Upper Hoh Road
Bank Failure Risk Reduction Study

Jefferson County, WA
and
Olympic National Park, WA





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Upper Hoh Road Bank Failure Risk Reduction Study

Section 1
Introduction



Riprap revetment County Mile Post (CMP) 7.8.

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Background

One of the major roads leading into Olympic National Park (OLYM) is the Upper Hoh Road located off of US Highway 101 on the far western side of Olympic National Park. The road is the only entryway into the Hoh Rain Forest and Visitor Center. The Upper Hoh Road is approximately 18 miles in length. Jefferson County owns and maintains the portion of the road from the junction with US 101 to the OLYM boundary, approximately 12 miles. The OLYM owns and maintains the remaining 6 miles.

Management of the road to provide constant safe access to residents, business, and Park visitors, has become increasingly difficult over the past 20 years. Portions of the Upper Hoh Road are located within and adjacent to the Hoh River's channel migration zone. This location combined with the increasing frequency and severity of winter storm events (most recently in 2004, 2006, 2007, and 2009) has resulted in an increasing number of roadway washouts which either completely prevents access or creates unsafe roadway conditions for visitors, Park personnel, and local residents. In some cases the damage resulted in road closures, permitting no access to the Hoh Rain Forest and the Park's Hoh Rain Forest Visitor Center for weeks at a time (and many months in 1996). Response to these storm events and maintenance of the road in its current location has resulted in a continuing outlay of limited maintenance funds to maintain safe access and to mitigate for adverse impacts those actions have on threatened and endangered fish species.

In 1998 the Hoh Tribe requested the U.S. Bureau of Reclamation (BOR) to prepare a geomorphic study to better understand the existing and historical channel processes on the Hoh River, and how human activities may have impacted those processes. The study, entitled *Geomorphic Assessment of Hoh River in Washington State,* published in 2004, identifies areas of risk for further lateral erosion in the historic channel migration zone and provided some general management considerations to deal with these areas of concern. The report recommended more detailed data collection and analysis for developing a management approach at any specific particular location.

In 2009, OLYM published a report entitled *Olympic National Park, Road Hazards and Solutions Report*. This report examined two methods to address roadway locations, demonstrated to be vulnerable to damage from severe storm events, within OLYM. The two different methods evaluated included a site-specific approach versus a natural systems engineering approach and, the report concluded that a natural systems engineering approach would likely provide a more long-term fix while improving the ecological conditions. Six sites along the Upper Hoh River Road within the Park were included in this evaluation.

Jefferson County approached Western Federal Lands Highway Division (WFLHD) in September 2012 to complete an Upper Hoh Road Bank Failure Risk Reduction Study that develops an efficient and effective comprehensive road management strategy for mitigating high risk sites along the Upper Hoh Road. WFLHD would use the information from the two earlier reports and from the site visits for developing the road management strategy. The WFLHD study would include the prioritization of sites, regardless of management jurisdictions, the development of a full range of treatment options for each site, and initial cost estimates for each option including construction, Preliminary Engineering (PE), Construction Engineering (CE), and ROW.

Not all options from the two earlier reports are included or fully developed. Treatment options developed are intended to represent a full range of types, costs, and environmental impacts. All treatment options where expected to provide a similar level of road failure risk reduction. Other treatment options or combinations of presented options exist. Selection and refinement of

treatment options will be completed as part of future mitigation projects. Figure 1-1 locates the five Jefferson County sites. Figure 1-2 locates the six Park sites.

Report Limitations

This report is intended to be used primarily as a planning document for future budgeting purposes and determining the initial order in which the County and Park could proactively address sites of concern. The conceptual costs estimates are intended to provide a relative comparison only between the options and should be expected to change. The ranges of solutions presented are not considered comprehensive or complete. Preparation of a geomorphic site assessment, recommended in these reports, may reveal conditions that would require additional or alternative forms of treatment. Also, other solutions may be presented during the scoping and alternatives analysis required by the National Environmental Policy Act.

Report Methodology

The information contained in this study was obtained from site visits conducted from December 2012 through April 2013, conversations with resource staff from Jefferson County, OLYM, the Hoh Tribe, the Hoh River Trust, and previously prepared studies describe above. Additional work and verification of design details and options are needed. River and/or stream modeling of the Hoh River or tributaries were not done for this planning document.

Report Organization

This report is divided into three sections. Section 1 includes this introduction section.

Section 2 addresses specific sites identified in the BOR 2004 and the OLYM 2009 reports. Existing site conditions, a preliminary list of solutions options, and a general discussion of environmental impacts and clearances required are presented for each site.

Section 3 presents larger, more system wide proposals to address the roadway maintenance challenges associated with the interaction between the Upper Hoh Road and the Hoh River. These proposals involve wholesale relocation of a large portion of the existing Upper Hoh Road.

Steering Committee, Site ranking and Recommendations

Through discussion with Jefferson County and OLYM, a steering committee was formed for providing overall direction and guidance on this report. The steering committee is comprised of representatives from Jefferson County, OLYM, Hoh Tribe, Hoh River Trust, FHWA-Washington Division office, Washington Department of Transportation, and Washington Department of Fish and Wildlife (WDFW). The general makeup of the committee was developed to include various stakeholders and organizations that have an interest in the Hoh River Corridor. The committee's objective is to identify a project or set of projects that help to preserve vehicular access to Olympic National Park's Hoh Rain Forest by addressing immediate access issues on the Upper Hoh Road along the Hoh River in Jefferson County, WA.

WFLHD prepared an initial site listing based on discussion with OLYM and the Jefferson County. These sites were discussed at the initial January 22, 2013, steering committee meeting. With facilitation by WFLHD the steering committee developed site ranking criteria. The draft site ranking criteria was further refined through a second meeting and the final site ranking criteria is included in the first section of this report.

The committee established five criteria to rank and prioritize the sites:

1. Anticipated timeframe the threat would happen.

2. Potential impact to vehicle access to the corridor.
3. Potential impact from the event to natural resources.
4. Potential advantage of a proactive response versus an emergency response (or reactive response).
5. Potential for a solution to provide resource improvement.

The attached tables summarizes the sites and presents a methodology developed by the Project Task Group for evaluating and prioritizing the sites according to risk, impact, and cost. Table 1-1 summarizes the County sites. Table 1-2 summarizes the OLYM sites.

The criteria and scoring for the alternatives shown in the Alternative Summary and Ranking table for each priority site were developed and discussed at the steering committee meetings. Initial scoring of the alternatives was developed by WFL and then discussed and modified at the following meetings. Committee members provided additional comments and revisions of the scoring based on discussions at other meetings and during follow up discussions. These Alternative Summary and Ranking tables show that multiple alternatives score equally well for many of the sites.

This report provides ranking for site priorities and ranking of the alternatives at each site, however, the tables do not present recommendations. The steering committee members agreed with the site priorities and in general the overall ranking of the alternatives, however, the preferred or recommended alternative will be determined as the design of the options are developed and through the NEPA process.

Environmental Information

Site-specific detailed information will be included for each site. To avoid unnecessary duplication, environmental information that applies to all sites is provided in this section.

Considered treatment options that provide less negative interaction with the river channel and its natural processes and more positive habitat elements tend to cost more than those options having more negative river interaction and less positive habitat elements. Complex and more costly solutions provide greater protection and restoration of natural channel processes and of the aquatic resources supported by them. Final selection and design of treatment options should consider the benefit gained to the environment from more complex and costly solutions.

Most environmental information provided in this study was obtained via web searches and conversations with regulatory staff. This information is adequate for estimating level of effort to acquire environmental clearances, but will need to be verified in field surveys to secure environmental compliance.

The road is located in a coastal management zone. Unless otherwise noted, all projects would likely require a coastal zone consistency review and concurrence by the Washington State Department of Ecology (DOC), the administering agency for these consistency determinations.

Within OLYM boundaries, the road extends through a designated wilderness area. The roadway and its accompanying corridor, a minimum of 100-feet from the existing centerline, are not located within the wilderness area. To the west of OLYM's boundary, there is no designated wilderness up to U.S. 101. Alternatives that would involve relocating the road into wilderness areas would require congressional legislation of boundary adjustments. Wilderness acreage would need to be added elsewhere to accomplish the OLYM's goal of no net loss.

