ICICLE CREEK BOULDER FIELD FISH PASSAGE DESIGN

BASIS OF DESIGN REPORT - SRFB PROJECT # 13-1342

Prepared for

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1 INTRODUCTION AND BACKGROUND INFORMATION

The goal of this project is to provide designs for fish passage at two locations on Icicle Creek: the boulder falls, and the diversion dam (Figure 1). Fish passability and a detailed description of these sites were documented by Dominguez et al. (2013). A geomorphic assessment was completed for the boulder field area and a detailed engineering study of the City of Leavenworth water line. These studies provided information which served to shape the development of possible designs. At both sites, an alternatives analysis was conducted and a stakeholder group was convened to discuss the design options and select a preferred option. At the Boulder Field, six different options to improve fish passage were considered. Option 5 was recommended by the design team and approved by the technical advisory group, which consists of a step/pool fishway along the left bank of the boulder field abutting the toe of the road fill. Removal of a portion of the Icicle Irrigation District (IID) unimproved gravel access road and relocation of the City of Leavenworth waterline is required under this option.

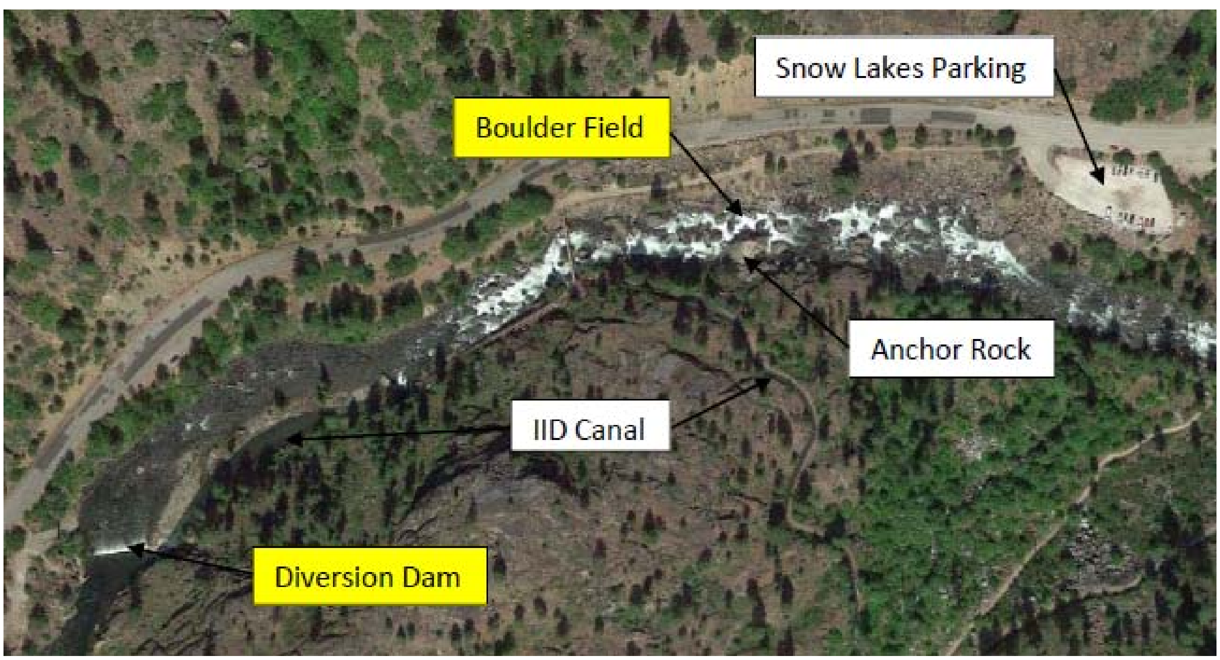

Figure 1 – Site descriptions for the Icicle Creek Fish Passage Design Project.

2 BOULDER FIELD ALTERNATIVES ANALYSIS/DESIGNS

Design Background

The Fish Passage Assessment Project (Dominguez et al., 2013) identified a migration timing and range of creek flows for passage from 20 to 1000 cfs for Bull Trout and 100 to 1200 cfs for Steelhead. The smallest fish size targeted for passage was a 12-inch sub-adult Bull Trout. Observations on site at 20 cfs, demonstrated the need for more flow to achieve fish passage due to water seeping through the voids in the boulder field. Above 2000 cfs it was observed that the entire channel upstream and downstream of the boulder field becomes marginally passable due to high velocity and turbulence throughout the channel. More recent observations, indicate a flow of 60 to 80 cfs is needed to fully water up the creek channel for fish passage at low flow through the bolder field area.

In spring 2016, the advisory group requested further information about the Steelhead Migration Timing. Data was provided by WDFW on Redd Observations in Peshastin Creek (WDFW). Peshastin Creek flows into the Wenatchee River eight miles downstream of Icicle Creek and has some very similar attributes as the Icicle. A summary of redds observed from 2005 to 2012 for specific years is shown in Figure 2. Redd observations cover the months of March, April, May and the first weeks of June. April and May are the highest stream flows months for Peshastin Creek. For Icicle Creek May and June are typically the highest flow months, though recent hydrographs suggest the peak may be shifting. If Steelhead migration timing into Icicle Creek is similar to Peshastin, these months can be analyzed for expected stream flows in Icicle Creek (Figure 3.) The stream flow data comes from the USGS gage 12458000 above Snow Creek.

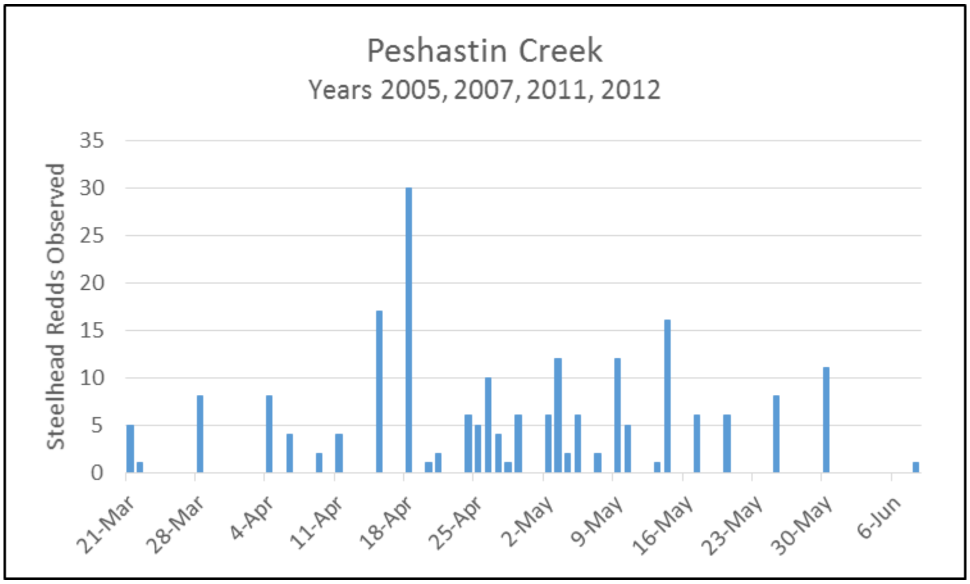

Figure 2 – Steelhead redd observation in Peshastin Creek for selected years. Bars represent total counts for each date based on a four year period.

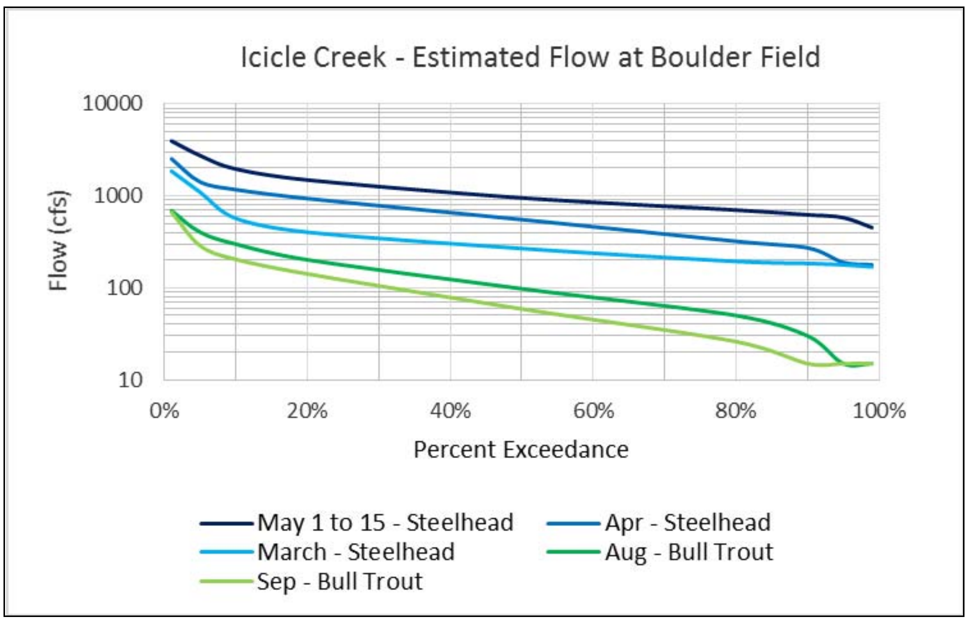

Figure 3 – Calculated flows at the Boulder Field for Selected Months of Fish Passage. August and September flows include a reduction for the Diversion Upstream.

