Site and Reach Assessment
SR 410 American River
Hells Crossing Bridge 214, Yakima County

Work Order MS5454

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Executive Summary

Washington State Highway 410 (SR 410) east of Chinook Pass in Yakima County is a rural collector distributor highway. It is a seasonally significant route over the Cascade Mountains connecting densely-populated Western Washington with the agricultural centers in the Naches and Yakima River valleys. The 410/214 bridge, also known as “Hells Crossing,” is located at an elevation of 3340 feet. The river and bridge are both located in a subalpine glacially-carved valley. At the bridge the American River transitions from a broad U-shaped valley upstream to a V-shaped cross section downstream of the bridge. Upstream the floodplain width is approximately 1300 to 2000 feet, while downstream the floodplain widths narrow to the 200 to 300 foot range.

The valley walls adjoining the American River floodplain are very steep, being situated between Fifes Ridge and American Ridge, two major mountain ranges in the region. The headwaters of the American River are at American Lake, located at an elevation of 5260 feet within the William O. Douglas Wilderness Area in the Mount Baker-Snoqualmie National Forest.

Bridge number 410/214 is a concrete slab structure 150 feet long and 34 feet wide, with three piers. Built in 1989, it spans the American River at milepost 83.5 next to the US Forest Service (USFS) Hells Crossing Campground. At the 410/214 bridge the American River is a 4th order stream with 70 square miles of contributing area, all of which are in alpine or subalpine terrain. The American River runs beneath the bridge at river mile 6.0 and discharges into the Naches River system at river mile 30. The 410/214 bridge receives highly variable seasonal stream flows due to its elevation, rain-on-snow events, and spring snowmelt. The mid-span pier is angled to parallel the main flowpath of the river. There are two concrete spread footings that have been heavily armored by rock due to scour holes that formed shortly after the bridge’s construction. Woody debris accumulations may be altering the hydraulics of the stream channel to create localized regions of high shear stresses that may influence the scour problem.

The reach assessment describes the riverine and geomorphic processes upstream and downstream of the project site that influence the long-term stability of the 410/214 bridge and its approach structures. USGS gaging station 12448500 is located just upstream of the American/Bumping River confluence at river mile 0.5 and provides the hydrologic information needed to develop the reach assessment.

The site and reach assessments are prepared following guidance provided by Chapters 2 to 5 of the Integrated Streambank Protection Guidelines or “ISPG” (Aquatic Habitat Guidelines Program, 2003). The ISPG site/reach assessment is consistent with the Level 1 geomorphic assessment described in FHWA’s HEC 20: Stream Stability at Highway Structures, 3rd edition. ISPG is primarily a methodology for problem identification and alternatives analysis. It has no legal or regulatory standing in itself. It is used in this analysis to provide a standardized methodology and terminology for the analysis.
Introduction

This report presents a site and reach assessment for the 410/214 Hells Crossing Bridge (hereafter referred to as the 410/214 bridge) bank erosion project. The 410/214 bridge is located from MP 83.47 to 83.49, 14.26 highway miles to the east of Chinook Pass (see Figure 1). SR 410 between Chinook Pass and the 410/214 bridge is a rural unlimited access highway that lies entirely in alpine and sub-alpine terrain within the Mt. Baker-Snoqualmie National Forest. SR 410 is aligned in the floodplain and parallels the American River from USFS Lodgepole Campground at MP 76.7 to the 410/214 bridge at MP 83.5. Aside from some mining claims, a few seasonal residences, and USFS campgrounds along the American River, the upstream watershed is undeveloped and has very little potential for development because of its location in a National Forest and the American River’s status as a wild and scenic river. Most visitation of the American River valley is for summer recreation and fall hunting seasons. SR 410 is closed throughout the winter due to avalanche danger near Chinook Pass and generally opens in May.

The name “Hells Crossing” refers to the difficulty crossing the American River with pack animals in the early 20th century, while working mines in the Sunshine Mining District in the Morse Creek drainage near Chinook Pass. According to one early report, it "...was a bad one for packers and for freighters hauling to the mines; large boulders in the ford made bad footing for horses; even when shod they would slip off the rocks and founder. Later there were two crossings which were both quite difficult” (Tacoma Public Library).

![Figure 1. Location of Hells Crossing Bridge.](image-url)
Site Assessment

The issue at the 410/214 bridge is accelerating left bank erosion located approximately 50 meters upstream. A large log jam consisting of several dozen individual log members has formed since the 1996 floods (see Figure 2). At high flows and bank-full conditions, woody debris tends to get racked on the existing log jam, making it larger with time.

Figure 2. Large log jam located upstream of the 410/214 bridge at Hells Crossing.

It appears that the larger members of the log jam were recruited locally (autochthonous), having fallen into the river as the left bank continues to erode and individual trees become undermined until the root wad becomes exposed and the trees eventually fall into the American River. These larger members have tended to fall perpendicular to the eroding bank, with some members nearly spanning the entire bank-full width of the American River.

