter reading estimated at $25/meter.*

[4] *Water use reductions based on 100% conversion to upgraded sprinkler systems (Section 3.2)*

3.7 Change in Crop Types or Land Use

In theory converting crops that have a relatively high water demand to other types with lower demand might provide significant water savings (**Figure 6**). However, no choice is more central to farming economics than crop choice, and it is unlikely that any incentive based program to convert crops is likely to result in significant changes in crop type or water savings. Conversion from orchard to residential is also likely to have a relatively insignificant impact on water use. Although lawn has a lower peak ET demand, the growing season is longer and the total acre-feet used per acre is roughly equivalent.

Pears are the dominant crop in the Hood River basin. Recent trends have seen some replacement of pears with cherries, blueberries, and, to a limited extent, wine grapes. Encouraging further conversion to cherries or blueberries would not benefit water conservation, as these crops have generally as high or higher water use than pears (**Figure 6**). Conversion from pears to wine grapes is the most likely treatment that could yield a water savings. In addition, as the climate becomes warmer the Hood River basin may become a more desirable terroir for wine grape production.



	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Pear	0.000	0.0	0.3	1.9	4.8	8.2	6.8	0.9	0.0
Alfalfa	0.000	0.4	2.7	4.8	5.9	7.3	5.9	3.6	0.6
Apple	0.000	0.0	0.2	2.7	6.5	8.5	6.9	3.1	0.1
Blueberry	0.000	0.0	0.7	4.4	6.7	8.2	6.4	3.8	0.1
Cherry	0.000	0.0	0.7	4.4	7.2	8.9	6.4	2.0	0.0
Lawn	0.003	0.7	2.8	4.5	5.5	6.9	5.6	3.4	0.6
Pasture	0.003	0.6	2.3	3.8	4.7	5.8	4.7	2.7	0.3
Wine Grape	0.000	0.0	0.2	2.3	4.5	5.6	4.6	2.1	0.0

Figure 6. Average monthly ET demand by crop types found in the Hood River Basin

Pears require on average 19 inches of irrigation water over the April to September growing season. Wine grapes require 15.4 inches of irrigation water. Conversion from pears to wine grapes would provide 3.6 inches of water savings. Approximately 1,200 acres of pears would need to be converted to wine grapes to realize a one cfs average increase in streamflow over the April – September growing period. This would represent 8.4% of the entire 14,300 acres of pear production in the Hood River basin irrigation districts.

3.8 Hydropower Rebalancing

Hydropower water rights in the Basin are the same year-around even though streamflow is considerably higher in the winter than the summer. Rebalancing to produce more power in the winter and less in the summer would result in an increase in summer streamflow at no net cost. The goal of rebalancing would be to decease hydropower water use when low streamflows are limiting available habitat, and then offset any lost revenue by increasing production during periods of higher streamflow and less habitat sensitivity. Both the MFID and FID maintain hydropower plants. Hydropower water use ranges from 80 – 140 CFS on average, and peaks in winter and spring, with a reduction during irrigation.

3.9 Seasonal Leasing of Hydropower Water Rights

The potential exists for an entity (e.g., conservation organization) to lease water that is currently used for hydropower production in the summer. This would entail paying a hydropower producer (i.e., Famers Irrigation District or Middle Fork Irrigation Districts) to leave water instream as opposed to diverting it for hydropower production. Implementation of any program would require a detailed analysis of changes in turbine efficiencies and head loss. Nonetheless, the cost of a lease can be roughly approximated by what the revenue would have been if that water was used for production. In reality, it is likely that a small fee (e.g., 15% markup) would be added to any agreement to compensate the hydropower producer for increased operational costs. However, this fee in not included in the cost scenario presented for Farmers Irrigation District in Section 5.4.5.

3.10 Groundwater Recharge

Alluvial and basalt aquifers in the Hood River Valley are naturally recharged from percolation of snow melt, rain, and river and lake seepage. Aquifer recharge also occurs through engineered systems such as canals and ponds. In instances where the aquifer is hydraulically connected to a river or stream, a portion of recharged water returns to the rivers and streams as base flow, which provides cool water to streams and acts as an underground reservoir slowly releasing water to the stream.

Managed aquifer recharge (MAR) refers to recharging the aquifer system through enhanced surface infiltration. Under this method, water is ponded on the soil surface or applied through shallow perforated pipe and the infiltrated water percolates through permeable material on its path to the aquifer. Groundwater recharge may also be increased through restoration activities which act to decrease runoff or increase water inundated surface areas. Both of these methods have the potential to increase groundwater recharge for the purpose of increasing base flow during critical low surface water flow periods.

3.10.1 **Using existing infrastructure**

Surface recharge operations are composed of five basic components: (1) diversion of water from the source; (2) conveyance of water from the diversion to the infiltration location; (3) spreading of water and/or decreasing flow velocities; (4) infiltration and recharge of the underlying aquifer; and (5) maintenance of the recharge facility to maintain infiltration rates. Each component is further discussed below.

1. Water Diversion: Existing irrigation district diversions could be utilized.
2. Water Conveyance: Conveyance of water may occur through an open channel or enclosed line. Existing irrigation district conveyance systems could be used to move water to the infiltration location. In some instances, an extension from the main line would be needed to

move water to the target location, but the focus should be to locate recharge facilities as close to existing infrastructure as possible.

3. Water Spreading: Water spreading follows typical flood irrigation methods. The constructed recharge basin is graded to promote surface spreading over the entirety of the basin. Alternatively, existing canals or channels can be utilized and optimized by increasing residence time in the canal/channel (e.g. construction of L-berms).
4. Infiltration and Recharge: Recharge facilities, if built and sited correctly, require little attention during recharge operations. However, infiltration rates should be monitored to determine when site maintenance is required to maintain target recharge rates.
5. Maintenance: Over time, deposition and accumulation of suspended solids on the surface of the spreading basin results in clogging of the infiltration surface and decreased infiltration rates. The formation of biofilms on the soil surface also contributes to clogging. Regular drying of the recharge basin to promote cracking of the clogging layer or physical removal of the clogging layer will likely be necessary. The reoccurrence period of maintenance to maintain infiltration rates will ultimately be determined by the performance of the basin.

Within the Hood River Valley, existing irrigation district water conveyance infrastructure provides opportunity to perform MAR in locations that are hydrologically optimum for increasing base flows during typical low surface water flow periods (e.g. June through September). MAR would be performed during the winter and spring when surface water is available for diversion. Examples of potential MAR opportunities during the winter and spring months include:

1. Running water through unlined canals to utilize seepage through the canals.
2. Designing sediment settling ponds to also function as recharge basins during non-irrigation season.
3. Constructing recharge basins near existing canal networks that can be used to divert water to the recharge basin.
4. Constructing subsurface infiltration galleries (i.e. buried perforated pipe) to recharge water in locations where available surface area is insufficient.

Because surface recharge relies on the downward percolation of water to recharge the aquifer, the target aquifer cannot be overlaid by impermeable strata that restricts water flow below the location of infiltration. An assessment of near surface geology (McClaughry et al. 2012) consisting of permeable sediment and volcaniclastic rocks and overlying hydrologic soil group for the Hood River Valley is presented in **Figure 7**. Near surface geology amenable to surface recharge exist in areas serviced by MFID, FID, and EFID, and existing irrigation district infrastructure could potentially be used for MAR.

Within the sediment and volcanoclastic rock areas, surface soil permeability was estimated based on United States Department of Agriculture Soil Survey[7]. **Table 4** summarizes the range in permeability for each hydrologic soil group and the approximate surface area needed to recharge 1,000 acre-feet over a seven month period, which is the length of time that sufficient water (i.e., 50% exceedance stream flow) is present in the Hood River for diversion and aquifer recharge[8]. Recharge areas range from less than 1.6 acres for high permeability soils to greater than 39 acres for low permeability soils. In order to increase site permeability and decrease required recharge area it is possible to excavate the permeability limiting soil layer if the soil layer is not too deep or too thick.

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[7] http://websoilsurvey.nrcs.usda.gov/app/help/citation.htm

[8] available at http://apps.wrd.state.or.us/apps/wars/wars_display_wa_tables/search_for_WAB.aspx

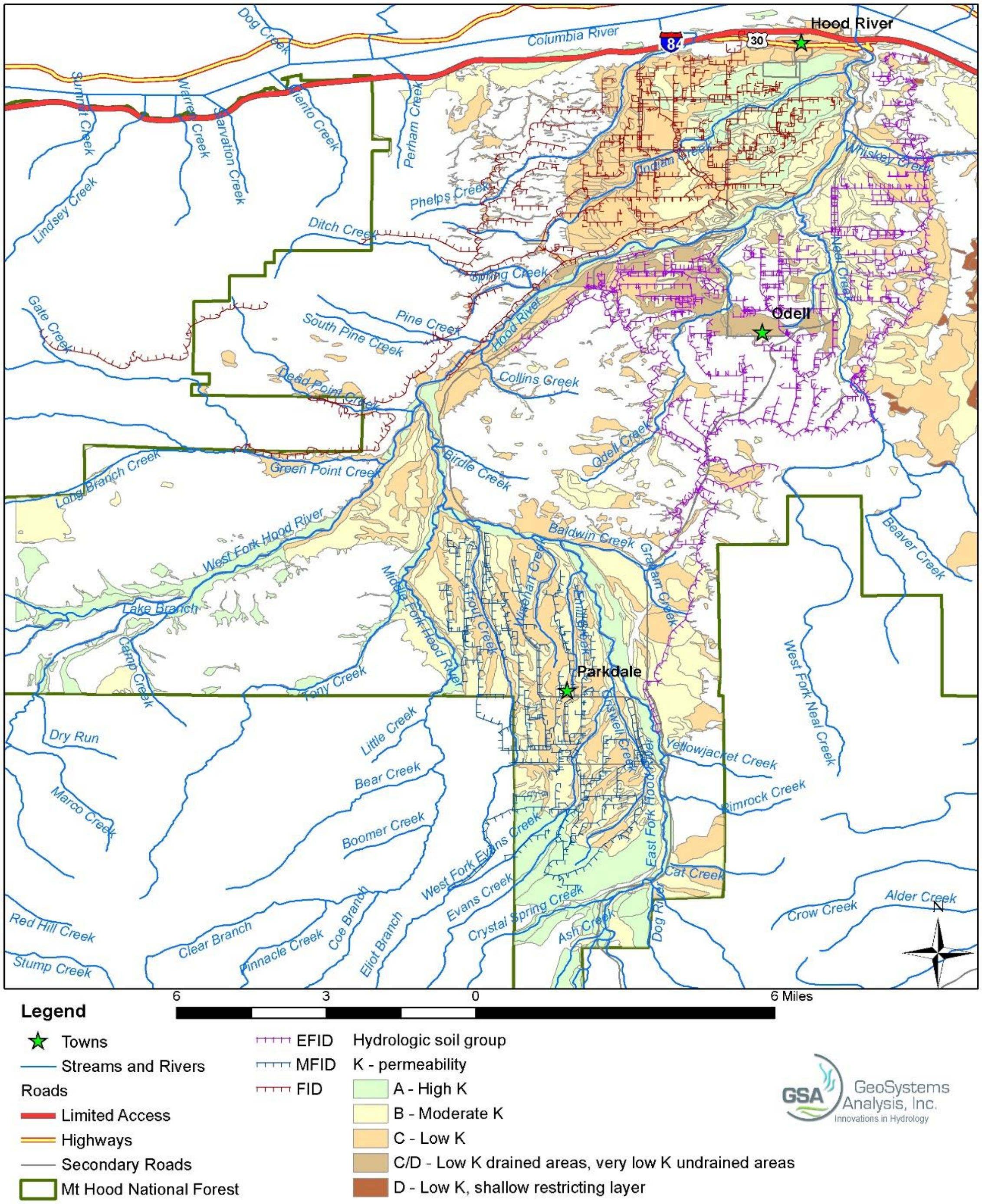

Figure 7. Hood River Valley hydrologic soil groups in sediments and volcanoclastic surface geologic units.