Photo 1 – Icicle Creek channel just downstream of the Anchor Rock. The flow in the left photo is 20 cfs, the top right is 1000 cfs and the lower right 2800 cfs.

Five options were investigated to improve fish passage at the Boulder Field site. Most options were proposed along the left bank where the potential exists for removing the road, if a suitable path can be found for the waterline (Figure 4).

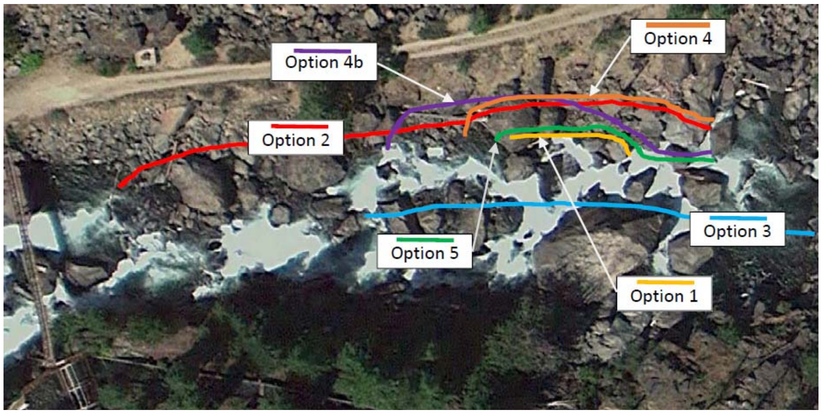

Figure 4 – Plan view layout of proposed path of each Option.

The proposed channel width for Options 2 and 4b would be 15 to 20 feet. This is the maximum width obtainable based on a 1.4:1 slope for the rock excavation and having a top of cut matching the existing slopes. Because the gradient is so steep (too steep for a roughened channel design), fish passage was calculated from the equation for a pool and weir fishway based on pool volume and energy dissipation (Equation 1);

Q = Pool Volume/16*Hydraulic Drop **Equation 1**

Option	Slope (%)	Length (ft)	Drops (ft)	Icicle Creek Flow at Max Design Flow[1] (cfs)	Minimum Fish Size Passable (inches)
1	22	85	5 to 7	350	18
2	11	270	2.2 to 3.3	900	12
4b	14	160	3.5 to 4.5	800	13
5	20	130	4.0 to 5.0	700 to 800	14

Table 1 – Summary of design variables for fish passage options. [1] Based on the existing flow distribution (stage vs discharge measurement) and calibrated HEC RAS Model.

Option 2 has the lowest slope (11 percent). Originally it was thought that this option would function as a roughened channel at high flow. However, the slope (see Figure 5), and bed material size exceed what is considered an acceptable range for a roughened channel. Roughened channels of this type may be considered experimental and need physical modeling to verify the range of passability. Option 2 could become more viable if the channel could be isolated from flood flows, but given the narrow constriction of the channel this is not likely possible.

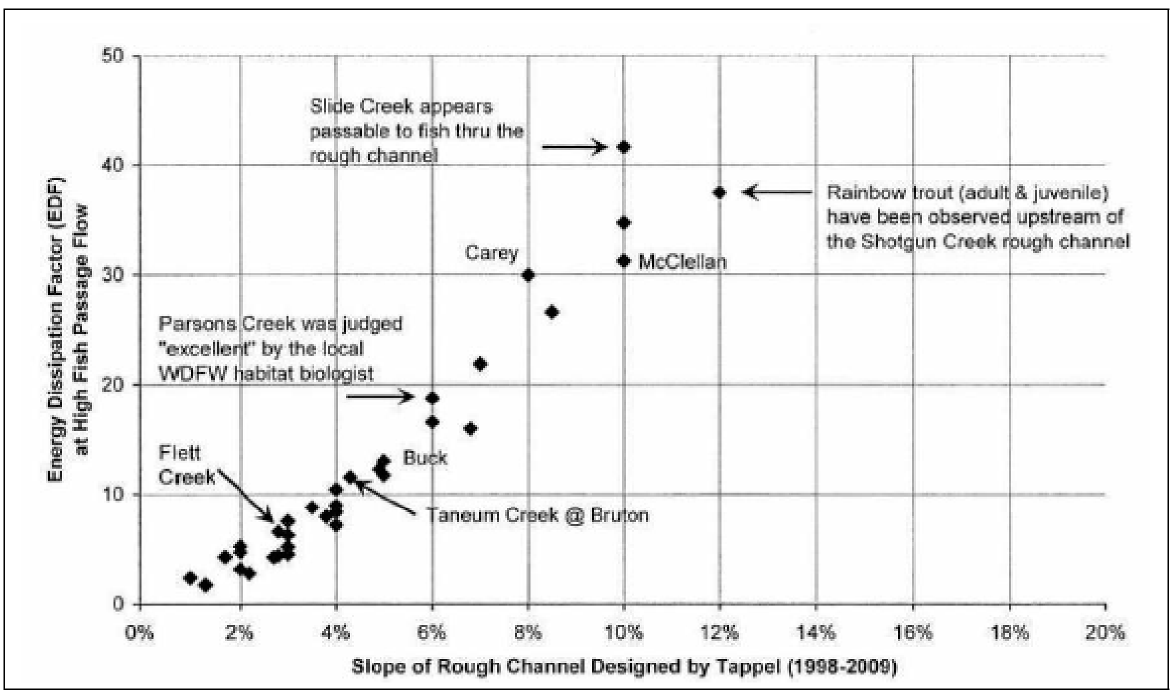

Figure 5 – Figure 6.9 from WDFW Water Crossing Guidelines for Roughened Channel Design.

Option 1: Improve Existing Passage

Option 1 would improve passage over the existing conditions by removing boulders which partially block the passage routes along the left bank toe, and enlarging the existing pools to allow for a wider range of passable flows. The passage route would have an elevation drop of 1360 to 1335 (25 feet) in over 113 feet of length (22 percent slope overall). There would be four to five major drops, each in the 5 to 6 foot range. The existing route may be passable from creek flows of 80 cfs up to 200 cfs. This option would extend the passage range to about 350 cfs, and improve passage at the lower flows. The existing drops have narrow slots and gaps where fish have to "squeeze through" in addition to leaping and/or swimming. Approximately 180 feet of the access road would have to be removed and the waterline relocated. Five or six large boulders would have to be fractured and removed, and two or three pools would need to be excavated. Based on the area available, the typical pool size would be 15 feet by 15 feet with a pool depth of 8 feet. With an average drop of 5.5 feet, the design flow range for the fishway would be 40 to 130 cfs.

Flows of 40 and 130 cfs through the fishway portion corresponds to Icicle Creek flows of 150 and 350 cfs, respectively. The limitation of this design option is the flow and drop. The high fish passage design flow is 1200 cfs for Steelhead, and this option would only provide passage up to 350 cfs (20 percent of the time in April). Also, the smallest fish size which would be able to pass would average about 18 inches, which is larger than the target design of 12 inches.

Option 2: Left Bank Floodplain Roughened Channel/Step Pool Channel

This option would require 340 feet of the existing road to be removed and the waterline relocated. The overall drop would be from elevation 1373 to 1337 (36 feet) in a length of 330 feet (11% slope). At low flow the form of the roughened channel would take the shape of a step/pool channel. The drops would average 2.2 to 3.3 feet with a spacing of 20 to 30 feet. The steps would be either existing exposed boulders or formed by rocks 3 to 5 feet in diameter placed with an excavator and potentially grouted. Pool depths would average 6 feet.

