

**Site and Reach Assessment
Middle Fork Wildcat Creek
At SR 8, MP 5.01
Bridge No. 8/13**

Work Order MS 5454

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Site and Reach Assessment, Middle Fork Wildcat Creek at SR 8



Washington State Department of Transportation
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Summary and Recommendations

The Middle Fork of Wildcat Creek crosses beneath State Route (SR) 8 through a bottomless concrete box culvert near Milepost 5.01. Scour and erosion at the outlet has exposed shallow footings, and caused the left bank wingwall to collapse in 2005. This has led to a series of repairs that affect fish habitat and impair fish passage.

The wingwall was reconstructed in the summer of 2005, and a series of boulder structures was installed to control streambed erosion. This repair protects the culvert foundations, but several of the boulder structures have settled. High velocities also remove fine material, causing pools to dewater. This has created a two to three foot drop at the outlet that does not meet fish passage criteria for salmon that use Wildcat Creek.

The scour and erosion problems are partly caused by flow confinement that creates high velocities in the culvert. Channel incision in downstream reaches of Wildcat Creek has also lowered the natural streambed by more than five feet. The boulder structures in the SR 8 culvert prevent this channel bed erosion from progressing upstream where it could threaten Elma – McCleary Road.

Tables 3 and 4 in the “Treatment Alternatives” section of this report summarize pros and cons as well as risks for several alternative solutions. We recommend a new bridge (Alternative 5) as the long-term solution to erosion and fish passage problems. This is the only alternative that fully addresses flow constriction and high velocities caused by the culvert, and restores natural movement of wood, water, sediment, and fish beneath the highway. Footings for the new bridge would be placed well below the potential scour depth, greatly reducing risks to the structure. Grade control structures may be needed beneath the bridge to reduce the risk of progressive streambed erosion and damage to upstream structures and properties.

All of the alternatives that use the existing outlet involve significant risk of failure because of the high flow energy, wide channel, and limited distance between the culvert outlet and a sharp bend in the downstream channel. The only alternative that stays within the WSDOT right-of-way is a concrete fishway that steps flow down through a series of pools and weirs (Alternative 4), which would be difficult and expensive to construct, and need almost constant sediment removal to maintain the pool depths required for energy dissipation and fish passage.

Other alternatives involve constructing either a roughened channel (Alternative 3) or a series of log sills (Alternative 2) that slope the streambed down at 4.5 percent, meeting the natural channel about 53 feet beyond the WSDOT right-of-way boundary. If an interim solution is needed, we recommend the roughened channel, primarily because log sills in such a wide channel could be flanked and would require extensive construction and maintenance on adjacent streambanks. The roughened channel would consist of a coarse streambed with large material designed to withstand scour and provide resting places for fish. The success of this alternative will depend greatly on proper sizing of streambed material to limit bed erosion and channel dewatering.

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Introduction

This report presents a site and reach assessment of streambed erosion and fish passage problems in the Middle Fork of Wildcat Creek at State Route (SR) 8 Culvert 8/13. Scour and erosion at the culvert outlet has exposed shallow footings, and caused the left bank wingwall to collapse in 2005. The steep drop at the outlet also creates a fish passage barrier. The report analyzes site and reach conditions to identify the mechanisms and causes of these problems, and evaluates several alternative solutions.

Site Assessment

Culvert Design and Repair History

The Middle Fork of Wildcat Creek crosses beneath SR 8 through a bottomless concrete box culvert near Milepost 5.01 (Figure 1). The culvert was constructed in 1962, and is 25 feet high, 20 feet wide, and 125.8 feet long. Sloping wingwalls (26 feet high, 26 feet long, and flared at 20 degrees) support the embankments at the culvert outlets (WSDOT, 2007). The walls of the culvert rest on shallow spread footings. When the culvert was constructed the tops of the footings were covered by 2.5 feet of streambed material (Figure 2). By 2000 the creek bed had cut downward more than four feet, nearly exposing the bottoms of the culvert and wing wall footings.

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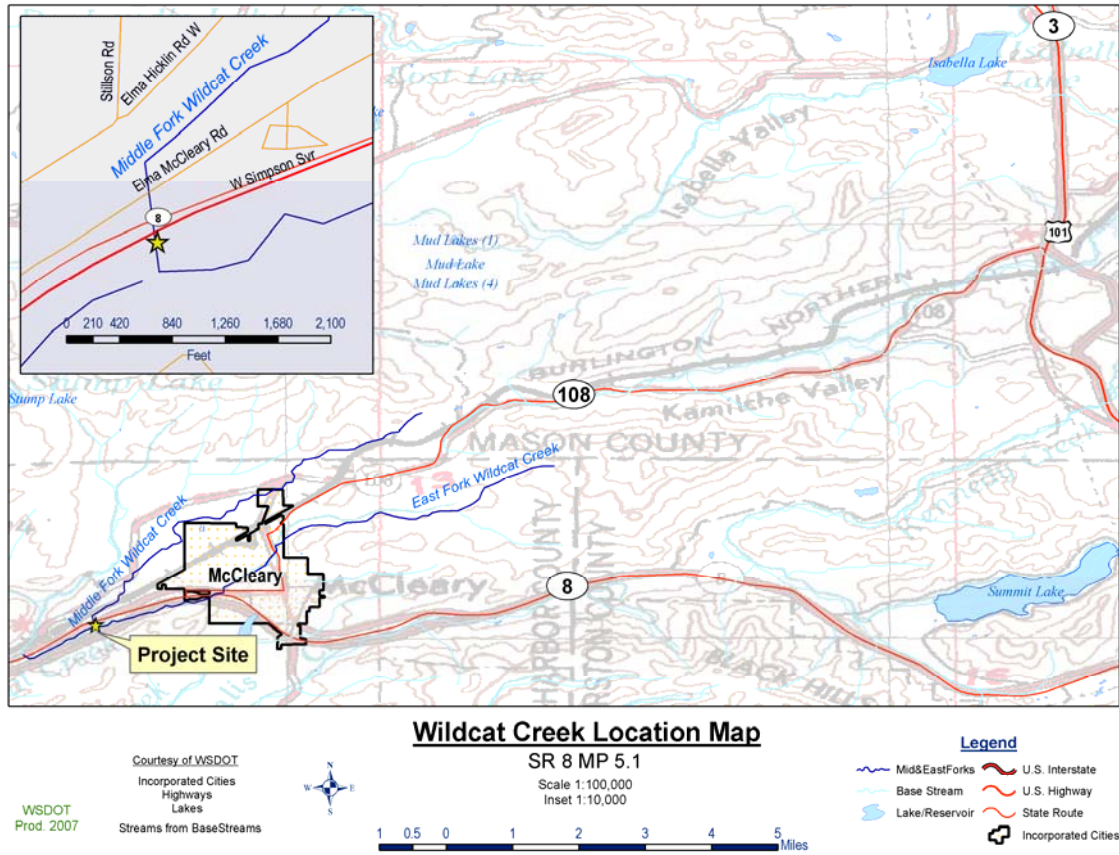


Figure 1. Project Location Map.

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8/13 WILDCAT CREEK

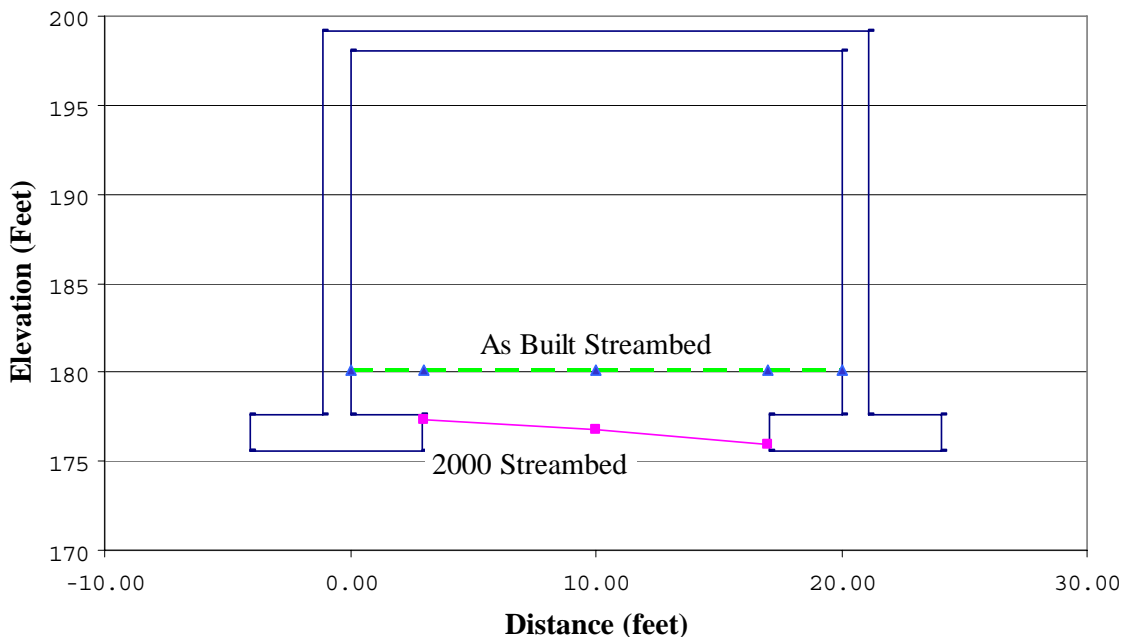


Figure 2. Historical Cross Section Surveys of the SR 8 Wildcat Creek Culvert

Washington State Department of Transportation (WSDOT) Bridge Inspection Reports from 1995-2005 show a history of problems at the culvert associated with streambed erosion (WSDOT, 2007). The 1995-2003 reports note increasing exposure of the culvert and wing wall footings. Wing walls were tipping out one to two inches at the top. In the winter of 2005 the southeast outlet wingwall failed and tipped into the creek.

An emergency repair was completed in September 2005 to replace the failed wing wall. The southeast wingwall is now on deeper footings, but the other wingwall foundations are still shallow and vulnerable to undermining. During this repair WSDOT covered all footings with heavy loose riprap, and installed nine boulder drop structures in the culvert and at the exit to control erosion and maintain fish passage (Figure 3). These boulder drop structures were designed to create a series of pools, with a maximum drop of about one foot between pools. The first structure (A-4) is located just upstream of the inlet, and was not visible in April 2007. The next four structures (A-3, A-2, A-1, and A) control the gradient within the culvert. The last four structures step flow down from the outlet to a deep pool near the WSDOT right-of-way boundary. Two rootwads are anchored into heavy loose riprap on each bank at the bottom drop structure (Figure 4).

