DRAFT MEMORANDUM

Project No.: 120045-007-04a

November 20, 2014

To: Mike Kaputa, Director
Chelan County Natural Resources Department

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Re: **Icicle Creek Conservation Plan Survey**

Introduction

The purpose of this memorandum is to summarize conservation efforts made by major water diverters from Icicle Creek and identify potential water conservation projects that could be implemented by these diverters in an effort to promote higher stream flows in Icicle Creek and meet other adopted Guiding Principles[1]. This memorandum supports Chelan County's (County) development of the Icicle Basin Comprehensive Water Management Plan. Icicle Creek, located in Chelan County, Washington and drains to a primary sub-basin of Water Resource Inventory Area (WRIA) 45 and is a major tributary to the Wenatchee River.

During the course of this effort, Aspect Consulting, LLC (Aspect) conducted interviews with three of the major diverters: City of Leavenworth (City), Cascade Orchards Irrigation Company (COIC), and Icicle Creek-Peshastin Irrigation District (IPID), and reviewed available literature to compile project descriptions, schedules, budgets, magnitude of quantities (Qi and Qa), and possible opportunities and effects on Icicle Creek for each diverter. A summary of key findings is provided below, followed by a detailed discussion of typical conservation projects undertaken in Washington, each major diverter's recent conservation efforts, and the likely effect of those efforts on Icicle Creek.

Summary of Key Findings

Aspect considered the potential effect of conservation improvements on the Guiding Principles. In some cases, very good data and information on both historic and future projects is available. In other cases, limited data is available or conservation opportunities are only thought of as preliminary concepts. Based on available data and our analysis, we conclude the following:

- Conservation would have direct instream flow benefit on Icicle Creek. A significant portion of the water diverted from Icicle Creek is exported from the sub-basin, so any conservation from out-of-basin infrastructure would materially improve Icicle Creek's instream flows.

[1] The Guiding Principles generally include improved instream flow and habitat, improved agricultural and Leavenworth National Fish Hatchery reliability, increased municipal supply, protection of Treaty and non-Treaty harvest, compliance with state and federal laws, including those for the Alpine Lakes Wilderness Area. The Guiding Principles can be found at the following website: http://co.chelan.wa.us/nr/data/files/FINALIWGOperatingProcedures.pdf.

However, conservation would likely also retime return flow from late season to earlier in the year, which would diminish flows in the low-flow time period.

- Conservation could increase agricultural reliability, by better matching supply and demand, and providing more flexibility and control through features like telemetry and re-regulation reservoirs.
- Limited conservation opportunities exist for conveyance improvements within the IPID, likely targeted to the few remaining unlined or partially-lined sections of the canal. Cost per acre-foot for these opportunities is likely to be higher because the easier infrastructure upgrades have already been accomplished. Greater opportunities on a cost per acre-foot basis exist within the COIC, with total flow improvement on the order of 5 cubic feet per second (cfs).
- Limited conservation opportunities exist for on-farm improvements within IPID, where most farmers have already converted to high efficiency sprinklers to comply with IPID’s conservative share system. Some opportunities may exist within COIC, IPID, and City customers targeted at efficient lawn watering.
- Limited conservation opportunities exist for conveyance related infrastructure in the City’s source transmission system in the vicinity of the domestic water treatment plan. There may be some opportunity for additional conservation in the City of Leavenworth’s domestic water system related to re-use of reclaimed water as well as better implementation of conservation oriented rate structure.
- Excluding major capital improvement projects such as pump exchange, pipeline conversion/replacement projects, total conservation opportunities might be on the order of 10 cfs to 20 cfs, with average costs ranging from $1,000 to $2,000 per acre-foot.
- Pump exchange projects have the potential to save an additional 10 cfs to 117 cfs with potential capital costs of less than $1,000 / acre-foot.
- Pipeline conversion projects (conversion from canal to pipeline) could have the potential for up to 10-cfs savings with potential capital cost of $3,000 to $6,000 per acre foot.

Background and Scope

Aspect has been providing technical support to the County, and the Icicle Work Group (IWG) and Steering Committee, which were formed to provide broad stakeholder collaboration on the Icicle Basin Comprehensive Water Management Plan. At the May 2014 IWG meeting, the stakeholders requested a list of recent conservation efforts implemented by major water diverters from Icicle Creek, including the City, COICIPID. The purpose of this study is to identify the range of conservation projects that either have been implemented or could potentially be implemented by existing major water rights holders on Icicle Creek, and the effect of that implementation on the Guiding Principles.

Conservation Project Summary

Generally, conserving water is to the benefit of both the individual purveyor and Washington State (and available water supplies). Conserving water reduces the scope and size of conveyance infrastructure, and operations and maintenance costs. Conservation is not typically implemented as a result of mandates and is often done voluntarily.