Based on water levels measured at the upstream end of the channel and calibration of a HEC RAS model for the reach, flows in the channel would vary as a function of Icicle Creek flows as follows:

Flow in Icicle Creek (cfs)	Flow in Option 2 Channel (cfs)
200	50
1000	350
11,000	3500

In terms of hydraulics, Option 2 would operate like a pool and weir fishway at low flow and a roughened channel at higher flows. The pools would operate across a range of flows from 30 cfs up to about 250 cfs. Above 250 cfs, the fish passage channel would start to function more like a roughened channel or boulder cascade. Roughness rocks in the channel would extend above the design water surface. The flow of 250 cfs corresponds to a flow of about 900 cfs in Icicle Creek. At around 350 cfs (which is the desired high design flow for the channel), the flow depth would increase to a point where the flow would transition to "streaming". The onset of streaming flow was defined by the following equation from Rajaratnam et al. 1988,

$$Q = 0.25\sqrt{g}bS_0L^{3/2}$$

Where; b = channel width or width of step, S_0 = slope and L = pool length or step spacing.
The uncertainty in design is from 250 cfs and above. The bed material size for a stable roughened channel would vary from 4 to 6 feet in diameter. With bed material of this size, the roughness would not be submerged. The rocks would project above the water surface. The hydraulics of the channel at this flow would function more like a boulder cascade. Additional flow will also likely be introduced from the main channel just above the Anchor Rock. For good passage at this higher flow range, a physical model may be needed to better understand the hydraulics.

Option 3: Channel Profile Regrade

Further discussion from stakeholder members eliminated this Option due to the overall disturbance and the potential negative impacts of filling in the plunge pool.

Option 3 would regrade 380 feet of channel. Approximately 200 feet would be a channel cut upstream and 180 feet channel fill downstream. The 20 foot deep plunge pool downstream would be filled in. The design overall slope would be 9.5 percent. Similar to Option 2, the road would have to be removed and water line relocated. A fish passage way would not be constructed and only boulders which are obstructing the channel regrade would be removed. Successful passage would require several large floods in the 5 to 10 year range to sort material and then hopefully start to form fish passage routes. The overall slope and material size would mimic the natural condition of sections of Icicle Creek downstream of the project site. The key here is removing the width and boulder constrictions to allow the channel to regrade naturally.

Option 4: 14 Percent Step Pool Channel

Under Option 4 the channel length would be 160 feet and the overall drop from elevation 1363 to 1340 (23 feet). Individual drops for the fishway would average 3.8 feet per step, but would range from 3.5 to 4.5 feet. The overall channel slope would be 14 percent. The flow distribution in the fish passage channel would vary as a function of flow in Icicle Creek (see Table 2).

Icicle Creek Flow	Flow in Option 4 Channel	Water Surface Elevation	Notes
200 cfs	50 cfs	1364	Plunging Flow
1000 cfs	350 cfs	1368	Streaming Flow
11,000 cfs	3500 cfs	1372	Channel Stability Design Flow

Table 2 – Flow Distribution in Icicle Creek at STA 288 (Upstream End of Option 4 Channel)

The flow distribution was based on the HEC RAS model (see

Figure 7). The model was calibrated based on measured water surface elevations at flows from 40 to 2800 cfs. There is a natural feature in Icicle Creek upstream of the Anchor Rock which separates the flow into two channels. In addition, the right side of the Anchor Rock has a 30 foot wide section of boulders which block flood flows and could be lowered 5 to 6 feet to encourage more flow to the right bank. At a depth of 4 feet, up to 600 cfs of flow could be directed away from the fish passage channel. This would reduce the flow through the center portion of the channel and reduce the turbulence near the downstream end of the fishway. Figure 8 shows a cross section within the Anchor Rock; the Option 4 Channel is shown on the left bank.

The transition from plunging to streaming flow in the channel was calculated at 350 to 400 cfs. At this flow the hydraulics in the Option 4 Channel may be too turbulent for fish passage. Passage should be good up to a flow of 200 to 230 cfs, which corresponds to an Icicle Creek total flow of approximately 800 cfs. Good passage is defined as meeting the fishway pool volume criteria as calculated by Equation 1, modified for a rough rock channel versus a concrete pool and weir fishway.

The passage "window" for this scenario is shown in Figure 10. The design would meet the preferred window of passage 15 percent of the time in May, 70 percent of the time in April, and 90 percent of the time in August and September (not considering the irrigation diversion flows). Passage would be good, except for the high flow months of May and June. This analysis does not take into account the flow distribution from the proposed channel modifications. With the potential right bank flow modification near the Anchor Rock, this could extend the passage range. From 800 to 1200 cfs, the stage increases about 2 feet in the creek channel. Another consideration would be a flow control slot (or constriction) at the channel entrance. This would also reduce flows into the channel for all the other stages but may be difficult to maintain.

Note: During a site review in July of 2015 when flows at the site dropped to less than 10 cfs, the design team was able to survey under the boulder field at the downstream end on the left bank and discovered that Boulder 26, see Figure 6 **(the proposed fishway downstream end) was suspended 6 feet over the pool and was resting on a boulder. There was a deep pool underneath. It was agreed to on site that the downstream end of the fishway would need to move upstream and to the right. This new layout made the fishway channel extend further**

upstream and increased the overall excavation. It was also determined that the new location of the downstream end of the fishway would be affected by turbulence from spill in the main channel and that two boulders would have to be removed in the main spill area to create a better pool and deflect some of the flow in a more direct path downstream. This new layout and plan was named Option 4b.

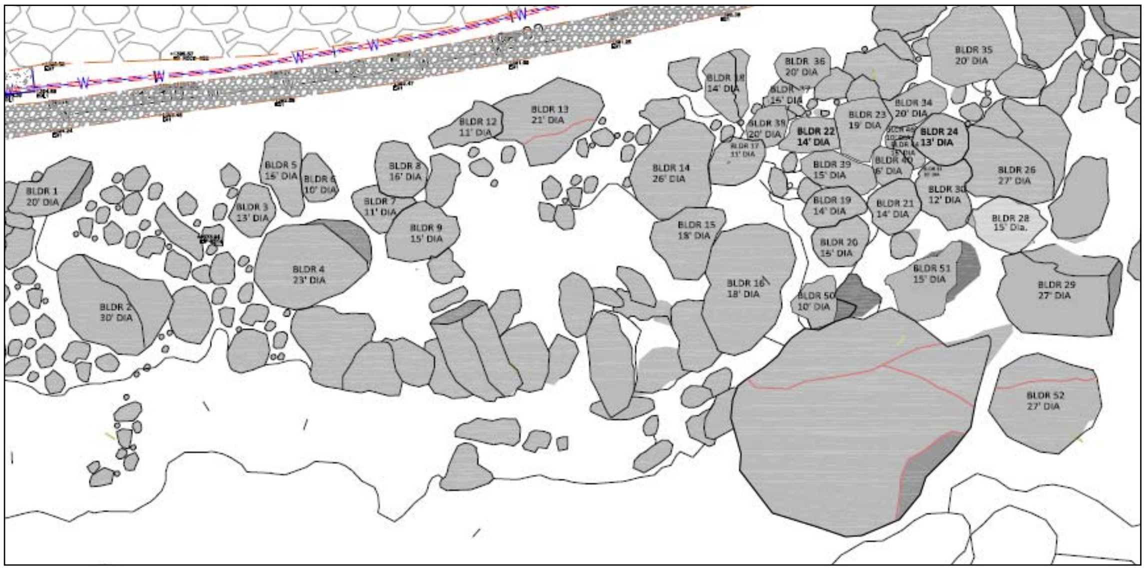

Figure 6 – Boulder numbering layout, from left (upstream) to downstream.