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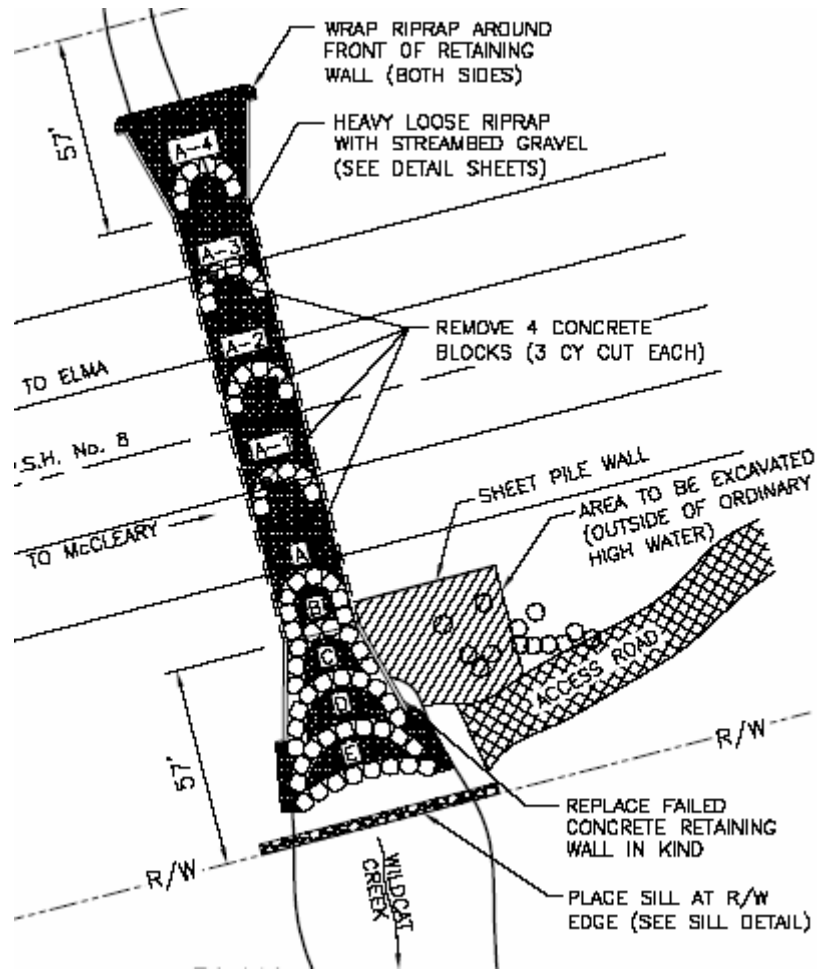


Figure 3. Design of the Wildcat Creek Drop Structures

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Figure 4. Photos of As-Built and Current Conditions at the Culvert Outlet

Flow Conditions in the Culvert

Figure 5 compares the design profile to drop structure elevations surveyed in 2007. The channel bed slopes at about 1.4 percent between the inlet and outlet. Drop Structure B at the culvert outlet is relatively stable, with a minimum elevation close to the design level. The downstream structures have settled substantially, dropping one to two feet relative to the design profile. The low point in Structure C is now about two feet lower than designed.

The boulder structures were originally covered with fine streambed material to provide substrate and fill interstitial spaces (Figure 4). High flow energy at the outlet removed most of this fine material in the 2005-06 rainy season. WSDOT replaced the lost streambed material in the summer of 2006 with cobbles of 10 inches or less and gravels (Bob Barnard, personal communication). Much of this washed out again in the winter of 2007. This loss of fine material causes leakage and lowering of water levels in the pools behind the boulder structures.

Pool dewatering and boulder settling combine to create elevation drops that impede fish passage. The water surface now drops two to three feet between the B and C pools, depending on flow levels.

High velocities in the culvert also contribute to fish passage problems. The culvert constricts the channel, and the smooth culvert walls reduce flow resistance. Velocities estimated for January fish passage flows approach 5 feet per second in the culvert. Flood velocities exceed 10 feet per second.

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Channel Conditions Upstream and Downstream of the Culvert

The creek crosses beneath a railroad trestle and Elma – McCleary Road about 250 feet upstream of SR 8, and approaches the culvert inlet in a plane-bed channel lined with gravel. Figure 5 shows the profile of the streambed as surveyed in April, 2007. The streambed between the county bridge and the SR 8 culvert inlet slopes at about 1.1 percent. The slope flattens out near SR 8 to about 0.4 percent, indicating that the streambed has aggraded at the culvert inlet. This aggradation has buried Structure A-4, and is probably caused by backwater from channel confinement at the inlet.

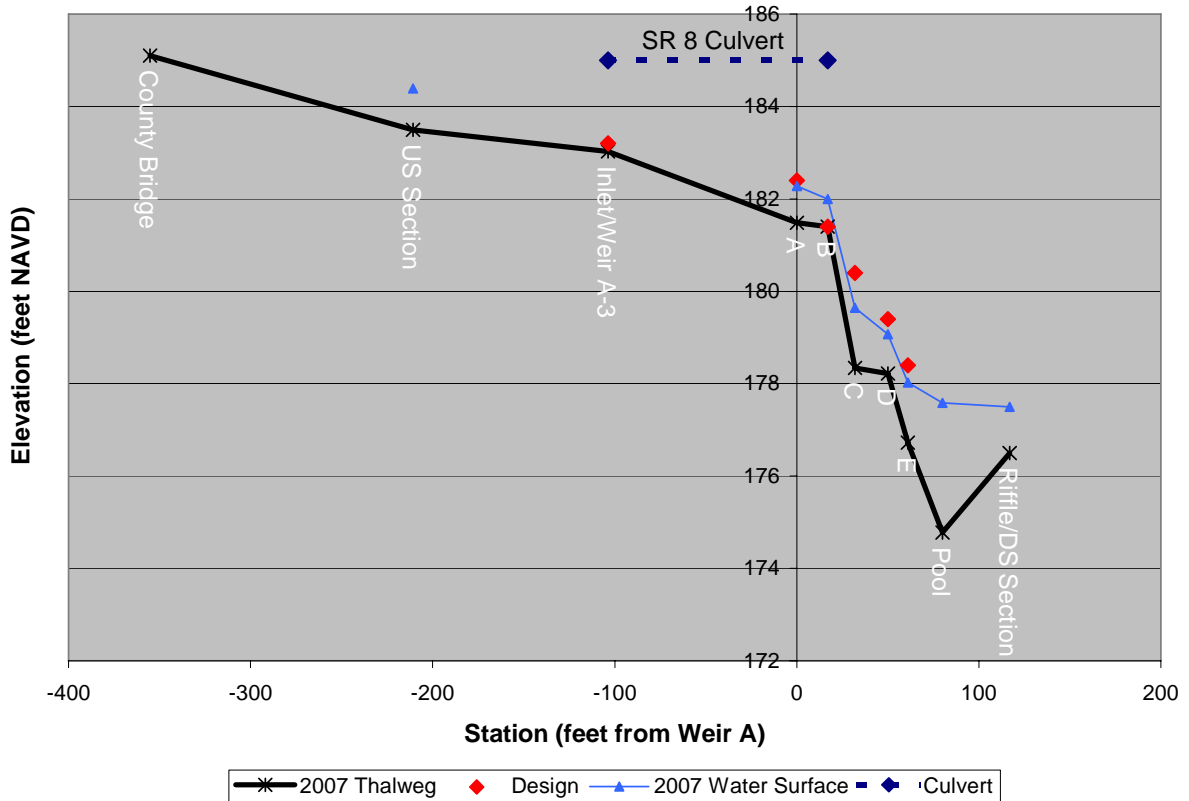


Figure 5. Streambed Profile of Wildcat Creek near SR 8

Figure 6 shows a typical cross-section of the channel and floodplain in the segment upstream of SR 8. The active channel is about 25 feet wide. A 20-foot wide floodplain bench lies about three feet above the channel bottom on the left bank. Scour marks and surface deposition indicate that this bench is frequently flooded. Ordinary High Water is indicated by a scour line on the slope above the left bank floodplain, and by an erosion scarp at the transition between canary grass and Himalayan blackberry on the right bank. The total channel and floodplain width is about 44 feet at Ordinary High Water.

At the culvert outlet the channel drops over a cascade of boulder structures before discharging into a 3 to 4-foot deep pool. This pool tails out into a riffle about 100 feet downstream of the culvert outlet, at an elevation 4.9 feet below the top of Structure B. This riffle is composed of cobbles and gravel, and slopes at about 1.2 percent. Below the tail out

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the riffle bends sharply to the west, exposing a high scarp of exposed glacial outwash on the left bank. The creek meets the East Fork about 330 feet downstream of SR 8.

Figure 7 shows a cross section of Wildcat Creek at the top of the riffle (just below the pool tail out). Low flows spread shallowly across a 26-foot-wide bed of gravel and cobble. The channel is deepest along the toe of the curving left bank. On the right bank the channel transitions onto a 19-foot-wide gravel bar. The right bank above the gravel bar is nearly vertical, and transitions onto an upland terrace that may flood during extreme events. The left bank consists of a steep scarp that transitions into a forested slope. Distinct scour marks and undercut tree roots mark Ordinary High Water on each bank. The total width at Ordinary High Water is about 49 feet, including the low flow channel and adjacent gravel bar.

Figure 8 compares typical sediment size distributions in the upstream and downstream cross sections. These were derived from bank-to-bank Wolman pebble counts taken in April 2007 at the two surveyed cross-sections. The upstream channel had a D50 of about 19 mm. All sampled material fell in the sand and gravel size classes. The downstream riffle was coarser, with a D50 of 24 mm and a broader range of size classes (from sands to large cobbles). The riffle becomes coarser downstream of the sampled section, with more cobbles and large gravels.

