# MILL CREEK FISH PASSAGE – N. 9$^{TH}$ AVENUE EXTENSION

## BASIS FOR DESIGN REPORT - SRFB PROJECT # 12-1634

**Figure 1 - Upstream view of project area at 25 cfs. The overbank areas are sloped 1:5, which designates this segment as a Reach Type 3 per the Mill Creek Assessment Report.**


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# 1 INTRODUCTION AND BACKGROUND INFORMATION

The report covers fish passage analysis and design for 1520 feet of concrete flume in Mill Creek between N. 9th Ave and N. 5th Ave in Walla Walla, WA. Final designs and contract bid documents were completed for a 1280 foot section of Reach Type 3 Channel, and conceptual design and fish passability was completed for the two bridge crossings at N. 6th and N. 5th Avenue. A summary description of the work completed is shown in Table 1. Stationing is in reference to the Corps Mill Creek Channel Improvement Projects where STA 0+00 was identified as the Union Pacific Railroad Crossing downstream. See Figure 2 for a site map.

| STA | Length (ft) | Reach Type | Description/Work Completed This Phase |
|---|---|---|---|
| *7+05 to 9+75* | *270* | *2* | *Flume Transition/Construction Completed in 2011* |
| 9+75 to 19+44 | 969 | 3 | Above N. 9th Ave/Final Designs |
| 19+44 to 20+81 | 137 | 4 | N. 6th Ave Bridge and Pier/Conceptual Alternatives |
| 20+81 to 23+92 | 311 | 3 | Between N. 6th and N. 5th Ave Bridge/Final Designs |
| 23+92 to 24+95 | 103 | 4 | N. 5th Ave Bridge and Pier/Conceptual Alternatives |

**Table 1 – Description of Reach Lengths and Locations and Design Work Completed.**

The objective of the Mill Creek Fish Passage Project is to improve fish passage, while not increasing flooding or creating obstructions to maintenance crews which annually clean debris from the channel. This segment of the Mill Creek Flood Control Channel is referenced as a Reach Type 3 (Trapezoidal Flume with 6 foot baffles) and Reach Type 4 (Trapezoidal Split Flume with 3 foot baffles) per the Mill Creek Fish Passage Assessment (Powers, et.al. 2009) . That study will be referenced throughout this report as The Assessment. Another study, the Mill Creek Fish Passage Conceptual Design Final Report (Powers, 2010) provides detailed conceptual design and cost information on why, for example, the roughened channel design option was selected. That study will be referred to throughout this report as The Conceptual Design Report. Some of the design decisions for the Project were made during Mill Creek Work Group Meetings (MCWG). A detailed physical model of the concrete flume was developed by Northwest Hydraulics in Seattle, WA. Members of the MCWG observed the model and commented on design features (Northwest Hydraulics, 2011). It is important to note when reviewing the Northwest Hydraulics Report that the document is split into a Reach Type 3 and a Reach Type 6 analysis. Reach Type 3 refers to the trapezoidal shape (i.e. sloping overbank areas) which dominates throughout the flume, and Reach Type 6 refers to the sections of flume where the overbank is flat. **The N. 9th Avenue Extension Project is a combination of Reach Type 3 and 4**. References to this model study will be noted as Flume Physical Model. A Basis of Design Report has been completed for four other projects on Mill Creek from 2011 to 2013. Also included in Appendix B is design validation information for the Roughness Panels for a Reach Type 6 section of channel which was recently constructed bewteen Spokane and Colville Street. It is not the intent of this report to repeat informatioin which is available in these other studies, but to present new information based on new data. All of these documents can be found at the following FTP site.

*Open internet explorer and in the address bar paste the following:*
*waterfallengineering.com/ppowers/files/TSS/millcreek*

*When you are prompted for a user name and password:*

*Username: millcreek*
*Password: waterfall*

# 2 N. 9TH AVE

## Existing

This project will modify the concrete flume upstream of N. 9th Avenue (**Error! Reference source not found.** - Cover), in downtown Walla Walla, WA, and extend upstream to N. 5th Avenue. The modified channel length will be 1280 feet. This will add on to the previously completed project downstream (270 feet), for a total length of approximately 1239 feet up to the bridge at N. 6th Ave. The slope of the concrete flume averages 1.0 percent, see Figure 3.


**Figure 2 – Project site map. Mill Creek flow is from right to left. The downstream end of the concrete flume is STA 7+05. STA 0+00 is the Union Pacific Railroad.**

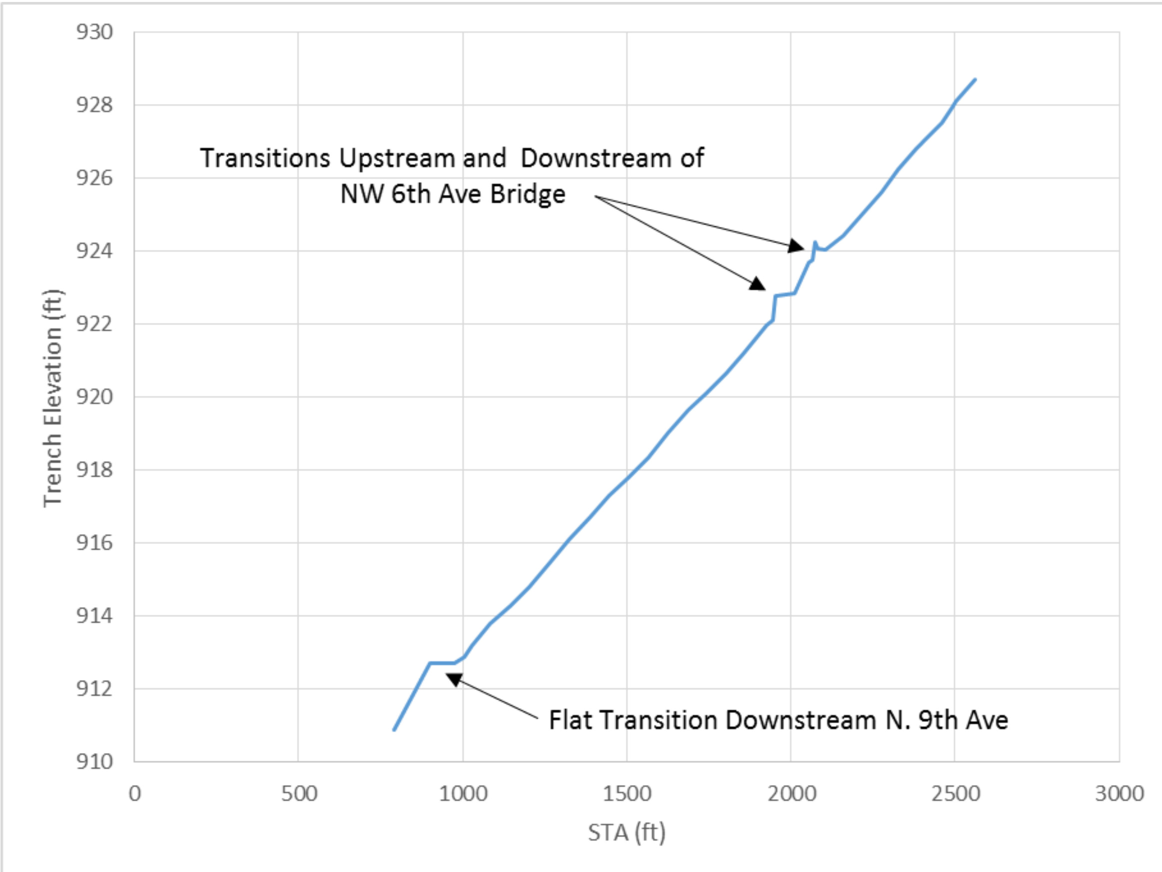


**Figure 3 – Trench Slope of Concrete Flume Calculated at Each Baffle and Transition From Baffles to Bridge Piers. The average slope is 1.0 percent.**

The trench width is 9 feet with side walls 1.67 feet high. Baffles 12 inches high are spaced at 60 feet on center. The baffles are 6 feet long with a 3 foot low flow slot. The low flow slots alternate back and forth. Currently at low flow fish passage is poor due to shallow depth, and at high flow the velocities in the flume exceed the swimming ability of most fish. At some flows fish can pass. In the 30 to 60 cfs range, the depth is sufficient for passage and the roughness created by the baffles reduces the velocity so some fish can pass. The overbank areas of the channel are 20.5 feet wide (each side). The total width of the flume averages 50 feet.

To calculate the hydraulics for each design flow, a HEC RAS model was developed with Manning's n values which were calculated from the Flume Physical Model. Model details and other variables to calculation methodologies are provided in Chapter 5.

### Proposed

The baffles in the trench will be removed and replaced with similar concrete baffles, all on the left side, spaced 20 feet on center with a height of 10 inches (0.83 feet). This closer spacing will provide fish passage at low flow as the water depth is increased. In the left overbank area (as viewed downstream), a 7 foot wide section will be removed next to the trench and replaced with a lowered and roughened channel surface, see Figure 4 and Figure 5. In addition, resting pools (12 feet long by 7 feet wide) will be spaced approximately every 80 to 100 feet within the roughened channel. The roughened channel will reduce the velocities so fish can pass, and the resting pools provide a factor of safety and opportunity for fish to rest and recover. Cover rocks will be embedded into the resting pool bottoms.

**Figure 4 - Mill Creek 1:8 Physical Model Reach Type 3. View upstream showing resting pool with cover rocks, baffles and roughened channel.**

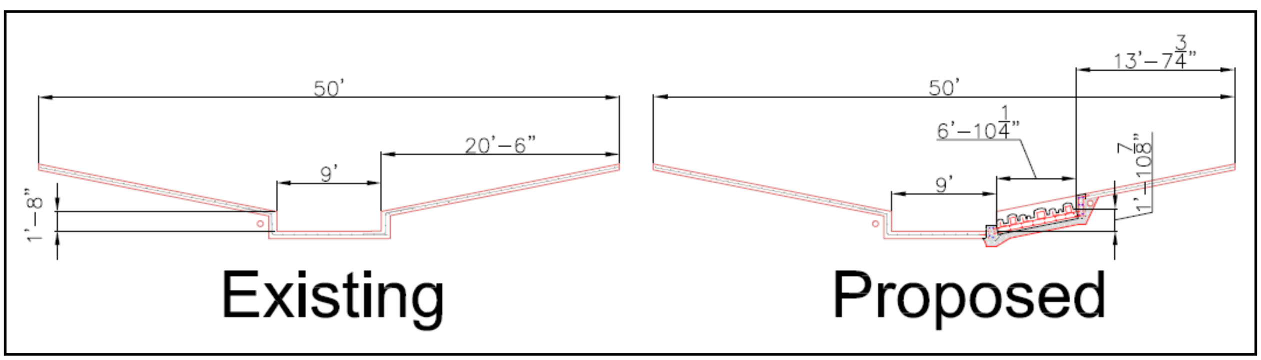


**Figure 5 – Existing and Proposed Cross Sections of Concrete Flume in Proposed Project Area (Reach Type 3).**

The hydraulic conditions resulting from the design are shown in Figure 22. A 325 foot section of modified channel was modeled for the fish passage calculations. Fish Passage is calculated using the Fish Energetics Model described in <u>The Assessment</u>. Figure 13, provides the typical maximum distance a fish can swim as a function of water velocity. The following is a description of passability with the proposed design at the four design flows. This information is summarized in Table 2. These flows represent a range of flows from 90 percent to the 10 percent exceedance flows.

<u>10 cfs</u>: Ten (10) cfs is the low passage design flow. The baffle spacing at 20 feet with a 2 foot wide low flow notch will provide a minimum depth of one foot. The velocity is very low between baffles and fish can rest and recover to pass.

<u>92 cfs</u>: This flow is the 50 percent exceedance flow for passage. The velocities in the roughened channel area vary from 1.6 to 2.4 fps, with a bulk average of 2.2 fps. A 26 inch Steelhead can pass the 325 feet with 82 percent of their energy left. The results are similar for a 27 inch Chinook. A 12 inch Bull Trout can swim a maximum of 195 feet, and would need the resting pools to pass. The resting pools are spaced at 80 feet. At 80 feet, a 12 inch Bull Trout would have 60% of their energy left.

<u>194 cfs</u>: This flow is the high fish passage design flow for Spring Chinook and Bull Trout. The velocities in the roughened channel area vary from 1.6 to 3.9 fps, with a bulk average of 3.1 fps. A 26 inch Steelhead can pass 325 feet with 43 percent of their energy left. The results are similar for a 27 inch Chinook. A 12 inch Bull Trout can swim a maximum of 140 feet, and would need the resting pools to pass.

<u>320 cfs</u>: This flow is the high fish passage design flow for Steelhead. The velocities in the roughened channel area vary from 2.1 to 5.1 fps, with a bulk average of 4.2 fps. A 26 inch Steelhead can swim a maximum distance of 204 feet, and would need the resting pools to pass. The resting pools are spaced at 80 feet. At 80 feet, a 26 inch Steelhead would have 80% of their energy left.

| | | | Percent Energy Left After Swimming 325 Feet or Maximum Swimming Distance | | |
|---|---|---|---|---|---|
| **Flow (cfs)** | Average Velocity Range (fps) | Roughened Channel Bulk Average Velocity (fps) | 26″ Steelhead | 27″ Chinook | 12″ Bull Trout |
| **92** | 1.6 to 2.4 | 2.2 | 82% | 82% | 195 feet |
| **194** | 1.6 to 3.9 | 3.1 | 44% | 44% | 140 feet |
| **320** | 2.1 to 5.1 | 4.2 | 204 feet | N/A | N/A |

**Table 2 – Summary of Fish Passage Conditions Modeled with 325 feet of modified Reach Type 3 Channel.**

## 3 N. 6TH AVE BRIDGE

The N. 6th Ave Bridge is located at STA 20+11. This segment is a Reach Type 4 (Trapezoidal Channel with a Pier) as identified in The Assessment. The bridge is supported by a center pier in the channel (see Figure 6).

### Description and Passability

**Figure 6 – View Upstream of the N. 6th Ave Bridge Pier at 25 cfs.**

The 6th Ave Bridge was built in the 1920s. City of Walla Walla Engineers have indicated the bridge is past the design life. The bridge rating is "adequate," but should be replaced. The pier is 121 feet long, and splits the concrete flume into two channels. The trench width of these channels varies from 4.4 to 6.4 feet. The wall height of the trench is 2.3 feet (compared to 1.7 feet for Reach Type 3). This difference in trench wall height is due to the increased width from the bridge center pier cutting further into the 5:1 sloping overbank area. The overall flume width remains constant through the bridge area, but the addition of the center pier extends the trench further into the outside flume wall dimensions. There is only one baffle set within the pier length. The baffle spacing is 85 and 96 feet, respectively. A combination of the increased baffle spacing and a higher trench wall results in hydraulic conditions which makes fish passage more difficult.