All water rights appropriations in Washington State, regardless of purpose of use, are limited to beneficial uses which allow for, but limit, some amount of loss/leakage or otherwise unaccountable excess diversion. For example, in piped conveyance systems, loss/leakage quantities on the order of 10% are typically viewed as an acceptable limit (e.g., Washington State Department of Health [DOH] standards in Water System Design Manual; DOH, 2009). However, much higher amounts of loss/leakage from canals is often allowable (approaching 50% in some cases, as in the Methow Valley Irrigation District waste case). Other losses related to on-farm irrigation application inefficiencies are also allowable to some extent. For example, irrigation application efficiencies for acceptable irrigation methods may range from 35% to 95% (Ecology, 2011).

In some cases, such as for municipal uses, purveyors must meet specific Water Use Efficiency (WUE) requirements as detailed in Washington Administrative Code (WAC) 246-290. These WUE requirements include forecasting demand, publicly establishing water savings goals for customers, and developing a WUE program to meet those goals—often through the implementation of conservation projects. They must also limit pipe leaks to acceptable standards—10% for large systems (over 500 connections) and 20% for smaller systems (less than 500 connections).

Types of Conservation Projects

Water conservation projects focus on long-term reduction of water demand. Typical conservation projects and strategies target residential, commercial, and irrigation customers through a variety of infrastructure improvements, water management strategies, supply and demand coordination, public outreach, and conservation-oriented water rates. Often times, conservation projects focus on identifying wasteful practices that clearly violate water use efficiency standards or otherwise exceed beneficial use limits. These opportunities would tend to have the highest consensus for support by broad stakeholder group including the water rights holder. There are however, many other types of conservation projects that focus on identifying water use that can be curtailed regardless of whether a truly wasteful practice exists – while still maintaining benefit for the user of water. Various types of conservation strategies and project categories are provided in the following sections.

Distribution Improvements (piping/lining)

Conservation measures for water distribution systems—most commonly irrigation systems—typically focus on improving conveyance through updating or converting irrigation piping and/or lining. The most common strategies are converting open-ditch irrigation water conveyance systems to more efficient delivery pipe or placing an impermeable liner within an unlined irrigation ditch. Irrigation canals without liners or with failing liners can lose 30 to 50% of their irrigation water through seepage (Ecology, 2007) and canal-lining technologies can minimize seepage losses at reasonable costs. Improving irrigation distribution can result in a range of water conservation saving benefits (Deschutes Water Alliance, 2006) including:

- Reducing the diversion at the head gate and freeing up water for instream flow and other district water needs;
- Eliminating conflict between urban/suburban landowners;
- Substantially reducing or eliminating operations and maintenance needs;
- Providing gravity pressure, which conserves energy;
- Improving reliability and control of water delivery to more closely match demand fluctuation, which reduces a need for surplus transport flows; and

- Supporting development of small hydropower facilities, which can increase revenue.

Irrigation Water Management (soil moisture probes, lawn watering guidelines)

Irrigation water management (IWM) is a conservation strategy to apply irrigation water to satisfy crop needs without wasting water, soil, or plant nutrients. Strategies used to achieve IWM goals include soil moisture probes, education about lawn watering best practices, and installation of water efficient irrigation methods such as micro-spray heads and drip systems. The benefits of proper irrigation water management typically include reducing excessive use of water for irrigation purposes, preventing excessive soil erosion, minimizing pumping costs, and maintaining or improving the quality of groundwater and surface water (Ecology, 2007).

Supply/Demand Coordination (telemetry, re-regulation reservoirs)

Coordinating supply and demand of water resources is a conservation strategy that relies on water resource data analysis to efficiently use irrigation and water supply infrastructure.

Telemetry

Installing telemetry (automated collection of water data) systems at irrigation flow meters can result in increased water and supply demand efficiency. Remote telemetry systems for irrigation projects typically include level sensors, flow meters, low power transmitters, wireless radio, satellite, and internet technologies. By automating the measurement of water use, telemetry identifies supply/demand inefficiencies, and allows purveyors to better coordinate supply (water diversion) with demand (customers) to prevent excess supply going unused.

Re-regulation Reservoirs

In the context of this memorandum, re-regulation reservoirs apply to irrigation canal systems as a way to temporarily manage excess supply at various points along the canal. Because customer demand is not always known, and can fluctuate rapidly, irrigation canal systems often have to estimate demand and adjust instantaneous diversion accordingly. For hydraulics reasons, the cross section and carrying capacity of canals get smaller along their alignment, thus any excess diversion at a given point in the canal can pose a capacity/conveyance problem, which could overtop the canal and pose a flooding risk. Therefore, canals are typically designed with “spill systems” that allow any excess supply to overflow and return to the river system at various points along the alignment. This “spill system” represents excess diversion that is not needed by customer demand at any given time. Re-regulation reservoirs can be used to temporarily capture this spill, store it, and release it back to the canal during times when demand exceeds supply—allowing for a tighter operation and reduced diversion. In concept, multiple re-regulation reservoirs (i.e., up to one at each designated spill location) could be implemented along a canal.

