Site and Reach Assessment
Sund and Miller Creeks
At US101

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# Site and Reach Assessment, US101 at Sund and Miller Creeks

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Summary

Report findings:

- Sund and Miller Creeks are very similar in hydrology, geology, geomorphology, and soils.
- Development at the fan/delta junction has restricted the flow of sediment through the channel.
- Each stream is cut off from significant portions of the pre-settlement delta.
- A change in channel gradient occurs near where US101 crosses each stream.
- The natural decrease in sediment transport capacity is augmented by the constricting bridges on each stream.
- In the last few years, the highway has been getting overtopped by floodwaters and debris.
- Development in the areas around each bridge is intricately tied to the bridge structure itself.

Report recommendations:

- On Sund Creek, construct a low flow channel that will route sediment toward the distal edge of the delta, relieving sedimentation on a temporary basis.
- On Miller Creek, “partial delta restoration” should be implemented; this would involve property acquisition upstream and downstream of the bridge, adjacent to the stream’s left bank. A new bridge should be constructed, about 90 feet in length. This bridge would be about two feet higher than the existing bridge.
1.0 Introduction

Sund and Miller Creeks are two small streams that drain directly into Hood Canal in Mason County (Figure 1). U.S. Highway 101 (US101) crosses each stream on bridges built in 1925 and widened in 1980. The drainages of the creeks are both very steep and are underlain by unstable soils. The result has been deposition at the bridges which has caused overtopping of each bridge during the winters of 2007 and 2009. Portions of the concrete have been chipped by impact of sediment particles. In each case, the highway was closed temporarily.

This report describes the methods used to investigate these issues, followed by the site analysis, the reach analysis, mechanisms of failure, alternatives considered, and the recommended alternative.

Figure 1. Sund and Miller Creek Location Map.
2.0 Methods

This study included literature and data review as well as field reconnaissance. We also conducted synthesis of relevant aerial photos, ground photos taken at the site, topographic maps, geologic maps and reports, fish distribution data, and hydrologic data. Sources of information include:

- Aerial photos taken in 2006.
- Ground photos obtained by environmental staff during site visits in 2009.
- GIS coverages of 24K USGS topographic maps, soils, and geology for this area.
- Fish distribution information available from the Washington Lakes and Rivers Information System (WLRIS).
- Engineering records from WSDOT headquarters.
- Existing literature and data, as listed in the “References” section of this report.

To understand the nature of sediment transport, a longitudinal profile and cross-sections were surveyed using a self-leveling level, a surveyor’s tape, and a stadia rod. The thalweg profile of each stream was surveyed. To characterize sediment size, pebble counts were conducted upstream of the highway. A “random walk” pebble count was conducted upstream from each bridge at representative locations.
3.0 Site Assessment

3.1 MP329: Sund Creek

Sund Creek drains the east slope of Dow Mountain, originating near the summit and emptying into Hood Canal just below the US101 stream crossing. The bridge was widened by 14 feet (7 foot shoulders added) in 1980. The area around the mouth of the creek is developed with residential and commercial structures. The vicinity of the stream crossing is shown in Figure 2, which includes the 2006 aerial photograph of the area. Note how the delta of Sund Creek has recently grown, but only in a limited portion of the historical delta area. There is evidence of erosion of the delta area to the north of the existing channel.

Where US101 crosses Sund Creek, the channel has been confined, and sediment has been building up. However, until the last two years, there have been no reports of any maintenance issues at this location (Larry Deemer, Maintenance Supervisor, personal communication, 2009), although low clearance under the bridge was first documented in 1994. The stream channel was excavated in 2007 and in 2009. In 2009, the streambed was excavated both upstream and downstream of the bridge. Figures 3 and 4 show recent pictures of the upstream side of the bridge, before and after excavation. The southbound side of the north abutment was damaged during the 2009 flood.