Outside of OLYM, designated critical habitat for marbled murrelet and northern spotted owl is found within the project corridor. Although much of the park contains high-quality habitat that is considered important for the recovery of the species, no critical habitat has been formally designated within OLYM for marbled murrelet, northern spotted owl. This is because critical habitat for these species is not thought to require special management consideration or protection beyond that which is appropriate for a national park. The Hoh River is designated as critical habitat for bull trout throughout the project area. Conducting protocol surveys for marbled murrelet and northern spotted owls should be considered so that, if none is located, noise restrictions would not be required during project construction.

Throughout the 17-mile project corridor, the road is at times immediately adjacent to and crosses essential fish habitat.

With regards to cultural resources, though a good portion of the road may have been constructed by the civilian conservation corps in the 1930's (http://www.nps.gov/history/history/online_books/olym/hrs/chap5.htm), the road has not been determined to be eligible for listing on the National Register of Historic Places. Also the majority of the road is situated on a deposition terrace, less than 1000 years old, within the Hoh River floodplain. Given the frequent flooding experienced by the roadway segments examined in this report, it is unlikely that there are in-situ cultural resources within those areas. As a result, any work within the existing roadway prism is unlikely to affect cultural resources. However, options involving realigning the road or the active river channel may affect previously unknown cultural resources. For those options, a literature search and pedestrian survey, with some possible testing, would be needed.

Known Section 4(f) resources have not been identified for any of the sites of concern. As with cultural resources, options involving realigning the road or active river channel may affect previously unidentified Section (4f) resources. Such options will require resource surveys.

As a Federal Agency, WFLHD normally does not acquire the Hydraulic Project Approval as there is no nexus with a Federal law. According to FHWA legal counsel, acquiring such permits is tantamount to waiving Federal sovereign immunity, something only Congress has the authority to do. Nonetheless, FHWA is obligated to and intends to coordinate with State and local agencies regarding any proposed work.

It is assumed that for all alternatives requiring in-water work, the planned work will need to occur during the in-water work period established by the WDFW. For the Hoh River the in-water work period is limited to August 1 through August 15. Waivers to perform in-water work outside of this period may be applied for.

Executive Order 11988, Floodplain Management, established federal policies for protecting floodplains and floodways. The intention of the associated regulations is to avoid, to the extent practical, adverse impacts to floodplains; minimize the impact of floods to human safety, health, and welfare; and avoid supporting land use development that is incompatible with the natural and beneficial floodplain values. When avoidance is not possible, the policies require appropriate consideration of methods to assess and minimize adverse impacts.

Any bank erosion protection option will have an impact on natural channel and floodplain processes. Additional analysis is needed for identifying extent and location of private property impacts. Treatment options selected for final design and implementation would need to comply fully with Executive Order 11988 to be eligible for Federal funds.

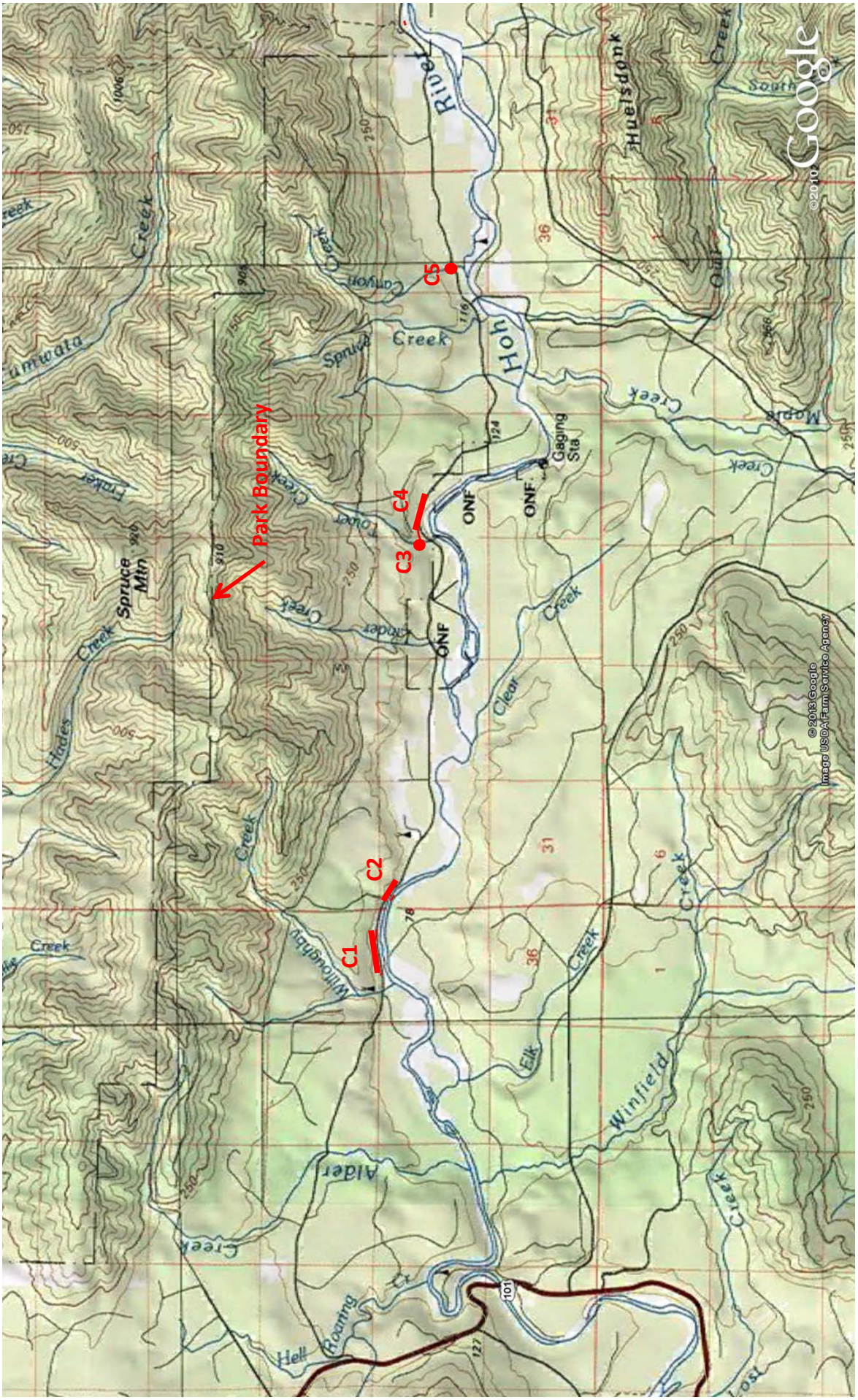


Figure 1-1. County Sites

C1 Site location.

