Wild Fish Conservancy
NORTHWEST
SCIENCE EDUCATION ADVOCACY

August 30, 2011
Waterwheel Creek Restoration Project
Design Memo
Revised February 21, 2012

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Waterwheel Creek is a tributary to Cherry Creek, which flows into the Snoqualmie River near the town of Duvall. A series of irrigation ditches or laterals drain the valley that was historically occupied by Cherry Creek and its lower tributaries. The Wild Fish Conservancy is proposing to fill Laterals B, C and D which currently drain Waterwheel Creek and the surrounding valley floor above Lateral A (Figure 5), and replace them with a naturalized channel that will improve habitat for fish without compromising agricultural drainage.

Specific design objectives include:

- Abandon and fill Laterals B, C, D, and create a new channel that exceeds the combined conveyance capacity of existing laterals.
- Improve floodwater conveyance. The new channel will be wider, deeper, and have greater localized water velocities. Two banks instead of six = less Reed Canary grass encroachment.
- Plant a native riparian corridor to shade out Reed Canary grass, lower stream temperatures, stabilize banks and discourage lateral channel migration. A planting plan to be developed in consultation with WDFW and the Tulalip Tribes.
- Increased channel sinuosity and instream wood to provide better fish habitat (migration and rearing habitat for coho and Chinook salmon, cutthroat and rainbow/steelhead trout).

GLO plat maps created in 1873 indicate that the project area was historically a consistently wet marsh. These maps provide us with an approximation of historic channel sinuosity prior to the re-routing and re-shaping of waterways within the Cherry Creek watershed. The valley characteristics fit those that are characteristically associated with low-gradient Rosgen C-type channels. According to Rosgen, naturally occurring type-C channels have a minimum sinuosity of 1.2, and a minimum width:depth ratio of 12, although the sinuosity of the historic channel was much higher than this.

The short term design objective is to design a stable channel that conveys enough flow to prevent excessive sediment deposition that may lead to an avulsion of the channel if it flows across an un-vegetated floodplain. It is assumed that this channel will be dynamic, and that adjacent soils are composed primarily of silts, sands and organic materials that are generally uncohesive and easily eroded, unless updated. The new channel will convey flows more efficiently than the existing laterals, and the flow field will be more varied during high flow due to the added sinuosity and variations in bed elevation. While enhanced habitat diversity improves conditions for fish, the rate of natural lateral channel migration across un-vegetated floodplains would be expected to be high in the absence of vegetation. One concern is that the channel migrates and leaves behind a lower floodplain terrace flows may dissipate and lose their capacity to maintain the kind perennial stream channel that provides summer rearing habitat for juvenile Chinook and other salmonids. Lateral channel migration also has the potential to undermine the dike that currently isolates the mainstem of Cherry Creek from its historic floodplain. Aggressive planting of deep-rooted vegetation along the channel's banks will help to discourage lateral channel migration and widening.

Culverts located on the lower end of laterals B, C and D limit drainage as floods recede. Under existing conditions, water ponds behind the culverts in laterals B,C and D as floodwaters recede. The flow capacity of the existing laterals B, C and D has steadily declined in recent years as the laterals have been invaded by Reed Canarygrass. The Reed Canarygrass and associated soils currently occupy a large portion of the existing volume of laterals B and C. That and the roughness the Reed Canary grass creates pushes the flow up and out of the channel and onto the floodplain sooner than if there was no Reed Canary grass. The growth of Reed Canary grass will be limited within the deeper, shaded waters of the proposed channel. If these laterals are maintained as secondary drainage ditches, then substantial deposition of sediment and/or accumulation and growth of in-channel vegetation can be expected within the existing laterals as the flow that currently transports sediment within laterals B, C and D is re-routed through the restored Waterwheel Creek. During low flow conditions, average velocities within the re-aligned channel will be higher after all three ditches have been consolidated into a single channel, and finer-sized sediments are more likely to be transported through the new channel to Cherry Creek rather than deposited in the laterals.