3.2 MP330: Miller Creek

Miller Creek’s character is very similar to that of Sund Creek, in drainage size, aspect, elevation, and channel type (Figure 5). The issues are also the same as at Sund Creek. The bridge crossing the creek on US101 has been overtopped in recent years when the stream has aggraded up to the level of the bridge deck.

However, the alluvial fan/delta at Miller Creek is more developed than at Sund Creek. What used to be an alluvial fan and delta is now highly constricted by adjacent property owners, who have constructed concrete walls lining the channel, at least on one side, for hundreds of feet, primarily upstream of the bridge. The roadway, without dredging of the creek, would be closed every time even a minor flood event occurs.

Like the bridge on Sund Creek, the Miller Creek bridge was widened by 14 feet (7 foot shoulders added) in 1980. The as-built drawing (WSDOT, 1981) indicate that the channel was four feet deep following construction. Aggradation problems began appearing on bridge inspection reports recently, beginning in 2004 (WSDOT 2004). By 2008, channel excavation was recommended to improve flow capacity under the bridge. Excavation was conducted on an emergency basis in December 2007 and in January 2009, on both the upstream and downstream sides. Figures 6 and 7 show the upstream area before and after excavation in January 2009.
Figure 2. Aerial photograph (A) and topographic map (B) of Sund Creek vicinity.
Figure 3. US101 crossing at Sund Creek, January 2009.

Figure 4. US101 Crossing of Sund Creek, February 2009.
Note excavated area compared to January.
Figure 5. Aerial photograph (A) and topographic map (B) of Miller Creek vicinity.
Figure 6. Photograph of stream crossing of Miller Creek. January 2009.

Figure 7. Miller Creek bridge, February 2009.
Note the excavated area.
4.0 Reach Assessment

4.1 Watershed Conditions and Land Cover

Each watershed is primarily zoned for timber harvest. Logging has been extensive in both watersheds in the last 10 years, especially so in the Sund Creek watershed. There are also numerous logging roads. Aside from these roads and a very small amount of residential streets, US101 is the only other road in each watershed.

The lowermost portions of the watersheds are characterized by residential development. The proximity to Hood Canal has made land at the mouths of tributary streams valuable real estate. There is only minor commercial development, consisting of campgrounds and a small store on Sund Creek.

4.2 Geology and Soils

The rocks of both watersheds are dominated by Eocene-age volcanic rock in their upper portions, with glacial drift in the middle and lower reaches of each watershed (Figure 8). Where the streams cut into the till, advance glacial outwash is exposed. The volcanic rocks include basalt and basaltic breccias. There is a small amount of marine sedimentary rock exposed in the lower portion of each watershed.

Recently discovered evidence indicates that the region is tectonically active. There are relatively recent displacements at the surface due to movement on the Saddle Mountain Fault. Fault scarps that offset Holocene sediment (glacial till) appear just west of the boundaries of Sund and Miller Creek watersheds. Recent work (Witter et al, 2008) indicates that these scarps were created during an earthquake that occurred around 1100 years before present (yr B.P.).

Soils of the area, being quite young geologically, are influenced mostly by the parent materials (Figure 9). The lower portions of each watershed are dominated by gravelly sandy soils formed in glacial deposits. The upper, steeper portions of each watershed are underlain by thin, poorly developed soils on bedrock.

The inner gorge of each stream is subject to landslides. During a site visit to the middle portion of each watershed, debris avalanches were observed to have emanated from the top of the slope of the gorge. In addition, even in the small section of each stream observed, there were numerous stream side landslides. Also, there were recent landslides observed in the sidecast of the main road. One of these is shown in Figure 10. In Miller Creek, a recent damming of the stream was observed. The large wedge of deposits above the stream crossing was concordant with the height of the road. The deposits have subsequently been incised. The road crossing of Sund Creek was blown out, likely within the last two years. A temporary crossing was also recently blown out. Given the condition of the small segment of upper channel observed, and given the form of the inner gorge (as evident on LIDAR imagery), we conclude that the entire inner gorge is very unstable, and can produce large amounts of sediment.
Figure 8. Geologic map of the Sund and Miller Creek watersheds.
Figure 9. Generalized soil mapping units of Sund and Miller Creek watersheds.
Figure 10. Landslide in Miller Creek watershed.
(A) looking downhill with Miller Creek below.
(B) head scarp of the landslide is found in road sidecast.
4.3 Geomorphology