Public Outreach and Conservation-Oriented Rate Structures

Public Outreach

Washington State’s WUE requirements require public outreach to educate customers on water use efficiency related to municipal systems. Outreach typically includes developing regular written materials and annual reports that are sent to customers, hosting public information sessions and educational workshops, and having information booths at public events like local fairs and festivals. Outreach and education programs typically inform customers of WUE options through promoting/incentivizing hardware measures (e.g., upgrading to water-efficient showerheads) as well as behavior change strategies (e.g., turning off the sink while brushing). Promoting hardware measures are more easily measured than behavior change strategies, but both can lead to long-term decreased water use and better conservation awareness among residential and commercial water customers.

Although not mandated by law, a similar public outreach can apply to irrigation users as well. For example, high efficient irrigation application methods such as micro-spray and drip systems, soil-moisture probes and rain sensors should be promoted by a purveyor in order to reduce on-farm water use.

Conservation-oriented Rate Structures

Implementing a conservation-oriented approach to selling water can promote efficient use and benefit customers and water purveyors. The block rate structure (a set price charged for a defined number of water units) is the most common approach to pricing water for water purveyors. There are four typical block rate structures used by water purveyors:

1. **Uniform –** the unit of price of water stays constant;
2. **Increasing block –** the unit price of water increases as consumption increases;
3. **Decreasing block –** the unit price water decreases as consumption increases; and
4. **Seasonal –** the unit price of water rises and falls according to water demands and weather.

Of these four block rate approaches, increasing block and seasonal rate structures are the most conservation-oriented and focused on improved WUE savings.

Summary of Major Diverters

There are three major diverters from Icicle Creek that are the subject of this conservation survey—the City, IPID, and COIC with a combined total diversion water rights of approximately 130 cfs. Information related to past conservation projects and potential future conservation opportunities for each diverter was obtained through a combination of direct conversation, email correspondence, independent research, or discussion with third parties. In some cases, very good data and information on both historic and future projects are available. In other cases, limited data is available or conservation opportunities are only thought of as preliminary concepts. To the extent feasible, the effectiveness of conservation projects has been quantified in terms of a cost/benefit relationship to provide for some comparison amongst various projects.

Icicle/Peshastin Irrigation District (IPID)

IPID Overview

In 2011, the Peshastin Irrigation District (PID) and the Icicle Irrigation District (IID) signed a joint operating agreement and are trying to merge into one district. According to conversations with Tony Jantzer, IPID district manager, the IID provides 4,314 acre-shares (1-share is provided for 1-acre of land) and PID provides 3,724 acre-shares. Each share is entitled to 6.75 gallons per minute (gpm) instantaneous use. This gpm/share allotment is on the lower end of the spectrum compared to other local irrigation districts, indicating that opportunities for on-farm conservation of water is somewhat limited. For sake of comparison, the Cascade Irrigation District (Ellensburg) users are entitled to 8 gpm per share in drought years. Typically, adjudications used a 0.02 cfs/acre (9 gpm/acre) estimate of instantaneous use.

IPID’s irrigation canal system is gravity fed with most of the system lined or piped, with the exception of several partially lined or unlined sections in the upper reaches of the canal system.

IPID's diversionary water rights from Icicle Creek total approximately 117 cfs and occur at River Mile 5.7.

Past Conservation Projects

Peshastin Irrigation District Canal to Pipeline Conversion. The project converted 9,900 linear feet of unlined canal into a piped system and was completed in 2011. The piped section includes the end of the Peshastin ditch from Brender Creek to the end of Pioneer Street in Cashmere. The project was partially funded by Ecology's Office of Columbia River with the total project cost of $2 million (M). IPID has spent an additional $100,000 on maintenance to improve screening. Mr. Jantzer estimates the project has resulted in 1.2 cfs and 360 acre-feet of water savings and has indicated that this conversion was relatively cost-effective because it was located at the end of the ditch and was therefore a relatively small diameter pipe (30-inch). In his opinion, similar projects further upstream may not be quite as cost effective due to the need for much larger diameter pipes.

Peshastin Irrigation District automated head gate/spill automated control. IPID installed automated control gates to limit excess spill at one of their major spillways. According to Mr. Jantzer, the project cost $140,000 to $150,000 with a proposed estimated water savings of approximately 1 to 2 cfs. Mr. Jantzer indicated that future improved monitoring equipment would be needed in order for the project to work as intended.