Table 4. Soil permeability range and estimated area to recharge 1,000 acre-feet over a seven month period

Hydrologic Soil Group	Permeability Description	Permeability Range (inches/hr)	Recharge Basin Area (acre)[9]
A	High	>1.42	<1.6
B	Moderate	0.57 to 1.42	1.6 to 4.1
C	Slow	0.06 to 0.57	4.1 to 39
C/D	Very Slow under-drained areas	<0.06	>39
D	Very Slow	<0.06	>39

Assuming that all recharged water returns to streams (i.e. no water loss to soil or aquifer storage) and return flow is at a steady-state over the entire year would yield a contribution to stream flow of 1.38 cfs per 1,000 acre feet of recharge. Assuming that the upper end of the range of acres are needed for 1,000 acre-feet of recharge (**Table 5,** column 2) yields the number of acres needed per cfs of discharge to a stream (Table 5, column 3,). Column 4 of Table 5 gives the total number of acres available in the lower basin by hydrologic soil group that are within sedimentary or volcaniclastic geologic types. However, given the constraints of terrain, proximity to existing infrastructure, existing land uses, and regulation, it is likely that only a small part of the total acreage would be available. For the purposes of this exercise we assume that only 1% of the total area is available (column 5, Table 5). Column 6 of Table 5 gives the potential steady-state return flow to the stream system given the preceding assumptions. It is important to note that during the seven month recharge period surface water diversions would be in excess of return flow.

Table 5. Summary of available area within the Hood River Basin and potential groundwater yield.

Hydrologic Soil Group	Acres needed for 1,000 ac-ft recharge	Acres needed per cfs discharge	Acres in lower basin	1% of total acres	Potential ground-water yield (cfs)
A	1.6	1.16	6,264	62.6	54.1
B	4.1	2.97	15,831	158.3	53.3
C	39	28.23	16,451	164.5	5.8
C/D	39	28.23	1,484	14.8	0.5
D	39	28.23	363	3.6	0.1
			Totals	**403.9**	**113.9**

The cost to implement a MAR approach would be highly variable and difficult to estimate at this preliminary stage as they are highly dependent on location. Primary capital costs would include property, excavation, diversion, and canal/piping to the basin. As an example, a recent cost estimate for a 2.5 acre facility in Wasco County was over $200,000, which included 7 feet of excavation and a pumped diversion from a nearby tributary. This did not include a hydrogeologic assessment. Operation and maintenance was estimated to be $16k/year, which included electrical costs and labor to monitor the system and the maintain grounds.

The environmental benefits of a project like this would occur downstream of the project location, which, given the location of potential sites would likely be downstream of the EFID diversion. Given

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[9] Assumes 1,000 acre-ft of recharge over a seven month period

the uncertainty of the project location or size it is not possible to evaluate the environmental benefits at the IFIM locations.

3.10.2 **Basin-Scale Restoration**

Restoration of lands can act to increase groundwater recharge in two primary ways, 1) decreased runoff resulting in greater water infiltration, and 2) reconnecting streams with off-channel habitat and floodplains.

It is difficult to estimate the magnitude of increased recharge by restoration activities since restoration often creates increased infiltration conditions dispersed over a large, often heterogeneous area. For example, Wyatt (2013) reported that thinning treatment on 37 conifer-dominated watersheds showed an increase in groundwater table height that was attributed to more groundwater recharge; however, there was no correlation between percent of area treated and the amount of groundwater recharge increase. Most recharge benefit can be achieved by reestablishing floodplain connectivity, which creates naturally occurring focused recharge areas. As a means to quantify the potential changes to recharge due to restoration activities, particularly in upland areas, water balance models that account for changes in evapotranspiration and runoff can be employed.

3.11 Forest Management and Water Supply

Eighty percent of the Hood River basin is forested, and most of the precipitation that falls within the basin falls on forested areas. A portion of the precipitation (either as rain or snow) falling on forests may be retained by the canopy and return to the atmosphere, the remainder eventually reaching the ground surface where it may travel overland or enter into the soil profile. A portion of the water entering the soil profile will be stored, a portion will return to the atmosphere by evapotranspiration of the forest, and the remainder will migrate to streams and other waterbodies as shallow groundwater flow (interflow) or will recharge deeper groundwater aquifers.

Intuitively the type, density and structure of the forest would be expected to influence the quantity of water that is lost to evapotranspiration, and replacing forest types with a high interception and evapotranspiration demand with forests having a relatively lower demand would be expected to yield more water to the basins streams and aquifers. Although this is theoretically true, the magnitude of any water yield increases associated with changing forest types is very small and is rapidly lost as vigorous younger forests regrow (NRC 2008). Paired watershed studies conducted in Oregon and other western states confirm the relatively small and short-lived increases in water yield associated with forest harvest (e.g., Harr 1983).

An additional mechanism by which forest management impacts water yield and water quality is through the road systems built and maintained to access and manage forest lands. Roads act as impervious surfaces, and water and sediment generated from road surfaces are quickly and efficiently transferred to either the outbound slope or to the roadside drainage network (NRC

2008). Road cut slopes can further capture shallow groundwater moving downslope thorough the soil profile. Systems with a high-degree of connectivity between the road drainage and stream networks may experience a much more rapid and efficient transfer of water and sediment to the stream system, resulting in earlier-season removal of waters from the system and degraded water quality. Position of the roads within the watershed may have an effect on the magnitude of road drainage impacts, with mid-slope roads possibly having the biggest impacts.

Presently we do not know the magnitude of hydrologic impacts from roads in the Hood River Basin. If it were determined that roads and road drainage were having a significant effect on basin hydrology there are several opportunities to reduce or eliminate these impacts. Application of best management practices to reduce the connectivity of the road drainage system with the stream system would likely reduce the impacts. Increasing the number of cross-drains, out sloping road surfaces, using water bars, particularly on limited access roads, and in some cases the elimination of the roads themselves would all help to reduce or eliminate road drainage impacts. Once the magnitude of the impacts is known then an evaluation of possible remediation can be developed.

4 Conservation Benefits by Irrigation District

The previous section outlined the primary water conservation strategies for the Hood River Basin. Most of these strategies are associated with irrigation and irrigation-related activities (e.g. conveyance, etc.). This section of the report provides more specifics on the applicable actions by irrigation district, and summarizes the aquatic habitat benefits that would be associated with implementing the strategies.

A major underlying assumption of these strategies and their estimated habitat benefits is that irrigation (i.e., crop) needs will be met, but irrigators will not be applying their full legal water right. Meeting crop needs means providing sufficient water to maximize net crop value. In addition, the habitat benefits calculated below assume that water saved will be left instream at the point of diversion, as opposed to being applied to new acres or used to generate additional hydropower in the summer.

4.1 Calculating Habitat Benefits

We estimated the habitat benefits of each strategy using results from two recent Instream Flow Incremental Methodology (IFIM) studies conducted in the basin. The Middle Fork IFIM (WPN 2013) was conducted in 2011 and 2012, and included five locations in the Middle Fork Hood River Subbasin.[10] Normandeau Associates (2014) conducted an IFIM study at five additional sites, including the West Fork Hood River, Greenpoint Creek, Neal Creek, and two sites on the East Fork Hood River (Error! Reference source not found.**8**). These IFIM studies developed relationships

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[10] IFIM sites were on Clear Branch (two sites; above and below Coe Branch), Coe Branch, Eliot Branch, and the mainstem Middle Fork near the mouth.

etween streamflow and habitat quantity. Habitat quantity was calculated as the Weighted Usable Area (WUA), which is a weighted index of the amount of habitat, for a particular species and life stage (i.e., spawning, juvenile rearing). Habitat-flow relationships were developed for salmonid species and life stages found at each IFIM location. For the purpose of this report, we are focusing on spawning and juvenile rearing habitat for spring chinook, coho, steelhead and bull trout. Bull trout WUA were only calculated for the Middle Fork and West Fork locations. Habitat in Clear Branch below the Laurance Lake dam is the most responsive to changes in stream flow, and was the only reach used in the MFID for this analysis. Species and life stage timing is given in

Table 6. It should be noted that changes to WUA presented in this section are based on current (i.e., baseline) stream flows. Presentation and discussion of potential future WUA values under climate change is covered in Section 6.

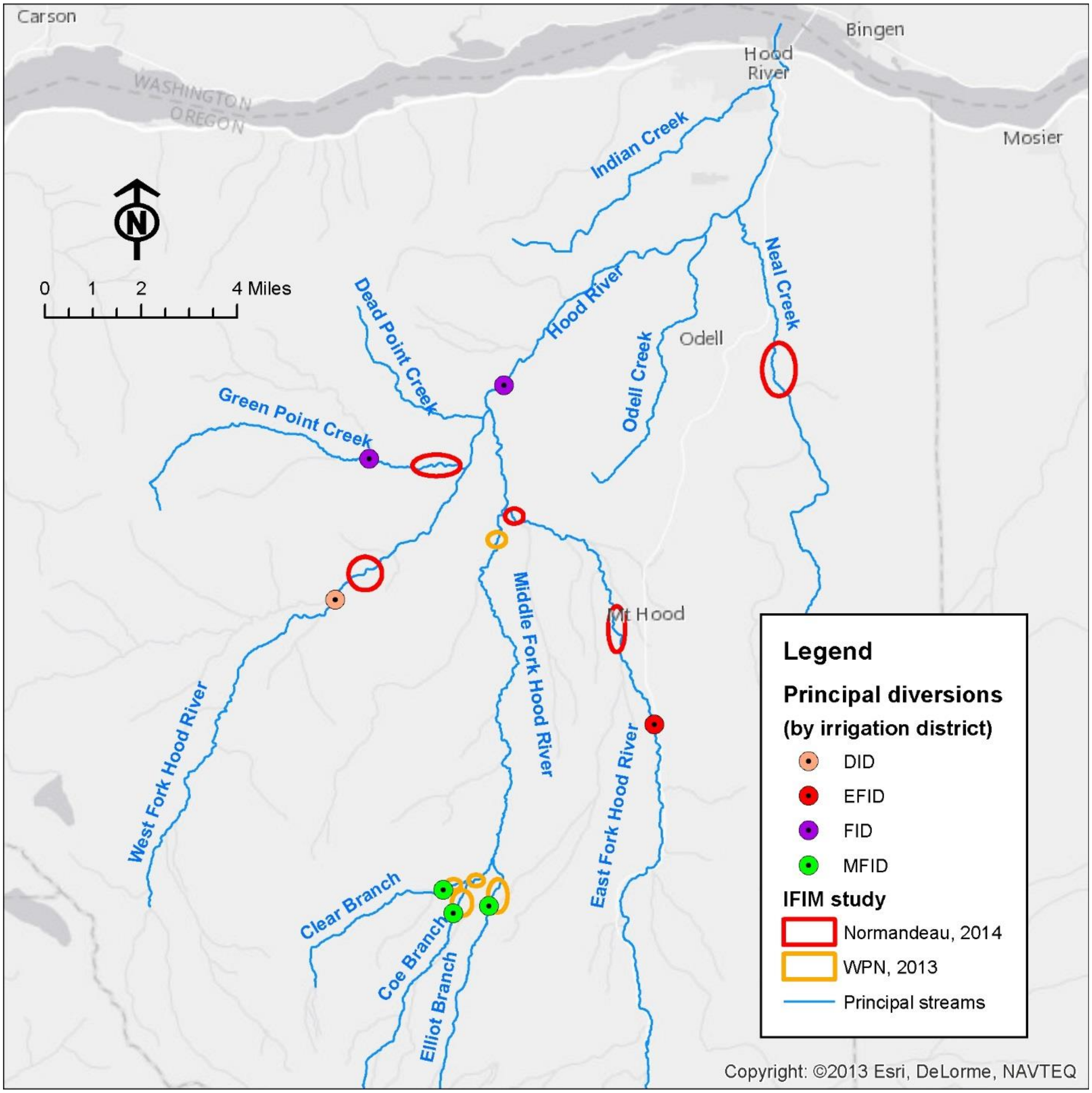

Figure 8. Locations of IFIM study reaches and principle irrigation district points of diversion