Sund and Miller Creeks are similar in nature. The streams are relatively small tributaries to Hood Canal, and drain the east slopes of Dow Mountain. They cross the relatively flat plateau of glacial deposits before dropping steeply down to the saltwater. The bridge crossings of both streams are located just about at the mean higher high water level, at the head of the delta. This is a naturally depositional reach. The streams lose their energy as the gradient decreases and as the water reaches the base level, which is Hood Canal.

Longitudinal profiles and selected cross-sections of each stream were surveyed. The profile for Sund Creek is shown in Figure 11. The high tide mark was surveyed by capturing the location of the highest debris left in the channel. Note the deep excavation in the channel and the steep slope created on the upstream side. Similarly, Figure 12 shows the longitudinal profile of Miller Creek.

Figure 11. Longitudinal profile of Sund Creek.

In Figure 2, progradation of the Sund Creek delta is evident. It is most evident where the channel has been recently confined, on the right (south) side of the delta. This portion extends farther into Hood Canal than the area behind the levee (to the north in the photo) and streambank armoring. The same is true for Miller Creek where the prograding area is limited to the area immediately downslope of the confined stream channel. Additionally, it appears as though the rest of the pre-settlement delta may be degrading. That portion of the delta is not being replenished by gravel deposition, due to the channelization of Miller Creek. Unmodified streams in a deltaic environment are free to change locations as various depositional events occur. Thus, sediment is distributed across the delta/fan...
surface, over time. This is not the case when the channel is confined to a portion of the fan. Wave action and settling of the deposited sediment can lead to coastline erosion.

The slope of the Sund Creek channel upstream from the bridge is about 2.2 percent. The slope of Miller Creek above the bridge is about 2.4 percent (this is consistent with the slope calculated from LIDAR data). Interestingly, the slope of Sund Creek downstream of the bridge is significantly less than upstream (0.8 percent), while the slope of Miller Creek downstream from the bridge is about the same as upstream (2.1 percent). The LIDAR profile of Miller Creek has a slope of one percent below the bridge which suggests that a pulse of sediment may have been deposited on the fan after the LIDAR was flown (2005). This sediment pulse could be attributed to the 2007 storm.

Channel cross sections were taken upstream and downstream of the bridge on each creek. The resultant plots are shown in Figures 13 and 14. The channel cross section on both creeks has been heavily influenced by human activity, much of it due to recent dredging, but also due to long-term modifications of bank armoring. On Sund Creek, the bankfull width, measured upstream from the bridge, averaged 30 feet. The bankfull depth, artificially modified by excavation and sidecasting, was about four feet. The channel downstream from the bridge has been extensively modified and therefore bankfull width from that portion of the reach is not meaningful, although it is useful to compare to upstream, noting that the excavated width is about the same as upstream. The 1980 as-
built groundline indicates that at the time of construction, there the bridge clearance was about eight feet.

In addition, two inset terraces on Sund Creek were identified (Figure 15) and surveyed. We speculate that these terraces were deposited during specific events, the upper terrace during the December 3, 2007 storm event, and the lower terrace during the January 3, 2009 storm event. The slope of the more recent terrace mirrors that of the thalweg slope (about 2.2 percent), while the older terrace has a slope of 3.4 percent. The earlier storm event may have resulted in greater deposition in the reach.