The span of the 410/214 bridge is relatively short, 60 percent of the upstream and downstream bank-full widths. Mobile logs from the upstream riparian areas get racked on the bridge structure itself as well as on the upstream log jams, although it appear that most of these transported (allochthonous) logs are of smaller caliper, significantly shorter, and appear to be racked on the log jam in random orientations.

The presence of the log jam above the 410/214 bridge has two major effects on localized hydrology:

1. Formation of a large gravel bar directly upstream of the log jam, inhibiting transport of sediment bedload through the bridge opening. With the bedload significantly reduced, the overall kinetic energy of the system is converted into higher water velocities, which can increase erosivity.
2. The addition of the gravel bar creates a split thalweg at high flows and stages. The left branch of the split thalweg becomes directed toward the river’s left bank. The kinetic energy from the split thalweg has been continuously undermining the left bank, exposing tree root wads and eventually results in these trees falling into the river and accumulating on the jam. This erosional pattern has progressed to the point where the east-bound approach to the 410/214 bridge is being threatened.
Reach Assessment

Watershed Conditions

Land Cover:

At the 410/214 bridge, the American River drains 70.0 square miles of the Mount Baker–Snoqualmie National Forest directly to the east of Chinook Pass in Yakima County (see Figure 3). Of this drainage area 58.86 square miles, or 83.6 percent is within either the William O. Douglas or Norse Peak Wilderness areas. Intact forests cover nearly 78 percent of the contributing watershed, with most of the remaining areas being SR 410, various Forest Service roads, Forest Service campgrounds, and exposed bedrock or thin soiled parklands in the alpine areas in the adjoining Naches Mountain ranges. The American River watershed can be geomorphically characterized by three dominant east-west trending landforms: the American River floodplain, and the two steep mountain ranges that parallel the floodplain, including American Ridge to the south and Fifes Ridge and Gold Hill to the North. Table 1 details land use characteristics in the drainage area.

Figure 3. American River Watershed at the 410/214 bridge site.

Aside from SR 410 and nearby Forest Service roads, the only large areas in the American River watershed that are not within designated wilderness is within the Morse Creek drainage. This unprotected area was once known as the Summit Mining District and was a popular mineral activity area between 1885 and 1920. The placer mineral content in this area was poor but historic remains of this earlier mining activity is still evident. There are 97 recreation residences within eight tracts in the American drainage, four patented mining claims, and several unpatented claims in the Morse Creek area, which led to its exclusion from the Norse Peak Wilderness when it was designated in 1984 by Congress.
Site and Reach Assessment, American River at 410/214 Bridge

State Route 410, a designated “All American Highway” has an annual daily traffic count of only 760 vehicles per day which reflects the seasonal closure of the highway due to avalanche concerns. WSDOT annually closes the gates accessing SR 410 at the Crystal Mountain Boulevard junction west of Chinook Pass at MP 57.59 and at MP 74.53, 0.2 mile west of the Morse Creek Bridge 410/202, because of high avalanche risks during the fall, winter, and early spring. The gates generally close in November once risk of avalanches become significant and re-open after the highway is cleared of snow, which generally happens in May or June. The low traffic for SR 410 in the vicinity of the 410/214 bridge reflects the seasonal closures and the remoteness of the project site.

Under the Wild and Scenic Rivers Act of 1968 the American River at the 410/214 bridge is eligible for classification as a scenic river. The reaches upstream of the Rainier Fork are also eligible as a wild river. Overall, the upper American River is one of the more pristine rivers in the state due to its lack of development or industrial-scale forestry.

Table 1. Land Cover Characteristics – American River Watershed at Hells Crossing Bridge 410/214.

<table>
<thead>
<tr>
<th>Land Cover</th>
<th>Type</th>
<th>Area (acres)</th>
<th>Percent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR 410</td>
<td>Impervious</td>
<td>43.0</td>
<td>0.10 percent</td>
</tr>
<tr>
<td>Forest Service Roads</td>
<td>Impervious</td>
<td>16.5</td>
<td>0.04 percent</td>
</tr>
<tr>
<td>Grand Fir Forest</td>
<td>Pervious/natural</td>
<td>25678.4</td>
<td>57.22 percent</td>
</tr>
<tr>
<td>Interior Western Red Cedar or Hemlock Forest</td>
<td>Pervious/natural</td>
<td>3250.0</td>
<td>7.26 percent</td>
</tr>
<tr>
<td>Subalpine Fir Forest</td>
<td>Pervious/natural</td>
<td>6002.1</td>
<td>13.41 percent</td>
</tr>
<tr>
<td>Alpine Parkland/Rock</td>
<td>Impervious/natural</td>
<td>9838.7</td>
<td>21.98 percent</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td>44769.3 (70.0 mi²)</td>
<td>100 percent</td>
</tr>
</tbody>
</table>

Geology and Soils:

The American River watershed upstream of the 410/214 bridge has two major geologic components:

- Valley floor deposits consisting of Holocene alluvium, and deposits of debris, alluvial fans, land slides, and Pleistocene glacial till and outwash.