On-Farm Efficiencies. Presently, on-farm efficiency is nearly maximized throughout IPID. In order to live within the narrow allotment of 6.75 gpm per acre and remain competitive with their crops, the majority of water users have converted to micro-spray or drip systems, which result in extremely high water use efficiencies. Per Ecology 1210 (Ecology, 2011), application efficiencies for micro-spray and drip systems average 85 and 88%, respectively. Some farmers have implemented soil moisture sensors in attempts to further reduce on-farm water use; however, there are some farmers that have complained this has led to poor crop results and can be difficult to manage.

Canal Lining. IPID has a long history of lining their canals and repairing leaking portions of already lined canals. Presently only a small portion of their canals remain unlined.

Future Conservation Opportunities

Pump Exchange/Change in Point of Diversion. Several pump exchange projects are being considered and studied by the District. Copies of these reports are available on the County's website[2].

Estimated costs and savings: Savings for these alternatives range from 14 to 117 cfs in Icicle Creek with additional benefit to the Wenatchee River. The capital cost associated with the range of these alternatives is between $4.6M and $13M[3].

Converting IPID lined/unlined canal to piping. Per Mr. Jantzer, the entire IPID canal system could become pressurized/piped for a significant cost (this has not been evaluated by Aspect).

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[2] http://www.co.chelan.wa.us/nr/planning/icicle_work_group/

[3] Forsgren Associates Inc., Icicle Irrigation District, Instream Flow Improvement, Options Analysis Study, July 22, 2014.

Estimated costs and savings: His estimation that reduced diversions from Icicle Creek as the result of such an improvement would be limited to approximately 10 cfs. This project has not been studied but capital costs would be significant and would most likely cost well in excess of $10M.

Canal Lining. As described above, several sections of the canal are presently entirely unlined or are only partially lined. Those include:

- Approximately 1/3-mile of "Beat-4" is partially lined (Anderson Canyon Section);
- Approximately 2 to 3 miles of "Beat-3" are partially lined;
- Approximately 1/2 mile of "Beat-2" is partially lined;
- A large portion of "Beat-1" is unlined or only partially lined (totaling approximately 2 to 3 miles); and
- All tunnels are unlined, totaling approximately 1 mile. The Tunnel on "Beat-3" is thought to be extremely leaky due to the presence of sandstone.

Estimated costs and savings: No formal studies or cost estimates related to lining the remaining IPID canals has been performed. Assuming an average canal lining cost of approximately $65 per linear foot (likely very conservative), the estimated cost to line the entire remaining IPID canal system would be approximately $2.3M based upon the estimated approximately 36,000 linear feet of unlined or partially lined canal in the system. The estimated cost of lining the remaining tunnels may be approximately $1M, assuming a much higher unit cost of $190/linear foot.

Multiple re-regulation reservoir opportunities. Mr. Jantzer indicated that re-regulation reservoirs could be installed at various locations throughout the IPID canal system to limit spill and therefore limit excess diversion from Icicle Creek during certain times or circumstances. Many of these re-regulation opportunities have not been studied and it is believed that many of the sites would require both pumping and telemetry improvements in order to properly function. Mr. Janzter indicated that there may be potential opportunities for re-regulation reservoirs in the following vicinities:

- Williams Canyon;
- Anderson Canyon;
- Fairview Canyon;
- Mission Creek Tributary;
- Monitor; and
- Peshastin Creek Confluence.

Estimated costs and savings: It is estimated that the average re-regulation reservoir would be approximately 2 to 3 acre-feet in capacity, provide up to 0.25 to 0.5 cfs in reduced spill and corresponding diversion, and cost approximately $30,000 per reservoir.

Likely Effect of Potential IPID Projects on Icicle Creek Stream Flows

Most of the aforementioned conservation projects have direct benefit to Icicle Creek both in terms of quantity and timing of water saved. Spillage from the canal directly discharges to Icicle Creek or the Wenatchee River without consumptive losses or significant change in timing of flows. Therefore, every cfs of reduced diversion related to reduced spillage would result in an equal and instantaneous increase in flow between the diversion and the spill return on either Icicle Creek or the Wenatchee River. Water for on-farm use is exported from the Icicle Creek drainage, and every cfs of reduced diversion for this use would result in an equal and instantaneous increase in flow downstream of the diversion relative to current conditions.

Hydrogeologic Conditions of IPID Canal System near Icicle Creek

Based on review of online geologic maps from the Washington State Department of Natural Resources (DNR), the IPID canal traverses areas with two distinct geologic and hydrogeologic regimes: (1) a granitic bedrock-dominated area, and (2) an unconsolidated glacial sediment-dominated area.

Granitic Bedrock-dominated Area

Upstream of about River Mile 4 on Icicle Creek is underlain by granitic bedrock. Over this reach, the canal is typically within about 500 to 1,000 feet of Icicle Creek. Hydrogeologic conditions of the shallow bedrock is unknown, but water leaking from the canal likely flows toward the creek through thin surface soils, talus slopes, or a fractured bedrock surface overlying more competent, low permeability bedrock. There would be a delay or lag in timing between when the surface diversion occurs and when water leaking from the canal returns to the creek. Based on the steep slopes and relatively short distances between the canal and the creek and the expected high transmitting capacity of shallow fractured bedrock and talus, the travel times for water leaking from the canal to reach the creek are likely on the order of days to weeks.