Miller Creek was also surveyed. The creek is highly confined on the upstream side of the highway (see Figure 14). Within 300 feet of the bridge it is constrained by a concrete retaining wall on the left bank, and a revetment for most of the length of the right bank. Encroachment on the stream channel is extreme; houses and back yards abut the stream. Additionally, the stream appears to have aggraded, and flow occasionally overtops the retaining wall on the left bank, as evidenced by use of sandbags, scattered debris, and torn fencing. Cross-sections were surveyed and are shown in Figure 15. However, because of the highly altered nature of the channel, these cross-sections are not very meaningful. They do, however, allow a comparison of the reaches upstream and downstream of the bridge. It is apparent that the channel is highly confined on the upstream reach, and less confined on the downstream side. The width to depth ratio upstream averages about 6:1, while downstream it is 12.5:1. The 1980 as-built groundline indicates that at the time of construction, there the bridge clearance was about eight feet.

Several of the houses along the stream in this reach are highly vulnerable to flood damage. The photo in Figure 14 shows two of the houses most at risk. It was evident that the creek was close to flowing over the retaining wall at some point, as there were sandbags place on top of the wall and there was debris left among the sandbags. We speculate that without the excavation at the bridge, flooding would have been substantial on the left bank of the creek, upstream from the bridge.
Figure 13. Sund Creek cross-sections upstream and downstream of US101 bridge.

Figure 14. Profile and slope of terraces on Sund Creek.

The upper terrace is thought to be from 2007, while the lower is from the January 2009 storm event.
Figure 15. Miller Creek from about 170 feet upstream from the bridge.

Note the sandbags on top of the retaining wall in the center of the photo. Flow direction is into the photo.
Figure 16. Cross-sections on Miller Creek.
Pebble counts were conducted on both streams, upstream of the bridges. One random-walk method pebble count was conducted for each stream. The results are shown in Figure 17. The sediment size on both creeks is similar. The mean particle diameter on Sund Creek is 28 mm, while on Miller Creek it is 30 mm.

Figure 17. Pebble count data for Sund and Miller Creeks.

4.4 Hydrology and Flow Conditions

The hydrology of both watersheds is typical for the southeastern Olympic Peninsula. The watersheds are dominated by rainfall, although the higher elevation portions receive some amount of snowfall each year. Both creeks had several cubic feet per second (cfs) of flow (by visual estimation) on January 9, while on February 13 there was no surface flow in either stream.

There are no stream flow gages in either watershed. The USGS’ StreamStats program was used (USGS 2008) to estimate the stream flow for certain floods. StreamStats uses regional regression equations and geographic information systems to calculate flow. The StreamStats results are shown in Table 1. The 2-year flood for Sund Creek is about 130 cfs, while the 2-year flood for Miller Creek is 106 cfs.
Table 1. Peak flood flow estimates for Sund and Miller creeks.

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<th>Parameter</th>
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<th>Miller Creek</th>
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<td>Drainage Area (square miles)</td>
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<td>Mean Annual Precipitation (inches)</td>
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<td>80.9</td>
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<tr>
<td>PK2</td>
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<td>PK500</td>
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4.5 Riparian Conditions and Large Woody Debris

The channel and riparian zones on both streams are so highly altered that there is virtually no functional wood in the channels. The riparian zone of Sund Creek is moderately intact. A mixture of cedar, big leaf maple, and Douglas-fir are found along the banks. At Miller Creek, the channel is confined between retaining walls and rip rap and there is little or no riparian canopy.

4.6 Water Quality

There is no water quality data on either of these streams, but they are likely classified as Class AA waters. Neither stream is listed in the 2008 303(d) listing of impaired water bodies. However, the portion of Hood Canal to which the streams drain is listed as impaired for dissolved oxygen. This portion of Hood Canal is the subject of ongoing research into the causes and potential fixes for the low amount of dissolved oxygen (hypoxia), which is contributing to “dead zones” within the canal (Hood Canal Dissolved Oxygen Program website, 2009).