Table 6. Species and life stage periods of use (Normandeau Associates 2014)

Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Spring Chinook	juvenile rearing	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	spawning								■	■	■		
Coho	juvenile rearing	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	spawning									■	■	■	■
Steelhead	juvenile rearing	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	spawning		■	■	■	■	■						
Bull trout	adult rearing	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	spawning									■	■		

Principle points of diversion for irrigation districts are shown in Error! Reference source not ound.**8**. Additional points of diversion exist (particularly for FID), however for the purposes of this analysis it was assumed that any water savings associated with a given conservation strategy were realized at the points of diversion shown here. Any benefits to aquatic habitat would occur downstream of these locations to the mouth of the Hood River. The total length of stream downstream of each point of diversion is given in **Table 7**.

Table 7. Miles of stream downstream of the principal points of diversion shown in Error! Reference ource not found.**8**

Stream	EFID	DID	MFID	FID (Hood)	FID (Green Pt.)
Hood River	14.9	14.9	14.9	11.8	12.5
Middle Fork Hood River	-	-	10.1	-	-
East Fork Hood River	7.0	-	-	-	-
West Fork Hood River	-	5.7	-	-	1.4
Clear Branch	-	-	0.6	-	-
Green Point Creek	-	-	-	-	2.3
Total	21.8	20.6	25.5	11.8	16.3

4.2 Dee Irrigation District

4.2.1 Irrigation Water Management

Converting inefficient sprinkler systems and use of irrigation scheduling would save an average of 1.0 cfs during the months of May through September (see **Table 2**). These savings would be realized at the West Fork Hood River IFIM location (Error! Reference source not found.**8**). The verage percent change in WUA by species and lifestage at the West Fork IFIM location associated with water savings from sprinkler conversions are given in **Table 8**.

Table 8. Average percent change in WUA by species and life stage at the West Fork Hood River IFIM site associated with water conservation strategies.

Species	Life stage	Sprinkler conversion	Conveyance	All DID strategies combined
Bull trout	Spawning	0%	0%	0%
	Juv. Rearing	-0%	-0%	-0%
Spring Chinook	Spawning	1%	1%	2%
	Juv. Rearing	0%	0%	0%
Coho	Spawning	0%	0%	1%
	Juv. Rearing	-0%	-0%	-0%
Winter steelhead	Spawning	-0%	-0%	-0%
	Juv. Rearing	0%	0%	0%

Note that the values calculated in **Table 8** and in subsequent tables for other irrigation districts are the average change in habitat over the entire period of use (

Table 6) for a given species and life stage. These values were calculated for each month using the change in the "80% exceedance stream flow" for each month, associated with the implementation of a given conservation strategy. The "80% exceedance stream flow" is the flow that is met or exceeded 80% of the time for a given month. This flow can be thought of as the flow that is experienced in a dry year. Given the likelihood of lower summertime flows in the future given projected climate change it seemed reasonable to use the 80% exceedance flow in the following evaluation of impacts to fish habitat.

Please note that an entry of "-" indicates that there is no change as a result implementation of the strategy. All changes are rounded to the nearest integer percent value, consequently values of "0%" or "-0%" indicate that the change in WUA is greater than zero but less than one-half percent plus or minus.

All changes in WUA are 1% or less. The biggest increase in WUA (1%) is for chinook spawning. A total of 20.6 miles of stream are affected by this savings (Table 7); 5.7 miles in the West Fork, and 14.9 miles in the Hood River mainstem. Summary metrics for this treatment strategy are given in **Appendix A**.

4.2.2 Conveyance

Dee Irrigation District is in the process of securing funds to pressurize their distribution piping, which will reduce water use by eliminating six end spills. This project would include installation of a single pump to pressurize the entire distribution system. This project is estimated to cost $3,500,000 and have an estimated saving of 1.5 cfs over the April-September period. Water savings associated with this piping project are applicable to the West Fork Hood River IFIM location (Error! eference source not found.). The percent change in WUA by species and lifestage associated with water savings at the West Fork IFIM location are given in **Table 8**. The biggest increase in WUA (1%) is for chinook spawning. All other changes in WUA are less than 1%. Summary metrics for this treatment strategy are given in **Appendix A**.

4.2.3 Implementation of all strategies

The DID has not identified opportunities to make any other significant operational changes that would result in water savings. The combined habitat benefits of sprinkler conversion and conveyance are shown in **Table 8**. Chinook spawning WUA would increase by 2%, and coho WUA by 1%; all other changes in WUA would be less than 1% for the combined treatments.

4.3 East Fork and Mt. Hood Irrigation Districts

4.3.1 Sprinkler conversion

Water savings associated with sprinkler conversion in East Fork Irrigation District are discussed in section 3 above. An average of 15.4 cfs could be saved during the months of May through September (Table 2). These savings would be realized at the two East Fork Hood River IFIM locations. The average percent change in WUA at the 80% exceedance flow (dry year) by species and lifestage associated with water savings are given in **Table 9**. Chinook spawning WUA increases an average of 52%, coho spawning increases 15%, and Steelhead spawning 1%. Rearing habitat increases 11% for chinook, 10% for coho and 12% for steelhead. A total of 21.8 miles of stream are affected by savings at the EFID diversion (**Table 7**); 7.0 miles in the East Fork, and 14.9 miles in the Hood River mainstem. Summary metrics for this treatment strategy are given in **Appendix A**.

Table 9. Average percent change in WUA by species and life stage at the two East Fork Hood River IFIM sites associated with water conservation strategies.

Species	Life stage	EFID Sprinkler conversion	MHID Sprinkler conversion	EFID conveyance	EFID Regulating Reservoir & Telemetry	EFID Eliminate spring spray & frost diversions	EFID New POD on mainstem Hood River	EFID New storage	All strategies combined
Spring Chinook	Spawning	52%	3%	159%	53%	-	8%	68%	203%
	Juv. Rearing	11%	1%	4%	8%	-0%	2%	13%	-2%
Coho	Spawning	15%	1%	27%	19%	-	2%	21%	30%
	Juv. Rearing	10%	1%	2%	8%	0%	2%	12%	-4%
Winter steelhead	Spawning	1%	0%	1%	0%	-1%	0%	-	1%
	Juv. Rearing	12%	1%	14%	10%	-0%	2%	14%	11%

Water savings associated with sprinkler conversion in the Mount Hood Irrigation District would be realized at the EFID diversion on the East Fork. Water savings associated with sprinkler conversion in Mount Hood Irrigation District are applicable to the two East Fork Hood River IFIM locations. The percent change in WUA by species and lifestage associated with water savings are given in **Table 9**. Chinook spawning WUA increases an average of 3%, coho spawning increases 1%, and Steelhead spawning increases less than 1%. Rearing habitat increases 1% for chinook, coho and steelhead.

4.3.2 Conveyance

Mount Hood Irrigation District's distribution system is entirely piped, and it has no overflows or seepage.

East Fork Irrigation District has been in the process of converting open canals to pipe over many years; however, it has not made as much progress as the other districts. This is mostly because EFID is much bigger than FID and MFID, yet it does not have hydropower revenue to invest in district improvements, as do FID and MFID. The estimated cost to pipe the remainder of the EFID district is

$28,000,000, with an estimated water savings of 7,816 acre-feet per year, or an equivalent of 10.8 cfs averaged over the year as canal seepage. It is assumed that this loss is proportional to diverted flow over the entire year.

In addition to seepage loss there are currently losses due to overflow that would be eliminated if the system was piped. EFID currently diverts the maximum expected irrigation demand and then overflows any amount that is greater than actual instantaneous demand. East Fork Irrigation District's Water Management and Conservation Plan (EFID 2011) estimates that an additional 8.85 cfs is lost to overflows averaged over the year.

The district also diverts a significant amount of water in the spring for orchardists to use for spray and frost control; however, only a fraction of that water actually gets used. Piping would eliminate this loss and diversion would be reduced by approximately 25 cfs in the springtime. It is assumed that this loss is proportional to diverted flow in March, April and May.

The savings from elimination of seepage, overflow losses, and excess diversion for spring frost control and spray, total 25.9 cfs averaged over the entire year, assuming that these savings are proportional to monthly use (March – May) for frost control/spray, and annually for other losses. Water savings associated with this piping project are applicable to the two East Fork Hood River IFIM location.

The percent change in WUA by species and lifestage associated with water savings are given in **Table 9**. Chinook spawning WUA increases an average of 159%, coho spawning increases 27%, and Steelhead spawning 1%. Rearing habitat increases 4% for chinook, 2% for coho and 14% for steelhead. Summary metrics for this treatment strategy are given in **Appendix A**.

4.3.3 Regulating Reservoir & Telemetry

Although eliminating all open conveyance (i.e., canals) is the ideal solution, operational changes could be implemented that would have a smaller impact, but would come at a fraction of the price. One operational change that was considered was to eliminate overflows (estimated at 8.85 cfs annually; described above) through the use of a regulating reservoir (also known as "surge ponds") and telemetry. Although piping the entire system is the ideal solution, a combination of telemetry stations with a few regulating surge ponds may significantly reduce spills at a fraction of the cost. The estimated cost for the regulating reservoir / telemetry option is $269,000.

Water savings associated with the overflow losses are applicable to the two East Fork Hood River IFIM locations. The percent change in WUA by species and lifestage associated with water savings are given in **Table 9**. Chinook spawning WUA increases an average of 53%, coho spawning increases 19%, and Steelhead spawning by <1%. Rearing habitat increases 8% for chinook, 8% for coho and 10% for steelhead. Summary metrics for this treatment strategy are given in **Appendix A**.

4.3.4 Elimination of springtime spray and frost control diversions:

As noted above, EFID also diverts a significant amount of water in the spring for orchardists to use for spray and frost control; however, only a fraction of that water actually gets used. Piping would eliminate this loss and diversion would be reduced by approximately 25 cfs in the springtime for an annualized savings of 6.25 cfs. Implementation of this this as a stand-alone project could occur in a relatively short timeline. EFID estimates the total use for spray and frost control is 350 acre-feet per year. Replacing this with water from the Crystal Springs Water District at the current rate of $5.50 per 1,000 gallons would cost $627,264 annually at the current rates.

Water savings associated with the elimination of springtime spray and frost control diversions are applicable to the two East Fork Hood River IFIM location. The percent change in WUA by species and lifestage associated with water savings are given in **Table 9**. Changes in WUA are very small for all species and life stages. Summary metrics for this treatment strategy are given in **Appendix A**.