We recommend filling Lateral B for the following reasons:

(a) water quality is severely degraded in Lateral B and poses a risk to fish.
(b) leaving Lateral B open will not improve drainage.
(c) currently, the mid-section of Lateral B is barely visible due to Reed Canarygrass encroachment (see Figure 1).

(d) flow through the lower end of Lateral B is currently limited by the flow capacity of the downstream culvert, which serves to drain only DFW administered land.
(e) the live (freeboard) storage capacity of the proposed channel is more than double that of lateral B, and the total volume of excavated material from the proposed channel exceeds the total combined volumes of laterals B, C, and D, thus meeting compensatory storage requirements.

No contingency plan is necessary because water will drain into Lateral A over a large area after the dike has been removed (see Figure 3). Water will also continue to drain out through Lateral E.

Figure 1. Laterals B and C are choked with Reed Canarygrass and barely visible in the latest aerial photograph taken in 2011.

Wild Fish Conservancy engineers conducted a survey of Laterals A and B during low flow using a laser level and an inflatable raft to obtain essential survey data needed for the design. Water surface elevations were recorded and measured maximum water depths at twelve locations: eight on Lateral B; three along Lateral A; and one on Cherry Creek directly below the sluice and flap gates. The survey revealed that the Lateral A bed profile is essentially flat. At the observed flow (05/08/10), there was no measurable change in the water depth in Lateral A between Lateral B and the pump house. All gates were open and the pump was operating at the time of the survey with two of three pipes conveying water. The water surface elevation at the lower end of Lateral B was equal to the water surface elevation in Cherry Creek at the point of confluence. In other words, Lateral A was backwatered to Lateral B (and probably to Lateral D and beyond).

The water depth in Lateral A was approximately 6 ½ feet throughout its length at the time of the survey. The bed surface in Cherry Creek below Lateral A was too deep to reach from the pump house deck (deeper than six feet). There was no visible control point downstream where the stream bed became visible beneath the water surface, which suggests that the water depth in Cherry Creek directly below Lateral A may occasionally drop below 6 ½ feet. A more precise estimate of the water depth in Lateral A during low flow could be obtained by floating Cherry Creek from the pump house down to the first observable riffle.

The pump station is located approximately 3,128 feet above the Snoqualmie River confluence. R2 Consultants simulated water surface elevations at Cherry Creek station 3055. At the time the LiDAR was flown, the water surface elevation in Cherry Creek at this point was somewhere between 25.8 and 27.3 feet above sea level, which according to R2 corresponds to flows in Cherry Creek between 6 to 46 cfs. At 6 cfs (the minimum flow that was modeled) the water surface elevation in Cherry Creek drops to approximately 26 feet above sea level. This information combined with information on low flow water surface elevations in Lateral A would allow us to estimate water depths in Waterwheel Creek throughout the year, although this information was not considered to be necessary in developing the design as the new channel bed. (In the absence of any grade controls, the re-aligned channel can be expected to erode down to match the bed elevation within Lateral A.)

The average water surface gradient in Lateral B at the time of the WFC survey was 0.09%. R2 Consultants used an energy gradient of 0.06% to calculate a bankfull flow of 60 cfs through Lateral B. Although R2 Consultants appeared to have underestimated the energy gradient, the growth of Reed Canarygrass within the channel reduces the flow capacity of the channel considerably. No gravel was observed in Lateral B. The bed material that was observed was composed entirely of silts, detritus and other organics, and abundant algae within the lower 100 feet of the ditch where Reed Canary grass is sparse. Average velocities within the re-aligned channel are certain to be higher. Riffles may be maintained in the re-aligned channel by creating variations in the bed profile, although the persistence of these riffles is dependant on changes in the channel's position and width over time.