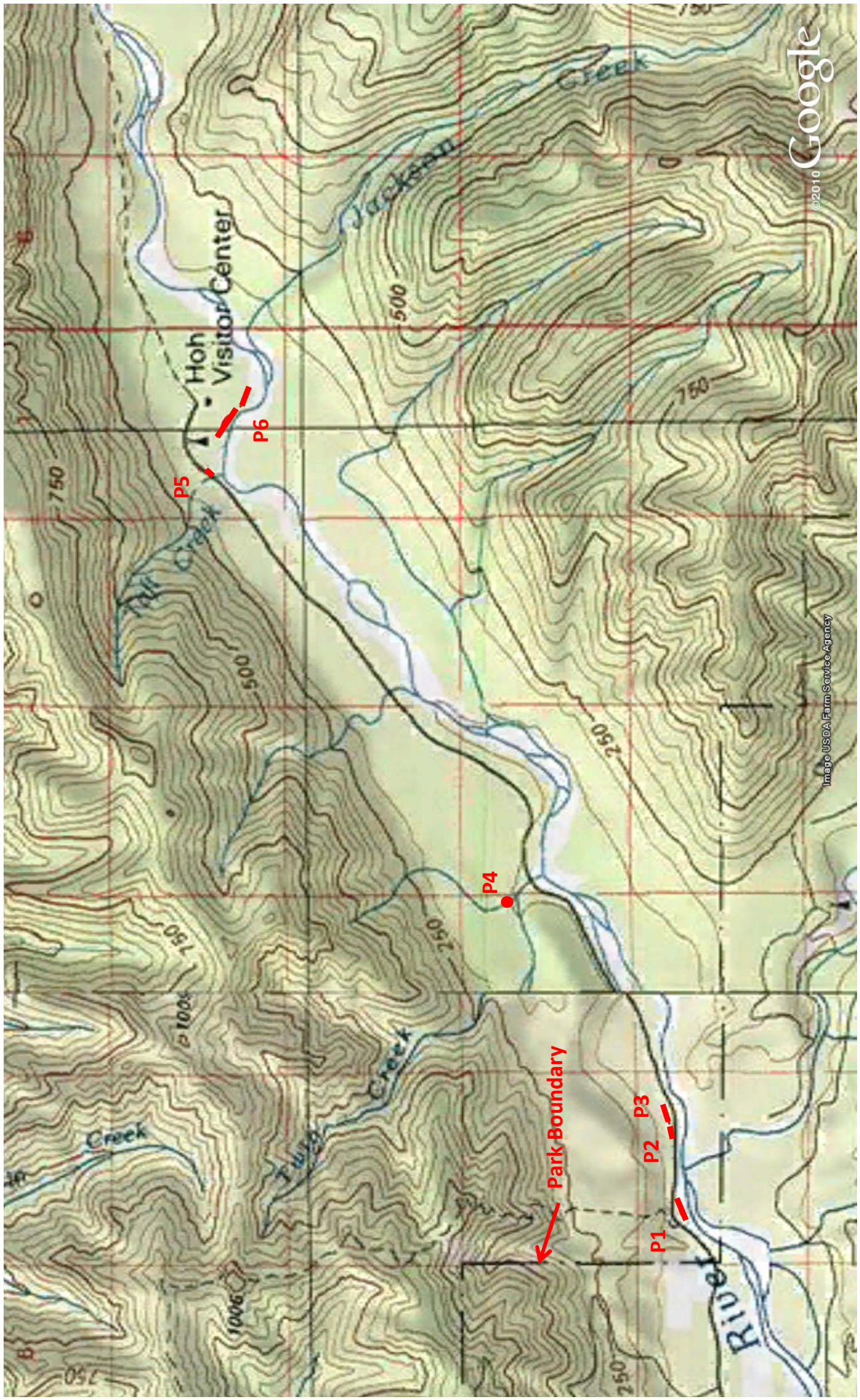


Figure 1-2. Olympic National Park Sites

P1 Site location.

Table 1-1. Upper Hoh River Road Proposed Work Site Evaluation and Prioritization

Jefferson County Sites

Site # and Name:	C1	CMP 3.7 - 4.0	C2	CMP 4.4	C3	Tower Creek Bridge	C4	CMP - 7.8	C5	Canyon Creek Culvert
Threat:		**bank stabilization**		**bank stabilization**		**bridge**		**bank stabilization**		**culvert**
Evaluation Criteria										
Timeframe the threat to prevent traffic access at the site Time frame is based on historical record.	**3**	1 year - 5 years	**5**	1 year	**3**	5-10 year	**5**	1 year	**3**	5 - 10 years
RANKING*:										
Impact to Access: Considerations in this ranking include a) potential magnitude of impact to corridor access; b) effect to residences and public due to lack of access; c) likely timeline to reestablish access and overall potential damage.	**5**	2 to 3 months (total closure) no detour. Early in the road (impact to residents and county)	**5**	2 to 3 months (total closure) no detour. Early in the road (impact to residents and county)	**5**	Complete loss of service and given size affects the ability to agency to obtain the funding needed and duration creates 3 to 6 month closure.	**5**	Complete loss of service with about 600 feet of roadway threatened	**3**	1 to 2 months total closure.
RANKING:**										
Impact from the EVENT to Natural Resources: Considerations in this ranking include: a) the potential magnitude of the damage to natural resources; b) length of time it will take for the resource to recover from the damage; c) whether resource is protected under Tribal, state, or Federal law (T&E species);	**3**	Moderate sediment load going down the river. Natural sediment from bank erosion from this site. Not that high of a bank. Failure of the existing protection is a concern and road materials.	**3**	Moderate sediment load going down the river. Natural sediment from bank erosion from this site. Not that high of a bank. Failure of the existing protection is a concern and road materials.	**5**	Significant sediment load going down the river.	**5**	Significant sediment load going down the river.	**5**	Moderate sediment load going down the river. There is sensitive spawning habitat in the vicinity, off channel habitat that was previously damaged. Side streams has debris flow in high water events.
RANKING:**										
Proactive vs. Emergency Response: Often a proactive response can served to minimize impacts to natural and social resources compared to emergency responses. Consideration in this ranking includes assessing whether the impacts are from a proactive response are considerably less than impacts resulting from a catastrophic event and emergency repair. Could the proactive save a step in the process. When you proactively replace you can provide access through the site during bridge construction	**5**	The emergency response would not be as sensitive for replacement bank stabilization and likely would not be able to provide enhanced bank stabilization. The proactive would have a softer stream bank approach	**5**	The emergency response would not be as sensitive for replacement bank stabilization and likely would not be able to provide enhanced bank stabilization. The proactive would have a softer stream bank approach	**3**	Emergency repair and proactive solution would likely be the similar. Proactive solution would provide access during construction	**5**	The emergency response would not be as sensitive for replacement bank stabilization and likely would not be able to provide enhanced bank stabilization. The downstream side of the site would be Forest Service land and would be late successional reserve (challenge for relocation for bypasses or re-location)	**3**	Two alternatives discussed: Either Plan A: A bridge in the proactive solution. Plan B: The proposed solution would be likely the same in an emergency event or a proactive event. NOTE: The benefit for this being proactive would be to avoid the temporary solution to pass traffic.
RANKING:**										
Potential for a SOLUTION to provide Resource Improvement (Proactive): Is there the potential to improve a resource in the vicinity of the project? **(**tie breaker, all other things being equal which site address a resource issue) Ranking the magnitude of that improvement	**5**	Ability to provide a solution that improves river function with bank protection method	**5**	Ability to provide a solution that improves river function with bank protection method	***3***	Tower creek is improved, but not greatly improved (as passage is provided)	***5***	Ability to provide a solution that improves river function with bank protection method	***3***	Fish passage issue and the habitat upstream is not as significant
RANKING*:**										
Totals:	**21**		**23**		**19**		**25**		**17**	
Ranking	**3**		**2**		**4**		**1**		**5**	

* The ranking for this criterion reflects the likelihood (low, moderate, high) for this threat to occur in the near future.

** The ranking for these criteria reflects the perceived degree (low, moderate, and high) of impact to the issue or resource if no action were taken to minimize or eliminate the anticipated threat.

*** The ranking for this criterion reflects the potential of experience a secondary benefit of improving natural habitat.
Rankings are 1-low, 3-moderate, and 5-high

