Hood River Basin
Water Conservation Assessment

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Prepared for:

Hood River County
601 State Street
Hood River, OR 97031

Prepared by:

Niklas Christensen, PE, CWRE
Watershed Professionals Network LLC
701 June Street, Hood River, OR 97031
www.watershednet.com

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Executive Summary

The Hood River Basin (Basin) provides water to approximately 40,000 people, 26,000 acres of agriculture, and 16 native fish species. Due to population increases, a significant amount of irrigated agriculture in the Basin, and reduced streamflow being the primary factor inhibiting recovery of Endangered Species Act (ESA) listed fish, it is increasingly important to implement water conservation programs. The major water uses in the Basin are irrigation, drinking (potable) water, and hydropower. As described in this report, significant water conservation can be achieved in these three areas. Industrial water use is relatively minor; therefore, limited gains can be achieved through industrial water conservation. Similarly, although water is used for fish production, limited potential exists for reductions in this use.

Potable water conservation can be achieved through three primary pathways: retrofitting indoor fixtures (0.4 to 0.6 cubic feet per second [cfs] reduction of use), outdoor water reduction through education and landscape conversion (0 to 0.58 cfs reduction), and implementing a use-based rate structure (0.9 to 2.2 cfs reduction). In general, all potable water conservation actions should be implemented, as feasible, even though The Dalles, which uses 50 percent of the Basin's total potable water, reduces the effectiveness of conservation measures. This occurs for two reasons: 1) The Dalles is outside the Basin, so it has less economic and political will to implement conservation measures, and 2) The Dalles supplements its Basin water with groundwater in the summer; pumping groundwater is more expensive than drawing water from the Basin, so any reductions in The Dalles' overall water use would likely not affect its withdrawals from the Basin.

Irrigation diversions occur from April 15 through September 30 and peak at 235 cfs. Irrigation water conservation could be achieved through on-farm water conservation and eliminating losses in conveyance systems. On-farm use could be reduced by 16 cfs through a program converting 49 percent of remaining traditional irrigation systems (impact sprinklers) to more efficient systems (micro or rotator sprinklers and soil moisture sensors). Eliminating losses in conveyance systems would reduce irrigation use by 35 cfs. The biggest losses occur through end-spills and canal seepage within East Fork Irrigation District (EFID). 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. 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. Also, as with potable water, changes to water rate structure might encourage more efficient water use, but the economics of agriculture could make this approach difficult to implement.

Of the Basin irrigation districts, EFID has the most potential to achieve significant water conservation through operational changes. This could be accomplished by installing a regulating reservoir with telemetry and by eliminating its springtime diversion for spray water, which may be achieved by coordinating with Crystal Springs Water District to provide water for spraying. Middle Fork and Mount Hood irrigation districts (MFID and MHID) also have potential operational changes. MFID is considering a project to pipe its Coe Creek diversion to an existing sediment pond, which would allow Coe Creek water to be used during peak irrigation season. (Currently, turbidity is too high in the summer.) MHID could reduce or eliminate the overflows at the two locations where the district receives water from EFID. Although these overflows occur within MHID infrastructure, the likely solution for eliminating them is telemetry and a surge pond used by EFID.

Annual hydropower revenue could be increased by $17,700 in Farmers Irrigation District and $18,415 in MFID by implementing on-farm water conservation. While EFID's high flow rates would generate considerable power during irrigation season, the lack of flow outside of irrigation season makes the installation of a new hydropower facility economically infeasible.

The Hood River system has a high sediment load due to the considerable amount of glacial runoff it receives. Sediment causes wear on high-efficiency sprinklers and drip irrigation systems, reducing their efficiency and potentially dissuading some growers from converting to such systems. Sediment also causes wear on turbines in hydropower facilities, requiring more frequent maintenance and more frequent turbine replacement and, therefore, higher costs. For these reasons, additional sediment control measures should be implemented. The high flow rates in the Basin make active treatment technologies like chemical coagulation, electrical coagulation, and filtration impractical; therefore, physical settling should be targeted. EFID could develop a new settling basin, and MFID could improve its existing settling basin by installing silt curtains, as well as connect the Coe Creek diversion to the settling basin.

Conservation measures presented in this report should be evaluated in the context of their ability to increase instream flow while ensuring adequate irrigation and potable water supply. Since peak water demand is during irrigation season when streamflow is the lowest, water conservation projects should target this time of year. Information from the instream flow study being conducted by Normandeau Associates, as well as the climate change, groundwater, storage, and water supply study being conducted by the United States Bureau of Reclamation should be combined into a comprehensive, Basin-wide water conservation strategy.

1 Introduction

This report is in support of the Hood River Water Planning Group's Water Supply and Storage Feasibility Study (Study). The Study is being conducted through a $250,000 in-kind contribution from the United States Bureau of Reclamation (Reclamation) and a $250,000 grant to Hood River County from the Oregon Water Resource Department (OWRD). The Study is investigating the long-term reliability of the Hood River Basin (Basin) water resource system. Key focuses of the Study are water demands in the Basin; potential effects of climate change on water supply; and the ability of water conservation, groundwater use, or additional surface water storage to mitigate for any negative impacts from supply or demand changes in the future. This report builds off an analysis of existing water use in the Basin, which was documented by Watershed Professionals Network in the Hood River Basin Water Use Assessment (Watershed Professionals Network, 2013).

Water use in the Hood River Basin can be divided into the following categories: potable, irrigation, hydropower, and industrial. Potential water conservation opportunities are presented in this report for the first three; the fourth (industrial) is not discussed herein because it constitutes less than 1 percent of overall Basin water use. The major pathways to water conservation are evaluated within Section 2 (potable water), Section 3 (irrigation water), and Section 4 (hydropower). Estimates of the potential reductions in water use that can be achieved are provided, as well as cost estimates, where possible. Because existing sediment levels in the Hood River limit the potential for irrigation water conservation, Section 5 addresses sediment control.

This report serves as a stand-alone assessment and is also intended to inform water conservation scenarios evaluated by Reclamation in its water resource modeling. Results should be evaluated in the context of overall Basin goals to develop a comprehensive, Basin-wide water conservation strategy. This would include considering information from the instream flow study being conducted by Normandeau Associates, as well as a climate change and water supply study being conducted by Reclamation. Combining results from all three studies would help to optimize water conservation strategies that would mitigate climate change impacts as well as meet specific Basin needs, such as elevating stream flow in a particular stream reach at a particular time of year for certain fish species.

2 Potable Water Conservation

The Hood River watershed supplies potable water to seven water districts. Located within the Basin, Crystal Springs Water District, City of Hood River, and Ice Fountain Water District are the bigger ones, while Oak Grove Water Company, Parkdale Water Company, and Odell Water Company are much smaller. Located outside of the watershed (but drawing water from within) is the City of The Dalles. All the districts within the Basin receive their water from springs, while City of The Dalles receives its water from Dog River. Sections below detail existing water use; projected water use increases due to population growth; and potential indoor-, outdoor-, and rate-structure-based water conservation opportunities.

2.1 Existing Water Use

Existing (2013) water use for the seven potable water districts is shown below in Figure 1, Table 1, and Table 2. These existing water use values are based on data compiled from the Hood River Basin Water Use Assessment (Watershed Professionals Network, 2013).

2.2 Projected Water Use due to Population Change

Hood River County population forecasts (ECONorthwest, 2008) were used to estimate water use increases due to changes in population. These forecasts go to year 2040; however, the same trends were extrapolated out to year 2050 to facilitate using this data with climate projections from Reclamation's Basin Study. The average annual growth rate within the Hood River city limits is expected to be 2.0 percent, while the growth rate within rural areas is expected to be 0.8 percent, for a County-wide average of 1.29 percent). The Dalles is not within Hood River County and, therefore, not contained within the County population estimates, so the 2-percent growth rate used for the urban portion of Hood River County (i.e., City of Hood River) was used to project population in The Dalles.

Table 1 presents the estimated average annual population growth rate for each water district, current and projected number of user accounts, and current and projected water use. Table 2 shows current monthly use in the seven water districts, Table 3 shows projected monthly use in 2050, and Table 4 shows the estimated percent change in monthly use between 2013 and 2050. Figure 2 shows projected monthly use and Figure 3 shows a comparison between current (2013) and projected 2050 annual use. The percent change in water use does not increase at the same rate as population due to increases in development density (e.g. City of Hood River has 208 percent change in population but only a 152 percent change in water use). As such, water use estimates are based on scaling up indoor use by projected population increases and not scaling up outdoor use (indoor water use is estimated as the December through February average use since very little outdoor water use occurs during that time of year).

In Crystal Springs Water District, only 40 percent of diverted water goes to actual metered use, and the rest goes to overflows and system leakage (Crystal Springs Master Plan, 2006). Because of this, Crystal Springs Water District's full water use values are not scaled up, but only the 40 percent that goes to metered use. This results in the projected 34 percent increase in population only causing a 9 percent increase in water use (though even this may be an over-estimate as any increase in use should be able to be served through reducing overflows). The Dalles is unique in that it typically takes the full flow of Dog River at its diversion point during May through September (Larry McCollum, City of The Dalles, personal communications). Since The Dalles already takes the full flow of water, increases in population will not impact its Dog River diversion but will instead require it to pump additional groundwater from May to September each year to meet demand. Increases in population will, however, result in increased Dog River use during the other months of the year.

Table 1. Population growth rates, accounts, and water use for potable water districts served by the Hood River Basin for the period 2013 to 2050.

Water District	Growth Rate (%)	Accounts			Water Use		
		2013	2050	Change (%)	2013 (MG)	2050 (MG)	Change (%)
City of Hood River	2.0%	3,029	6,302	108%	394	597	52%
Crystal Springs	0.8%	2,238	3,005	34%	515	563	9%
Ice Fountain	0.8%	1,922	2,581	34%	180	222	23%
Oak Grove	0.8%	124	167	34%	18	22	23%
Odell	0.8%	147	197	34%	21	26	23%
Parkdale	0.8%	172	231	34%	25	31	23%
The Dalles[1]	2.0%	4,700	9,779	108%	1099	1,480	35%
Total	1.39%[1]	12,332	22,263	81%	2,252	2,942	31%

[1] The Dalles is not within the Basin; however, the city receives water from Dog River, which is a tributary to East Fork Hood River.

MG = million gallons

- All units CFS unless otherwise noted -

Table 2. Current potable water use served by the Hood River Basin.

Water District	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Avg.	MG/yr
City of Hood River	1.91	1.41	1.25	1.23	1.04	0.98	1.13	1.24	1.71	2.58	2.80	2.76	1.67	393.9
Crystal Springs	2.13	2.10	2.11	2.11	1.98	2.25	2.13	2.16	2.20	2.25	2.41	2.37	2.18	515.0
Ice Fountain	0.63	0.57	0.69	0.69	0.62	0.79	0.86	0.87	1.01	0.85	0.83	0.75	0.76	179.7
Oak Grove	0.06	0.05	0.04	0.04	0.05	0.05	0.09	0.12	0.13	0.09	0.10	0.09	0.08	18.2
Odell	0.06	0.06	0.05	0.05	0.06	0.06	0.11	0.14	0.16	0.11	0.12	0.11	0.09	21.4
Parkdale	0.08	0.07	0.06	0.06	0.07	0.07	0.13	0.16	0.19	0.13	0.14	0.13	0.11	25.3
The Dalles[1]	2.56	3.13	3.61	4.49	3.42	4.16	5.04	7.31	8.52	6.43	4.22	3.02	4.66	1098
Total	7.43	7.39	7.81	8.66	7.23	8.36	9.49	12.00	13.92	12.44	10.62	9.23	9.55	2252

[1] The Dalles is not within the Basin; however, the city receives water from Dog River, which is a tributary to East Fork Hood River.

MG/yr = million gallons per year

Table 3. Estimated year 2050 potable water use served by the Hood River Basin.

Water District	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Avg.	MG/yr
City of Hood River	2.77	2.27	2.11	2.09	1.90	1.84	1.99	2.10	2.57	3.44	3.66	3.62	2.53	597.3
Crystal Springs	2.63	2.59	2.60	2.60	2.44	2.77	2.63	2.66	2.71	2.77	2.97	2.92	2.69	563.1
Ice Fountain	0.78	0.70	0.85	0.85	0.76	0.97	1.05	1.08	1.25	1.04	1.02	0.92	0.94	221.7
Oak Grove	0.07	0.06	0.05	0.05	0.06	0.06	0.11	0.15	0.17	0.11	0.12	0.11	0.09	22.4
Odell	0.07	0.07	0.06	0.06	0.07	0.07	0.14	0.17	0.20	0.14	0.15	0.14	0.11	26.4
Parkdale	0.10	0.09	0.07	0.07	0.09	0.09	0.16	0.20	0.23	0.16	0.17	0.16	0.13	31.2
The Dalles[1]	4.43	5.43	6.26	7.78	5.93	7.22	8.75	*7.31*[2]	*8.52*[2]	*6.43*[2]	*4.22*[2]	*3.02*[2]	*6.27*[2]	1480
Total	13.42	11.21	12.01	13.51	11.26	13.03	14.83	13.67	15.64	14.10	12.32	10.90	12.99	2998

[1] The Dalles is not within the Basin; however, the city receives water from Dog River, which is a tributary to East Fork Hood River.

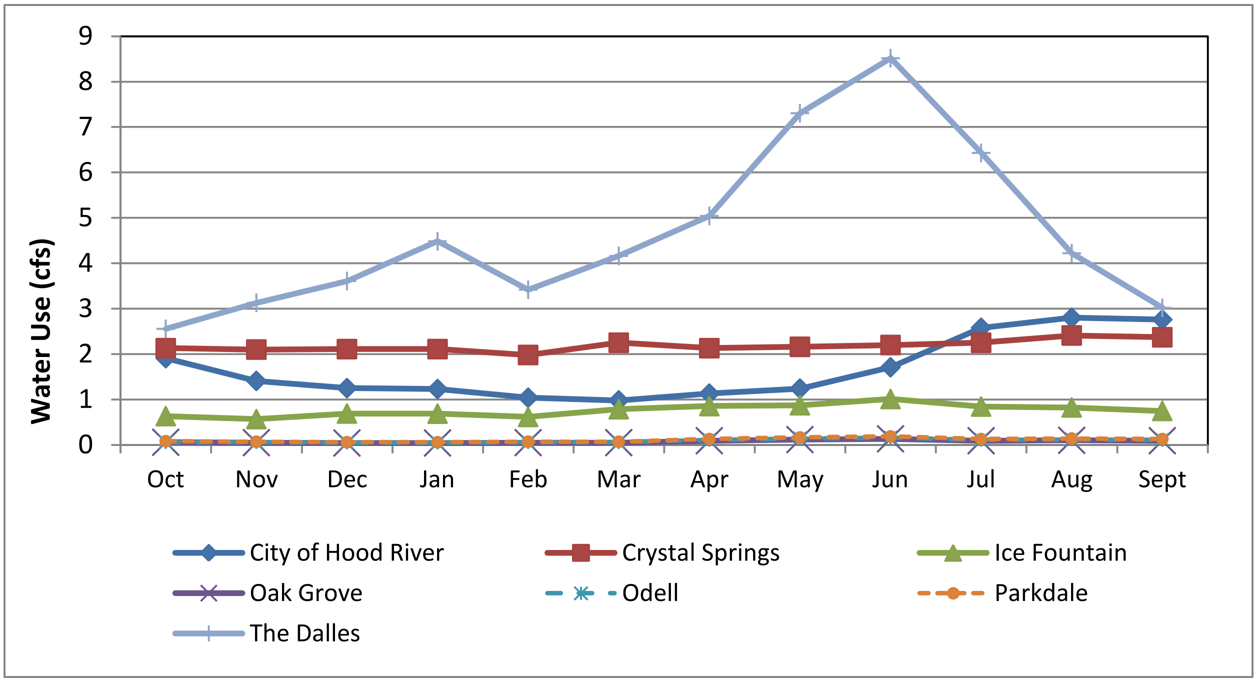
[2] May through September values not scaled up because increased demand during this period will be served by groundwater sources within The Dalles watershed.

Table 4. Percent change in potable water use served by the Hood River Basin[1] between 2013 and 2050.

Water District	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Avg
City of Hood River	145%	161%	169%	170%	183%	188%	176%	170%	150%	133%	131%	131%	152%
Crystal Springs	109%	109%	109%	109%	109%	109%	109%	109%	109%	109%	109%	109%	109%
Ice Fountain	123%	123%	123%	123%	123%	123%	123%	123%	123%	123%	123%	123%	123%
Oak Grove	123%	123%	123%	123%	123%	123%	123%	123%	123%	123%	123%	123%	123%
Odell	123%	123%	123%	123%	123%	123%	123%	123%	123%	123%	123%	123%	123%
Parkdale	123%	123%	123%	123%	123%	123%	123%	123%	123%	123%	123%	123%	123%
The Dalles[1]	173%	173%	173%	173%	173%	173%	173%	100%[2]	100%[2]	100%[2]	100%[2]	100%[2]	135%[2]
Total	142%	148%	150%	153%	152%	152%	153%	111%	110%	111%	113%	114%	131%

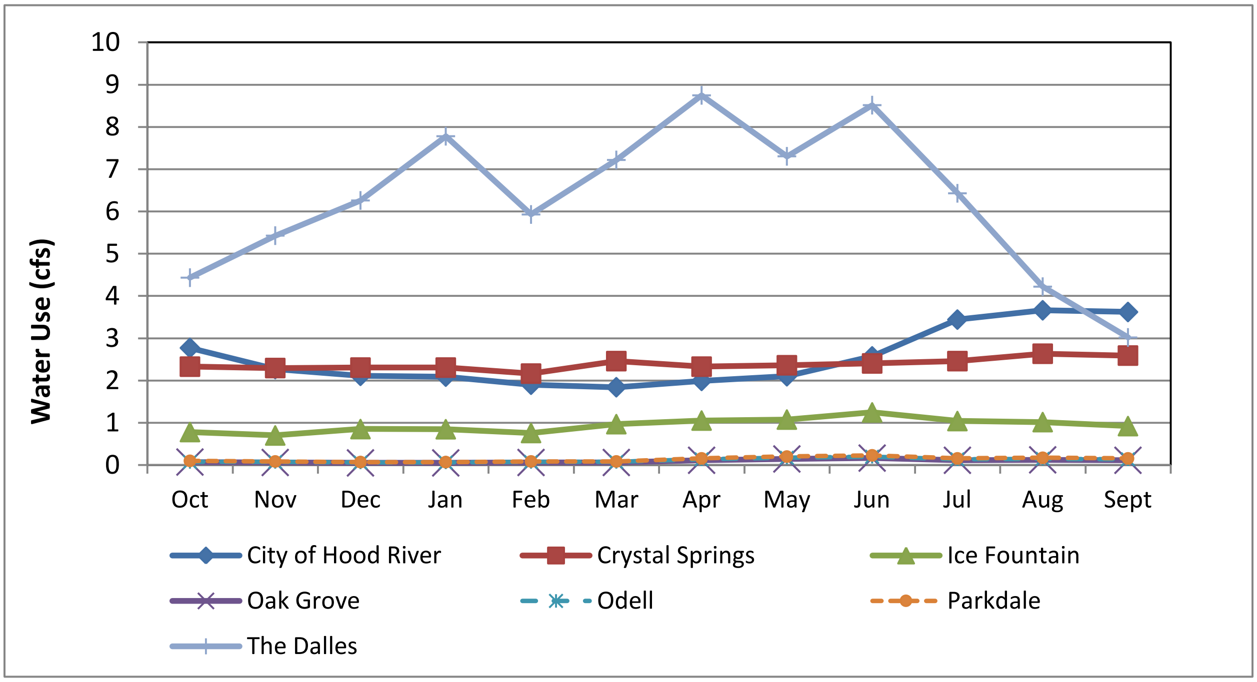
[1] *The Dalles is not within the Basin; however, the city receives water from Dog River, which is a tributary to East Fork Hood River.*

[2] *May through September values not scaled up because increased demand during this period will be served by groundwater sources within The Dalles watershed.*



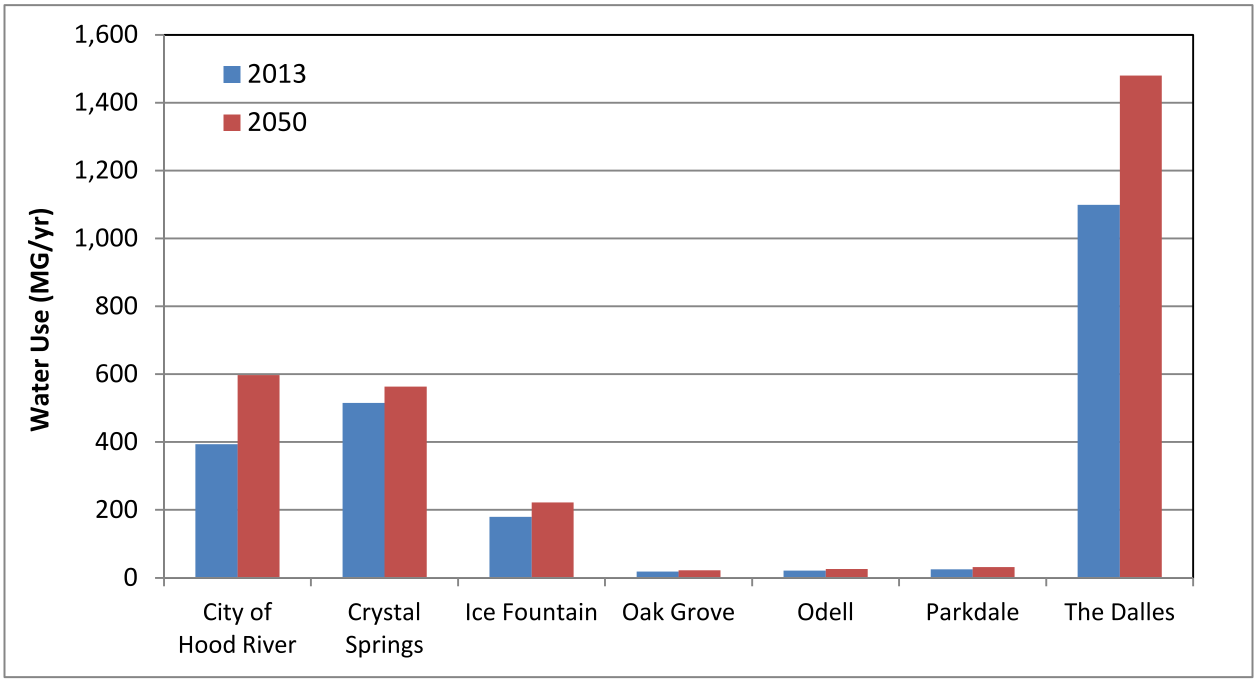
Notes: The Dalles is outside the Basin; however, the city receives water from Dog River, which is a tributary to East Fork Hood River.

Figure 1. Current potable water use in the Hood River Basin, by potable water districts[1].



Notes: The Dalles is outside the Basin; however, the city receives water from Dog River, which is a tributary to East Fork Hood River.

Figure 2. Projected year 2050 potable water use in the Hood River Basin, by water district[1].

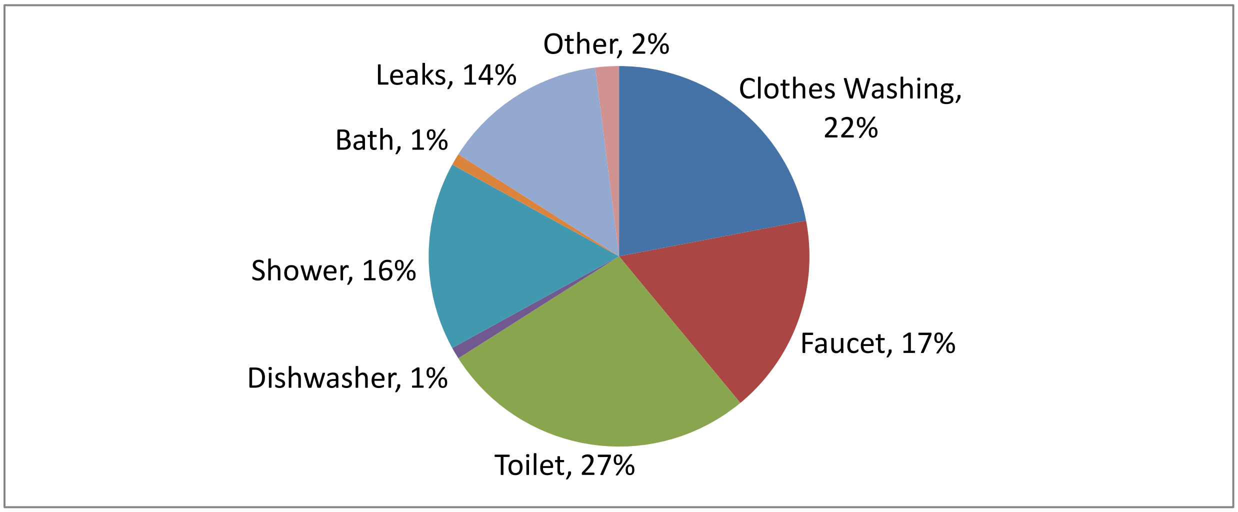


Notes: *The Dalles is outside the Basin; however, the city receives water from Dog River, which is a tributary to East Fork Hood River.*

Figure 3. Comparison of annual water use for years 2013 and 2050 for potable water districts served by the Hood River Basin.[1]

2.3 Indoor Water Conservation

Domestic indoor water use goes primarily to toilets, clothes washers, faucets, and showers (Figure 4, Colorado State University, 2010). Because these are the main users of indoor water, indoor water conservation is typically achieved through retrofitting these fixtures as well as rate structure incentives. For areas similar to Hood River County, retrofits typically focus on showerheads and toilets as they are the most cost-effective ways to achieve water conservation (Hood River, 2013). Areas that have greater water shortages (e.g., Las Vegas) will typically take this further and also actively pursue higher cost fixtures such as dishwashers and clothes washing machines. Although changes to rate structure affect indoor water use, they also affect outdoor use and are, therefore, evaluated in a separate section (Section 2.5) of this document.



Source: Colorado State University, 2010.

Figure 4. Locations of water use in the typical American household.

2.3.1 **High-Efficiency Toilets**

The amount of water conservation that can be achieved through a toilet retrofit program is dependent on the number of households having older, low-efficiency toilets, the number of homes that would convert to newer toilets, the amount of water used by older toilets, and the amount of water used by newer, high-efficiency toilets.

The year in which a home was constructed can indicate the type of toilets in the home. Building code changes in 1980 and in 1992 each required installation of higher-efficiency toilets. The City of Hood River Water Management and Conservation Plan (2013) reports that 53 percent of homes within the city limits were built before 1980, 14 percent were built between 1980 and 1992, and 33 percent were built after 1992 (Table 5). In the absence of detailed data on home construction in the rest of Hood River County, these same percentage estimates are applied to the other water districts analyzed.

Table 5. Population, accounts, people per account, and number of homes constructed by year for the potable water districts served by the Hood River Basin.

Water District	Population	Accounts	People/ Account	Homes built by Period		
				Pre-1980	1981-1992	Post-1992
City of Hood River	7,590	3,029	2.5	1,605	424	1,000
Crystal Springs	6,000	2,238	2.7	1,186	313	739
Ice Fountain	Not avail.	1,922	Not avail.	1,019	269	634
Oak Grove	315	124	2.5	66	17	41
Odell	Not avail.	147	Not avail.	78	21	49
Parkdale	Not avail.	172	Not avail.	91	24	57
The Dalles[1]	12,500	4,700	2.7	2,491	658	1,551
Total	Not avail.	12,332	2.6	6,536	1,727	4,070

[1] The Dalles is outside the Basin; however, the city receives water from Dog River, which is a tributary to East Fork Hood River.