4.3.5 New EFID POD on mainstem Hood River

EFID serves 200 acres located between the mainstem Hood River and Highway 281 that could potentially be gravity fed or pumped from the Hood River. Creating a new diversion for this acreage would allow approximately 2.5 cfs to stay in the river for 12 miles, including 7 miles of the East Fork Hood River where 2.5 cfs represents approximately 15% of August flow in an 80th percentile year.

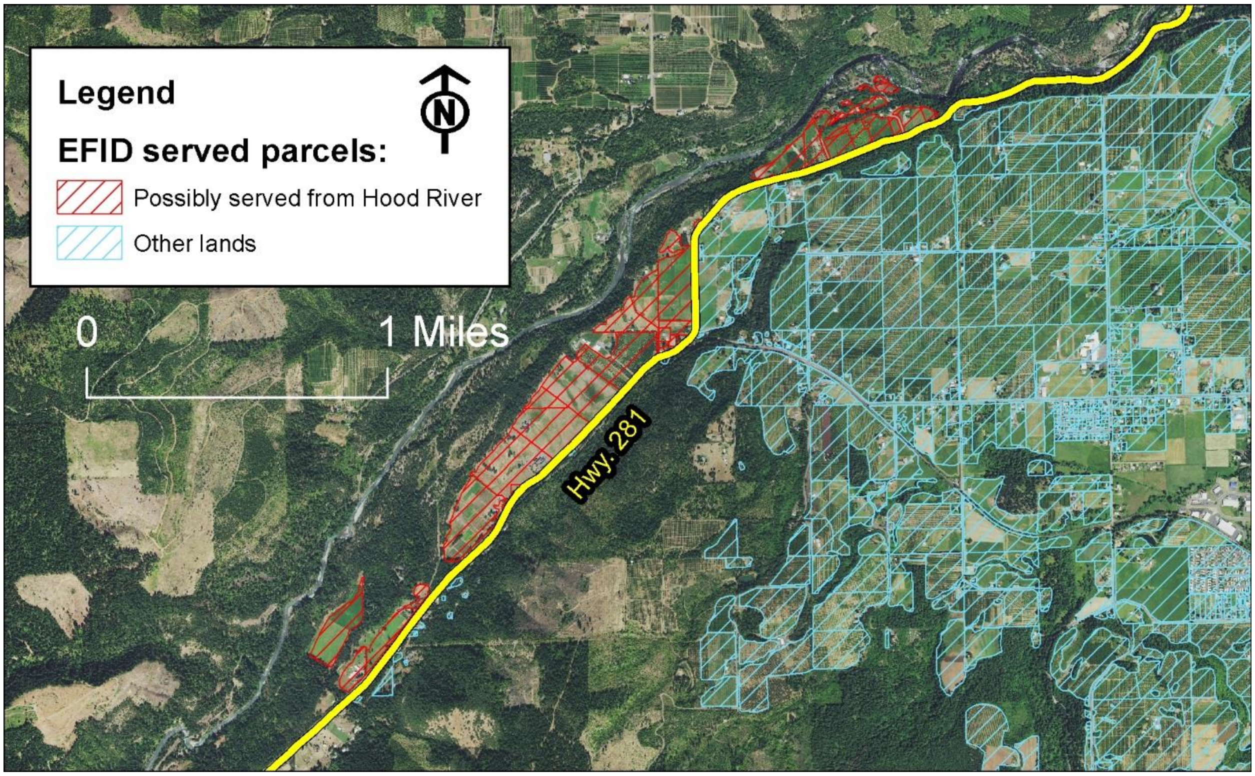

Figure 9. Irrigated lands served by EFID that could potentially be served directly from the Hood River.

Ideally a suitable diversion location could be found that would reduce costs, however, in a worst case scenario irrigation water must be lifted by pump from the river elevation (approximately 600' msl) to the irrigated land (approximately 800' msl). Based on this elevation difference, a 2.5 cfs flow rate, energy losses, and the required pressure for sprinklers, a 130-hp pump would be required. The capital cost for this pump and pipe system are shown in **Table 10**, while the annual cost of operating this pump from June through September are shown in **Table 11**.

Table 10. Capital cost for pump and pipe system to serve EFID acreage near Highway 281.

Pump Size (HP)	Pump Cost ($)	Pipe Length (feet)	Pipe Size (inch)	Pipe Unit Cost ($/ft)	Pipe Cost ($)	**Total Cost ($)**
130	25,000	1,600	8	50	80,000	105,000

Table 11. Head, flow, and annual pumping cost to serve EFID acreage near Highway 281 for three months.

Total Head (ft)	Flow (cfs)	Total Volume (ac-ft)	Pump Size (HP)	Pump Hours (hours)	Annual Cost ($)
364	2.5	451	130	2,196	23,400

Water savings associated with a new EFID diversion on the Hood River mainstem are applicable to the two East Fork Hood River IFIM location. The percent change in WUA by species and lifestage associated with water savings are given in **Table 9**. Chinook spawning WUA increases an average of 8%, coho spawning increases 2%, and Steelhead spawning by <1%. Rearing habitat increases 2%

for chinook, coho, and steelhead. Summary metrics for this treatment strategy are given in **Appendix A**.

4.3.6 New EFID POD on Columbia River

The potential exists for EFID to serve its lower-elevation acreage from the Columbia River, similar to what has been done in The Dalles. This would require lifting the water a greater elevation than if it were to be pumped from the Hood River, however, the Columbia River is not limited by low summer streamflows like the Hood River. The cost of pumping from the Columbia increases with the elevation it must be pumped and the flow rate, so the amount of acreage to be served from the Columbia River should be optimized for both the relationship between irrigated acreage and elevation and for the critical amount of streamflow that should be achieved in the East Fork and main stem Hood River.

Error! Reference source not found.**10** shows the relationship between elevation and the cumulative cres served (left axis) and the cumulative reduction in water that would need to be diverted (right axis) if pumped water from the Columbia was substituted for East Fork water. An inflection point occurs in the relationship at approximately the 770' elevation point, beyond which there are a decreasing number of acres served along with a decreasing rate in water savings. Error! Reference source not found.**11** shows the location of the 770-foot contour elevation relative to the distribution of EFID-served lands in the lower Hood River valley. Note that there are "islands" that are above the 770' contour that would require pumping to additional higher elevations. The capital and annual cost of pumping 44.5 cfs to those acreages from the Columbia River are given in **Table 12**.

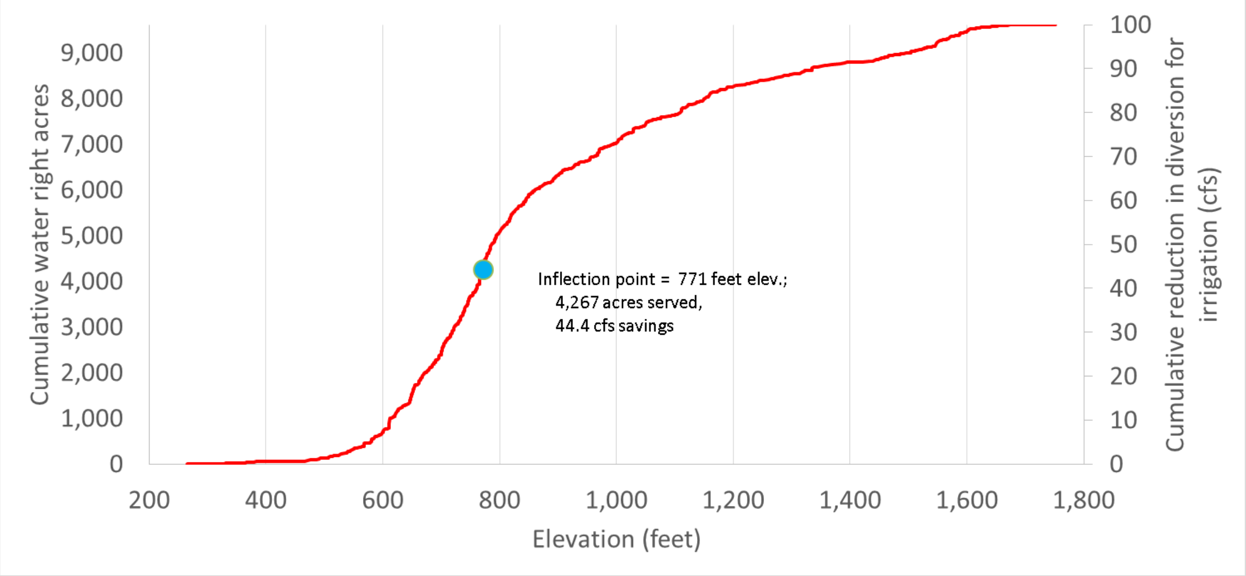

Figure 10. Relationship between elevation and cumulative acreage served and cumulative water savings associated with replacing EFID water with water pumped from the Columbia River.

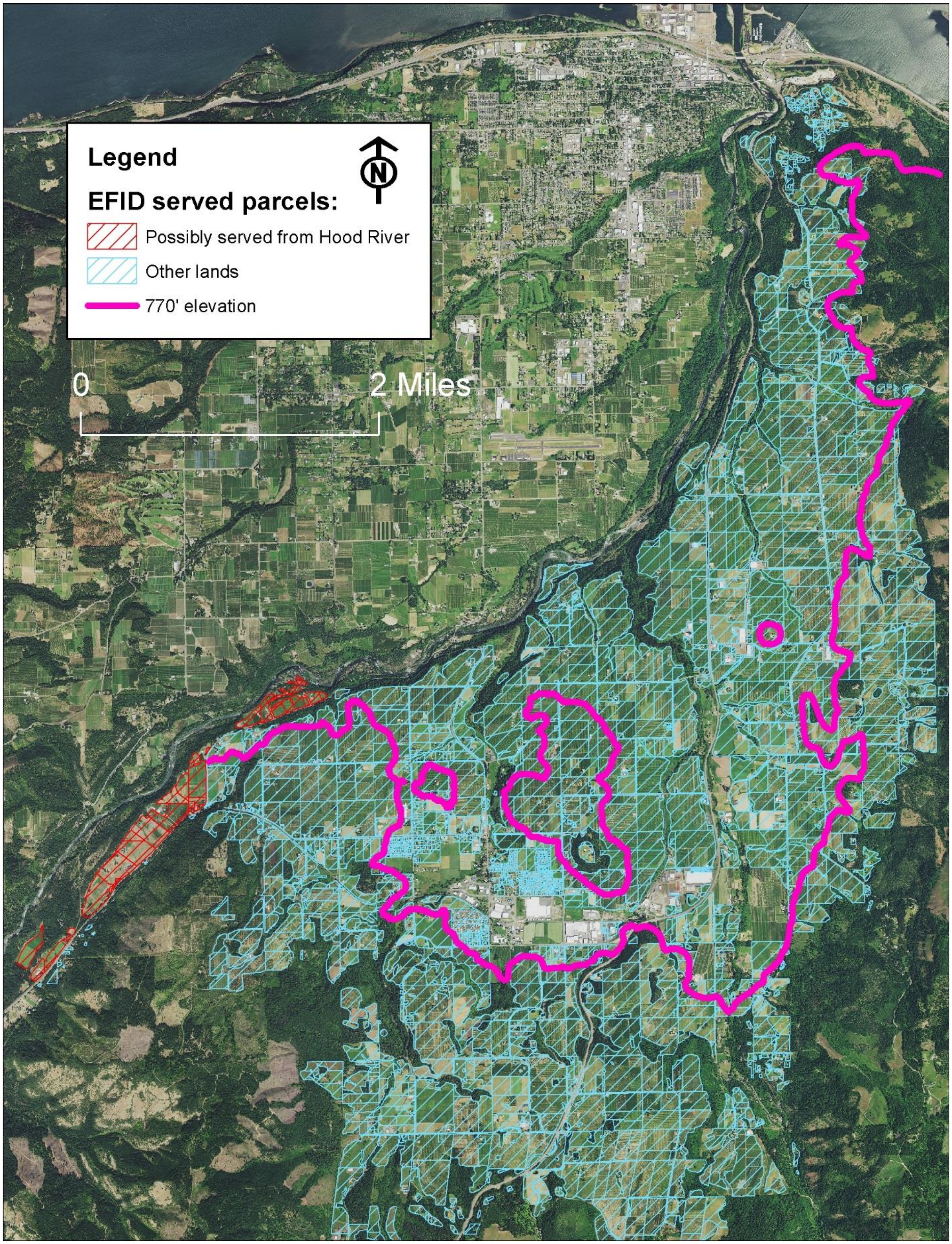

Figure 11. EFID-served lands in the lower Hood River Valley in relationship to the 770-foot contour elevation

Table 12. Capital cost for pump and pipe system to serve EFID acreage below the 770' elevation level from the Columbia River and annual operating cost for a three month period.