Table 1-2. Upper Hoh River Road Proposed Work Site Evaluation and Prioritization

Olympic National Park Sites

Site # and Name:	P1	PMP 0.2 - 0.4	P2	PMP 0.8	P3	PMP 0.9	P4	East Twin Creek	P5	PMP 5.8	P6	Camp Ground
Threat:		**bank stabilization**		**bank stabilization**		**bank stabilization**		**culvert**		**bank stabilization**		**bank stabilization**
Evaluation Criteria												
Timeframe the threat to prevent traffic access at the site Time frame is based on historical record.	**5**	0 - 2 years. Immediate action needed. Simple, temporary fix could delay need for permanent fix.	**3**	0-5 years	**3**	0-5 years	**1**	5-10 years culvert well off the channel with a deep fill still has a drop out of it.	**1**	5 - 10 years utilities are not only 3 feet from stream and roadway edge is near river	**5**	0-2 years. Immediate action needed.
RANKING*:												
Impact to Access: Considerations in this ranking include a) potential magnitude of impact to corridor access; b) effect to residences and public due to lack of access; c) likely timeline to reestablish access and overall potential damage.	**1**	1 month closure	**3**	moderate : 1 -2 months (total closure) no detour.	**3**	moderate : 1 -2 months (total closure) no detour.	**5**	high: 4 -6 months (total closure) no detour.	**1**	low : 1 months closure	**1**	minimal impact to access
RANKING:**												
Impact from the EVENT to Natural Resources: Considerations in this ranking include: a) the potential magnitude of the damage to natural resources; b) length of time it will take for the resource to recover from the damage; c) whether resource is protected under Tribal, state, or Federal law (T&E species);	**1**	Low sediment load going down the river.	**1**	Low sediment load going down the river.	**1**	Low sediment load going down the river.	**5**	Moderate sediment load going down the river.	**1**	Low sediment load going down the river.	**1**	Low sediment load going down the river.
RANKING:**												
Proactive vs. Emergency Response: Often a proactive response can served to minimize impacts to natural and social resources compared to emergency responses. Consideration in this ranking includes assessing whether the impacts are from a proactive response are considerably less than impacts resulting from a catastrophic event and emergency repair. Could the proactive save a step in the process. When you proactively replace you can provide access through the site during bridge construction	**3**	The emergency response would not be as sensitive for replacement bank stabilization and likely would not be able to provide enhanced bank stabilization.	**3**	The emergency response would not be as sensitive for replacement bank stabilization and likely would not be able to provide enhanced bank stabilization.	**3**	The emergency response would not be as sensitive for replacement bank stabilization and likely would not be able to provide enhanced bank stabilization.	**1**	The proposed solution would be likely the same in an emergency event or a proactive event. NOTE: The benefit for this being proactive would be to avoid the temporary solution to pass traffic.	**3**	The emergency response would not be as sensitive for replacement bank stabilization and likely would not be able to provide enhanced bank stabilization.	**3**	The emergency response would not be as sensitive for replacement bank stabilization and likely would not be able to provide enhanced bank stabilization.
RANKING:**												
Potential for a SOLUTION to provide Resource Improvement (Proactive): Is there the potential to improve a resource in the vicinity of the project? **(**tie breaker, all other things being equal which site address a resource issue) Ranking the magnitude of that improvement	***5***	Ability to provide a solution that improves river function with bank protection method	***5***	Ability to provide a solution that improves river function with bank protection method	***5***	Ability to provide a solution that improves river function with bank protection method	***5***	*Provides an improvement for fish access to high quality fish habitat a lot of improvement for fish especially within the twin system*	***5***	Ability to provide a solution that improves river function with bank protection method	***5***	Ability to provide a solution that improves river function with bank protection method
RANKING*:**												
Totals:	**15**		**15**		**15**		**17**		**11**		**15**	
Ranking	**3**		**4**		**5**		**1**		**6**		**2**	

* The ranking for this criterion reflects the likelihood (low, moderate, high) for this threat to occur in the near future.

** The ranking for these criteria reflects the perceived degree (low, moderate, and high) of impact to the issue or resource if no action were taken to minimize or eliminate the anticipated threat.

*** The ranking for this criterion reflects the potential of experience a secondary benefit of improving natural habitat.
Rankings are 1-low, 3-moderate, and 5-high

Upper Hoh Road Bank Failure Risk Reduction Study

Section 2
Individual Site Evaluations



Existing typical vegetated riprap armoring.

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C1 - COUNTY MILEPOST 3.7 - 4.0

BANK STABILIZATION



SITE C1 – COUNTY MILEPOST 3.7 - 4.0 BANK STABILIZATION

Site Conditions

The site parallels the outside bank of a river bend (Fig. C1-1). Approximately 3,900 lineal feet of riprap revetment along the apex of the river bend appears to be generally effectively controlling road embankment erosion. The 2 to 4 feet diameter riprap comprising the revetment is generally properly graded and placed. Revetments are in three segments. Upstream, middle, and downstream segments are approximately 1,350, 400, and 750 feet long, respectively. Upstream segment is also the downstream revetment segment for site C2. The remaining 1,400 feet of riprap revetment is included with site C2. Upstream segment is densely planted with willow and alder and appears stable (Photo C1c-2). Currently, the upstream segment is behind a point bar and does not experience impinging flow. Down-valley translation of an upstream meander channel could expose the segment to impinging stream flows. Middle segment is densely planted with willow and appears stable (Photo C1b-6). Approximately 550 feet of the downstream segment is densely planted with willow and alder and appears stable (Photo C1a-2). The remaining 200 feet of the downstream segment appears less stable.

Distance of stream bank between the upstream and middle revetment segments is approximately 500 feet. Distance of stream bank between the middle and downstream revetment segments is approximately 260 feet.

Toe erosion and undermining of the stream bank is occurring;

- Downstream of the downstream revetment segment (C1a – 100 feet).
- Between the downstream and middle revetment segments (C1b – 260 feet eroding bank and 200 feet high-risk revetment).
- Between the middle and upstream revetment segments (C1c – 500 feet).

-C1a

The stream bank toe is approximately 20 feet away and 12 feet below the road pavement edge. Mid-channel sediment deposits deflect stream flow towards the stream bank, aggravating the bank erosion (Photo C1a-1, 5 and 6). A large woody debris jam approximately 20 feet from the stream bank deflects stream flow towards the bank, creating a particularly vulnerable spot 15 feet long (Photo C1a-2 to 5).

-C1b

The stream bank toe is approximately 10 to 15 feet away and 16 feet below the road pavement edge (Photo C1b-2 to 5). A point bar opposite the site directs stream flow towards the stream bank, aggravating the bank erosion. A large woody debris jam, approximately 15 to 20 feet from the stream bank deflects stream flow towards the bank, creating a particularly vulnerable spot 100 feet long (Photo C1b-3 to 5).

Immediately downstream of the eroding stream bank is approximately 200 feet of the downstream revetment segment that is nearly devoid of alder and willows and has a 1.5(h):1(v) and steeper finished surface slope appears less stable (Fig. C1-1, Site C1b, Photo C1b-1). Riprap has been dislodged from toe and mid slope areas. The segment is at the maximum point of stream bank curvature and likely experiences high shear stress when floods occur. Continued riprap loss could result in dismantling of the revetment and damage to the road. Based on current channel alignment and expected limited channel alignment shifts and

assuming revetment maintenance is completed; the risk of a catastrophic road embankment failure is low. Without revetment maintenance, the risk becomes moderately high.

-C1c

The stream bank toe is approximately 15 to 20 feet away and 18 feet below the road pavement edge. A point bar opposite the site directs stream flow towards the stream bank, aggravating the bank erosion (Photo C1c-1 and 3).

At all locations cobbles and small boulders naturally armoring the toe and large trees growing in the stream bank inhibits the bank erosion. An erosion resistant poorly consolidated alluvium terrace deposit has limited river bend migration to the north and south. The terrace deposit represents the historical channel migration zone (HCMZ) right and left (looking downstream) boundaries (Geomorphic Assessment of the Hoh River in Washington State, Bureau of Reclamation, July 2004). Width of the HCMZ is approximately 500 feet. The road embankment coincides with the HCMZ right boundary and valley wall. Based on historical satellite imagery, the active channel has not changed significantly in width and location since 1994 (Fig. C1-2).

Continued stream bank erosion could undermine the road. Based on current channel alignment and expected limited channel alignment shifts, the risk of a catastrophic road embankment failure is moderate. Water depth at typically normal annual low flow conditions is estimated to be 4 to 6 feet.

Considered Options

Continuing maintenance, relocating the road, installing additional bank stabilization, minor active river channel shift, and major active river channel shift were considered. Table C1-1 presents an evaluation and ranking of the options against design selection criteria.

Riprap is expected to be lost during extreme flooding, requiring replenishment for maintaining the riprap installation's effectiveness. Total Capital and Annualized Total Capital Costs provided in Table C1-1 assume 20 percent of the riprap in an installation is replaced every 50 years.

Douglas fir and hemlock are the most commonly available logs in the area. Douglas-fir logs can remain durable in wetting-drying conditions for 25 to 60 years (Tech. Supp. 14J, Use of Large Woody Material for Habitat and Bank Protection, Part 654, National Engineering Handbook, USDA, Natural Resources Conservation Service). Hemlock is the least durable of the conifers. Because the tree quality and species to be used in the structures is not known, Total Capital and Annualized Total Capital Costs provided in Table C1-1 assume wood used in the alternatives is replaced every 30 years.

<u>Continue Maintenance</u>

Continued maintenance involves monitoring approximately 860 feet of stream bank (C1a, C1b, and C1c) and 200 feet of the downstream revetment segment (C1b) for excessive bank erosion and riprap loss. Stream bank toe erosion upstream and downstream of the existing riprap revetments could progress to the point that undermining of the road is imminent. Continued maintenance is placing riprap in an emergency action or after flooding as needed for preventing a road closure. Placing riprap as an emergency action may be hazardous or difficult. The emergency-placed riprap may not be effective in controlling the erosion.