  Pleistocene alpine glacial processes were responsible for the steep U-shaped glacial trough landforms which characterize the American River valley upstream of the 410/214 bridge. The friable semi-consolidated glacial sediments generally exist on terraces on the

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valley floor but are not generally part of the active channel migration zone. The valley floor Holocene alluvium located at the 410/214 bridge site has been observed to be very friable and non-resistant to shear stresses imposed by flows entrained against the left bank.

A distinctive feature of the American River valley is a dense pattern of steep perpendicular first order drainages. Shallow landslides and debris flows are significant sources of sediment delivery and are deposited along the grade break between the glacial till terraces and scoured volcanic bedrock. As these fans coalesce they can cause stream confinement, alter channel morphology, and change localized stream gradients. A combination of a large sediment supply and low stream gradients, common in the upstream reach, are favorable conditions for inducing split flows and channel braiding.

The American River has both meandering and braided reaches. Directly upstream of the 410/214 bridge, the American River channel alternates from braiding/split flows to meandering. From a sequence of aerial photos from 1990, 2000, 2005 and a cadastral drawing completed in 1942, there are indications that the reach upstream of the bridge has been becoming more sinuous through time, with sinuosity increasing from an estimated 1.1 to 1.3 at the present.

- The mountainous uplands (Naches Mountains) that parallel the upper American River valley.

The mountainous uplands have over 4,500 feet in relief from the highest peaks to the valley floor. These volcanic facies tend to be resistant to shear stresses and water-caused erosion. The bulk of the upland area is composed of the Fifes Peak Formation, a composite of lava flows, mud flows, and volcanic clastic rock from 50 to 500 feet thick. This formation is thought to be about 25 million years old, and lies on top of the earlier Stevens Ridge Formation, a slightly thicker layer of ash flows and volcanic clastic rock. In the Chinook Pass/Morse Creek areas, these lava flows were intruded by granitic plutons 10 to 15 million years ago. The mineralized contact zone along the perimeter of the plutons has been heavily prospected for both placer and lode gold. The resultant Sunshine Mining District recorded nearly 50 active claims in the headwaters of Morse and Silver Creeks, and extensive hydraulic mining. Placer Lake, located at the headwaters of Morse Creek, is a man-made impoundment that was used to provide water and power for placer mining on the mining claims in the Morse Creek basin.

At the 410/214 bridge site, the right bank directly upstream is also the geologic contact between the friable alluvium and the more cohesive volcanic bedrock. Therefore the right bank is much more able to withstand shear stresses imparted by entrainment of the river’s thalweg than the left bank. Redirecting the American River’s thalweg to the right bank should be considered an important mechanism to protect the 410/214 bridge structure for the long term.

Figure 4 shows the soils distribution at the project site and associated stream reach. Figure 5 is the corresponding legend to the map. The map shows a nearly 1:1 correlation between the American River floodplain and the distribution of Holocene alluvium in the valley.
Figure 4. Soil Survey Map of Hells Crossing Vicinity Soils.
Geomorphology:

The project reach is situated between American Ridge and Fifes Ridge and is completely within the Mount Baker – Snoqualmie National Forest. The mainstem American River, a fifth field watershed, can be subdivided into six sub-watersheds: Lower American, Upper American, Headwaters American, Union Creek, and Timber/Kettle Creek. The demarcation between the Upper and Lower American sub-watersheds is at the confluence with the Bumping River, located 6.0 river miles downstream of the 410/214 bridge. The floodplain of the American River valley upstream of the 410/214 bridge to the confluence with the Rainier Fork measures between 2000 feet and 2400 feet wide. The channel morphology alternates between braided, meandering and straight single-thread patterns, depending on the localized stream gradient and sediment supply.

**Hydrology and Flow Conditions**

The hydrology of the American River, including flood and design flow rates, is heavily influenced by snowmelt and rain-on-snow events. Historical records at USGS stream gage 12448500, located on the American River just upstream of the American/Bumping confluence...
6.0 river miles downstream of the 410/214 bridge, were used to estimate flow statistics for the site and reach. The May/June high flow events are caused primarily by snowmelt from the high ranges (American Ridge to the north and Fifes Ridge to the south) that parallel the American River. The December through February high flow events are likely caused by unusually warm “pineapple express” storms that melt much of the existing snowpack, compounding the high in-stream flows. Over a 67-year recording period, annual high flows occurred 54 times (80.6 percent) in the May/June melt off window and 13 times in November through February rain-on-snow window. It is notable that the four highest historic recorded flows in the American River at gage 12448500 occurred during the December through February time window, which affects the design flows at the 410/214 bridge site.