Retrofitting homes built before 1980 with new, high-efficiency toilets would result in saving 57.2 gallons per household per day (gphd), while retrofitting homes built between 1980 and 1992 would result in savings of 20.8 gphd (Hood River, 2013). Although water conservation could be gained by replacing toilets in homes built after 1992, the gains would be small relative to pre-1992 homes. Therefore, any subsidies (which would likely be necessary for a successful retrofit program) should target older homes. Water savings presented in Table 6 are based on 70 percent of homes built before 1980 converting to new, low- flush toilets (57.2 gphd savings), 50 percent of homes built between 1980 and 1992 converting (20.8 gphd), plus an additional 10 percent of pre-1980 homes at the 20.8 gphd rate (assumes 20 percent of pre-1980 homes had converted to 1980-1992 technology, of which 50 percent now further convert to new low flow toilets).

Basin-wide, between 181,000 and 293,000 gallons per day could be saved based on this implementation rate, depending on the time of year (Table 6 and Figure 5). As discussed earlier, The Dalles takes the full flow of Dog River in the spring and summer, and supplements any deficit by pumping groundwater. Because groundwater is more expensive to pump, any reduction in water demand achieved by installing low-flow toilets would reduce the amount of groundwater pumped by the city but would not actually have any impact on the city's diversion from Dog River. The range of values presented in Table 6 rows "The Dalles" and "Total" reflect this, with the lower values representing May through September, and the higher values representing October through April.

Table 6. Number of homes participating in toilet retrofit program and resulting water reductions.

Water District	Number of Homes Participating	Water Conservation (gpd)		Total		
		From pre-1980 homes	From 1981-1992 homes	gpd	MG/yr	cfs
City of Hood River	1,496	64,279	7,749	72,028	26.3	0.111
Crystal Springs	1,106	47,493	5,726	53,219	19.4	0.082
Ice Fountain	949	40,787	4,917	45,704	16.7	0.071
Oak Grove	61	2,631	317	2,949	1.1	0.005
Odell	73	3,120	376	3,496	1.3	0.005
Parkdale	85	3,650	440	4,090	1.5	0.006
The Dalles[1]	2,322	0 - 99,740	0 - 12,024	0 -111,764	20.4	0 - 0.172
Total[1]	6,092	161,960 - 261,700	19,526 - 31,550	181,486-293,250	86.6	0.281 - 0.367

[1] The range of values presented in rows "The Dalles" and "Total" reflect The Dalles drawing groundwater in May through September; any water reductions from low-flow fixtures would go towards reducing groundwater use, not Dog River use.

gpd = gallons per day

MG/yr = million gallons per year

cfs = cubic feet per second

The cost of achieving the implementation rate and water savings described above can be estimated by multiplying the number of homes participating by the amount of subsidy that would need to be offered to each home (Table 7). A new, low-flow toilet costs approximately $300 plus $150 for installation. The Hood River Water Management and Conservation Plan (2013) estimates that a 50 percent rebate ($225 dollars per home) would need to be offered to achieve high participation in the program. If the City of The Dalles were included, the total cost of the program could be $1.37 million dollars. However, an argument can be made not to include The Dalles since a toilet retrofit program would not contribute to summer water conservation within the Hood River Basin. If The Dalles were not included, the total cost would be $850,000. Toilets have an estimated lifespan of 30 years, making the cost per 1,000 gallons conserved $0.43. The Dalles has a higher cost ($0.85 per 1000 gallons) since it has the same cost per toilet, but the Dog River diversion would only be reduced in October through April of each year.

Table 7. Number of homes, cost, water savings, and cost per savings for toilet retrofit program.

Water District	Number of Homes Participating	Cost	cfs	Cost/cfs	MG/yr	Cost/1000 gallons[1]
City of Hood River	1,496	$336,673	0.11	$3,022,857	26.3	$0.4269
Crystal Springs	1,106	$248,754	0.08	$3,022,857	19.4	$0.4269
Ice Fountain	949	$213,630	0.07	$3,022,857	16.7	$0.4269
Oak Grove	61	$13,783	0.00	$3,022,857	1.1	$0.4269
Odell	73	$16,339	0.01	$3,022,857	1.3	$0.4269
Parkdale	85	$19,118	0.01	$3,022,857	1.5	$0.4269
The Dalles	2,322	$522,405	0.09[2]	$6,045,714[2]	20.4	$0.8537
Total	6,092	$1,370,702	0.37	$3,734,510	86.6	$0.5274

[1] Cost per 1,000 gallons based on 30-year life of fixtures.

[2] Values for The Dalles based on annual averages.

cfs = cubic feet per second

MG/yr = million gallons per year

2.3.2 **Showerhead Exchange**

Water conservation gains from a showerhead exchange program can be quantified using methods similar to those used to evaluate toilet replacement. Older (pre-1980) showerheads are estimated to use 10 gallons per minute (gpm), conventional showerheads installed since 1980 consume 4.5 gpm, while current state guidelines require fixtures to consume 2.5 gpm or less. Based on number of residents per home (number) and typical length and frequency of shower, showerhead replacement would result in a 21 gallon per household per day (gphd) reduction for replacement of pre-1980 showerheads, and an 11.2 gphd reduction for replacement of post-1980 showerheads. Similar to the toilet exchange program, actual water savings would vary from 0.117 cubic feet per second (cfs) to 0.189 cfs depending on the time of year (Table 8 and Figure 5). Basin-wide, a total of 36.1 million gallons per year could be saved.

Table 8. Number of homes participating in showerhead retrofit program and resulting water reductions.

Water District	Number of Homes Participating	Water Conservation (gpd)		Total		
		From pre-1980 homes	From 1981-1992 homes	gpd	MG/yr	cfs
City of Hood River	1,836	23,666	6,366	30,033	11.0	0.046
Crystal Springs	1,356	17,486	4,704	22,190	8.1	0.034
Ice Fountain	1,165	15,017	4,040	19,057	7.0	0.029
Oak Grove	75	969	261	1,229	0.4	0.002
Odell	89	1,149	309	1,458	0.5	0.002
Parkdale	104	1,344	362	1,705	0.6	0.003
The Dalles	2,848	36,722	9,879	0 - 46,601	8.5	0- 0.072
Total	7,473	96,353	25,920	122,273	36.1	0.117 - 0.189

[1] The range of values presented in rows "The Dalles" and "Total" reflect The Dalles drawing groundwater in May through September; therefore, any water reductions from low-flow fixtures would go towards reducing groundwater use, not Dog River use.

gpd = gallons per day

MG/yr = million gallons per year

cfs = cubic feet per second

A showerheads exchange program would be much less expensive to subsidize than a toilet exchange program (Table 9). If a $50 rebate (which would cover the cost of most showerheads) were offered, the total cost would be $374,000. If The Dalles were left out, the cost would be $231,000. Showerheads have a typical lifespan of 15 years, making the cost per 1000 gallons of water conserved $0.56. As with the toilet exchange program, the cost would be higher in The Dalles since water savings would be achieved during only part of the year.

Table 9. Number of homes participating, cost, water savings, and cost per savings for showerhead retrofit program.

Water District	Number of Homes Participating	Cost	cfs	Cost/cfs	MG/yr	Cost/1000 gallons
City of Hood River	1,836	$91,779	0.0464	$1,976,324	11.0	$0.5582
Crystal Springs	1,356	$67,811	0.0343	$1,976,324	8.1	$0.5582
Ice Fountain	1,165	$58,237	0.0295	$1,976,324	7.0	$0.5582
Oak Grove	75	$3,757	0.0019	$1,976,324	0.4	$0.5582
Odell	89	$4,454	0.0023	$1,976,324	0.5	$0.5582
Parkdale	104	$5,212	0.0026	$1,976,324	0.6	$0.5582
The Dalles	2,848	$142,410	0.0721[2]	$3,952,649[2]	8.5	$1.1163
Total	7,473	$373,660	0.1891	$2,441,598	36.1	$0.6896

[1] Cost per 1,000 gallons based on 15-year life of fixtures.

[2] Values for The Dalles based on annual averages.

cfs = cubic feet per second

MG/yr = million gallons per year

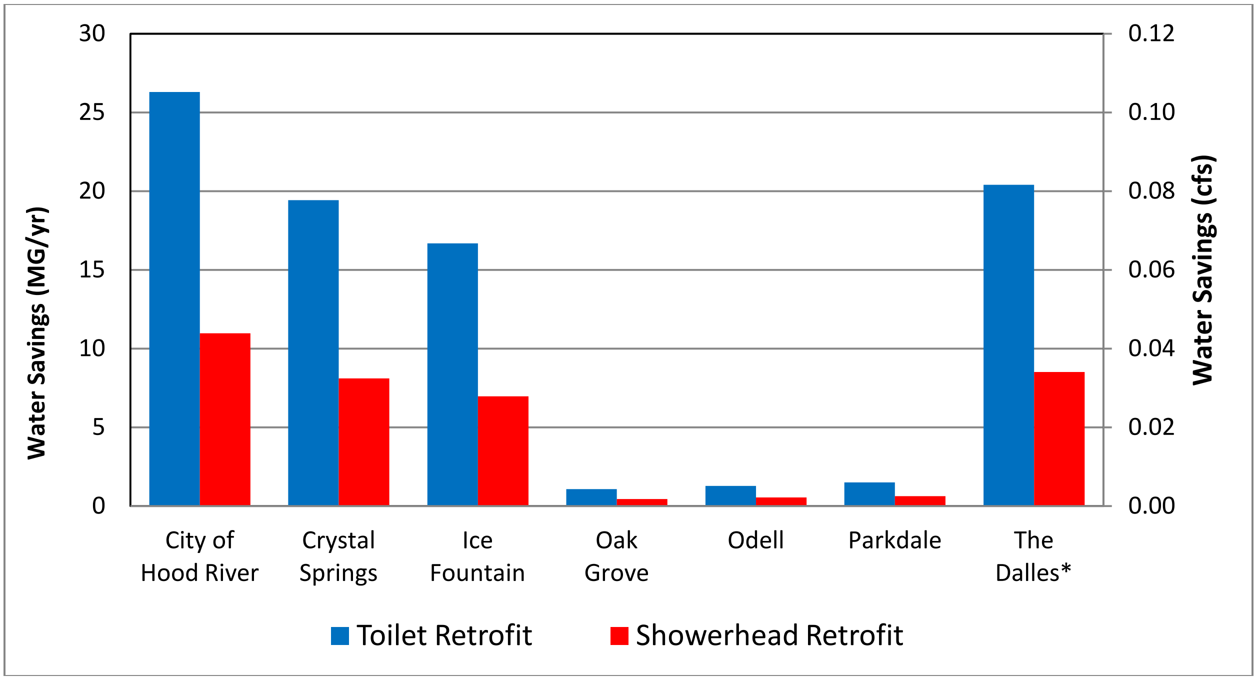


Figure 5. Annual (MG/yr) and instantaneous (cfs) water savings achieved through toilet and showerhead retrofits.

2.4 Outdoor Water Conservation

Outdoor water use accounts for around 30 percent of all residential use in the United States, of which up to 50 percent is estimated to be lost to evaporation and seepage (EPA, 2008). From a water conservation perspective, targeting outdoor use makes sense because it is highest in the summertime, which is typically when stream flow is the lowest. Cities or water districts typically use multiple pathways to reduce outdoor water use. The City of Portland, Oregon, for example, conducts public outreach campaigns, has water-efficient landscape demonstration projects, and conducts voluntary water audits, while Las Vegas, Nevada, performs most of the same activities as Portland and also pays residents $1/square foot to remove lawn. Because outdoor water conservation is accomplished through a host of methods, this report does not analyze individual methods but, instead, evaluates the overall water savings if outdoor water use were reduced by 25 percent. This value was chosen because it is at the high-end of what has been achieved in other areas (National Wildlife Federation, 2010).

Since none of the Basin's districts track the amount of water that is used outdoors versus indoors, outdoor water use is estimated by subtracting the average December through February use from each month's actual water use (Table 10 and Figure 6). Table 11 and Figure 7 show how much water would be saved if this use were reduced by 25 percent. The City of The Dalles is not shown because its summertime use is supplemented by other sources, and any reduction in its outdoor water use would translate into reduction from those sources instead of Dog River.

The estimates show that the City of Hood River has the highest outdoor water use in the Basin at 124 million gallons per year (MG/yr), while most of Crystal Springs and Ice Fountain are served with irrigation water and, therefore, have lower outdoor water usage of 25 to 30 MG/yr. Potential savings range from 31 MG/yr for the City of Hood River, around 7 MG/yr for Crystal Springs and Ice Fountain, down to 2 to 3 MG/yr for Odell Water District, Parkdale Water Company, and Oak Grove Water Company.

Table 10. Estimated outdoor water use for potable water districts in the Hood River Basin.

Water District	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	MG/yr	% of all
City of Hood River	0.74	0.24	0.08	0.06	0.00	0.00	0.00	0.07	0.54	1.41	1.63	1.59	124.4	32%
Crystal Springs	0.06	0.03	0.04	0.04	0.00	0.18	0.06	0.09	0.13	0.18	0.34	0.30	29.2	6%
Ice Fountain	0.00	0.00	0.03	0.02	0.00	0.12	0.19	0.21	0.35	0.18	0.16	0.08	26.3	15%
Oak Grove	0.01	0.01	0.00	0.00	0.01	0.01	0.05	0.07	0.09	0.05	0.06	0.05	7.7	42%
Odell	0.01	0.01	0.00	0.00	0.01	0.01	0.06	0.09	0.11	0.06	0.07	0.06	9.0	42%
Parkdale	0.02	0.01	0.00	0.00	0.01	0.01	0.07	0.10	0.12	0.07	0.08	0.07	10.7	42%
Total	0.84	0.29	0.15	0.12	0.02	0.32	0.42	0.63	1.34	1.94	2.33	2.14	207.4	18%

MG/yr = million gallons per year

Table 11. Potential outdoor water conservation for potable water districts in the Hood River Basin based on 25 percent use reduction.

Water District	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	MG/yr
City of Hood River	0.18	0.06	0.02	0.01	0.00	0.00	0.00	0.02	0.13	0.35	0.41	0.40	31.1
Crystal Springs	0.02	0.01	0.01	0.01	0.00	0.05	0.02	0.02	0.03	0.05	0.09	0.08	7.3
Ice Fountain	0.00	0.00	0.01	0.01	0.00	0.03	0.05	0.05	0.09	0.04	0.04	0.02	6.6
Oak Grove	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.01	0.01	0.01	1.9
Odell	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.01	0.02	0.01	2.2
Parkdale	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.03	0.02	0.02	0.02	2.7
Total	0.21	0.07	0.04	0.03	0.01	0.08	0.11	0.16	0.33	0.49	0.58	0.54	51.84

MG/yr = million gallons per year

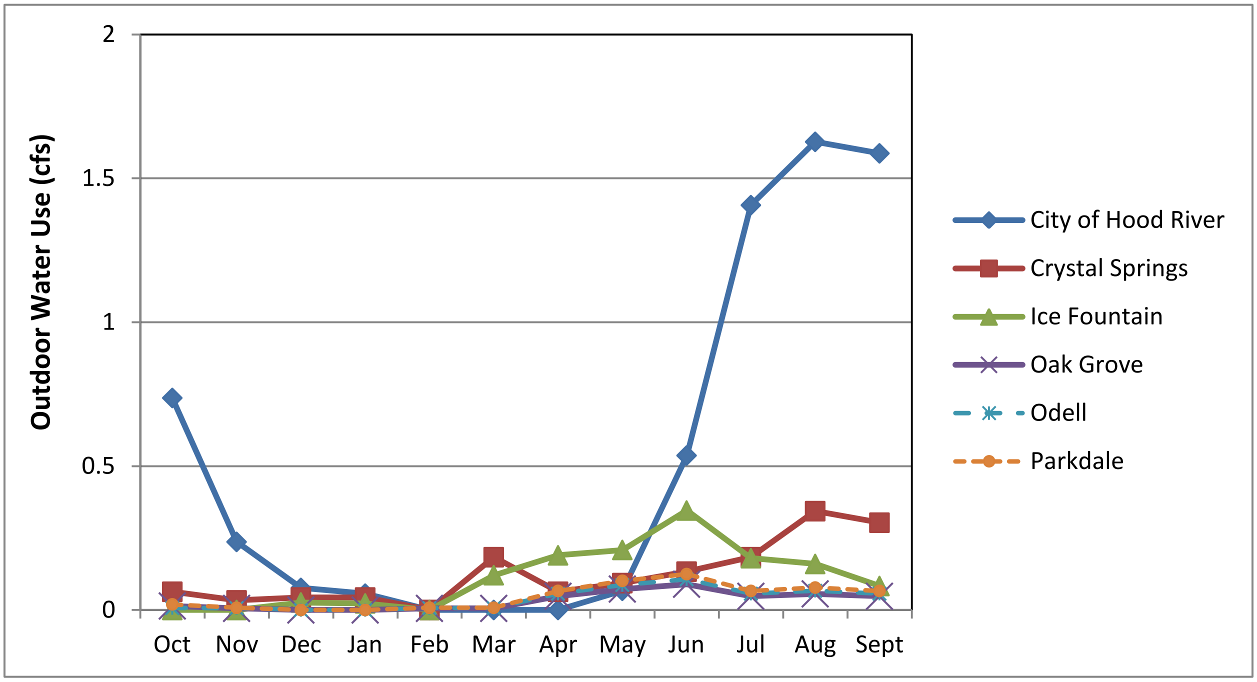


Figure 6. Existing outdoor water use for potable water districts in Hood River County.

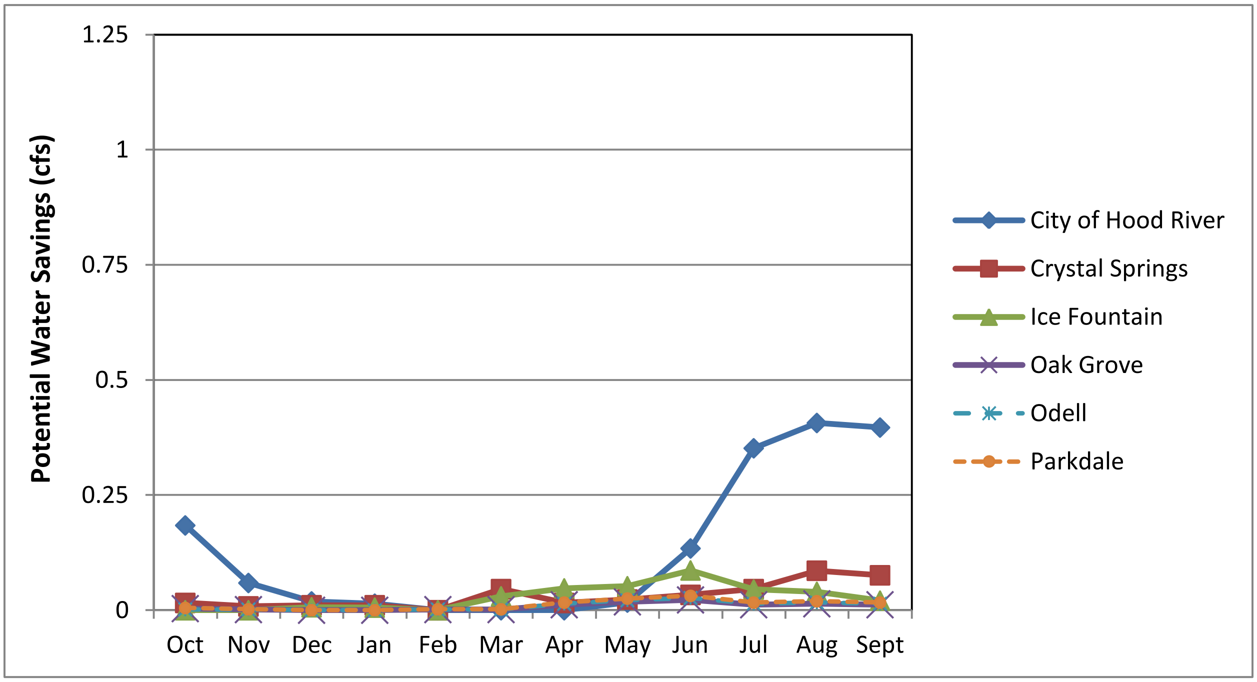


Figure 7. Potential outdoor water savings for potable water districts in Hood River County based on 25 percent reduction of existing use.

2.5 Use-Based Rate Structure

Increasing the cost of water is one of the most effective tools in changing long-term water use habits. This can be implemented through either changing the fixed base cost of water or through a progressive rate structure that charges water users a higher unit cost the more water they use. Both have the ability to substantially reduce water use without significant financial costs incurred by residents (cost of retrofitting fixtures) or by governments (cost of subsidies for retrofitting fixtures), but instead require some amount of political will or acceptance by voters.

Studies have shown a range of elasticity with price changes; however, it is generally accepted that the price change for short-term water use has an elasticity of -0.4 and that for long-term water use has an elasticity of -0.6 (Kenney, 2008). For a 25 percent change in rates, this would translate into a 10 percent decrease in short-term use (-0.4 x 25% = -10%) and a 15 percent decrease in long-term use (-0.6 x 25% = -15%). Table 12 and Figure 8 show an estimate of water reductions that could be achieved with a 25 percent rate increase.

It should be noted that this would be an aggressive and potentially politically unpopular increase; however it does show the upper end of what may be achieved. The City of Hood River currently has a declining block-rate structure: the cost is $28.74 for the first 5,000 gallons used ($5.748 per 1000 gallons), then $1.78 per 1000 gallons thereafter. The City has no current plans to make changes to its rate structure. Considering this, a progressive rate structure is unlikely to be implemented in the near future.

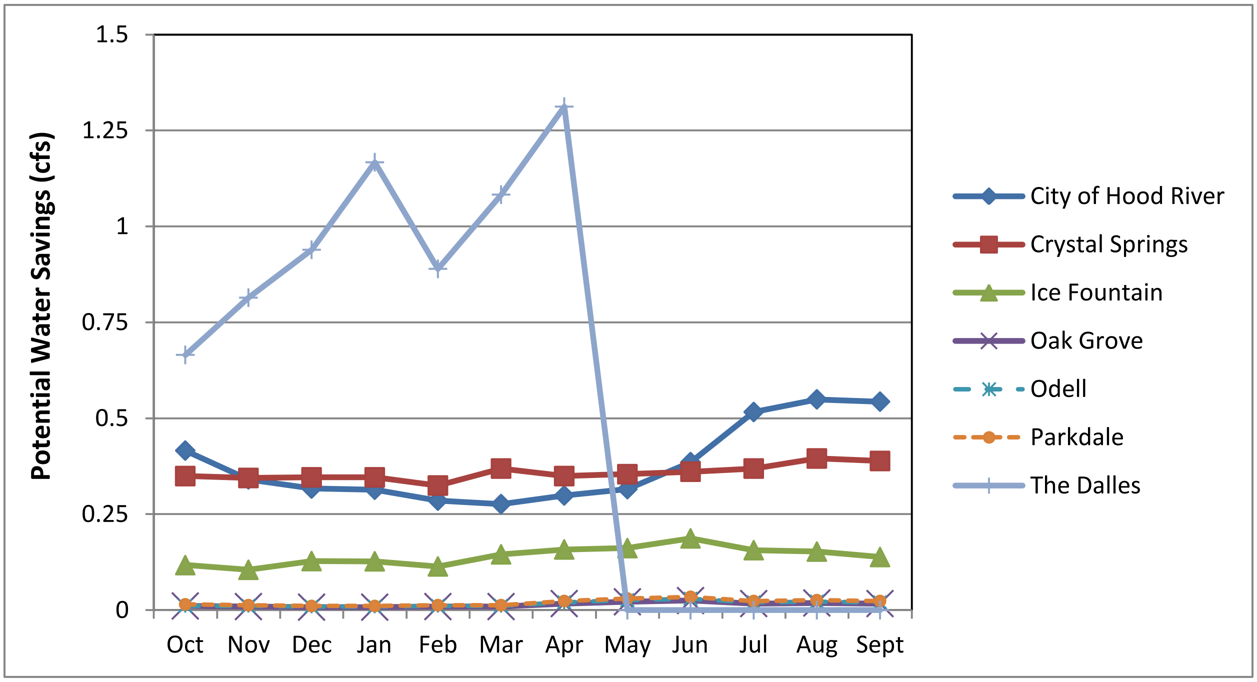


Figure 8. Potential water use reductions for potable water districts in the Basin based on a 25 percent rate increase.

Table 12. Estimated water use reductions (cfs) for potable water districts in the Basin based on a 25 percent rate increase.

Water District	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Avg
City of Hood River	0.42	0.34	0.32	0.31	0.29	0.28	0.30	0.32	0.39	0.52	0.55	0.54	0.38
Crystal Springs	0.35	0.34	0.35	0.35	0.32	0.37	0.35	0.35	0.36	0.37	0.40	0.39	0.36
Ice Fountain	0.12	0.11	0.13	0.13	0.11	0.15	0.16	0.16	0.19	0.16	0.15	0.14	0.14
Oak Grove	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.01
Odell	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.03	0.02	0.02	0.02	0.02
Parkdale	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.03	0.02	0.03	0.02	0.02
The Dalles	0.67	0.81	0.94	1.17	0.89	1.08	1.31	0.00	0.00	0.00	0.00	0.00	0.57
Total	1.58	1.64	1.76	1.98	1.65	1.91	2.18	0.91	1.02	1.10	1.16	1.13	1.50

cfs = cubic feet per second

2.6 Discussion

Of the water conservation strategies described in Section 2, rate structure changes have the greatest potential to reduce potable water use (Figure 9 and Table 13). (Water conservation estimates shown in Figure 9 and Table 13 are based on assumptions described previously in Section 2). Rate structure changes do not have any associated capital cost, but they may be politically difficult to implement (especially in The Dalles, as described below). Reductions in outdoor water use would have negligible impacts in the winter but just over 0.5 cfs in the summer. Toilet and showerhead retrofit programs, combined, would result in 0.56 cfs reductions in winter and 0.4 cfs reductions in summer. However, such programs are typically implemented to ensure adequate potable water supply and, because of their cost, they are not often implemented as a basin-wide water conservation strategy.

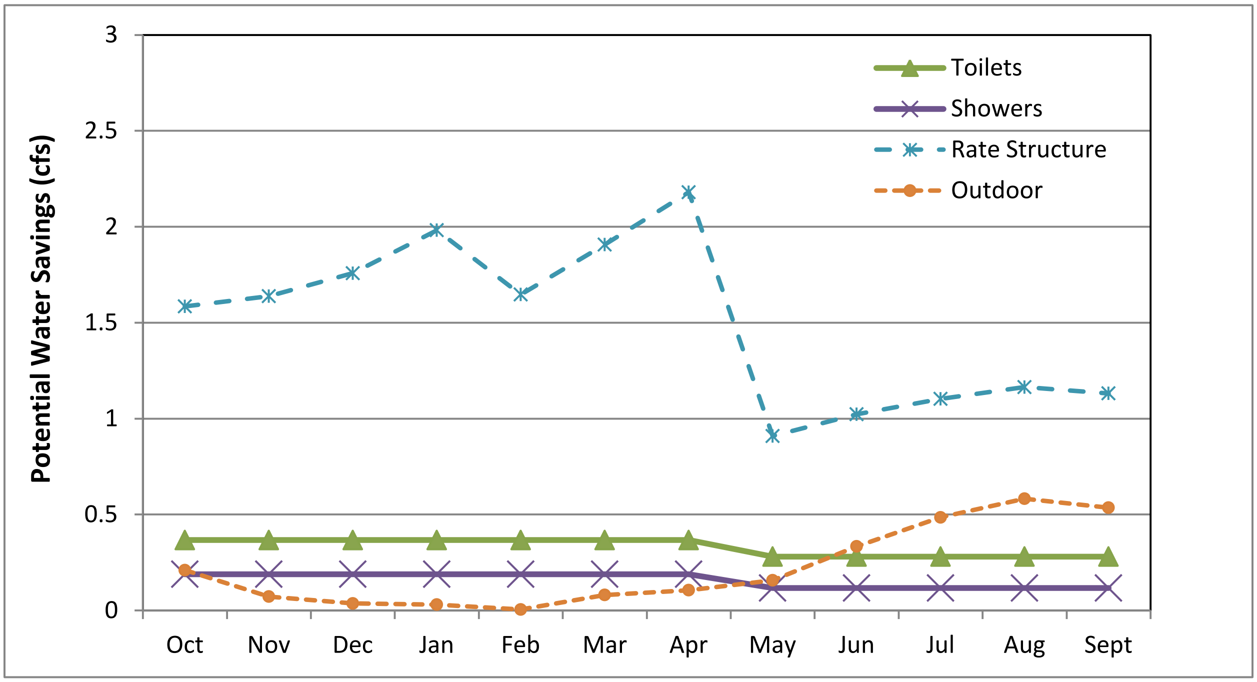


Figure 9. Water savings achievable from conservation measures.