A Total Expected Cost analysis (HEC-17, FHWA, April 1981) was used for estimating total expected cost repairing flood-induced road damage over a 50-year service-life. Based on observed riprap revetment condition, proximity of channel to roadway, and amount of natural

bank armoring, the analysis assumes damage requiring repair of the existing revetments or addition of new riprap revetment placed as an emergency action for stabilizing an eroding river bank occurs for flood events equal to and larger than the 25-year flood event. Based on review of historical satellite imagery, length of bank typically exposed to impinging flood flow is estimated to be approximately 300 feet. Based on vegetation distribution and age and estimated riprap placement sequencing, the length of past revetment installations ranged from 200 to 500 feet. Assuming 300 feet total for each flood damage event and a cost of $1,000 per foot, the total expected annual cost is $21,000 (Table C1-2).

Relocate Road

Shifting the road at least 100 to 200 feet away from the active river channel edge provides a riparian buffer wide enough for containing a reconstructed stream bank area, eliminating the need for continuous revetment bank stabilization. The 260 feet high terrace slope is immediately adjacent to the existing roadway. A shift would mean an alignment that crosses the terrace slope. Slumping observed on the terrace slope suggests the terrace slope is not geotechnically stable. A new road alignment located across the terrace slope would experience landslides and debris flows that could potentially bury the road with debris. The road alignment may require significant foundation stabilization for mitigating landslides. Length of reroute is estimated to be 3,000 to 4,000 feet for connecting the new road to lower risk existing road segments.

Existing riprap revetment is removed and approximately 80 to 100 feet wide by 1,800 feet long area of the stream bank is reconstructed. The erodible newly reconstructed stream bank would allow lateral bank erosion and migration to the north. Streambarbs constructed from the existing revetment riprap, Engineered-log-jams (ELJ's), and planted vegetation control the bank erosion and lateral migration and preserve a riparian buffer between the active river channel and the new road embankment. The alternative requires monitoring and repair of the streambarbs and ELJ's to remain effective in controlling the bank erosion and lateral migration.

Estimated construction cost for the new road, existing road removal, 10 streambarbs, 5 ELJ's, and stream bank reconstruction is summarized in Table C1-3. Stabilizing landslides may require significantly more money. Road construction is expected to occur outside the active flow channel. Revetment removal, streambarb, ELJs, and stream bank construction is expected to occur within the active flow channel. Turbidity released is expected to be limited in extent and duration. Access for construction is assumed from the existing road. Constructing the new road alignment first and then switching the Upper Hoh Road traffic over before removing the existing road reduces traffic impacts to one-lane closures and short-term delays.

Stabilize Existing Road Embankment

Approximately 860 feet of stream bank (C1a, C1b, and C1c) and 200 feet of the downstream revetment segment (C1b) are proposed for stabilization.

Options considered;

- Complex roughened large rock toe.
- Complex log crib wall.
- Riprap with roughened rock toe, large woody debris (LWD), and riparian plantings.
- Riprap with streambarbs.

Based on field evidence, the sites will experience high shear stress, 10 to 14 feet deep flood flows, and abundant floating debris. It is critical that the stabilization methods be properly

designed and anchored for maintaining effectiveness and surviving the expected flood conditions.

Construction for all the alternatives is expected to occur entirely within the active flow channel and requires excavating into the streambed and stream bank. Stream work would be accomplished in flowing water. Assuming the work is completed during low flow periods, turbidity released is expected to be limited in extent and duration. Access for construction is assumed down a temporary access route built of riprap and logs. The access route would be removed after construction is completed. Upper Hoh Road traffic impacts are expected to be limited to one-lane closures and short-term delays.

-Complex roughened large rock toe (Appendix A, Sheet 4).

The approach involves placing a rock toe between the expected scour depth and ordinary high water level, total height approximately 10 to 12 feet and 5 feet thick. Log bundles spaced 6 to 10 feet are placed at the bottom of the rock toe. Soil placed above the rock toe in overlapping layers of erosion control blanket, approximately 6 to 12 feet. The rock toe and soil ballast the logs and reduce the risk of the logs floating away. Estimated construction cost for the complex roughened large rock toe is summarized in Table C1-3.

-Complex log crib wall (Appendix A, Sheet 5).

The approach involves placing a log crib wall made of rough logs between the expected scour depth and ordinary high water level, approximately 10 to 12 feet high. Stone is placed within the log crib wall for ballast. Logs with attached root wads extending into the stream bank provide roughness and additional wall stability. All logs are cabled together for enhancing stability. Designs typically include piles driven to refusal or minimum depth of 10 feet. The cobble and boulder stream bed material will likely prevent the piles from being cost-effectively driven or excavated. They are assumed eliminated in the proposed design. Approximately 6 to 12 feet of soil is placed above the crib wall and planted. Estimated construction cost for the complex log crib wall is summarized in Table C1-3.

-Riprap with Roughened Rock Toe, LWD, and Riparian Plantings (Appendix A, Sheet 9).

The approach involves placing a riprap revetment between the expected scour depth and 50-year flood event water level, approximately 12 to 15 feet high, 5 feet thick, and 2(h):1(v) slope. A launchable riprap toe 8 feet wide and 5 feet thick reduces the risk of scour and channel incision undermining the revetment and provides additional stability. Logs or log bundles spaced 6 to 10 feet are placed along the revetment toe for providing roughness and channel complexity. The logs are buried in the road embankment for reducing the risk of them floating away. Willow and alder are planted throughout the revetment and bank area above the revetment. Estimated construction cost is summarized in Table C1-3.

-Riprap with Streambarbs (Appendix A, Sheet 11).

The approach involves placing a riprap revetment between the expected scour depth and 50-year flood event water level, approximately 12 to 15 feet high, 5 feet thick, and 2(h):1(v) slope. Instead of a launchable riprap toe, 10 to 12 - 40 to 50 feet long streambarbs are proposed for reducing shear stress and deflecting the river flow away from the revetment. The streambarbs reduce the risk of scour and channel incision undermining the revetment, promote sediment deposition and retention along the bank toe, and creates channel complexity. The bank, riprap, streambarbs, and channel area between the streambarbs would be augmented with streambed material, large woody debris, and planted with riparian vegetation for establishing a riparian buffer. Estimated construction cost is summarized in Table C1-3.

Minor Active River Channel Shift

An environmentally desirable approach would be to nudge the active river channel over enough from the road to reestablish a riparian buffer. Ideally, the buffer would have the same erosion resistance of a natural, wooded and vegetated river bank. The buffer would need to be wide enough to allow some bank erosion without threatening the roadway. It would be made by placing alluvial material over existing riprap revetment and unstable bank areas. To promote vegetation establishment and soil mass stability, the finished surface of the buffer area should not be steeper than 5(h):1(v). Assuming a 10 feet high bank, the width of the new buffer area would be at least 50 feet. Existing relative stable riparian buffers observed along the river are at least 40 to 50 feet wide and densely vegetated with alder and fir. The new buffer area would be prone to erosion from active channel migration. The erosive forces are expected to be too large for passive and bio-engineering methods to be effective by themselves. Hardened, more erosion resistant components in the buffer system are needed for mitigating the erosive forces.

-Engineered-log-jam Groins.

ELJ's groins constructed perpendicular to the stream bank and extending through the new buffer area would control channel location and deflect river flow away from new buffer area (Appendix A, Sheet 10). An ELJ's buoyancy and sliding analysis (Design Guidelines for Reintroducing Wood in Australian Streams, Abbe/Brooks, 2006) was completed assuming 6 feet design flow depth, 5 feet design scour depth, 8 feet per second average flow velocity, 1.5 velocity correction factor, and 18-inch average trunk diameter. The river bed contains cobbles and small boulders. Piles would need to penetrate the river bottom at least 20 to 30 feet for providing adequate resistance to buoyancy and sliding. Tree trunk piles would likely splinter before reaching the desired design depth. As wood decays, it losses strength and cannot resist the shear stresses created by a sliding ELJ mass. Driving steel piles for pinning the ELJ structure to the river bottom would be expensive and leave a tangle of steel piles protruding from the river bottom. Based on the analysis, an ELJ structure 15 feet wide and ballasted with stone is needed for achieving a minimum sliding factor-of-safety of 2.0, the minimum needed for unknown flow conditions and resisting expected additional woody debris accumulation.