4.7 Fish Utilization and Habitat Availability

The shoreline in the vicinity of both creeks has been designated as critical habitat for Summer Chinook, nearshore critical habitat for bull trout, and summer chum.

On both Sund and Miller Creeks, coho presence has been documented below the bridges (WDFW SalmonScape website 2009, http://wdfw.wa.gov/mapping/salmonscape/). Spawning habitat is shown as “potential” above the bridges of both creeks. Coho stock are listed as having a “healthy” status. Fall chum spawning occurs on both creeks upstream and downstream of the highway bridges. Fall chum stock status is listed as “healthy.” Resident cutthroat trout are also shown as using Sund and Miller Creeks, though no stock status was available from SalmonScape.
5.0 Evaluation of Treatment Alternatives

5.1 Mechanisms and Causes

**Sund Creek**

The issue at Sund Creek is sedimentation in the reach over which the highway crosses. Fundamentally, the location of the road at the apex of the stream’s delta is the main factor contributing to aggradation. This is a natural location for sediment deposition. Although there wasn’t a history of problems and this site, such issues are expected at this position within the stream system. The highway is located just at the base level (high tide) of the stream, and so is the natural location for sedimentation.

According to maintenance personnel, Sund Creek has only recently become a problem site. The 2007 and 2009 aggradation events happened during extreme precipitation events, after which slope failures would be expected. In a limited survey of the middle portions of the watershed, we found numerous sediment sources that directly deliver sediment to the stream. There are road fill failures, streambank failures, road cutslope failures, and stream crossing failures. The road maintained by the Department of Natural Resources has may be a key contributor of sediment. Because of the highly erodible nature of the channel banks and valley sidewall, Sund Creek will likely produce high levels of sediment for the foreseeable future.

Furthermore, development that has taken place around the stream has confined it. Prior to development, the stream would occasionally deposit sediment, and then adjust by avulsing (changing locations). The stream would thus wander back and forth across the delta. With the development at the mouth, and armoring of the streambanks, the stream can no longer distribute its sediment load across the delta. The sediment gets deposited in the confined channel, aggrading, decreasing the slope, and increasing the risk of overtopping the highway. The bridge itself is also a contributor, as the constriction it presents on the stream causes aggradation upstream.

**Miller Creek**

Miller Creek has been subjected to many of the same forces as Sund Creek, and the fundamental causes are the same. An increased sediment load, combined with the position of the bridge at the head of the delta fan, sets up the situation for aggradation. The confinement of the channel is more extreme on Miller than on Sund Creek, however. The retaining walls on either side of the channel constrict channel movement such that there is very little sediment storage available, and the stream is completely cut off from its floodplain. In addition, there are two bends in the stream channel immediately upstream of the bridge, which contribute to the tendency for aggradation through backwater effects. The lower bend is at the bridge itself. Habitat quality is also significantly lower than on Sund Creek, due to lack of riparian canopy and near shore vegetation, with no potential for recruitment.

5.2 Abating the Primary Mechanisms of Failure

There are three basic ways of addressing sedimentation at the bridges. Deposition at the bridge can be treated by either removing the sediment periodically, by restoring delta function to the creek and raising the bridge, or by decreasing the sediment load itself. The
latter is unlikely and beyond the purview of WSDOT, since it takes place in the upper watershed, well outside the right-of-way. In addition, inner gorge failures such as are present upstream are very difficult to treat.