Unconsolidated Glacial Sediment-dominated Area

Surficial geology along the reach of the canal extending downstream from about River Mile 4 on Icicle Creek is mapped as glacial deposits, with alluvium associated with Icicle Creek mapped to the west along the valley bottom. Review of drillers' logs for wells located immediately to the east of the canal indicate the glacial deposits are mixture of clay, silt, sand, gravel, and boulders interpreted to be low permeability glacial till. The logs indicate granitic or sedimentary bedrock underling the glacial deposits.

It is likely that water leaking from the canal in this reach migrates downward through the till to the water table, in either saturated bedrock or glacial deposits, before migrating laterally toward Icicle Creek. The travel times for water leaking from the canal to reach the creek is highly uncertain, but likely on the order of months to years, given the expected low permeability of the glacial deposits. The long travel times also likely attenuate the seasonal leakage from the canal, such that water lost from the canal in this reach may discharge to the creek over most or all of the year, as opposed to only during and immediately after the irrigation season.

Likely Stream Flow Effects of IPID Canal Lining and Conversion Projects

Projects related to canal lining or pipe conversion have a more complicated impact on Icicle Creek, as the timing and location of water lost to leakage that returns to Icicle Creek must be accounted for in assessing overall effects on flow. The fate of water that leaks from the IPID canal is difficult to assess given the varied glacial and bedrock surficial geology underlying the canal, however, general conclusions can be drawn based on the understanding of hydrogeologic conditions described above.

Reduced diversion from Icicle Creek due to lining or pipe conversion of reach of the canal's overlying bedrock (i.e., above River Mile 4) would result in an equal and instantaneous increase in flow immediately downstream of the diversion. The increase in flow relative to current conditions would decrease downstream of the diversion where leakage that currently returns to the creek would be eliminated. At some point near or downstream of River Mile 4 there would be little to no increase in flows due to lining of this reach. Outside the irrigation season there would be no effect on stream flows.

Reduced diversions from Icicle Creek enabled by canal lining or pipe conversion in areas underlain by glacial till (i.e., downstream of River Mile 4) would result in an equal and instantaneous increase in flow immediately downstream of the diversion to below River Mile 4. If the above expectations for travel times from the canal, through the glacial till and to the creek hold true, the reach downstream from River Mile 4 would experience an increase in flow during the irrigation season equal to the reduced diversion minus a portion of the current leakage. Outside the irrigation season, this reach could experience a decrease in flow equal to the portion of the leakage that currently returns to the creek.

Cascade-Orchard Irrigation Company (COIC)

COIC Overview

The COIC irrigation system is an approximately a 2-mile-long unlined ditch system that meanders along Icicle Creek Road (northwest of Icicle Creek). Any excess diversion from Icicle Creek returns to the Wenatchee River as surface water flow via an outfall near the Icicle Creek Road Bridge. COIC holds an adjudicated water rights certificate for diversion of up to 11.9 cfs from Icicle Creek at River Mile 4.5 for the purpose of irrigation of 600 acres (2,064.5 acre-feet per year). No known system mapping or comprehensive plans for COIC are publically available. However, some publically available information is known and was summarized by Greg McLaughlin, who is a project manager at the Washington Water Trust, and is currently working for COIC on various issues.

Past Conservation Projects

According to Mr. McLaughlin, most conservation-based projects at COIC have happened via installation of more efficient irrigation systems by individual property owners. All other activities include maintenance of earthen ditch, indicating opportunities for improved performance by way of either ditch lining or piping efforts.

Future Conservation Opportunities

Pump Exchange Project. Based upon the configuration of their system, there may be opportunity for a pump exchange project (conversion from gravity diversion on Icicle to pumped diversion on Wenatchee). A potential pump exchange project could involve the installation of a surface water pumping station, coupled with pipeline improvements to replace the current conveyance system.

There are 3 alternatives for this project that may be valuable to consider through future study[4]:

- **Alternative 1 –** Bifurcated Option; part pump-back/part gravity diversion. This alternative may provide a reasonable balance between water conserved and capital/operations and maintenance (O&M) cost.
- **Alternative 2 –** Pump-back from Wenatchee River, change of point of diversion; COIC customers only. This alternative would be higher capital and O&M cost but could eliminate the full COIC diversion from Icicle Creek.

[4] Personal Correspondence, Ryan Brownlee with Greg McLaughlin of Washington Water Trust, October 28th, 2014.