Each ELJ groin would be 60 feet long and constructed of three 15 feet wide by 20 feet long modules. Assuming 2 to 3 feet gaps between logs and 8 layers, approximately 50 logs are needed for each module and 150 for each groin. Based on the stability analysis, 150 cubic yards of ballast stone is needed for each ELJ groin for achieving minimum sliding and buoyancy factor-of-safeties of 2.0, the minimum needed for unknown flow conditions and resisting expected additional woody debris accumulation. The logs are cabled together for keeping them in place against expected flow depth and velocity and additional woody debris accumulation.

-Riprap Streambarbs.

Streambarbs are an alternative to using ELJ groins for controlling channel location and reducing erosive forces (Appendix A, Sheet 10). Each stream barb would be angled upstream 30 degree relative the bank line and approximately 100 feet long for fitting within the new riparian buffer. Assuming Class 8 riprap, crest width is 8 feet. Barb thickness is 8 feet at base and 6 feet at tip. Barb bottom width is 32 feet at base and 23 feet at tip. Approximately 470 cubic yards of riprap is needed for each stream barb.

Based on review of historical satellite imagery, length of bank typically exposed to impinging flood flow is estimated to be approximately 300 feet. The radius of curvature for active channel is 500 to 800 feet. To effectively deflect the impinging river flow away from the new bank area, the ELJ groins or stream barbs would need to be spaced every 100 to 150 feet. Assuming

2,000 feet of unstable bank and existing riprap revetment is covered with new stream bank; approximately 15 to 20 ELJ groins or stream barbs are needed.

The existing revetment is assumed left in place. Stream bank area is constructed between the ELJ groins or stream barbs by placing conserved and imported stream bed and bank material. Willow and cottonwood trees are planted throughout the area. Willow fascines are placed along the lower 3 to 6 feet of the bank toe for controlling erosion. Large wood is incorporated randomly throughout the bank area.

Estimated construction cost is summarized in Table C1-3. Work will be within the active river channel and requires temporarily diverting the river flow. Flow defection is assumed accomplished with large sandbags or water-inflated bladders. Dewatering the work area would be extremely difficult and expensive. Excavation and placing logs, stone, and new stream bank fill material is assumed to take place in the water ponded behind the flow diversion structure. Turbidity released is expected to be limited in extent and duration. Access for construction is assumed down a ramp constructed over the existing riprap revetment. The ramp could provide permanent access for maintenance. Upper Hoh Road traffic impacts are expected to be limited to one-lane closures and short-term delays.

The HCMZ is narrows at the site relative to upstream and downstream reaches. Consequently, it is expected that any active channel relocation would likely induce dramatic bank erosion and stream avulsion, resulting in unnatural changes in the HCMZ boundaries and the likely loss of private property downstream.

Executive Order 11988, Floodplain Management, established federal policies for protecting floodplains and floodways. The intention of the associated regulations is to avoid, to the extent practical, adverse impacts to floodplains; minimize the impact of floods to human safety, health, and welfare; and avoid supporting land use development that is incompatible with the natural and beneficial floodplain values. When avoidance is not possible, the policies require appropriate consideration of methods to assess and minimize adverse impacts. If the option is considered, additional analysis is needed for identifying extent and location of private property impacts. If found violating Executive Order 11988, relocating the active river channel would not be eligible for Federal funds.

Major Active River Channel Shift

Shifting the active river channel away from the road eliminates the current riprap revetment failure risk and road loss risk from bank erosion occurring between and downstream of the existing revetments. Shifting the active river channel to flow across the point bar opposite the existing riprap revetment could be accomplished with 8 to 10 ELJ's, each at least 20 feet wide and 60 to 100 feet long. All would be constructed within the active river channel. Top of the ELJ's are set equal to 100-year water surface, estimated to be approximately 5 to 6 feet above the point bar surface. Bottom of the ELJ's are set below the active channel thalweg elevation and expected scour depth, approximately 6 feet below the point bar surface. Each engineered-log-jam is ballasted with stone and logs cabled together for keeping them in place against expected flow depth and velocity and additional woody debris accumulation.

The existing revetment is assumed left in place. No stream bank area is reconstructed. Off-channel rearing and resting habitat is created along the toe of the existing riprap revetment. A new 100 feet wide active flow channel would be constructed across the point bar for diverting stream flow away from the construction area. Alluvial and plant materials from the channel excavation would be used for the habitat reconstruction.

Estimated construction cost is summarized in Table C1-3. Construction requires temporarily diverting the river flow. Turbidity released is expected to be limited in extent and duration. Access for construction is assumed down a ramp constructed over the existing riprap revetment. The ramp could provide permanent access for maintenance. Upper Hoh Road traffic impacts are expected to be limited to one-lane closures and short-term delays.

The HCMZ is narrows at the site relative to upstream and downstream reaches. Consequently, it is expected that any active channel relocation would likely induce dramatic bank erosion and stream avulsion, resulting in unnatural changes in the HCMZ boundaries and the likely loss of private property downstream.

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Environmental Clearance Considerations

This section of the Upper Hoh Road extends through primarily state trust lands with designated critical marbled murrelet critical habitat located immediately adjacent to the north side of the road and designated bull trout critical habitat in the Hoh River. Designated northern spotted owl critical habitat is located approximately 3 miles to the east. Individuals of both species may be present in the forest immediately north of the road at this location. No wetlands were identified on the National Wetland Inventory Maps. A wetland survey and, if needed, delineation, would need to be conducted to confirm this negative finding.

Environmental considerations for the treatment options at this location are as follows.

<u>Continue Maintenance</u>

Continued maintenance would require periodic replacement of material below the ordinary high water mark where there is currently riprap revetment. The Seattle District of the U.S. Army Corps of Engineers (Corps) has indicated that such work is exempt from Section 404 of the Clean Water Act provided that all work occurs within the existing road prism. Consequently, no state water quality permitting would be required.

In the event that one of the areas of concern should fail during a storm event, the roadway failure would release a large amount of sediment into the river. Assuming this sediment release occurs concurrently with the storm event it is unlikely that this would result in a considerable increase over the background condition.

Repair of the road after failure would likely cause considerable environmental impacts. The need to quickly reestablish access would permit no design time typically needed for more habitat-friendly solutions, thus relying on the use of conventional methods including riprap. Also, work would likely need to occur outside of the in-water work window. The need for rapid response to an emergency situation will result in environmental impacts to sensitive habitats that would likely warrant expensive mitigation. If this option is pursued, Jefferson County may want to consider developing, in advance, an emergency plan in coordination with the U.S. Fish

and Wildlife Service (Service) and the Washington Department Fish and Wildlife (WDFW) for developing more habitat-friendly designs that can be implemented in the event of a failure. Such a plan may reduce mitigation costs.

Relocate Road

Given the proximity of designated marbled murrelet habitat to the road at this location, relocation would involve removal of critical habitat. Relocation of the road may improve aquatic habitat for the threatened bull trout as the existing riprap revetment would be removed and a streambank length of 1800 feet would be restored using streambarbs, ELJ's, and vegetation. A biological assessment would need to be prepared evaluating the effects to the marbled murrelet, the northern spotted owl, and the bull trout.

If wetlands are determined to be present in the road relocation area, permitting from the Corps and the Washington Department of Ecology (DOE) would be required. If the waters of the US would be impacted only by the removal of the riprap revetment and the restoration of the steambank, then a Nationwide permit may cover this work. If no protocol surveys are done for the marbled murrelet or the northern spotted owl, or if protocol surveys are done and species presence is confirmed, construction would have to adhere to seasonal and daily noise restrictions.

Stabilize Existing Road Embankment

Due to lack of design detail, no distinction is made in terms of environmental impacts for each of the four stabilization methods discussed in this report. However, based on conversations with the Corps, the more natural and "softened" (logs and vegetation) the bank stabilization method, the easier it will be to permit the activity. Riprap alone is the most difficult bank stabilization method to be permitted.