Sediment deposition and bed aggradation above the sluice and flap gates in Lateral A may reduce flow from Lateral A into Cherry Creek if gravel deposits are present below the surface of the re-aligned channel alignment. Any gravel present may be retained by burying logs beneath the stream bed during construction. Although this may locally raise the bed elevations, some variation in the design grade is desirable as it will tend to promote the sorting of bed material. Initially, the average bed surface gradient in the re-aligned (5000-foot long) channel may be as high as 0.1%. This grade may decline over time however as the creek seeks an upstream equilibrium. The magnitude of the increase in the sediment transport capacity will depend on the extent to which the new channel is backwatered during various flows. The extent to which the new channel is backwatered at any given flow in turn will depend on the water surface elevation in Cherry Creek.

The proposed cross sectional area of the new channel near its confluence with Lateral A is 265 ft^2 and the average stream channel gradient is 0.00217 or approximately 0.22%. Flow through the proposed channel was estimated using XSPro. Detailed results are presented on the last page of this memo. Results suggest that the proposed channel is capable of conveying a *minimum* of 362 cfs[1] when the flood stage in Cherry valley is equal to 28 feet, provided that the outlet is not backwatered and both the downstream flow through the mainstem of Cherry Creek and the combined flow capacity of the pump and gates exceed the flow capacity of the proposed channel. The actual flow when the flood stage is equal to 28 feet is likely to be higher as water is drawn from the floodplain into the lower end of the channel. If either the flow in Cherry Creek or the combined flow rate through the gates and pump is lower than the flow capacity of the proposed channel at any given time, then the proposed channel is no longer limiting flow.

HEC-RAS modeling of Laterals B, C and D indicates that the combined flow through the three laterals is equal to approximately 80 cfs when the flood stage is at 28 feet.[2] (The same conditions that apply to the proposed channel also apply to Laterals B, C and D.) These results suggest that the proposed channel is capable of conveying at least three times as much flow as Laterals B, C and D. A comparison of the combined cross sectional area occupied by the three culverts that drain the existing laterals with the cross sectional area near the lower end of the proposed channel supports this conclusion (see Figure 2). In addition, the new channel geometry will improve drainage of groundwater in the spring. This will cause the areas surrounding the new channel to become drier sooner in the spring, and draw cool groundwater into the low-flow channel during the summer.

The lower length of Lateral B that is to be filled affects drainage only on WDFW administered land. The project will not adversely affect and may *enhance* drainage of WDFW property and other agricultural properties under certain conditions. Filling of Lateral B will not occur within the vicinity of the Balser property.

[1] The actual flow within the proposed channel is likely to be higher than this since water flowing over the banks and into the channel from above which increases the head and therefore increases the average energy gradient within the lower reach of the proposed channel. The roughness coefficient used to estimate flow within the proposed channel is conservative. Actual flow resistance is likely to be lower which would also increase flow within the proposed channel.

[2] "Cherry Creek Hydraulic Model Simulation Results for SRT and Orifice Alternatives", Memo to the Wild Fish Conservancy, R2 Resource Consultants, Inc., January 29, 2004.