- **Alternative 3 –** Pump-back from Wenatchee River, change of point of diversion for COIC, and partner with LNFH. This alternative would be similar to Alternative 2 with the exception that LNFH (who presently shares a diversion on Icicle Creek) would be sought as a partner to increase overall project benefit and defray capital and O&M cost.

Estimated costs and savings: It is important to note, that none of these projects/alternatives have been studied, nor is COIC or Leavenworth National Fish Hatchery yet proponents of these projects. Rather, they have been conceptualized by various third parties such as the Washington Water Trust, and others. It is estimated by Greg McLaughlin of Washington Water Trust that up to 50% water savings may be realized through a pump-back scenario, with up to 12 to 24 cfs of actual benefit to the stream depending on the alternative. Due to the lack of studies, there are no cost estimates prepared at this time. However, it is believed that this type of improvement would likely exceed $1M in capital costs and include additional recurring O&M and utility costs.

Canal Lining Project. An alternative project that may be considered would be lining the existing canal to reduce seepage related conveyance loss. Although not known or verified, it is reasonable to assume that up to 50% of COIC's diversion is lost through seepage along the unlined canal, which is common/typical for unlined canals. While this seepage may have some benefit to Icicle Creek in terms of late season return flow, the direct benefit of potentially up to 6 cfs may be realized in Icicle Creek with a canal lining project (coupled with tighter control of diversion to limit excess spill to the Wenatchee River).

Estimated costs and savings: While this project has not been studied nor cost estimates prepared, a canal lining project such as this could cost between $250,000 and $300,000 based upon an estimated lining cost of $25 to $30 per linear foot.

On-Property Efficiencies. There may be opportunities for on-property efficiency projects which have yet to be explored, studied, or evaluated. There is some evidence that much of the irrigated uses are related to landscaping/lawns and it is unclear whether any public outreach has been performed to promote use of rain sensors, soil-moisture probes, etc. Furthermore, education on alternative landscaping methods, such as xeriscape, could be performed in an effort to become more efficient with water use.

Estimated costs and savings: Assuming 7 cfs represents total irrigation requirement for all customers and approximately 5% additional on-property efficiencies may be gained through various on farm conservation improvements, approximately 0.35 cfs of conservation savings may be achieved through this category.

Likely Effect of Potential COIC Projects on Icicle Creek Stream Flows

Most of the aforementioned conservation project have direct benefit to Icicle Creek both in terms of quantity and timing of water saved. Spillage from the canal directly discharges to Icicle Creek or the Wenatchee River without consumptive losses or significant change in timing of flows. Therefore, every cfs of reduced diversion related to reduced spillage would result in an equal and instantaneous increase in flow between the diversion and the spill return on either Icicle Creek or the Wenatchee River. On-farm use is largely consumptive, and every cfs of reduced diversion for this use would result in an equal and instantaneous increase in flow downstream of the diversion relative to current conditions.

Hydrogeologic Conditions of COIC Canal System near Icicle Creek

Review of geologic maps from DNR indicate the entire length of the COIC canal, from the diversion to the Wenatchee River, overlies unconsolidated alluvium of Icicle Creek. The shallow alluvium is in hydraulic connection with the creek, with groundwater discharging to and supporting flows in the creek. Reported hydraulic conductivity of the alluvium ranges from about 280 to 420 feet per day (ft/day) based on aquifer tests at the Leavenworth National Fish Hatchery (Bureau of Reclamation, 2010). The hydraulic gradient (change in groundwater elevation over distance) between the canal and the creek is unknown, but is estimated to be about 0.02 feet per foot based on the approximately 50-foot elevation difference over an average 2,500-foot horizontal distance between the canal and the creek. An effective porosity of the alluvium of 0.10 is assumed, based on the stratified sand, gravel, and silt materials.

Likely Stream Flow Effects of COIC Canal Lining and Conversion Projects

Projects related to canal lining or pipe conversion have a more complicated impact on the creek, as the timing and location of water lost to leakage that returns to the creek must be accounted for in assessing overall effects on flow. Leakage from the canal is expected to recharge a shallow aquifer system and ultimately discharge to the creek and/or the Wenatchee River as return flows; however, there would be a delay or lag in timing between the diversion and when water migrates through the aquifer and returns to the creek. The following evaluates the potential lag in timing and the net effects on Icicle Creek of canal lining or pipe conversion.

A groundwater velocity can be calculated as the product of the hydraulic conductivity and gradient divided by the effective porosity. Applying the above values, results in a groundwater velocity of about 56 to 85 ft/day. Dividing the velocity by the travel distance between the canal and the creek (2,500 feet) results in approximate travel times, or lag, between leakage from the canal and discharge to the creek. The estimated lag between the canal and the creek is about 30 to 45 days. There is considerable uncertainty in these estimates, but they provide an initial basis for evaluating effects of the potential conservation projects on stream flows.