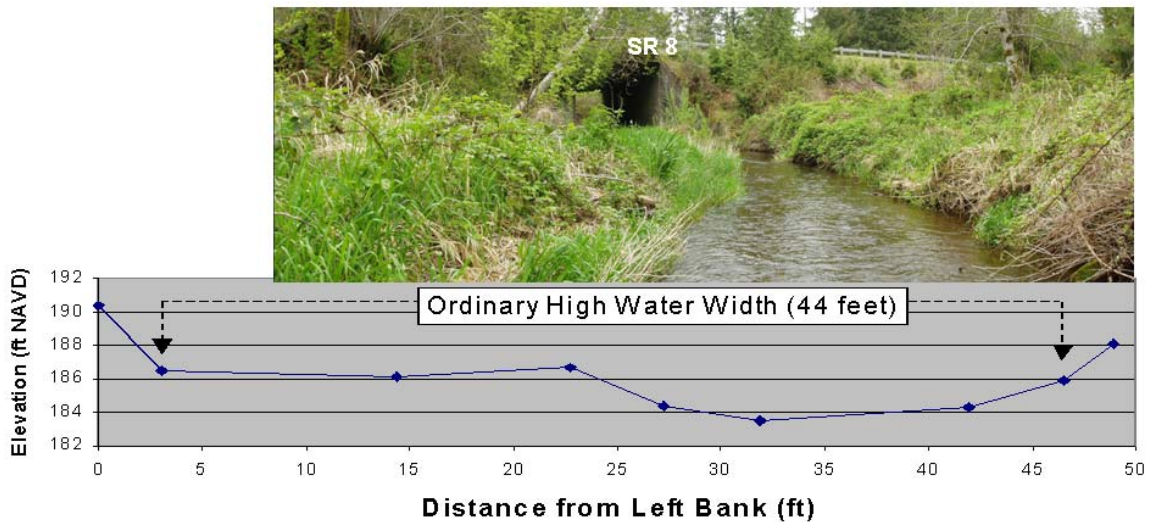


Figure 6. Cross Section of Wildcat Creek upstream of SR 8

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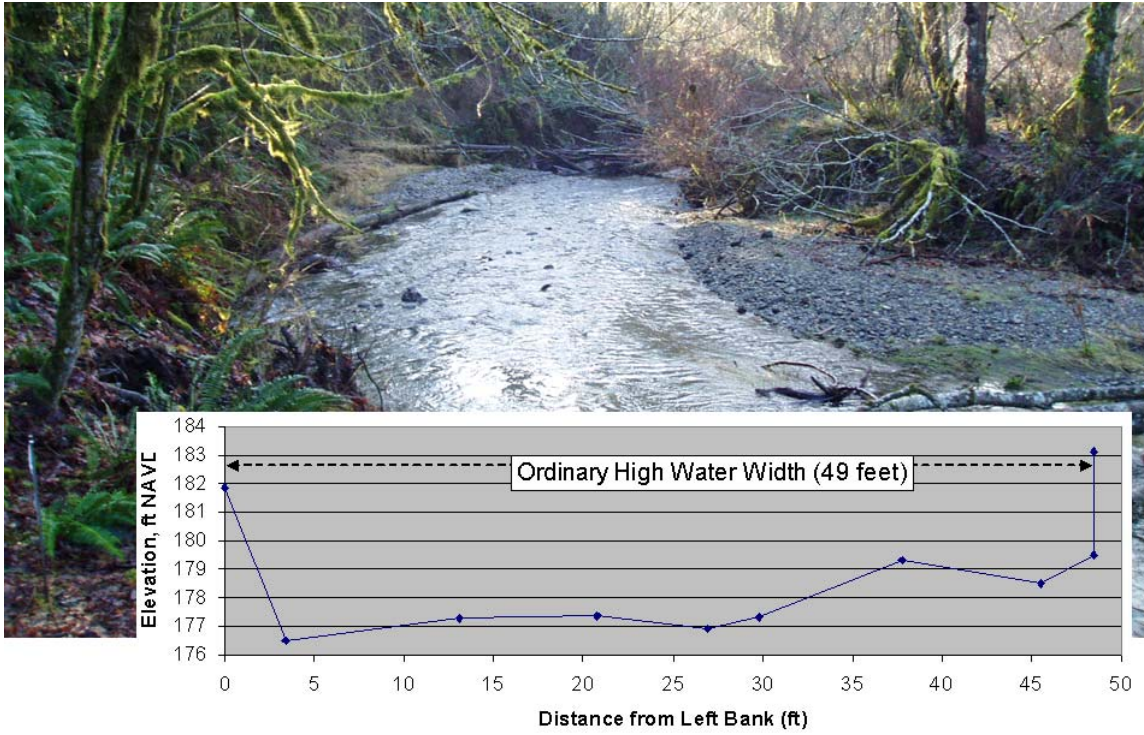


Figure 7. Cross Section of Wildcat Creek downstream of SR 8

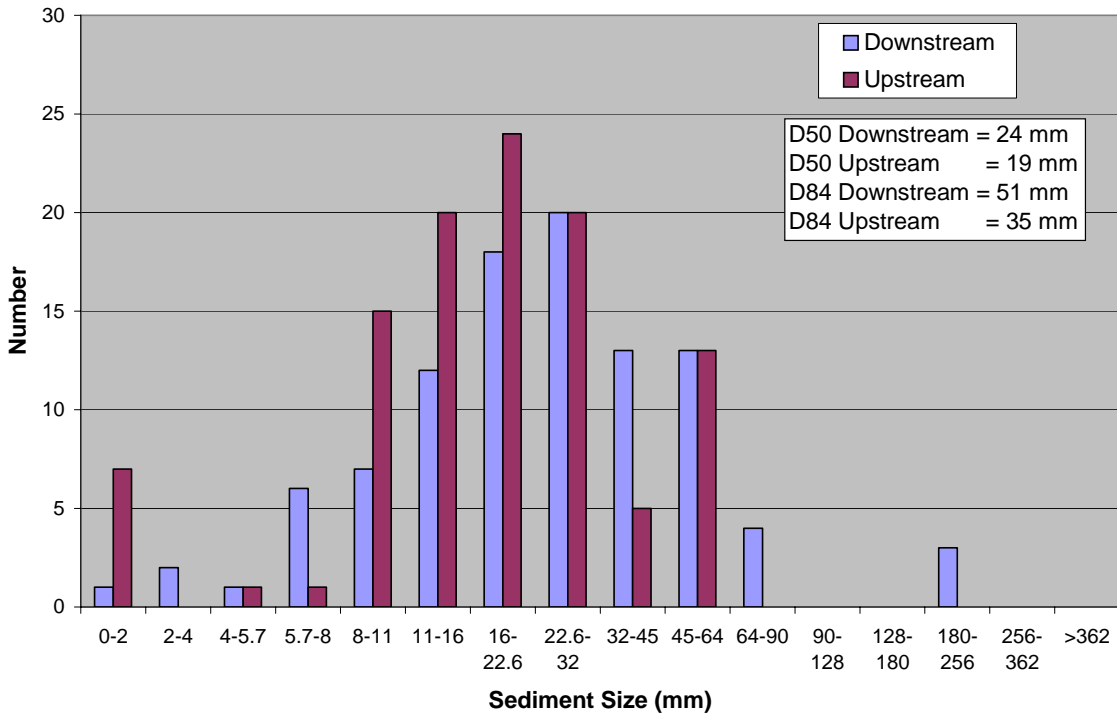


Figure 8. Sediment Size Distributions in the Wildcat Creek Channel

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Riparian Habitat

WSDOT photos of riparian conditions prior to 2005 show deciduous trees growing just outside the Ordinary High Water (OHW) level providing shade and cover on both banks. Native herbaceous plants covered the creek banks and portions of the streambed below the OHW, providing overhanging refugia areas.

The 2005 culvert repair removed all vegetation below the OHW from both banks between the culvert outlet and the WSDOT right-of-way boundary (57 feet below the outlet). Clearing for construction access also removed all riparian trees from a 50-foot wide by 150 foot stretch of left bank. Shade at the site is currently fair, primarily because of cover provided by the remaining trees on the right bank and riparian forest downstream of the repair. The riparian forest in these areas consists of 40 percent conifers (western red-cedar and Douglas-fir) and 60 percent deciduous shrubs and trees (big leaf maple, black cottonwood, and alder).

Aquatic Conditions

The 2001 Bridge inspection photos show a culvert bed and outlet dominated by concrete rubble and large boulders, thought to be early attempts at a roughened channel. This coarse substrate provided no habitat for spawning. The culvert confined flow, leading to high velocities that probably impaired fish passage within the culvert.

Changes in the culvert bed after the 2005 repair have not improved fish passage. Boulder drop structures at the outlet have settled and lost fine bed material, lowering pool levels and creating drops greater than the 0.8-foot maximum allowed for passage of chum and adult trout.

Immediately downstream is a large, approximately four foot deep scour pool which transitions into a long riffle composed of cobble, gravel and a large amount of fines, which is not preferred spawning habitat for chum, steelhead, coho or cutthroat. During a site visit on June 25, 2007 with WDFW, there were coho fry rearing in this pond. The WDFW biologist also noted the pool creates ideal conditions for poaching chum that can't negotiate the fish barrier. Immediately downstream of the tailout were some scour holes with woody debris above them that would serve as cutthroat holding and rearing areas. Mid-stream in this area, 50 feet downstream of pool could serve as chum and steelhead spawning areas after a good winter flush, there are currently too many fines in the substrate; the eggs would be suffocated. About 100 feet downstream is a natural logjam, immediately downstream of that is ideal chum spawning habitat.

Coho and cutthroat fry were observed rearing in pools at the inlet to the culvert which then went into a continuous riffle that would be used for spawning of chum if access were given. According to WDFW the county road bridge located upstream is currently not a barrier to fish passage.

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Reach Assessment

This reach assessment focuses on the Middle Fork Wildcat Creek from its confluence with the East Fork to a point about 1200 feet upstream of Elma – McCleary Road. We also examine watershed-scale conditions where appropriate.

Watershed Conditions and Land Cover

The Middle Fork of Wildcat Creek drains 5.77 square miles, and joins the East Fork just downstream of SR 8 (Figure 9). Wildcat Creek then parallels SR 8 for several miles before entering the lower reaches of Cloquallum Creek. Cloquallum Creek flows into the Chehalis River near Elma, and is in the Lower Chehalis Watershed Resource Inventory Area 22.

The watershed begins on hillslopes covered by private timberland. The lower half of the watershed transitions onto a relatively flat plain covered by rural residential and agricultural uses. The City of McCleary spreads over much of the East Fork and portions of the Middle Fork basin. Land cover in the Cloquallum basin (including Wildcat Creek) consists of 89 percent Forest, 3.2 percent Agriculture, two percent Urban, and 5.8 percent other (Envirovision, 2000). Over 73 percent of the land cover is considered to be “hydrologically immature” (Washington State Conservation Commission, 2001).