The slope of the trench averages one percent, but has short segments up to 6 percent slope, and is not level across a channel section. A plan view schematic is shown in Figure 7.

A HEC RAS model was developed for the site. The model was calibrated based on depth and velocity measurements at flows of 92 and 180 cfs. Figure 8, is a graphical representation of the fish passability. At the 92 cfs, the N. 6th Ave Bridge is a barrier. This is significant, as 92 cfs represents an average creek flow.

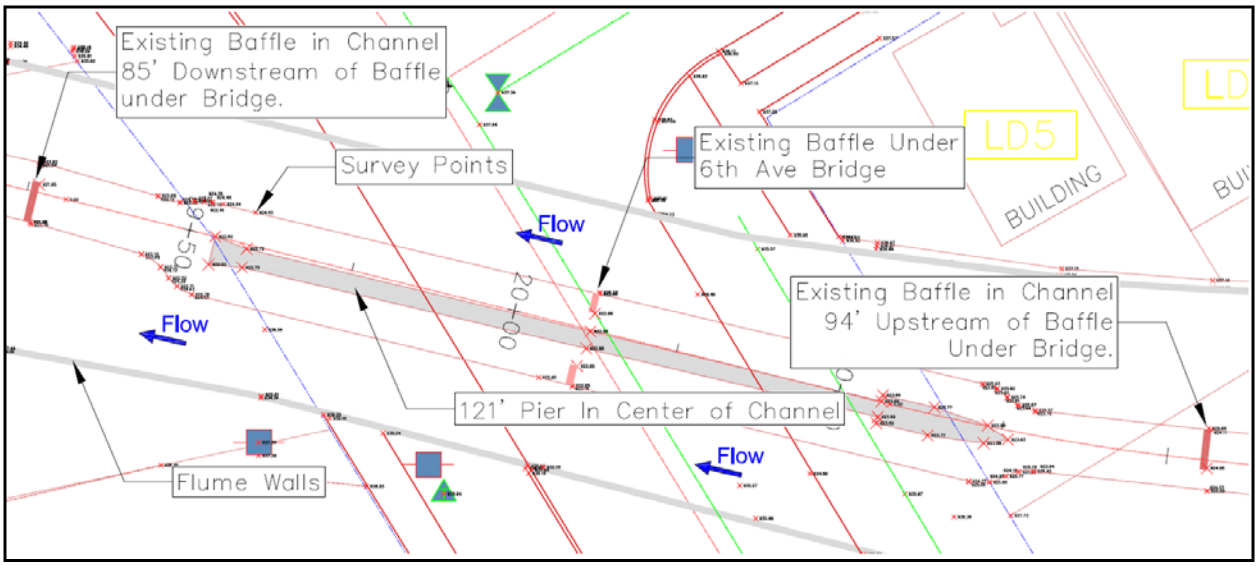


**Figure 7 – N. 6th Ave Bridge Plan View. Flow is from right to left. The shaded area is the concrete pier.**

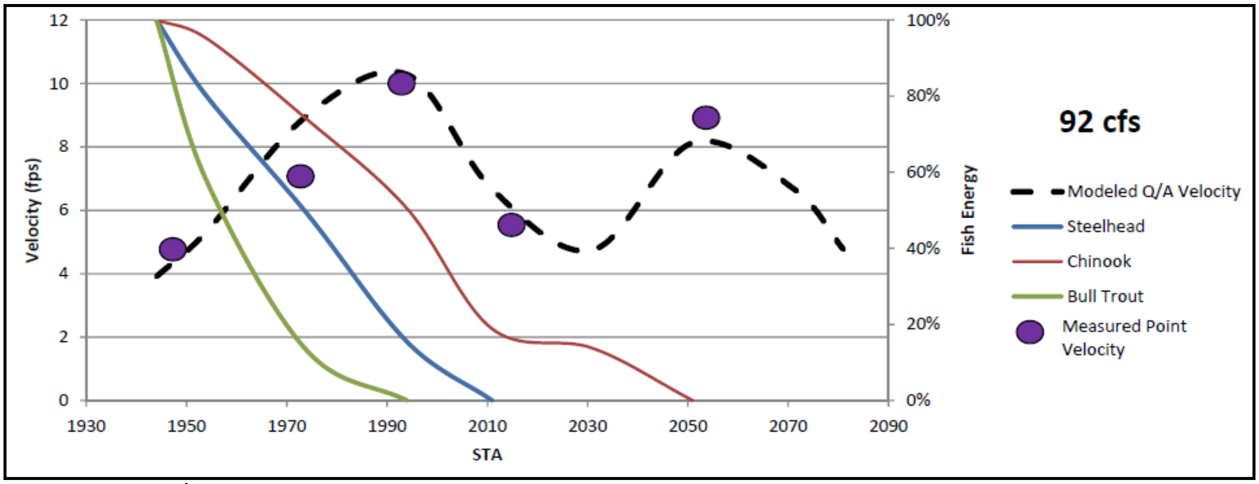


**Figure 8 – N 6th Ave. Velocity and Fish Energy at 92 cfs. The black dashed line is the (Q/A) velocity shown on the left vertical axis, and the color lines represent how a fishes energy is used up as they attempt to pass upstream shown on the right vertical axis. The purple color dots are point velocities measured.**

The N. 6th Ave bridge section was analyzed at other flows to develop an overall passability. For Steelhead there was some passage calculated at 20 cfs and 250 cfs, but the overall passability was only 18%. The calculations assumed fish started with 100 percent of their energy for consistency with comparing passage for other Reach Types. For Spring Chinook the results were similar with a calculated passability of 16 percent. For Bull Trout the passability was calculated at 0 percent. The overall passability for all three species as a total was calculated at only 11 percent.

The Assessment study calculated an overall passability of 37 percent. This assumes fish start to pass with 100 percent of their energy. The difference is due to the more accurate hydraulic modeling. The N. 6th Ave Bridge (and other Reach Type 4 segments) have very complex hydraulics due to the increased baffle spacing (or lack of), and a higher trench wall. Velocities are high enough where fish have to use a burst swimming mode to pass.

### Conceptual Design Options

Four options were considered for passage correction and are shown in Figure 9. This figure provides an assessment of the pros and cons for various attributes of the overall project. Sketches for the designs are shown in Appendix A. The following is a description of the options.

Option 1- Lowered Trench with Baffles: This would be the lowest cost option but would only improve fish passage at flows from 10 to 40 cfs. The main problem with this option is the potential increase in floodwater elevations at a location where high water levels are already a potential problem. To account for this the trench floor is lowered 0.8 feet. Preliminary HEC RAS modeling shows at one foot increase in water surface elevation without lowering the trench. Fish Passage is estimated at 30 percent.

Option 2 – Roughness Panels/Baffles and Resting Pools: This option would be very similar to the current method of fish passage correction being used in the Reach Type 3 channel, but only about one-half of the roughness panels and resting pools would be used to maintain room for maintenance vehicles in the overbank area. The main uncertainty with this option is the hydraulic complexity of flow within the three foot wide proposed fish passage route created by the roughness panels. The estimated cost for this option is $ 103,400 (the cost per foot is $798). A cost estimate for this option is provided in Appendix D.

Option 3 – Replacing the Bridge with a full spanning structure: This option would eliminate the pier would then allow the roughness panels, baffles and resting pools to be built similar to the Reach Type 3 design, while still having room for maintenance vehicles to pass. The downside of this option is the cost, estimated to be a total of $1.4 million (design and construction). For a pier length of 121 feet, this equates to a unit cost of $10,800 per foot of channel compared to the current costs for the Reach Type 3 designs which are $800 per foot. A significant benefit of replacing the bridge would be to improve flood capacity and reduce the risk of debris hanging up on the pier.

Figure 9 is a Alternatives Analysis which considers the importance of different attributes (fish passage, channel maintenance, flooding and cost). Each attribute has a value assigned to the importance relative to the main project objective. Considering all these variables, Option 2 has the highest score. More discussion with project stakeholders and hydraulic modeling is needed. A physical model may be required to verify flooding conditions and fish passage velocities.

| **Design Options** | **Attribute** | | | | | **Notes** |
|---|---|---|---|---|---|---|
| *Rating Note: Each Design Option is rated from 1 to 10, 10 = fully addresses the attribute and, 1 = does not address the attribute.* | **Final Ranking** | **[1]Fish Passage (5)** | **[2]Channel Maintenance (4)** | **[3]Flooding (3)** | **[4]Cost (5)** | |
| Option 0: Do Nothing | 82 | 1 | 5 | 4 | 10 | Existing Passage 8% |
| Option 1: Lowered Trench/Baffles | 77 | 3 | 4 | 5 | 7 | Low Flow Passage Improvements, Potential Flood Rise Problems 30% Passage |
| **Option 2: 3' Wide Roughened Channel/Baffles/Resting Pools** | 95 | 7 | 4 | 6 | 6 | Good Passage Improvements Some Maintenance Vehicle Restriction Due to Arch 82% Passage But Some Uncertainty With 3' Wide Roughness Panels |
| Option 3: New Bridge/No Pier/Reach Type 3 Extension | 90 | 8 | 7 | 8 | 1 | Passage Similar to Reach Type 3 90% Passage |

Notes: 1) Fish Passage: 10 = Excellent Passage, 1 = Poor Passage
2) Channel Maintenance: 10 = Improved Access for Maintenance, 1 = Blocks or Restricts Maintenance
3) Flooding: 10 = Flooding Decease, 1 = Flood Increase
4) Cost: 10 = Low Cost, 1 = High Cost

**Figure 9 – N. 6th Ave Bridge Alternatives Analysis Matrix for Conceptual Design Options.**

# 4 N. 5TH AVE BRIDGE

### Description and Passability

The N. 5th Ave Bridge crossing is located at STA 24+35 (424 feet upstream of N. 6th Ave), see Figure 10. The pier in the channel under the bridge is 88 feet long. The channel geometry formed by the pier footing varies. In some areas the width is 6 feet, in other areas where concrete extends out into the channel the width is only 3.8 feet. A plan view of the pier and channel is shown in Figure 11.

**Figure 10 – View Upstream N. 5th Ave Bridge.**

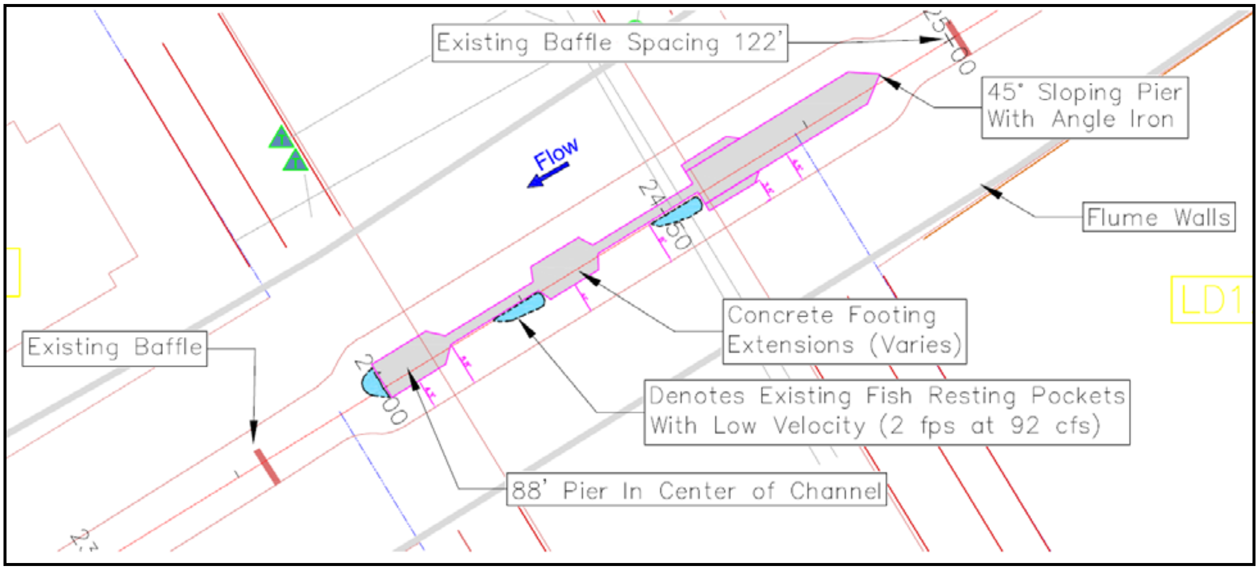


**Figure 11 – N 5th Ave Bridge Plan View of Existing Layout.**

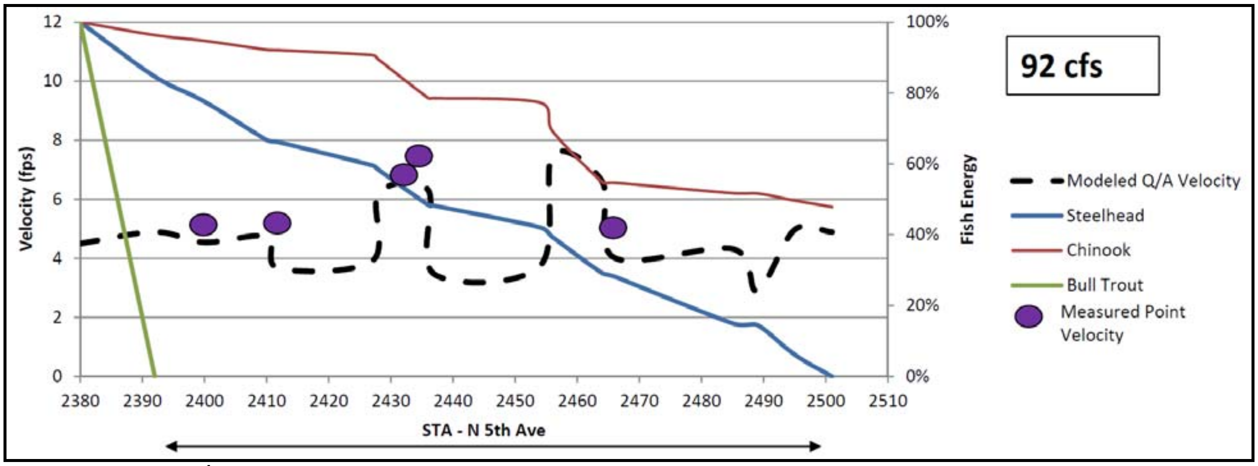


**Figure 12 – N. 5th Ave Bridge Velocities and Fish Energy at 92 cfs. Measured point velocities were used to calibrate the HEC RAS model. The higher velocities represent the narrow constructions in the channel.**

The N. 5th Ave bridge section was analyzed over a range of flows to develop an overall passability. For Steelhead the passability was estimated at 63 percent, Chinook at 42 percent and Bull Trout at 0 percent. Again the calculations assumed fish started with 100 percent of their energy for consistency with comparing passage for other Reach Types. The overall passability for all three species as a total was calculated at 36 percent. These calculations are based on fish swimming against a Q/A velocity. There are two areas within the N 5th Ave Pier where the concrete footing projects out into the channel abruptly enough to create a eddy downstream. Velocities were measured in these area at 2 fps, when the main channel velocity was 7.9 fps. By observation it does appear fish could hold and rest here, so the actual passability may be higher and some Bull Trout may pass.