Assuming a typical irrigation season of May through early October and using the travel times discussed above, the majority of return flows from canal leakage are expected to reach the creek during the irrigation season on the order of 1 to 2 months after water is first diverted. Water diverted late in the irrigation season that leaks from the canal would reach the creek outside the irrigation season after diversions have stopped. Based on this, reduced diversions associated with canal lining or pipe conversion would result in increased stream flows equal to the reduction in diversion early in the irrigation season, before the return flows associated with leakage would have reached the creek. Stream flows would increase by less than the reduction in diversions later in the irrigation season as return flows that would have reached the creek and supported flows are eliminated. Finally, after the irrigation season, when diversions have ceased, there may be a slight reduction in stream flow without the leakage return flows.

City of Leavenworth

City Overview

The City of Leavenworth's (City) water supply systems serves approximately 1,380 connections (Leavenworth, 2012).The City's water supply comes from both groundwater wells south of the City golf course and surface water withdrawn from Icicle Creek. The Icicle Creek surface water withdrawal serves the City's water treatment plant (WTP). During peak demand in summer irrigation season, the WTP treats approximately 2.0 million gallons per day (Leavenworth, 2012). The City's 2002 comprehensive water system plan calculated the City's Equivalent Residential

Unit (ERU) at 389 gpd. Since then, the City has reduced ERU usage to 304 gpd in 2012. The City has saved approximately 85 gpd/ERU since 2002 (Leavenworth, 2012).

Past Conservation Projects

Since 2008, the City has undertaken many capital improvement projects consisting of distribution, storage, and metering projects that have decreased water loss or otherwise improved accountability of water. These improvements (totaling approximately $3.6M, capital cost) are provided in the following table:

Year	Project	Cost
2008	Icicle Road Reservoir Reconstruction	$2,212,618
	9th Street Watermain	$295,258
	Commercial Street Watermain	$134,539
	Meter Upgrades	$3,336
2009	Meter Upgrades	$10,648
2010	Meter Upgrades	$12,714
2012	Meter Upgrades	$8,370
	Front/Div-14th Watermain	$233,708
	Source Water Meters	$5,453
2013	Meter Upgrades	$1,483
	East Leavenworth Road Watermain	$681,009
	Front Street Watermain	$9,900
	Source Water Meters	$1,877
Total		**$3,610,913**

Icicle Road Reservoir Reconstruction (2008) and the East Leavenworth Road Watermain Replacement. Of the improvements, those with the most significant impact on water conservation are the Icicle Road Reservoir Reconstruction (2008) and the East Leavenworth Road Watermain Replacement (2013). According to Joel Walinski, City Administrator, the Icicle Road Reservoir lacked adequate overflow prevention measures (such as an altitude valve), therefore, the reservoir would frequently overflow—contributing to significant water loss. The East Leavenworth Road water main was among the oldest and leakiest stretch of water transmission lines in the City's system. According to Mr. Walinski, the history of this water main includes approximately 25 detectable leaks that were repaired over the past 10 years prior to replacement. In 2014, the City also repaired the water main crossing of Icicle Creek (bridge crossing) which had significant leakage.

Voluntary Conservation Efforts. In addition to capital improvements, the City has undertaken significant voluntary conservation efforts associated with much of their water use as a customer. Leavenworth is currently the largest water customer with 7.5 million gallons of use in 2009. According to Mr. Walinski, the City has installed and updated the rain sensors on all of their irrigated lawn surfaces and staff performs soil moisture testing on a routine basis. They have also converted water supply to City Cemetery from the domestic system to irrigation water supply, to access irrigation water when available.

The City promotes water use efficiency and conservation of water to their customer base through various programs including providing conservation education in quarterly newsletter, providing for low-flow shower head rebate program, and education on water efficient landscaping such as xeriscaping.

The City has also taken measures to detect customer leaks and periodically evaluates customer metering in search of anomalous meter reading (indicating leaks). The City also recently bench- tested a random sample of approximately 20 residential water meters and determined that in general, residential metering in the system is fairly accurate.

Conservation Improvements Water Savings. The aforementioned improvements that have been made since 2008 have had a noticeable impact on both metered source production and metered customer consumption. While it is nearly impossible to estimate the water savings from one individual project, the aggregate impact is very evident. From the time period of 2009 to 2013, metered source production reduced by 56 million gallons (from 335 million gallons to 279 million gallons) and metered customer use reduced by 37 million gallons (from 319 million gallons to 282 million gallons) despite total service connections increasing by 20 connections (from 1,360 to 1,380) over that period.

Relevant information related to source production, customer demand, and distribution system leakage from the time period 2009 to 2013 is provided in the table below.