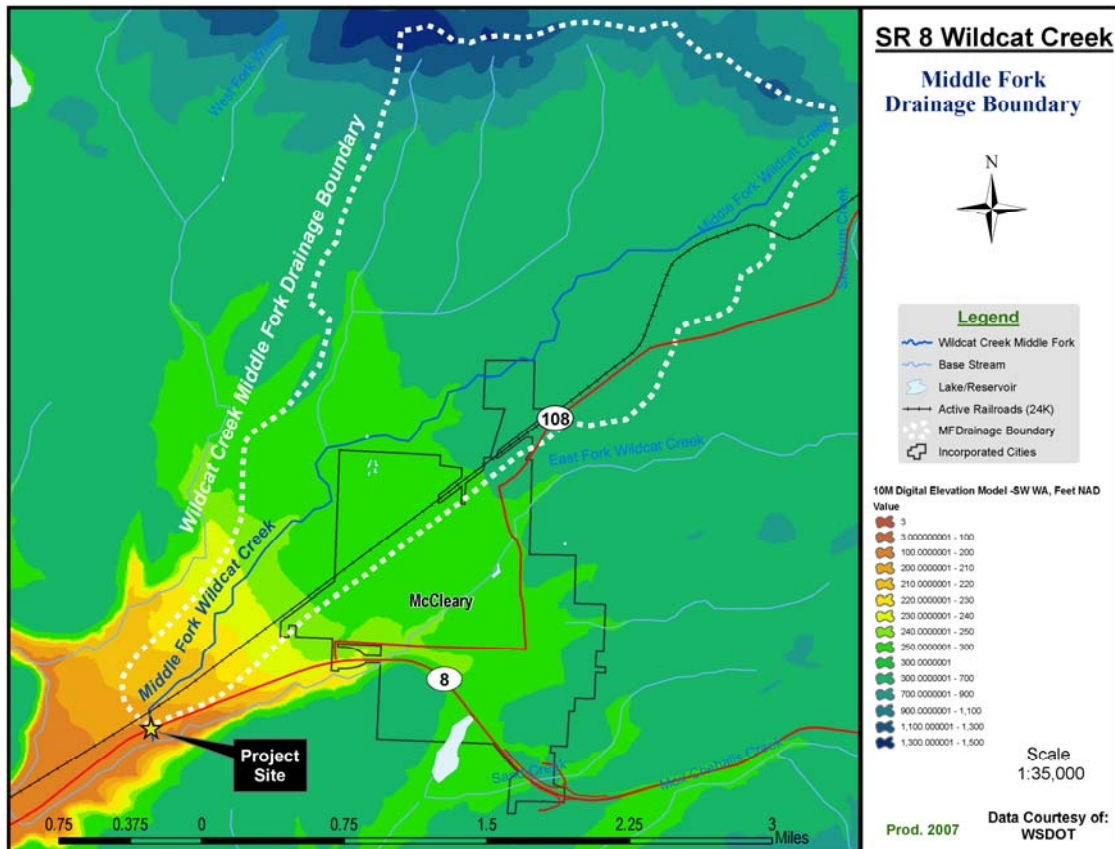


Figure 9. The Middle Fork Wildcat Creek Watershed

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Geology and Soils

The Middle Fork of Wildcat Creek begins in hills underlain by basalt and marine sedimentary rock. The creek and its upper tributaries emerge from these hills onto a plain of continental glacial outwash deposited by Fraser-age meltwater (Figure 10). At SR 8 the creek spills off the outwash plain and transitions onto alluvial deposits associated with the East Fork and mainstem of Wildcat Creek. A test hole drilled near the SR 8 culvert shows silty and sandy gravel down to a depth of more than 38 feet (WSDOT, 2007).

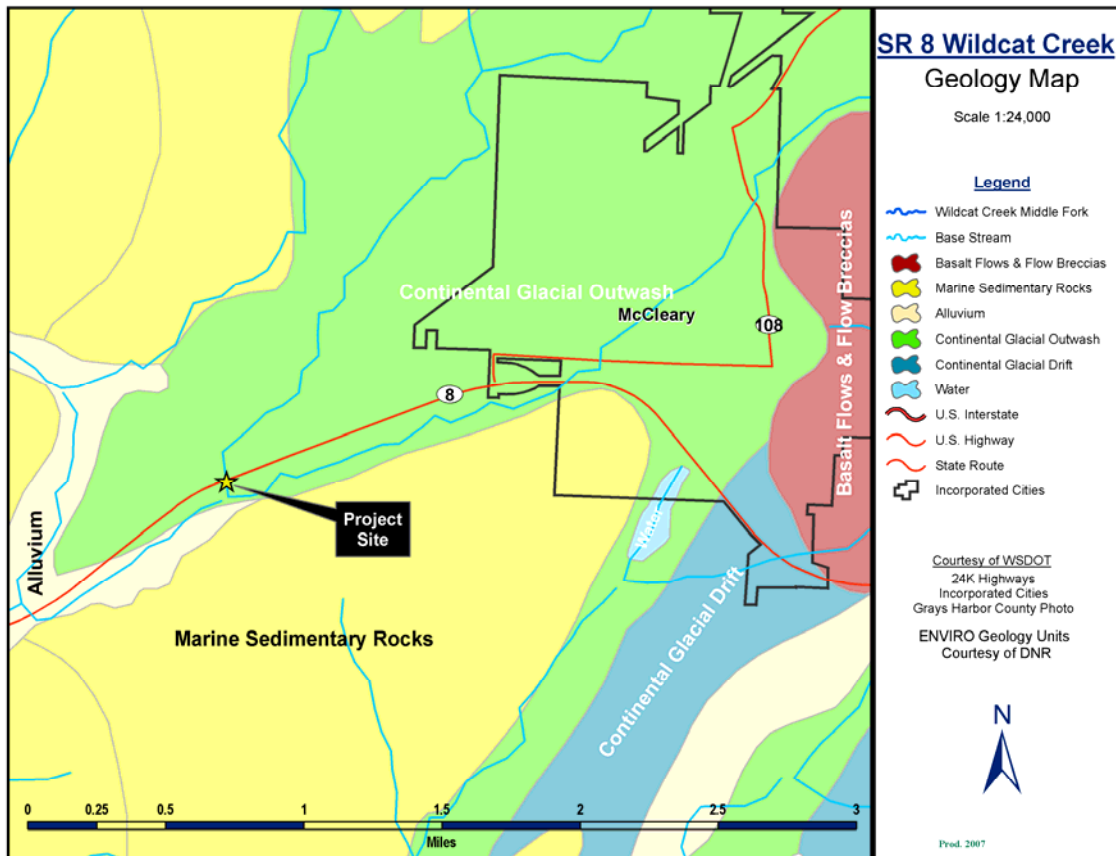


Figure 10. Geology of the Middle Fork Wildcat Creek Watershed

Soils in the lower reaches of the Middle Fork reflect its glacial history. The project site and most of the lower basin are covered by gravelly sandy loams derived from glacial till and outwash (USDA, 1979). The upper layers of the soil have very rapid permeability, but are underlain by dense glacial drift that perches water in the winter and spring. Further upstream the creek flows through deep, well-drained gravelly loams that form on glacial outwash terraces.

Hydrology

The Wildcat Creek basin receives an average of 70 inches of annual precipitation, mostly as rain. Outwash deposits in the lower half of the basin have rapid infiltration rates. Most

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stormwater runoff is therefore produced from the shallow soils in the headwaters, and from paved and compacted surfaces in developed portions of the lower watershed.

The coarse glacial deposits that underlie the Wildcat Creek basin contain a sole-source aquifer that is an important water source for the City of McCleary and surrounding rural areas. Groundwater in this aquifer is likely in direct connectivity to surface flow in Wildcat Creek, and flows from the northeast down the Middle Fork valley towards the Middle Fork/East Fork confluence (Hart Crowser, 1994). This groundwater provides an important source for dry-weather flow in the stream.

There is little historic stream gauging information in the Wildcat Creek basin. Table 1 summarizes peak flows estimated using USGS regression equations (Sumioka et al., 1998). Ten percent exceedance fish passage flows were estimated using regression equations from the Washington State Department of Fish and Wildlife (WDFW, 2003).

Table 1. Peak flood flow statistics for Middle Fork Wildcat Creek at SR 8.

Event	Flow estimated by regression equation (cfs)	Flow estimate plus one Standard Error (cfs)
2-year	342	452
10-year	530	705
25-year	626	839
50-year	706	961
100-year	790	1083
January Fish Passage Flow	131	165
May Fish Passage Flow	33	43

In some cases WDFW recommends adding a standard error of 26 to 31 percent to the estimated fish passage flows to account for uncertainty in the regression equations. We compared regression estimates to gage records at several nearby USGS flow gages. Regression estimates for Cloquallum Creek and the East Fork Satsop were slightly higher than the measured January 10 percent exceedance flows. Estimates at Kennedy Creek were only 4.5 percent lower than the measured flows. We therefore recommend using the regression estimates directly for fish passage design in Wildcat Creek, without adding the standard error.

Historical Channel Alterations

The Wildcat Creek basin has a long history of channel alterations to accommodate logging, agriculture, and roads. Splash dams were used to transport logs in the early 1900s (Washington State Conservation Commission, 2001). Scour from splash dams has contributed to channel incision, low levels of Large Woody Debris, and loss of channel complexity.

In the early 1960s Wildcat Creek was extensively modified above and below the Middle Fork confluence to accommodate SR 8 (Thompson, 2004). During highway construction it was straightened and realigned into a new channel that parallels the southern edge of the highway right-of-way boundary. The creek was reconstructed as a trapezoidal channel with rock-lined banks. WSDOT continued to clear the channel and remove woody debris

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until 1995. Much of the original riprap is now covered by vegetation or has fallen into the stream.

Historical Channel Migration

Figure 11 compares channel alignments shown in aerial photos from 1966, 1981, and 2005. In 1966 the creek corridor still showed the impacts of highway construction, when most riparian areas below SR 8 were cleared of mature vegetation. Tree cover in later photos obscures much of the channel, but there is no evidence that the Middle Fork has migrated substantially from its 1966 alignment. Similarly, the East Fork upstream of the confluence is completely obscured by trees and shows little active channel movement or gravel bar growth. This indicates that both forks upstream of the confluence are incised into glacial deposits.

Wildcat Creek below the Middle Fork confluence shows more significant changes. This channel shows extensive sedimentation and gravel bar formation in several meander bends. These bends have responded by migrating westward/downstream. Reaches below the confluence flow less steeply through alluvial deposits, and have become deposition zones that are reshaping the artificial channel created during highway construction.

Channel Profile and Sediment Transport

The Middle Fork begins in steep hills about 6 miles upstream of its mouth, and flows steeply for about one mile before emerging onto a plain of glacial deposits. The creek flows across this plain at an overall gradient of about 0.6 to 0.7 percent. The lower valley profile generally consists of a series of flatter steps (0.2 to 0.4 percent gradient) connected by steeper segments flowing at about one percent gradient (Figure 12). The project reach is located in a steeper segment that begins about 1200 feet above Elma -McCleary Road and approaches the SR 8 culvert at a slope of about 1.1 percent. This gradient creates a plane-bed channel with rapid, shallow flow over gravels and cobbles.