Bridge 410/214 is located 5.4 river miles upstream of gage 12448500. The contributing watershed area is correspondingly smaller, resulting in smaller peak and design flows. A comparison between key flow recurrence intervals estimated using StreamStats software and historic gage 12448500 flow data shows a large discrepancy in peak flows, probably due to the inability of the regression equation to accurately estimate the magnitude of rain-on-snow and snowmelt events which.

On November 2 through 6, 2006 a significant “pineapple express” storm attacked Washington State, producing unusually high flows that occur on a recurrence interval of more than 10 years, according to the data from gage 12448500. From the morning of November 2 to midnight on November 7 measured flow rates in the American River increased from 40 cfs to 2300 cfs. Digital photos taken by Scott Anfinson of WSDOT’s South Central Region Maintenance Office suggest that at low flows (less than 100 cfs) most of the flow volume and kinetic energy becomes directed at the right bank. At higher flows and river stages, a significant percentage of the flow energy is directed toward the actively-eroding left bank.

Peak flow statistics for the storm were estimated using recurrence interval statistics derived from historic gage 12448500 and a scaling factor that reduced the peak flows at the gage to reflect the smaller contributing watershed at the 410/214 bridge site.

### Table 2: Peak flood flow statistics for the 410/214 bridge project site.

<table>
<thead>
<tr>
<th>Recurrence Interval</th>
<th>Flow (ft$^3$/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q2</td>
<td>1205</td>
</tr>
<tr>
<td>Q5</td>
<td>1850</td>
</tr>
<tr>
<td>Q10</td>
<td>2335</td>
</tr>
<tr>
<td>Q25</td>
<td>3005</td>
</tr>
<tr>
<td>Q50</td>
<td>3480</td>
</tr>
<tr>
<td>Q100</td>
<td>3965</td>
</tr>
<tr>
<td>Q500</td>
<td>5100</td>
</tr>
</tbody>
</table>
Channel Geometry and Flow Characteristics

Channel Geometry:
The American River channel upstream of the 410/214 bridge alternates between straight single thread, meandering, and braided geometries. The morphology of the river depends on the reach’s gradient and sediment supply. The reach upstream of the 410/214 bridge has a very low gradient - 0.43 percent. Aside from streambank erosion, which are part of the natural channel migration process but may be enhanced by the SR 410 corridor and dispersed-use activities such as camping and hunting.

Channel Alignment and Profile:
The American River upstream of the 410/214 bridge currently has a sinuosity ratio of 1.2, indicating a mostly straight thread channel and very little meandering. A sinuosity ratio of 1.5 or greater is generally considered to be a meandering channel. The river gradient directly upstream of the 410/214 bridge is 1.0 percent, with the downstream reach having a 5.0 percent gradient (see Figure 6).

![American River Profile in the Vicinity of 410/214 bridge](image)

**Figure 6. American River Profile in the Vicinity of 410/214 bridge, located at MP 83.5.**

Channel Migration and Avulsion Risk:
The risk of an avulsion due to flanking of the 410/214 bridge through the right bank highway approach is very high. A log jam that has been accumulating for approximately 10 years is now positioned directly upstream of the 410/214 bridge. In October 2006 the log jam measured 9000 square feet. Most of the larger trees trapped in the log jam are oriented mostly perpendicular to the stream flow and nearly span the entire width of the river. Directly upstream of the log jam a large gravel bar has formed, measured at 7500 square feet.

At the upstream terminus of the gravel bar, the flows split into two channels. One of the flow paths becomes entrained on the right bank. The right bank is at the southernmost edge of the alluvium/bedrock contact. No significant streambank erosion was observed on the right bank, probably due to the cohesiveness of the bedrock substrate. The right bank is the geologic contact between the bedrock and the floodplain alluvium, which has little cohesiveness or shear resistance.
Site and Reach Assessment, American River at 410/214 Bridge

The other flow path is directed into the log jam, where a complex network of localized flow paths weaves through the log jam. This has had several effects on the localized stream hydraulics. A gravel bar has accreted directly upstream of the log jam. The median pebble size (D50) of the gravel bar sediments was estimated at approximately three inches in diameter. Erosional scallop patterns have formed along the left bank of the American River for more than 200 feet upstream of the 410/214 bridge.

Local Scour:

At low flows the thalweg of the American River splits at the gravel bar that has accreted at the upstream end of the log jam. Most of the larger individual members in the log jam are autochthonous (locally recruited), likely from the continuously-eroding left bank upstream of the 410/214 bridge. This erosional pattern appears to be migrating upstream, as active undermining of trees at the edge of the riparian zone was observed in October 2006. The localized scour pattern is severe and threatens both the eastern approach to the 410/214 bridge and also the paved turnout pocket to the east of the bridge.