Figure 2. Cross Section of Proposed Channel: 250 feet above Lateral A

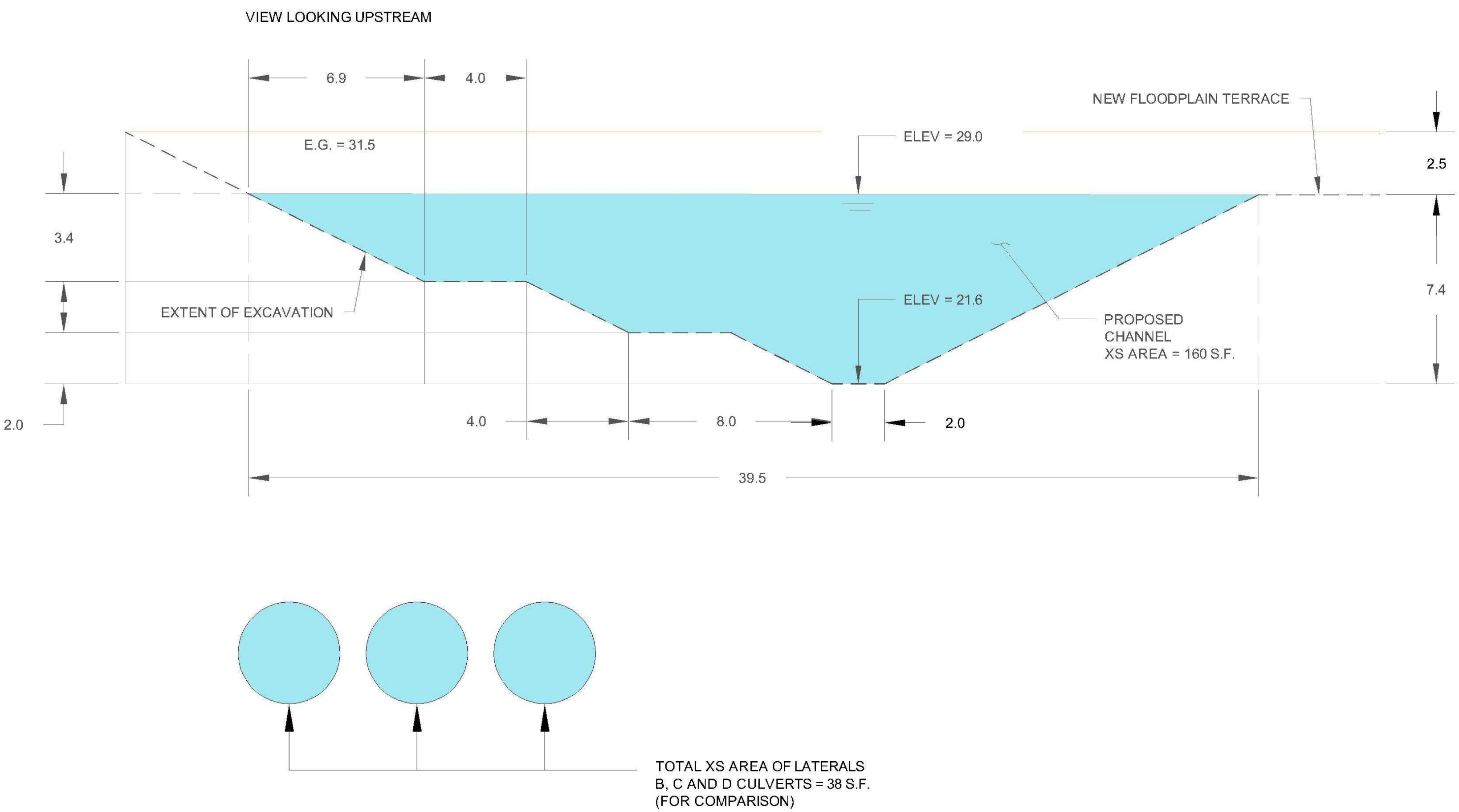
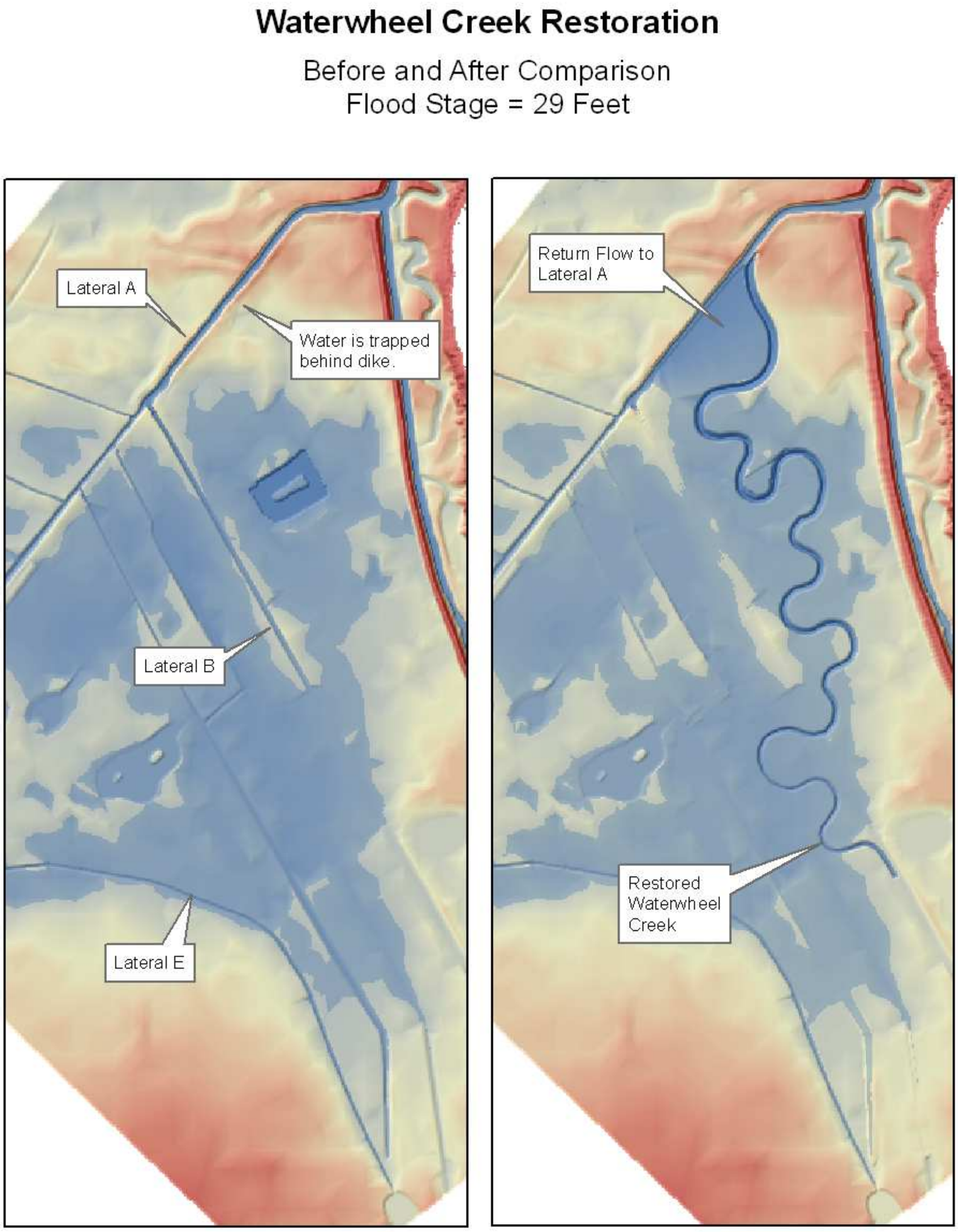