The City of The Dalles is the single largest user of potable water from the Hood River Basin, using 50 percent of all potable water used in the Basin each year. This will limit the effectiveness of potable water conservation in the Basin; any water conservation measure implemented without them will result in significantly diminished returns. This will occur for two reasons. The first is The Dalles relies on additional (more expensive) groundwater sources in the summer, so any water conservation achieved in The Dalles reduces the City's consumption of that source and leaves its withdrawal of Hood River Basin water essentially unchanged. For example, Figure 9 shows that a progressive rate structure is the most effective water conservation tool; however, its effectiveness drops off in May when The Dalles begins to supplement Dog River water with groundwater. Also, because The Dalles is outside of the Hood River Basin, there may be less political and economic will in The Dalles to implement water conservation measures that would benefit the Basin.

Table 13. Current water use, estimated year 2050 water use, and potential water conservation measures.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	MG/yr	% of savings
Current Use	7.4	7.4	7.8	8.7	7.2	8.4	9.5	12.0	13.9	12.4	10.6	9.2	2252.3	
2050 Use	10.6	10.9	11.7	13.2	11.0	12.7	14.5	13.4	15.3	13.8	12.0	10.6	2942.2	
Toilets	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.28	0.28	0.28	0.28	0.28	78.1	15%
Showers	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.12	0.12	0.12	0.12	0.12	37.5	7%
Rate Structure	1.58	1.64	1.76	1.98	1.65	1.91	2.18	0.91	1.02	1.10	1.16	1.13	354.4	68%
Outdoor	0.21	0.07	0.04	0.03	0.01	0.08	0.11	0.16	0.33	0.49	0.58	0.54	51.8	10%
Total	2.4	2.3	2.4	2.6	2.2	2.5	2.8	1.5	1.8	2.0	2.1	2.1	521.8	100%

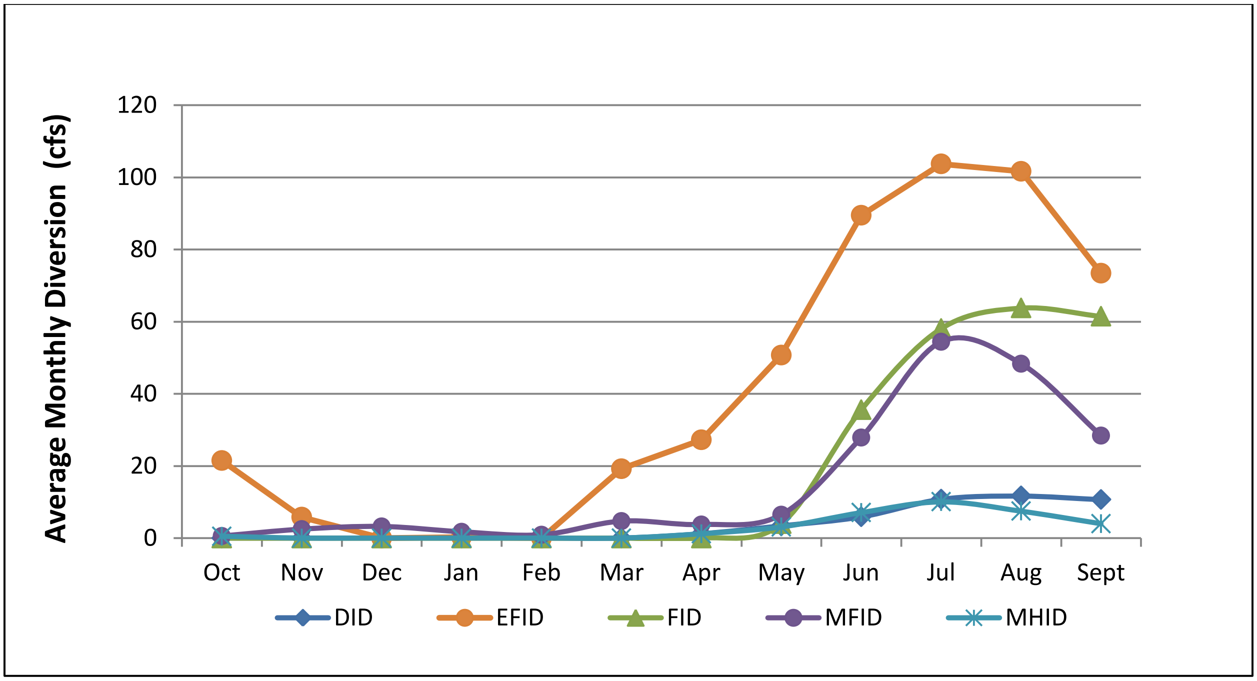
Note: All units are cubic feet per second (cfs) unless otherwise noted.

MG/yr = million gallons per year

3 Irrigation Water Conservation

The irrigation season in Hood River County is from April 15 through October 1. At its peak, irrigation diverts up to 235 cfs from Hood River. Because its peak diversions are so high (15 times that of potable water diversions), small reductions in irrigation use would result in significant water savings. It should be noted that, although these savings can be high during the summer, they have very limited ability to affect stream flows outside of irrigation season. The exception to this is the filling of Laurance Lake and Green Point Reservoir, which can reduce stream flow while they are filling.

Figure 10 shows the average irrigation and agricultural diversions, by month, for the irrigation districts in the Hood River Basin. Those districts include: Dee Irrigation District (DID), East Fork Irrigation District (EFID), Farmers Irrigation District (FID), Middle Fork Irrigation District (MFID), and Mount Hood Irrigation District (MHID).



Note: Does not include any water used for hydropower.

Figure 10. Average monthly irrigation plus agricultural diversion for irrigation districts in the Hood River Basin.

Irrigation water use can be reduced through four primary pathways: 1) reducing on-farm use through conversion to more efficient sprinklers and the use of soil moisture sensors, 2) replacing open canals with pipe to reduce seepage and overflows, 3) having a use-based rate structure, and 4) operational changes. Potential water reductions achievable through each of these methods, actual crop needs, and the likely benefits from conserved water are discussed below.

3.1 Irrigation Water Demand

The objective of irrigation water use is to satisfy crops' evapotransporative (ET) demands. As such, an irrigation system that has no overflows or canal seepage, and that applies just the correct amount of water to the crops, should be able to use the same amount of water as published crop ET requirement tables. Reclamation's AgriMet website (http://www.usbr.gov/pn/agrimet/) publishes crop- and location-specific ET data for major crops in the United States, of which values for Hood River are presented in Table 14 and Figure 11. These values are specific to irrigation season (i.e., full bloom through 3 to 4 weeks after harvest) and can, therefore, be compared directly against irrigation water use.

For pears (the most common crop type grown in the Hood River Basin), the growing season ET demand ranges from 20.6 inches in Dee Flats up to 25.8 inches near the City of Hood River. Currently, this demand is met by both precipitation and irrigation water supply. During April through October, Hood River receives 7.75 inches of precipitation on average, of which a majority goes to meet ET demands and the rest runs off as overland flow. Assuming an average ET demand for pears of 23.3 inches (see Table 14), and assuming 70 percent of precipitation goes to meet ET demand (5.4 inches), then the remaining ET demand for pears that must be met by irrigation supply would be 17.9 inches. Although each crop type and each part of the Hood River Basin has specific ET demands this value of 17.9 inches (1.49 feet) is a reasonable approximate goal for on-farm water use, given that pears are the most common crop in the Basin. For reference, typical irrigation water rights are 3.0 feet per year, which is roughly double the AgriMet calculated ET demand.

Table 14. Crop evapotranspiration demand in inches per growing season.

	Dee Flats[1]	Hood River[2]	Pine Grove[3]	Parkdale[4]	Average
Alfalfa	29.9	32.5	30.3	30.7	30.9
Pasture	24	25.8	24.2	24.4	24.6
Lawn	28.8	31.2	29.2	29.5	29.7
Apples	26.7	30.2	26.6	28.2	27.9
Pears	20.6	25.8	22.3	24.3	23.3
Cherries	28.5	32.7	28	29.7	29.7
Wine Grapes	n/a	20.7	18.8	18.8	19.4
Blueberries	29.2	33.6	29.5	30.3	30.7

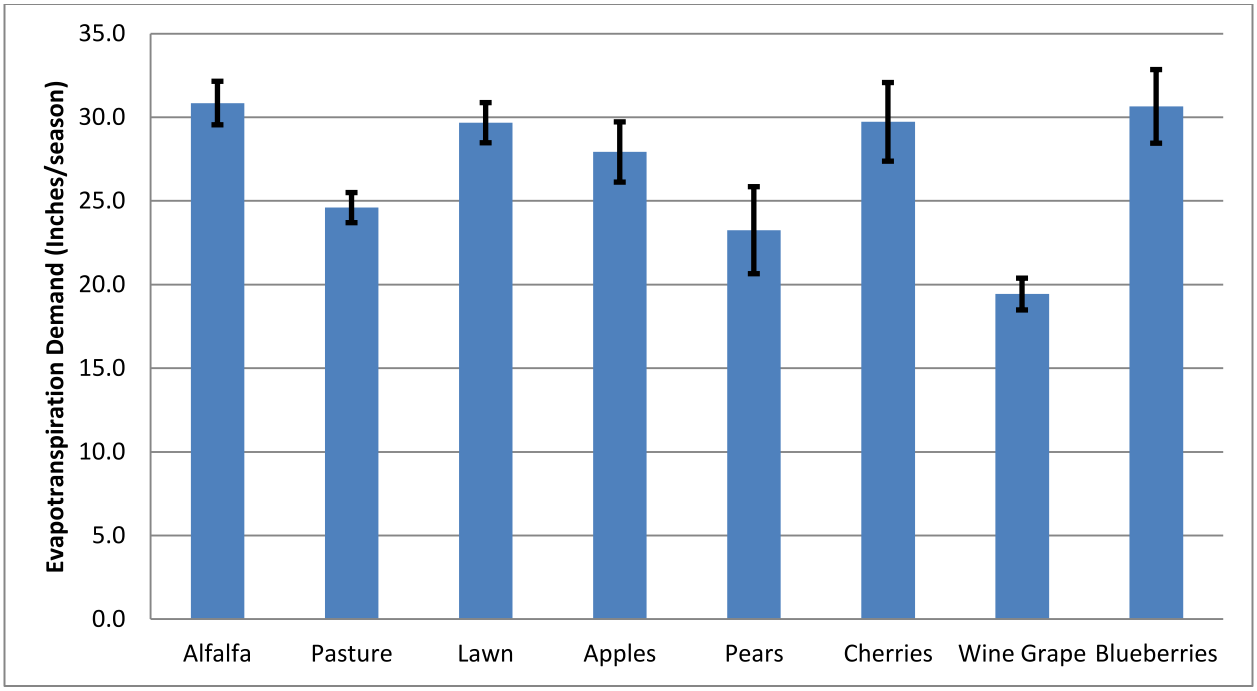
Source: Reclamation, 2013.

[1] *Dee Flat station is located on the north end of the flat.*

[2] *Hood River station is at the OSU Extension Office.*

[3] *Pine Grove station is just south of the Pine Grove Grange Hall.*

[4] *Parkdale station is near Old Parkdale Rd and Woodworth Rd.*



Note: Error bars show range from Table 14.

Figure 11. Average Hood River Basin growing season crop evapotranspiration values.

3.2 Sprinkler Conversion and Soil Moisture Sensors

Older, traditional irrigation systems typically consist of hand lines (moved by hand) or wheel lines (the actual line sits on wheels) with impact sprinklers on them, while newer, upgraded systems typically consist of micro or rotator sprinklers with poly-tubes. The newer systems use considerably less water than the older impact-sprinkler systems; therefore, converting any acreage under the older systems to the newer ones would result in reducing overall water use. Quantifying the actual amount of water that can be conserved is dependent on annual water use of each type of sprinkler, the amount of acreage using each type of sprinkler, and how much acreage is converted to more efficient systems. Each of these three variables is discussed further below.

Two recent studies have documented water use by each application method specifically in Hood River County. The Hood River Soil and Water Conservation District (SWCD) measured water use on 32 farms from 2010 to 2013 as part of the Hood River Irrigation Upgrade Flow Meter Monitoring study (Hood River SWCD, 2013). This study found that water use on the one hand line monitored for the study was 3.64 feet per year, while water use on the upgraded systems averaged 1.55 feet per year. A separate study performed by Irrinet and FID from 2006 to 2007 monitored water use on 10 irrigation systems (Irrinet, 2007). This study monitored older systems before and after upgrading and, therefore, has 10 water use measurements for conventional systems and 10 water use measurements for upgraded systems. Results from the SWCD and Irrinet studies (Table 15) were averaged based on sample size and are used in the calculations throughout this section of this report.

It should be noted that in Section 3.1, crop irrigation demand was calculated to be 1.49 feet and, therefore, the actual measured use of micro-sprinklers (newer irrigation systems) coupled with soil moisture sensors is fairly close (within 0.5 inch) to the minimum amount of water that should be applied. Water required for spray is not included in the irrigation demand calculations; however, it is equal to only approximately 0.003 feet per acre—an estimate based on spraying pears, which assumes 8 to 10 applications using 100 gallons per acre for each application (Brian Nakamura, EFID, personal communications).

The water use calculations in this section are for on-farm use only and do not always match measured water use in each of the districts. In DID, for example, Table 17 shows calculated existing use as 1,699 acre-feet per year; however, actual measured use in DID is 2,966 acre-feet per year. Although this difference (1,267 acre-feet per year) is quite significant, it is almost entirely attributable to losses in the DID system. The measured water use data includes 4.5 cfs of losses (3 cfs in conveyance system plus 1.5 cfs of overflows) which, over the course of irrigation season, adds up to 1,100 acre-feet. Taking this into account, the 1,699 acre-feet per year of on-farm use plus the 1,100 acre-feet per year of losses is within 167 acre-feet per year (6 percent) of actual measured use. The remaining difference (180 acre-feet per year) is likely from a combination of overestimating the amount of acres using upgraded systems, underestimating water use of a particular application method, or there being additional canal or overflow losses.

Table 15. Sprinkler types, water use, and sample size from Hood River SWCD (2013) and Irrinet (2007) studies.

Sprinkler System		Sample Size		Notes
Type	Efficiency (ft/yr)	SWCD Study	Irrinet Study	
Wheel line / Impact	3	0	0	Set at full water right based on feedback from irrigation district managers.
Hand line / Solid set impact	2.39	1	10	One estimate of 3.64 feet from SWCD and 10 estimates averaging 2.25 feet from Irrinet study.
Rotator / Micro	1.53	32/10[1]	10	Based on average of 1.51 feet from Irrinet study and average of 1.55 feet from SWCD study.
Drip	1.4	0	1	Based on one system from Irrinet study.

[1] *SWCD study based on 32 farms, however, only the 10 farms that had "medium" water management practices were used in calculating averages.*

ac-ft/yr = acre-feet per year

SWCD = Hood River County Soil and Water Conservation District

The method used for determining the amount of acreage under each application method varied among the irrigation districts and is, therefore, discussed in more detail within each irrigation district's applicable section. For estimating the amount of acreage that could be converted from older systems to upgraded systems, each irrigation district manager was solicited for input on what they thought a reasonable conversion rate could be. Although estimates from each manager varied, the general consensus was that an aggressive program could result in converting 49 percent of acreage in 10 years (this rate was based on compounding a 20 percent conversion rate every 3.33 years to 10 years). This rate may be considered an optimistic percentage of acreage to convert in 10 years; however, the results below are based on the 49 percent value only—even if the conversion takes more time, the calculated water savings are still valid.

Estimates are also presented below for what it would cost within each district to convert a given amount of acreage to a more efficient irrigation system. These costs are based on the Irrinet study (Irrinet, 2007), which concluded that the average cost of a new system would be $1,200 per acre (based on $6/tree and average orchards having 200 trees/acre). Although not analyzed herein, 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.

3.2.1 **Dee Irrigation District**

To obtain an estimate of the existing amount of acreage using each application method, values in the Dee Irrigation District Potential System Improvements study (Farmers Conservation Alliance, 2008) were averaged with estimates obtained from the DID manager in 2013 (Table 16 and Figure 12). Averaging these two sets of data results in an estimate of 370 acres under conventional impact sprinklers, 370 acres under upgraded systems, and 130 acres using drip systems.

Table 16. Estimates of Dee Irrigation District sprinkler types by acreage.

Irrigation System	Estimate from Dee Irrigation District	Estimate from Farmers Conservation Alliance	Best Estimate	
	Acres	%	%	Acres
Wheel line	0	0	0	0
Hand line/ Impact	270	588	42.5%	370
Micro/Rotator	470	282	42.5%	370
Drip	130	0	15%	130
Total	870	100	100	870

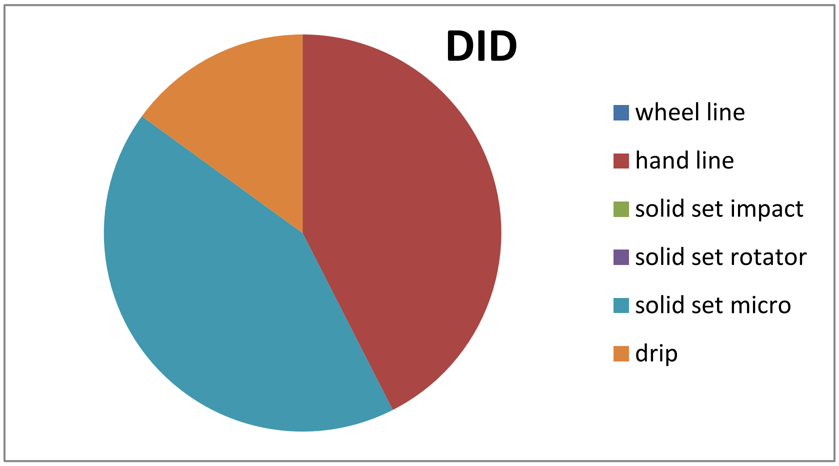


Figure 12. Estimate of Dee Irrigation District sprinkler systems by acreage.

Based on the data above and DID converting 49 percent of its area under impact sprinklers, DID can reduce its acreage using impact sprinklers from 370 acres to 189 acres while increasing the acreage using upgraded systems from 370 acres to 551 acres (Table 17). This shift of 181 acres would reduce DID's water use by 155 acre-feet per year, or 0.5 cfs during irrigation season (Table 18). As noted above, DID's calculated water use in Table 17 of 1,632 acre-feet per year is less than its actual measured use; however, the difference is almost entirely attributable to canal losses and overflows that are included in DID's measured use.

Table 17. Dee Irrigation District sprinkler conversion water reduction calculation.

Sprinkler System		Existing Conditions		Conservation Scenario		Notes
Type	Efficiency (ft/yr)	Acres	Use (ac-ft/yr)	Acres	Use (ac-ft/yr)	
Wheel line	3	0	0	0	0	None (or small amount) in DID.
Hand line / Solid Set Impact	2.389	370	884	189	453	Assumes 49% reduction over 10 years.
Micro / Rotator	1.53	370	566	551	842	Acreage increased to account for shift from impact sprinklers.
Drip	1.4	130	182	0	182	None (or small amount) in DID.
Total of above		870	1,632	870	1,477	

ac-ft/yr = acre-feet per year

Table 18. Summary of Dee Irrigation District on-farm water reduction based on Table 17.

Total Acreage (ac)	870	
Acres Converted (ac)	181	
Calculated Existing Use	1.88 ft/yr	Calculated as existing use based on Table 17.
Calculated Projected Use	1.70 ft/yr	Calculated as projected use based on Table 17.
Water Savings (%)	9.5%	Based on annual reduction in Table 17.
Water Savings (ac-ft/yr)	155 ac-ft/yr	Based on annual reduction in Table 17.
Water Savings (cfs)	0.5 cfs	Based on dividing reduction over May – September.
Cost ($)	$217,200	Based on $1,200/acre from Irrinet (2007) study.

3.2.2 East Fork Irrigation District

Estimates for acreage under different sprinkler types in EFID are based on a survey sent out by EFID in 2008 as well as calling land owners in spring 2013 who had not responded to the 2008 survey. The 2008 survey covered 4,653 acres, while the follow-up in 2013 added another 1,719 acres (totals from both surveys contained in column "Survey" in Table 19). After scaling up these values to account for missed acreage, it is estimated that 361 acres in EFID are wheel lines with impact sprinklers; 2,857 acres are hand lines with impacts; 2,551 acres are solid set impacts; 1,106 acres are solid set rotators; 2,086 acres are solid set micros; and 188 acres have drip systems (Table 19 and Figure 13).

Table 19. Estimates of East Fork Irrigation District sprinkler types by acreage.

Irrigation System	Survey		Correction	Best Estimate	
	Acres	%	Acres	%	Acres
Wheel line/ Impact	251	3%	361	4%	361
Hand line/ Impact	1,990	22%	2,857	31%	2,857
Solid set impact	1,776	19%	2,551	28%	2,551
Solid set rotator	770	8%	1,106	12%	1,106
Solid set micro	1,453	16%	2,086	23%	2,086
Drip	131	1%	188	2%	188
Unaccounted for	2,777	30%			
Total	6,372		9,149		9,149

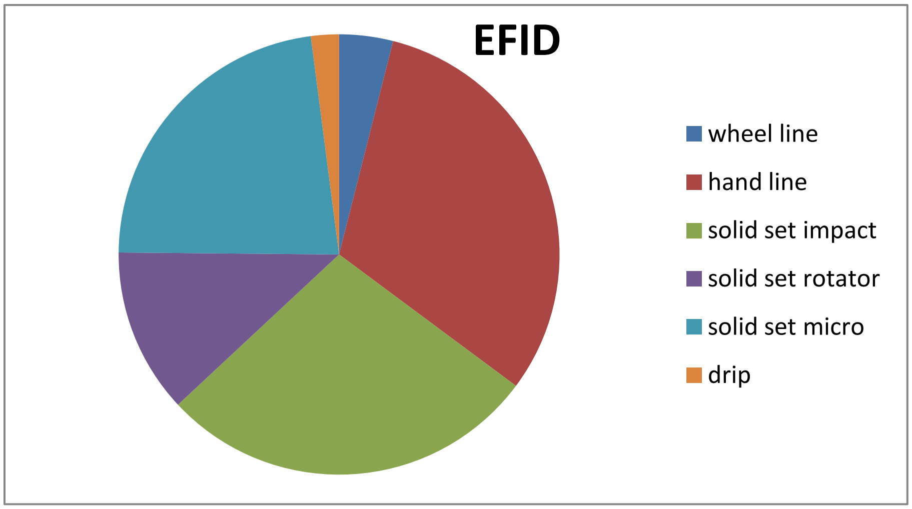


Figure 13. Estimate of East Fork Irrigation District sprinkler systems by acreage.

Based on estimates of acreage from Table 19 and the 49 percent conversion rate, 2,639 acres in EFID would be converted from using impact sprinklers to upgraded rotator and micro systems (Table 20). Although the acreage using wheel lines would remain fairly constant, since they are used for hay and installations of micro sprinklers is impractical, it would decrease by 19 acres to account for a 10 percent increase in drip systems. The conversion of 2,658 acres would result in conserving 2,297 acre-feet per year (subtracting 16,582 from 19,149 in Table 20). This 2,297 acre-feet conserved is 12 percent of EFID's calculated water use, which, divided out over May through September, equals a constant savings of 7.6 cfs (Table 21). Based on the cost estimate of $1,200 per acre from the Irrinet study (2007), converting the 2,297 acres of impact sprinklers to upgraded systems would cost roughly $2,756,000.

Table 20. East Fork Irrigation District sprinkler conversion water reduction calculation.

Sprinkler System		Existing Conditions		Conservation Scenario		Notes
Type	Efficiency (ft/yr)	Acres	Use (ac-ft/yr)	Acres	Use (ac-ft/yr)	
Wheel line	3	361	1,083	342	1,026	Used for hay and pasture; limited conversion applied.
Hand line	2.389	2,857	6,825	1,463	3,495	Assumes 49% reduction over 10 years.
Solid set impact	2.389	2,551	6,094	1,306	3,120	
Solid set rotator	1.53	1,106	1,692	2,020	3,091	Solid set rotator and micro acres increased to account for conversion from hand line and impact.
Solid set micro	1.53	2,086	3,192	3,811	5,831	
Drip	1.4	188	263	207	289	Limited conversion to drip.
Total of above		9,149	19,149	9,149	16,852	

ac-ft/yr = acre-feet per year

Table 21. Summary of East Fork Irrigation District water reduction based on Table 20.

Total Acreage (ac)	9,149	
Acres Converted (ac)	2,658	
Calculated Existing Use	2.09 ft/yr	Calculated as existing use based on Table 20.
Calculated Projected Use	1.84 ft/yr	Calculated as projected use based on Table 20.
Water Savings (%)	12.0%	Based on annual reduction in Table 20.
Water Savings (ac-ft/yr)	2,297 ac-ft/yr	Based on annual reduction in Table 20.
Water Savings (cfs)	7.6 cfs	Based on dividing reduction over May – September.
Cost ($)	$2,756,312	Based on $1,200/acre from Irrinet (2007) study.

As with DID, EFID's measured use is higher and includes any water used for spray or frost control, as well as water lost to overflows or canal seepage. It is also possible that, when customers responded to the survey, they overstated the amount of acreage that uses upgraded systems, and, therefore, the calculated on-farm water use in Table 20 is lower than in reality. For MFID, for example (discussed in Section 3.2.4), their survey defaulted to the highest use application method per tax lot; and therefore, the calculated water use is slightly higher than the actual measured use. Nonetheless, EFID's measured water use is 29,915 acre-feet per year, while the calculated on-farm use in Table 20 is 19,149 acre-feet per year. This difference of 10,766 acre-feet per year is equal to a constant 32.4 cfs from April 15 through September.

3.2.3 Farmers Irrigation District

Farmers Irrigation District covers 5,869 acres, of which 46 percent is orchard, 44 percent residential, 5 percent pasture, 4 percent golf courses, 1 percent vineyards, and 0.5 percent schools (Table 22, Figure 14, FID personal communications). The FID Water Management and Conservation Plan (FID, 2011) states that 95 percent of residential water users and 85 percent of orchards have converted to micro-sprinklers. Based on this data, it is estimated that 696 acres use impact sprinklers (pasture area plus 15 percent of orchards); 2,246 acres of orchard use micro/rotator sprinklers; 126 acres are low-efficiency residential; 2,396 acres are high-efficiency residential; 64 acres are drip, and 240 acres are golf courses (Table 23).

Table 22. Land-use type and associated area in Farmers Irrigation District.