The Middle Fork has eroded substantially from its mouth to the SR 8 culvert outlet, exposing footings that were originally buried by several feet of streambed material. Channel alternations during construction of SR 8 may have artificially lowered the Wildcat Creek bed, causing the Middle Fork to incise and headcut up from the confluence. The SR 8 culvert is a key control point in the profile of the Middle Fork, preventing this headcut from progressing upstream. There are several structures immediately upstream of SR 8 that could be undermined by a progressive headcut, including the Elma – McCleary Road bridge and the adjacent railroad trestle.

Water Quality

The Middle Fork of Wildcat Creek is not on the State 2004 303(d) list of impaired waters (Washington State Department of Ecology, 2007). Segments of the East Fork and the mainstem are listed for high water temperatures and low dissolved oxygen levels, and are covered by a Total Maximum Daily Load (TMDL) study for Simpson Timber.

The McCleary wastewater treatment plant discharges into the East Fork of Wildcat Creek. Excessive nitrogen and phosphorus loadings have in the past caused eutrophication in the creek. A TMDL was approved in 1993 for chlorine, fecal coliform, ammonia-N, and BOD, and a subsequent upgrade of the plant has eliminated many of these problems.

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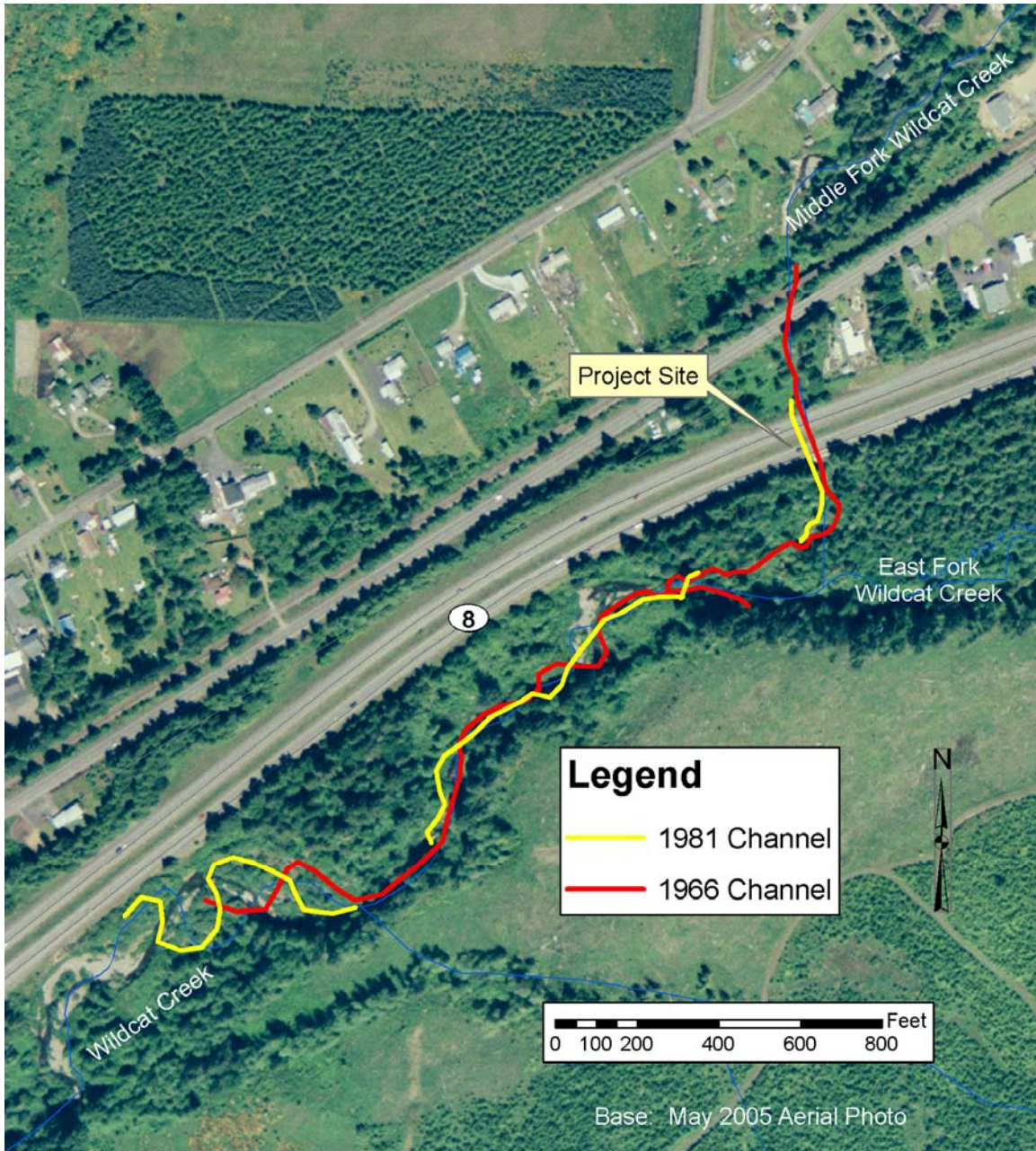


Figure 11. Channel Alignments shown in Historical Aerial Photos

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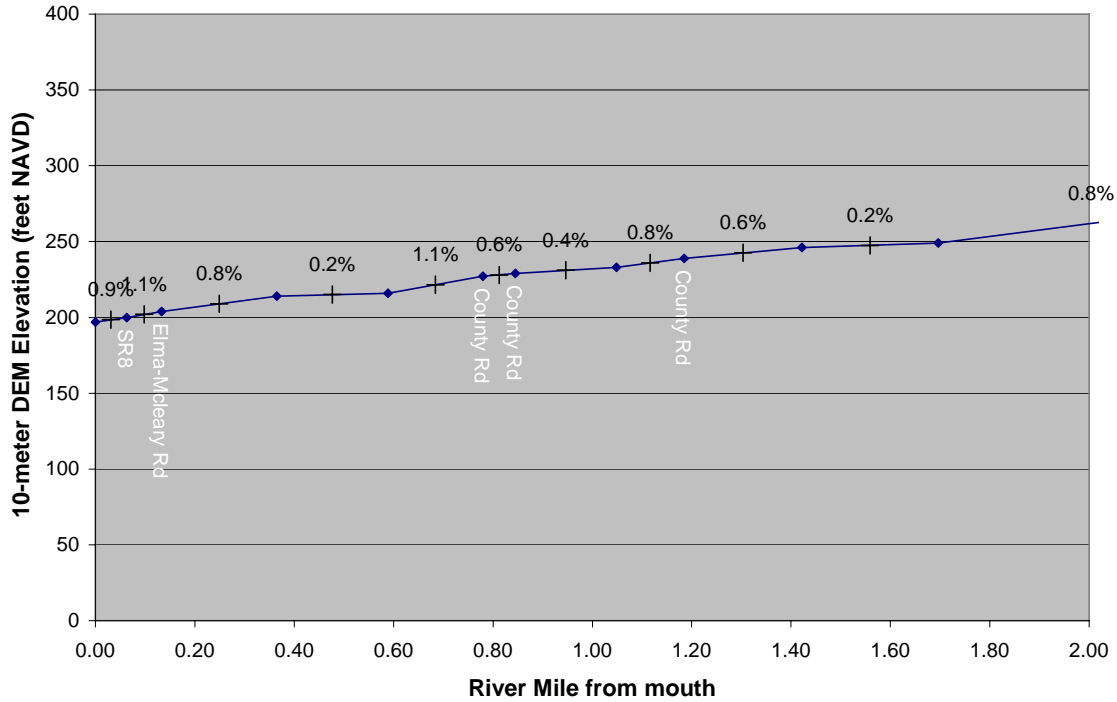


Figure 12. Profile of the Lower Middle Fork Wildcat Creek Valley

Riparian Conditions

Aside from scattered remnant trees which offer no shade the riparian area within 50 feet of the creek banks has been cleared between Elma – McCleary Road and the SR 8 culvert inlet. Reed canary grass and Himalayan blackberry cover streambanks and floodplains immediately upstream of the culvert. . The Limiting Factors Analysis for the Chehalis Basin rated riparian conditions in Wildcat Creek as “poor” (Washington State Conservation Commission, 2001). The Wildcat Creek riparian corridor was cleared during construction of SR 8 in the 1960s. Portions of the corridor have since regenerated with alders and scattered conifers. 1988 photos show riparian conditions along Wildcat Creek up to McCleary as 17 percent intact, 71 percent altered, and 12 percent absent (Envirovision, 2000).

Large Woody Debris

A railroad trestle bridge just upstream of Elma – McCleary Road has a large impact on the recruitment of Large Woody Debris (LWD). According to the local WDFW Area Habitat Biologist the rail owner/operator has a Hydraulic Project Approval to remove the LWD from the upstream side of the bridge and place it downstream. However, we have not observed significant LWD recruitment between the railroad trestle and SR 8. In January 2007 a pair of fallen trees spanned the channel below the culvert outlet pool, and a small logjam spanned the channel at the downstream end of a riffle in the next downstream meander bend.

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WSDOT cleared riparian areas in the 1960s, and regularly removed woody debris from Wildcat Creek along SR 8 until 1995. Woody debris and logjams made up of alders and smaller conifers now accumulate in the channel as the riparian forest recovers, but large trees are mostly absent.

Fish Utilization and Habitat Availability

The Middle Fork of Wildcat Creek hosts runs of coho, winter steelhead, fall chum, and coastal cutthroat trout (Figure 13). Figure 14 summarizes the timing for migration, spawning, rearing, and inter-gravel development of the fish species that occur in the basin. Coho and winter steelhead spawn throughout the lower reaches and into the headwaters. Fall chum spawn in the lower reaches of the creek. Fall Chinook are found in the East Fork and mainstem of Wildcat Creek up to and above the mouth of the Middle Fork. None of these species are endangered or threatened in the Chehalis basin (see Table 2).

Table 2. Salmonid Stock Status in the Middle Fork Wildcat Creek Basin.

Species	Primary Utilization	SASI Status	ESA Status
Coho (<i>Oncorhynchus kisutch</i>)	Spawning	Healthy	Not Warranted
Winter steelhead (<i>O. mykiss</i>)	Spawning, Migration	Healthy	Not Warranted
Fall Chum (<i>O. keta</i>)	Spawning	Healthy	Not Warranted
Coastal cutthroat trout (<i>O. clarki clarki</i>)	Unknown	Not Rated	Federal Species of Concern

The Limiting Factors Analysis for Salmon and Steelhead in the Chehalis Basin rated the Cloquallum basin (which includes Wildcat Creek) as a medium-priority area, and recommended the following restoration actions (Washington State Conservation Commission, 2001):

- Reconnect potential off-channel habitat and restore wetlands.
- Reduce bank armoring.
- Increase instream LWD to help address channel incision and flow issues.
- Correct high impact road sediment delivery problems via push-outs, cross drains, and sediment traps etc.
- Reduce livestock access
- Reduce roads and logging activities in sensitive areas near stream.
- Plant trees in open areas, conifers in hardwood stands to improve riparian conditions
- Reduce surface water withdrawals
- Increase aquifer recharge and improve hydrologic maturity.