The Assessment study calculated an overall passability of 24 percent. The difference is due to the more accurate hydraulic modeling. The N. 5th Ave Bridge (and other Reach Type 4 segments) have very complex hydraulics due to no baffles, and a higher trench wall.

### Conceptual Design Options

Design options for developed for the N. 5th Bridge site are similar to the N. 6th Bridge site. The only difference is the current level of calculated passability. All other dimensions are similar.

# 5 OTHER DESIGN INFORMATION

## Mannings n

The Manning coefficient, *n*, is an empirically derived coefficient, which is dependent on many factors. Values were developed from the Flume Physical Model (NHC, 2011) for the design flows used in this study (Table 4). Table 4 requires some explanation. The entire concept of providing passage in the Mill Creek Channel relies on roughness providing a reduced velocity boundary layer in a newly constructed portion of channel. This segmentation of flow areas within the cross section of the channel and the Manning's n derived for each section is an important design variable. Manning's n values were calculated by measuring velocities in each section of the channel and portioning out the areas based on the measured depth and area. The column labeled "Type" in **Error! Reference source not found.** denotes the channel configuration. The baffles only configuration is the same as the proposed without the roughened channel. This was done in the interest of better understanding the costs and potential options for retrofit of the trench section with baffles only. For 3500 cfs the values were calculated from a logarithmic regression equation.

The Manning's n values for the center (or trench), only apply to the existing and proposed configurations tested. There are (1 foot high, 6 foot long, 60 foot spacing) for the existing and the proposed conditions (0.8 feet high, 7 foot long, 20 foot spacing.

| Flow (cfs) | Type | Left Smooth | Left | Center | Right | Composite |
|---|---|---|---|---|---|---|
| 92 | Existing | | 0.022 | 0.044 | 0.018 | 0.037 |
| | Proposed | | 0.062 | 0.052 | 0.018 | 0.047 |
| | | | | | | |
| 194 | Existing | | 0.023 | 0.033 | 0.022 | 0.028 |
| | Proposed | | 0.052 | 0.048 | 0.015 | 0.04 |
| | | | | | | |
| 320 | Existing | | 0.017 | 0.027 | 0.02 | 0.023 |
| | Proposed | 0.011 | 0.044 | 0.047 | 0.016 | 0.035 |
| | | | | | | |
| 1000 | Existing | | 0.016 | 0.03 | 0.016 | 0.021 |
| | Proposed | 0.014 | 0.035 | 0.036 | 0.015 | 0.026 |
| | | | | | | |
| 3500 | Existing | | | | | 0.015 |
| | Proposed | | | | | 0.019 |

**Table 4 - Manning's n roughness values measured from the Mill Creek Channel Physical Model Study (NHC, 2011). Left and Right are viewed downstream.**

### Energetics Model Passage Compared to WDFW Culvert Criteria

Figure 13 is a comparison of the maximum swimming distance obtained based on calculations using the fish energetics model to the recommended culvert length criteria from Bates (2003). For example if the water velocity is 4 fps the energetics model calculates the maximum distance a 26 inch Steelhead can swim is about 310 feet. At 310 feet the fish has zero energy left. At this same velocity the maximum length of a culvert per the WDFW Culvert criteria would be about 100 feet. This figure also shows a blue dashed line for the distance a Steelhead could swim to a point where 60 percent of their energy is left (160 feet). At 40 percent energy left the distance would be 210 feet.

This is a difficult comparison to make as the roughness panels provide a wide range of velocities for fish to pass. If fish swim or attempt to rest near the bottom of the panels the velocities are in the 1 to 2 fps or less range. At these velocities Steelhead can actually rest and recover energy. In either case, the resting pools are spaced at 80 feet, based on the requirement to pass smaller sized Bull Trout.

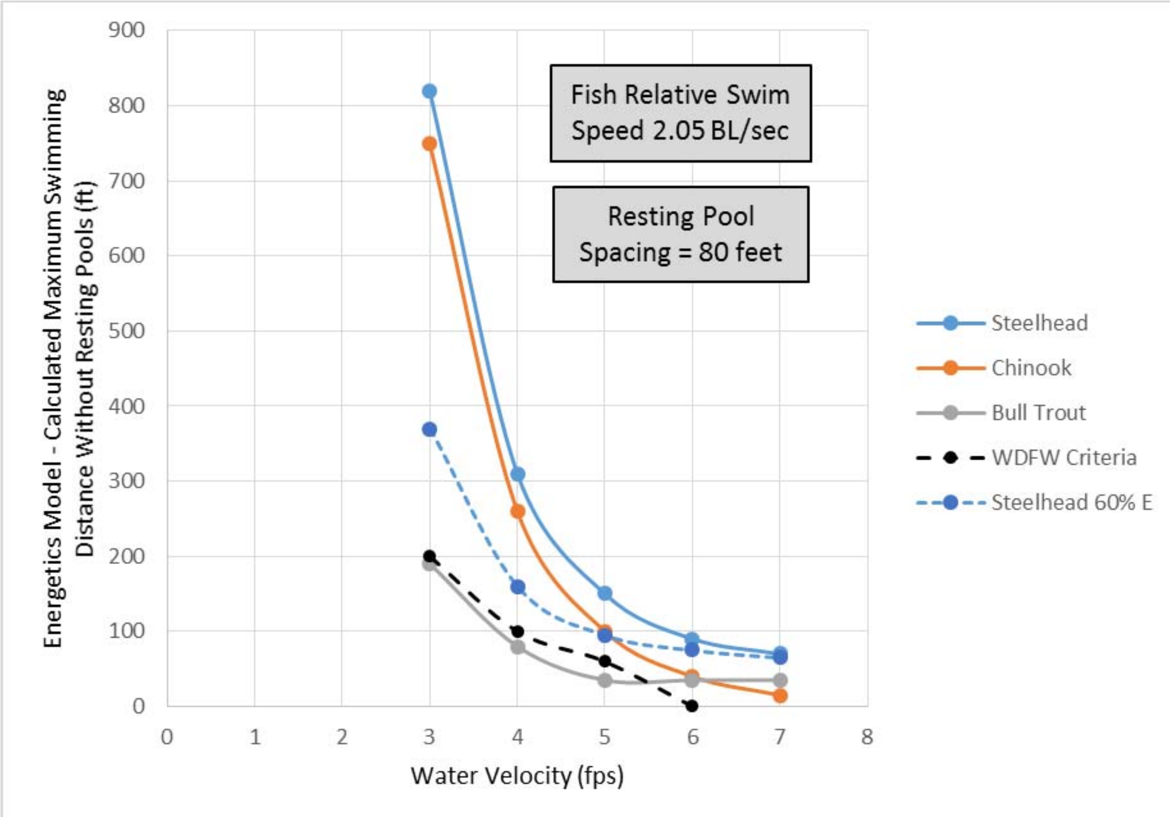


**Figure 13 – Maximum calculated swimming distance based on Fish Energetics Model. The blue dashed line represents the distance a Steelhead could swim with 60 percent of their energy left. The black dashed line represents the maximum allowable culvert length per WDFW guidelines.**

### Resting Pools

The resting pools will be spaced at 80 feet. The spacing is based on passing Bull Trout at 194 cfs. At this flow, Bull Trout have 60 percent of their energy left, and therefore should be able to rest and recover. The size of the effective resting area varies with flow. Near the bottom the velocities are much lower as compared to the surface. At 92 cfs, the entire are of the resting pool has low velocities. As the flow increases to 194 and 320 cfs, the resting area moves to the left bank and within one foot of the bottom (see Figure 14). Three cover rocks are provided in each resting pool for cover.

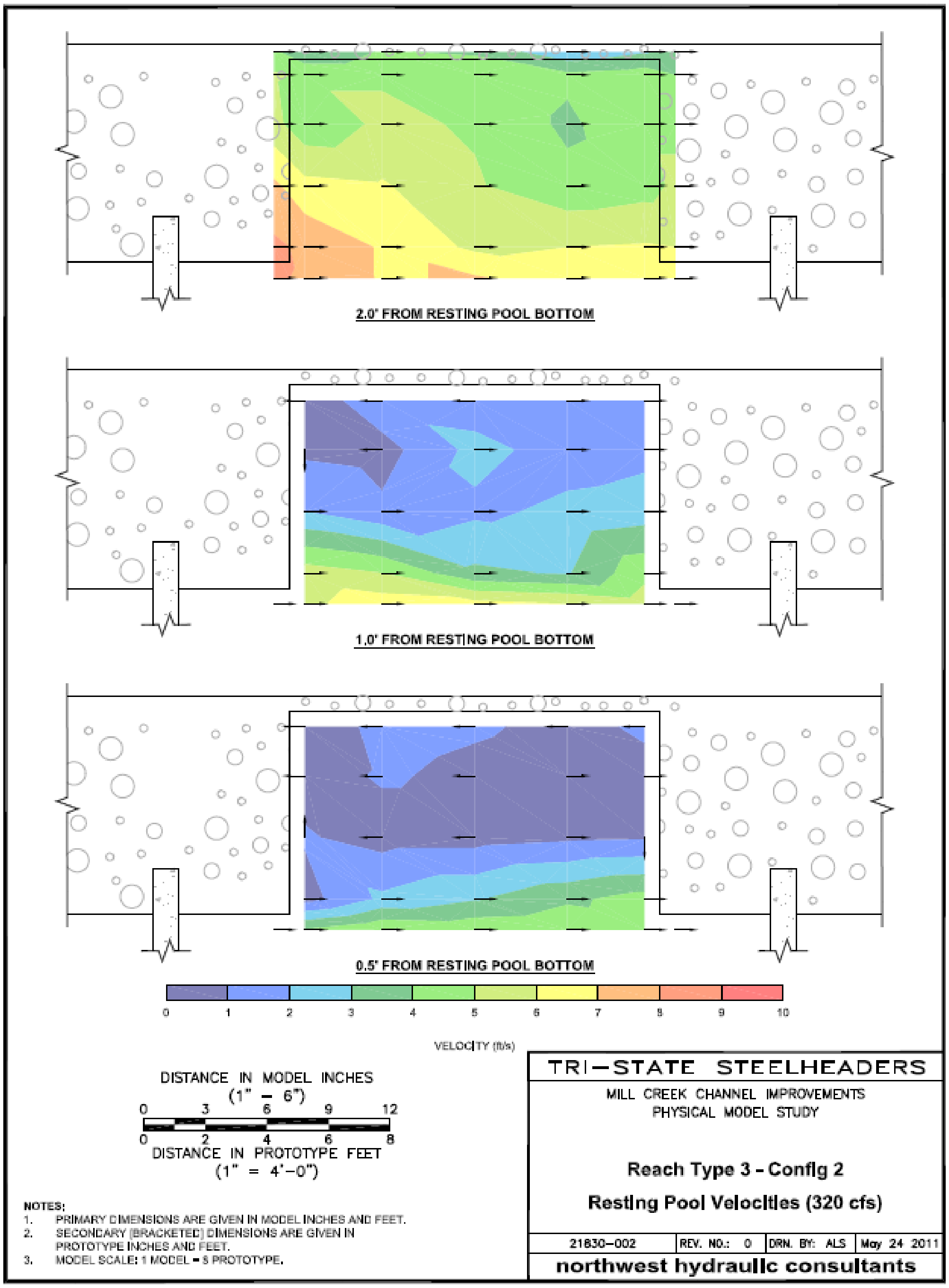


**Figure 14 – Resting Pool Velocities at 320 cfs Without Cover Rocks.**

## Roughness Panels

The roughness panel details are provided in the project plans. For the Spokane to Colville Project, two steel forms were developed to form the panels (see Figure 15). The general height and spacing have not changed. The changes which have been made are to 1) make the top of the roughness elements rounded, and 2) add two 12 inch wide roughness elements with a slight two inch depression on the downstream side to create a fish holding area in addition to the resting pools. The design changes were discussed and agreed to by a technical panel of the MCWG. The performance of the new roughness panels is documented in Appendix B.