Bank stabilization would likely have no permanent impacts to designated marbled murrelet or northern spotted owl critical or suitable habitat. Temporary impacts would likely occur for all three listed species, thereby requiring the preparation of a biological assessment. In addition to complying with the in-water work window, certain construction activities may be limited to certain times of the day or season to minimize disturbing the marbled murrelet and the northern spotted owl. Placement of fill will trigger the need for a permit under Section 404 of the Clean Water Act and 401 certification. Whether an individual permit or the simpler nationwide permit is sufficient depends on the design and extent of impacts.

Scope of work and the limited in-water work window would likely require a petition for a waiver and extension from the WDFW.

Minor and Major Active River Channel Shift

This could have a dramatic effect on the existing river system. The extent to which the option helps or harms the aquatic habitat would need determined through modeling and formal consultation with the Service, the Hoh Tribe, and the WDFW. This work would require an individual permit from the Corps and 401 Certification from the DOE.

A biological assessment would need to be prepared evaluating short and long term impacts to bull trout and short term construction impacts to the marbled murrelet and the northern spotted owl.

In addition, geomorphic assessments would need to be conducted for assessing effect this option may have on downstream properties.

Due to the scope of work and the limited in-water work window, WDFW would likely need to be petitioned for an extension.

Each ELJ requires a number of trees to be cut down. Approximately 1,500 and 3,000 logs are needed for the minor and major active river channel shift options, respectively. Cutting these trees would have a direct impact on some forest's ecosystem and watershed's health.



ACMZ - Active Channel Migration Zone, Geomorphic Assessment of Hoh River in Washington State, USBR, July 2004.

Imagery date 9/25/2011

Figure C1-1. Site Location

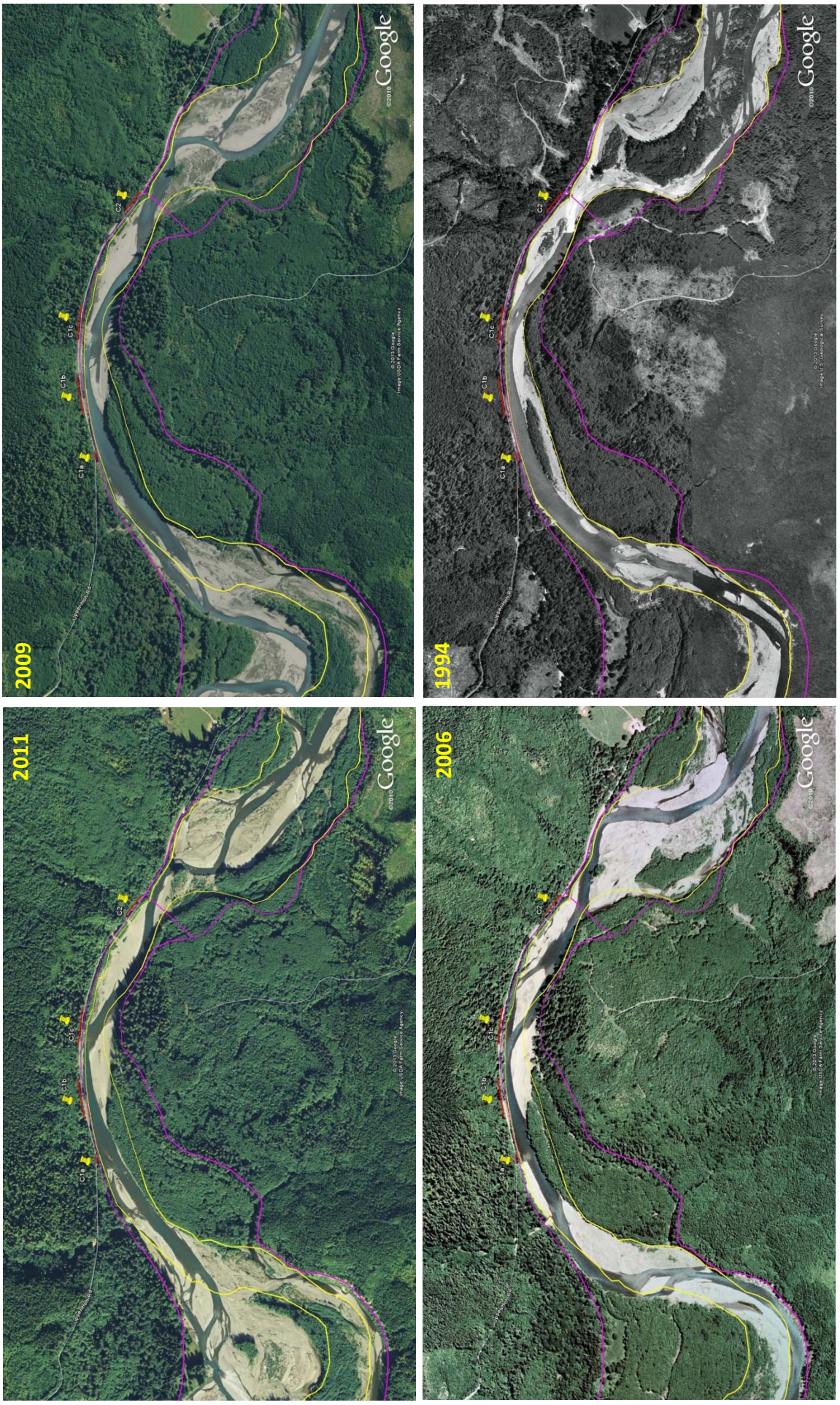


Figure C1-2. Historical Satellite Imagery

Photos

C1a - CMP 3.7 Bank Stabilization



PHOTO C1a- 1

Downstream end of existing riprap revetment - looking downstream at eroding stream bank.

Large woody debris deflects stream flow towards stream bank, aggravating erosion.



PHOTO C1a- 2

Downstream end of existing riprap revetment - looking upstream at existing riprap revetment.

Heavily wooded riprap revetment appears moderately stable.



PHOTO C1a- 3

Bank erosion within 20 feet of road pavement edge.

12 feet high stream bank undercut and eroding. Large woody debris deflects stream flow towards stream bank, aggravating erosion.

12/12/2012

Photos

C1a - CMP 3.7 Bank Stabilization



PHOTO C1a- 4

Bank erosion within 20 feet of road pavement edge.

12 feet high stream bank undercut and eroding. Large woody debris deflects stream flow towards stream bank, aggravating erosion.



PHOTO C1a- 5

Mid-channel sediment deposits and large woody debris adjacent to site.

Large woody debris deflects stream flow towards stream bank, aggravating erosion. Woody debris jam could become larger and persist overtime.



PHOTO C1a- 6

Mid-channel sediment deposits and large woody debris adjacent to site.

Large woody debris deflects stream flow towards stream bank, aggravating erosion. Woody debris jam could become larger and persist overtime.

12/12/2012

Photos

C1b - CMP 3.9 Bank Stabilization



PHOTO C1b- 1

Downstream riprap revetment segment - looking upstream.

Finished slope is steep, some riprap has been dislodged from middle slope and toe areas.



PHOTO C1b- 2

Gap in bank erosion control between downstream and middle revetment segments - looking downstream.

16 feet high stream bank undercut and eroding. Trees have and are falling into the river. Middle revetment segment appears stable.



PHOTO C1b- 3

Bank erosions site at MP C3.9 - looking upstream.

16 feet high stream bank. Erosion scarp within 10 feet of road pavement edge. Large woody debris deflects stream flow towards bank, aggravating erosion.

12/12/2012

Photos

C1b - CMP 3.9 Bank Stabilization



PHOTO C1b- 4

Bank erosions site at MP C3.9 - looking downstream.

16 feet high stream bank. Erosion scarp within 10 feet of road pavement edge. Large woody debris deflects stream flow towards bank, aggravating erosion. Downstream riprap revetment segment in top center photo.



PHOTO C1b- 5

Bank erosions site at MP C3.9 - existing downstream riprap revetment segment upstream end.

Large woody debris deflects stream flow towards bank, aggravating erosion. Some riprap has been dislodged.



PHOTO C1b- 6

Middle riprap revetment segment - looking upstream from C1b.

Riprap appears moderately stable.

12/12/2012

Photos

C1c - CMP 4.0 Bank Stabilization



PHOTO C1c- 1

Gap in bank erosion control between upstream and middle revetment segments - looking upstream.