Land Use Type	Area (acres)	Percent of Irrigated Acres (%)
Orchards – High Efficiency	2,246	39%
Orchard – Low Efficiency	396	7%
Residential – High Efficiency	2,396	41%
Residential – Low Efficiency	126	2%
Pasture	300	5%
Golf courses	240	4%
Vineyards	64	1%
Schools	27	0.5%
Instream leases	73	n/a
Irrigated Acres	5,795	
Total Acres	5,869	

Source: FID Water Management and Conservation Plan (FID, 2011)

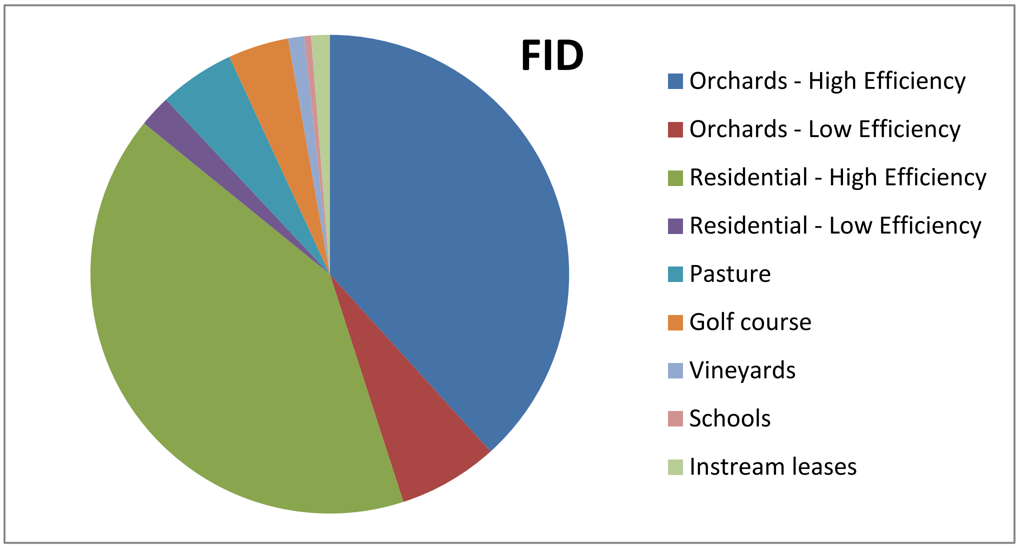


Figure 14. Estimate of Farmers Irrigation District sprinkler systems by acreage.

Table 23. Farmers Irrigation District sprinkler conversion water reduction calculation.

Sprinkler System		Existing Conditions		Conservation Scenario		Notes
Type	Efficiency (ft/yr)	Acres	Use (ac-ft/yr)	Acres	Use (ac-ft/yr)	
Wheel line	3	300	900	300	900	Used for hay and pasture; no conversion applied.
Hand line	2.389	396	947	203	485	Assumes 49% reduction over 10 years.
Micro/ rotator	1.53	2,246	3,436	2,439	3,732	Solid set rotator and micro acres increased to account for conversion from hand line and impact.
Drip	1.4	64	89	64	89	No conversion to drip applied.
Residential Low effic.	3	126	378	25	76	
Residential High effic.	2	2,396	4,792	2,497	4,994	Based on water use data supplied by one residential user group.
Golf course/ school Low effic.	3	267	801	134	401	
Golf course/ school High effic.	2	0	0	134	267	
Total of above		5,795[1]	11,343	5,795[1]	10,942	

[1] Water rights on 73.4 acres of FID allocated to instream leases.

ac-ft/yr = acre-feet per year

Calculated existing water use is 11,343 acre-feet per year, while the conversion of 529 acres to more efficient technology results in a use of 10,942 acre-feet per year. This small amount of savings (only 401 acre-feet per year) is due the fact that 85 percent of orchards and 95 percent of residential are already converted (FID, 2011), leaving little room for additional conversion. The 401 acre-feet per year of savings would be 3.5 percent of calculated use, or a constant 1.3 cfs during irrigation season, and would cost $634,000 (Table 24).

Farmers Irrigation District's calculated use of 11,343 acre-feet per year is lower than FID's actual measured use of 13,468 acre-feet per year. The difference between these two values can be attributed to a combination of canal seepage in Farmers Canal, an overestimation of how many acres are already converted to upgraded irrigation systems, and/or the SWCD (2013) and Irrinet (2007) studies not being representative of water use for a particular application method.

Table 24. Summary of Farmers Irrigation District water reduction based on Table 23.

Total Acreage	5,868 acres	
Converted Acres	529 acres	
Existing Use	1.96 ft/yr	Calculated as existing use based on Table 23.
Projected Use	1.89 ft/yr	Calculated as projected use based on Table 23.
Water Savings (%)	3.5 %	Based on annual reduction in Table 23.
Water Savings (ac-ft/yr)	401 ac-ft/yr	Based on annual reduction in Table 23.
Water Savings (cfs)	1.3 cfs	Based on dividing reduction over May – September.
Cost ($)	$634,385	Based on $1,200/acre from Irrinet (2007) study.

3.2.4 **Middle Fork Irrigation District**

Middle Fork Irrigation District has surveyed sprinklers types in its district through two methods in recent years. The first survey was performed in 2012 and consisted of an MFID employee visiting every tax lot and noting the least efficient application method (columns “Field Survey” in Table 25). For example, if a tax lot had impact sprinklers and micro sprinklers, impact sprinklers were recorded for that lot. This defaulting to the least efficient method allows MFID to track lots where efficiency could be improved; however, it also results in overestimating existing use. The second survey performed by MFID was a mail survey sent out in 2013 (column “Questionnaire” in Table 25). Forty-two respondents with a total of 2,016 acres among them indicated that 69 percent of land used impact sprinklers and 31 percent used micro sprinklers. These two data sources were combined and used to calculate potential efficiency gains in MFID (columns “Best Estimate” in Table 25 and Figure 15).

Table 25. Estimates of Middle Fork Irrigation District sprinkler types by acreage.

Irrigation System	Field Survey		Questionnaire	Best Estimate	
	Acres	%	%	%	Acres
Wheel line	216	3%	-	3%	216
Hand line	4553	71%	69%	50%	3181
Solid set impact	301	5%	-	18%	1113
Solid set rotator	421	7%	31%	10%	646
Solid set micro	905	14%	-	20%	1241
Drip	0	0%	-	0%	0
Total	6396				6396

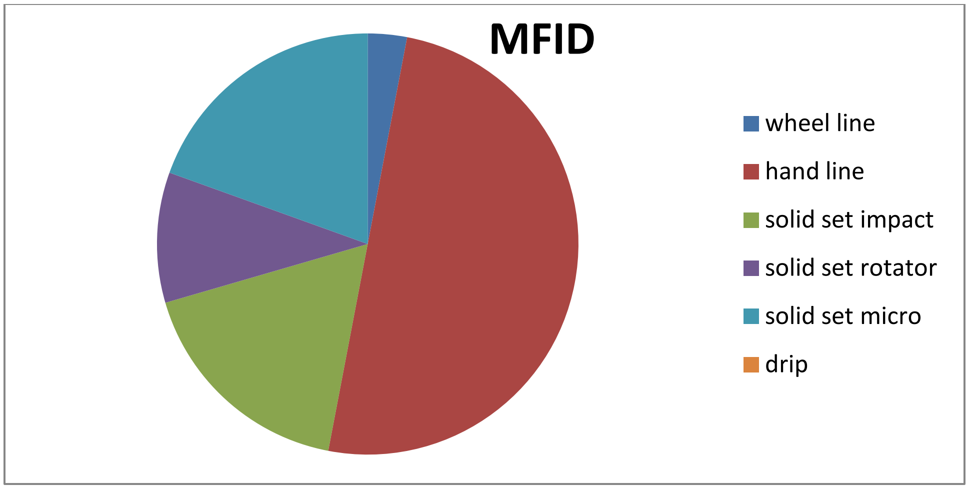


Figure 15. Estimate of Middle Fork Irrigation District sprinkler systems by acreage.

Based on the “Best Estimate” column from Table 25 and the data from the SWCD (2013) and Irrinet (2007) studies, MFID calculated existing water use is 13,790 acre-feet per year (Table 26). Converting 49 percent of the acreage under impact sprinklers to upgraded systems would result in conserving 1,800 acre-feet per year. This 1,800 acre-feet per year is approximately 13 percent of MFID’s calculated water use, which is a constant 6.0 cfs from May through September (Table 27). The cost of converting the 2,096 acres would be $2,515,200.

As with EFID and FID, there is a discrepancy between calculated water use in Table 26 (13,790 acre-feet per year) and actual measured water use (11,043 acre-feet per year). Although this overestimation is expected (as the field survey performed by MFID defaulted to the least-efficient sprinkler type), it means the conservation numbers presented here should be seen as an upper bound on potential water savings if 49 percent of inefficient acreage were converted over. If the current acreage under inefficient sprinklers is less, then there are fewer acres available for conversion to upgraded sprinklers and lower water savings.

Table 26. Middle Fork Irrigation District sprinkler conversion water reduction calculation.

Sprinkler System		Existing Conditions		Conservation Scenario		Notes
Type	Efficiency (ft/yr)	Acres	Use (ac-ft/yr)	Acres	Use (ac-ft/yr)	
Wheel line	3	215	644	215	644	Used for hay and pasture; no conversion applied.
Hand line	2.389	3,181	7,599	1,629	3,891	Assumes 49% decrease over 10 years
Solid set impact	2.389	1,113	2,660	570	1,362	
Solid set rotator	1.53	646	989	1,364	2,087	Solid set rotator and micro acres increased to account for conversion from hand line and impact.
Solid set micro	1.53	1,241	1,898	2,618	4,006	
Drip	1.4	0	0	0	0	
Total of above		6,396	13,790	6,396	11,990	

ac-ft/yr = acre-feet per year

Table 27. Summary of Middle Fork Irrigation District water reduction based on Table 26.

Total Acreage (acres)	6,396	
Converted Acreage (acres)	2,096	
Existing Use	2.16 ft/yr	Calculated as existing use based on Table 26.
Projected Use	1.87 ft/yr	Calculated as projected use based on Table 26.
Water Savings (%)	13.1%	Based on annual reduction in Table 26.
Water Savings (ac-ft/yr)	1,800 ac-ft/yr	Based on annual reduction in Table 26.
Water Savings (cfs)	6.0 cfs	Based on 1,800 ac-ft divided out over May – September.
Cost ($)	$2,515,200	Based on $1,200/acre from Irrinet (2007) study.

3.2.5 **Mount Hood Irrigation District**

Sprinkler types in MHID were estimated by the MHID manager in spring 2013 (Table 28 and Figure 16). The manager estimated that 25 percent (378 acres) of the district is served by wheel lines, 35 percent (389 acres) by hand lines, 40 percent (444 acres) by micro sprinklers, and a negligible amount by drip irrigation systems.

Table 28. Estimate of Mount Hood Irrigation District sprinkler types by acreage.

Irrigation System	Estimate from MHID Manager		Best Estimate	
	Acres	%	%	Acres
Wheel line	-	25	25	378
Hand / impact	-	35	35	389
Micro / rotator	-	40	40	444
Drip	-	0	0	0
Total	1,110			1,110

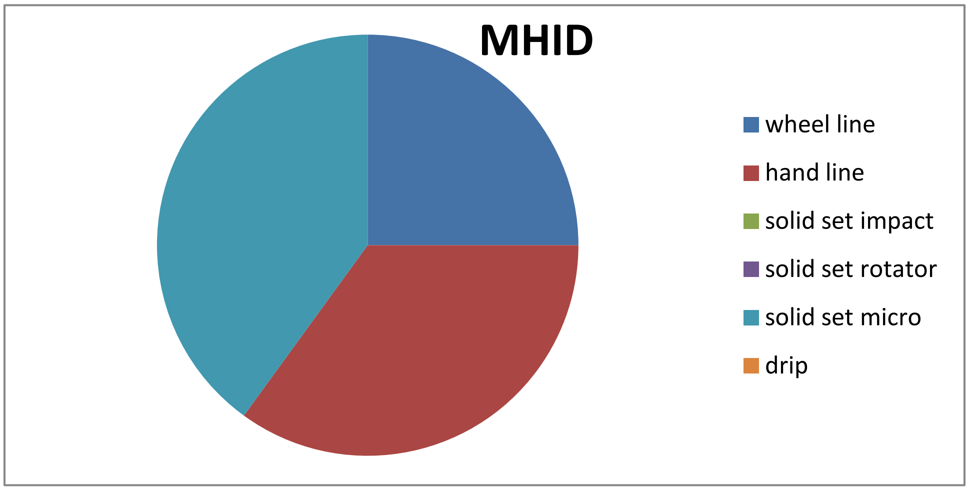


Figure 16. Estimate of Mount Hood Irrigation District sprinkler systems by acreage.

Based on the data above, MHID’s calculated existing on-farm water use is 2,440 acre-feet per year, while its projected use under the water conservation scenario is 2,277 acre-feet per year (Table 29). This savings of 163 acre-feet per year is equal to a constant 0.5 cfs from May through September, and would come at a cost of $227,500 (Table 30). These savings are relatively small compared to other irrigation districts because only 35 percent of the district may be upgraded (no upgrades are applied to wheel lines since they are used for hay and pasture). For comparison, MFID is estimated to have 69 percent of its area available for upgrades, and, therefore, would have a higher percentage of conserved water.

Table 29. Mount Hood Irrigation District sprinkler conversion water reduction calculation.

Sprinkler System		Existing Conditions		Conservation Scenario		Notes
Type	Efficiency (ft/yr)	Acres	Use (ac-ft/yr)	Acres	Use (ac-ft/yr)	
Wheel line	3	278	833	278	833	Used for hay and pasture; no conversion applied.
Hand/ impact	2.389	389	928	199	475	Assumes 49% reduction over 10 years.
Micro/ rotator	1.53	444	679	634	969	Solid set rotator and micro acres increased to account for conversion from hand line and impact.
Drip	1.4	0	0	0	0	
Total of above		1,100	2,440	1,100	2,277	

ac-ft/yr = acre-feet per year

Table 30. Summary of Mount Hood Irrigation District water reduction based on Table 29.

Total Area (acres)	1,100 acres	
Converted Area (acres)	190 acres	
Existing Use	2.20 ft/yr	Calculated as existing use based on Table 29.
Projected Use	2.05 ft/yr	Calculated as projected use based on Table 29.
Water Savings (%)	6.7%	Based on annual reduction in Table 29.
Water Savings (ac-ft/yr)	163 ac-ft/yr	Based on annual reduction in Table 29.
Water Savings (cfs)	0.5 cfs	Based on 163 ac-ft divided out over May – September.
Cost ($)	$227,506	Based on $1,200/acre from Irrinet (2007) study.

3.3 Installation of Pipe

Converting open conveyance canals to pipe conserves water by eliminating canal seepage and overflows (often referred to as "end-spills"). This conversion to pipe has been actively pursued in the Basin for decades, and each district has a different amount of open canals that are left to be converted.

3.3.1 Dee Irrigation District

Dee Irrigation District replaced the entire four miles of their open conveyance canal with pipe in the fall of 2012. This conversion is estimated to save roughly 3 cfs that was historically lost to canal seepage. Dee Irrigation District is considering an additional pipe project that would reduce water use and allow pressurization of the distribution system (Farmers Conservation Alliance, 2008). This project would involve installation of a single pump to pressure the entire distribution system. At the same time that the new pump is installed, the distribution system would need to be replaced because the existing pipe is open to the atmosphere in places and is generally not compatible with being entirely pressurized. The new pipe would eliminate existing leaks as well as the need for by-pass flows at water boxes where pumps are currently located. This project is estimated to save 1.5 cfs and to reduce pumping costs. The 44 pumps currently operating in DID cost approximately $30,000 per year to operate. Although the cost of operating the proposed single pump is not known, it will likely be on the order of 30 percent less.

Recent and proposed projects are presented in Table 31 to facilitate adjustment of data presented in the Hood River Basin Water Use Assessment (Watershed Professionals Network, 2013). For example, piping of DID's main conveyance canal occurred in the fall of 2012, while DID's water use in the Hood River Basin Water Use Assessment is based on years 2002 through 2012. Because the water use data is from before the piping project, current DID use was calculates as equal to the historical use minus the savings from the project (approximately 3 cfs). Potential future conservation opportunities that are available (i.e., currently not implemented) could save an additional 1.5 cfs.

Table 31. Recent and Proposed Pipe Installations in Dee Irrigation District.

Status	Location	Length	Diameter	Cost ($)	Estimated Savings
Completed in fall of 2012	Entire canal from West Fork diversion to Dee	4.5 miles	36 inches	$2,270,000	3 cfs
Proposed	Entire distribution system	6.8 miles	2 – 24 inches	$1,436,000[1]	1.5 cfs

Notes: [1] *Cost for proposed pipe installation planning-level estimate only. Costs based on $40/lf for engineering, design, materials, and installation based on comparable projects.*

3.3.2 East Fork Irrigation District

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. Without detailed flow measurements it is difficult to determine how much water is lost to canal seepage and overflows; however, it is possible to estimate losses based on water use data and the on-farm use calculations in Section 3.2.2. Flow measurements taken by OWRD show that EFID uses, on average, 29,915 acre-feet per year, while the on-farm use is calculated at 19,149 acre-feet per year. Although some of this difference may be attributable to potential inaccuracies in the EFID sprinkler survey data; it does provide information on operational losses from the system.

East Fork Irrigation District's average use of 29,915 acre-feet per year includes water used for spray and frost control. Based on 8 to 10 applications per year of 100 gallons per acre (Brian Nakamura, EFID, personal communication), EFID uses 25.3 acre-feet for spray. The EFID manager estimated that less than 1 percent of diverted water is used for frost control in March and April, and that 10 percent is used for frost control in May (John Buckley, EFID Manager, personal communications). Based on these estimates, EFID's total use for spray and frost control is 350 acre-feet per year, leaving 10,416 acre-feet per year unaccounted for. East Fork Irrigation District's Water Management and Conservation Plan (EFID, 2011) estimates that 8.85 cfs is lost to overflows that could potentially account for an additional 2,600 acre-feet per year, leaving 7,816 acre-feet per year to be attributed to canal seepage. It should be stressed that, with the exception of EFID's measured water use (29,915 acre-feet per year), all numbers presented in this paragraph are estimates only. It is likely that EFID's overflows are greater and canal seepage lower. It may also be that EFID's on-farm water use is higher than calculated in Section 3.2.2, or that spray control water is higher than 25.3 acre-feet per year. Nonetheless, the numbers show that considerable water conservation would be achieved by piping the EFID system.

Whereas the other districts have piped almost their entire conveyance systems, it is likely not economically feasible for EFID to do the same. The district has over 20 miles of open canals, 61 overflow points, and considerable elevation change, putting the cost to pipe the entire system around 28 million dollars (Tables 32 and 33). This cost is based on using high density polyethylene pipe for 24" pipe diameters and smaller and using low-head pipe (e.g., ADS) for bigger diameter pipe (see notes under Table 33 for pipe unit cost information). The type of pipe to install (i.e. high-pressure versus low-pressure) has a significant impact on cost per foot and therefore a more detailed EFID optimization plan would be necessary to more accurately determine the cost of piping the district. And although piping the entire district is an appropriate long-term goal, a smaller, more focused conservation plan could achieve a high percentage of water savings for a fraction of the cost of piping the whole system.

Not all open canals lose water at the same rate, nor do all end-spills overflow at the same rate, so loss measurements should be performed throughout the district to quantify where and at what rate water is exiting the system. Several other factors should also be taken into account at the same time, including the location of the overflows; potential to address both seepage losses and overflows with same pipe project; locations where pressure reducing valves, telemetry or system optimization would reduce the need for pipe; and costs. If these factors (i.e. overflow rates, costs, etc.) are roughly equal, the overflow furthest from the main diversion (off the Eastside Canal) should be targeted first because it dewaters the river for the longest length. It is possible that in some locations (e.g., Main Canal) a small surge pond with telemetry may be a less expensive option than pipe. Installation of pipe also has the potential to provide water under sufficient head to drive sprinklers, thereby reducing the need for on-farm pumping. As mentioned earlier, all this information should be combined into a single system optimization plan along with cost estimates to determine where the least amount of funds would result in the highest level of water conservation (Note: EFID optimization plan is currently being done with funding from the Confederated Tribes of the Warm Springs).

Table 32. Potential pipe installations in East Fork Irrigation District.

Canal	Pipe (miles)	Open Ditch (miles)	Overflow Lines[1] (miles)	Private Lines[2] (miles)	Total (miles)
Central	28.8	0.0	4.5	2.0	37.4
Dukes Valley	14.9	6.8	2.5	3.3	24.2
Eastside	20.2	4.4	2.3	3.1	31.3
Highline	0.3	2.3	0.0	1.3	3.6
Main	2.1	6.8	0.0	0.2	11.2
Neal Creek Lateral	0.2	1.0	0.0	0.0	0.2
Christopher Ditch	0.5	0.6	0.0	0.0	0.2
Total	67.0	21.9	9.3	9.9	108.0

[1] *Overflow lines combine for 61 overflow points in EFID.*

[2] *Private lines not owned by EFID.*

Table 33. Planning level cost estimate for potential pipe installations in East Fork Irrigation District.

Canal	Pipe				Other	Total Cost ($)
	Length[1] (feet)	Diameter[2] (inches)	Unit Cost[3] ($/foot)	Cost ($)	PRV[4] ($)	
Central	0	n/a	n/a	n/a	$96,000	96,000
Dukes Valley	35,904	36”	$175	$6,283,200	$72,333	6,355,533
Eastside	23,232	48"	$150	$3,484,800	$41,000	3,525,800
Highline	12,144	24"	$100	$1,214,400	$4,333	1,218,733
Main	35,904	2 X 66"	$450	$16,156,800	$14,833	16,171,633
Neal Creek Lat	5,280	24"	$100	$528,000	$2,000	530,000
Christopher Ditch	3,168	12"	$75	$237,600	$1,833	239,433
Total	115,632	n/a		$27,904,800	$136,333	28,041,133

[1] *Length is equal to “Open Ditch” column in table 32.*

[2] *Diameter based on matching existing pipe diameters. Pipe diameters in actual installation will likely vary.*

[3] *Unit costs inclusive (e.g. engineering, materials, installation) and based on recent DID, EFID and FID costs: 6” HDPE $20/foot, 10” DI $70/foot, 12” HDPE $75/foot, 24” HDPE $100/foot, 45% 36” ADS $110/ft (DID main canal), 42” ADS and 55% 36” Puramax $145/foot (FID Lowline), dual 48” ADS $195/foot (FID Farmers), 72” and smaller $398/foot (EFID Central).*

[4] *Cost for pressure reducing valves estimated at one valve per 3 miles of pipe. Based on flow rates valves estimated at, $10,000 per valve in Central and Dukes Valley and $3,000 per valve in Eastside and Highline.*

3.3.3 Farmers Irrigation District

Farmers Irrigation District has actively pursued converting open conveyance canals to pipe and, by 2010, had converted over 99 percent of its system pipe (FID, 2011). The only FID canal that has not been convert is the Farmers Canal, which conveys 73 cfs from the main stem of the Hood River. A 3.7–mile portion of this canal is scheduled to be piped in the fall of 2013, while the remaining 2.8 miles will be piped as funds allow. Although the main reason for piping this canal is to reduce FID's vulnerability to landslides or other weather related events, this project is expected to achieve a small amount of water savings by eliminating canal seepage. No flow transects have been performed to estimate seepage, but FID has flow meters at the upstream and downstream ends of the canal from which it is estimated that approximately 1 cfs is lost to seepage (Jerry Bryan, FID, personal communications).

3.3.4 Middle Fork Irrigation District

Similar to FID, MFID has actively pursued piping it distribution system. With the completion of piping 2 miles of the Glacier Pipeline in 2011, 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. As such, although MFID is replacing older pipes, it does not have plans to install pipelines in new locations for the sake of reducing seepage. The district is considering one piping project, which would connect the Coe Creek diversion to the sediment basin. However, the objective of that project is sediment removal; therefore, it is discussed in Section 5.2.7.2.

3.3.5 Mount Hood Irrigation District

Mount Hood Irrigation District's distribution system is entirely piped, and it has no overflows or seepage. Overflows occur at the two locations where it receives water from EFID; however, eliminating these overflows will likely be accomplished through operational changes and are, therefore, discussed in Section 3.4.1.

3.4 Operational Changes

Although the most readily apparent way to reduce water use is through sprinkler conversions and piping projects, operational changes also have the potential to have significant conservation benefits. 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.

Of the Basin's irrigation districts, DID and FID have no opportunities to make significant operational changes, MFID and MHID have some potential to make changes, and EFID has significant potential. MFID is considering a project to pipe its Coe Creek diversion to the existing sediment pond, which would allow Coe Creek water to be used during peak irrigation season. (Currently, turbidity is too high in the summer.) Although this would be an operational change, the main benefit would be sediment removal. Potential operational changes for MHID should be aimed at reducing or eliminating the overflows at the two locations where MHID receives water from EFID. Although these overflows occur within MHID infrastructure, the likely solution for eliminating them is telemetry and a surge pond used by EFID.

3.4.1 East Fork Irrigation District

Because of the significant amount of open conveyance in EFID and it likely being cost-prohibitive to pipe the entire system, operational changes should be implemented with the goal of matching the diversion from the Hood River to actual irrigation demand in the system. The EFID system does not currently have any automated way of sensing demands in the system, the ability to regulate diversions to meet demands, nor the ability to store water to meet fluctuations in demand. At present, EFID diverts the maximum expected irrigation demand and then overflows any amount that is greater than actual instantaneous demand. 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 district also diverts a significant amount of water in the spring for orchardists to use for spray; however, only a fraction of that water actually gets used. If EFID were to negotiate with Crystal Springs Water District to deliver that water, the diversion would be reduced by approximately 25 cfs in the springtime.

3.4.1.1 Regulating Reservoir with Telemetry

As discussed in Section 3.3.2, some locations within EFID have short sections of open canal where the most cost-effective solution is installing pipe. Other locations have long, open canals where a surge pond and telemetry would be appropriate. For the EFID Main Canal, for example, a surge pond at the Distribution Center connected via telemetry to the EFID diversion from the East Fork Hood River could eliminate overflows at the Distribution Center. The travel time from the EFID diversion to the Distribution Center is four hours, and the flow leaving it is typically plus or minus 5 cfs of the average (John Buckley, EFID manager, personal communications). A 3.3-acre-foot surge pond that stores 1.65 acre-feet of water (5 cfs for 4 hours) would have the ability to meet an additional 5 cfs of demand through its existing storage. It also would be able to store excess water if the demand is reduced by 5 cfs. As the storage volume in the pond increases or decreases from the target of 1.65 acre-feet, telemetry would send a signal to the EFID headgate to increase or decrease the diversion (e.g., if storage decreases in the pond, the headgate would allow more water into the system).

Although the main Distribution Center is likely the most appropriate location for a surge pond, there are other potential locations in the district. The Eastside Canal serves 3,263 acres through a mostly open canal system. The canal has roughly 20 overflow points associated with it that should be eliminated where feasible. As an alternative, small ponds installed near the end and middle of the system would have potential to absorb variability in demand, thereby reducing the amount of water sent to overflows. Such a system could work without telemetry where the flow in the canal is set at the average (daily or weekly) demand, and then any reductions or increases in demand would either add to or subtract from existing storage. The benefit of storage is that diversion can be limited to average demand instead of the maximum potential demand.

Actual design of a telemetry and surge pond system must be accomplished through a thorough EFID system optimization plan. Installation of pipe eliminates the need for telemetry and surge ponds (because the closed system does not allow any water to be lost), so all open canal systems that have considerable seepage or that do not lend themselves to surge ponds (e.g., those with significant elevation changes) should be identified for pipe installation. Locations where pipe installation is cost-prohibitive should then be explored for surge pond/telemetry solutions. Due to the elevation changes and the length of conveyance system in EFID, it is likely that some sort of system modeling (e.g., EPA-SWMM) should be done to help identify appropriate locations for surge ponds.