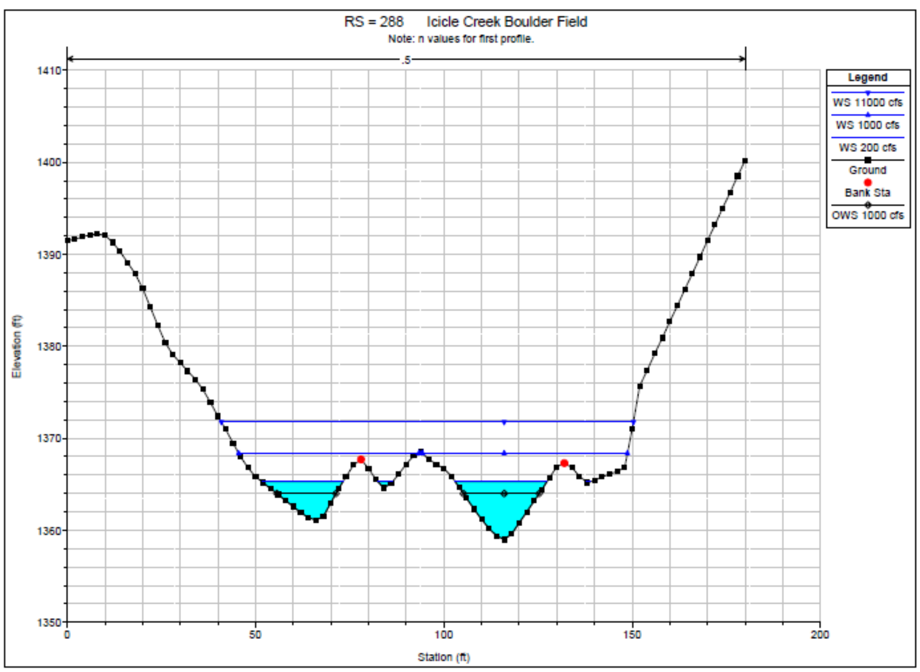

Figure 7 – Cross Section at STA 288, near the upstream end of the Option 4 channel flow entrance.

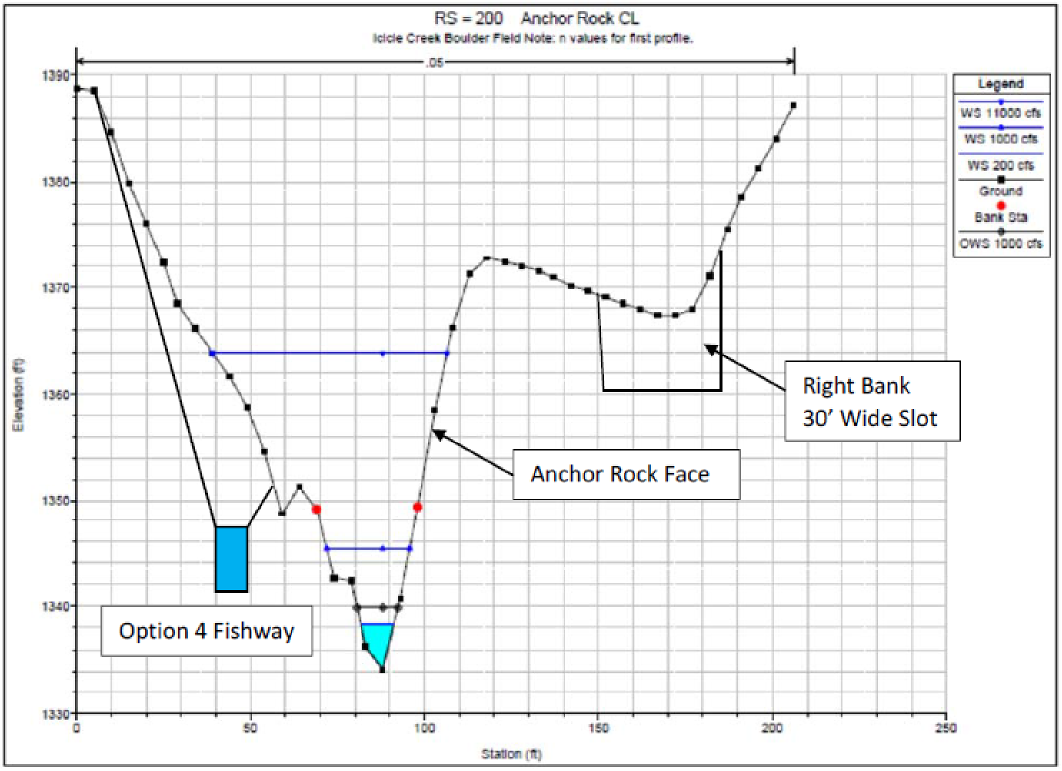

Figure 8 – HEC RAS Cross Section at STA 200 at Anchor Rock showing Option 4 Fishway and Concept of Right Bank Slot.

Option 5:

When the Option 4 layout was modified and Option 4b created, the extent of excavation around Boulder 14 (**Figure** 6), changed to the point that Boulder 14 had to be removed. In addition, closer inspection of the pool under Boulder 14 revealed a "small cave" and a very deep, stable pool which could be utilized and possibly enhanced. Looking at the risk and potential level of disturbance, Option 5 was developed as an additional alternative (see Figure 9). Under this option three new steps and pools would be developed downstream of Boulder 14. Drops would range from 4 to 5 feet per step. Pools would be 8 feet deep at low flow. The key to making Option 5 effective for fish passage is raising of the tailwater by placing boulders in the gaps of existing large boulders and modifying the main flow path down the falls by removing two large boulders which deflect the flow. These modifications to the main falls will only be noticeable at flows less than 1000 cfs. Above 1000 cfs, water flow from high velocity and turbulence will overwhelm all of these modifications.

A new consideration in evaluating drops for fish passage is the drop proposed relative to drops at other falls upstream on Icicle Creek. Gage Falls, Bridge Falls and Icicle Gorge Falls all have drops around 6 feet at low flow. To optimize the hydraulic function of Option 5, some manipulation of boulders and debris upstream of Boulder 14 would be required in addition to minor changes in the channel. Based on water levels measured at the upstream end of the channel and calibration of a HEC RAS model for the reach, flows in the channel would vary as a function of Icicle Creek flows as follows:

Flow in Icicle Creek (cfs)	Flow in Option 5 Channel (cfs)
60	18
450	63
800	210

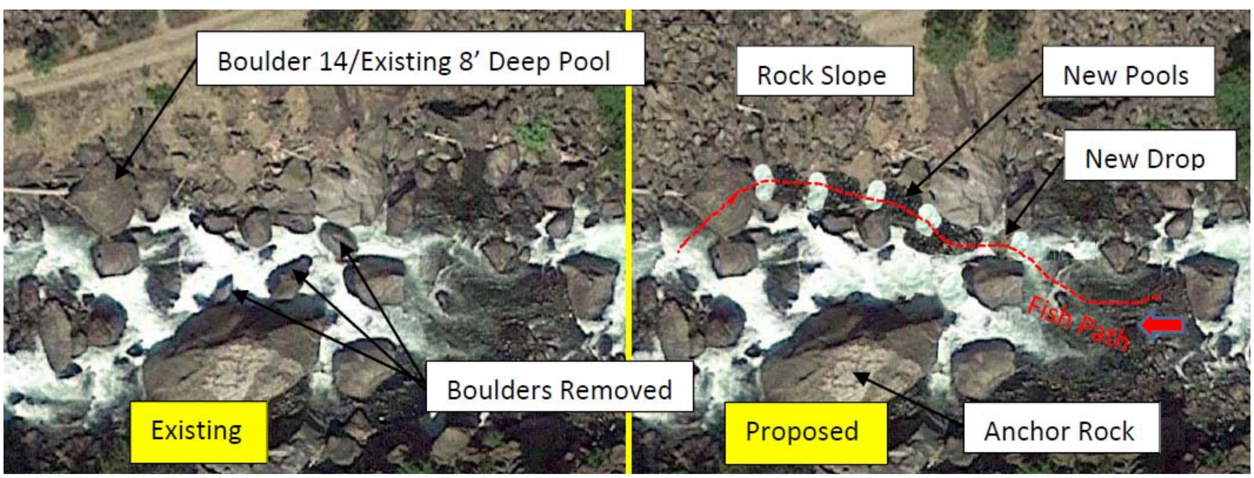

Figure 9 – Option 5 layout. Photo to left is existing at 600 cfs, Photo to right is proposed. Design is similar to Option 4b Preliminary design without the removal of Boulder 14 and increased drops.

Summary of Design Options

The upper fish passage design flow for each Option is shown in Figure 10. There are two time frames when these options do not address fish passage. One is for Steelhead during high flows in late May, the other is during extreme low flows in the summer for Bull Trout when flow is diverted upstream.