**Figure 15 - Left Photo is the Steel Form Flipped Upside down, and the Right Photo is the Final Poured Form. The Overall Roughness Height, Density and Spacing within the Values Used in the Physical Model Study.**

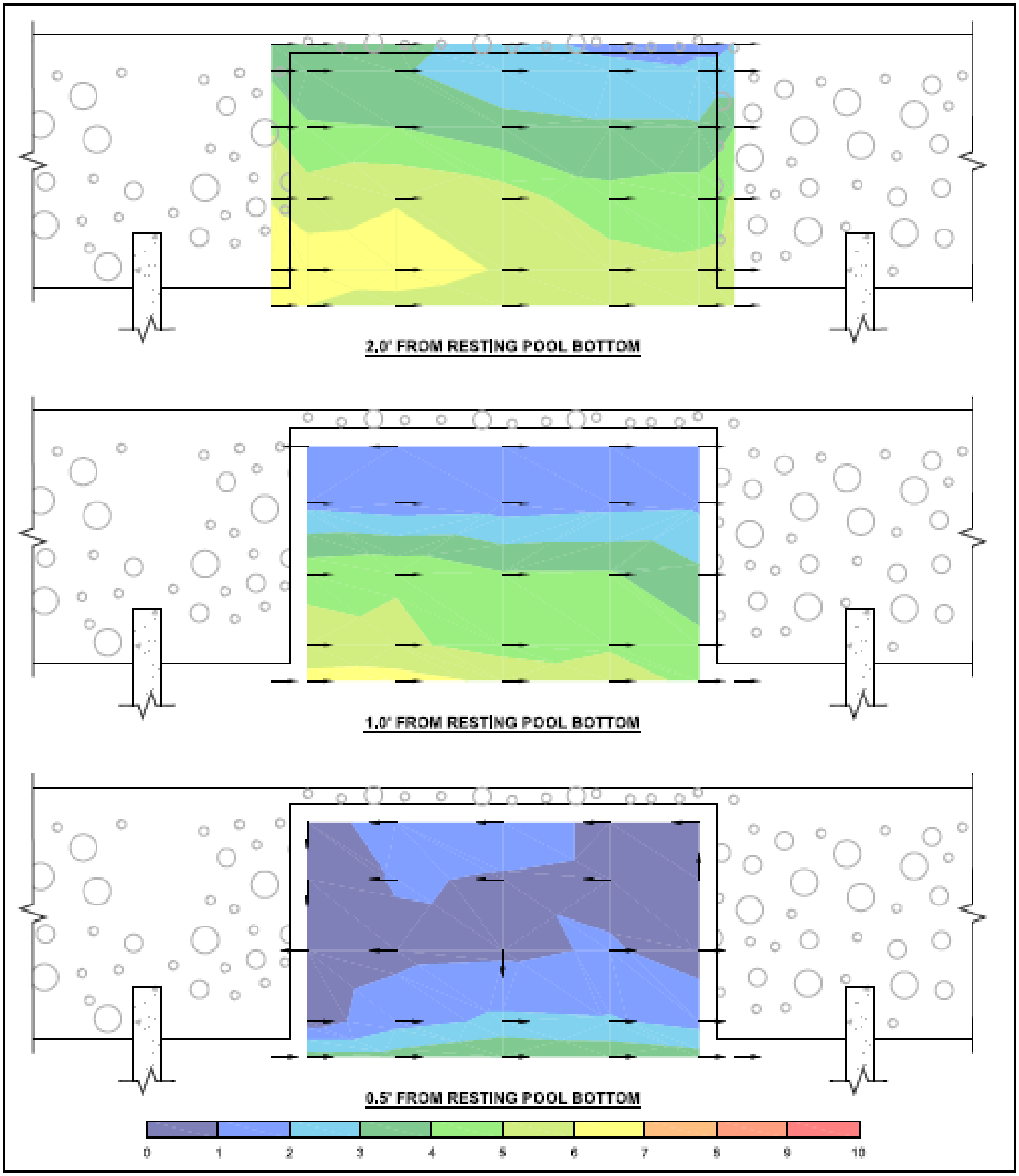


**Figure 16 - Resting pool velocities at 194 cfs for the Reach Type 3 Channel Retrofit.**

# 6 FLOOD FLOW ANALYSIS

## Water Surface Elevations

One goal of the Mill Creek Fish Passage Project is make sure the fish passage designs do not increase flooding. The criteria provided by the Mill Creek Work Group are no rise in water elevation at the 100 year flood of 3500 cfs. The Flume Physical Model Study (Northwest Hydraulics, 2011) developed composite roughness values for 92, 194, 320 and 1000 cfs. These composite values were used in HEC RAS to calculate the before and after conditions within the project reach. For the 3500 cfs flow, roughness values were extrapolated. For the proposed condition the HEC RAS model was modified from STA 980 to STA 1515. The resulting output is shown in Figure 17, which shows a slight reduction in the water surface profile with the proposed design. The exception is the standing waves at the transition to the section of flume with a flat slope under the N. 9th Ave Bridge. This is also the current proposed location for the Ford to allow maintanence vehicles to turn around.

Analyzing flood flows in the flume above 500 cfs with HEC RAS becomes very complex due to the standing waves and transition to supercritical flow. Based on results from the Flume Physical Model, the flow at 1000 cfs was near critical for both the baseline and proposed conditions. The baffles in the flume are effective at controlling the depth at low to medium flows, but at some point they become submerged enough and are less effective. In the Steady Flow Analysis box from HEC RAS the Subcritical Flow Regime was selected for the calculations. This is likley a conservative approach in terms of water depth as it gives the greatest depth. The Mixed flow regime was tested and the results show a lowering of the water depth by about two feet at 3500 cfs. Ultimatley the results of the Flume Physical Model, which did not show a flood rise provide the highest level of certainty.

## Superelevation

One dimensional Steady State models (HEC RAS), assume a constant water surface elevation across the cross section. When water flows around a bend a mass of water concentrates to the outside resulting in higher elevations on the outside and lower elevations on the inside. This difference in elevation across the channel can be estimated by the following equation:

$$\Delta y = CV^2W/gR$$

where; $\Delta y$ = difference between channel centerline and outside of bend, C = coefficient based on channel shape, flow regime, etc, V is the average channel velocity, W is the water surface width, g is the gravitational constant and R is the radius of curvature at the channel centerline. Figure 18 is a summary table of the calculations. In the worse case scenario, there is 1.24 feet of superelevation at STA 22+50 at 3500 cfs, assuming supercritical flow. The overall effect of the proposed project design is to slightly lower velocities with similar hydraulic properties. The result is likley a decrease in superelevation, but for all practical purposes the difference is within the error range of the calculations.

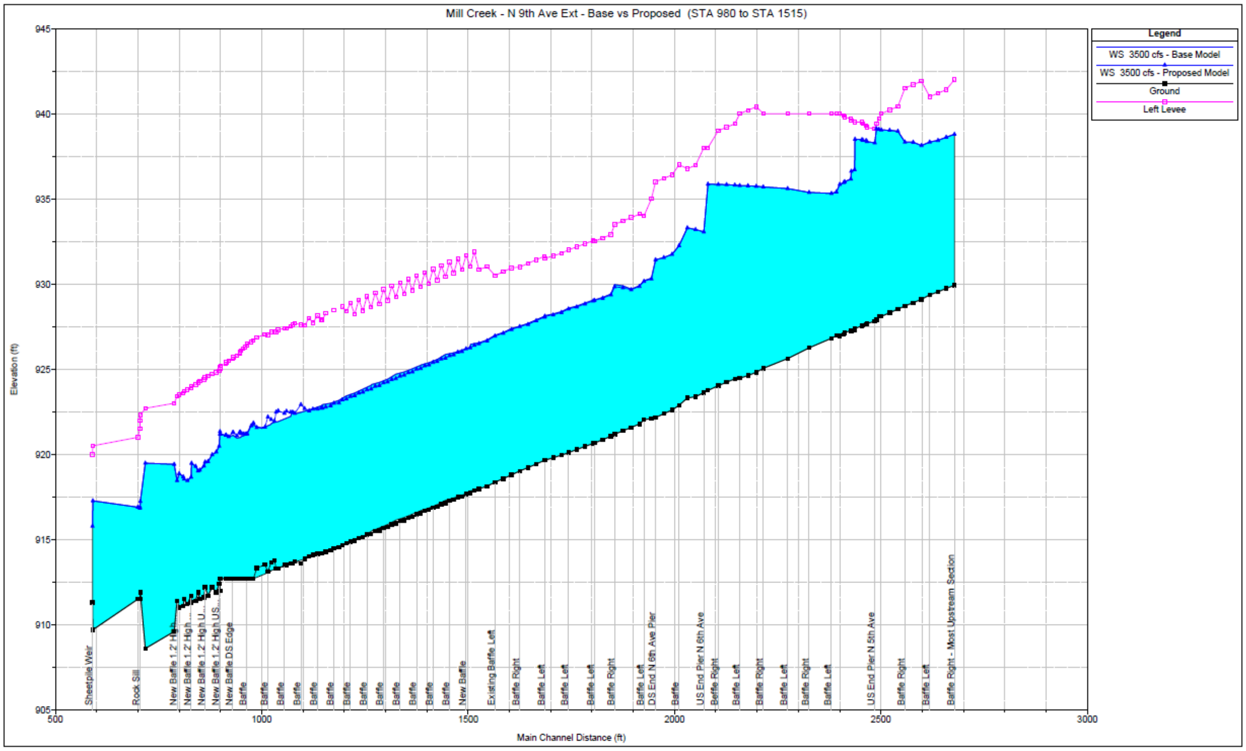


**Figure 17 – Mill Creek HEC RAS water surface profiles for the existing and proposed conditions from the end of the flume to just upstream of N. 5th Ave. Flow is 3500 cfs. The proposed conditions were only modeled up to STA 15+15 for comparison purposes and to look at trends.**

| | | | | | | | STA 18+00 | STA 22+50 |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Radius of Curvature | |
| | | | | | | | 427.1 | 350.2 |
| | Q | d | A (sq ft) | V (fps) | Width (ft) | Froude | Superelevation (ft) | |
| | 92 | 2.4 | 24.3 | 3.8 | 16.3 | 0.4 | 0.01 | 0.01 |
| | | 2.1 | 19.8 | 4.6 | 13.3 | 0.6 | 0.01 | 0.01 |
| | | 2.3 | 22.7 | 4.1 | 15.3 | 0.5 | 0.01 | 0.01 |
| | | 2 | 18.5 | 5.0 | 12.3 | 0.6 | 0.01 | 0.01 |
| | | **2.2** | | **4.4** | **14.3** | **0.5** | | |
| | | | | | | | | |
| | 194 | 3.1 | 38.1 | 5.1 | 23.3 | 0.5 | 0.02 | 0.03 |
| | | 2.2 | 21.2 | 9.1 | 14.3 | 1.1 | 0.04 | 0.05 |
| | | 2.5 | 25.9 | 7.5 | 17.3 | 0.8 | 0.04 | 0.04 |
| | | 2.9 | 33.7 | 5.8 | 21.3 | 0.6 | 0.03 | 0.03 |
| | | **2.7** | | **6.9** | **19.1** | **0.8** | | |
| | | | | | | | | |
| | 320 | 3.2 | 40.5 | 7.9 | 24.3 | 0.8 | 0.06 | 0.07 |
| | | 2.7 | 29.6 | 10.8 | 19.3 | 1.2 | 0.08 | 0.10 |
| | | 3 | 35.8 | 8.9 | 22.3 | 0.9 | 0.06 | 0.08 |
| | | 2.8 | 31.6 | 10.1 | 20.3 | 1.1 | 0.08 | 0.09 |
| | | **2.9** | | **9.4** | **21.6** | **1.0** | | |
| | | | | | | | | |
| Mixed | 3500 | 6.6 | 180.9 | 19.3 | 50 | 1.3 | 0.68 | 0.83 |
| | | 6.4 | 169.5 | 20.7 | 50 | 1.4 | 0.78 | 0.95 |
| | | 6.2 | 158.4 | 22.1 | 50 | 1.6 | 0.89 | 1.08 |
| | | 6 | 147.7 | 23.7 | 50 | 1.7 | 1.02 | 1.24 |
| | | **6.3** | | **21.4** | | **1.5** | | |
| | | | | | | | | |
| Subcritical | 3500 | 8.5 | 309.7 | 11.3 | 50 | 0.7 | 0.23 | 0.28 |
| | | 8.4 | 302.1 | 11.6 | 50 | 0.7 | 0.24 | 0.30 |
| | | 8.2 | 287.0 | 12.2 | 50 | 0.8 | 0.27 | 0.33 |
| | | 7.9 | 265.2 | 13.2 | 50 | 0.8 | 0.32 | 0.39 |
| | | | | **12.1** | | **0.7** | | |

**Figure 18 – Superelevation calculations for the Mill Creek channel at two bends at STA 18+00 downstream of N. 6th Ave and STA 22+50 upstream of N. 6th Ave. within the proposed project area.**

## 7 MAINTENANCE CONSIDERATIONS

During construction the contractor will be required to provide access as needed for maintenance vehicles to cross the channel during mid-September. The construction access points and flow diversion has not yet been designed but the layout will be similar to the layout for the N. 9th Avenue Fish Passage Project with a 36 inch diameter bypass pipe. Due to the cost of the pipe, the contractor may select to build a partial plywood along the toe of the wall. For the permanent condition passage of maintenance vehicles will not be obstructed on the right bank. The left bank width will be reduced from 20.5 to 13.5 feet. A Ford is currently proposed (see Figure 21). The location is just upstream of the N. 9th Ave Bridge. The concept of the ford is based on one constructed in a Reach Type 6 Channel Section (flat overbank). This design incorporates an additional transition from the Reach Type 3 sloping bank. The overall length of the Ford is 45 feet. A HEC RAS model was developed to assess the hydraulic changes associated with the design. The velocities are shown in Figure 22. For 194 cfs, typical velocities within the fish passage roughened channel vary from 3 to 3.5 fps. Within the Ford area the velocities drop to 2 fps. Velocities in the existing channel vary from 5 to 7 fps.

The layout and dimensions of this proposed Ford should be field tested to verify compatibility with current and future maintenance vehicles. The construction cost of this Ford is significant (estimated at $64,500). Other options for a crossing at this point should be considered before construction proceeds.

# 8 STRUCTURAL DESIGN MODIFICATIONS

This chapter outlines several concepts, design modifications and adjustments that are planned for future installations of the roughness panels. During the previous five construction projects completed from 2011 to 2013, the structural design and subsequent construction have been consistent. Construction has included baffles, resting pools and roughness panels. Designs were approved by review from the Mill Creek Work Group and the USCOE and have been constructed and appear to be working well. They have exhibited water depth and velocities that meet and exceed fish passage criteria established (see Appendix D). To summarize, the systems are working well yet it was important to understand if there were aspects that could be made smaller, simpler or reduce the size and extent of certain materials and construction details.

## Recent Construction and Observations

The construction of fish passage systems at Mill Creek have included cutting the existing concrete, excavating the channel subgrade, forming and pouring resting pools and installing roughness panels. During construction inspection of the Spokane to Colville Fish Passage

Project several design items were observed which seemed to far exceed structural design criteria based on observations of the underlying soil and could lead to improved overall construction efficiencies and reduced costs. These included:

- Reducing the excavation and backfill compaction under the roughness panels. It was observed that the excavated material was the same quality as the imported material (Figure 19).
- Reducing the rebar and concrete thickness in the enclosure curbs between the roughness panels.
- Consider the resting pools to be precast to reduce forming time.
- Reduce the slab thickness of the precast roughness panels.
- Reduce the number of dowels which tie into the existing concrete. This is extremely time consuming.
- Modify or remove the fish resting pockets. Hydraulic measurements indicated minimal benefit and a potential velocity increase due the open area.