Head Cut:

Head cutting on the main stem American River as it weaves through the floodplain next to SR 410 was not observed at either the site or reach scale. However, many of the steep 1st order tributaries upstream and downstream of the 410/214 bridge exhibits significant amounts of head cutting directly upslope of the valley toe slopes, including Parker Creek, Miner Creek, Survey Creek, and Union Creek on the north and with Kettle Creek and Mesatchee Creek on the south. Associated with the head cuts are large debris/colluvial fans which are significant sediment sources in many reaches. The reach directly upstream of the 410/214 bridge does not appear to have any steep tributaries, so sediment supplies should be moderate to low. With a relatively small sediment supply, large-scale aggradation is not a significant problem and neither is braiding.

Preferential Flow Pathway:

At low flows the American River is wadeable. The river’s thalweg splits at the upstream end of the mid-channel gravel bar upstream of the accreted log jam and the flow distribution is approximately 2/3:1/3, favoring the right bank pathway. At higher flow rates, the flows also split, but more energy becomes directed at the left bank and a series of swirling, complex eddies form within and around the log jam creating a very complex series of localized flow paths.

Figure 7 shows the American River’s morphology directly upstream of the SR 410/214 bridge. The two nearest upstream meanders are dimensioned in the figure. The nearest meander to the project site is located 590 feet upstream of the project site, rotates counterclockwise, has a radius of 285 feet, and is leading to southward channel migration. The next nearest upstream meander is located 1500 feet upstream of the project site, rotates clockwise, has a radius of 430 feet, and is causing southern channel migration. In general both of the upstream meanders both have large radii of curvature, low amplitudes, low sinuosities, and very similar energy slopes as the project site. The left bank erosion at the project site may partially be a function of incipient clockwise meandering channel migration at the project site, to the north. If the 2 nearest upstream meanders represent the “typical” physical dimensions for meanders within this reach, the American River channel at the project site can be expected to migrate northward (toward the left bank) between 110 and 130 feet from the centerline of the American River. With a mean bankfull channel width of 70 feet at the project site, it can be anticipated that the American
River’s channel has the potential to migrate northward an additional 75 to 95 feet if the morphology of the upstream meanders are replicated. If unabated, this degree of channel movement would cut through the current SR 410 road prism near the 214 bridge approach. Table 3 shows the dimensions and mean bed shear stresses for the project site and the 2 nearest upstream meanders in the reach.

Table 3 – Shear stress profiles in the SR 410/214 bridge reach

<table>
<thead>
<tr>
<th>Description</th>
<th>Meander radius (ft)</th>
<th>Mean Bed Shear Stress (lbs/ft²)</th>
<th>Suspension Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Site</td>
<td>Straight*</td>
<td>1.29</td>
<td>Small cobbles (&lt;2.5”)</td>
</tr>
<tr>
<td>Nearest upstream meander</td>
<td>285</td>
<td>2.07</td>
<td>Large cobbles (&lt;5”)</td>
</tr>
<tr>
<td>2nd upstream meander</td>
<td>430</td>
<td>1.69</td>
<td>Large cobbles</td>
</tr>
</tbody>
</table>

* - shear stresses may be much smaller or greater due to localized velocity vectors induced by split flows and complex flow pathways during high flow events.
Riparian Conditions

The valley bottom of the American River upstream and downstream of the 410/214 bridge has a mostly-intact riparian corridor with the exception of the SR 410 right-of-way, six Forest Service roads, and three Forest Service campgrounds that are located adjacent to the river. It is estimated that the riparian corridor is more than 85 percent intact. The relatively intact riparian conditions ensure that a continuing supply of woody debris will be delivered to the 410/214 bridge site.

Large Woody Debris

The prominent wood accumulation located 200 feet upstream of bridge 410/214 is likely a “combination jam” composed of both allochthonous and autochthonous members. There are three fundamental categories of woody debris (WD) accumulations, or “jams,” based on whether or not the constituent WD was fluvially transported. Autochthonous or in-situ jams are made of WD that has not moved from the point where it first entered the channel, although it may have rotated, or the channel may have moved. Transport or allochthonous jams are made of WD that has moved some distance downstream by fluvial processes. Combination jams consist
of substantial quantities of both in situ key members and racked and loose members that clearly had been waterborne.

Historical photographs of the reach at the 410/214 bridge (figures 8 – 11) indicate that a significant stand of timber existed prior to 1996 along the left bank upstream of the 410/214 bridge. The autochthonous WD was deposited initially at their present location by bank input debris, undermining the left bank during the historically significant flood events of 1996. These initial WD members fell mostly perpendicular to the flow path of the river that acted as log steps that nearly spanned the entire channel width. These log steps or “sweepers,” as they are known in the whitewater kayaking circles, then recruited additional WD being swept down river. The log jam was initially started by tree boles which fell directly into the channel from their growth locations as a result of left bank erosion in 1996. During the October 2006 site visit, we observed several trees located directly adjacent to and upstream of the 410/214 bridge that were undermined and was threatening to fall into the American River. Figure 10 shows an entire stand of trees that has been undermined and fallen laterally into the American River. Note the close proximity of the erosional scallops to the guardrail and paved turnout at MP 83.5 (bridge 410/214 is located in the background).