Costs presented below are planning level only; actual cost of any regulating reservoir will be highly dependent on exact location and the amount of excavation or fill required. Nonetheless, Table 34 provides a rough estimate for cost associated with design and construction of a 3.3 acre-foot regulating reservoir. Direct construction costs of $163,000 plus standard contingency and design markups equal a total cost of $269,000.

Table 34. Planning level cost estimate for regulating reservoir and telemetry in East Fork Irrigation District.

Item	Quantity	Unit	Unit Cost[1]	Amount	Notes
Excavation	2662	CY[2]	20	$53,240	1.65 ac-ft of excav. Some material left on site to berm edges for additional 1.65 ac-ft of storage.
Select Fill	807	CY[2]	$54	$43,560	Select fill to reduce seepage (0.5 acre footprint by 1' deep).
Inlet and Outlet	2	Each	$3,000	$6,000	
Telemetry	2	Each	$10,000	$20,000	At reservoir and headgate.
Automated Headgate	1	Each	$30,000	$30,000	Pneumatic controls for headgate. Order of magnitude estimate only.
Fence and Ramp	1	Each	$10,000	$10,000	Required for dredging and to limit access.
Total Direct Costs:				**$162,800**	
Markups					
Mobilization			4%	$6,512	
Contingency			20%	$32,560	
Design and Engineering			25%	$40,700	
Permitting			LS	$10,000	
Construction Management			10%	$16,280	
Total Project Cost:				**$268,852**	

[1] *Unit costs are inclusive (e.g., material, haul, placement, and compaction).*

[2] *CY is cubic yard.*

3.4.1.2 Alternative Source of Spray Water

East Fork Irrigation District diverts 19.2 cfs in March and 27.8 cfs in April to provide spray and frost control water; however, only a small fraction of that diversion actually gets used for those purposes. Of the 2,839 acre-feet EFID diverts during those two months, approximately 350 acre-feet gets used—the remaining 2,489 acre-feet go to operational losses.

Similar to what FID did with Ice Fountain Water District many years ago, EFID could potentially negotiate with Crystal Springs Water District to provide spray water. This would allow EFID to not have to charge its entire system for the small springtime demand and would reduce diversions in the spring by an average of 25 cfs.

The natural discharge of the Crystal Springs Water District peaks during March and April. In addition, the district uses only about 40 percent of the water it diverts, so Crystal Springs has more than sufficient supply to meet EFID's demand for spray water. Other potential issues exist, but they may be mitigated if the water savings were leased instream for some amount of revenue. Some orchardists may want to switch to larger lines since a typical ¾-inch residential tap could take too long to fill a sprayer—or central filling stations could be provided. Drawing this amount of water for short periods of time could also cause water hammer in Crystal Springs system, but requiring the use of gate valves instead of ball valves would likely eliminate it. There would be a cost to both Crystal Springs Water District and to orchardists to make such a change.

If this idea were to be developed further, four main factors should be considered. The water savings would be in the spring when stream flow is generally high; therefore, this may not be a critical period to implement water conservation measures. There would be a cost of physical changes to the system (e.g., upsizing taps), as well as operating costs that would need to be paid to Crystal Springs Water District. In FID's use of Ice Fountain water, these costs were covered by increased hydropower revenue that resulted from the additional water in FID's system. In EFID, these costs would need to be covered by instream leases or outside sources. It was estimated that very little water is used for frost control in March and April; however, this demand should be evaluated further. Lastly, if EFID were to be entirely piped someday, it would no longer be beneficial to use Crystal Springs water. In that case, this would be a short-term solution that may not justify the costs.

3.5 Use-Based Rate Structure

As shown for potable water districts in Section 2.5, 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 impossible 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 (see Section 3.1). Based on the methods in Section 3.2 (Sprinkler Conversion and Soil Moisture Sensors) and using a 100 percent conversion rate, potential Basin-wide water reduction would be near 32 cfs (Table 35). 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 35 are specific to implementing a use-based rate structure. To achieve the water reduction values shown in Table 35, 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 $13,600,000, based on $1,200 per acre (Irrinet, 2007).

Table 35. 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)*

3.6 Benefits of Conserved Irrigation Water

If water conserved through efforts such as those described in this report is simply applied to additional acreage, nearly all of the benefits would be toward agricultural production and the economy. No more water would be left in the streams, so there would be no benefit to stream flows or aquatic habitat. However, if conserved water goes toward reducing the overall irrigation demand, water diversions would be reduced. This would increase stream flows and improve aquatic habitat. It would also reduce on-farm costs and has the potential to increase hydropower production.

Water conserved through efficiency projects cannot be applied to new lands automatically. Usually the water simply goes to shore up the existing supply (in the case of a district) or less water could be diverted over time. If an irrigator wants to put the water on additional acres they would need to file a Conserved Water Application through OWRD. If approved, a portion of the water is applied to new land and a portion goes instream. Although the exact portion of water that gets allocated instream versus to new acreage depends on the amount of public funding, it's typically split 25% instream and 75% to new acreage.

For example, for DID's recent pipe project, the funds came primarily from the Confederated Tribes of the Warm Springs, which requested that the water be left instream. DID has no additional acreage it can irrigate and as a result this project is transferring the full 3 cfs of conserved water from an irrigation water right to a 3 cfs instream water right. Some water conservation projects (e.g., Glacier Creek Pipeline (MFID) and Stanley-Smith Pipeline (FID)) leave water instream but do transfer the water to new instream water right. Both these projects leave roughly 70% of the conserved water instream by no longer diverting it, but the water is not protected (i.e. legally required) to be left instream in the future.

In evaluating the results of water conservation, it is also important to consider if the district has hydropower facilities. If it does, any water conserved during irrigation season typically goes to additional hydropower generation and then is returned to the river. Although the same amount of water may be diverted, it is no longer consumptively used, and therefore stream flow is increased downstream of the hydropower bypass reach. If a district does not have hydropower facilities, then conserved water typically remains instream.

3.7 Discussion

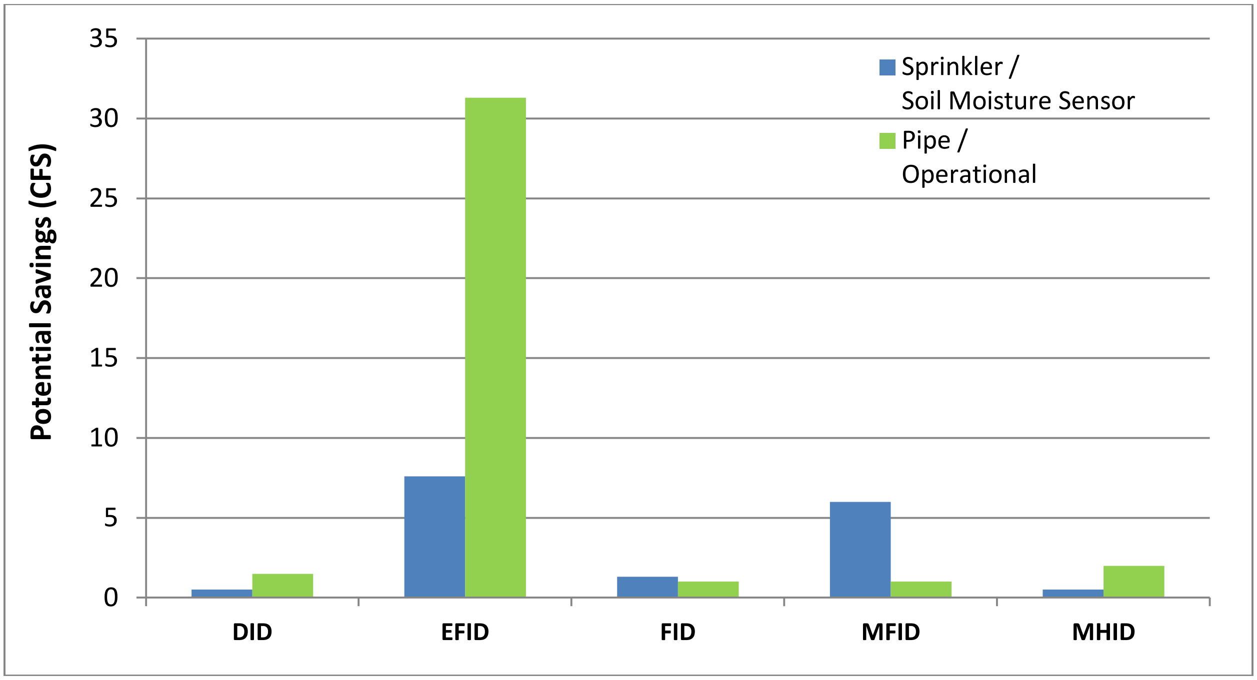
On-farm water conservation can be achieved by converting older, traditional irrigation systems to newer systems with micro or rotator sprinklers and soil moisture sensors (Section 3.2). An aggressive program, upgrading 20 percent of impact sprinklers every 3.3 years, would result in converting 49 percent of land over 10 years and could achieve a Basin-wide reduction of approximately 15.9 cfs (Figure 17). This may be a high-end estimate for a 49 percent conversion rate (due to potentially overestimating the amount of impact sprinklers in MFID), but nonetheless, this amount of water savings is readily achievable through sprinkler conversion. Although it may take a considerable amount of time, and it may be unrealistic to expect upgrades for some areas such as hay and pasture, the Basin may be able to convert even more acreage from impact sprinklers to newer, water-efficient systems. If all possible areas in the Basin were converted to upgraded systems and water use was equal to crop requirements (this may require a use-based rate structure), total on-farm water reduction would be approximately 31.7 cfs.

Water conservation that could be achieved through the installation of pipe or operational changes varies from district to district. A recent study in DID estimated that 1.5 cfs are lost to leakage and overflows within the distribution system. Based on the length of pipe required and general unit costs, eliminating this 1.5 cfs of loss would cost approximately $1,436,000. In MHID, the two locations at which it receives water from EFID each overflow approximately 1 cfs. Although these losses could be eliminated by piping the EFID Main Canal, that is likely cost-prohibitive, so some sort of operation change may be the best solution. A surge pond with telemetry at the EFID Distribution Center would cost around $270,000; however, this would eliminate overflows at MHID and the EFID Distribution Center.

Both FID and MFID have piped almost their entire systems and, therefore, water conservation that could be achieved through additional pipe or operational projects is limited in those districts. Although there are no estimates of seepage in FID's Farmers Canal, its length (6.5 miles) and flow rate (typically 73 cfs) suggest it loses at least 1 cfs to seepage. In MFID, Eliot Ditch is the only open conveyance system left; however, due to the fine sediment load and steep gradient, it is believed to lose a minimal amount of water to seepage. Of these two remaining open canals in FID and MFID, Farmers Canal will be piped in Fall 2013, while MFID has determined that it is not appropriate or economically feasible to pipe the Eliot Ditch.

Estimating the amount of water conservation that can be achieved in EFID through the installation of pipe is more difficult because very few measurements of overflow rates or canal seepage exist. In the absence of overflow and seepage measurements, the on-farm water use calculation (Section 3.2) was subtracted from actual district use to estimate these losses. Although using the on-farm calculation introduces errors (since it is based on estimates of sprinkler efficiency and an inexact survey of the district), this method provides the best available approximation of potential reductions through pipe and/or operational changes.

EFID's average annual water use is 29,915 acre-feet, while the on-farm calculation shows a required use of 19,149 acre-feet. After accounting for the 2 cfs loss where MHID receives overflow from EFID, this difference is equal to a constant 31 cfs from April 15 through September. Because this is a rough estimate of water loss, and because it is likely cost-prohibitive to pipe the entire EFID system, flow measurements should be conducted within EFID to determine where and how much water is lost to seepage and overflows. This information, along with detailed cost estimates and amount of money available for system upgrades, should be used to create an EFID system optimization plan.



Notes: Sprinkler / Soil Moisture Sensor based on 49% conversion rate from Section 3.2.

Figure 17. Potential water savings from sprinkler upgrades/soil moisture sensors and from pipe/operational changes.

4 Hydropower

The Hood River Basin has five major hydropower facilities, three of which are operated by MFID, and two of which are operated by FID. A sixth, smaller facility on Odell Creek is in the preliminary planning stages for being decommissioned. Although the potable water districts convey water year-round, and some convey water over significant elevation changes (creating head), the flow rates are on the order of only a few cubic feet per second and would not generate a significant amount of hydropower.

Of the existing major hydropower facilities, FID's have very limited potential for efficiency gains, while MFID may be able to generate more hydropower by connecting its Coe Creek diversion to the sediment pond. A number of factors must be considered in determining the potential for new hydropower development in the Basin's irrigation districts. They include, but are not limited to: elevation change and flow rates, whether the district has hydropower water rights, available hydropower generation technologies, development and operation costs, and competing water demands (such as for aquatic habitat). Based on these factors, the Basin's irrigation districts' potential for hydropower installation or improvements is discussed below.

4.1 Dee Irrigation District

Due to three main factors, DID is not suitable for installation of a new hydropower facility. The elevation change over the main conveyance system is small—only 12 feet over four miles. In addition, the flow rates after the new pipe installation in 2012 will average only roughly 3.1 cfs over the year (zero for half the year and up to 8.8 cfs during irrigation season). This lack of elevation change and low flows make hydropower infeasible. In addition, any head extracted from the system during irrigation season would need to be added (i.e., pumped) back in to the system to provide proper head for sprinkler operation. The West Fork Hood River is also prime aquatic habitat, so any effort to obtain a hydropower water right outside of irrigation season would likely not be in the best interest of Basin stakeholders.

4.2 East Fork Irrigation District

East Fork Irrigation District has over 1,300 feet of elevation relief within its conveyance system, making it potentially suitable for generating hydropower. The elevation drop is approximately 150 feet between the diversion off of the East Fork Hood River and the main distribution center near Neal Creek Road, during which it conveys around 90 percent of its total diversion. From the distribution center to the lower parts of the district it drops another 1,200 feet. Although this elevation drop is greater (creating more head for hydropower), the flow rates are lower because the irrigation supply is divided into separate lines for distribution to different areas.

Peak irrigation season flow rates are quite suitable for hydropower generation. However, the significant range of flows (as low as zero outside of irrigation season) are significant barriers to feasibility. Discharge in the EFID main canal downstream of MHID's first turnout is given in Table 37 below. Peak irrigation season discharge is above 100 cfs, but that only lasts for two months, and any facility would need to be sized for the lower flow that occurs over a longer period of time. While May through September all have flows greater than 50 cfs (considered a rough threshold for feasibility in today's energy markets), this is less than six months. Such a short period of relatively high flows make development of a new hydropower facility economically challenging, especially when considering existing flow rates and water rights.

Should EFID decide to pursue a hydropower facility it would need to obtain a water right specifically for it. Although it is likely EFID could obtain a water right to generate with the same water it currently uses for irrigation, if EFID wanted to operate a hydropower facility year-round, it would need to obtain a water right for diverting additional water from the East Fork Hood River which would likely be politically contentious and difficult (OWRD water master, personal communications).

Two locations within EFID are especially suitable for hydropower facilities. The first is on EFID's main canal, just upstream of where it crosses under Highway 35 before the distribution center. The open canal discharges into a 5-foot diameter pipe and drops 45 feet over a 150-foot horizontal distance. The second suitable location is not one specific point, but could be many places along the main canal upstream of the distribution center. No one spot has sufficient elevation drop; however, regrading of the canal and/or installation of lower slope pipe could generate the required elevation change. Both of these locations are upstream of the EFID distribution center and have higher flow rates than any individual lines below.

4.2.1 **Potential Generation Systems**

Because of the relatively low available head and the variable flow rates in EFID, two somewhat non-traditional technologies would be most suitable. Natel Energy uses horizontal fixed foils on a two-stage impulse turbine to produce energy in high-flow, low-pressure settings. Lucid Energy systems use in-pipe vertical turbines to extract energy while using very little head. Other, more traditional systems have much higher capital costs that would be difficult to recapture.

Natel Energy systems are designed to be low-cost, easy-to-install facilities that work well in high flow, low-pressure settings, making them an ideal candidate for an EFID facility. A Natel facility could work along the EFID main canal, with some regrading, or at the drop structure upstream of Highway 35.

Estimates are provided below for capital cost, annual cost, energy production, revenue, and net present value (NPV) for 100-kilowatt (kW) and 200 kW systems (Table 36). Based on feedback from a Natel Energy representative (Eric Thompson, personal communication), cost for equipment and installation is estimated at $3.50 per watt for the 100 kW system, and $3.25 per watt for the 200 kW system. Operating head for both systems is 32.8 feet, and system efficiency is 70 percent, resulting in 460,000 and 641,000 kilowatt hours (kW-hr) produced from the 100 and 200 kW systems, respectively (Table 37). Electricity rates used to calculate revenue are based on Pacific Power Oregon Schedule 37 option one rates for facilities generating 10,000 kW or less (Table 38) (Pacific Power, 2012). Based on flow rates given in Table 37 and an estimated 30-year life of the system, the NPV of both systems are negative, indicating that neither system is economically feasible at this time.

Lucid Energy systems are prefabricated pipe sections that contain vertical axis turbine blades. An existing section of irrigation pipe can be replaced with a Lucid Energy section. Although the configuration is quite different than a Natel Energy system, it is also a low-head, medium-to-high-flow system. A Lucid Energy representative recommended a 42-inch system capable of handling up to 90 cfs (Josh Thomas, personal communication). Although this system extracts only 14 feet of head, it needs to operate in a pressurized environment. The only suitable location in the EFID system, therefore, is at the drop just upstream of Highway 35 and the main EFID distribution center.

Table 36 presents capital cost, annual cost, energy production, revenue, net present value, and other variables for a 42-inch system. Capital cost for the system and installation would $2,550,000, while annual revenue would range from $10,000 at year 2013 rates to $23,800 at 2030 rates (Table 39). As with the Natel Energy system, the NPV is negative, indicating that it is not economically feasible.

Table 36. Hydropower production variables, capital and annual costs, revenue, net present value variables, and net present value for Natel Energy and Lucid Energy systems.

	Natel Energy Systems		Lucid Energy System
	100 kW	200 kW	42-inch/90 cfs
Head	32.8 feet	32.8 feet	14 feet
Flow rates	Variable, see Tables 37 and 38		
Efficiency	70%	70%	80%
Equipment and installation	$350,000	$650,000	$2,550,000
Annual Maintenance	Average of $5,000/year		
Annual production (kW-hr)	460,755	642,000	310,366
Average Annual Revenue[1]	$27,169	$37,834	$18,301
NPV term	30 years		
NPV discount rate	5%		
NPV	-$93,408	-$262,756	-$2,285,404

[1]Actual annual revenues used in NPV calculations presented in Table 39.

kW = kilowatt

kW-hr = kilowatt hour

NPV = net present value

Table 37. Estimated system discharge, power generation, energy production, and revenues from 200 kW and 100 kW Natel Energy hydropower systems

System		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Total
All	Discharge (cfs)	20.5	5.7	0	0	0	18.8	25.5	46.6	80.6	91.5	92.1	68.0	n/a
200 kW System	Power(kW)	39.9	11.1	0	0	0	36.6	49.6	90.6	156.7	177.9	179.1	132.2	n/a
	Energy(kW-hr)	29,658	7,980	0	0	0	27,198	35,701	67,417	112,844	132,375	133,243	95,204	642,000
	Revenue($)	1,802	485	-	-	-	1,653	2,170	4,097	6,858	8,045	8,098	5,786	38,995
100 kW System	Power(kW)	39.9	11.1	0	0	0	36.6	49.6	90.6	100.0	100.0	100.0	100.0	n/a
	Energy(kW-hr)	29,658	7,980	0	0	0	27,198	35,701	67,417	72,000	74,400	74,400	72,000	460,755
	Revenue($)	1,802	485	-	-	-	1,653	2,170	4,097	4,376	4,522	4,522	4,376	28,002

Note: Calculations assume head of 30 feet, efficiency of 0.7, and revenue of $0.061 per kW-hr

cfs = cubic feet per second

kW = kilowatt

kW-hr = kilowatt hour

Table 38. Estimated system discharge, power generation, energy production, and revenues from 90 cfs Lucid Energy hydropower systems

System		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Total
All	Discharge (cfs)	20.5	5.7	0	0	0	18.8	25.5	46.6	80.6	90	90	68.0	n/a
90 cfs System	Power(kW)	19.4	5.4	0	0	0	17.8	24.2	44.2	76.4	85.3	85.3	64.5	n/a
	Energy(kW-hr)	14,464	3,892	0	0	0	13,264	17,411	32,878	55,032	63,498	63,498	46,429	310,366
	Revenue($)	579	156	0	0	0	531	696	1,315	2,201	2,540	2,540	1,857	18,932

Note: Calculations assume head of 14 feet, efficiency of 0.8, and revenue of $0.061 per kW-hr

Table 39. Potential energy prices and annual revenue from Natel and Lucid hydropower systems in East Fork Irrigation District.

Year	Energy Price (cents/kW-hr)[1]			Annual Revenue ($)		
	On-Peak	Off-Peak	Blended	Natel Energy (200 kW)	Natel Energy (100 kW)	Lucid Energy (90 cfs)
2013	3.72	2.62	3.17	20,339	14,606	9,839
2014	4.13	2.8	3.47	22,232	15,965	10,754
2015	4.39	2.99	3.69	23,676	17,002	11,453
2016	6.04	3.69	4.87	31,215	22,416	15,099
2017	6.32	3.91	5.12	32,819	23,568	15,875
2018	6.66	4.21	5.44	34,872	25,042	16,868
2019	6.99	4.5	5.75	36,861	26,470	17,831
2020	6.94	4.41	5.68	36,412	26,148	17,613
2021	7.23	4.65	5.94	38,112	27,369	18,436
2022	7.67	5.04	6.36	40,775	29,281	19,724
2023	7.92	5.24	6.58	42,219	30,318	20,422
2024	7.89	5.16	6.53	41,866	30,064	20,251
2025	8.09	5.32	6.71	43,021	30,894	20,810
2026	8.39	5.57	6.98	44,785	32,161	21,664
2027	8.66	5.78	7.22	46,325	33,267	22,408
2028	8.88	5.95	7.42	47,576	34,165	23,014
2029	9.07	6.09	7.58	48,635	34,925	23,526
2030	9.20	6.16	7.68	49,276	35,386	23,836
2031	9.201	6.16	7.68	49,276	35,386	23,836
2032	9.201	6.16	7.68	49,276	35,386	23,836
Total	n/a	n/a	n/a	559,817	779,570	377,095

[1] *Energy price from current Pacific Power Oregon Schedule 37 rates (Pacific Power, 2012)*

4.2.2 **Discussion**

The feasibility of hydropower in EFID depends on three main factors: 1) the cost of equipment purchase and installation, 2) the revenue per kW-hr that EFID would receive through a power purchase agreement, and 3) EFID's water right and the annual discharge through the turbine. Although a new hydropower installation in EFID does not make financial sense at this time, the cost of new installations is expected to decrease over the next 20 years (Eric Thompson, Natel Energy, personal communication) while the power purchase price increases from 3.72¢/kW-hr in 2013 to 9.2¢/kW-hr by 2030, indicating that at some point in the future it will. Since this calculation is dependent on the cost of new installations it is difficult to predict when this will be, therefore EFID should revisit these calculations in approximately 8-10 years.

4.3 Farmers Irrigation District

Farmers Irrigation District is required to reduce the amount of discharge through its hydropower turbines during the summer to meet irrigation demand (Figure 18) Additional water in the system, resulting from water conservation measures in FID, will lead directly to additional hydropower revenue. Although FID has been actively pursuing water conservation for decades, additional conservation can be achieved through converting more conventional irrigation systems to high-efficiency irrigation systems.

As shown in Section 3.2, converting 49 percent of land that is currently irrigated with impact sprinklers would reduce irrigation water use by 3.5 percent in FID. This water savings would result in an additional 236 acre-feet per year through FID's hydropower Plant #3 and 472 additional acre-feet through Plant #2 (Tables 40 and 41). Based on FID monthly plant discharge and energy production data, Plant #2 generates 37.7 megawatt hours (MW-hr) per month per cfs, and Plant #3 generates 18.9 MW-hr per month per cfs (Figure 19). At these rates, the on-farm water conservation would generate an additional 294 MW-hr per year. At $0.06 per kW-hr, that is equal to $17,657 (Table 41).

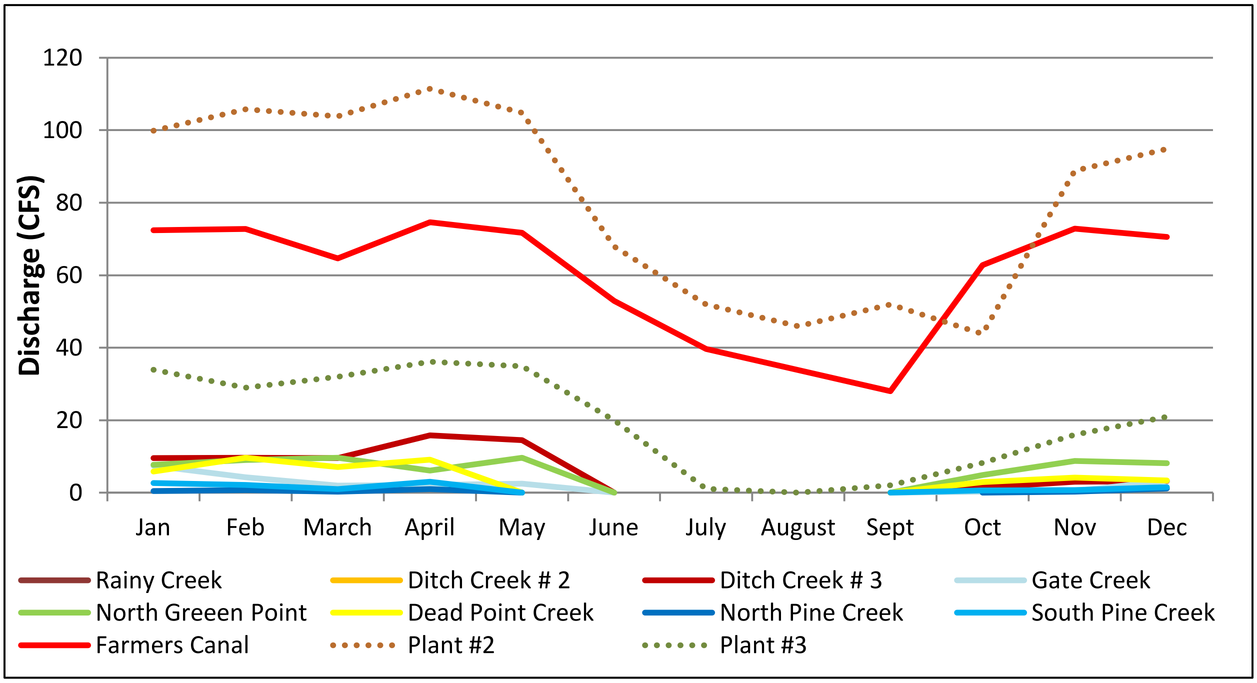


Figure 18. Hydropower water use for Farmers Irrigation District in 2011.