**Figure 19 - Typical Excavated material from Mill Creek Channel.**

This list of the possible design changes were presented to the MCWG on March 13th, 2014 and was discussed in detail. The various changes were presented and agreement was made as to whether to proceed with a change or not and leave the design as it was for previous and successful construction earlier in time. The following list describes the changes and the results of the MCWG meeting and guidance that was agreed to for use in future projects.

### Proposed Changes

Fish Resting Pockets - Precast concrete roughness panel forms were fabricated from steel in 2013 for form durability and consistency of precast concrete panel construction. The idea to change the form to remove one or both of the resting pockets for adult steelhead or other fish that may utilize the pocket was considered. The steel forms would be modified by removing the steel pocket in the form and replacing it with a roughness block or potentially three or four blocks of random size to fill the area that was blocked for the resting pocket. Discussion during the

MCWG meeting resulted in the decision to keep the resting pockets as originally designed was the preferred alternative.

Additional discussions were considered for the reinforcing steel stub out locations that allow a cross tie of panel to panel reinforcement that may require steel form modifications if changed. It was determined that no change in the location of these stub outs was required and the steel forms did not need to be modified. If any steel form changes were required it was to build another one or two steel forms to reduce delivery time for the precast concrete roughness panels.

Roughness Panels - The original precast concrete panel slab thickness was 10 inches. Consideration was made to reduce it to 8 inches. This reduced thickness would use less concrete and accelerate transport and installation time and reduce equipment size thus reducing costs. It may also would make the panels more susceptible to cracking during curing and handling. After discussions in the MCWG meeting it was decide to leave the thickness of the panels at 10 inches.

Panel to Panel Enclosure Curbs – Upstream and downstream of N. 6th Ave flume makes several bends. The angle deflections of the square roughness panel to panel spacing is approximately 5 degrees and will require special attention at these bends. The potential change was considered to create a special detail to allow for connection of each panel to the adjacent one with bolts, hinged connectors or even a special precast insert that could be threaded into each panel.

It was determined that the stub out pieces of reinforcing steel would remain the same, an additional lap piece would be added as required, the cross tie steel would be placed perpendicular to the flow lines and a slight bending of the stub out during installation was all that was needed. The connection was satisfactory for the existing bends in the channel with the slight modification to the detail.

**Figure 20 - Panel to Panel Enclosure Curbs 10 inches.**

Other Enclosure Curbs - The roughness panels are connected to each other and to the new geometry of the channel with 10 inch steel reinforced concrete curbs (Figure 20). These curbs account for any geometry anomalies in the channel and provide a reinforced concrete connection to each panel and the rest of the channel structure. Some panels connect to another panel or a resting pool or at the ends of the phased construction, to the existing Mill Creek channel. The original 10 inch curbs were considered to be reduced to save in concrete cost. After consideration of the structural importance of the panel to channel resting pools and existing terminus area connections it was determined to leave the design as is. However the panel to panel curbs were determined to be reduced from 10 inches to an average width of 5 inches. The bends will be afforded with the panel to panel orientation of up to 5 degrees and a 5 inch minimum spacing opening up to 7 or 8 inches between panels to allow adjustment for the bend.

Roughness Panel Subgrade - The subgrade beneath the roughness panels was originally excavated and reconstructed with a 6 inch thick layer of compacted crushed gravel backfill. Through most of the length of the new constructed panel installations, the subgrade was more than adequate for placement of the panels. The over excavation and re-compaction of 6 inches was deemed not necessary. It was decided to reduce the subgrade excavation and the thickness of the panel bedding from 6" to 3" of compacted crushed gravel. This will reduce the amount of excavated material to be removed from the flume and therefore imported by half.

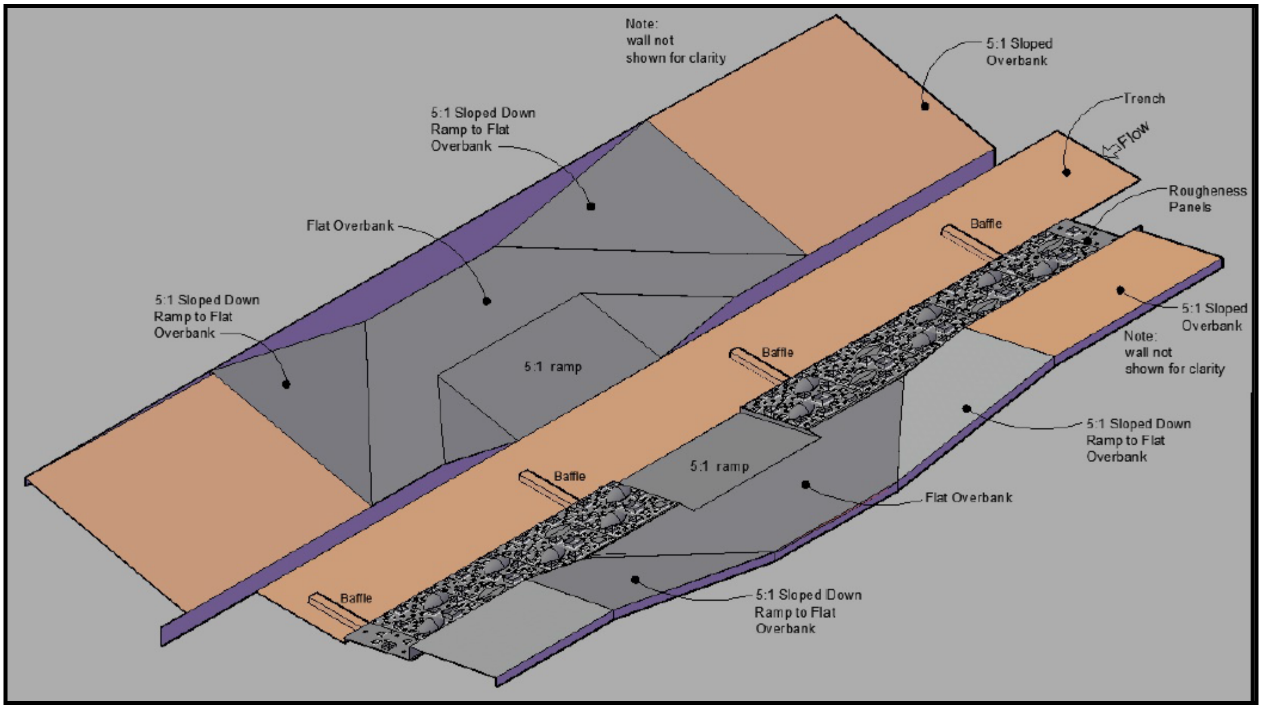


**Figure 21 – 3D Sketch of Ford. Proposed location is just upstream of the N. 9th Ave Bridge.**

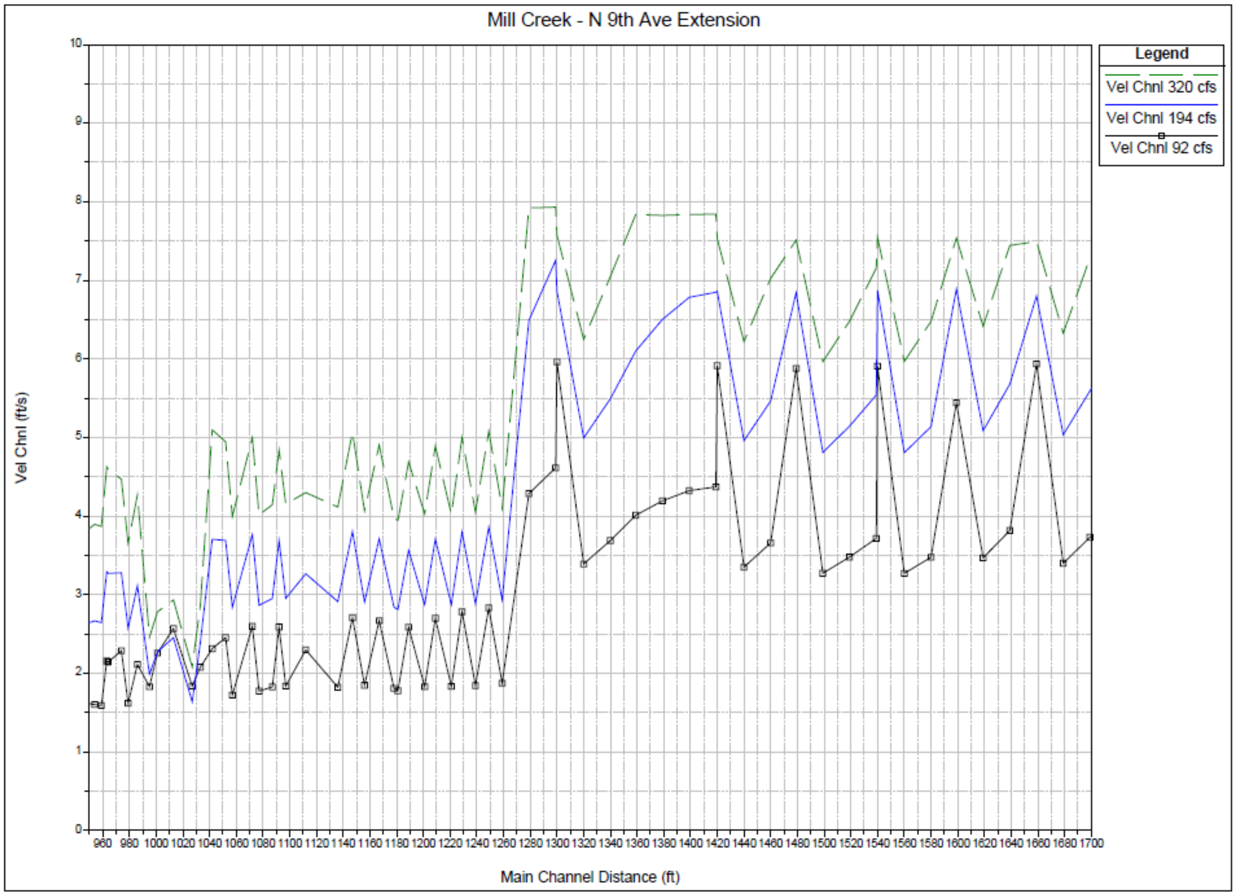


**Figure 22 – HEC RAS Output of Velocity in the Channel at 92, 194 and 320 cfs for proposed and existing conditions. STA 1010 is the Ford. STA 1020 to 1275 represents the proposed velocities, STA 1280 to 1700 represents the existing conditions.**

## 9 PASSAGE SUMMARY UPDATE

Since work for the original assessment report in 2009, more channel survey, field measurements of depth and velocity and verification modeling have been done to calculate passability. Figure 23, is a current summary of fish passability. It is difficult to compare reaches because of the varying length. The most significant change is the passability estimate for N. 6th Ave. Even though this is a short reach length (127 feet), the passability is very low. From this analysis, there is concern about the passability of other channel sections with piers and no baffles, such as Roosevelt Street which have not been surveyed. These sites should be identified and surveyed and modeled in more detail to complete a final update for passability in the flume.

| Sorted by Average Percent Passage<br>Mill Creek Fish Passage Assessment Project Update, 7/1/2014 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Reach Type | Reach Length | Steelhead % Pass | Chinook % Pass | Bull Trout % Pass | Average % Pass | Color Code | Update Year | Notes |
| 3 | 1380' | 9% | 16% | 0% | 8% | | 2009 | *1380 feet Reach Type 3, Partially Updated, Steelhead Can Swim 150 to 300 feet* |
| 4 - 6th Ave | 127' | 18% | 16% | 0% | 11% | | 2014 | *Passage at 400 cfs in overbank Not Verified, Modeled Only* |
| 5 | 178' | 33% | 40% | 0% | 24% | | 2009 | *These Reach Types need to be updated with new Model Data and Recent Design Validation Velocities. Reach Type 7 has been surveyed and partial modeling done from recent Spokane to Colville Project.* |
| 7 | 420' | 33% | 40% | 0% | 24% | | 2009 | |
| 8 | 222' | 39% | 42% | 4% | 28% | | 2009 | |
| 10 | 100 | 47% | 41% | 0% | 29% | | 2009 | |
| 9 | 117' | 47% | 50% | 0% | 32% | | 2009 | |
| 12 | N/A | 37% | 30% | 31% | 33% | | 2009 | *Reach Type 12 is the Division Intake and Fishway* |
| 4 - 5th Ave | 89' | 65% | 42% | 0% | 36% | | 2014 | *Passage Higher Due to Low Velocities in Overbank, Not well Verified, Modeled Only. Also Two Potential Resting Pockets With Velocities in the 2 to 3 fps range* |
| 1 | N/A | 59% | 42% | 89% | 63% | | 2009 | *These are the sills, which are mainly a low flow passage problem.* |
| 2 | 200 | 100% | 97% | 93% | 97% | | 2011 | *Passage Correction in 2011* |
| 6 | 380 | 99% | 99% | 94% | 97% | | 2013 | *Passage Correction in 2013* |
| 11 | 60 | 100% | 99% | 100% | 100% | | 2011 | *Passage Correction in 2011* |

**Figure 23 – Mill Creek Flume Fish Passage Assessment Update.**

## 10 COST ESTIMATE

This will be the fourth project constructed in Mill Creek of similar design. The cost estimates are based on actual costs and bids received. The highest level of uncertainty involves two items, 1) construction access and staging and 2) pumping groundwater from the excavated area. Each design has improved incrementally with regards to these two items. For this site, the potential for two access points and the development of an infiltration pond for sediment contaminated water is very encouraging. Coordination with landowners and the City will be required to further develop the details of this in the final design. The estimated construction cost is $940,800 (See Appendix C). The unit construction cost without the Ford is $687/foot.

## 11 REFERENCES

Bates, Ken. *Design of Road Culverts for Fish Passage.* Washington State Department of Fish and Wildlife, 2003.

P. Powers, B. Burns, K. Bates, J. Kidder. *Mill Creek Fish Passage Assessment.* Walla Walla, WA: Tri State Steelheaders Fisheries Enhancement Group, 2009.

Powers, P. *Mill Creek Fish Passage Conceptual Design Final Report.* Walla Walla: Tri State Steelheaders, 2010.

Service, National Marine Fisheries. *Anadromous Salmonid Passage Facility Criteria.* Portland, OR: National Marine Fisheries Service Northwest Region, 2008.