Figure 3. Drainage patterns before and after construction



Construction of the new channel involves the removal of decades of sediment that has raised the ground surface southwest of the lateral A/Cherry Creek confluence. The proposed stream channel thus creates a fundamental change in the way in which floodwaters recede that substantially improves drainage and prevents ponding of floodwaters above lateral A. The critical flood stage is defined as the stage at which the flow through Lateral E exceeds the flow through Laterals B, C and D. This stage (equal to approximately 29 feet) occurs just before water begins to overtop the access road that runs along the southeast edge of Lateral A.

Once the flood stage in Cherry valley rises above 29 feet, flow through Laterals B, C and D is negligible compared to the rate at which water flows over the access road into Lateral A and around the upper end of Lateral A (along the primary flood return path, see Figure 4). Above critical stage, drainage is controlled by factors other than drainage through Laterals B, C, D and E (specifically, the flow capacity of the sluice and flap gates at the lower end of Lateral A and the Snoqualmie River stage). We are only concerned therefore with the effect that the proposed project will have on drainage when the flood stage is below 29 feet.

Figure 4. Critical Flood Stage

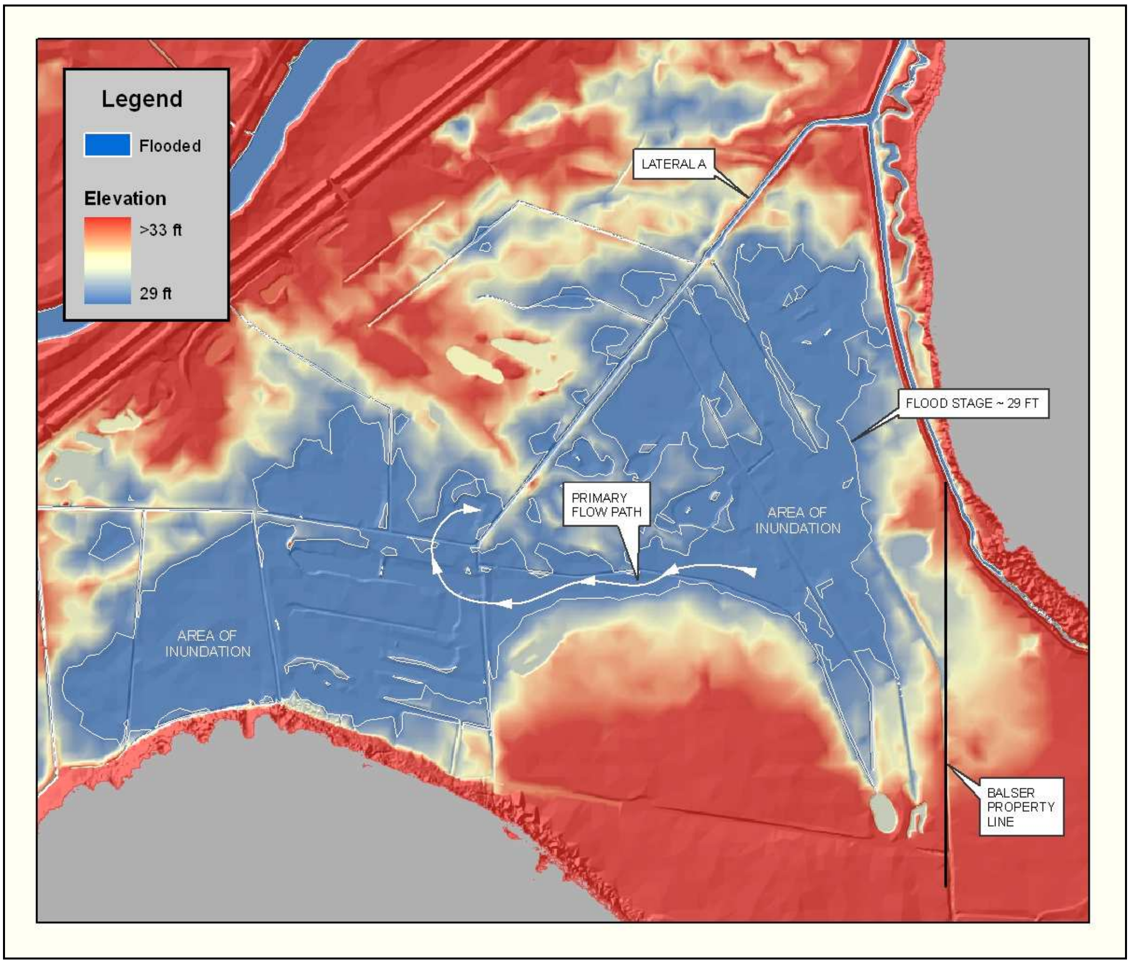
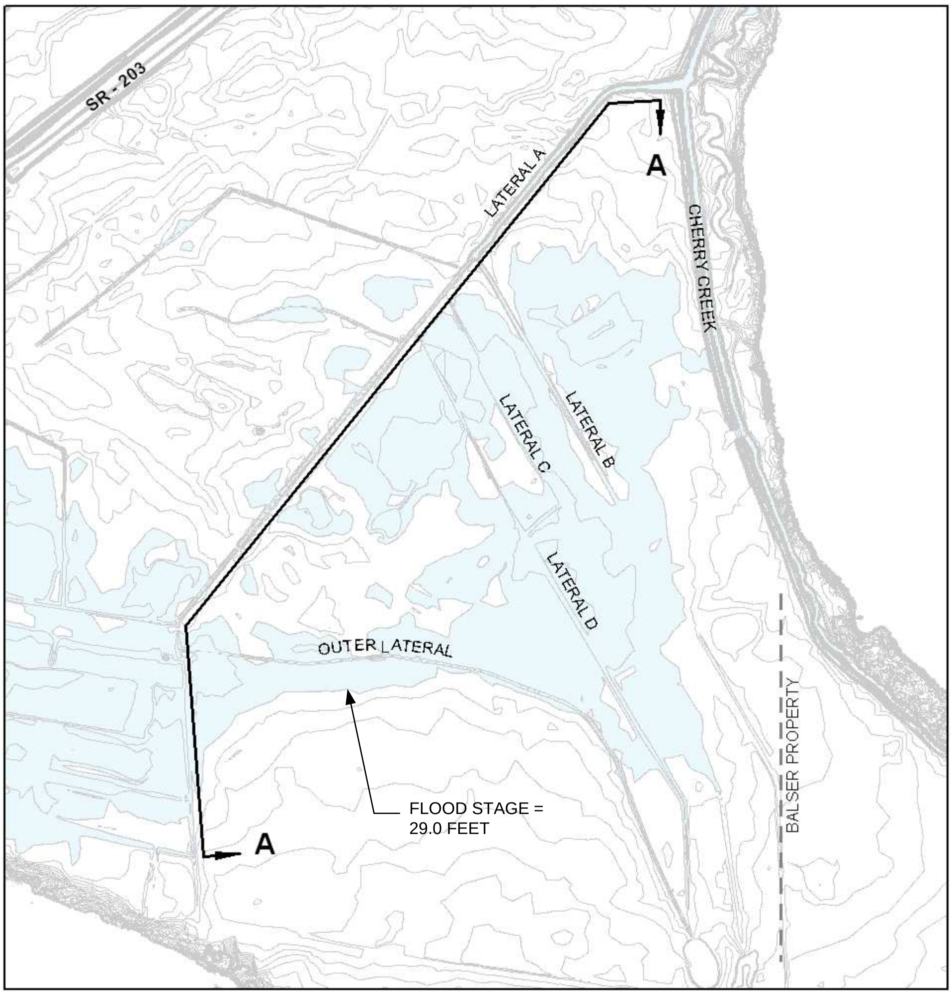
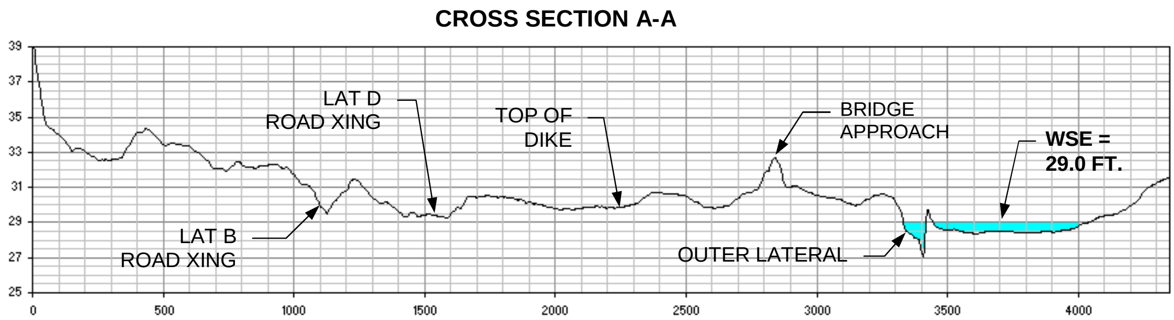