Figure 8. Bridge 410/214 and an intact stand of trees on the left bank of the American River on 11/15/1999.
Figure 9. Roadside along American River on 11/15/1999; note stand of trees.

Figure 10. Roadside along American River on (10/25/2005); note the stand of trees that have fallen since 1999.
Figure 11. American River flanking bridge through left bank approach (November 2006).

**Water Quality**

Upstream of the 410/214 bridge, the river is not on Ecology’s 303(d) list of impaired waters. There is no significant potential for land development or commercial forestry upstream of the 410/214 bridge due to the fact that most of the land within the contributing watershed are protected by the Norse Peak and William O. Douglas Wilderness Areas. Water quality in the upstream reach above the 410/214 bridge is typically excellent and is capable of supporting all known beneficial uses and functions.

**Localized Erosive and Hydrodynamic Effects**

The large woody debris jam upstream of the 410/214 bridge induces many complex localized flowpaths, including eddies, velocity dead zones, and lateral flows relative to the thalweg and log jam. It is likely that these irregular flow paths change direction and intensity as the base flow rates change. Removal or relocation of the wood accumulation would likely eliminate these localized shear effects and would act to consolidate flows and hydraulic effects toward the center of the channel.

**Fish Utilization and Habitat Availability**

Steelhead, resident redband/rainbow trout, bull trout, brook trout, and spring Chinook salmon are all known to occur within the American River upstream of the 410/214 bridge. Specifically, the Hells Crossing log jam has been marked as fish habitat by USFS probably due to the general lack of in-stream woody debris or deep pools within the reach. Steelhead are known to reside in the American River downstream of the mouth of Mesatchee Creek. Bull trout/Dolly Varden spawning has been documented to occur at the confluence of the American River and Kettle, Timber, and Union Creeks. None of these recognized spawning areas resides in the reaches
upstream or downstream of the 410/214 bridge. In 1992, fishing for bull trout/Dolly Varden was prohibited in the Naches drainage, including the American River. Beginning in 1998, a total fishing season closure was imposed on the upper American River. The accumulated log jam located upstream of the 410/214 bridge probably does not provide any noticeable spawning habitat, as the substrate beneath the jam is very fine grained, mostly fine sands and silts, unlike the upstream cobble bar that has sediment with a D50 in the 2.5 to 3.0 inch range.
Evaluation of Treatment Alternatives

Mechanisms and Causes of Geomorphic Failure

The woody and gravel accumulations upstream of the 410/214 bridge is largely due to two factors. The first factor is the length of the current bridge span is approximately 50 percent of the bankfull width of the American River at Hells Crossing, causing a major constriction in the river. The bridge opening is constricted even more by the heavy rock armor surrounding the width and the mid-span pier is not wide enough to pass the majority of the woody debris that is routinely recruited into the American River. The riparian areas adjacent to the American River upstream of the 410/214 bridge are nearly 100 percent intact, being within a national forest with no commercial logging potential or other types of development that can affect forest cover. Approximately 84 percent of the contributing watershed is within designated wilderness areas.

Site-Reach Based Failure Mechanism Interaction

The split flows that occur above the accreted gravel bar in the upstream segment of the project reach forces part of the thalweg against the left bridge approach, threatening to flank the bridge by eroding through the adjacent road prism.

Primary Mechanisms of Failure

The site conditions have deteriorated to the extent that a catastrophic precipitation event, such as a significant rain-on-snow event, could result in shear stresses high enough to undermine the pavement on the eastern 410/214 bridge approach and the adjacent turnout area. The mechanism of failure in such an instance would be toe erosion in a sharp bend exacerbated by reduced vegetative cover.

Abating the Primary Mechanisms of Failure

The primary mechanism of failure is local scour associated with an obstruction, which is in this case a substantial log jam and associated accreted gravel bar. The left bank directly upstream of the 410/214 bridge is eroding rapidly and needs immediate protection. The flows split during high flows, directing a significant amount of flow energy toward the left bank directly upstream of the 410/214 bridge. Given that the soil substrate at the left bank is an unconsolidated alluvium, rapid erosion during periods of high flow can be expected during high shear stress events and has been repeatedly observed at the project site since 1999. To prevent this situation from recurring on a (nearly) annual basis, several actions are needed.

- Emergency-ready protection of the SR 410 road grade west of the 410/214 bridge in the form of an avulsion sill or buried groin structure;
- Relocation of most, if not all of the large (24" diameter or larger) logs in the jam to locations where they can either protect the toe of the actively eroding left bank (with a log toe) or can assist in deflecting and diffusing erosive flows (an engineered log jam);
- Multiple, redundant anchoring systems, such as cabling and bank-side deadmen, to secure the relocated large logs in place;
- A long-term maintenance plan to facilitate removal or relocation of future wood accumulations upstream of the SR 410/214 bridge, possibly utilizing the existing programmatic HPA for LWM/debris removal from WSDOT bridges (GH-F3591-01).
Site and Reach Assessment, American River at 410/214 Bridge

Treatment Alternatives

Introduction

Matrices 1 and 2 in Chapter 5 of the ISPG screen site and reach treatments for their suitability once the mechanism(s) for failure and the treatments are selected. Of the site and reach-based alternatives selected (below) to abate the primary mechanism of failure, all are listed as having “good” suitability in matrices 1 and 2 with the exception of the avulsion sill, which isn’t specifically listed in the treatment alternatives. If channel migration continues as it has without treatment – a reasonable assumption – the avulsion sill will eventually become a rip-rap revetment once bank erosion exposes the sill, which is also classified in the ISPG matrices as “good.”