Northwest Hydraulic Consultants (NHC). *Mill Creek Channel Improvement Physical Model Study.* Final Report, 2011.

# APPENDIX A – DESIGN DRAWINGS

1. **FINAL DRAWINGS: N. 9TH AVE EXTENSION PROJECT**

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## 2. CONCEPTUAL DRAWINGS: N. 6$^{TH}$ AVE AND N. 5$^{TH}$ AVE BRIDGES

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## APPENDIX B:  REACH TYPE 6 DESIGN VALIDATION – ROUGHNESS PANELS AND RESTING POOLS

Field measurements were made to validate the water prototype velocities within the fish passage corridor for the recently completed fish passage project on Mill Creek between Spokane and Colville Street.  This is a Reach Type 6 channel, and the roughness panels are sloped 1:6.1. For the Reach Type 3 design above 9th Street the roughness panel slope will be 1:5. Measurements were made on January 13, 2014 from 12 pm to 5 pm and on January 14, 2014 from 8 am to 2 pm.  The objective was to 1) observe and document overall flow patterns relative to fish passage, and 2) measure velocities in locations where fish are assumed to pass and rest (resting pools, roughness panels and fish resting pocket).  The fish resting pockets were a "new" design feature added for the 2013 construction so particular attention was paid to the hydraulics around these.  The stream flow varied from 170 to 210 cfs (USGS gage 14015000 Mill Creek at Walla Walla), see Figure 24.  The flow should have been more consistent but there was some flow manipulation above the 14013000 USGS gage (Mill Creek near Walla Walla).  The gage is located 14 miles upstream of the 14015000 gage.

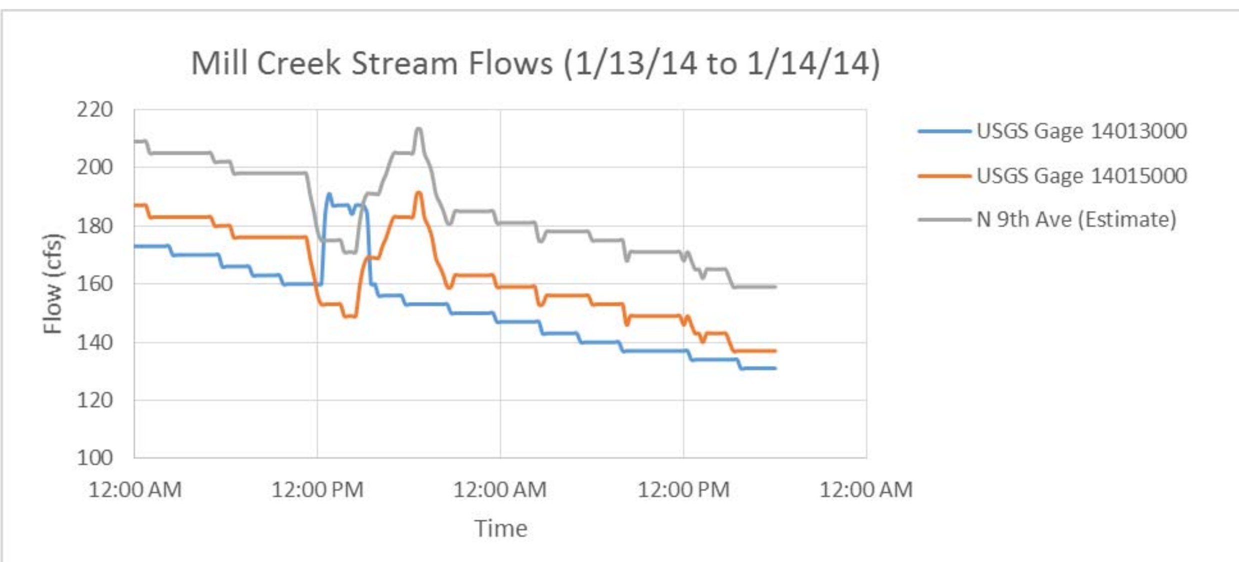


**Figure 24 – Mill Creek stream flows during design validation period.  The increase in flow from 14015000 to N 9th Ave is based on two measurements made.  The difference in the timing of peaks between the two gages was 6 hours.**

The location and methods used for data collection is shown in Figure 25. Figure 26 is a photo for comparison purposes of the baseline channel to the modified channel, and Figure 27 shows the competed fish passage elements.

Velocities were measured with a Swoffer 2100 flow meter. The display averaging feature was used which averages the velocities over a 20 second time period. In some instances where anomalies were observed, the five second interval was used to better understand the varying velocities.

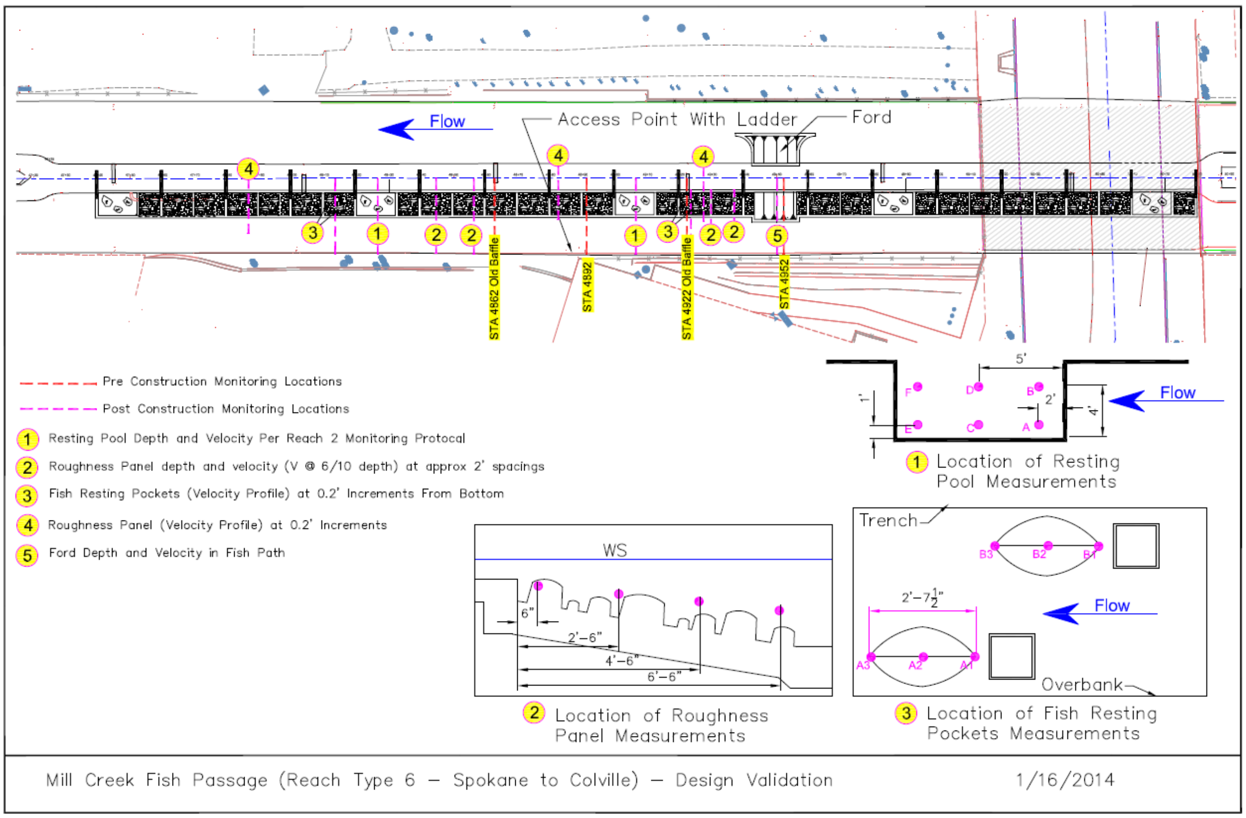


**Figure 25 – Design validation locations in the Mill Creek Channel downstream of Spokane Street, in Walla Walla.**

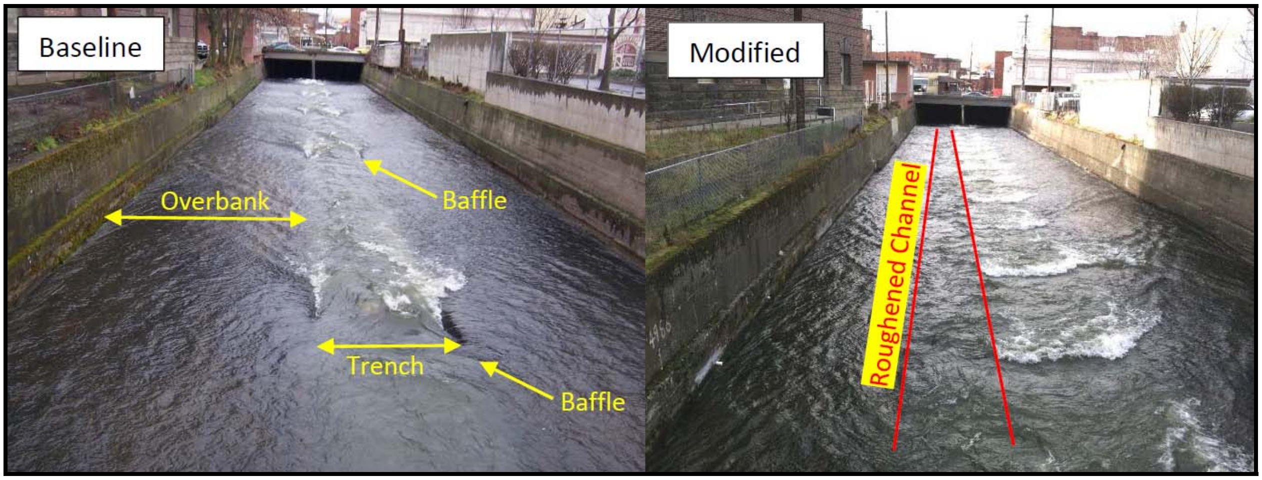


**Figure 26 – Photo of Baseline and Modified Mill Creek Channel downstream of Spokane Street. The red lines in the Modified Photo denote the 5 to 6 foot wide fish passage corridor created by the roughness panels.**

**Figure 27 – View from Spokane Street of the completed fish passage elements (baffles, roughness panels and resting pools). The ramp in the foreground was developed as a ford for County maintenance vehicles to cross the channel.**

## General Observations

Access to the channel on foot is limited to flows less than 210 cfs. At this flow the velocity and depth in the overbank area is 6 to 7 fps, and 0.7 feet, respectively. With spikes on the bottom of boots one can just stand up. To measure velocities at higher flows would require a cable system across the top of the concrete flume walls. Also, at 180 cfs you cannot wade across the channel, so access for measuring flows is limited to one bank and the roughened channel. The depth and velocity combination in the roughened channel is wadable.

A continuous reduced velocity boundary layer was observed along the path of the roughness panels (Figure 26). The width of this boundary layer varies from 4 to 6 feet depending on the location with respect to the baffles and resting pools. A "sweet spot" is apparent at a water depth of 1.5 (defined by a location where the velocities are good for fish, there is adequate cover, consistent flow patterns and low velocity area immediately towards the left bank). A fly fisherman might recognize this as a good place to drift a dry fly. The center channel velocity is too high, the overbank too shallow.

Flow does not dissipate in the resting pools. Most of the flow streams over the top. No difference could be observed in the hydraulics of the fish resting pockets. The fish resting pockets were small trenched out areas located downstream of 12 inch wide roughness elements (Figure 28).


**Figure 28 – Photo of Fish Passage Elements: Baffles, Resting Pools and Fish Resting Pockets within Roughness Panels.**

## Measured Velocities

### Resting Pools

Velocities were measured in the resting pools six inches from the pool bottom and six inches below the water surface at six different plan view locations (see Figure 29 and Figure 30).

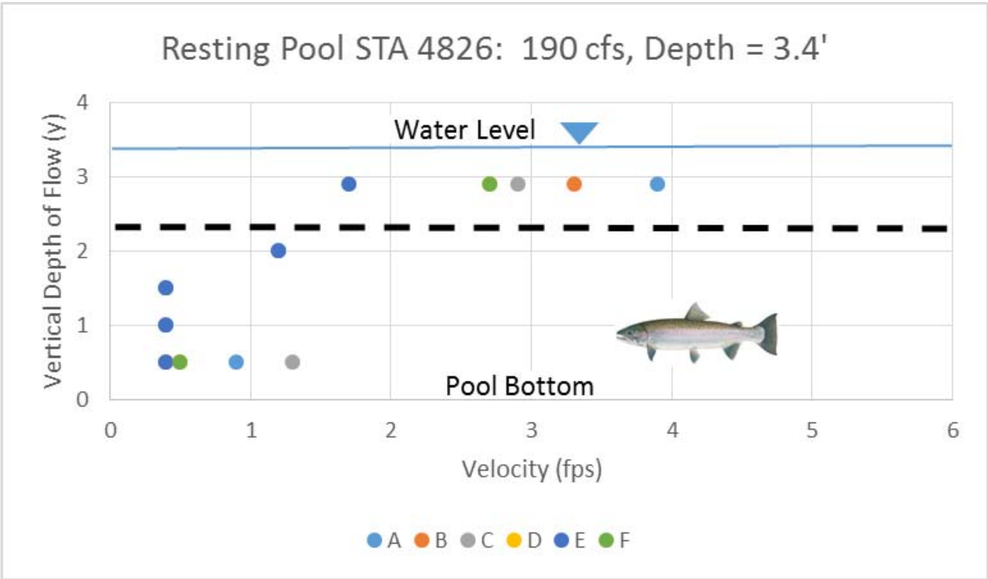


**Figure 29 – Resting Pool velocities at STA 4826. The black dashed line in the location of the roughness panel invert elevation. Points A to F are located as shown in Figure 25.**

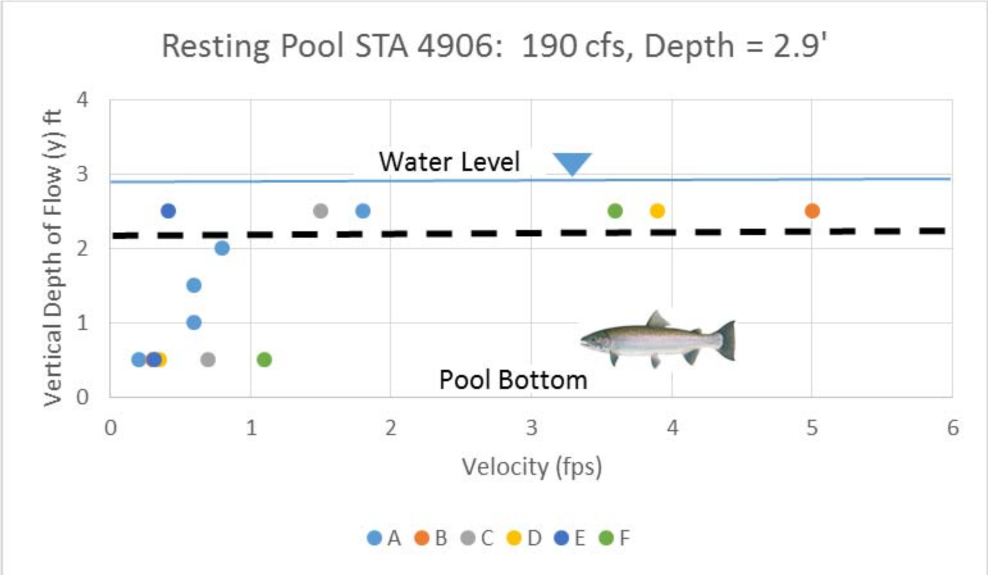


**Figure 30 – Resting Pool velocities at STA 4906. The black dashed line in the location of the roughness panel invert elevation. Points A to F area as located as shown in Figure 25.**

Target resting velocities are one body length per second (1BL/sec). For a 26 inch Steelhead this would be 2.2 fps and for a 12 inch Bull Trout 1.0 fps. All of the velocities below the invert elevation of the roughness panels are below the target velocities. The highest velocities occur near point B which is the furthest upstream and furthest out towards the center of the channel. The lowest velocities occur near the bottom and furthest left and downstream. The main role of the cover rocks in the pools is for cover. The results compare very well to the physical model test results for Reach Type 6 (NHC, 2011-Figure 5-3).