Figure5. Cross Section of Cherry Valley Floodplain
near Critical Flood Stage





It is clear that the project will enhance drainage and lower the risk of flooding on WDFW property. Attempting to quantify the extent to which drainage is enhanced as a result of the proposed project would require extensive, long-term monitoring of basin precipitation, flow and drainage patterns as well as additional hydrodynamic modeling of flood events within Cherry valley. If WDFW feels that this level of effort is necessary to support internal administrative, management or political processes or decisions and wishes to contract with WFC, then we would be willing to consider providing technical support to the Department to assess drainage patterns within Cherry valley. However we cannot justify and find no practical reason to conduct this kind of extensive investigation for the purposes of assessing the effects of the project on flood risks or fish habitat suitability.

Flooding of the lower valley properties to the northwest of Lateral A occurs either (1) when the lower valley is backwatered by Cherry Creek/Lateral A and/or the Snoqualmie River from below; or (2) when floodwaters entering Cherry Valley from above overtop Lateral E and end-run the dike that runs along the southeastern edge of Lateral A. It is conceivable that the project might temporarily increase the flood risk to lower valley properties under certain limited conditions if we make the following assumptions: (a) that the upper valley southwest of Lateral A currently acts as a retention basin that stores water and reduces the flood frequency and magnitude within the lower valley northwest of Lateral A; and (b) that by increasing flow into Lateral A from below you increase the length of time that Lateral A is backwatered (and thus flooded). These assumptions may be true under certain conditions, but only when the flood stage drops below 29 feet. (Above 29 feet water is spilling over the road dike into Lateral A and the effects of the drainage ditches in conveying water are trivial by comparison.) If outflow from Lateral A into Cherry Creek is greater than inflow into Lateral A from above, then adding flow to Lateral A reduces the flood risk to the lower valley properties because there is excess flow capacity in Lateral A. The only time that releasing more water into Lateral A might make things worse within the lower valley is when (a) the flood stage is below 29 feet; and (b) inflow into Lateral A exceeds outflow from Lateral A into Cherry Creek. By retaining water behind the road dike, you are increasing flow through Lateral E. The net effect on flooding of lower valley properties is likely to be minimal.

Of course if the Department of Fish and Wildlife replaces the three culverts at the lower ends of Laterals B, C and D (which they have indicated they will do if the channel restoration project does not move forward) then the question of how the project will affect the lower valley properties is irrelevant because the culvert replacement project will remove the flow restrictions created by the culverts and negate any positive effect that water retention southeast of Lateral A may have on reducing the flood risk to the lower valley properties

*******************************WinXSPRO*********************************

Run Date: 08/29/11
Analysis Procedure: Hydraulics
Cross Section Number: 2
Survey Date: N/A

Subsections/Dividing positions
None

Resistance Method: Manning's n

SECTION	A
Low Stage n	0.050
High Stage n	0.050

Unadjusted horizontal distances used

STAGE	#SEC	AREA	PERIM	WIDTH	R	DHYD	SLOPE	n	VAVG	Q	SHEAR
(ft)		(sq ft)	(ft)	(ft)	(ft)		(ft/ft)		(ft/s)	(cfs)	(psf)
26	T	58.46	29.58	27.49	1.98	2.13	0.0022	0.05	2.19	127.8	0.27
27	T	87.95	34.06	31.5	2.58	2.79	0.0022	0.05	2.61	229.83	0.35
28	T	121.45	38.53	35.5	3.15	3.42	0.0022	0.05	2.98	362.44	0.43
29	T	158.95	43	39.5	3.7	4.02	0.0022	0.05	3.32	527.47	0.5

STAGE	ALPHA	FROUDE
26	1	0.264193
27	1	0.275562
28	1	0.284325
29	1	0.291529