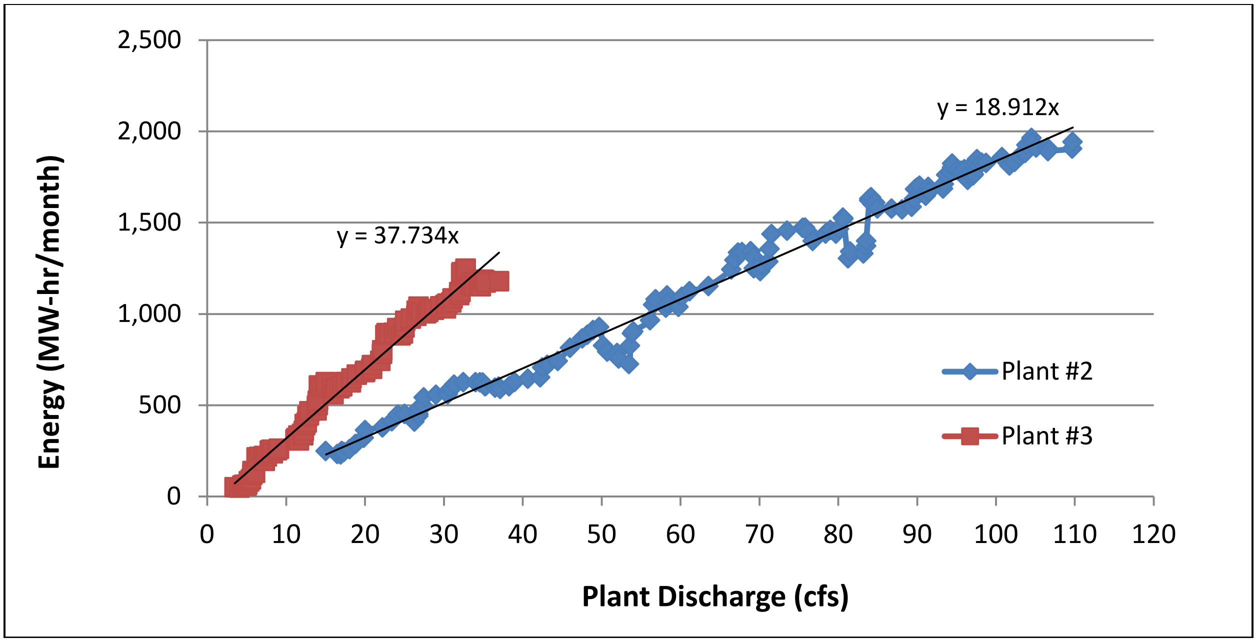


Figure 19. Monthly energy production as a function of plant discharge for Farmers Irrigation District hydropower plants.

Table 40. Irrigation use and Plant #2 and #3 discharge under existing conditions (2011) and with additional on-farm water conservation, Farmers Irrigation District.

	Plant	Average Monthly Discharge (cfs)					Total (ac-ft)
		May	Jun	Jul	Aug	Sept	
Irrigation Use	n/a	4.0	35.6	58.1	63.8	61.5	13,467
Plant Discharge- Existing	#3	34.9	20.0	1.1	-	2.1	3,514
	#2	104.8	67.9	51.9	45.9	51.9	19,503
Plant Discharge- Conservation[1]	#3	35.0	20.6	2.1	1.1	3.2	3,750
	#2	104.9	69.1	53.9	48.1	54.1	19,976

[1] On-farm conservation calculated in Section 3.2 as 3.5%. Applies half of conserved water upstream of Plant #3 and half downstream of Plant #3.

Table 41. Estimated additional plant discharge, energy production, and revenue achieved through 3.5 percent on-farm water conservation, Farmers Irrigation District.

	Plant	May	Jun	Jul	Aug	Sept	Total
Additional Plant Discharge (cfs)	#3	0.07	0.62	1.02	1.12	1.08	236 ac-ft
	#2	0.14	1.24	2.03	2.23	2.15	472 ac-ft
Additional Energy (MW-hr/month)[1]	#3	2.64	23.40	38.30	42.07	40.56	147.0
	#2	2.65	23.45	38.39	42.17	40.66	147.3
Additional Revenue[2]	#3	$158	$1,404	$2,298	$2,524	$2,434	$8,818
	#2	$159	$1,407	$2,303	$2,530	$2,439	$8,839

[1] Additional energy calculated at 37.7 MW-hr per month per cfs for Plant # 3 and 18.9 MW-hr per month per cfs for Plant #2.

[2] *Revenue calculated at $0.06/kW-hr*

4.4 Middle Fork Irrigation District

Middle Fork Irrigation District has three hydropower facilities, Plants #1, #2, and #3, which are located in series. Plant #1 receives water from Laurance Lake and Coe Creek, while Plants #2 and #3 receive tailwater from Plant #1 and from the Eliot Creek diversion downstream of the sediment pond. Outside of irrigation season, most water that travels through Plant #1 also travels through Plants #2 and #3. During irrigation season, however, a significant portion of the discharge that travels through Plant #1 gets turned out to consumptive use before reaching Plant #3 (Figure 20).

Similar to FID, MFID has been proactively managed to maximize hydropower efficiency while delivering reliable irrigation water. While there are few opportunities for further system improvements, two potentials do exist. One, additional water conservation, has been actively pursued by MFID. The other, connecting the Coe Creek diversion to the sediment pond, has been proposed but not thoroughly evaluated. These two opportunities are discussed further below.

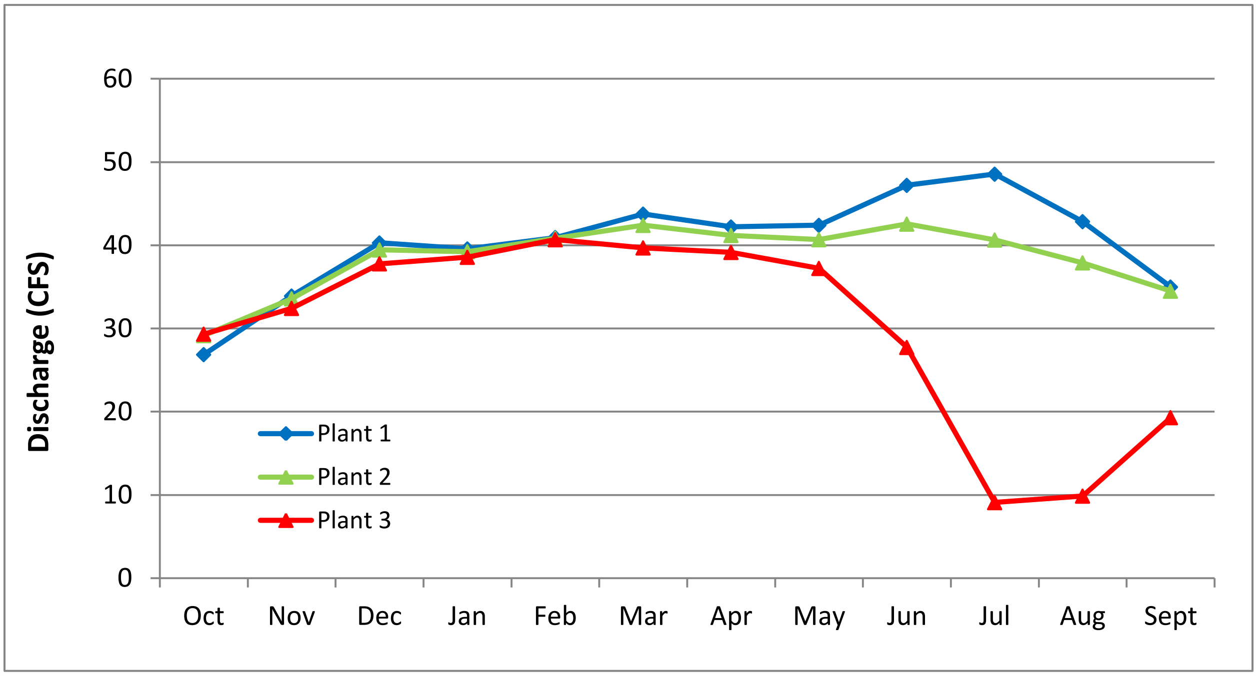


Figure 20. Average monthly discharge through Middle Fork Irrigation District hydropower plants.

4.4.1 Water Conservation

As stated above, during irrigation season a significant portion of the discharge that travels through Plant #1 gets turned out to consumptive use before reaching Plant #3. This deficit peaks in July, with an average of 48 cfs at Plant #1 but only 9 cfs at Plant #3 (Table 42). During irrigation season, any reduction in irrigation demand on the western side of the district (where demand is served by the hydropower penstocks) is water that could be used to generate power at Plants #2 and #3. Although MFID has piped the entire system (with the exception of the Eliot Creek diversion, which is not feasible due to sediment), thereby eliminating both seepage and all district overflows, additional water conservation can be achieved through conversion of on-farm irrigation systems. Conversion of impact sprinklers to high-efficiency micro or rotator sprinkler systems can reduce irrigation water consumption by roughly 13 percent over the next ten years (see Section 3.2 for details). Table 42 shows the irrigation withdrawal between Plant #1 and #3, the existing average flow through Plants #1-#3, and the estimated flows through plants #1-#3 if a 13 percent reduction in on-farm use was achieved.

Table 42. Irrigation use and hydropower plant discharge under existing conditions and with additional on-farm water conservation, Middle Fork Irrigation District.

	Plant	Average Monthly Discharge (cfs)					Total (ac-ft)
		May	Jun	Jul	Aug	Sept	
Irrigation use between Plant #1 and #3	n/a	5.2	19.5	39.4	32.9	15.7	6806
Plant Discharge- Existing	#1	42.4	47.2	48.5	42.8	35	13038
	#2	40.7	42.6	40.6	37.9	34.5	11855
	#3	37.2	27.7	9.1	9.9	19.3	6232
Plant Discharge- Conservation[1]	#1	42.4	47.5	49.2	43.1	35.3	13132
	#2	40.9	43.5	42.3	38.9	34.8	12102
	#3	37.9	30.6	14.9	14.5	21.6	7211

[1] On-farm conservation calculated in Section 3.2 as 13.1%. Applies conservation between hydropower plants based on existing use.

cfs = cubic feet per second

ac-ft = acre-feet

Based on MFID weekly plant discharge and energy production data, Plant #1 generates 31.7 MW-hr per month per cfs, Plant #2 generates 13.8 MW-hr per month per cfs, and Plant #3 generates 8.3 MW-hr per month per cfs (Figure 21). At these rates, the on-farm water conservation would generate an additional 307 MW-hr per year. At $0.06 per kW-hr, that is equal to $18,415 (Table 43).

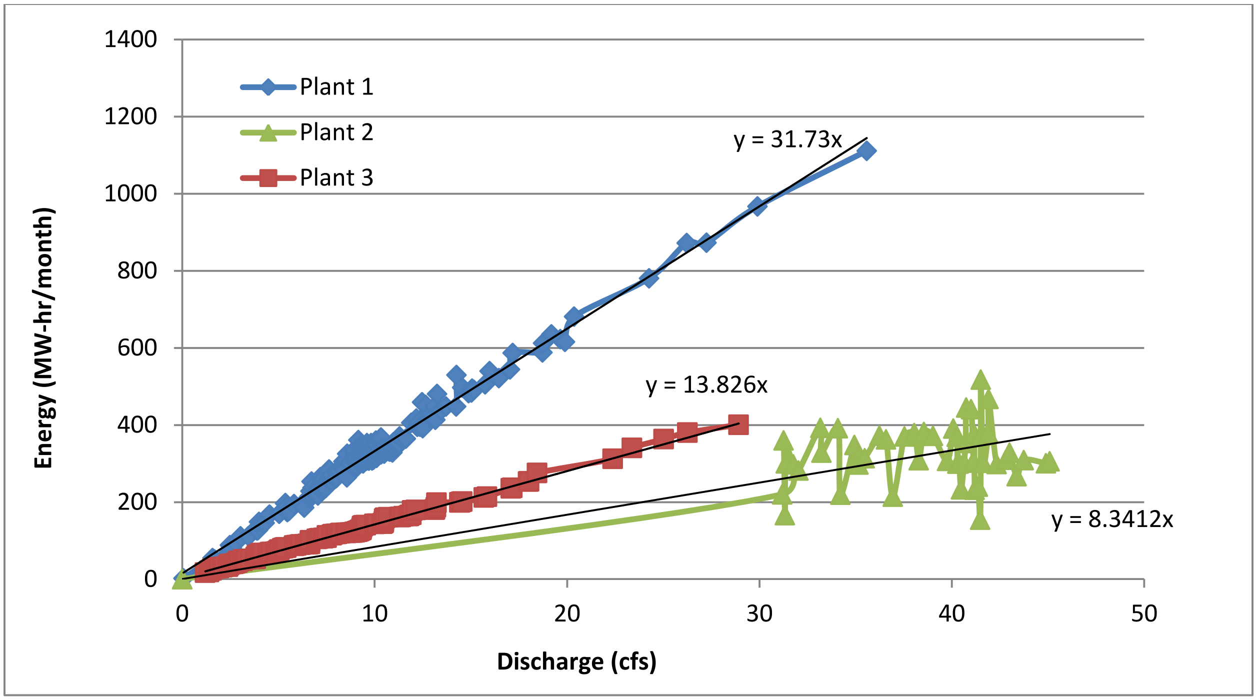


Figure 21. Monthly energy production as a function of plant discharge for Middle Fork Irrigation District hydropower plants.

Table 43. Estimated additional plant discharge, energy production, and revenue achieved through 13.1 percent on-farm water conservation, Middle Fork Irrigation District.

	Plant	May	Jun	Jul	Aug	Sept	Total
Additional Plant Discharge (cfs)	#1	0.00	0.33	0.65	0.33	0.25	94 ac-ft
	#2	0.22	0.93	1.68	0.97	0.31	248 ac-ft
	#3	0.68	2.87	5.77	4.61	2.29	979 ac-ft
Additional Energy (MW-hr/month)[1]	#1	0.0	10.3	20.6	10.3	7.9	49.2 MW-hr
	#2	1.8	7.7	13.9	8.0	2.6	34.0 MW-hr
	#3	9.4	39.5	79.6	63.5	31.6	223.7MW-hr
Additional Revenue ($)[2]	#1	$0	$619	$1,237	$619	$476	$ 2,951
	#2	$110	$461	$837	$481	$154	$ 2,042
	#3	$563	$2,372	$4,778	$3,813	$1,896	$ 13,422

[1] *Additional energy calculated at 31.7 MW-hr per month per cfs for Plant # 1, 8.3 MW-hr per month per cfs for Plant #2, and 13.8 MW-hr per month per cfs for Plant #3.*

[2] *Revenue calculated at $0.06/kW-hr*

4.4.2 Connecting Coe Creek Diversion to Sediment Pond

Because the Coe Creek diversion is not connected to the sediment pond, MFID is forced to reduce the amount of Coe Creek water it diverts during July, August, and September due to the high concentration of glacial sediment. Connecting the Coe Creek diversion to the sediment pond (similar to what was done with the Eliot Creek diversion) would allow continued use of Coe Creek throughout the summer when irrigation demand is at its peak. Although the primary purpose for connecting the Coe Creek diversion would be to allow MFID to use sediment-laden Coe Creek runoff, thereby preserving Laurance Lake water during the summer, it would also have both positive and negative impacts on hydropower production. As described below, these impacts would largely offset each other. Nevertheless, connecting the Coe Creek diversion to the sediment pond would preserve storage of Laurance Lake water until later in the summer when streamflows are the lowest, hence the ability to use stored water is the most valuable.

The target flow rate for the Coe Creek diversion is roughly 25 cfs, but, due to sediment load in the creek, the diversion is reduced to 13.0 cfs, 9.5 cfs, and 9.4 cfs during July, August, and September, respectively (Table 44). This flow reduction results in MFID drawing an additional 2,615 acre-feet of Laurance Lake water to make up the deficit. Connecting the Coe diversion to the sediment pond would allow MFID to use that Laurance Lake water to increase downstream streamflows (i.e., below the bypass reach) and generate electricity in October and November instead, when the hydropower facilities are running at 11 cfs, and 6 cfs, respectively, below their capacities (Table 42). Although this increased flow in October and November would generate additional revenue, October and November have the lowest average lake elevations during the year. Lower lake elevations produce less head for Plant #1and therefore the lowest energy production per acre-foot of water used for hydropower. This would partially offset the benefit of holding the additional 2,615 acre-feet of Laurance Lake water during irrigation season. Also offsetting the benefit is the fact that water discharged from the sediment pond enters the hydropower system at the tailrace for Plant #1, so it does not contribute to Plant #1 production. The pond's discharge entering the hydropower system at the Plant #1 tailrace has significant impacts on power production because Plant #1 generates 90 percent more energy than Plants #2 and #3 combined and because July and August have relatively high lake levels.

Even though the benefits to hydropower production may be largely offset, the concept of connecting the Coe diversion to the sediment basin should be explored further because it could provide additional management flexibility that could be used to meet Basin goals. Exploring this concept would require a detailed analysis of the plant efficiency curves in the greater context of overall fisheries management goals for stream flow below Laurance Lake. Although limited streamflow data is available for Coe Creek, one recent study showed that the average August stream flow is on the order of 55 cfs (Nolin 2010), which indicates continued use of Coe Creek up to 25 cfs during this period should not be an issue (Figure 22).

Table 44. Coe Creek target diversion, actual diversion, and resulting deficit.

	Jul	Aug	Sept	Total (ac-ft)
Water Right (cfs)	29.5	29.5	29.5	n/a
Target Diversion (cfs)	25	25	25	n/a
Actual Diversion (cfs)	13	9.5	9.4	n/a
Deficit (cfs)	12	15.5	15.6	n/a
Deficit (ac-ft)	737	951	927	2,615

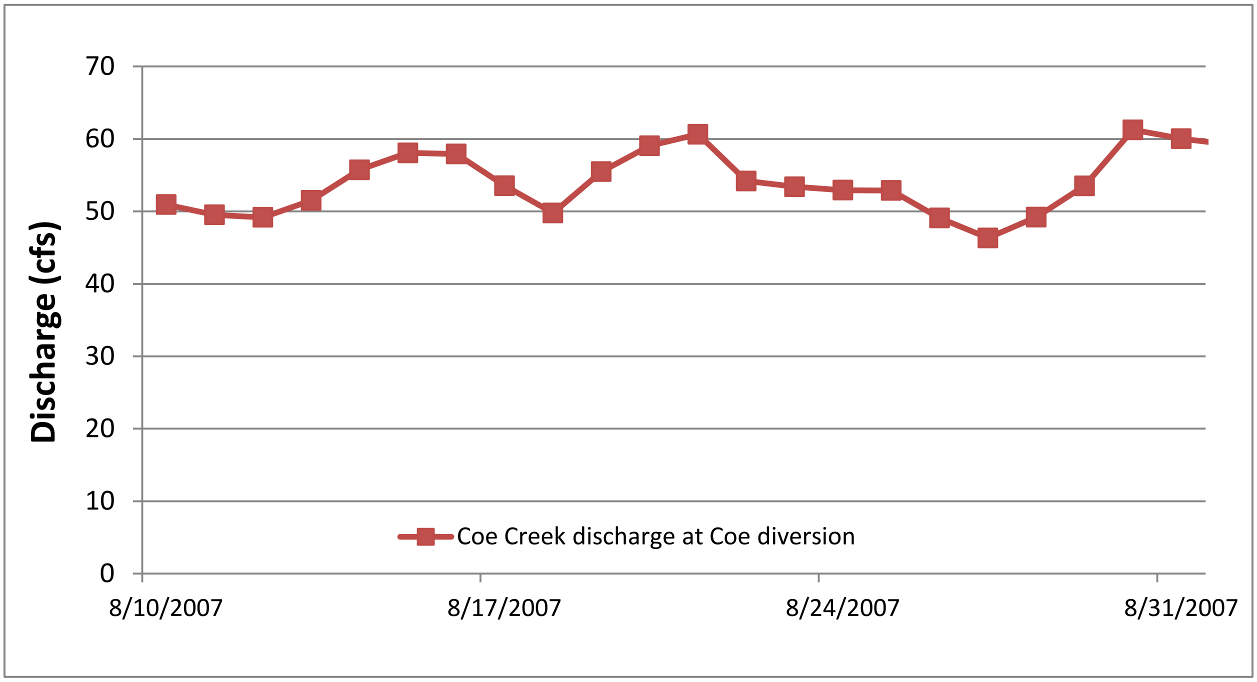


Figure 22. Coe Creek discharge at Coe Creek diversion during August 2007.

4.5 Mount Hood Irrigation District

Mount Hood Irrigation District has limited potential for generating hydropower. First, there is little elevation change. Second, flow rates in MHID range from zero to 10.1 cfs, with an annual average of 2.8 cfs—too low for cost-effective hydropower production. Third, MHID receives its water from EFID in two locations, both of which have a gravity line and a pumped line leaving from them. The pumped lines serve the higher elevation acreage, while the gravity lines feed the lower elevation acreage. A hydropower facility would extract head (pressure) from these lines which would then need to be added back in for sprinkler operation.

5 Sediment Control

Most of the irrigation districts in the Hood River Basin have sediment control facilities, yet sediment concentrations still affect water conservation and hydropower. Sediment limits the use of efficient irrigation systems, thereby reducing the potential for on-farm water conservation. Sediment also causes increased wear and maintenance of hydropower facilities. Micro sprinklers are efficient because their small nozzle diameter restricts water flow; however, over time, high sediment concentrations erode the nozzle material and increase the diameter. This either reduces the lifespan of a micro sprinkler or reduces the long-term efficiency of the nozzle. Replacement costs may dissuade some growers from converting to micro sprinkler systems. Very high sediment concentrations also have the potential to clog drip irrigation systems, which could make growers reluctant to install this technology. For hydropower facilities, turbine wear comes from both sediment concentration and cavitation.[1] Costs are incurred through more frequent maintenance and shorter turbine life spans, requiring more frequent turbine replacement.

Sediment control in the Basin is currently achieved through either settling ponds or horizontal, flat plate screens. East Fork Irrigation District has a 60-by-100-foot concrete settling basin just downstream of its diversion off of the East Fork Hood River. This sediment basin serves both EFID and MHID. EFID also has smaller facilities (typically sumps or expansion points within distribution canals) that provide additional sediment removal. Farmers Irrigation District operates six diversions with flat plate screens, all of which provide some degree of sediment control. FID is also constructing a new settling facility in Fall 2013 as part of its Farmers Canal piping project. Middle Fork Irrigation District has horizontal flat plate screens on its Eliot Creek and Coe Creek diversions, plus a 25-acre-foot settling pond that receives water from its Eliot Creek diversion. Dee Irrigation District receives relatively sediment-free water from the West Fork Hood River, No Name Creek, and Camp Creek, and therefore does not require a sediment control facility.

Typical flow rates and sediment concentrations are presented below along with an evaluation of a wide range of potential treatment technologies. The technologies are applicable to all irrigation districts; however, actual system sizing and cost estimates are presented for only EFID and MFID. With FID's new sediment facility constructed in Fall 2013, it is unlikely that FID will require any additional treatment. DID does not need any new sediment control, while MHID benefits from any facility operated by EFID (as long as the facility is upstream of MHID's first turnout).

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[1] Cavitation is the pitting and wearing away of solid surfaces (like metal) as a result of the collapse of partial vacuums in a liquid that are created by a swiftly moving solid body (like a propeller) or by high-intensity sound waves.

5.1 Flow Rates and Sediment Size and Composition

Potential flow rates for new sediment control facilities in EFID and MFID are presented below in Table 45 and Figures 23 and 24. The flow rates used for EFID are the average monthly flows downstream of its existing sediment control facility and are therefore applicable for designing a facility somewhere near this location. Although this is the ideal location for a facility since it would treat water for all of EFID and MHID, a facility could also be located near the EFID distribution center which could function as a surge pond as well (discussed in Section 3.4.1.1).

For MFID, flow rates are analyzed for both the Eliot Creek diversion and Coe Creek diversion. These creeks drain Eliot and Coe glaciers and therefore have very high summertime sediment concentrations. The Eliot Creek diversion is connected to MFID's 25-acre-foot sediment basin, but Coe Creek is not. Because of this, when sediment concentrations increase during the summer, MFID is forced to reduce its Coe Creek diversion and rely on Laurance Lake water instead. (See Section 5.2.7.2 for more information.) One potential for increased sediment removal in MFID is to connect the Coe Creek diversion to the existing sediment basin. This would remove sediment from the whole Hood River system, plus allow Laurance Lake water to be used for other beneficial purposes (e.g., hydropower, instream flow targets).

Any new sediment control facilities must be designed for specific sediment concentrations and particle sizes. Average monthly Nephelometric Turbidity Units (NTU) for the EFID, Coe Creek, and Eliot Creek diversions are also presented in Table 45 and Figures 23 and 24 (Hood River Production Program Review, 2003). For all three diversions, turbidity increases in the summertime and peaks in August during peak glacial melt. As shown in Table 45, turbidity at the EFID, Coe Creek, and Eliot Creek diversions average 14, 225, and 150 NTU during the summer, respectively (however; MFID see daily peaks as high as 1000 NTU). For comparison, the West Fork Hood River peaks at 6 NTU, and the main stem Hood River at 14 NTU.

Although the measure of turbidity (NTU) is helpful for a general characterization of the amount of suspended sediment in a liquid, it is insufficient in itself for designing a water quality treatment facility. Depending on the type of treatment proposed, conductivity, particle size, and particle composition can also be key design parameters. Conductivity is a measure of the ability of a substance to carry an electrical current, and is usually inversely proportional to stream flow (because groundwater has a greater ability to pick up dissolved ions). Data on conductivity in the Hood River Basin is limited; however, one study found that the August values in East Fork Hood River ranged from 115 micromhos per centimeter to 205 micromhos per centimeter, with an average of 160 micromhos per centimeter (USDA Forest Service, 1995). Although this is limited data, it corresponds with peak irrigation demand.

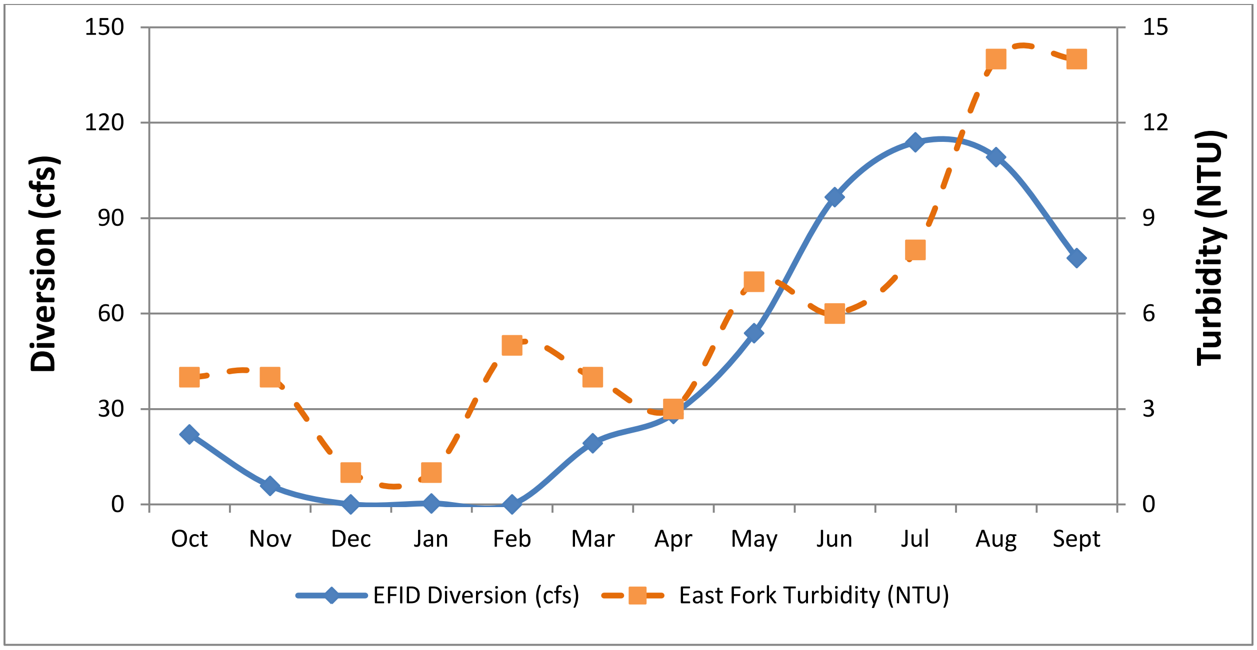
An additional design parameter that could be further investigated before any actual facility design is target sediment concentrations or particle sizes. Particles that are small enough may pass through micro systems without any clogging or wear; therefore they do not currently pose an impediment to further installations of these technologies. When contacted about target sediment size, Nelson Irrigation responded that they did not know what diameter would be acceptable, and that it would likely take a considerable amount research dollars to determine it (John Rowley, Nelson Irrigation, personal communication). Although a conclusive study may be beyond the scope and budget of what is necessary in designing any new facilities, some consideration should be paid to this as smaller sediments (e.g., clays) likely pass through all application methods and therefore do not need to be targeted for removal.