Site-Based Alternatives Considered

1. SR 410 Emergency Pavement Protection: Avulsion Sill/Buried Rock Toe

Flow statistics (derived from scaling flow data) show that there is approximately an 81 percent annual probability that in May or June the American River will experience channel-altering high flows at the 410/214 bridge site due to snow melt. The site-based erosion at the left bank has increased rapidly since 1999 and is now threatening to undermine the paved traffic pull-out area located directly to the east of the 410/214 bridge. There is the potential that a single high flow event could put SR 410 itself at risk. Being that the 410/214 bridge is located in a relatively remote area, immediate protection of the western SR 410 bridge approach is needed to avoid loss of access.

2. Continuous Log Toe Revetment at the Active Left Bank Erosion Location

A second action that will be needed for long-term stabilization of the eroding left bank is protection of the embankment’s toe slope using revetments. Channel bank revetment structures are typically installed in moderate to low radius of curvature bends (Rc <5) where extremely high stress will be exerted on unprotected new banks. The radius of curvature of the reach upstream of the 410/214 bridge has been measured at 1.33, making log revetments a suitable alternative for the reach. Log revetments are composed of whole trees (root wads, limbs, twigs, log protrusions, etc.) which provide a large amount of surface area and roughness to dissipate multi-dimensional velocity vectors present near the bank. Being buoyant wooden structures, they have a finite lifespan. Climate, the type of wood, velocities, flow depths. and exposure to air, all determine the lifespan of any wood structure.

3. Flow Deflection Engineered Log Jam Upstream of the Active Left Bank Erosional Area

This alternative (see Figure 12) would involve reconfiguration of the jam in its current location to serve as a more protective and predictable structure while still providing habitat value. Currently, the split flows around the accreted log jam and associated gravel bar located upstream of the 410/214 bridge periodically provide the shear stresses that have been eroding the left bank. The left bank at the project site is composed of highly erosive Holocene alluvial deposits, while the right bank is the geologic contact between the alluvium and Eocene volcanic rock. The right bank materials are therefore far more resistant to erosion than the left bank and, being at the base of a 7400 foot mountain (Goat Peak), the channel cannot migrate very far to the south.
Figure 12. Log Jam Deflector Structure.

Part of any comprehensive long-term repair of the current scour problem upstream of bridge 410/214 would entail eliminating the split flows by redirecting the river’s thalweg away from the left bank toward the right bank. Since the existing log jam provides a source of large, downed logs with intact root wads at the project site, these could be reconfigured against the left bank to eliminate the splitting of flows that is driving the erosive flanking of the bridge.

4. Rock Groin Deflector/Diffuser Structure

The potential mobility of individual members of unanchored logs in high flow conditions may be problematic for long-term stability of the structure. One way to stabilize an unanchored log system would be to create a hydraulic shadow using rip rap. The log members would then be shielded from high velocities and would be much less prone to being launched into the bridge structure. The disadvantage to this option is that there is no local source for large rip rap so it would need to be hauled in from a distant source, which could be cost-prohibitive.

5. Long-Term Maintenance Plan For Continuing Woody Debris Relocation

There will be a continuing supply of woody debris launched into the American River upstream of the 410/214 bridge because of its densely-forested and intact riparian zone. The constricted opening of the current bridge structure limits downstream passage of most woody debris because of its relatively short span, presence of a mid-channel pier, and the rip rap revetments surrounding the three piers. Additionally, the bridge opening is less than half of the bank-full width of the American River and will not be able to pass the larger members of drifting wood that are not captured by the above-mentioned flow deflection log jam or rock groin structures used to divert the river toward the right bank.

Reach-Based Alternatives Considered

1. Woody Debris Relocation Downstream of the 410/214 Bridge
The location of the accumulated wood debris jam and its associated upstream cobble bar will result in long-term instability of the American River channel directly upstream of the 410/214 bridge. From the recent history of this reach, it appears that most of the log members in the jam came from a nearby source – a stand of conifers that were previously located next to the left bank. These in-situ or allochthanous members have remained more-or-less in place since being undermined by the eroding left bank and eventually falling into the river following the geomorphically-altering floods of 1996. These in-situ members fell mostly perpendicularly to the previously-existing left bank.