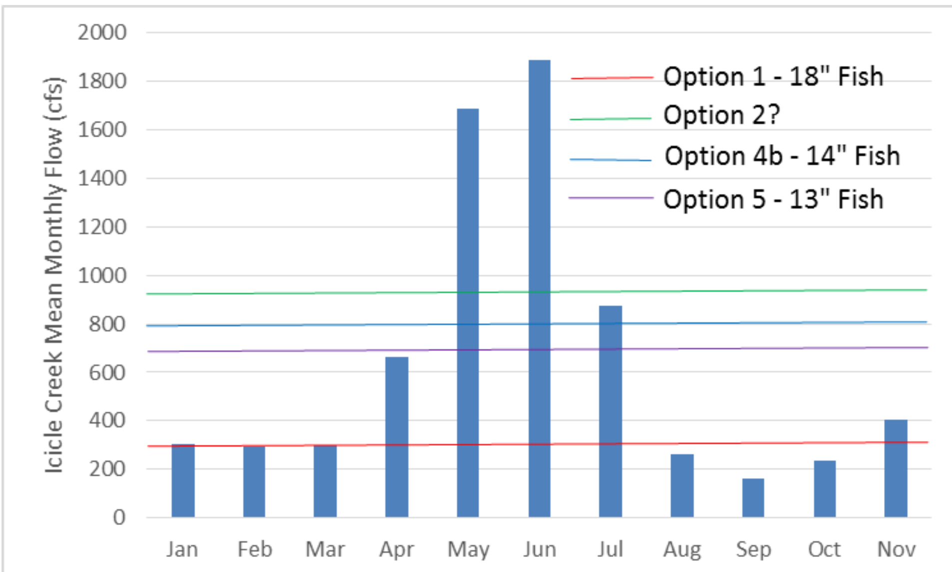

Figure 10 – Design options denoting smallest estimated fish size to pass and upper passage design flow range for plunging flow relative to mean monthly flows. Option 1 is the red line, Option 2 the green line, Option 4b is the blue line and Option 5 is the magenta line.

For the Option 5 design, further detail of the expected passage is provided in Table 3. In April and May passage may be limited by water turbulence/high flows in the fishway pools. In April, for Steelhead passage, fish would be able to pass 67 percent of the time. From May 1st to the 15th, Steelhead would have passage 30 percent of the time. These percentage values are taken from Figure 3. Based on the Peshastin Creek Redd counts, the May 15th date represents 85 percent of the total redd observations. In August and September passage is limited by low flows. In August, Bull Trout would have passage 72 percent of the time and 48 percent in September.

Month	Species	Passage Window	Percent of Run	Option 5 – Fish Passability Rating
March	Steelhead	92%	1%	Good
April	Steelhead	67%	55%	Good, Limited by High Flows
May 1 to 15	Steelhead	30%	85%	Fair, Limited by High Flows
Aug	Bull Trout	72%		Limited by Diversion Flows, Need 40 cfs
Sept	Bull Trout	48%		Limited by Diversion Flows, Need 60 cfs

Table 3 – Summary of Fish Passability Option 5, Design Flow Range 700 to 60 cfs.

<u>Other Design Issues</u>

In the area of the Anchor Rock the channel width is reduced from 130 to 30 feet. The flow accelerates in this narrow area around 400 to 600 cfs. This acceleration creates a high level of turbulence in the lower portion of the channel along the left bank toe. At 1200 cfs, this turbulence starts to extend into the area where the downstream end of the new fishway channel would be located. This turbulence would likely create a barrier and prevent fish from ever finding the fishway. One option to reduce this turbulence would be to break away rock on the right bank between the anchor rock and right floodplain wall. If a slot were cut and the rock elevation lowered 6 to 7 feet, there would be a flow of 500 to 600 cfs over this area at creek flows of 12,000 cfs. This may reduce some of the turbulence along the left bank and extend the potential passage range. A slot may also provide a flow relief during peak floods which may assist is extending the longevity of the design and reducing the risk of bank erosion issues. A HEC RAS model evaluated the magnitude of this potential flow split, but the one-dimensional restriction of the model cannot evaluate the situation accurately. A two-dimensional model analysis is needed. Upon final design it is recommended that a two-dimensional model be run to verify these design variables.

3 DIVERSION DAM DESIGN

The diversion dam is a concrete structure 110 feet long. The dam is only 2.2 feet high but creates a barrier to fish passage when the water level of Icicle Creek drops lower than the crest. (Figure 12). A rating curve was developed for the forebay and tailwater and is show in Figure 11. At 400 cfs the downstream apron is backwatered, the drop is only 2 feet and adult fish can swim over the dam. Referring back to Figure 3, during the months of August and September (Bull Trout migration timing), 400 cfs occurs less than 10 percent of the time. For April and May (Steelhead migration timing), 400 cfs occurs about 80 percent of the time. The forebay rating curve in Figure 11 is shown as being level because flash boards are installed to maintain the water level needed to get flow into the IID canal. These flashboards also provide a higher water level for flow diversion into the City of Leavenworth intake for their water supply.

The proposed preliminary design to improve fish passage at the diversion dam is a pool and chute fishway. Pool and Chute fishways have been used successfully for low head diversions, especially where the main passage problem is low flow (Powers, 2001). From low flow to 200 cfs most of the flow would be in the fishway with little or no flow over the dam. At 300 cfs the dam starts to become passable as the fishway becomes too turbulent for passage. The fishway could be closed at this time or weirs removed. During the final design phase of the fishway, coordination with the City of Leavenworth and the Icicle Irrigation District will be important to understand the fishway operation. Design drawings are provided in Appendix B.

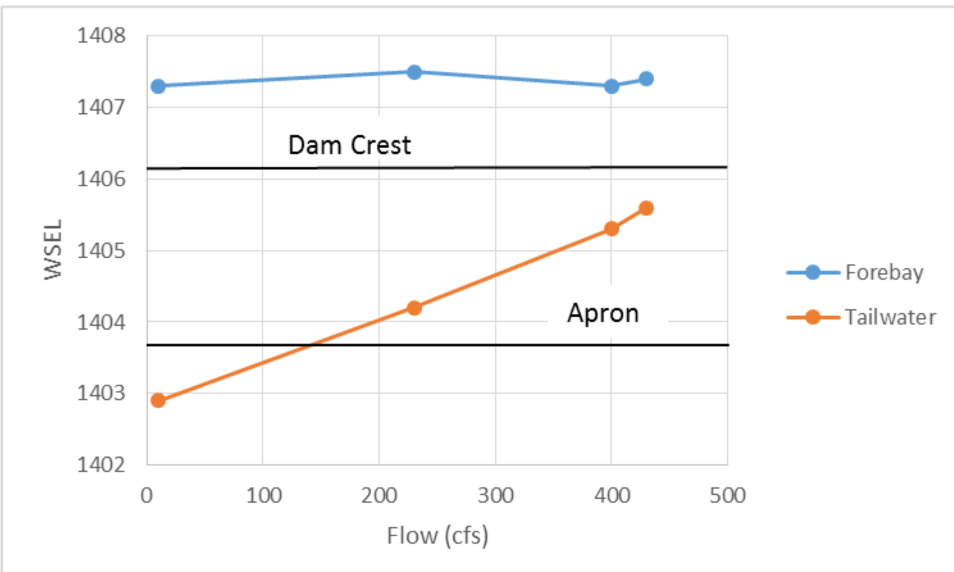

Figure 11 – Forebay and tailwater rating curves for the concrete diversion dam on Icicle Creek. The apron is concrete and broken at the downstream end.

Figure 12 – Diversion Dam on Icicle Creek at low flow. Flashboards are 12" high.

4 HYDRAULIC MODELING

A HEC RAS model was developed for the existing channel and the proposed conditions for Option 4. The model extends 400 feet upstream and 300 feet downstream of the Anchor Rock. Flows were analyzed in the range from 200 to 20,000 cfs. Most of the analysis looked at depth, velocity and shear stress at 11,000 cfs which is the calculated 20 year peak flood event and the design flow which was selected to evaluate channel hydraulics. A photo at 12,000 cfs (Figure 13) allowed some approximations of water surface elevations. Manning's n values were varied in a trial and error method until the calculated water surface elevation matched the observed. The hydraulic gradient varies from 5 percent downstream of the Anchor Rock, to 17 percent within the Anchor Rock area to 7 percent upstream.

Figure 13 – Icicle Creek at 12,000 cfs (not verified), Dominguez, 2013.