### *Roughness Panel Velocities*

Velocities within the roughness panels were measured at four different cross sections. Measurements were taken at 6/10 of the depth approximately every foot across the section. The flow rate was 190 cfs. The average velocity in the roughened channel was 3.1 fps, but ranged from 2.9 to 3.7 fps, for each cross section. The depth averaged 1.5 feet. The average velocity calculated from the HEC RAS model at 194 cfs (which was used in the fish energetics calculation) was 3.2 fps, but ranged from 2.7 to 4.2 fps. The velocity measurements at each point are shown in Figure 31. Velocities increase as depth increases. The average velocities in the physical model study were 0.8 fps higher than the velocities in the prototype. The roughness height and spacing have not changed.

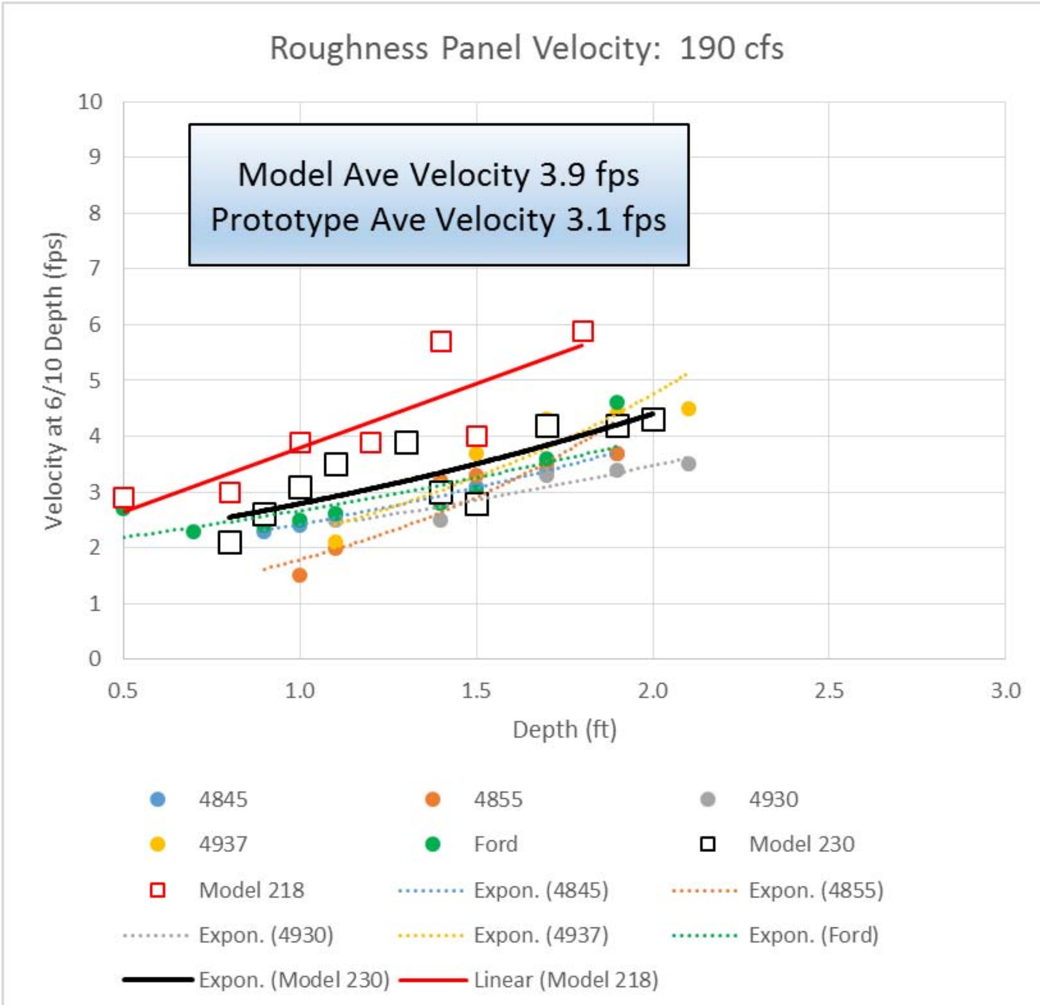


**Figure 31 – Velocities measured in the roughness panels at 190 cfs for five cross sections. The dots are the prototype and the boxes data from the physical model study. The dotted green line and points is a section through the ford.**

### *Fish Resting Pockets*

Velocities were measured in the fish resting pocket areas as shown in Figure 25. The "football" shaped areas were intended for adult steelhead to rest in behind roughness elements which were 12 inches wide by 6.5 inches high. There are two fish resting pockets per roughness panel. Locations A and B are designated by shallower and deeper water respectively. Points 1, 2 and 3 indicate where the velocity was measured relative to a distance downstream of the roughness element (Point 1 is immediately behind, Point 2 in the middle of the "football" shaped resting area, and Point 3 at the downstream end of the resting area. The total length of this resting area is 27 inches. The resting area is countersunk 2 inches below the invert of the roughness panel.

Velocities at Point 1, start off at less than 0.5 fps, below the roughness element but increase quickly above it (Figure 32). At Point 2 (Figure 33), the velocities start off at 1.0 to 1.6 fps and again increase quickly above the roughness element. The base of the flow meter was being held in the bottom of the resting pocket which again was two inches deep. So the distance from the bottom of the pocket to the top of the roughness element upstream was about 0.7 feet. At Point 3 (Figure 34), the velocities start off at 1.4 fps and increase to 2.2 fps. There is a significant increase in velocity from location A to B. Location B has velocities in the fish resting area at Point 3 of 3 fps. This is above the resting pool criteria for Steelhead of 2.2 fps. Figure 35 is a combination of all the measurements made.

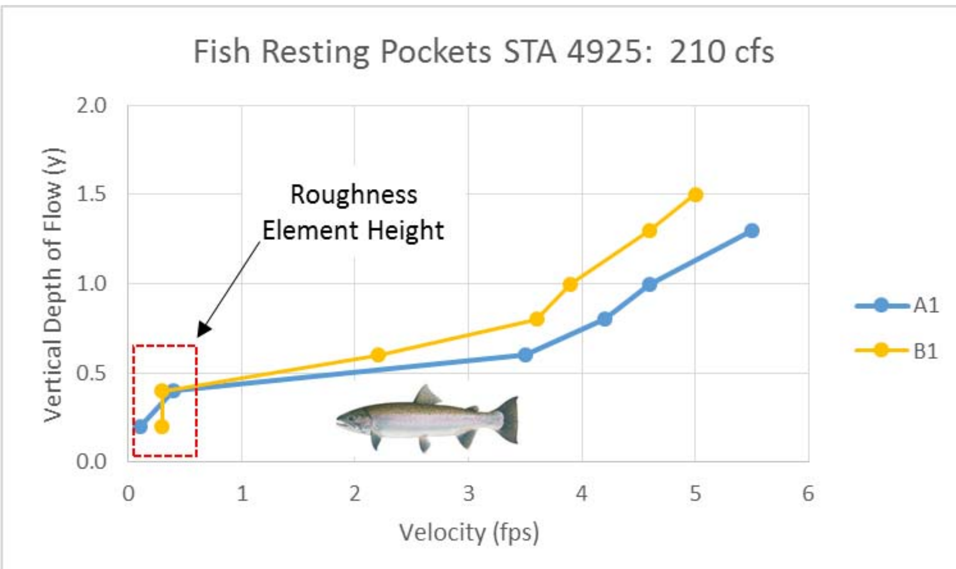


**Figure 32 – Fish Resting Pocket velocities at Point 1 (immediately downstream) of the roughness element. The dashed red box is representative of the height of the roughness element.**


**Figure 33 - Fish Resting Pocket velocities at Point 2 (center of the resting pocket). The dashed red box is representative of the height of the roughness element.**


**Figure 34 - Fish Resting Pocket velocities at Point 3 (downstream end of the resting pocket). The dashed red box is representative of the height of the roughness element.**

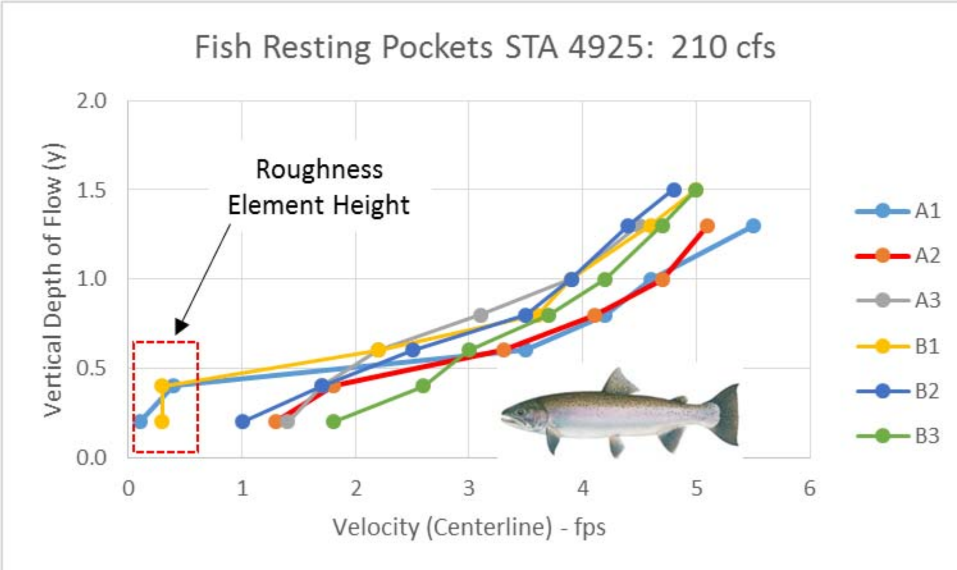


**Figure 35 – Combination of Fish Resting Pocket velocities for all measurements.**

### *Roughness Panel Velocity Profiles*

The last set of measurements made was how the velocity varied within the vertical water column. The roughness elements heights are 2.5, 4.0 and 6.5 inches. Velocities below the 6.5 inches are very low. Small fish less than 12 inches in length could likely use this “boundary layer”, but larger fish using it effectively is uncertain. This boundary layer is very turbulent and velocities vary greatly depending on the location relative to roughness elements. The three profiles measured are somewhat random in terms of location as one could not see the base of the flow meter. The base of the flow meter was not set on the top of roughness elements. Figure 36 and Figure 37 show the data collected. The average velocity of the roughness panels was calculated at 3.1 fps, but there exists a range of velocities from 2 to 4 fps if fish move down or up in the water column. The data from Figure 37, shows a trend for the fish resting pockets compared to the overall roughness panel which may indicate the velocity actually increases in the open area created by the “football” shaped resting pockets. Likely more data is needed to verify this and it may be very flow dependent.