Periodic removal of sediment has been practiced at this location since the bridges were built. According to local residents, owners of neighboring properties would “clean out” Miller and Sund Creeks. During the height of the January 2009 flood, WSDOT maintenance crews were removing sediment every day for several days. They removed an estimated 250 cubic yards of sediment per day from Sund Creek and 300 cubic yards of sediment per day from Miller Creek. This practice is effective at addressing the immediate problems of road closure and threats to the bridges. However, it does not address the long term problem of aggradation at each bridge. During each aggradation event, a wedge of sediment is deposited, which is thickest in the downstream direction. Excavation near the bridge removes a portion of the wedge, but it does not remove the entire wedge. The excavation creates a steep slope on the upstream side. During the next major storm event, this slope is highly susceptible to erosion. The stream will head cut and will fill up the excavation with the sediment that was immediately upstream from it. The larger the excavation, the greater the amount of time (or number of storms) that the excavation is able to trap sediment from. However, in general the excavation is limited to the right of way. Some similar situations have called for a sediment trap, which is either in line (within the stream channel) or off-line (which involves carefully engineering diversion during floods).

Another way of providing storage for excess sediment is to restore at least part of the historic delta. The channel has been narrowed so much by the bridge and bank hardening upstream and downstream that sediment can no longer spread out. Full restoration of delta function would involve a buyout of the entire community at each site, and is not considered feasible. A partial restoration of delta function would allow sediment to be distributed across a broader delta surface than currently. Channel aggradation rate would decrease, as there would be more storage volume. The expansion of deltaic surface would allow the channel to migrate more freely, and provide sediment storage. This would also restore some of the nearshore habitat function that has been lost.
6.0 Treatment Alternatives

6.1 Introduction and objectives
The problems of continued, repetitive excavation from the creek bed on each stream needs to be addressed. The amount of excavation allowed under the Hydraulic Project Approval for annual maintenance, 50 cubic yards, is not sufficient to keep the channel open and prevent highway closure during floods. The primary objectives in any project to abate these problems are to:

- Minimize highway closures due to flooding.
- Minimize future maintenance costs.
- Ensure the safety and integrity of the highway.
- Maximize natural movement of sediment, woody debris, and water through the reach.
- Minimize impacts to fish and wildlife species, particularly those that are listed as endangered, threatened, or sensitive.
- Account for future sea level rise.

6.2 Alternatives Considered
Table 2 summarizes the alternatives and their advantages and disadvantages. We considered five main alternatives, No Action (continued periodic dredging as needed), excavation of a low water channel, construction of a “relief channel,” partial delta restoration, and installation of a sediment trap upstream from the bridge. The basic elements of alternatives were the same for both stream crossings.

6.2.1 No Action
Under this alternative, no specific measures would be taken to address the threats to the roadway at each site. Further response would be in emergency actions only. Mitigation could be required for the resulting instream work. The no action alternative applies to both sites. Emergency actions would likely include excavation of the stream channels within the right-of-way to prevent overtopping of the bridges and channel avulsion. Depending on the storm event, and landslides occurring upstream, deposition at the bridges might cause overtopping of the highway as in 2007 and January 2009.

6.2.2 Excavation of low water channels
Under this alternative, a channel would be excavated on each creek below the bridge that would create extra sediment storage capacity. A conceptual outline of these channels is included in Figures 18 and 19. On Sund Creek, based on an average width of 60 feet, and a depth of two feet, approximately 1300 cubic yards of sediment would be removed. On Miller Creek, based on an average width of 60 feet, and a depth of two feet, approximately 1400 cubic yards would be excavated. Channels of this size could accommodate an amount of sediment similar to that deposited during the 2007 storm event. However, small storms would also contribute sediment, and the channel would
need to be maintained to be effective at providing protection for the highway. In addition, the break in slope at the upstream end of the channel would be a depositional location. Should a large amount of sediment be deposited all at once at this location, it could create the same issues as under the No Action alternative. Periodic excavation would be necessary to maintain the channel’s storage capacity.