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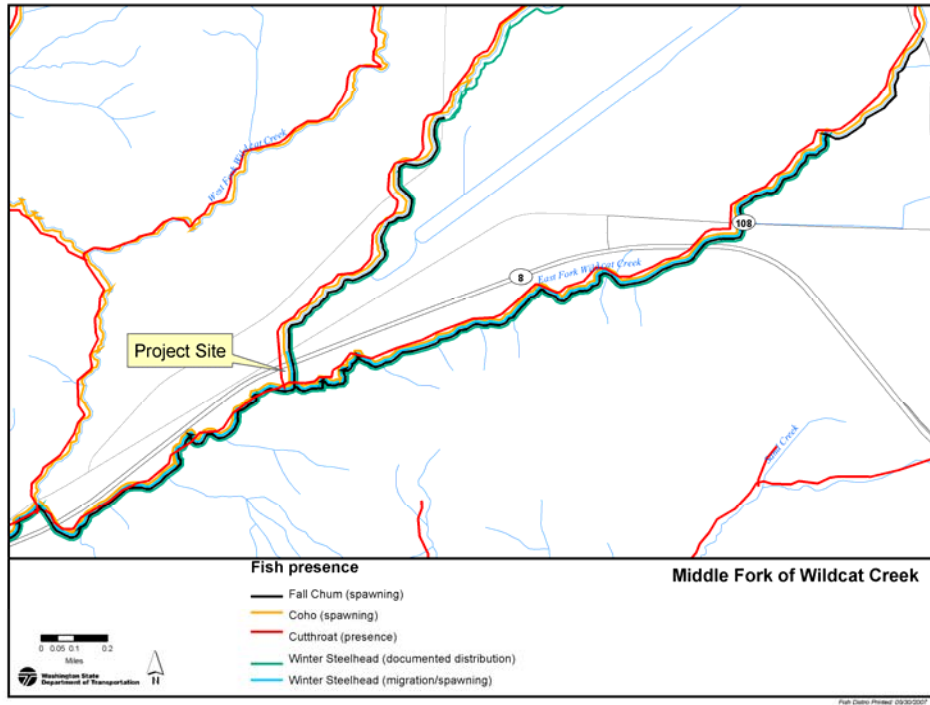


Figure 13. Fish Usage in the Wildcat Creek Basin

Species	Freshwater lifestage	Month												
		J	F	M	A	M	J	J	A	S	O	N	D	
Coho	Upstream migration													
	Spawning													
	intragravel development													
	rearing													
	Juv. outmigration													
Winter steel	Upstream migration													
	Spawning													
	intragravel development													
	rearing													
	Juv. outmigration													
Fall Chum	Upstream migration													
	Spawning													
	intragravel development													
	rearing													
	Juv. outmigration													
Coastal cutthroat trout	Upstream migration													
	Spawning													
	intragravel development													
	rearing													
	Juv. outmigration													

Figure 14. Timing of Fish Life Stages in the Wildcat Creek Basin

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Evaluation of Treatment Alternatives

Treatment alternatives that could address the mechanisms and causes of failure are described and analyzed below. Tables 3 and 4, starting on the next page, summarize pros and cons, relative costs, and risks associated with each alternative.

Mechanisms and Causes of Failure

The mechanisms of failure are scour and streambed erosion at the culvert outlet. This has undermined culvert foundations and created elevation differences that limit fish passage. High velocities at the outlet also scour out fine materials from interstitial spaces in the drop structures, causing dewatering and fish passage problems at low flows. The root causes of scour and streambed erosion include:

- Flow constriction in the culvert that creates high velocities at the outlet
- Channel incision in downstream reaches arising from historical channel alterations and hydrologic changes in the watershed. This channel incision has progressed up from the mouth of the Middle Fork to the SR 8 culvert.

Project Objectives

To the extent practicable, treatment alternatives should meet the following objectives:

- Ensure the safety and integrity of the structure.
- Provide fish passage for chum, coho, winter steelhead, and cutthroat trout. The maximum hydraulic drop allowed in fish passage structures for chum and adult trout is 0.8 feet (WDFW, 2003).
- Minimize the need for repairs to stabilize and protect the bridge/culvert foundations
- Avoid increases in flood risks to infrastructure and properties upstream and downstream of SR 8
- Avoid increases in streambed erosion that would threaten structures and properties upstream and downstream of SR 8
- Maximize natural movement of sediment, woody-debris, and water through the structure
- Minimize construction work outside of WSDOT's right-of-way. The downstream right-of-way boundary is about 57 feet from the downstream face of the bridge.
- Minimize channel maintenance outside of WSDOT's right-of-way

Alternative 1 – No Action

Description: The existing series of boulder drop structures would remain in place and control the flow of water through and out of the culvert. The existing layer of heavy loose riprap would continue to cover culvert footings.

Performance and Risks: While this alternative is protecting the structure for the short-term, it does not meet fish passage objectives. High velocities remove most material finer than boulders from interstitial spaces within the rock structures. Dewatering and settling of rock structures has created a drop of 2-3 feet at the culvert outlet.

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Table 3. Pros and Cons of Treatment Alternatives

Alternative	Pros	Cons
1. <u>No Action</u> <i>Low Cost</i>	Lowest cost Avoids short-term impacts associated with construction	Fails fish passage criteria Scour at outlet poses long-term risk to culvert foundations
2. <u>Log Sills</u> <i>Moderate Cost</i>	Provides grade control and fish passage Provides pool habitat and less risk of channel dewatering	Risk of flanking – channel is wider than preferred for log sills Extensive construction off right-of-way and on adjacent floodplains/streambanks High velocities and scour at outlet could undermine log sills
3. <u>Roughened Channel</u> <i>Moderate Cost</i>	Provides grade control and fish passage Avoids excavation on adjacent floodplains	Risk of channel dewatering if fine material is eroded Extensive construction off right-of-way Technique requires specialized engineering to properly size channel and substrate
4. <u>Fish Ladder</u> <i>High Cost</i>	Provides grade control and fish passage (if maintained properly and problems with energy dissipation are resolved) Minimal construction off the WSDOT right-of-way	Difficult to meet energy dissipation criterion for fish passage without unrealistic pool depths Frequent maintenance needed to remove sediment and maintain pool depths High engineering and construction costs
5. <u>New Bridge</u> <i>Very High Cost</i> Recommended long-term solution	Resolves high velocities caused by flow constriction Restores natural movement of debris, sediment, fish, and water Minimizes risk to structure foundations	Highest cost Grade control needed to limit upstream progression of streambed erosion and possible damage to upstream structures

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Table 4. Risk Analysis of Treatment Alternatives.

Failure Mode	Consequences	Likelihood				
		1. No Action	2. Log Sills	3. Roughened Channel	4. Fish Ladder	5. New Bridges
Excessive hydraulic drop at outlet	Fails to meet fish passage criteria	Very High	Low	Low	Low	Very Low
Insufficient energy dissipation in pools	Poor fish passage	High	Low	Low	Very High	Very Low
Scour undermines culvert wingwalls	Structural failure, in-channel repair	Moderate	Low	Low	Very Low	Very Low
Streambed erosion progresses upstream	Damage to upstream structures	Moderate	Low	Low	Very Low	Low
Scour removes fine bed material	Channel dewatering, poor fish passage	Very High	Low	Moderate	Very Low	Very Low
Sediment fills pools	Maintenance costs, poor fish passage	Very Low	Very Low	Very Low	Very High	Very Low
Erosion flanks or undermines channel structures	In-channel maintenance, property damage, poor fish passage	Moderate	Moderate	Low	Low	Low
Channel maintenance needed off right-of-way	Need easement or right of access	Low	Moderate	Low	Low	Low

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The boulders in Structure B at the outlet are currently stable, and prevent erosion from progressing upstream. However, there has been substantial settling of boulder drop structures below the outlet, which may eventually undermine the riprap and wing wall foundations. The original shallow footings on the right bank wing wall are particularly vulnerable.

Habitat impacts: The existing structure is a barrier to fish migration, preventing access to spawning and rearing habitat in upstream reaches of Wildcat Creek. The current structure is what is left of a seven percent slope roughened channel with material that did not remain intact under high flows. The boulders do not have any holding ponds and the material that was removed by high flows has moved downstream. The no-action alternative will not allow improvements to riparian habitat, will allow continued poaching issues within the four foot pond at the base of the boulder drop where chum stack up because of the barrier, and will also allow continued bank erosion resulting from extremely high flows. The no-action alternative would avoid in-water work and associated short-term impacts to riparian and aquatic habitat.

Alternative 2 – Series of Log Sills and Pools at the Outlet

Description: The existing boulder structures below the outlet (structures C-E) would be removed and replaced by a series of log sills/weirs designed to specifications described in the WDFW culvert manual (WDFW, 2003). The sills would each create a drop of less than 0.8 feet.

Figure 15 shows the streambed profile for this alternative. Seven pools spaced 15 feet apart would step down and meet the existing streambed in the downstream riffle about 110 feet below the culvert outlet. The first log sill should be located at least 20 feet from the outlet. The series of pools would create an overall gradient of 4.5 percent from the culvert outlet to the base of the last structure. The existing streambed would be re-graded and filled to meet the more gradual profile down to the riffle. The most extensive fill would occur in the deep scour pool at the right-of-way boundary, where logs would lie 3-5 feet above the current elevation of the streambed.

The top pool would backwater and tie into a grade control structure at the culvert outlet. This grade control structure is needed to prevent erosion from progressing up the culvert bed if the downstream logs fail. The existing rock Structure B could provide this grade control, or could be replaced with a buried concrete sill to provide higher reliability. The outlet control structure should be submerged by the backwater from the first downstream log sill.

The ends of the first two log sills would be buried in heavy, loose riprap placed along the base of the culvert wingwalls and anchored to concrete blocks. This riprap would help anchor logs, and would also protect the walls if the weirs are flanked or undermined. Below the wingwall, logs would be placed in trenches in the adjacent streambanks, anchored to concrete blocks, and covered with rock and soil. Bank protection would also be needed between structures to discourage flanking.