Pump Size (HP)	Pump Cost ($)	Pipe Length (feet)	Pipe Size (inch)	Pipe Unit Cost ($/ft)	Pipe Cost ($)	**Total Capital Cost ($)**	**Annual Cost ($)**
4,500	1,200,000	19,800	36	175	3,465,000	4,665,000	810,000

Unfortunately, as seen in **Figure 10**, water must be lifted over 400' feet before any significant acreage is served, which likely makes this a cost-prohibitive option, and as such no analysis of effects on habitat was performed.

4.3.7 New Storage

EFID has the greatest amount of irrigated acreage and the largest irrigation demand, but does not have any existing reservoir storage. The Hood River Basin Study evaluated nine sites, and a preliminary analysis determined the most feasible and cost-effective site is on the West Fork of Neal Creek. The preliminary analysis determined that approximately 2,557 ac-ft of storage would be available with a 130' tall by 1,000' long dam. The cost for this facility ranges considerably depending on where the fill material is sourced from. If local material is available for dam construction, the estimated cost of the facility is $13,000,000. However, if fill material must be hauled in from greater than 20 miles, the cost would escalate up to $28,000,000 (Hood River County 2013). It should be stressed that the determination that the West Fork Neal Creek site is the best site is based on a preliminary analysis only, and that a more in-depth analysis should be performed to confirm this is the best site, as well as confirm sufficient water supply to fill the reservoir regularly. Additionally, any further analysis of the site should determine if local material is available and suitable for dam construction.

The site would store winter and spring runoff and use it to meet irrigation demand during the summer, in-turn reducing the demand from the East Fork Hood River. The stored water would increase water resource reliability by providing additional water that would not otherwise be available, and increased instream flows in the East Fork Hood River and downstream during the summer. Additional analysis needs to be conducted to determine the fill and release schedule that would have the least impact on instream flows during the winter and spring (when water is going into storage), and the greatest positive impact during releases. It's likely that the storage should be held until the streamflow in the Basin recedes to a certain level and then it should be released to allow EFID to reduce their diversion from the East Fork Hood River.

Results from an initial evaluation are presented. Water savings associated with a new EFID storage reservoir on West Fork Neal Creek are applicable to the two East Fork Hood River IFIM location (**Error! Reference source not found.**8; Table 9). Water savings associated with this project are expected to increase flow below the EFID diversion by 21 cfs in August and September. The percent change in WUA by species and lifestage associated with water savings are given in **Table 9**. Chinook spawning WUA increases an average of 68%, coho spawning increases 21%, and Steelhead spawning shows no change. Rearing habitat increases 13% for chinook, 12% for coho, and 14% for steelhead. Summary metrics for this treatment strategy are given in **Appendix A**.

Impacts to instream habitat associated with filling the reservoir are applicable to the IFIM location on Neal Creek. These impacts assume a constant fill rate if 7 cfs during the months of December through May. In practice the reservoir would largely be filled during high flow events (winter rain-on-snow and spring snowmelt).

Coho spawning would be slightly impacted (1% decrease in WUA), as would steelhead spawning (3% decrease). Coho juvenile rearing would decrease 3% on average, and steelhead juvenile rearing would decrease 1%.

Table 13. Average percent change in WUA by species and life stage at the Neal Creek IFIM site associated with water conservation strategies.

Species	Life stage	EFID New storage
Coho	Spawning	-1%
	Juv. Rearing	-3%
Winter steelhead	Spawning	2%
	Juv. Rearing	-1%

Depending on location of the reservoir, a total of 19.4 miles of stream are affected by the reservoir filling; 9.0 miles on the West Fork Neal Creek, 5.8 miles in Neal Creek, and 4.6 miles in the Hood River mainstem. Summary metrics for this treatment strategy are given in **Appendix A**.

4.3.8 Implementation of all strategies

The combined habitat benefits of all water conservation strategies are shown in the final column of **Table 9**. Implementation of all strategies would result in an average increase in chinook spawning WUA of 203%, an increase in coho WUA of 30%, an increase in steelhead WUA of 1%. Chinook rearing would decrease by 2%, coho rearing decrease by 4%, and there would be an 11% increase in steelhead rearing.

4.4 Farmers Irrigation District

4.4.1 Sprinkler Conversion

Water savings associated with sprinkler conversion in Farmers Irrigation District would save an average of 1.9 cfs during the months of May through September, which would be realized at the Greenpoint Creek diversion, or at the mainstem Hood River diversion, or apportioned out between them. For the purposes of this analysis the water savings were assumed to occur in Greenpoint Creek, and the Greenpoint IFIM location was used to assess the habitat benefit of this water savings.

The average percent change in WUA at the 80% exceedance flow (dry year) by species and lifestage associated with water savings are given in **Table 14**. Chinook spawning WUA increases an average of 5%, coho spawning increases 3%, and Steelhead spawning 1%. Rearing habitat increases 1% for chinook, -1% for coho and 12 for steelhead. A total of 16.3 miles of stream are affected by this savings (Table 7); 2.3 miles in Greenpoint Creek, 1.4 miles in the West Fork, and 12.5 miles in the Hood River mainstem. Summary metrics for this treatment strategy are given in **Appendix A**.

Table 14. Average percent change in WUA by species and life stage at the Greenpoint Creek IFIM site associated with water conservation strategies.

Species	Life stage	FID Sprinkler conversion	FID Hydro rebalancing	FID Expanded storage in Kingsley Reservoir	FID Water Lease	All FID strategies combined
Spring Chinook	Spawning	5%	14%	5%	9%	30%
	Juv. Rearing	1%	2%	1%	1%	3%
Coho	Spawning	3%	6%	3%	5%	10%
	Juv. Rearing	-1%	-2%	-1%	-1%	-4%
Winter steelhead	Spawning	1%	1%	-	-	1%
	Juv. Rearing	1%	3%	1%	2%	7%

4.4.2 Conveyance

Farmers Irrigation District has over 99% of its system piped, and therefore has no significant opportunities to make changes that would result in water savings.

4.4.3 Hydropower rebalancing

FID operates two hydropower plants; Plant #3 which receives inflow from Greenpoint and Deadpoint Creeks, and Plant #2 which receives tailwater from Plant #3 and flow from the mainstem Hood River. Existing water rights allow for 35 cfs through Plant 3 (upper plant) and 108 cfs through Plant 2 (lower, by Powerdale). Both plants have the ability to run an additional 5 cfs over the current peak capacity.

FID diverts 73 cfs directly from the Hood River which feeds only the lower plant (Plant 2). This 73 cfs is combined with the 35 cfs tailwater from Plant 3 to make the total 108 cfs seen at Plant 2. The diversion from the Hood River cannot be increased much above 73 cfs, therefore a wintertime increase of 5 cfs would likely come from one of the FID Greenpoint diversions. This would increase flow through both plants.

FID currently has a flow agreement with ODFW to maintain 20-40 cfs within Greenpoint Creek. The 25 cfs value for September is often not achieved due to low flows. Implementation of a hydropower rebalancing agreement would have the possibility of helping to achieve the flow agreement if summer hydro flows were reduced, and winter flows increased to balance the generating load.

Ideally a hydro rebalancing plan would be revenue neutral (power foregone at one point in time would be replaced by power generated at another point in time that had similar value). However, efficiencies will decrease slightly with the extra 5 cfs, therefore a detailed hydraulic/economic analysis would need to be conducted prior to implementation.

One approach to rebalancing the FID hydropower is shown in Error! Reference source not found.. In his scenario hydropower withdrawals from Greenpoint creek are eliminated in the summer and rebalanced with increased withdrawal in the remaining months.

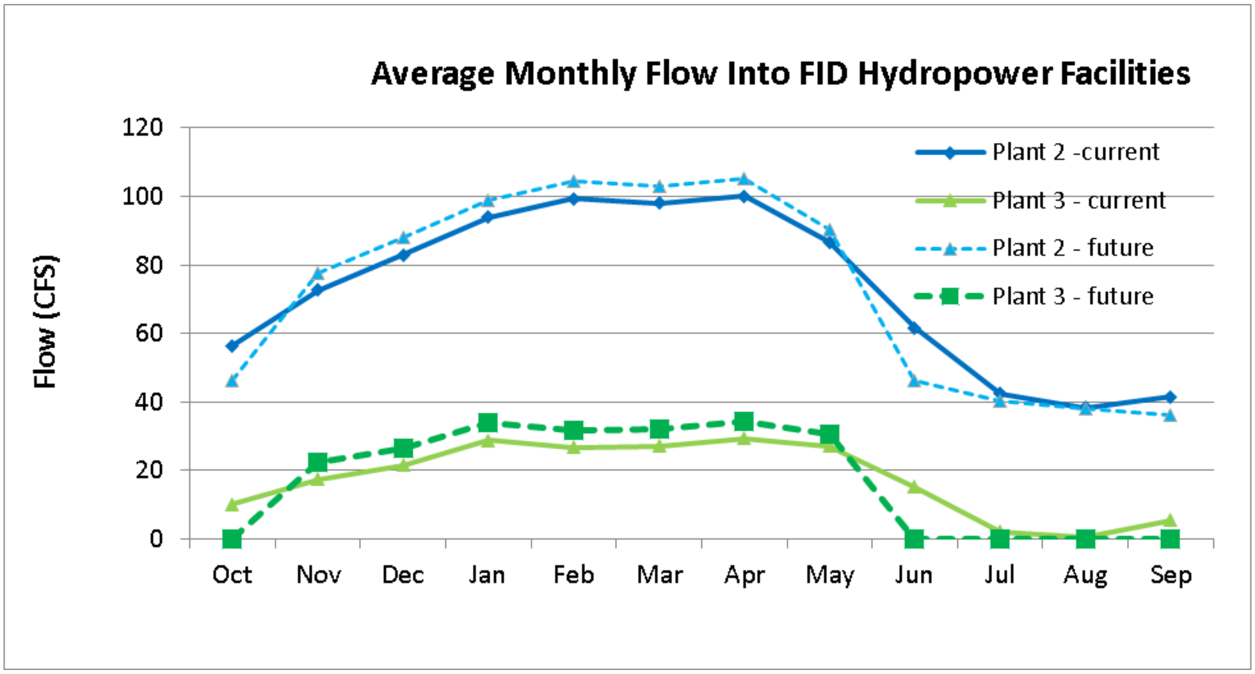

Figure 12. Possible hydro rebalancing scenario for FID hydropower facilities.