Table 45. Flow rates and NTU values for locations in East Fork Irrigation District and Middle Fork Irrigation District that could benefit from additional sediment control.

District	Location	Units	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
EFID	EFID Diversion	cfs	22.0	5.8	0	0	0	19.2	28.4	53.8	96.6	113.8	109.2	77.4
		NTU	4	4	1	1	5	4	3	7	6	8	14	14
MFID	Coe Creek Diversion	cfs	9.7	12.8	11.8	11.4	14.8	15.9	16.9	15.1	14.9	13	9.5	9.4
		NTU	5	0	0	0	0	0	0	5	25	55	225	20
	Eliot Creek Diversion	cfs	2.2	0.2	0	0	0	0	0	0	2.7	7.8	9	7.1
		NTU	30	0	0	0	0	0	0	30	30	100	150	100

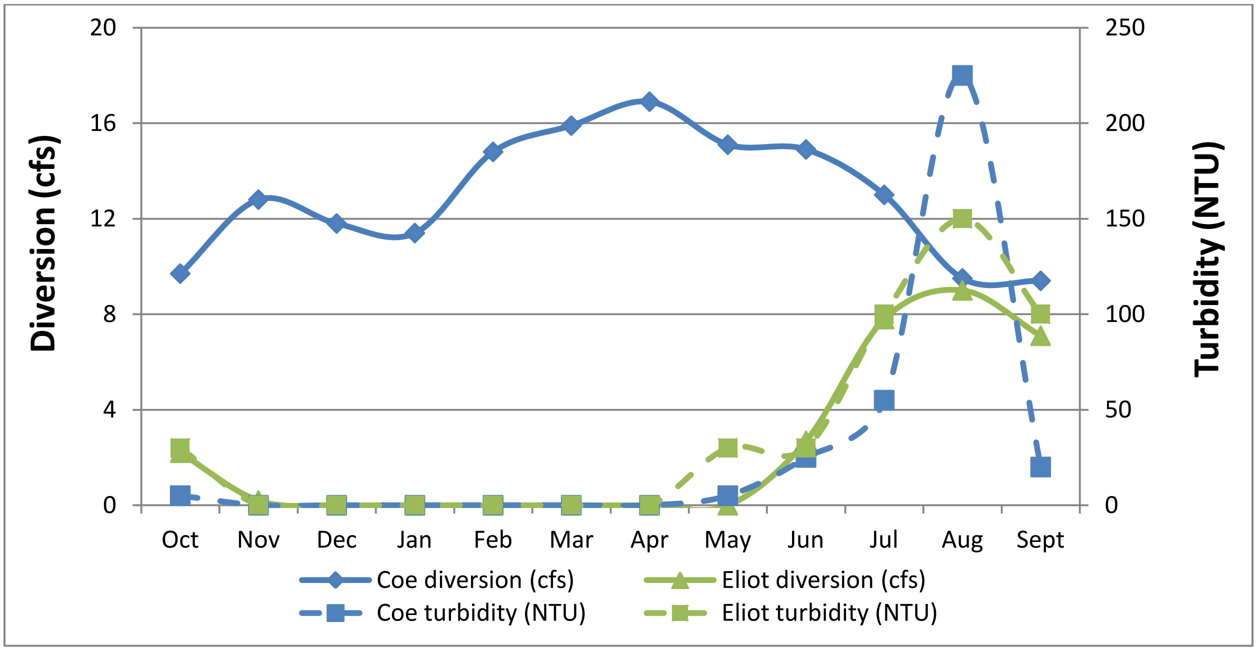
cfs = cubic feet per second

NTU = Nephelometric Turbidity Units



Source of NTU data: Hood River Production Program Review, 2003

Figure 23. Average monthly turbidity, East Fork Irrigation District diversion and East Fork Hood River.



Source of NTU data: Hood River Production Program Review, 2003

Figure 24. Average monthly diversion and turbidity at Coe Creek and Eliot Creek diversions.

Data regarding particle size and composition of runoff in the Basin is also limited. Because of the similarity of these parameters across all glacial streams (Andrew Fountain, Portland State University, personal communication), surrogate data is used from the Bhagirathi River in the central Himalaya (Haritashya et al., 2010). Table 46 shows that sand comprises 24 percent of the sediment load, silt comprises 69 percent, and clay comprises 7 percent. Table 47 shows the typical particle type and composition of glacial runoff. Figure 25 shows the cumulative weight of the suspended particles as a function of particle size (e.g., 24% of the weight of the suspended sediments is contained in particles 0.2 millimeters and larger). Although this information can be used for a planning level assessment, any actual facility design should be based on water quality sampling specific to the location and period of year during which treatment will occur.

Table 46. Typical particle sizes by percent contained in glacial runoff.

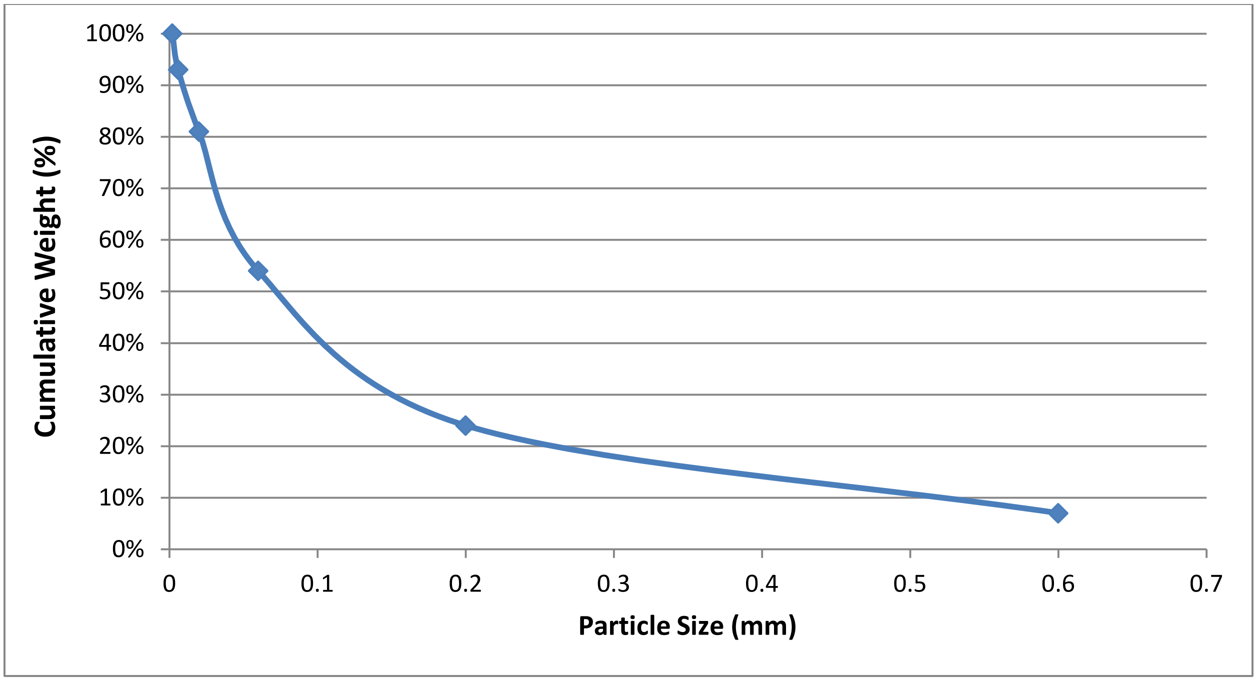
	Particle Size (mm)	Percentage by weight
Clay	<0.002	7%
Fine Silt	0.002-0.006	12%
Medium Silt	0.006-0.02	27%
Coarse Silt	0.02-0.06	30%
Fine Sand	0.06-0.2	17%
Medium Sand	0.2-0.6	7%

Source: Haritashya et al., 2010
mm=millimeters

Table 47. Typical particle type and composition of glacial runoff.

Particle Type (diameter in mm)	Composition	Percentage by weight
Clay (<0.002 mm)	Quartz	39%
	Illite	38%
	Kaolinite	20%
Silt (0.002 - 0.06 mm)	Quartz	60%
	Mica	20%
	Feldspar	15%
Sand (0.06 - 0.6 mm)	Quartz	57%
	Feldspar	28%
Total	Quartz	57%
	Mica	17%
	Feldspar	11%
	Illite	10%
	Kaolinite	5%

Source: Haritashya et al., 2010
mm=millimeters



Source: Haritashya et al., 2010

Figure 25. Cumulative weight of particles bigger than a given diameter.

5.2 Potential Sediment Control Technologies

Additional sediment control through electro-coagulation, chemical-coagulation, filtration, vortex separation, settling, and turbidity curtains are discussed below. Although many of these systems are designed for lower, steadier flow rates, they are analyzed here nonetheless to give a comprehensive assessment of potential treatment technologies.

5.2.1 Electro-coagulation

Electro-coagulation is an electro-chemical process that removes suspended solids from water by using electricity and sacrificial metal plates. It works by passing sediment-rich water through the charged plates, which removes any electrical charges and facilitates flocculation. The neutrally charged water then enters a separation chamber where the solids are removed. Electro-coagulation has the advantage over chemical-coagulation in that it does not add additional material to the water (i.e., chemicals); therefore it does not create an additional waste stream.

Several firms were contacted about their electro-coagulation system's ability to remove particles similar to those in glacial meltwater (Tables 46 and 47). All firms replied that their systems could remove up to 95 percent of the particles, but the systems were typically geared towards lower flow rates associated with treating industrial wastewater or drinking water, and that a system designed to treat flow rates such as those at the EFID, Coe Creek, and Eliot Creek diversions (Table 48) would likely be prohibitively expensive. Nonetheless, system design and cost estimates were obtained from Kaselco and WaterTectonics.

The capital cost of a Kaselco treatment system for East Fork Irrigation District would be $14.5 million (Table 48). Operating costs at 100 cfs are: power for $650 per hour, electrode replacement for $5,400 per hour, flocculation polymers for $2,100 per hour, and reagents for pH adjustment at $2,000 per hour. These hourly costs for June, July, and August (months with peak sediment concentrations) equal $19,764,000 per year. Scaling these costs to MFID equal a $2,900,000 capital cost and 3,952,800 annual operating costs. The WaterTectonics treatment system would have a much higher capital cost ($45 million), which is partly due to a more expensive solids separation unit, but a lower annual operating cost ($2 million) (Table 48). All costs above are higher than typical because of the low conductivity of glacial runoff and the need to add calcium chloride.

Table 48. Comparison of estimated capital and annual operating costs for Kaselco and WaterTectonics electro-coagulation treatment systems for East Fork Irrigation District and Middle Fork Irrigation District.

System	Irrigation District	Peak Flow Rate (cfs)	Capital Cost	Annual Cost
Kaselco	EFID/MHID	100	$14,500,000	$19,764,000
	MFID	20	$2,900,000	$3,952,800
WaterTectonics	EFID/MHID	100	$45,000,000	$10,000,000
	MFID	20	$9,000,000	$2,000,000

Source: Thomas C. Leggiere, Kaselco, Personal communication.

Source: TJ Mothersbaugh, WaterTectonics, personal communication.

5.2.2 Chemical Coagulation

Chemical coagulation uses the addition of chemicals to promote flocculation of particles which can then be removed. Which chemical to use is highly dependent upon the water being treated, however, all firms contacted stated that chitosan would likely be the most cost-effective for this application. Similar to electro-coagulation, after the flocculant has been created, the sediment must be removed. Most applications use a sand filter to remove sediment where the effluent is discharged. The sand filter is dredged or removed periodically, depending on influent sediment levels (Figure 26).

Cost estimates were obtained for WaterTectonics chitosan sand filtration systems for both EFID and MFID (TJ Mothersbaugh, WaterTectonic, personal communication) (Table 49). Capital costs would be $6,491,000 for an EFID system and $1,485,000 for a system for MFID. Annual costs were calculated using peak flow rates for June, July and August and are based on the following unit prices: chitosan $8.00 per 1,000 gallons, sand media $0.25 per 1,000 gallons, and energy $0.20 per 1,000 gallons. Total annual operating costs would be $47,603,000 for EFID and $6,379,000 for MFID.

There are some potential toxicity concerns related to the use of chitosan for agricultural application. Any district proposing to use this technology would likely need to go through a potentially lengthy permitting process. In theory, most chitosan would be removed by the sand filtration process; however, some trace residual amounts typically remain present in the effluent stream. The Oregon Department of Environmental Quality reported no known use of chitosan for removing sediment in agricultural irrigation systems; Therefore the potential of getting a permit is somewhat uncertain (Bonnie Lamb, Oregon Department of Environmental Quality, personal communication). The permitting process was not evaluated further due to the already prohibitively high costs of this treatment technology.

Table 49. Estimated capital and annual operating costs of chitosan-enhanced sand filtration systems for East Fork Irrigation District and Middle Fork Irrigation District.

District	Design Flow (cfs)	Capital Cost			Annual Operating Cost		
		Design & Install	System	Total	Chitosan & Filter Media	Energy	Total
EFID/MHID	100	$285,000	$6,206,343	$6,491,343	$46,715,771	$887,008	$47,602,779
MFID	20	$160,000	$1,325,000	$1,485,000	$6,259,913	$118,859	$6,378,772

Source: TJ Mothersbaugh, WaterTectonics, personal communication.

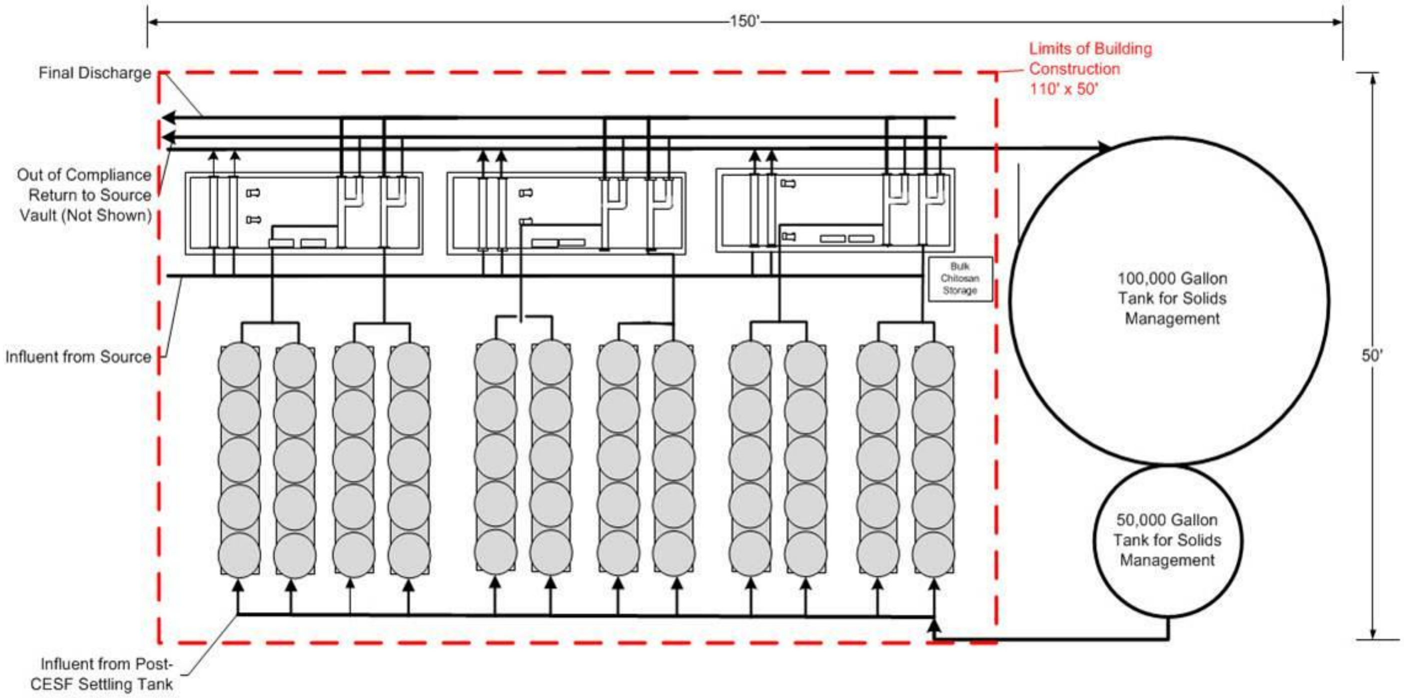


Figure courtesy of WaterTectonics

Figure 26. Typical layout of a chitosan-enhanced sand filtration system.

5.2.3 **Filtration**

Filtration is a pressure-driven purification process in which water and low molecular weight substances permeate a membrane while particles, colloids, and macromolecules are retained. The primary removal mechanism is size exclusion, although the electrical charge and surface chemistry of the particles or membrane may affect the purification efficiency. Typical systems use pumps to push water through 8-by-40-foot treatment trains that each handles 2.2 cfs (Figure 27). Additional 8-by-40-foot treatment units are added to reach the required capacity, making high-flow systems quite large. During normal operation, each unit is programmed to automatically backwash and air scour the membranes 2 to 4 times per hour. Roughly once per month, each unit is taken out of service for maintenance during which each membrane is cleaned with chemicals. Other filtration systems (e.g. Contech StormFilter) were evaluated, but most did not have a backwash system, so the lifespan of the actual filters would be prohibitively short.

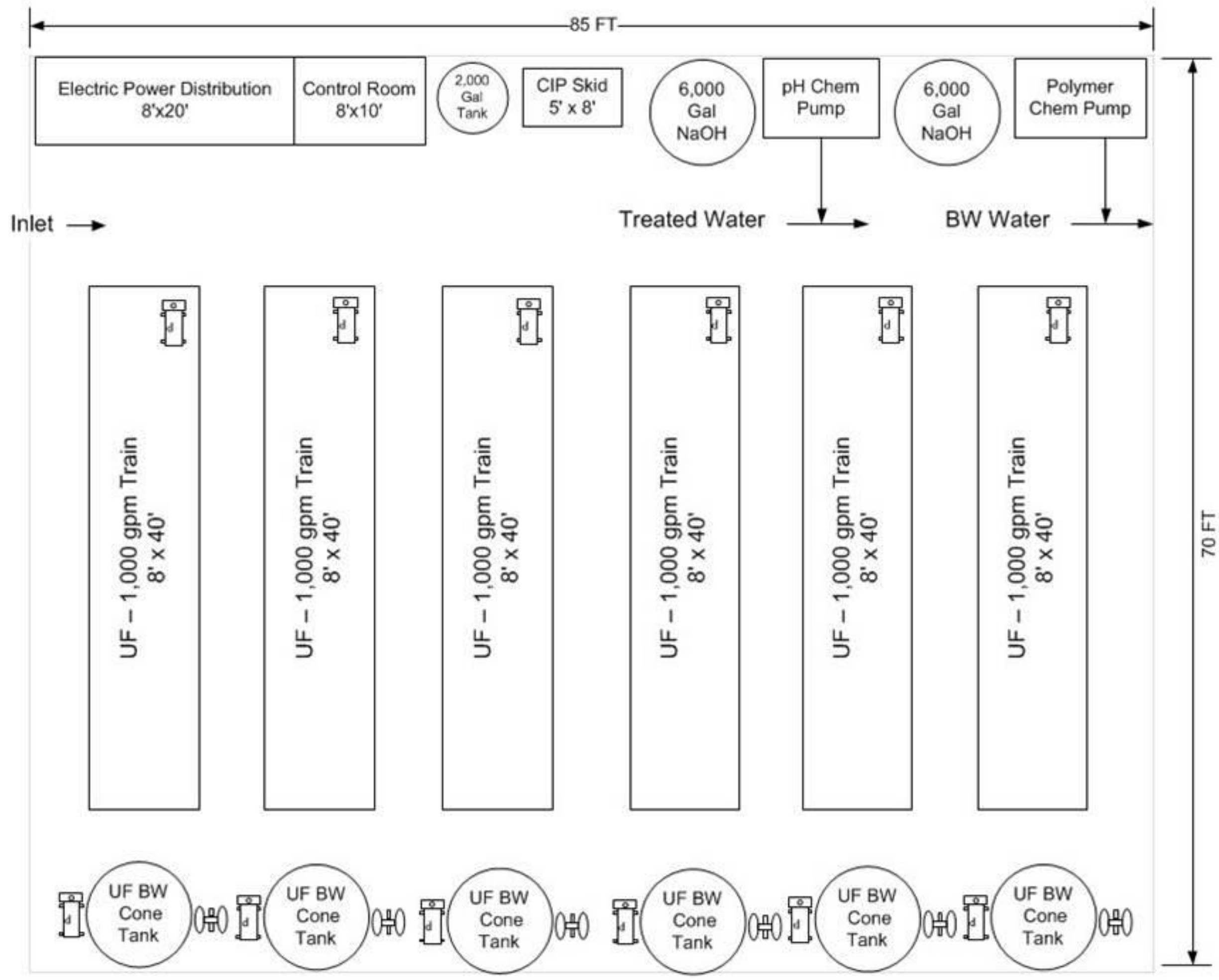


Figure courtesy of WaterTectonics

Figure 27. Typical layout of an ultra-filtration system.

Table 50 presents estimated capital and annual operating costs for a WaterTectonics filtration system for EFID and MFID. Capital costs for a system designed for EFID would be $7,685,000; capital costs for a system for MFID would be $2,625,000. Annual costs are $6,504,727 for EFID and $871,633 from MFID, of which approximately 30 percent is for membrane replacement and 70 percent is for energy consumption used in pushing water through the membrane as well as backwashing the system.

Table 50. Estimated capital costs and annual operating costs for filtration systems for East Fork Irrigation District and Middle Fork Irrigation District.

District	Design Flow (cfs)	Capital Cost			Annual Operating Cost		
		Design & Install	System	Total	Membrane	Energy	Total
EFID/MHID	100	$380,000	$7,305,000	$7,685,000	$2,069,686	$4,435,041	$6,504,727
MFID	20	$190,000	$2,435,000	$2,625,000	$277,337	$594,295	$871,633

Source: TJ Mothersbaugh, WaterTectonics, personal communication.

5.2.4 **Hydrodynamic Separation**

Hydrodynamic separators use continuous deflective separation to remove floatables and sediment from the influent water. Units such as the CDS system from Contech (Figure 28) are capable of removing 100 percent of particles 2.4 mm and bigger, and some amount of particles down to 0.1 mm at treatment flow rates of up to 6 cfs. Although these particle sizes and flow rates work well in stormwater applications, they are not well suited for treatment of irrigation water in the Hood River Basin. The smallest particle size they are designed to treat falls in the range of sand; therefore, they are unable to remove any meaningful amount of silt or clays. Although removing sand from the system would be helpful if no existing treatment were in place, both EFID and MFID already have treatment that is capable of removing sand-sized particles. Therefore, installing hydrodynamic separators in either district is unlikely to offer any additional benefits.

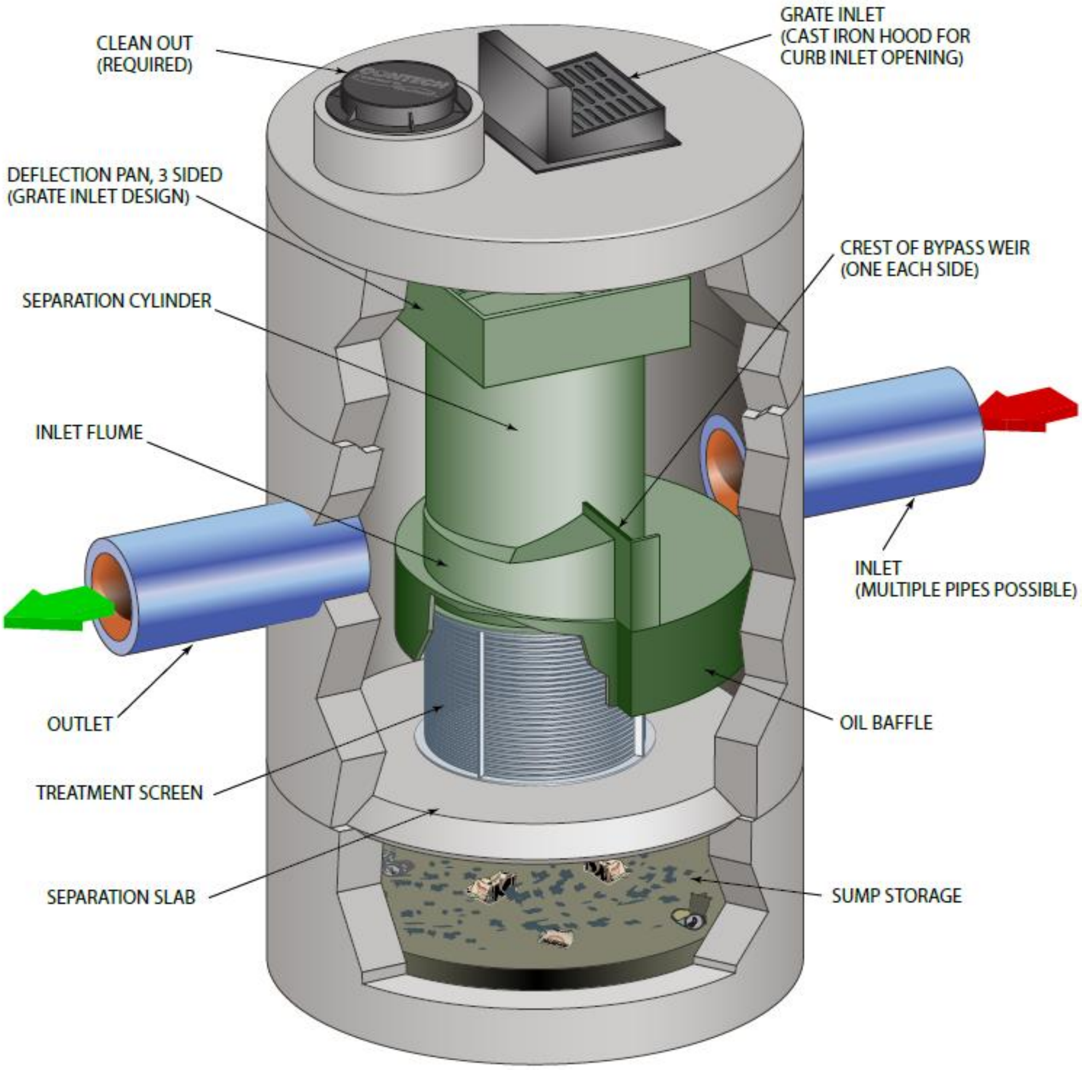


Figure courtesy of Contech (http://www.conteches.com/Products/Stormwater-Management/Treatment/CDS.aspx)

Figure 28. Schematic of Contech CDS system.

5.2.5 **Settling**

Natural settling is typically the most cost-effective solution for sediment removal if space is not a limiting factor or a significant cost. This is because settling uses gravity while other treatment technologies use electricity, chemicals, or both. It is mostly in urban areas where the cost of space is very expensive, or for treatment of bacteria or other constituents that do not settle well, that the more active treatment is the most cost-effective solution.

Settling velocity calculations are presented below along with potential new or improved facilities for EFID and MFID. Both districts are discussed separately, since their existing settling facilities and flow rates are significantly different from one other.