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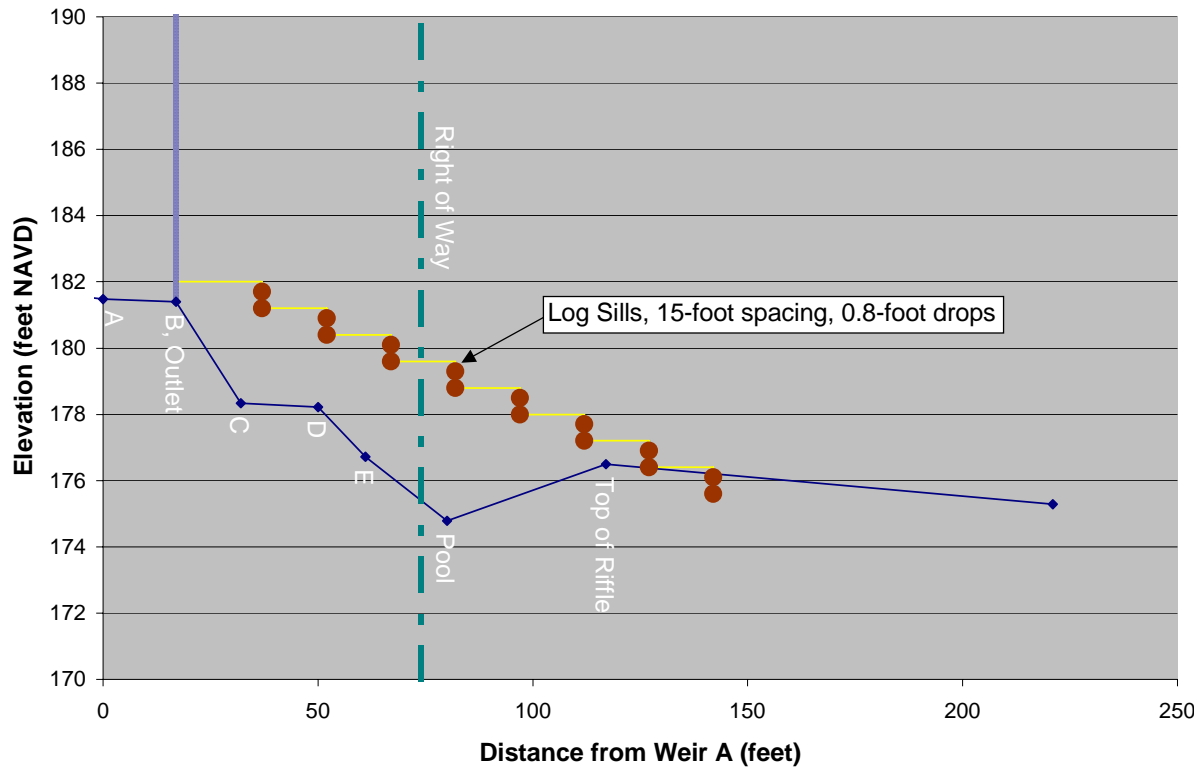


Figure 15. Streambed Profile for Log Sills (Alternative 2)

Performance and Risk: This alternative would require extensive construction work outside of the WSDOT right-of-way, both in-channel and on adjacent upland areas to anchor logs. The last structure would end at least 53 feet beyond the right-of-way boundary.

This alternative would probably require some future channel maintenance work inside and outside of the WSDOT right-of-way. Log sill structures work best with channels less than 30 feet wide (WDFW, 2003); in this case the channel toe width at the downstream riffle is about 45 feet. The widths of structures and the high energy of flow at the culvert outlet indicate a moderate risk of flanking or undermining of log sills. Flanking of the structures could cause bank erosion and damage to adjacent properties.

Habitat impacts: If this alternative performs as constructed it will improve fish passage. However, log sill structures in a wide channel and a flashy riverine system may not last and fish passage could be lost due to undermining and flanking of the structures. Construction of the log sills would require more removal of riparian vegetation (previous activities have removed it from the left bank) and more excavation into the adjacent upland along with extensive in-water work. The log structures and pools would replace about 57 linear feet of pool and rock weir habitat, 43 feet of deep pool habitat, and 25 feet of riffle habitat. If the structures fail, future channel work and maintenance would result in additional impacts to fish, aquatic habitat, and riparian habitat.

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Alternative 3 – Roughened Channel at the Outlet

Description: A new channel bed would be constructed with a linear slope from the culvert outlet to the downstream riffle. The bed would be constructed of a coarse mix of sediment that includes large rock sized to resist scour and provide hydraulic diversity. Scattered boulders would project above the streambed to create hydraulic shadows and resting places for fish as they negotiate the higher velocities in the steepened channel segment. The new channel would raise the streambed by about three to four feet in the scour pool at the right-of-way boundary. It would also bury the foundations of the culvert wingwalls. The heavy loose riprap that covers these foundations would be left in place, and could be further reinforced as long as the angular riprap is buried by new streambed material.

The top of the new channel would tie into a grade control structure at the culvert outlet that protects the culvert bed from erosion if the roughened channel fails. This grade control structure could consist of either the existing rock structure B, or a buried concrete sill tied into the culvert walls for higher reliability.

Figure 16 shows two alternative roughened channel profiles. The WDFW culvert manual recommends a maximum slope of three percent as a general guideline. However, this slope would extend the channel more than 200 feet below the culvert outlet, and would cover almost all of the next downstream riffle. Much of the roughened channel would be within a sharp bend, where flow curvature would increase risks of failure and damage to downstream properties. A steeper channel at 4.5 percent slope would end at the top of the downstream riffle and avoid the downstream bend in the channel. However, this would require a very coarse substrate (D84 of 1.3 feet) to reduce scour. The average velocity during January fish passage flows would be about 3.5 feet per second. Projecting boulders would create resting areas with significantly lower velocities.

Performance and Risks: This alternative would require construction work at least 53 feet beyond the WSDOT right-of-way. The extent of in-channel work would be similar to that required for log sills, but no excavation would be needed on adjacent streambanks and upland areas.

Roughened channels are less prone to flanking and bank erosion than log sills. To avoid the downstream bend the channel would have to slope steeper than recommended by WDFW guidelines, and would therefore have a higher risk of scour and removal of bed material. Proper design of roughened channels depends on accurate estimates of stream hydrology, hydraulics, and sediment properties. If the large elements of the channel bed are not sized properly, erosion could progress upstream and re-create the headcut that currently causes fish passage problems. Fine material could also be washed away, leading to dewatering problems similar to those that occur with the existing boulder structures.

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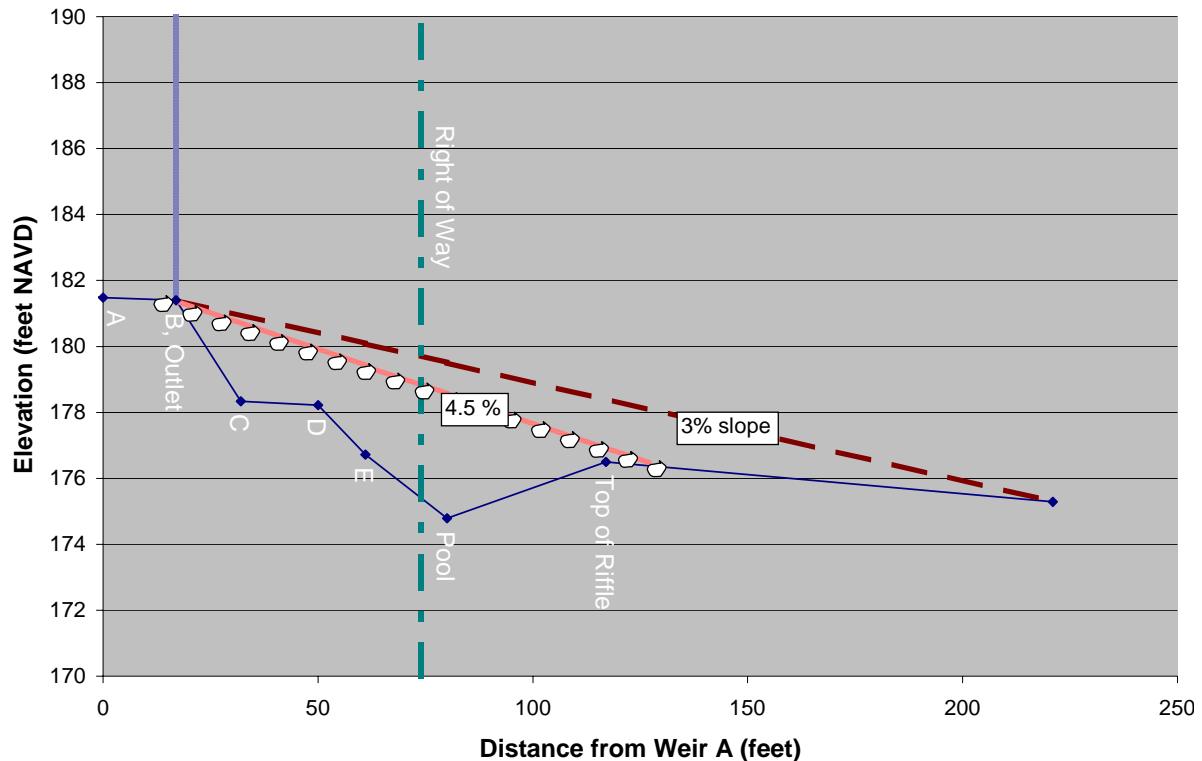


Figure 16. Streambed Profiles for a Roughened Channel (Alternative 3)

Habitat impacts: Although in-water construction is required for this alternative less riparian corridor would be impacted than with the log sill structures, resulting in more viable cover to the stream. Incorporating large woody debris to the extent practical without negatively impacting constructability would enhance the habitat functionality of the roughened channel. At a 4.5 percent slope this alternative would be fish passable and would also eliminate the holding pool at the base of the current cascade, reducing poaching opportunities. It would also avoid direct impacts to chum spawning habitat that occurs downstream of the proposed end of the roughened channel (Figure 17). The roughened channel would replace about 57 linear feet of pool and rock weir habitat, 43 feet of deep pool habitat, and 10 feet of riffle habitat.

Alternative 4 – Fish Ladder at the Outlet

Description: The boulder structures at the outlet would be removed and replaced with a concrete fish ladder, consisting of a series of lined pools and notched concrete weirs that step flow down to the natural streambed elevation near the WSDOT right-of-way boundary, 57 feet downstream of the culvert outlet. Stepping down with a maximum drop of 0.8 feet would require 6 pools with weirs spaced about 9.5 feet apart. Figure 18 shows how this alternative would alter the streambed profile.