Water savings associated with rebalancing FID hydropower are applicable to the Greenpoint IFIM location. The percent change in WUA by species and lifestage associated with water savings at the Greenpoint IFIM location are given in **Table 14**. Chinook spawning is increased by 14%, coho by

6%, and steelhead by 1%. Chinook rearing increases 2%, coho decreases 2% and steelhead increases 3%. Summary metrics for this treatment strategy are given in **Appendix A**.

4.4.4 Expanded Storage

FID's existing reservoir capacity is 938 ac-ft, of which 246 is in its lower reservoir, and 692 in its upper reservoir. FID is currently performing a water reliability and reservoir expansion feasibility study, from which initial results have indicated that FID should seek approximately 500 ac-ft of additional storage in its reservoir system. This additional volume could be achieved by either raising the upper reservoir by 9', or due to structural concerns with the lower reservoir, by raising the upper reservoir by 13' and decommissioning and removing the lower reservoir entirely. The storage volumes achieved and cost estimates for each of these options are shown in **Table 15**.

Table 15. Options for increasing the storage volume in FID's reservoir system.

Alternative	Upper Reservoir Volume (ac-ft)	Lower Reservoir Volume (ac-ft)	Total New Volume (ac-ft)	Project Cost ($)	Cost per ac-ft
Raise Upper Dam by Nine feet	1,439 (+501)	246 (no change)	501	1,740,000	3,473
Raise upper dam by 13', decommission lower dam	1,698 (+760)	0 (-246)	514	2,760,000	5,370

FID would not increase diversions to obtain new streamflow for storage expansion, but instead use a portion of its current hydropower diversion to fill any new volume. FID currently diverts 5 cfs from Rainy, Gate, and Cabin Creeks (all tributaries to Greenpoint Creek) in the winter for hydropower. FID would continue to divert the same 5 cfs from these sources but put approximately 2.7 cfs (depending on final additional storage volume) into storage and convey the remaining 2.3 cfs to hydropower.

The additional storage volume would be used to meet irrigation demand, hence reducing FID's reliance on summertime live flow. This both helps ensure water resource reliability for the district and increases streamflow during the critical summer period. If 500 acre-feet were used to replace current intake during the months of July-September, this would effectively increase stream flow in Greenpoint Creek by 2.8 cfs.

Water savings associated with expanding storage are applicable to the Greenpoint IFIM location. The percent change in WUA by species and lifestage associated with water savings at the Greenpoint IFIM location are given in **Table 14**. Chinook spawning is increased 5%, coho by 3%, and steelhead is unchanged. Chinook rearing increases 1%, coho decreases 1% and steelhead increases 1%. Summary metrics for this treatment strategy are given in **Appendix A**.

4.4.5 Instream Lease

Farmers Irrigation District has a return flow of 30-40 cfs from its Plant #2 hydropower facility during irrigation season, and as such, up to that amount could be available for an instream lease agreement (Plant #3 does not typically operate during irrigation season). Based on historical FID records, Plant #2 generates 18.9 MW-hr/month per cfs. At current power purchase price of $0.07 per kW-hr, each cfs leased would cost approximately $1,323 per month. A twenty cfs lease would cost $25,460 per month, or $79,380 for three months.

Ideally FID would maximize the reduction at its diversion from Greenpoint Creek which would allow water to stay in the river for Greenpoint, part of the West Fork Hood River, and the mainstem Hood River. However, a limited amount of water is available at the Greenpoint diversion (i.e. most of the Greenpoint diversion is used for irrigation demand) hence any diversion reduction not available at Greenpoint would need to be implemented at the diversion off of the mainstem Hood River. For the purposes of this analysis we assume that a 20 cfs lease for 3 months (July – September) would result in a 5 cfs reduction in the diversion from Greenpoint Creek, the balance of 15 cfs reduction being realized from mainstem Hood River diversions.

Water savings associated with this example instream lease are applicable to the Greenpoint IFIM location. The percent change in WUA by species and lifestage associated with water savings at the Greenpoint IFIM location are given in **Table 14**. Chinook spawning is increased 9%, coho by 5%, and steelhead is unchanged. Chinook rearing increases 1%, coho decreases 1% and steelhead increases 2%. Summary metrics for this treatment strategy are given in **Appendix A**.

4.4.6 Implementation of all strategies

The combined habitat benefits of all water conservation strategies are shown in the final column of Table 14. Implementation of all strategies would result in an average increase in chinook spawning WUA of 30%, an increase in coho WUA of 10%, an increase in steelhead WUA of 1%. Chinook rearing would increase by 3%, coho rearing decrease by 4%, and there would be a 7% increase in steelhead rearing.

4.5 Middle Fork Irrigation District

4.5.1 Sprinkler conversion

Water savings associated with sprinkler conversion in Middle Fork Irrigation District would save an average of 12.2 cfs, which would be saved during the months of May through September. Water savings associated with sprinkler conversion could be realized at any of the principal diversions: Clear Branch (Laurance Lake), Coe Branch, or Eliot Branch. However, for the purposes of this analysis it is assumed that the entire savings is realized in the Clear Branch, and the Clear Branch IFIM location was used to assess the habitat benefit of this water savings.

The average percent change in WUA at the 80% exceedance flow (dry year) by species and lifestage associated with water savings are given in **Table 16**. Bull trout spawning WUA increases an average of 36%, Chinook spawning increases 90%, coho spawning increases 41%, and Steelhead spawning 12%. Rearing habitat increases 4% for bull trout, 18% for chinook, and 29% for steelhead. A total of 25.53 miles of stream are affected by this savings; 0.6 miles in Clear Branch, 10.1 miles in the Middle Fork, and 14.9 miles in the Hood River mainstem. Summary metrics for this treatment strategy are given in **Appendix A**.

Table 16. Average percent change in WUA by species and life stage at the Clear Branch IFIM site associated with water conservation strategies.

Species	Life stage	MFID Sprinkler conversion	MFID Hydro rebalancing	MFID expanded storage in Laurance Lk.	MFID Adaptive management	All MFID strategies combined
Bulltrout	Spawning	36%	48%	11%	5%	53%
	Juv. Rearing	4%	1%	2%	1%	4%
Spring Chinook	Spawning	90%	83%	19%	10%	160%
	Juv. Rearing	18%	9%	4%	3%	16%
Coho	Spawning	41%	31%	8%	4%	71%
	Juv. Rearing	n/a	n/a	n/a	n/a	n/a
Winter steelhead	Spawning	12%	-13%	-	2%	-1%
	Juv. Rearing	29%	13%	6%	4%	36%

4.5.2 Conveyance

The MFID is entirely piped, with the exception of a canal between the Eliot Creek diversion and the sediment pond. This canal is referred to as the “Eliot Ditch,” and MFID has determined that due to the sediment load and other factors, it would not be of great benefit or economically feasible to pipe this section.

The district is pursuing a piping project, which would connect the Coe Creek diversion to the sediment basin. The objective of this project is sediment removal from irrigation water to facilitate use of high efficiency irrigation equipment on-farm (i.e., micro-sprinklers, drip). This would allow relatively more water to be used from Coe Creek in late summer. In turn, this would increase flows in Clear Branch, which has higher habitat quality due to the clarity of the water and low stream gradient. At the subbasin level there would be no change in water consumption, therefore it is not included as a strategy here.

4.5.3 **Hydropower rebalancing**

MFID has three hydropower plants located in series, with Plant #1 being the furthest upstream plant and Plant #3 being the furthest downstream plant. Outside of irrigation season all water that travels through Plant #1 also travels through Plant #3, but during irrigation season up to 40 cfs gets turned out for irrigation between the two plants (Figure 13). The average return flow from Plant #3 is 10 cfs in July and August and 20 cfs in September, and is the maximum amount of water that may be available to rebalance from the summer to the winter. The amount of potential increase in winter flow is equal to the difference between MFID's hydropower water right of (40 cfs) and its maximum flow rate through the plants (45 cfs at Plant #2) which is five cfs.

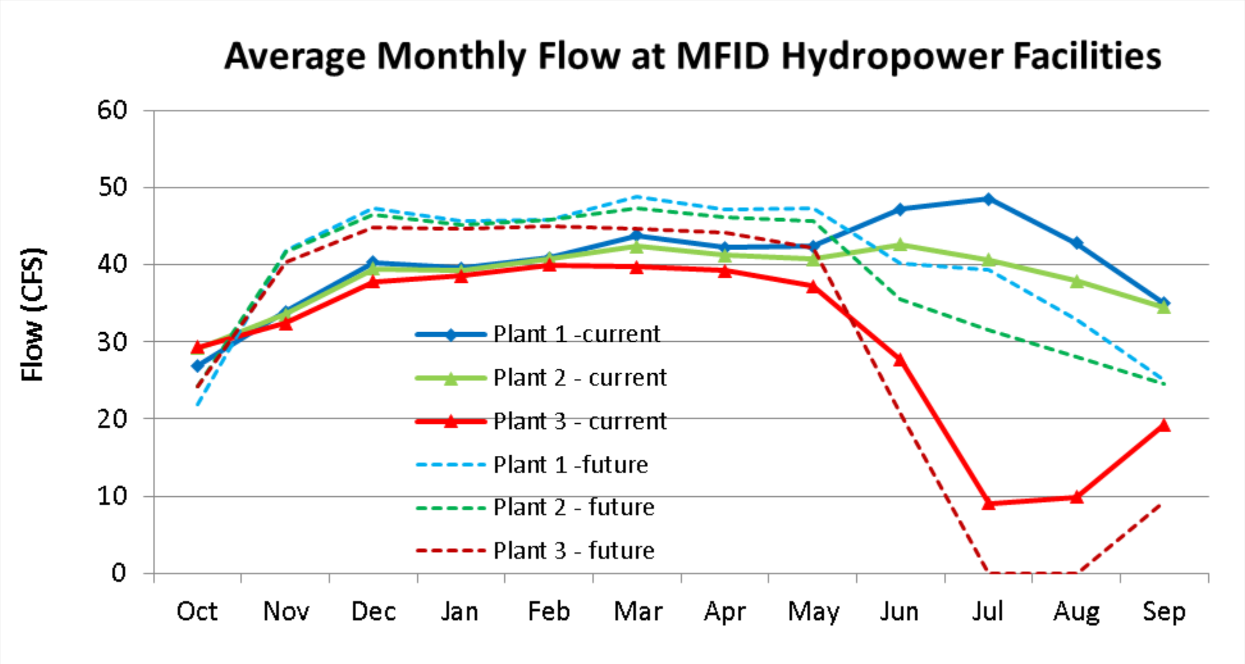

Figure 13. Average monthly flow into MFID's hydropower facilities.

Any agreement for hydropower rebalancing should have the goal of being revenue neutral and therefore would require a detailed analysis on increased head loss due to higher winter flow rates, impacts on lake levels, and other variables that would impact the economics of any agreement. However, for an initial analysis, an agreement could be as simple as MFID reducing hydropower flow up to 10 cfs during the summer months, and offsetting that lost revenue by increasing flow during the winter months.

Water savings associated with hydropower rebalancing are assumed to be realized at the Clear Branch IFIM location, which was used to assess the habitat benefit of this water savings.