Year	Number of Service Connections	Source Production (million-gallons)	Customer Demand (million-gallons)	Distribution System Leakage
2009	1,360	335	319	4.8%
2010	1,363	274	221	19.3%
2011	1,359	294	220	25.2
2012	1,374	294	226	23.5
2013[1]	1,380	279	282	-1.0%

Notes: [1] In 2013, metered customer use actually exceeded metered source production indicating a negative distribution system leakage (DSL) value. The negative DSL value could be explained by a number of possibilities, including inherent error involved with metering equipment or system characteristics such as carryover storage from one year to the next.

The numbers in the table above indicate that distribution system leakage increased from 4.8% to over 25% before dramatically reducing to within 1%. Based upon conversations with Mr., timing of various improvements and their associated impacts are visible in the reduction in source production, customer demand, and distribution system leakage over the past several years, which helps explain this wide fluctuation. Of note, the following impact to demand and associated projects are as follows:

1. The drop in source production from 335 million gallons to 274 million gallons in the time period from 2009 to 2010 is likely related to the completion of two storage replacement projects (Icicle Road Reservoir and Ski Hill Reservoir).

2. The drop in metered customer demand from 319 million gallons to 221 million gallons in the time period from 2009 to 2010 is likely attributable to commercial customer meter replacement. In that timeframe, the City replaced all of the water meters associated with commercial services, dramatically improving the accuracy of water accounting.
3. The drop in source production from 294 million gallons to 279 million gallons in the time period from 2012 to 2013 is likely attributable to source meter replacement. In that timeframe, the City replaced and upgraded meters at both the surface water and groundwater production sources.
4. The increase in customer demand from 226 million gallons to 282 million gallons in the time period from 2012 to 2013 is likely attributable to major development that occurred within the system that year; namely the completion of several hotel expansions and new business construction.

With respect to wide variation in distribution system leakage numbers observed from the time period 2009 to 2013, the combination of improvements performed in 2009/2010 (reservoir replacement and commercial meter replacement) had the effect of increasing the apparent distribution system leakage quantity in 2010 despite actual leakage quantity being reduced. It was not until 2012 that DSL numbers were more accurately measured due to the replacement of meters on both the surface water and groundwater sources.

Future Conservation Opportunities

A number of future conservation measures may be taken to further reduce water use or otherwise improve accountability of water. These projects include the following:

1. **Evaluation of Conservation Oriented Rate Structure –** The City initiated an inclining block rate structure for most of its customers with relatively large base allotment, blocks spaced at large intervals and commercial customer (inside City limits) exclusions. One apparent drawback to this system is customer meters are read only seasonally. This results in fairly ineffective execution of a conservation oriented rate structure. In the future, the City may consider reducing base volume allotment, reducing volume between rate block and applying inclining block rates to commercial customers within City limits. In 2012, the City applied for Public Works Trust Fund (PWTF) loans to replace and convert all of the residential meters in the system to a type that would allow for year-round reading – which would lend itself to implementation of a tighter managed inclining block rate structure. The funding was denied at that time due to PWTF state funding reductions and funding through this mechanism appears unlikely at the present time. The City is looking for alternative funding sources to complete this project.
2. **Evaluation of Reclaimed Water Opportunities –** Several of the largest water users in the City's system may be candidates for use of reclaimed water (treated wastewater) for non-potable uses such as lawn irrigation; however, willingness of this concept by various users has not be gaged. Furthermore, reclaimed water is not currently available in the City and significant capital improvements would be required. The City is presently undertaking studies related to reclaimed water use as part of a TMDL related to effluent discharge on the Wenatchee River. Concepts being considered include whether a City-owned Golf Course, City Parks, or Athletic Fields could utilize treated effluent from the City's wastewater treatment facility in lieu of potable water from the domestic system.

3. **Further water main replacement** – Existing transmission main from the treatment plant in vicinity of East Leavenworth Road and Icicle Creek Road are 50 to 60 years old and are known to exhibit periodic leaks, which are repaired when identified. There may be unknown leaks contributing to water loss that could be resolved with replacement of the water main.

4. **Customer Education –** The City will continue to provide educational materials to their customers once per year in their quarterly newsletter (*The Leavenworth Courier*) related to water use efficiency.

5. **Customer Leak Detection –** The City will continue to attempt to identify customer leaks based upon anomalous meter readings where possible. When leaks on the customer side of the meter are detected, the City will inform the customer of the potential problem in order to abate excessive leaks.

6. **Water Use Education for Landscape Professionals** – The City will continue to provide information for landscape professionals to promote efficient water use landscaping and irrigation methods (e.g., xeriscaping, drip irrigation, soil moisture sensors, rain sensors, etc.).

7. **Xeriscape Promotion to Customers –** The City will continue to promote customers about opportunities related to xeriscaping.

8. **Shower Head Rebate –** The City will continue to look for funding partners to fund programs to provide rebates for water efficient residential fixtures and faucets. One example being providing a rebate for low flow shower heads with an estimated savings potential of 87,600 gallons annually.

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Limitations

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