At 11,000 cfs, the average channel depth is 20.3 feet, with a maximum of 27 feet and a minimum of 15 feet. Velocities average 8 feet per second (fps), but range from 18 to 4 fps. Shear stress values average 63 lbs/sq ft with much higher values in the Anchor Rock area. It is difficult to predict a stable boulder size for this reach, but based on site observations, historical photos and information from residents on the creek it appears a stable boulder size is about 8 feet in diameter. Boulders in the 5 foot range may be stable but would need to be interlocked and contacting other larger stable boulders to remain stable.

In the Option 4 cross sections the left bank (viewed downstream) was widened by taking out the access road and sloping the bank. This increased the width by 20 to 30 feet within the Anchor Rock area. In addition, the right bank slot of the Anchor Rock was lowered to elevation 1362 (8 feet) to allow flood water to spill over this area. Currently all the water is blocked by several boulders in the slot and all the flow is forced into the center channel. The results of the modeling with these changes showed a 4 foot lowering of the water level based on these two modifications. Velocity and shear stress value changes were negligible. A 2D hydraulic model should be developed to better understand the flow distribution around the Anchor Rock and velocities along the left channel margin downstream of Boulder 14. Water elevations has been collected along the project reach in the main channel which would assist to verify the results of the 2D Model (see Figure 14). The HEC RAS output data is provided in Appendix E.

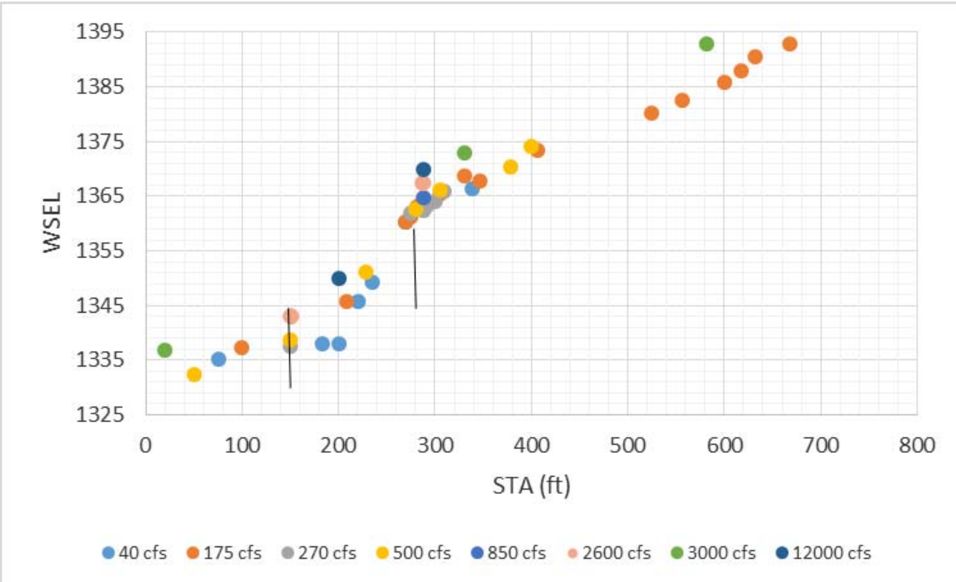

Figure 14 – Water surface elevations measured along the project reach. The two vertical lines represent the upstream and downstream extent of the proposed Option 5 Fishway.

5 CITY OF LEAVENWORTH WATERLINE

The City of Leavenworth has a water line within the project area. A detailed assessment of the waterline was completed by IntegriTech Consulting (see Appendix D). The report includes a history of the water system, description of the intake, dam and other facilities, calculations for pipeline and treatment plant capacity, water rights, and conceptual design options for relocating or moving the waterline relative to the proposed fish passage work. For the Option 5 design, the waterline is about 5 feet away from the proposed slope cut. Given the typical boulder sizes, removal of one boulder, or the shifting of one boulder could disturb the waterline.

6 GEOTECHNICAL ASSESSMENT

A detailed report on the geology of the Boulder Field area was completed by Toth Consulting, with input from Dr. Terry Swanson, Ph. D of University of Washington and is provided in Appendix C. This report covers boulder characteristics, engineering properties of the rock, construction considerations, a design memorandum from the Maple Leaf Powder Company on rock blasting and breaking issues and some actual rock breaking tests performed on rocks taken from the site.

7 RISK ASSESSMENT

The most significant factor affecting risk to the project is how the newly constructed channel will perform in a reach with such high stream power. What follows is a discussion of some of the design variables and a description of the risk and how it could be mitigated.

Flood Levels

Flood frequencies were documented in the original assessment report (Dominguez, 2013). The 20 year peak flood flow was used as the upper limit to assess channel velocities, shear stress and depth. The values calculated for shear stress are very high due the gradient in combination with the channel depth. Especially in the Anchor Rock area the shear stress values are extreme. Any design features should be assessed in terms of stability (short term and long term). The area proposed for work is on the left channel margin where velocities appear to be much less than the main channel. A two-dimensional model should be run to further confirm the hydraulic conditions for the selected option. Recent observations of floods has shown small woody debris to be deposited near the proposed fishway exit upstream and along the proposed fishway route downstream of the hydraulic shadow from Boulder 14.

Slope Excavation

There is some uncertainty about the underlying material in the area proposed for excavation. Initially the design team proposed test excavations in this area but there were permitting issues, and the location of the waterline was a concern. If the material is similar to the surface boulders, a combination of cracking boulders, excavating and some blasting with low velocity explosives may be required. Excavation depth would vary from 15 to 24 feet. Reference reach slopes upstream and downstream of the site were measured from survey data at 1.4 horizontal to 1 vertical (1.4:1). These slopes are a combination of large boulders spaced periodically with smaller boulders intermixed. The most stable areas are segments which have "anchor boulders" defined as boulders which are 10 to 20 feet in diameter that were deposited after the Icicle Glacier retreated and the Snow Creek Glacier dropped boulders into the Icicle Creek Valley. Both sides of the valley also have exposed bed rock. The transition line between boulders and bedrock is discussed in Appendix C. The proposed slope of the excavation is 1:1

within the fishway pools and 1.4:1 for the slope extended to an elevation up to the 20 year peak flood level. Above that point construction of a 1:4 rock wall is proposed to reduce the cut and match a stable grade below the Icicle Road.

If the channel slope below the design flood level exposes boulders smaller than 5 feet in diameter this material will likely be eroded from high velocity. Some natural adjustment of the slope in the long term may be required. To address this concern a design plan needs to be developed for construction to stabilize the slope. This plan should include details for slope construction including several design methods which can be used depending on the rock material exposed.

Boulder 14 Removal

Boulder 14 is on the left bank of the channel near the middle of the fishway (Figure 9). The boulder is about 26 feet in diameter. It is a major channel feature which if removed could cause significant short term channel changes along the left bank. These changes could be in the form of scour along the toe of the left bank (which is currently protected in the shadow of Boulder 14). It is difficult to address this risk due to the unknown conditions in the area proposed for excavation. Boulder 14 is partially resting on Boulder 15 and 17 and under Boulder 14 there is an open area or "cave". Within this cave is an 8 foot deep pool with nearly vertical walls on the left bank. If this pool could be used at part of the fishway without removing Boulder 14 the risk of bank erosion would be significantly less, but as boulders are removed around it some settling or revised configuration is likely.

One solution to reduce the risk to Boulder 14 would be to move the fishway alignment 12 feet to the left at the upstream end so Boulder 17 could remain. This would require additional slope excavation and eliminate the option of lowering the waterline in the current location, which is one of the proposed options for the waterline.

Difficulty Stabilizing Slopes during Excavation

Excavation would likely proceed from the top of the slope down. If excavation starts at the bottom, the slope above could become unstable. The waterline above these areas would likely have to be temporarily rerouted and placed on the surface (suspended?). Final design details for the waterline are critical before construction can proceed.

Construction Access and Public Safety

The site is located near the parking area for the Snow Lakes Trail and along the U. S. Forest Service (USFS) road to the Icicle Creek drainage. Hikers, fisherman, climbers, etc. have all been observed on site. During the final design a construction access plan needs to be coordinated with the proposed plan for the pipeline. This plan needs to include a traffic control element coordinated with the USFS, and show access routes and identify the proposed new access for the Irrigation District to service and maintain the fish screens. Rock breaking activities need to be clarified relative to the public use of the area. It has been noted several times during the project development that high velocity explosives may not be allowed on site due to the high level of public use in the area. This will limit the contractor's ability to remove rock and the may take more time for construction.