The upstream pool would be 20 feet wide to match the existing culvert, and subsequent pools would flair out downstream to tie in to the channel banks at the right-of-way boundary. The last weir would discharge into the deep pool at the right-of-way boundary.



Figure 17. Chum Spawning Habitat in the Downstream Riffle

Each pool would have to have enough volume to dissipate energy and discourage the formation of whitewater. WDFW recommends a maximum Energy Dissipation Factor (EDF) of about 4 ft-lbs/ft³/s for fish ladders. A 20-foot-wide pool with a hydraulic drop of 0.8 feet would have to be 8.5 feet deep to meet this criterion for the January fish passage flow. Pools this deep could compromise the integrity of adjacent foundations, and would tend to fill with sediment after each storm event. This alternative is therefore not likely to meet energy dissipation requirements for fish passage without almost constant maintenance.

Performance and Risks: This alternative by design avoids placing structures outside of the right-of-way. Some construction work would still be required just downstream of the right of way boundary to re-grade the existing deep pool and tie the last structure into the downstream streambed.

Fish ladders function best in controlled systems with low ranges of flows. The weir control structures and pools have narrow operating ranges, and are difficult to design for optimal fish passage conditions under the wide range of flows that occur in natural streams. As discussed above, the short distance from the culvert outlet to the right-of-way boundary limits the pool area available for energy dissipation. This leads to pool depth requirements that will be difficult to construct and impractical to maintain.

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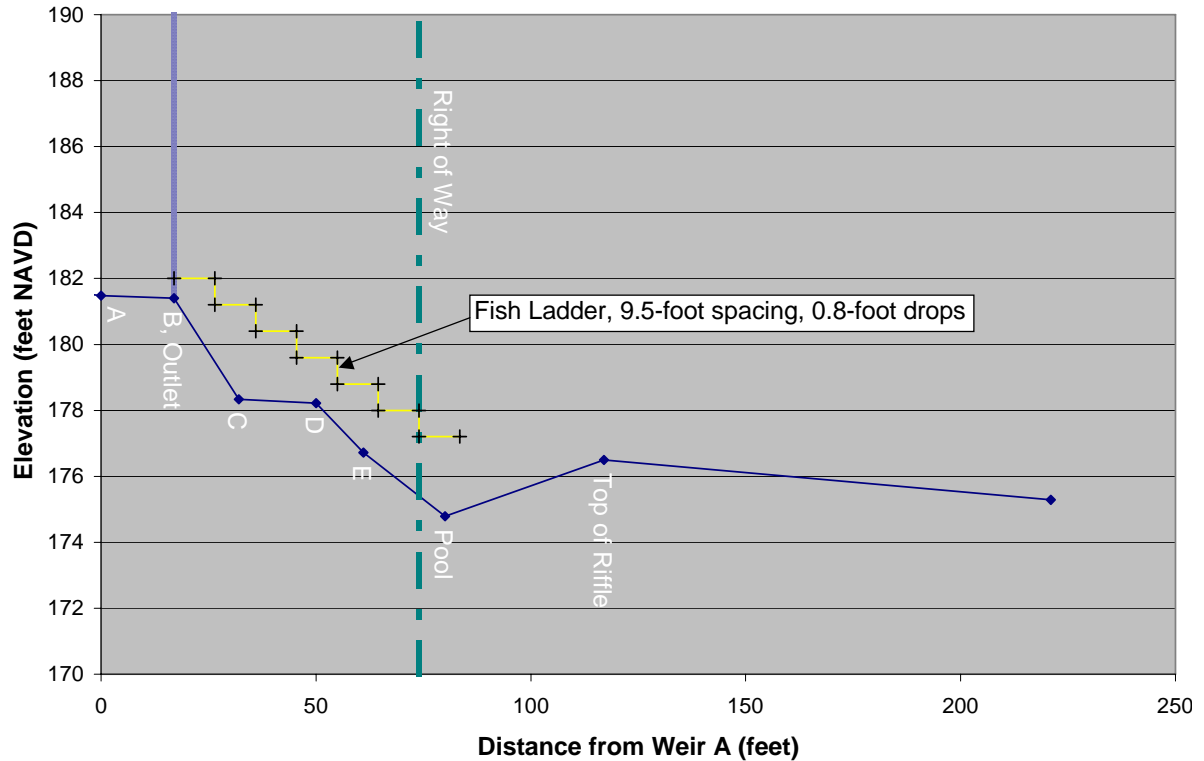


Figure 18. Streambed Profile for an Outlet Fish Ladder (Alternative 4)

A list of pool-chute fishways compiled in 2000 had an average cost of about \$50,000 per pool. This adjusts to about \$100,000 per pool to account for inflation and variability in construction conditions. A six pool fishway would therefore cost at least \$600,000.

Habitat impacts: A fish ladder is ecologically sterile, offers no habitat benefit, and provides no potential for recovery. The pools would require in-water sediment removal on a regular basis resulting in turbidity of the water. The turbidity will settle out downstream impacting spawning gravels and possibly in-gravel development. Construction of this structure would avoid most damage to existing riparian vegetation because it would mostly occur within the area impacted by the previous repair. The fish ladder would replace about 57 linear feet of pool and rock weir habitat.

Alternative 5 – New Bridge

Description: The entire SR8 culvert would be replaced with bridges that meet WDFW stream simulation criteria. The streambed would be re-graded beneath the structures to create a stable gradient that allows fish passage. Bridge footings would be placed below anticipated scour depths.

Measured widths at Ordinary High Water range from 44 to 49 feet upstream and downstream of the bridge. An effective span of 61 feet would therefore meet stream simulation requirements for fish passage.

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Performance and Risks: This alternative would reduce flow confinement and allow the natural movement of sediment and wood through the system. Without grade control, it could also allow downstream channel incision to progress and threaten upstream bridges and properties. Figure 19 shows how grade control structures could be used to control the streambed profile in this reach. Log sills spaced 30 feet apart would control the gradient within the WSDOT Right-of-Way at about 2.4 percent, and limit the risk of progressive incision that would harm upstream properties. This relatively long spacing and a more gradual profile would considerably reduce erosion and flanking risks for these log structures (in comparison to the log sills used in Alternative 2 above).

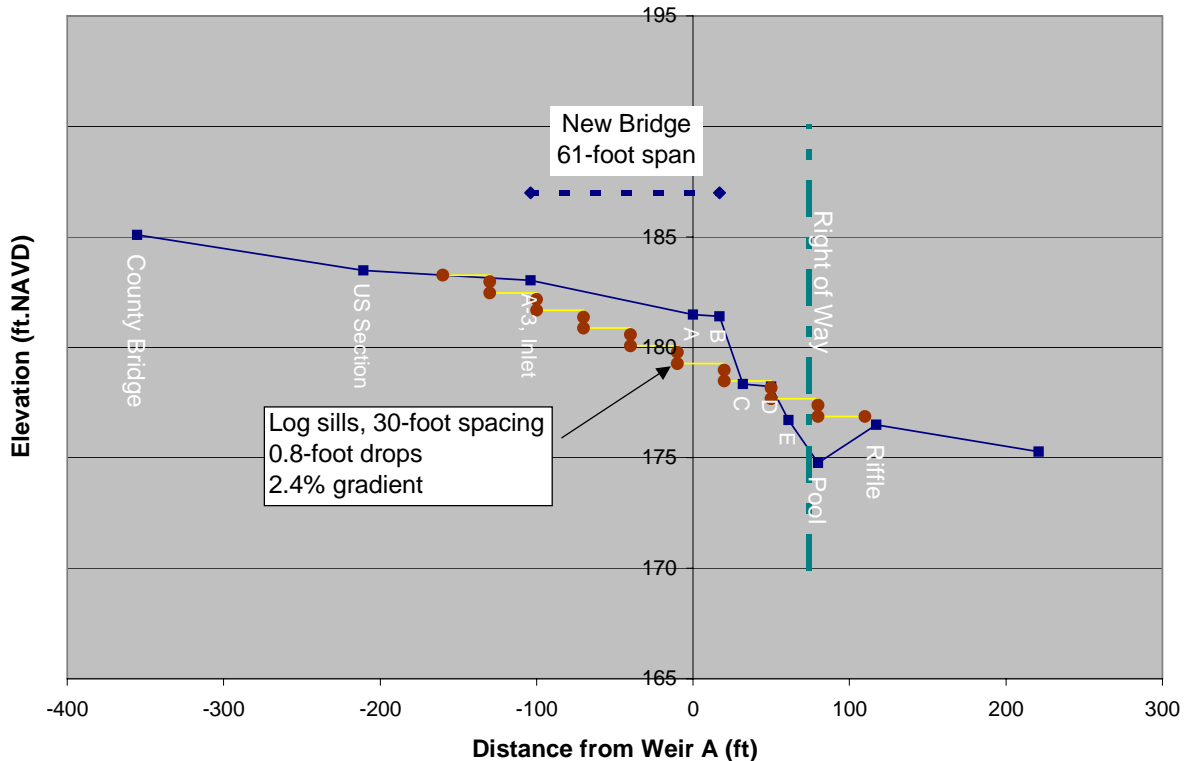


Figure 19. Streambed Profile for a New Bridge (Alternative 5)

Habitat impacts: A bridge would eliminate the need for in-water maintenance of another structure and would also eliminate the undermining, flanking and material loss of log sills or a 4.5 percent slope roughened channel. Fish passage would be completely restored with little to no chance of becoming a barrier in the future. Although riparian vegetation will be greatly impacted by construction of the bridge this is a short term impact with a long term fix that would allow complete reestablishment of a riparian corridor resulting in a shaded stream and low water temperatures. The regrade of the stream to the right-of-way will reduce or eliminate the four foot pool and therefore the easy poaching of fish holding in that area.

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Recommended Alternatives

The existing culvert is functionally obsolete, and will eventually need to be replaced. We therefore recommend a new bridge (Alternative 5) as the long-term solution to erosion and fish passage problems. This is the only alternative that fully addresses flow constriction and high velocities caused by the culvert, and restores natural movement of wood, water, sediment, and fish beneath the highway. Footings for the new bridge would be placed well below the potential scour depth, greatly reducing risks to the structure. Grade control structures may be needed beneath the bridge to reduce the risk of progressive streambed erosion and damage to upstream structures and properties.

All of the alternatives for grade control and fish passage at the existing outlet involve significant risk of failure. If an interim solution is required prior to bridge replacement, we recommend a roughened channel with a linear 4.5 percent slope (Alternative 3). This is steeper than normally recommended, but involves less risk of flanking and lower impacts to adjacent streambanks than log sills (Alternative 2). A fishway that stays within the WSDOT right-of-way (Alternative 4) will be difficult to construct and will not function properly without almost constant sediment removal.

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