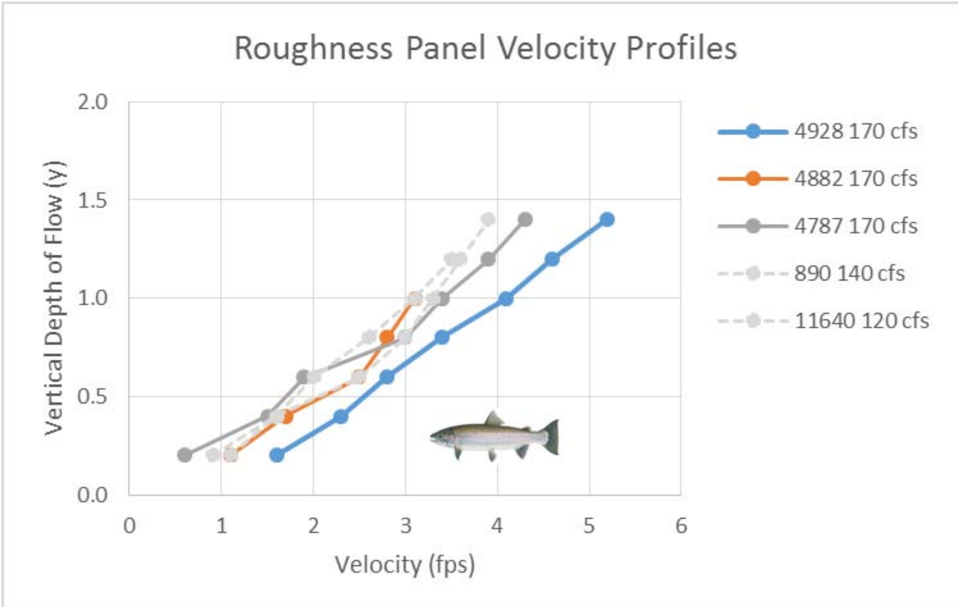


**Figure 36 – Three velocity profiles within the project area and two (light grey dashed lines) from the Transition Projects upstream of Roosevelt Street and downstream of 9th Street.**

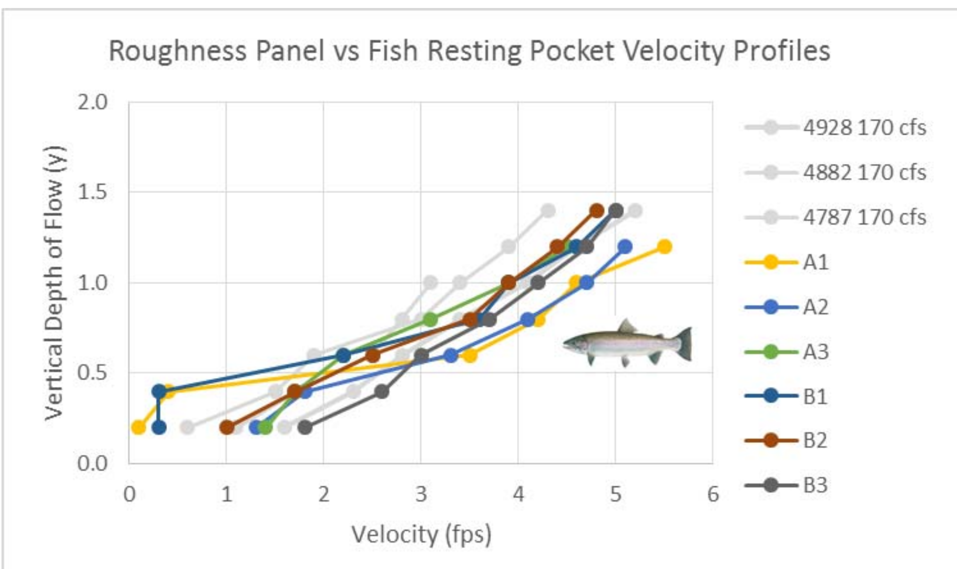


**Figure 37 – Velocity profiles within the roughness panels (grey lines) compared with velocity profiles taken around the Fish Resting Pockets (denoted at A1, B1, etc.).**

## Summary

Velocities were measured within the roughness panels and resting pools in the recently constructed Mill Creek Fish Passage Project from Spokane to Colville Street. Streams flows varied from 170 to 190 cfs. The following initial observations and recommendations are provided. This information will be presented to the Mill Creek Work Group (MCWG). The MCWG has been instrumental in driving the design and may have other recommendations.

- Target resting pool velocities are one body length per second (1BL/sec). For a 26 inch Steelhead this would be 2.2 fps and for a 12 inch Bull Trout 1.0 fps. All of the velocities measured below the invert elevation of the roughness panels were below these values.
- The average velocities in the roughened channel at 190 cfs is 3.1 fps. The average velocity calculated from the HEC RAS model was 3.2 fps. On average velocities are 0.8 fps less than was measured in the physical model.
- Fish Resting Pocket A does provide a unique, very low velocity resting area, but mainly for fish 12 to 14 inches in length. For larger fish (Steelhead) it appears the resting area does not extend far enough downstream. It was also observed while standing in the resting pockets that the overall velocities may actual increase more than what is typically found in the roughened channel due to the open area without roughness. To be effective for larger fish the roughness height would need to be increased from 6.5 inches to 9 or 10 inches. It is suggested that Location B be eliminated, and A modified with a higher roughness element. A discussion is needed with regards to raising the roughness height of one element on flood flows.
- Within the average velocities in the roughened channel (3.1 fps) there exists a range of velocities in the vertical water column fish could use from 2 to 4 fps.

# Appendix C – Cost estimates

## N. 9th Ave Extension

| Mill Creek Passage - N. 9th Avenue Extension | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Date: | 7/1/2014 | | | | | | | | |
| By: | Waterfall Engineering and Chinook Engineering | | | | | | | | |
| Design Level: | 100% | | | | | | | | |
| Project Length (ft): | 1275 | | | | | | | | |
| Resting Pools: | 16 | | | | | | | | |
| Roughness Panels: | 110 | | | | | | | | |
| Baffles: | 65 | | | | | | | | |
| **Description** | **Unit** | **CAD Quantity** | **t (in)** | **Mult** | **Bid Quantity** | **Cost** | **Amount** | **Sub Total** | ***Comments*** |
| **Mob, Access and Water Management** | | | | | | | | **$170,000** | |
| Mobilization | L.S. | 1 | | 1 | 1 | $70,000.00 | $70,000 | | *Average 11% of construction costs* |
| Access to Flume | L.S. | 1 | | 1 | 1 | $40,000.00 | $40,000 | | *Site to be Identified* |
| Water Management | L.S. | 1 | | 1 | 1 | $60,000.00 | $60,000 | | *2013 Low Bid Unit Cost $34,000, Average Bid $41,000 for 350 feet* |
| **Concrete Demolition** | | | | | | | | **$96,401** | |
| Concrete Slab cutting | L.F. | 2591 | | 1 | 2591 | $10.00 | $25,912 | | *2013 Low Bid Unit Cost $8, Average Bid $12* |
| Concrete Wall cutting (plain) | L.F. | 0 | 8 | | | $7.00 | $0 | | *per inch of depth* |
| Concrete Wall cutting (with rebar) | L.F. | 0 | 8 | | | $11.45 | $0 | | *per inch of depth* |
| Blades | ea. | 0 | | 1 | | $625.00 | $0 | | *12" = $625, 36" = $1750* |
| Concrete Removal | C.Y. | 279 | | 1.1 | 306 | $230.00 | $70,489 | | *2013 Low Bid Unit Cost $210, Average Bid $277* |
| Remove Whole Pieces | ea. | 0 | | | | $140.00 | $0 | | *1 to 2.5 cubic yards in size* |
| Loading Concrete | C.Y. | 109 | | | | $200.00 | $0 | | |
| Hauling | C.Y. | 109 | | | | $7.00 | $0 | | |
| Concrete Disposal | C.Y. | 109 | | | | $10.00 | $0 | | |
| **Reinforced Concrete Form and Pour** | | | | | | | $0 | **$420,341** | |
| Excavation and Disposal | C.Y. | 599 | | 1.1 | 659 | $55.00 | $36,230 | | *2013 Low Bid Unit Cost $44, Average Bid $84* |
| Disposal | C.Y. | 0 | | | | $30.00 | $0 | | *High cost for getting out of flume area* |
| Gravel Backfill | C.Y. | 100 | | 1.2 | 120 | $120.00 | $14,416 | | *2013 Low Bid Unit Cost $80, Average Bid $153* |
| Concrete Underpining | C.Y. | 0 | | | | $2,100.00 | $0 | | |
| CIP | C.Y. | 0 | | | | $1,300.00 | $0 | | |
| Grouting | S.F. | 0 | | | | $2.76 | $0 | | |
| Roughness Panels (Form and Pour) | C.Y. | 288 | | 1.02 | 293 | $687.00 | $201,579 | | *Narum Costs Minus Panel Forms* |
| Install Roughness Panels | ea. | 110 | | 1.02 | 112 | $300.00 | $33,660 | | *2013 Low Bid Unit Cost $270, Average Bid $1311* |
| CIP Concrete | C.Y. | 122 | | 1.1 | 134 | $1,000.00 | $134,456 | | *2013 Low Bid Unit Cost $740, Average Bid $1240* |
| Enclosure Curbs | C.Y. | 10 | | | | $0.00 | $0 | | |
| Baffles | C.Y. | 15 | | | | $0.00 | $0 | | |
| Resting Pools | C.Y. | 97 | | | | $0.00 | $0 | | |
| Habitat Boulders | L.S. | 48 | | 1 | 48 | $300.00 | $14,400 | | *2013 Low Bid Unit Cost $150, Average Bid $300* |
| **Ford** | | | | | | | | **$64,519** | |
| Concrete Cutting | L.F. | 198 | | 1 | 198 | $10.00 | $1,980 | | |
| Concrete Removal | C.Y. | 34 | | 1.1 | 37 | $230.00 | $8,602 | | |
| Excavation and Disposal | C.Y. | 126 | | 1.1 | 139 | $55.00 | $7,619 | | |
| Gravel Backfill | C.Y. | 16 | | 1.2 | 19 | $120.00 | $2,318 | | |
| CIP Concrete | C.Y. | 40 | | 1.1 | 44 | $1,000.00 | $44,000 | | |
| **Construction Subtotal** | | | | | | | | $751,260 | |
| Contingency | 15% | | | | | | | $112,689 | |
| Sales Tax | 8.9% | | | | | | | $76,900 | |
| **Construction Total** | | | | | | | | **$940,800** | |
| Construction Management | 7.0% | | | | | | | $65,900 | |
| **Project Total** | | | | | | | | **$1,006,700** | |

**Opinions of Probable Construction Cost**

In providing opinions of probable construction cost, the Client understands that the Consultant (Waterfall Engineering, L.L.C.) has no control over the cost or availability of labor, equipment or materials, or over market condition or the Contractor's method of pricing, and the consultant's opinions of probable construction costs are made on the basis of the Consultant's professional judgment and experience. The Consultant makes no warranty, express of implied that the bids or the negotiated cost of the Work will not vary from the Consultant's opinion of probable construction cost.

## N. 6th Ave Bridge – Option 2

| **Mill Creek Passage - N. 6th Ave Bridge** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Date: | 7/30/2014 | | | | | | | | |
| By: | Waterfall Engineering and Chinook Engineering | | | | | | | | |
| Design Level: | 10% | | | | | | | | |
| Project Length (ft): | 121 | | | | | | | | |
| Resting Pools: | 3 | | | | | | | | |
| Roughness Panels: | 11 | | | | | | | | |
| Baffles: | 7 | | | | | | | | |
| | | | | | | | | | |
| **Description** | **Unit** | **CAD Quantity** | **t (in)** | **Mult** | **Bid Quantity** | **Cost** | **Amount** | **Sub Total** | ***Comments*** |
| | | | | | | | | | |
| **Mob, Access and Water Management** | | | | | | | | **$43,000** | |
| Mobilization | L.S. | 1 | | 1 | 1 | $8,000.00 | $8,000 | | *Average 11% of construction costs* |
| Access to Flume | L.S. | 1 | | 1 | 1 | $15,000.00 | $15,000 | | *Site to be Identified* |
| Water Management | L.S. | 1 | | 1 | 1 | $20,000.00 | $20,000 | | *2013 Low Bid Unit Cost $34,000, Average Bid $41,000 for 350 feet* |
| **Concrete Demolition** | | | | | | | | **$9,522** | |
| Concrete Slab cutting | L.F. | 283 | | 1 | 283 | $10.00 | $2,832 | | *2013 Low Bid Unit Cost $8, Average Bid $12* |
| Concrete Wall cutting (plain) | L.F. | 0 | 8 | | | $7.00 | $0 | | *per inch of depth* |
| Concrete Wall cutting (with rebar) | L.F. | 0 | 8 | | | $11.45 | $0 | | *per inch of depth* |
| Blades | ea. | 0 | | 1 | | $625.00 | $0 | | *12" = $625, 36" = $1750* |
| Concrete Removal | C.Y. | 26 | | 1.1 | 29 | $230.00 | $6,690 | | *2013 Low Bid Unit Cost $210, Average Bid $277* |
| Remove Whole Pieces | ea. | 0 | | | | $140.00 | $0 | | *1 to 2.5 cubic yards in size* |
| Loading Concrete | C.Y. | 109 | | | | $200.00 | $0 | | |
| Hauling | C.Y. | 109 | | | | $7.00 | $0 | | |
| Concrete Disposal | C.Y. | 109 | | | | $10.00 | $0 | | |
| **Reinforced Concrete Form and Pour** | | | | | | | $0 | **$24,614** | |
| Excavation and Disposal | C.Y. | 58 | | 1.1 | 64 | $55.00 | $3,529 | | *2013 Low Bid Unit Cost $44, Average Bid $84* |
| Disposal | C.Y. | 0 | | | | $30.00 | $0 | | *High cost for getting out of flume area* |
| Gravel Backfill | C.Y. | 10 | | 1.2 | 11 | $120.00 | $1,368 | | *2013 Low Bid Unit Cost $80, Average Bid $153* |
| Concrete Underpining | C.Y. | 0 | | | | $2,100.00 | $0 | | |
| CIP | C.Y. | 0 | | | | $1,300.00 | $0 | | |
| Grouting | S.F. | 0 | | | | $2.76 | $0 | | |
| Roughness Panels (Form and Pour) | C.Y. | 13 | | 1.02 | 13 | $687.00 | $8,901 | | *Narum Costs Minus Panel Forms* |
| Install Roughness Panels | ea. | 11 | | 1.02 | 11 | $200.00 | $2,244 | | *2013 Low Bid Unit Cost $270, Average Bid $1311, Adjusted For 1/2 Panel* |
| CIP Concrete | C.Y. | 7.8 | | 1.1 | 8.6 | $1,000.00 | $8,573 | | *2013 Low Bid Unit Cost $740, Average Bid $1240* |
| Enclosure Curbs | C.Y. | 0.5 | | | | $0.00 | $0 | | |
| Baffles | C.Y. | 0.6 | | | | $0.00 | $0 | | |
| Resting Pools | C.Y. | 6.7 | | | | $0.00 | $0 | | |
| Habitat Boulders | L.S. | 6 | | 1 | 6 | $300.00 | $1,800 | | *2013 Low Bid Unit Cost $150, Average Bid $300* |
| | | | | | | | | | |
| **Construction Subtotal** | | | | | | | | $77,136 | |
| Contingency | 15% | | | | | | | $11,570 | |
| Sales Tax | 8.9% | | | | | | | $7,900 | |
| **Construction Total** | | | | | | | | **$96,600** | |
| Construction Management | 7.0% | | | | | | | $6,800 | |
| **Project Total** | | | | | | | | **$103,400** | |

**Opinions of Probable Construction Cost**

In providing opinions of probable construction cost, the Client understands that the Consultant (Waterfall Engineering, L.L.C.) has no control over the cost or availability of labor, equipment or materials, or over market condition or the Contractor's method of pricing, and the consultant's opinions of probable construction costs are made on the basis of the Consultant's professional judgment and experience. The Consultant makes no warranty, express of implied that the bids or the negotiated cost of the Work will not vary from the Consultant's opinion of probable construction cost.