8 COST ESTIMATES

Cost estimates were developed based on the preliminary designs for the Boulder Field and Diversion Dam. The design estimates were based on unit costs from the Means Construction Manual, past experience with instream construction, and meetings on site with other design experts and contractors in rock blasting and rock excavation.

9 OTHER FALLS UPSTREAM

Nelson et al. (2011) documented nine other falls upstream of the Boulder Field on Icicle Creek. Five of these sites were reviewed and evaluated for passability. Photos and notes of each site are provided in Appendix F. The three falls which appear to be potential partial fish impediments are Gage, Bridge and Icicle Gorge Falls. All three have drops in the 6 to 7 foot range. These falls are not likely a passage problem for Steelhead, but typically would block passage to Bull Trout with lengths less than 16 to 18 inches. The falls with the greatest potential to obstruct passage is Gage Falls (see Figure 16) for steelhead during high flow and Bridge Falls for bull trout during low flow. Water surface profiles were measured over Gage falls at two flows but velocity was not calculated. A combination of velocity and turbulence at higher flows could limit passage.

Site	River Mile	Vertical Drop (ft)
Boulder Falls	5.5	25
Gage Falls	6.0	6 to 7
Pothole Falls	6.5	< 6
Bridge Falls	9.5	7 to 8 (low flow)
July 4th Falls	11	< 5
Icicle Gorge Falls	16.5	6
Rock Falls	18.2	<5'
French/Complex Falls	21.5	No Review

Table 4 – Summary of falls upstream in Icicle Creek (Nelson, 2011)

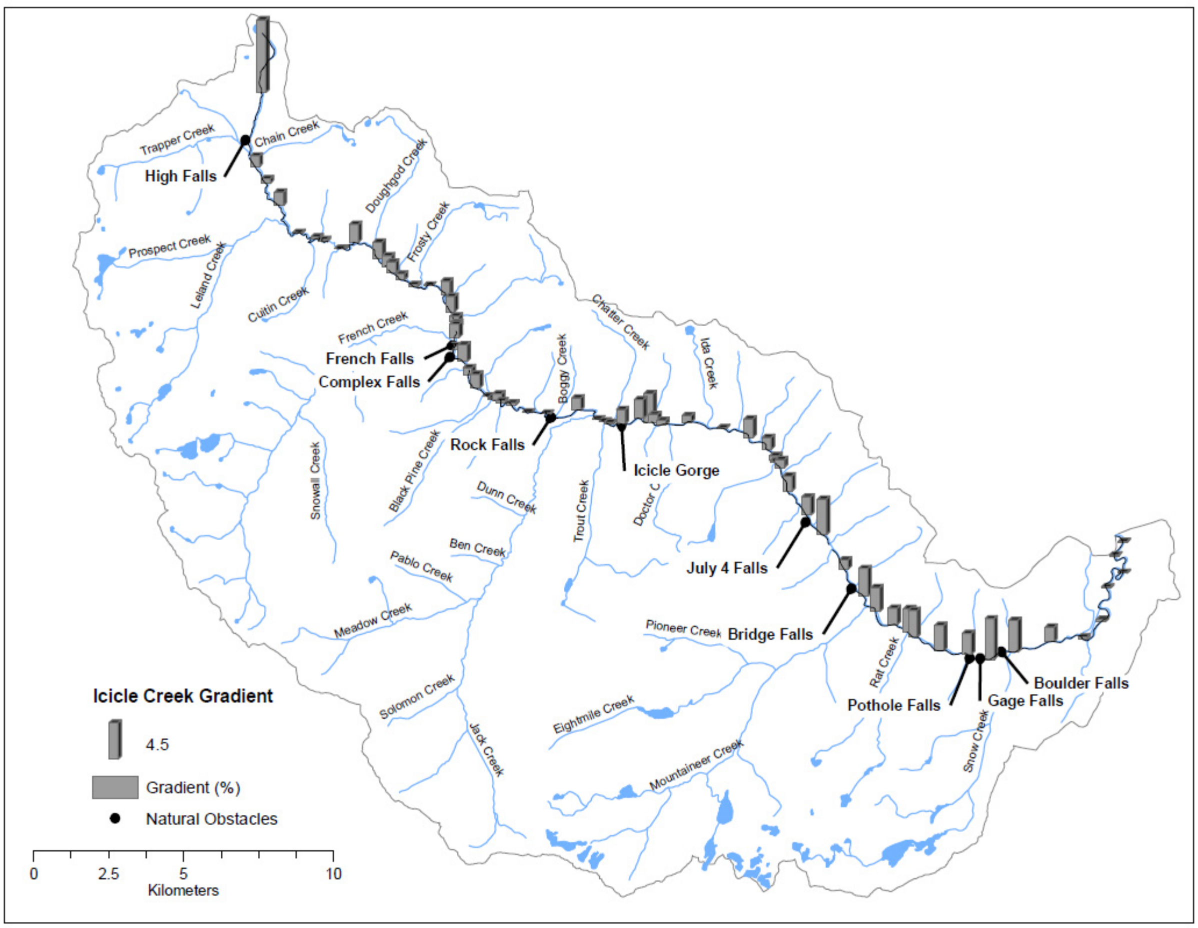

Figure 15 – Icicle Creek basin showing select natural falls from (Nelson et al. 2011).

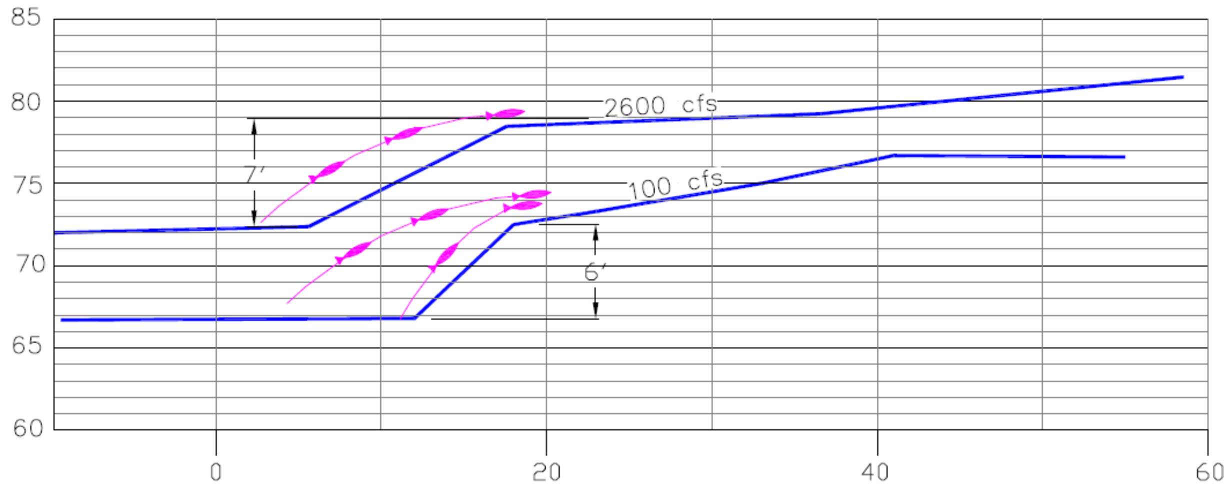

Figure 16 – Gage Falls on Icicle Creek at RM 6.0 at low and high flow. Measured water profiles at 100 and 2600 cfs with leaping curves (40 and 60°) for a 24 inch Steelhead superimposed. The channel is narrow and confined but at higher flows the falls backwaters from the channel downstream.

10 REFERENCES

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Rajaratnam, N and C. Katopodis. 1988. *Plunging and streaming flows in pool and weir Fishways*. Journal of Hydraulic Engineering. Vol. 114, No. 8.