The average change in habitat by species and lifestage associated with water savings from hydro rebalancing are given in **Table 16**. Bull trout spawning WUA increases an average of 48%, Chinook spawning increases 83%, coho spawning increases 31%, and Steelhead spawning decreases 13%. Rearing habitat increases 1% for bull trout, 9% for chinook, and 13% for steelhead. Summary metrics for this treatment strategy are given in **Appendix A**.

4.5.4 Expanded Storage

MFID's existing 2,500 acre-foot reservoir spills water every winter and spring, and additional storage volume would hold some of this spill over for use during irrigation season. Carrying this water over would allow a combination of keeping Laurance Lake (critical Bull Trout habitat) higher into the late summer, reservoir storage being available for irrigation demand, or for downstream releases.

An initial analysis determined that the most cost-effective method of increasing storage in Laurance Lake would be to install an inflatable Obermeyer weir on the dam's existing 80' long spillway. The blader would be inflated in the spring temporarily raising the spillway by 3'. The dam regularly has spills 2'-3' above the existing spillway, hence the addition of the 3' weir would not increase the maximum inundated area of the reservoir. The estimated cost of the weir and associated equipment is $250,000, which results in $675/ac-ft.

MFID has applied to OWRD for a grant to study the environmental impacts of the increased storage, however, an initial analysis indicates minimal negative impacts from decreased downstream flows in the spring, and significant positive impacts from increased in-lake habitat or downstream releases during irrigation season. If the full 370 acre-feet were carried through the summer for additional in-lake Bull Trout habitat, this would increase late summer storage in all years. If the 370 acre-feet were release downstream during the months of July-September, this would represent a 2 cfs increase in stream flow.

Water savings associated with expanded storage in Laurance Lake are assumed to be realized at the Clear Branch IFIM location, which was used to assess the habitat benefit of this water savings. The average change in habitat by species and lifestage associated with water savings from expanded storage in Laurance Lake are given in **Table 16**. Bull trout spawning WUA increases an average of 11%, Chinook spawning increases 19%, coho spawning increases 8%, and Steelhead spawning is unchanged. Rearing habitat increases 2% for bull trout, 4% for chinook, and 6% for steelhead. Summary metrics for this treatment strategy are given in **Appendix A**.

4.5.5 **Voluntary Fallowing**

In 2015 The Middle Fork Irrigation District offered patrons $300 per acre to forgo irrigation. Assuming an average production of 4 tons of alfalfa per acre, at a sales price of $200 per ton, yields a gross revenue of $800 per acre. Given labor and equipment costs the $300 per acre price to forego production seems to be a reasonable value to use. Approximately 175 acres of alfalfa would need to be fallowed to realize a one cfs average increase in streamflow over the April – September growing period. At $300/acre this treatment would cost $52,500.

Water savings associated with fallowing 175 acres are assumed to be realized at the Clear Branch IFIM location, which was used to assess the habitat benefit of this water savings. The average change in habitat by species and lifestage associated with this treatment are given in **Table 16.** Bull trout spawning WUA increases an average of 5%, Chinook spawning increases 10%, coho spawning increases 4%, and Steelhead spawning increases by 2%. Rearing habitat increases 1% for bull trout, 3% for chinook, and 2% for steelhead. Summary metrics for this treatment strategy are given in **Appendix A**.

4.5.6 **Implementation of all strategies**

The combined habitat benefits of all water conservation strategies are shown in the final column of **Table 16**. Implementation of all strategies would result in an average increase in bull trout spawning habitat of 53%, an increase of chinook spawning of 160%, an increase in coho spawning habitat of 71%, and a decrease in steelhead spawning habitat of 1%. Bull trout rearing habitat would increase 4%, chinook rearing increase by 16%, and steelhead rearing increase by 36%.

5 Cumulative Conservation Benefits under Climate Change

The most likely and cost-effective conservation actions to be implemented over the next 20 years include on-farm irrigation water management, conveyance system upgrades, expanded water storage in existing reservoirs, hydropower rebalancing, and voluntary fallowing of annual crops during dry (i.e., 80% exceedance or above). The estimated cumulative water savings for these strategies is 76 cfs (Table 1). **Figures 14**, **15**, and **16** show monthly, average summer stream flows under current and future conditions the East Fork, Middle Fork, and mainstem Hood River. Future stream flow is based on the median climate change scenario developed by the Bureau of Reclamation (2015). The conservation scenario includes all likely, cost-effective actions (i.e., totaling 76 cfs). Two key points should be noted from these figures: 1) this suite of conservation actions will likely maintain or slightly increase stream flows from current levels. This is good, but not ideal, as current streamflows are a limiting factor to the recovery of listed salmonids in the Basin; 2) Additional measures, such as groundwater recharge, new storage in EFID, and possible forest management have the potential to increase streamflows over 'historic' levels, which could contribute to recovery of listed fish species.

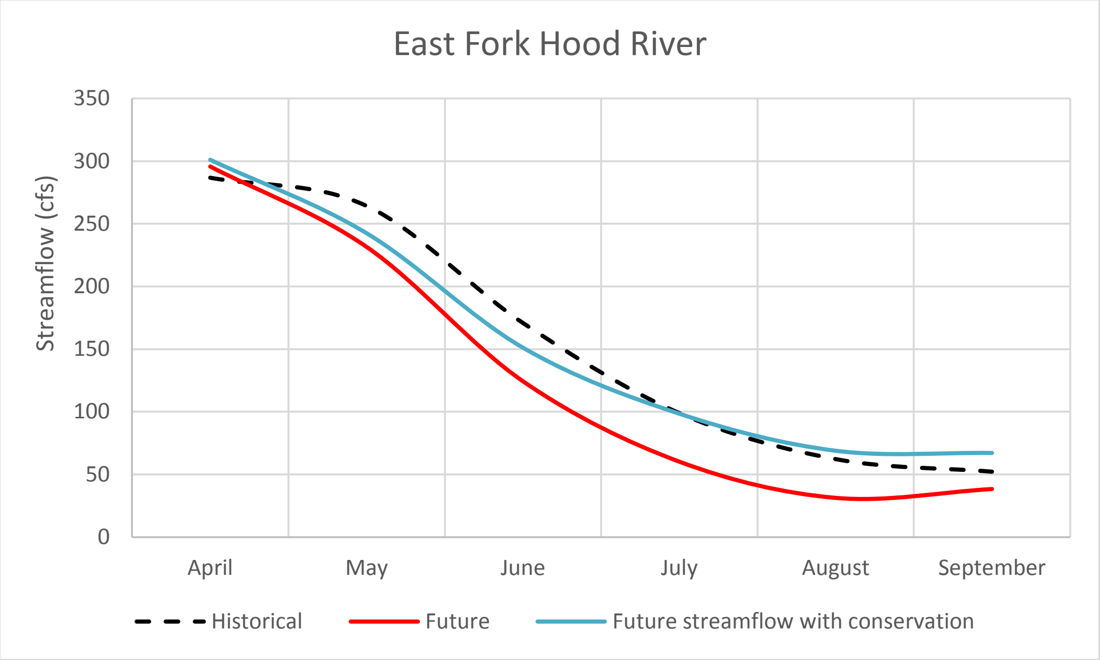

Figure 14. Future summer flows on the East Fork Hood River below EFID diversion. Future streamflow is shown with and without likely conservation actions.

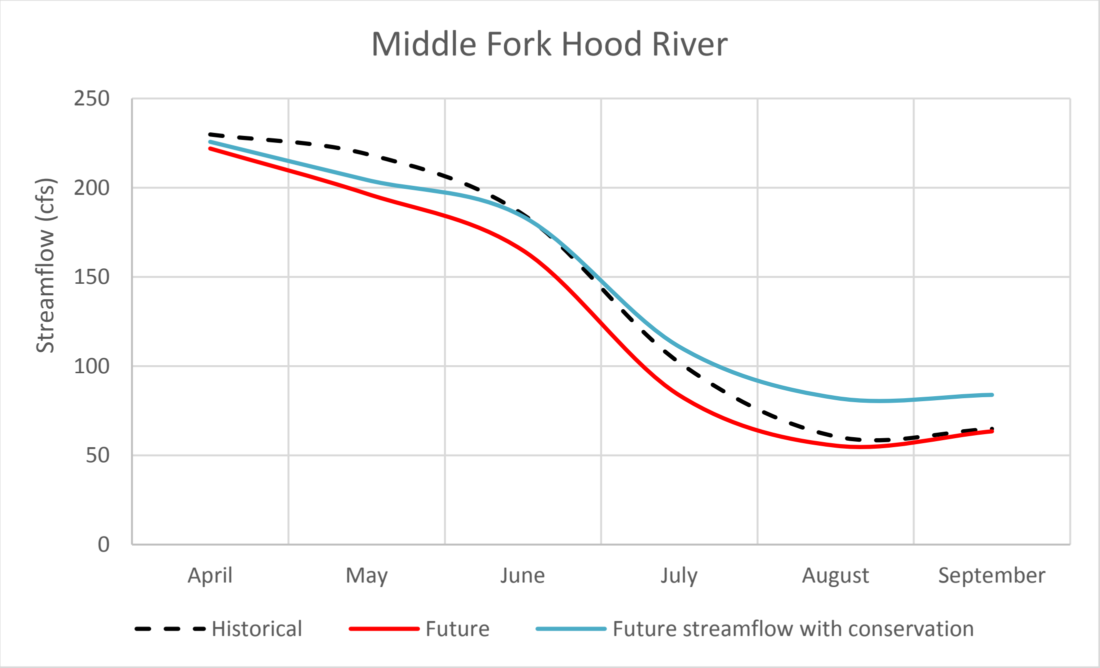

Figure 15. Future summer flows on the Middle Fork Hood River below MFID diversion. Future streamflow is shown with and without likely conservation actions.

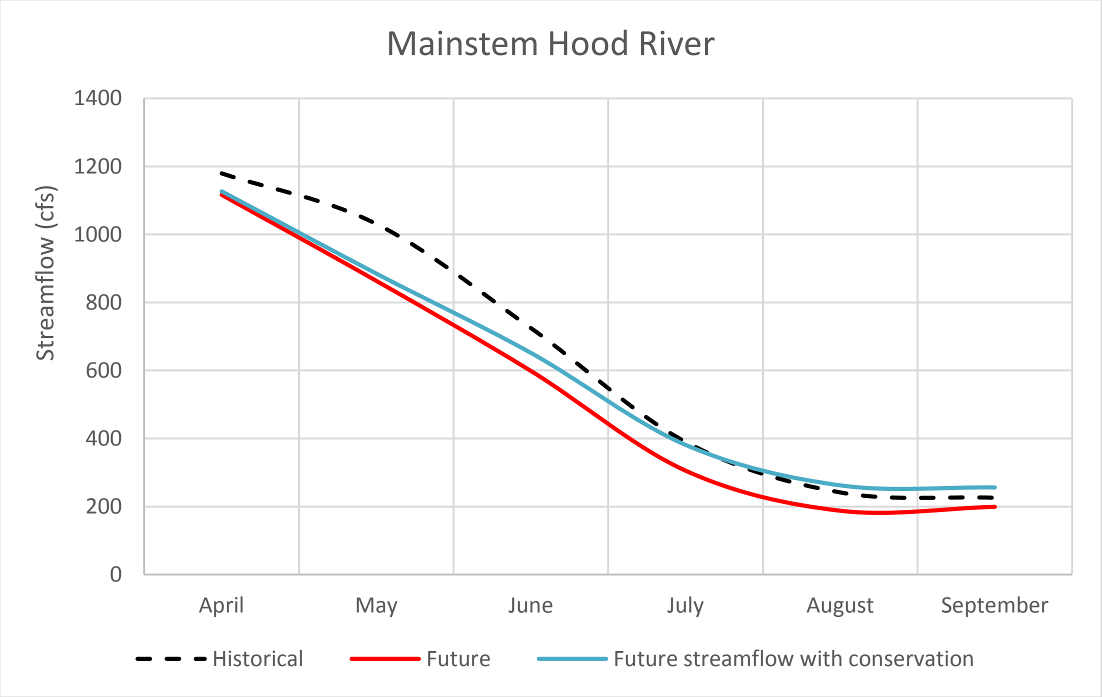

Figure 16. Future summer flows on the Hood River at Tucker Bridge. Future streamflow is shown with and without conservation.