6.2.3 Relief channel construction

As another means of increasing sediment storage capacity, a new channel could be constructed that would allow storage of flood deposits. This alternative would create a “controlled avulsion” of the stream channel. The junction with the existing channel on Sund Creek would be about 310 feet upstream of the existing bridge (Figure 18). The junction with the existing channel would be about 300 feet upstream of the existing bridge on Miller Creek, and would extend to Hood Canal as shown in Figure 19. The existing channel and bridge would remain in place, and a hardened overflow structure would be installed. The constructed channel would become the main channel, and the existing channel would be the overflow channel. Several parcels of property (including tidelands) would be acquired in order to construct the relief channel, and a new bridge, about 50 feet in length in each case, would be installed. Channel dimensions would be calculated based on a detailed estimate of the sediment budget of each watershed, along with 2-dimensional modeling of a debris flow event of a specific design discharge.

Over time, the relief channel would be subjected to sedimentation similar to that of the existing channel, and would require dredging. During this time, flow could be routed into the other (existing) channel, and the diversion structure moved over. In this way, flow could alternate between the two channels.

6.2.4 Sediment traps

Another way of increasing sediment storage, at least temporarily, would be to install a sediment trap and plan on periodic sediment removal. The sediment trap could be installed upstream from each bridge. A trapezoidal excavation would be made. The trap could be either in the existing channel or “off-line.” However, off-line traps, located away from the stream channel, can pose a risk of channel avulsion. The capacity would be based on a design debris flood (such as the 2007 storm event). The trap would need to be cleaned out periodically. This however could be done in the summer when the streams go dry.

The disadvantage of sediment traps is that they are subject to rapid filling, and could require excavation on a regular basis. Fish can be stranded in the sediment trap; this is one of the main arguments against their use. Furthermore, there is a public safety risk; if the trap is very deep, measures would be needed to restrict public access. Off-line sediment traps would also require property acquisition.

6.3 Preferred Alternative – partial delta restoration

Because partial delta restoration will reduce maintenance costs in the long run, and will help restore some function to the nearshore habitat, it is the preferred alternative. This alternative would involve the following elements:
• Acquire adjacent property
• Remove old bridges
• Construct new, longer, and higher bridges.
• Excavate fill to expand channel cross-section
• Plant appropriate riparian/nearshore vegetation

Figures 18, 19, and 20 show the historic extent of the alluvial fans, along with the current extent, and the potential extent if the re-establishment alternative is selected. Bridges would be expanded and would likely be one to two feet higher in elevation than they currently are.

**Sund Creek**

The area to be restored is shown in Figure 18. The partial restoration would involve acquiring several parcels in the immediate vicinity of the bridge. Figure 18 also includes the historical shorelines from the late 1880s. The historic shorelines serve as a loose guide to the area to be restored. The existing bridge would be removed, and would be replaced by a bridge approximately 60 feet in length. The restoration would involve removing fill on the acquired properties to expand the cross-section of the stream and re-establish to some extent the functioning of the delta. The restored delta would have a very large sediment storage capacity. The stream would no longer be constricted in this reach, and sediment would be able to deposit farther down on the delta slope. Figure 20 shows the approximate restoration area from an oblique view.

**Miller Creek**

The treatments on Miller Creek (Figure 19 and 20) would be similar to that on Sund Creek. The existing bridge would be removed, and would be replaced by a bridge approximately 90 in length. The elevation of the new bridge would be approximately 13 feet above mean lower low water. The properties immediately adjacent to the bridge (or portions thereof) would be acquired, for a total of five parcels. The Miller Creek bridge would not be canted as it currently is, with the low side facing into the upstream side. Approaches to the bridges would have to be built, and driveways extended to match the new elevation of roadway. Property would be acquired on both the east and west sides of the highway, though mostly north of the existing channel. The channel cross-section would be expanded both upstream and downstream of the new bridge. The right bank would receive the most treatments. The left bank would be established so as to tie in with the new bridge approach. The new streambanks would be planted with riparian and nearshore-appropriate vegetation.
Figure 18. Conceptual alternatives, Sund Creek.
Figure 19. Conceptual alternatives, Miller Creek.
Figure 20. Oblique views of Sund Creek fan.
The red lines indicate the historic extent of the fan (pre-settlement); light blue line indicates the current extent of the fan; green lines indicate proposed extent of fan after property acquisition.