5.2.5.1 Settling Velocity

The settling velocity of a particle is dependent on the size, shape, density, and electrostatic charge of the particle, the viscosity of the fluid in which it is suspended, and the type of flow (turbulent or laminar) within the settling facility. The size of the particles used in the velocity calculations below are at the low end of the range of the particle size for each sediment type given in Tables 45 and 46 (glacial runoff). For example, medium sand has a diameter from 0.2 to 0.6 mm—the settling velocity calculation is based on a diameter of 0.2 mm. Settling velocity increases with particle diameter, so using the smaller diameter ensures that all particles within the classification type settle out. Other variables used in the settling velocity calculations are: particles having a specific gravity of 2.65, particles having no electrostatic charge, particles being spherical, and the facility having type 1 sedimentation (i.e., characterized by relatively still fluid). Although these are the appropriate parameters to use for planning-level design, any actual facility design should be based on further water quality testing and optimizing the type of flow regime within the facility.

Table 51 and Figure 29 show that calculated settling velocities range from 47 feet per minute for coarse sand down to 0.000131 feet per minute for clay. Figure 30 shows the cumulative weight settled out for each of the calculated settling velocities. For example, from Table 51 and Figure 29, the settling velocity for fine sand is 0.0079 feet per second and the cumulative percentage of material that has a settling velocity equal to or greater 0.0079 feet per second is 24 percent. Settling velocities have diminishing returns. For example, a facility designed to remove 81 percent of sediment (settling velocity of 0.000078 feet per second) would need to be 36 times larger to remove100 percent of sediment (settling velocity of 0.0000022 feet per second). These relationships between sediment size, percentage of sediment at each size, settling velocities, and required residence times can be used to evaluate the amount of settling at existing facilities and to design new or improved facilities.

Table 51. Settling velocity calculations of typical glacial runoff.

Sediment Type	Particle Size (mm)	Diameter Used in Calculation (mm)	Percentage (by weight)	Cumulative Percentage Coarser (%)	Settling Velocity		
					Feet/second	Feet/min	Feet/day
Clay	<0.002	0.001	7%	100%	2.185E-06	0.000131	0.1888
Fine Silt	0.002-0.006	0.002	12%	93%	8.742E-06	0.000525	0.7553
Medium Silt	0.006-0.02	0.006	27%	81%	7.86774E-5	0.004721	6.797
Coarse Silt	0.02-0.06	0.02	30%	54%	8.7419E-4	0.052452	75.53
Fine Sand	0.06-0.2	0.06	17%	24%	0.007868	0.472065	679.0
Medium Sand	0.2-0.6	0.2	7%	7%	0.08742	5.245163	7,553
Coarse Sand	> 0.6	0.6	0[1]	0[1]	0.7868	47.20647	67,980

[1] *Particles bigger than 0.6 mm not included in cumulative weight.*

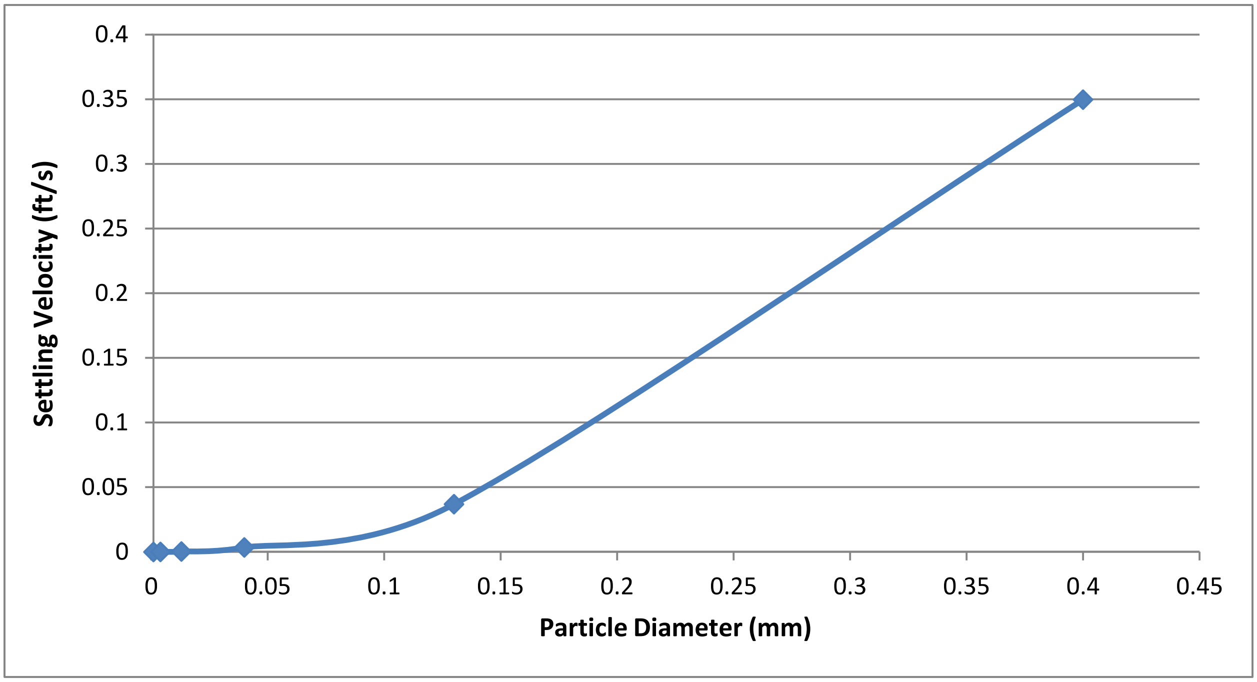
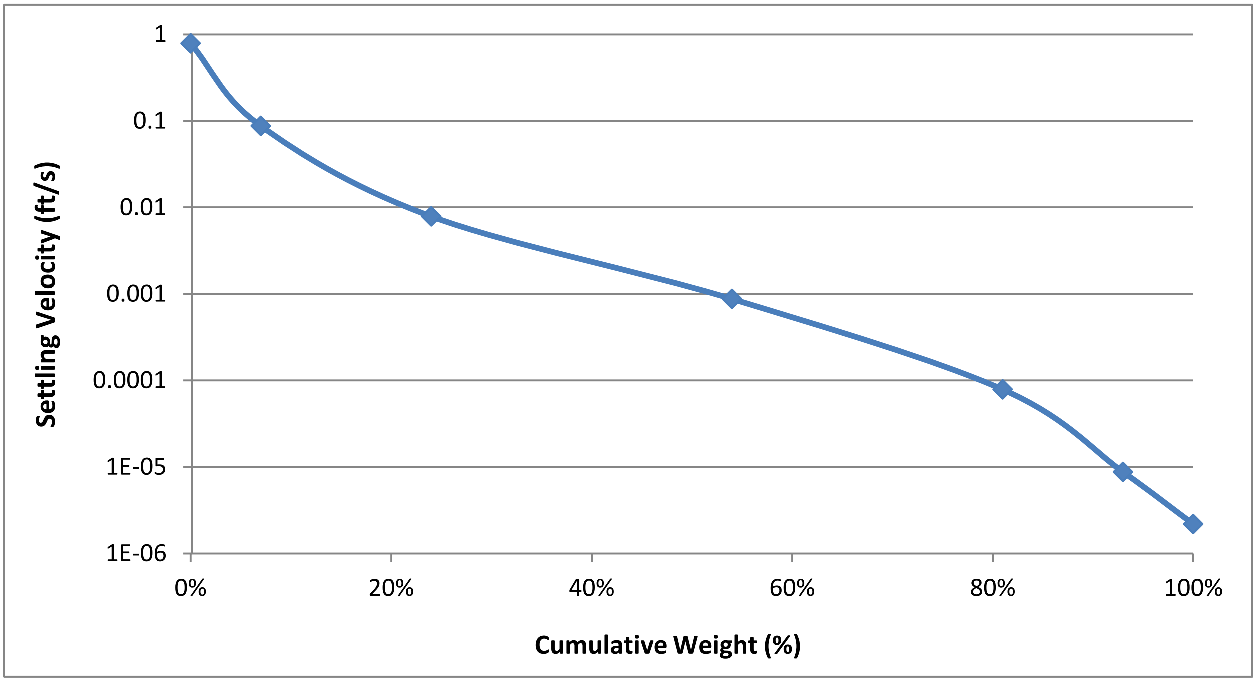


Figure 29. Settling velocity as a function of particle diameter.



Note: *For example, 24% of the suspended weight has a settling velocity less than 0.01 feet per second.*

Figure 30. Settling velocity as a function of cumulative weight.

5.2.6 **East Fork Irrigation District**

East Fork Irrigation District has a 100-by-65-foot concrete settling facility approximately one-half mile downstream from EFID's diversion off the East Fork Hood River. Within this facility are five 80--by-12-foot parallel chambers that are 3 feet deep at one end and 10 feet deep at the other end. During the peak of irrigation season, EFID conveys a total or 135 cfs through four of the chambers while keeping the fifth one offline. Roughly 20 cfs of the 135 cfs is used to convey sediment that has settled out in the facility back to the East Fork Hood River, while the remaining 115 cfs enter the EFID main canal to meet irrigation demand.

5.2.6.1 Existing Facility

Although EFID's existing facility removes an appreciable amount of sediment, no data is available on the particle size for which it is designed or on the removal efficiency for the overall sediment load. Calculations to determine that information are presented below.

Based on the water quality parameters and settling velocities from above (Section 5.1) and the existing EFID sediment facility configuration, 100 percent of sediment that has a diameter of at least 0.2 mm is settled out, 22 percent of sediment that has a diameter from 0.06 mm to 0.2 mm is settled out, and very little sediment smaller than 0.06 mm is settled out (Table 52). Weighing these settling percentages by their prevalence results in a total cumulative settling of 12 percent of the overall influent sediment load. These values assume the peak flow rate (135 cfs) traveling through four chambers. During off-peak months, less water travels through the facility, which increases the residence time and allows more material to settle out. This is dependent upon the number of chambers in use remaining constant, as shutting down a chamber decreases the available volume and settling effectiveness.

Table 52. Settling calculations for existing East Fork Irrigation District sediment facility.

Sediment Type	Percentage (by weight)	Particle Size (mm)	Settling Velocity (ft/second)	Feet Settled during Residence[1]	Percent of Sediment Type Settled	Percent of Total
Clay	7%	<0.002	2.19E-06	0.0004	0.006%	0%
Fine Silt	12%	0.002-0.006	8.74E-06	0.0016	0.025%	0%
Medium Silt	27%	0.006-0.02	7.87E-05	0.015	0.224%	0%
Coarse Silt	30%	0.02-0.06	0.000874	0.16	2.487%	1%
Fine Sand	17%	0.06-0.2	0.00787	1.45	22.379%	4%
Medium Sand	7%	0.2-0.6	0.0874	16.2	100.000%	7%
Coarse Sand	n/a	> 0.6	0.787	145.5	100.000%	n/a
Total						11.6%

[1] "Feet settled during residence" is calculated for peak irrigation season (135 cfs through facility) with four chambers in use, which results in a residence time of 185 seconds.

mm = millimeters

ft/second = feet per second

5.2.6.2 Potential New Facility

As shown above, the existing EFID facility removes roughly 12 percent of the total sediment load, so developing a larger, more effective facility would be beneficial. Several potential sites exist for a new facility: near the existing sediment facility, near the main EFID distribution center, or simply an expansion point along the main canal. An undeveloped piece of land lies just downstream of the existing facility that could receive outflow from it. Water could enter the area on the southwest corner, be spread out over the area, which is approximately 150 by 350 feet, and then discharge back into the main canal at the northeast corner. With some grading, this potential facility could have a roughly 1.2-acre surface area. Near the EFID distribution center, less land is available (roughly 0.5 acre). However, at this location, there is potential to have it serve a secondary purpose of providing operational storage to regulate downstream delivery. Although about 0.5 acre is currently available, it is adjacent to undeveloped land that could potentially be acquired by EFID.

Table 53 and Figure 31 show the percentage of sediment removed as a function of facility footprint. Facility depth does not affect settling effectiveness. The greater the depth, the greater the residence time, but the distance required for sediment to settle is also greater. Because of the non-linear relationship between particle diameter and setting velocity, and the non-uniform distribution of particle sizes (e.g., silt comprises 69 percent of sediment load while clay comprises 7 percent), there are diminishing returns on the size of any facility. Although only a rule of thumb, the inflection point typically indicates the optimal size from a cost-benefit standpoint. As shown on Figure 31, the inflection point is at 57.3 percent removal at 3.7 acres. For comparison, a 1.2-acre facility would achieve 37.6 percent sediment removal while a 0.5-acre facility would achieve 28.6 percent removal.

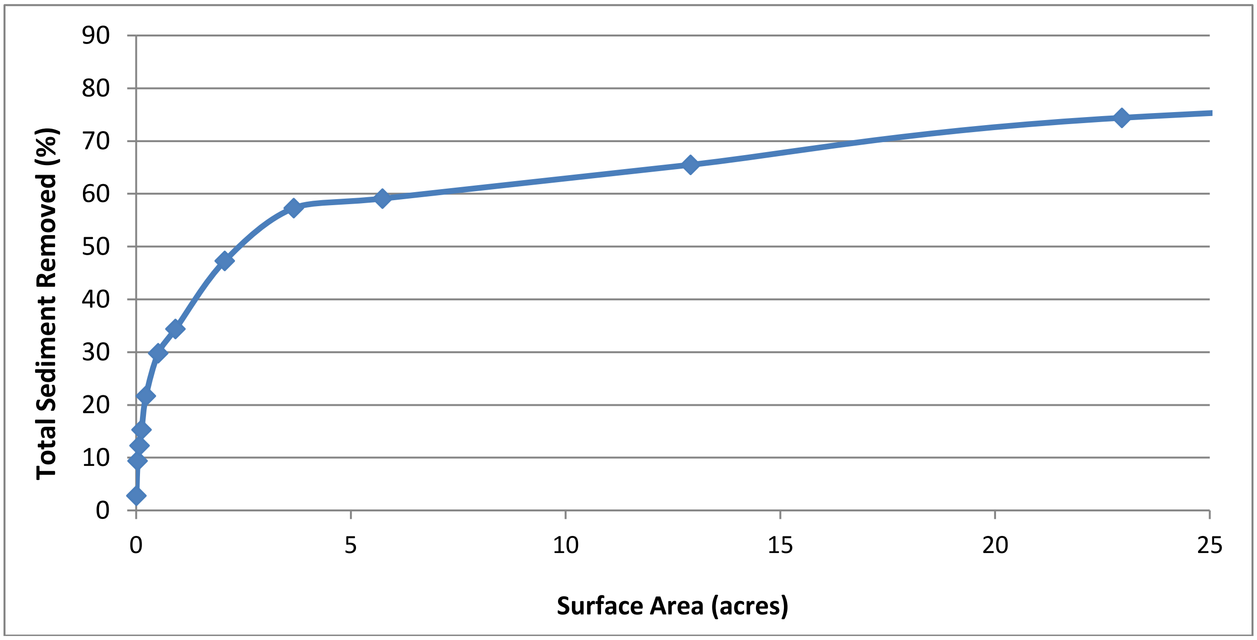


Figure 31. Sediment removal as function of facility size for potential new East Fork Irrigation District facility.

Table 53. Percent of sediment settled as function of facility size for potential new East Fork Irrigation District sediment facility.

Facility Dimensions (feet)	Area		Percent Settled (%)
	Square Feet	Acres	
20 x 20	400	0.009	2.8
40 x 40	1,600	0.037	9.4
60 x 60	3,600	0.083	12.3
75 x 75	5,625	0.129	15.3
100 x100	10,000	0.230	21.7
150 x 150	22,500	0.517	29.8
200 x 200	40,000	0.918	34.4
300 x 300	90,000	2.066	47.3
400 x 400	160,000	3.673	57.3
500 x 500	250,000	5.739	59.1
750 x 750	562,500	12.913	65.5
1,000 x 1,000	1,000,000	22.957	74.4
1,500 x 1,500	2,250,000	51.653	83.5
2,000 x 2,000	4,000,000	91.827	85.4
3,500 x 3,500	12,250,000	281.221	94.4
5,000 x 5,000	25,000,000	573.921	96.5
7,100 x 7,100	50,410,000	1,157.254	100

The cost of constructing a new settling facility is highly dependent on the elevation of the proposed land relative to the existing conveyance system (e.g. if the elevation is quite a bit higher then there would be significant excavation costs). Although an analysis of exact locations and elevations is beyond the scope of this report, Table 54 gives a rough planning level estimate for the construction of a 1.2 acre settling facility. Based on excavating 1 foot and using the spoils to berm the edges, the total cost including design and engineering is $194,000.

Table 54. Planning level cost estimate for potential new East Fork Irrigation District 1.2 acre settling basin.

Item	Quantity	Unit	Unit Cost[1]	Amount	Notes
Excavation	1936	CY	20	$38,720	1' of excavation. Spoils used to berm edges to generate basin volume.
Select Fill	968	CY	$54	$52,272	6" deep layer of select fill to reduce seepage.
Inlet and Outlet	2	Each	$5,000	$10,000	Designed to spread flow and reduce turbulence.
Telemetry	1	Each	$5,000	$5,000	Potentially only pressure transducer to track level (cost of $1,000).
Fence and Ramp	1	Each	$10,000	$10,000	Required for dredging and to limit access.
Total Direct Costs:				**$115,992**	
Markups					
Mobilization			4%	$4,640	
Contingency			20%	$23,198	
Design and Engineering			25%	$28,998	
Permitting			LS	$10,000	
Construction Management			10%	$11,599	
Total Project Cost:				**$194,427**	

[1] *Unit costs are inclusive (e.g. material, haul, placement, and compaction).*

5.2.6.3 Discussion

Since the larger particles are already removed in EFID's existing facility, any new sediment control facility built must be larger than the existing facility to be able to achieve meaningful sediment reduction. It may not be within EFID's budget to build a new facility aimed at only sediment removal; however, it is likely that any future EFID optimization plan would include a regulating reservoir/surge pond. Although such a facility would be designed specifically to eliminate overflows, it could be designed to also function as a sediment facility. Design and implementation of this dual-purpose facility should not be significantly more expensive than if it were a regulating reservoir only. It would likely include maximizing the size of the facility, as well as other items, such as including a ramp into the facility to allow periodic dredging.

5.2.7 Middle Fork Irrigation District

Middle Fork Irrigation District has an existing settling basin downstream of its Eliot Creek diversion. The settling basin has a surface area of 3.2 acres and a storage capacity of 25 acre-feet. The average flow rate into the pond peaks in August at 17.5 cfs.

Several firms, when contacted about the use of coagulants, replied that it is fairly typical of circular ponds similar to MFID's to have most of the flow travel directly across the middle and, therefore, have a lower residence time and lower removal effectiveness. The exact flow path across MFID's pond is unknown, so, to estimate the sediment removal effectiveness of MFID's existing facility, it was assumed that water flows over only the center 150 feet of the pond. Based on this assumption, the sediment concentrations in typical glacial runoff (Section 5.1), and a 17.5 cfs flow rate, MFID's existing facility should remove 61.7 percent of incoming sediment (Table 55). All sediment the size of coarse silt (0.02 mm – 0.06 mm) and larger would be removed.

Table 55. Estimated effectiveness of existing Middle Fork Irrigation District sediment basin, 150-foot-wide flow path.

Sediment Type	Percentage (by weight)	Particle Size (mm)	Settling Velocity (ft/second)	Feet Settled during residence	Percent of Sediment Type Settled	Percent of Total
Clay	7%	<0.002	2.19E-06	0.045	0.749%	0.1%
Fine Silt	12%	0.002-0.006	8.74E-06	0.180	2.997%	0%
Medium Silt	27%	0.006-0.02	7.87E-05	1.619	26.975%	7%
Coarse Silt	30%	0.02-0.06	0.000874	17.983	100.000%	30%
Fine Sand	17%	0.06-0.2	0.00787	161.851	100.000%	17%
Medium Sand	7%	0.2-0.6	0.0874	1798.342	100.000%	7%
Coarse Sand	n/a	> 0.6	0.787	16185.075	100.000%	n/a
Total						61.7%

Notes:

Sediment concentrations based on typical glacial runoff (Section 5.1 of this report).

"Feet settled during residence" is calculated for peak irrigation season (17.5 cfs through facility) with middle 150 feet of current pond in use, which results in a residence time of 5.7 hours.

mm = millimeters

ft/second = feet per second

5.2.7.1 Installing Silt Curtains in Existing Sediment Pond

As noted above, there is no information on the current flow path of water through MFID's existing facility, nor is there data on the effectiveness of the facility. However, if water flowed across the entire pond, rather than only part of it, more sediment would be removed. In addition, a greater amount of smaller sediments (smaller than coarse silt) would be removed. Table 56 shows that using the full pond (versus just the middle 150 feet) would increase the removal efficiency to 77.1 percent (versus 61.7 percent). The portion of medium silt, fine silt, and clay that would be removed is roughly twice that of the scenario with the 150-foot-wide flow path.

Table 56. Estimated effectiveness of existing Middle Fork Irrigation District sediment basin, full 450-foot width.

Sediment Type	Percentage (by weight)	Particle Size (mm)	Settling Velocity (ft/s)	Feet Settled during residence	Percent of Sediment Type Settled	Percent of Total
Clay	7%	<0.002	2.19E-06	0.135	2.2%	0.2%
Fine Silt	12%	0.002-0.006	8.74E-06	0.540	8.9%	1%
Medium Silt	27%	0.006-0.02	7.87E-05	4.856	80.9%	22%
Course Silt	30%	0.02-0.06	0.000874	53.950	100%	30%
Fine Sand	17%	0.06-0.2	0.00787	485.552	100%	17%
Medium Sand	7%	0.2-0.6	0.0874	5395.025	100%	7%
Course Sand	n/a	> 0.6	0.787	48555.225	100%	n/a
Total						77.1%

Notes:

Sediment concentrations based on typical glacial runoff (Section 5.1 of this report).

"Feet settled during residence" is calculated for peak irrigation season (17.5 cfs through facility) with full pond in use, which results in a residence time of 17.1 hours.

mm = millimeters

ft/second = feet per second

The most cost effective method of increasing flow path in the pond would be the installation of three silt curtains. The silt curtains would force the water back and forth across the pond, using the entire pond volume. A flow rate of 30 gpm per square foot is recommend for the ends of the curtains so as not to increase water velocity and remobilize sediment. At 9 cfs, an opening of 134 square feet would achieve a flow rate of 30 gpm per square foot.

Cost estimates for two different types of silt curtains were obtained from Granite Environmental (Table 57). Type 2, Department of Transportation polyvinyl chloride (PVC) curtains would cost approximately $20,000 for equipment, shipping, and installation, while curtains with an Elvaloy coating would be a little over $40,000. The performance of the curtains is the same. However, PVC curtains typically have a 2- to 4-year lifespan, while Elvaloy curtains typically last 10 or more years.

Table 57. Cost estimates for two options of silt curtains for Middle Fork Irrigation District sediment basin.

Type	Capital Cost ($)			
	Equipment	Shipping	Installation	Total
Type 2 DOT silt barrier (22 oz. PVC)	$17,344	$1,000	$1,500	$19,844
Baffle with Elvaloy coating	$37,880	$1,200	$1,500	$40,580

Source: Granite Environmental (http://www.erosionpollution.com)..

5.2.7.2 Connecting Coe Creek Diversion to Sediment Pond

As discussed in Section 4.4.2, MFID reduces its diversion from Coe Creek during the summer when Coe Creek becomes turbid with glacial runoff. The district's average diversion from Coe Creek in May before turbidity increases is 15.1 cfs, while in August the average diversion is reduced to 9.5 cfs. Connecting the Coe Creek diversion to the sediment pond would preserve Laurance Lake water for other uses later into season when stored water has the most benefit.

If the Coe Creek diversion was connected to the sediment pond the overall setting time would be reduced compared to current conditions. Based on the assumption that water is flowing over the middle 150 feet of the pond, the sediment concentrations in typical glacial runoff (Section 5.1), and a 30 cfs maximum flow rate (total flow from both Eliot and Coe Creeks), MFID's existing facility should remove 58.5 percent of incoming sediment (Table 58). If sediment curtains were also installed, the removal efficiency would be roughly 67.5 percent (Table 59). This is both greater than the pond's current removal efficiency (Table 55) and would allow greater operational flexibility. For example, Eliot Creek has higher turbidity in July and September, while Coe Creek has higher turbidity in August and selecting between the two of them would reduce overall sediment input.

Table 58. Estimated effectiveness of existing Middle Fork Irrigation District sediment basin with connection to Coe Creek diversion, 150-foot width.

Sediment Type	Percentage (by weight)	Particle Size (mm)	Settling Velocity (ft/second)	Feet Settled during residence	Percent of Sediment Type Settled	Percent of Total
Clay	7%	<0.002	2.19E-06	0.026	0.43%	0.0%
Fine Silt	12%	0.002-0.006	8.74E-06	0.105	1.74%	0%
Medium Silt	27%	0.006-0.02	7.87E-05	0.944	15.73%	4%
Coarse Silt	30%	0.02-0.06	0.000874	10.490	100%	30%
Fine Sand	17%	0.06-0.2	0.00787	94.413	100%	17%
Medium Sand	7%	0.2-0.6	0.0874	1049.033	100%	7%
Coarse Sand	n/a	> 0.6	0.787	9441.294	100%	n/a
Total						58.5%

Notes:

Sediment concentrations based on typical glacial runoff (Section 5.1 of this report).

"Feet settled during residence" is calculated for peak irrigation season (30 cfs through facility) with 150 feet of the pond in use, which results in a residence time of 3.3 hours.

mm = millimeters

ft/second = feet per second

Table 59. Estimated effectiveness of existing Middle Fork Irrigation District sediment basin with connection to Coe Creek diversion and silt curtains installed (450-foot width).

Sediment Type	Percentage (by weight)	Particle Size (mm)	Settling Velocity (ft/second)	Feet Settled during residence	Percent of Sediment Type Settled	Percent of Total
Clay	7%	<0.002	2.19E-06	0.079	1.311%	0.1%
Fine Silt	12%	0.002-0.006	8.74E-06	0.315	5.245%	1%
Medium Silt	27%	0.006-0.02	7.87E-05	2.832	47.206%	13%
Coarse Silt	30%	0.02-0.06	0.000874	31.471	100.000%	30%
Fine Sand	17%	0.06-0.2	0.00787	283.239	100.000%	17%
Medium Sand	7%	0.2-0.6	0.0874	3147.098	100.000%	7%
Coarse Sand	n/a	> 0.6	0.787	28323.881	100.000%	n/a
Total						67.5%

Notes:

Sediment concentrations based on typical glacial runoff (Section 5.1 of this report).

"Feet settled during residence" is calculated for peak irrigation season (30 cfs through facility) with full pond in use, which results in a residence time of 10.0 hours.

mm = millimeters

ft/second = feet per second

5.2.7.3 Discussion

This high-level analysis of installing silt curtains and/or connecting the Coe Creek diversion to the sediment basin indicates that such actions would benefit MFID. However, more detailed analysis should be completed before implementing either project.

The benefit of installing sediment curtains depends on whether the pond actually uses its full volume currently. Although unlikely, if the current flow path uses the full pond area, there would be little to no benefit from installing silt curtains.

The benefit of connecting the Coe Creek diversion to the sediment pond should be quantified through more detailed analysis. This connection project would have a significant capital cost, and it would affect Laurance lake levels, sediment concentrations within the MFID distribution system and downstream, and hydropower production. If further analysis shows that significant benefits could be achieved, MFID may be able to obtain funding from outside sources, if desired. In that case, the outside sources would likely require some degree of control over the Laurance Lake water that is preserved (potentially 2,615 acre-feet) in exchange for project funding.

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