6 Discussion & Recommendations

Section 3 describes the suite of likely and practical water conservation options for the Hood River basin, and section 4 provides detail of how these options might be implemented by irrigation district, which is aggregated into one Table in **Appendix A**. The choice of which options to implement, and where and when to implement them, will be based on funding opportunities, relative habitat benefits, irrigation district initiative, and landowner choices.

Over the next 20 years the potential exists to conserve at least 76 cfs, which will keep streamflows at or slightly above current flows (Figure 14, 15, 16). Accomplishing this will require significant and sustained fund raising, including local, state, and federal funding sources. The pace of funding acquisition and current likely sources are presented in **Table 17**.

Table 17. Likely Conservation Actions in the Next 20 Years.

Actions	Cost	Cost/year	Potential funding sources
On-farm irrigation: sprinkler upgrades, soil moisture monitoring	$10.4 million	~$500,000	OWRD, OWEB, irrigation districts, EQIP, others
Conveyance system upgrades (main & distribution lines)	$35 million	$1.75 M	OWRD, BOR, NRCS EQIP, EFID, FID, DID
Expanded water storage in existing reservoirs	~$2.4 million	2 projects	OWRD, NRCS, FID, MFID
Hydropower rebalancing	$0	n/a	TBD
Voluntary fallowing of annual crops/pastures		$400,000 (dry years)	Columbia Basin Water Transactions Fund, other?
	$47.8 million*		

In order to increase future streamflows to levels above historic/current streamflows, we will need to evaluate and implement additional conservation measures. These would likely include a new reservoir in the East Fork Irrigation District and the three concepts described below.

6.1 Groundwater Recharge Study

The following actions could be taken to develop managed aquifer recharge projects in the basin and to quantify the effects of aquifer recharge, restoration, and water management activities on groundwater and surface water availability.

- **Desktop aquifer recharge feasibility study.** Perform initial screening of potential recharge sites based on criteria such as overall location and presence of existing infrastructure, surface conditions, subsurface conditions, and land ownership. During this preliminary evaluation the basis for evaluating the surface and subsurface conditions is more subjective in nature, requiring information from existing studies in the basin. A screening/ranking criteria is then applied to select higher ranking sites for further consideration.
- **Detailed aquifer recharge site characterization.** Potential recharge sites that are identified in the screening study to possess optimal characteristics undergo a surface and subsurface characterization program to determine potential recharge volumes and contribution to stream return flows.

- **Shallow aquifer monitoring.** Install groundwater elevation monitoring wells in the shallow aquifer system to monitor seasonal changes to groundwater elevation and assess aquifer connection to nearby streams.
- **Seepage runs.** Perform seepage runs to identify gaining and losing stream reaches, which will guide siting of recharge basins that may provide most benefit to stream flows by reducing or reversing stream loss.
- **Hydrologic monitoring of restoration areas.** Identify areas that have recently been or will soon undergo restoration of vegetation and monitor hydrologic conditions to quantify the effect of restoration activities on groundwater recharge and stream flows. Example monitoring includes shallow aquifer elevation, soil water content, soil water percolation, and stream flow.
- **Basin-Scale surface water – groundwater model development.** Construct a calibrated basin-scale surface water groundwater model to simulate the influence of managed aquifer recharge, restoration and other water management activities (e.g. canal piping, water conservation) on stream flows and groundwater resources. Such models are data intensive and would be enhanced by additional shallow aquifer elevation and seepage run data. The calibrated model can serve as a tool to evaluate manage aquifer recharge in the basin in addition to analyzing water use, resource availability, and management alternatives that can form the development of a water management strategy that meets the requirements for instream flow and provides water for irrigators.

6.2 Basin-wide Instream Leasing Program Development

A feasibility study to develop an instream leasing program to fallow annual crops in dry years would include the following steps.

- Identify and develop a water bank committee to establish goals and inform/direct the study
- Evaluate the options available for water bank structure and operations
- Assess the potential demand for water bank supplies (e.g. instream and irrigation).
- Assess the potential water bank supply
- Evaluate the market conditions and pricing against the water bank goals
- Develop the water bank operational framework
- Develop the water bank feasibility report

6.3 Forest Management & Roads Analysis

The combined impacts of forest management activities on water and sediment yield and timing could be evaluated using tools that were developed as part of the Basin Study. The Distributed Hydrology Soils Vegetation Model (DHSVM) developed as part of the study is an ideal modeling platform to investigate possible impacts. The DHSVM has been used in several locations throughout the Pacific Northwest to evaluate timber harvest and road drainage impacts at the watershed scale (e.g., Cuo et al. 2009; La Marche and Lettenmaier 2001; VanShaar et al. 2002). Most components of the model have been calibrated and documented, however, in order to accurately represent the effects of the road drainage system on stream flows it will be necessary to have field data on road drainage connectivity, and the condition of road drainage ditches, cross-culverts, and road surface conditions. Much of the initial characterization of the drainage network could be initiated using the LiDAR data sets available for almost the entire Hood River basin.

6.4 Conclusion

Critical to the implementation of these strategies will be the understanding and support from all Basin stakeholders. This will require continuing outreach to partners, water users, and the community at-large in order to effect management changes, as well as acquire financial support for implementing the likely suite of conservation actions, which is estimated to cost nearly $50 million. Existing partnerships provide a solid foundation for this. However, new partnerships will likely be necessary to expand the pool of funding sources and develop widespread adoption of water conservation practices.

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Action	Cost	Water Savings (cfs)	Period of impact	Miles of Habitat Impacted	$/CFS/river mile	Change in habitat area (%)								Quality of habitat impacted
						Bulltrout Spawning	Bulltrout Rearing	Chinook Spawning	Chinook Rearing	Coho Spawning	Coho Rearing	Steelhead Spawning	Steelhead Rearing	
Dee Irrigation District														
Sprinkler conversion	$444,000	1	May - Sep; most signif. in dry years	20.6	$21,553	0%	-0%	1%	0%	0%	-0%	-0%	0%	excellent
Conveyance: Additional piping	$1,436,000	1.5	Apr - Sep; most signif. in dry years	20.6	$46,472	0%	-0%	1%	0%	0%	-0%	-0%	0%	excellent
Implementation of all strategies	$1,880,000	2.5	See above	20.6	$36,505	0%	-0%	2%	0%	1%	-0%	-0%	0%	excellent
East Fork & Mount Hood Irrigation Districts														
Sprinkler conversion (EFID)	$6,489,600	15.4	May - Sep; most signif. in dry years	21.8	$19,330	n/a	n/a	52%	11%	15%	10%	1%	12%	good
Sprinkler conversion (MHID)	$466,800	1.1	May - Sep; most signif. in dry years	21.8	$19,466	n/a	n/a	3%	1%	1%	1%	0%	1%	good
Conveyance: Additional piping	$35,000,000	25.9	All year (most in summer); most signif. in dry years	21.8	$61,989	n/a	n/a	159%	4%	27%	2%	1%	14%	good
Regulating reservoir & telemetry	$269,000	8.85	All year (most in summer); most signif. in dry years	21.8	$1,394	n/a	n/a	53%	8%	19%	8%	0%	10%	good
Springtime spray and frost control diversions	$627,264	6.25	All year (most in summer); most signif. in dry years	21.8	$4,604	n/a	n/a	-	-0%	-	0%	-1%	-0%	good
New EFID POD on mainstem Hood River	$105,000	2.5	Apr - Sep; most signif. in dry years	8	$5,250	n/a	n/a	8%	2%	2%	2%	0%	2%	excellent
New EFID POD on Columbia River	$4,665,000	44.4	Apr - Sep; most signif. in dry years	21.8	$4,820	n/a	n/a	137%	7%	30%	3%	-0%	15%	good
New storage: East Fork Hood River effects	$17,000,000	21	Aug - Sep; most signif. in dry years	21.8	TBD	n/a	n/a	68%	13%	21%	12%	-	14%	excellent
New storage: Neal Creek effects	$17,000,000	-7	Dec - May during reservoir fill	19.4	TBD	n/a	n/a	n/a	n/a	-1%	-3%	2%	-1%	good
Implementation of all strategies	$41,956,400	42.4	See above	21.8	TBD	n/a	n/a	203%	-2%	30%	-4%	1%	11%	good
Farmers Irrigation District														
Sprinkler conversion	$877,200	1.9	May - Sep; most signif. in dry years	16.3	$28,324	n/a	n/a	5%	1%	3%	-1%	1%	1%	excellent
Hydropower rebalancing	TBD (low)	6.7	Jun - Oct (benefits), impacts in other months	16.3	TBD	n/a	n/a	14%	2%	6%	-2%	1%	3%	excellent
New/expanded storage	$1,740,000	3	Jul - Sep (benefits), impacts in other months	16.3	$35,583	n/a	n/a	5%	1%	3%	-1%	-	1%	excellent
Instream lease: hydropower	$79,380	20	Jul - Sep	16.3	$243	n/a	n/a	9%	1%	5%	-1%	-	2%	excellent
Implementation of all strategies	$2,696,580	31.6	See above	16.3	$5,235	n/a	n/a	30%	3%	10%	-4%	1%	7%	excellent
Middle Fork Irrigation District														
Sprinkler conversion	$5,152,800	12.2	May - Sep; most signif. in dry years	25.5	$16,563	36%	4%	90%	18%	41%	n/a	12%	29%	excellent
Hydropower rebalancing	TBD (low)	8.2	Jun - Oct (benefits), impacts in other months	25.5	TBD	48%	1%	83%	9%	31%	n/a	-13%	13%	excellent
New/expanded storage	$250,000	2	Jul - Sep (benefits), impacts in other months	25.5	$4,902	11%	2%	19%	4%	8%	n/a	-	6%	excellent
Instream lease: hydropower	$131,190	10	Jul - Sep	25.5	$514	35%	3%	71%	14%	39%	n/a	-	21%	excellent
Instream lease: voluntary fallowing	$52,500	1	Apr - Sep; most signif. in dry years	25.5	$2,059	5%	1%	10%	3%	4%	n/a	2%	4%	excellent
Implementation of all strategies	$5,586,490	33.4	See above	25.5	$6,559	53%	4%	160%	16%	71%	n/a	-1%	36%	excellent
Other/further research needed														
GW recharge: using existing infrasturcture	Variable	Variable	Benefit in summer; impact in remainder of year	<= 21.8	expensive	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	excellent
GW recharge: basin-scale restoration	Unknown	Unknown	Unknown	Unknown	Unknown	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	Unknown
Snowpack Augmentation	n/a	Unknown	Unknown	n/a	n/a	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	n/a
Croptype replacement	n/a	Very low	Impractical	n/a	n/a	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	n/a