Figure 21. Oblique views of Miller Creek fan.
The red lines indicate the historic extent of the fan (pre-settlement); light blue line indicates the current extent of the fan; green lines indicate proposed extent of fan after property acquisition.
Table 2. Alternative summary matrix.

<table>
<thead>
<tr>
<th>Location</th>
<th>Alternative</th>
<th>Description</th>
<th>Advantages</th>
<th>Risks</th>
<th>Habitat Effects</th>
<th>Relative Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sund and Miller Creeks</td>
<td>No Action</td>
<td>Highway configuration remains the same; annual excavation; mitigation required</td>
<td>No additional permitting</td>
<td>Continued maintenance activity; more frequent road closures; avulsion; mitigation costs</td>
<td>Wood removed from system, incremental decrease in pool forming potential, downstream of bridge</td>
<td>Low (short term)</td>
</tr>
<tr>
<td>Low water channel</td>
<td>Excavate trapezoidal channel in delta downstream from bridge</td>
<td>Reduces maintenance somewhat; easy to construct</td>
<td>Requires frequent excavation; highway could still be overtopped</td>
<td></td>
<td>Degrades critical nearshore habitat for Chinook and Bull Trout</td>
<td>Low</td>
</tr>
<tr>
<td>Relief channel and delta</td>
<td>Create new distributary channel, with a junction with the existing channel upstream of the highway</td>
<td>Will increase sediment transport capacity temporarily; greatly decreases maintenance</td>
<td>Avulsion; requires extensive property acquisition</td>
<td></td>
<td>New channel habitat created; old channel will get de-watered</td>
<td>High</td>
</tr>
<tr>
<td>Excavate and maintain sediment trap</td>
<td>Dredge upstream and downstream to create a large sediment basin capable of storing 10,000 cubic yards</td>
<td>Eliminate annual maintenance excavation; prevent highway closures</td>
<td>Fish stranding; avulsion</td>
<td></td>
<td>Removes gravel from system; could lead to degradation of the delta</td>
<td>Low</td>
</tr>
<tr>
<td>Property buy-out, partial delta restoration</td>
<td>Acquire adjacent properties, remove streambank armoring upstream and downstream; replace bridge with high, longer span</td>
<td>Distributes sediment in natural pattern; greatly reduced maintenance; improved habitat</td>
<td>Requires property acquisition</td>
<td></td>
<td>Improved spawning and rearing; improved upper intertidal habitat</td>
<td>High</td>
</tr>
</tbody>
</table>
7.0 Conclusions

The problems at both Sund and Miller Creeks are similar. The bridges are located in a position vulnerable to deposition. Recent extreme storm events appear to have triggered a significant increase in sediment load, which has caused aggradation and overtopping of the highway at the crossings. In addition, the natural tendency of these streams to avulse and deposit sediment over a broad area of the deltas has been severely restricted by encroaching development. Miller Creek is the more confined of the two, having concrete retaining walls forming the right bank in the project reach.

Because the upper portion of each watershed appears to have chronic sediment sources, the best way to maintain the roadway over the long term is to expand the channel and replace the bridges on both. Expansion of the channel will remove the existing constriction, and at the same time allow the stream to wander across a wider area, distributing sediment across a wider part of its delta. This partial restoration of the delta will require acquisition of several parcels upstream and downstream of the bridge on both streams, excavation of the fill that forms the left banks of both streams, and establishment of appropriate riparian and nearshore vegetation.
8.0 References

http://apps.ecy.wa.gov/shorephotos/


Washington State Department of Fish and Wildlife. Salmon and Steelhead Habitat Inventory and Assessment Project (SSHIAP). http://wdfw.wa.gov/hab/sshiap/.

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