2. New Lengthened Bridge Span Without a Mid-Span Pier

The current 410/214 bridge was built in 1989, making it a relatively new structure. In general, bridges are designed to have a functional life span of at least 50 years. Given the relative short span (150 feet), combined with the bridge’s relative young age and an average daily traffic count (including seasonal closures) of only 760 vehicles per day makes it unlikely that funding could be found for bridge replacement. When a new bridge is being planned, designers should consider increasing the length of the span to match the bank-full width of the American River.

Evaluation of Risk Alternatives

Table 3 evaluates the various treatment options based on cost, risk of roadway failure, impacts to aquatic resources, and other considerations. As might be expected, the “no action” alternative has the lowest cost but the highest risk of road failure. Conversely, the “bridge replacement” option has the highest cost and the lowest risk of road failure.

Table 3. Evaluation of Risk Alternatives.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost</th>
<th>Risk of Roadway Failure</th>
<th>Impacts to Aquatic Resources</th>
<th>Other Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Action/ Emergency Response Only</td>
<td>Low</td>
<td>Very High</td>
<td>Reduction of habitat quality (bank smoothing, reduced cover)</td>
<td>An emergency response will likely be needed in the near future because channel migration will likely take out the bridge.</td>
</tr>
<tr>
<td>Avulsion Sill/Buried Rock Toe</td>
<td>Moderate</td>
<td>Low to moderate</td>
<td>Eventual bank armoring may simplify flow paths and reduce habitat complexity once the sill interacts with the river.</td>
<td>If constructed outside of the ordinary high water mark, as it should, no permits or consultations would be needed. Large rock will likely have to be hauled in from large distances.</td>
</tr>
<tr>
<td>Continuous Log Toe Revetment</td>
<td>Moderate</td>
<td>moderate</td>
<td>Very minor</td>
<td>Local log source may reduce costs.</td>
</tr>
<tr>
<td>Flow Deflection Engineered Log Jam</td>
<td>Moderate to High</td>
<td>Low to Moderate</td>
<td>Some habitat enhancement may be possible depending on placement</td>
<td>Would require a large crane to move selected logs and re-place them along the eroding bank.</td>
</tr>
<tr>
<td>Long-Term Maintenance Plan for Debris Removal</td>
<td>Moderate</td>
<td>Low</td>
<td>None</td>
<td>If the programmatic HPA for woody debris removal can be used, may reduce or eliminate some permit negotiations.</td>
</tr>
<tr>
<td>Woody Debris Relocation Downstream</td>
<td>Moderate</td>
<td>Low</td>
<td>Variable on configuration of wood placement downstream</td>
<td>Would require a large crane and trucks to move large logs downstream of the 410/214 bridge.</td>
</tr>
<tr>
<td>Bridge Replacement</td>
<td>Very High</td>
<td>Low</td>
<td>Variable depending on bridge design</td>
<td>The 410/214 is relatively young, being built in 1989.</td>
</tr>
</tbody>
</table>
Preferred Alternatives

The bank upstream of the bridge is eroding rapidly and threatening SR 410. Several actions are needed to abate the problem to the point where maintenance would only be needed on a recurrence interval of approximately 10 years.

The avulsion sill (site-based option 1) should be an immediate priority to protect the roadway, the turnout pocket, and the 410/214 bridge. A continuous log toe revetment (site-based option 2) would provide additional protection and could utilize many of the logs in the accumulated jam, which may reduce costs. A flow deflection log jam (site-based option 3) would assist in redirecting the American River’s thalweg toward the right bank, which is composed of shear-resistant volcanic rocks. Moving the remaining logs in the jam downstream of the 410/214 bridge (reach-based option 1) would eliminate the split flows that occur during high flows and river stages and would greatly reduce left bank erosion. A programmatic HPA permit for woody debris removal to a downstream reach currently exists and may be useful for this project.

Finally, due to the ongoing introduction of large wood upstream of the 410/214 bridge and the bridge’s limited span, a maintenance plan for periodic removal or reconfiguration of accumulated wood will likely be needed to clear future log jams from the vicinity of the structure. If reconfiguration of the jam downstream is unacceptable from a permitting standpoint, then reconfiguration of the jam into a protective structure (such as a combination of an ELJ at the site and a log toe revetment upstream) may be the best option. In addition a long term LWD management plan should be developed for this reach that establishes agreed-upon principles for balancing infrastructure protection and aquatic habitat concerns for the Hells Crossing site.
Conclusions

A comprehensive list of treatments are needed for long-term stability of the 410/214 bridge and its eastern approach. Construction of an avulsion sill built between the highway and the eroding cut bank should be an immediate priority. The other recommended actions – a continuous log toe revetment, a flow deflection log jam, moving the remaining logs in the jam downstream of the bridge, and a maintenance plan for periodic removal of accumulated wood – listed in the preferred alternative will likely require intensive negotiations with multiple agencies. It would also require additional hydrologic and geomorphic study in support of project design.
References


Washington State Department of Transportation. Bridge Engineering Information System (BEIST).