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APPENDIX A – BOULDER FIELD EXISTING AND OPTION 5 DESIGN DRAWINGS AND COST ESTIMATE

APPENDIX B – DIVERSION DAM DESIGN DRAWINGS AND COST ESTIMATE

APPENDIX C: GEOTECHNICAL ASSESSMENT OF THE ICICLE CREEK BOULDER FIELD STUDY REACH

APPENDIX D: CITY OF LEAVENWORTH WATERLINE ASSESSMENT

APPENDIX E: HEC RAS MODEL OUTPUT

Existing
Water Surface Profiles
Cross Sections
Output Data

Proposed Option 4
Water Surface Profiles
Cross Sections
Output Data

APPENDIX F: FALLS UPSTREAM – PHOTOS AND NOTES

Potential Barrier Name	Gage Falls
River Mile	6.0
Hydraulic Drop	Ranges from 6 to 7 feet
Description	Located approximately 0.5 miles upstream of Boulder Falls. Road repair from about 10 years ago due to left bank erosion. Large split boulder on right bank has the potential to topple into the channel and alter passage characteristics. Falls is confined and tailwater becomes very turbulent at high flow. Passage is best at lower flow.

Potential Barrier Name	Pothole Falls
River Mile	6.5
Hydraulic Drop	Not Measured, Less Than 6 feet Based on Observation
Description	A series of smaller bedrock and boulder falls that do not appear to be a significant barrier to fish passage.

Potential Barrier Name	Bridge Falls
River Mile	9.5
Hydraulic Drop	7 to 8 feet
Description	Significant boulder falls but has potential alternate passage routes along left bank of Icicle Creek. Higher flows spread out (channel not confined) to reduce turbulence.

Potential Barrier Name	July 4 Falls
River Mile	11
Hydraulic Drop	Not Measured, Less Than 5' Based on Observation
Description	A series of small falls that would be better characterized as cascades. These cascades are unlikely to be a significant barrier to fish passage.

Potential Barrier Name	Icicle Gorge Falls
River Mile	16.5
Hydraulic Drop	6' at low flow
Description	A series of smaller falls incised into bedrock that do not appear to be a significant barrier to fish. Witnessed a small trout jumping the largest of the falls. The crest is 30 feet wide with a 10' deep plunge pool. The tailwater control downstream is very narrow (10') so falls will likely backwater at higher flows.

Potential Barrier Name	Rock Falls
River Mile	18.2
Hydraulic Drop	Not measured, Less than 5’ from observation.
Description	A short series of small falls slotted into bedrock that does not appear to be a significant barrier to fish passage.

APPENDIX G: STAKEHOLDER MEETING NOTES

February 9, 2015.

The first meeting was with the City of Leavenworth to discuss the evaluation of the waterline, and the second was a more technical group to discuss the overall project and designs.

<u>City of Leavenworth Meeting:</u>
Attendees: Aaron Penvose (TU), Steve Toth, Pat Powers, Joel Walinski (City Administrator), Herb Amick (Public Works Director), Stan Adams (Treatment Plant Manager).

Aaron provided a summary of the project and the proposed geological test details. The City misunderstood the testing plan and thought blasting would be part of it and had originally wanted TU to sign some form of waiver. Pat and Steve provided additional detail on the process for the testing plan. Aaron and Pat also requested any information about the history, present and future plans for the waterline. Herb agreed to check the City files and see what information was available.

The City explained this was 50 percent of the Cities water and that there were wells, but they were mainly for redundancy. The existing 16 inch steel line carries about 2200 gpm. The City's main concern is working near the existing waterline. The line in this area is 80 plus years old but has not experienced problems with leaks.

Aaron, Pat and Steve explained the possible design options and what portion of the road access road may be removed. The City noted there were not any plans for updating the line or intake.

Aaron asked again about the liability issue during testing, and Joel agreed to reconsider and get back to Aaron. Approval will likely rest on two items 1) a utility locate with Pat and Steve field locating the actual test dig areas, and 2) a construction contract for the City to review.

Pat than asked if the waterline was relocated how or who would design that work for the City. Joel provided two contacts for local consultants who were familiar with the line. Pat will follow up to better inform the potential design options.

<u>Technical Advisory Committee</u>
Attendees: Aaron Penvose (TU), Bruce Heiner, Jeremy Cram, Amanda Barg (WDFW), Mark Nelson (FWS), Robes Parrish (FWS)
Tony Jantzer (IPID), Pat Powers, Steve Toth
Stan Adams (City of Leavenworth)
Kevin Smith and Kathryn McMillan, USFS
Mike Wyant and Bob Stroup (IVTU)

TU provided a review of the project, the Assessment from 2012, current timelines and deliverables. Drawings were handed out for the existing conditions, Option 1, 2 and 3.

Passage for coho and Spring Chinook was brought up by several different groups. The Assessment focused on Steelhead and Bull Trout and the flows during their migration seasons. There was not a resolution to this point, but the designs being considered would not preclude passage of Coho and/or Spring Chinook it they were present.

WDFW presented their case for passage above 600 cfs being a possibility because of the chinook redd and juvenile found upstream.

WDFW emphasized their policy on not providing passage at natural barriers and suggested the design options should focus on passage improvements which were more directly improving routes where there may have been some passage. They noted it would be difficult to permit removing major boulder elements which were historical features. They also suggested the design team coordinate permit review with NOAA and FWS to see what potential issues they might have.

There was general consensus that Option 3 should not be considered further. The main concern is the overall impact of filling the plunge pool and eliminating all the pool habitat. Even though long term passage may be better the loss of the pool could be significant.

The IPID noted that for Option 1 (or a modification to it), the existing access road should be removed in lieu of building another road down to the site.

There was preference for an option which combined features of Option 1 and 2. Pat reemphasized the difference between the two in terms of channel slope/drop and flow limitations. WDFW commented that since we have some level of passage now, that enhancing that with a potential to expand it later might be a good approach.

Pat presented another idea of lowering a 30 foot wide slot to the right of the Anchor Rock which would reduce the flow along the left bank and therefore the turbulence. This could improve the passage conditions near the entrance to the passage route for Option 1 and 2 at higher flows. There were no objections to making this potential modification.

The FWS asked a question about the certainty of success of the options. Pat answered that likely Option 2 had the highest certainty of meeting the fish passage criteria established.

There was discussion about the 12 inch sub-adult bull trout as the minimum fish size which needed passage. The point was discussed that smaller fish likely never passed the boulder field reach and only the larger fish would typically pass. WDFW felt the design should not be driven by the sub-adult fish and it would be reasonable to use a larger fish size. The USFS felt the 12 inch sub-adult should remain as smallest fish to provide upstream passage for.

March 19, 2015

Location: Leavenworth City Hall

Attendance:

Steve Toth, Toth Consulting
Kate Terrell, USFWS
Dan Davies, Trout Unlimited
Dick Rieman, Icicle Creek Watershed Council
Stan Adams, City of Leavenworth
Amanda Barg, WDFW
Chris Fisher, Colville Tribes
Justin Yeager, NMFS
Aaron Penvose, TU
Bruce Heiner, WDFW
Jeremy Cram, WDFW
Pat Powers, Waterfall Engineering
George Lange, TU Chapter

Aaron opened the meeting with the goals for the day and wants to keep discussion focus on design options pros and cons.

Pat presented new design information and new Option 4

Chris Fisher: Should consider a high flow and low flow channel.

Bruce: Options with flow control are not preferred, it would be better to just let the fishway function at a lower flow.

Jeremy: Option 4 preferred

Chris: Showed examples of Omak Creek where they blasted and removed 4000 cubic yards of material.

Amanda: Asked is designs like this have been used before? Pat responded with examples from the Chehalis and Willapa River where WDFW blasted bedrock to form rock fishways. Pat noted the big difference on Icicle is the excavation would go through a boulder field with loose rock.

Jeremy: With regards to high flow passage in May, not really a concern.

Dick: There are other passage problems upstream and downstream. These were discussed at the previous meeting.
Justin: Noted that Steelhead passage upstream is important

Dan: Suggest the preferred design be the one which meets the project objective.

Bruce: More discussion of inlet control

Pat: Noted a preference for phased construction, but Kate noted that would be a permitting problem. Kate suggested a different approach with adaptive management looking 3 to 5 years out for modifications.

Bruce: Question about TU commitment to maintenance. Concerns were brought up by several people about pools filling in.

Amanda: Suggested some monitoring. WDFW has a no net loss policy. Has concerns about making things worse. Likes the idea of flood flow relief on the right bank as Pat presented. Bruce not convinced this will have a benefit. Pat agreed this needs to be modeled to verify benefit.

Jeremy: WDFW committed long term to pit tag trapping.

Bruce: Need to address in design report maintenance needs and how passage will be monitored.

Bruce: Prefers Option 4

Chris: Need to maximize the opportunity for fish passage by making lower velocity boundary layer.