18 feet high stream bank undercut and eroding. Erosion scarp 15 to 20 feet of road pavement edge. Trees have and are falling into the river.



PHOTO C1c- 2

Upstream end of bank erosion gap - looking downstream.

Upstream revetment segment heavily treed and appears stable.



PHOTO C1c- 3

Gap in bank erosion control between upstream and middle revetment segments - looking upstream from C1b.

18 feet high stream bank undercut and eroding. Erosion scarp 15 to 20 feet of road pavement edge. Trees have and are falling into the river.

12/12/2012

Table C1-1. Alternative Summary and Ranking.

Upper Hoh River Road Site - C1 - MP 3.7 - 4.0 Bank Stabilization

						Bank Stabilization								Minor Active River Channel Shift				Major Active River Channel Shift	
OPTIONS	**Rank**	**Continued Maintenance**	**Rank**	**Relocate Road**	**Rank**	**Complex Roughened Large Rock Toe**	**Rank**	**Complex Log Crib Wall**	**Rank**	**Riprap with LWD and Plantings**	**Rank**	**Riprap with Streambarbs**	**Rank**	**ELJ Groins**	**Rank**	**Large Stream barbs**	**Rank**	
Road on the edge of the channel migration zone has less of an impact to the total channel zone.		**Place or replace riprap as needed for preventing road closure.**		**Offset Road 200 Feet with mitigation of existing roadway slope to riparian zone - install streambarbs and ELJ's for preserving riparian zone.**		**Rock toe with LWD.**		**Log crib wall with roughness elements.**		**Riprap similar to what is commonly used along Upper Hoh River Road embankment.**		**Bank area planted with willow and alder.**		**Construct new stream bank area over unstable and revetment areas.**		**Construct new stream bank area over unstable and revetment areas.**		**Shift active flow channel to flow across point bar away from revetment area.**
Ability to preserve and operate the roadway in a specific location (Most able 5, least able 1)	**3**	Reduces risk of a catastrophic road failure during extreme flood event.	**3**	Better than where it is, but the river may eventually migrate north and impact road again.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.
Roadway sustainability (life of solution) (Longest 5, shortest 1)	**1**	Increased maintenance in the future mitigating climate change or after large flood events.	**3**	Increase road life reduces future risk from river. Road near hillside may experience landslides and debris flows.	**3**	Requires moderate amount of wood replacement and maintenance.	**1**	Requires substantial amount of wood replacement and maintenance.	**3**	Requires moderate amount of wood replacement and maintenance.	**5**	Requires moderate level of maintenance.	**1**	Requires substantial amount of wood replacement and maintenance.	**5**	Requires moderate level of maintenance.	**1**	Requires substantial amount of wood replacement and maintenance.
Impact to hillside stability adjacent to site (Most likely 1; least likely 5)	**5**	No expected additional impacts.	**1**	Road near hillside may experience landslides and debris flows.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.
Potential to reduce erosion of banks adjacent to site (Most 5; Least 1)	**1**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**1**	Likely increase down stream right bank erosion.
Impacts to listed Threatened and Endangered (T&E) terrestrial species and habitat (Least 5; most 1)	**5**	No expected additional impacts.	**1**	Impacts upland areas and potentially T&E.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.
Impacts to listed T&E fish and habitat (Least 5; most 1)	**3**	Riprap placed along bank reduces habitat complexity.	**3**	Material placed in channel.	**3**	Material placed in channel.	**3**	Material placed in channel.	**3**	Material placed in channel.	**1**	Riprap along bank reduces habitat complexity. Barbs require significant excavation into channel bed.	**3**	Considerable temporary impacts from in-stream channel work.	**3**	Considerable temporary impacts from in-stream channel work.	**3**	Considerable temporary impacts from in-stream channel work.
Impact to upland habitat (Least 5; most 1)	**5**	No expected additional impacts.	**1**	Impacts upland areas.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.
Impacts to Wetlands and Waters of the U.S. (Least 5; most 1)	**3**	No expected additional impacts to wetlands; riprap placement in river.	**3**	Riprap placement in river.	**3**	No expected additional impacts to wetlands; riprap placement in river.	**3**	No expected additional impacts to wetlands.	**3**	No expected additional impacts to wetlands; riprap placement in river.	**1**	Riprap along bank reduces habitat complexity. Barbs require significant excavation into channel bed.	**1**	Requires major in stream construction.	**1**	Requires major in stream construction.	**1**	Requires major in stream construction.
Impact to Designated Wilderness area (Least 5; most 1)	**0**	No expected impacts.	**0**	Expected impacts.	**0**	No expected impacts.	**0**	No expected impacts.	**0**	No expected impacts.	**0**	No expected impacts.	**0**	No impacts.	**0**	No impacts.	**0**	No expected impacts.
Potential for Hoh River Enhancement (Greatest 5; Least 1)	**1**	Does not provide river enhancements.	**5**	Provides off-channel/side-channel habitat, allows river to fully access HCMZ.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Moves thalweg away from road, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.
Potential to maintain or improve river process and function (Most 5; Least 1)	**1**	Does not improve river process and function.	**5**	Provides off-channel/side-channel habitat, allows river to fully access HCMZ	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Moves thalweg away from road, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.
Potential for other habitat enhancements (Most 5; Least 1)	**1**	Does not provide other habitat enhancements.	**5**	Opportunity for improving fish access to off-channel habitat	**3**	Provides some woody debris for habitat complexity and biological processes.	**3**	Provides some woody debris for habitat complexity and biological processes.	**3**	Provides some woody debris for habitat complexity and biological processes.	**1**	Does not provide other habitat enhancements.	**5**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides some woody debris for habitat complexity and biological processes.	**5**	Provides woody debris for habitat complexity and biological processes.
Potential private property impacts (Least 5; Most 1)	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**3**	Some impacts expected from bank erosion downstream of site.	**3**	Some impacts expected from bank erosion downstream of site.	**1**	Impacts likely from bank erosion downstream of site.
Safety risk of design to public (Least 5; Most 1)	**5**	No expected increase in safety risk.	**3**	Boaters could become trapped in root wads.	**3**	Boaters could become trapped in root wads.	**1**	Public could fall down wall. Boaters could become trapped in root wads.	**3**	Boaters could become trapped in root wads.	**5**	No expected increase in safety risk.	**1**	Boaters could become trapped in ELJ's.	**3**	Boaters could become trapped in root wads.	**1**	Boaters could become trapped in ELJ's.
Total Construction cost	**5**	**NA**	**1**	**$8,902,400**	**3**	**$1,276,165**	**3**	**$1,595,632**	**3**	**$2,311,790**	**3**	**$2,309,472**	**1**	**$9,289,098**	**1**	**$5,399,862**	**1**	**$5,285,800**
Riprap and Wood Replacement (50 years)		**NA**		**$1,580,000**		**$349,800**		**$692,533**		**$505,267**		**$377,733**		**$4,488,000**		**$488,400**		**$3,000,000**
Total Capital Cost (50 years)		**NA**		**$13,698,240**		**$2,072,623**		**$2,846,636**		**$3,626,184**		**$3,495,521**		**$17,028,282**		**$7,778,214**		**$10,135,830**
Annualized Total Capital Cost (Least 5; Most 1)		**$21,000**		**$1,008,288**		**$152,560**		**$209,533**		**$266,913**		**$257,295**		**$1,253,402**		**$572,532**		**$746,069**
SCORE	**44**		**43**		**52**		**48**		**52**		**50**		**48**		**52**		**44**	

Table C1-2. Total Expected Cost

Project: Hoh River Road Bank Erosion Risk Study **Date: 3/14/2013**

Site: C1 - CMP 3.7 to 4.0 Bank Stabilization

Alternative: Continue Maintenance **By: S. Leon**

	Flood Frequency (yr)	Exceedance Probability	Flood Damage	Average Flood Damage	Delta Exceedance Probability	Annual Risk Cost
No damage.	2	**0.5**	$0			
				$0	**0.3**	**$0**
No damage.	5	**0.2**	$0			
				$0	**0.1**	**$0**
No damage.	10	**0.1**	$0			
				$150,000	**0.06**	**$9,000**
Place riprap.	25	**0.04**	$300,000			
				$300,000	**0.02**	**$6,000**
Place riprap.	50	**0.02**	$300,000			
				$300,000	**0.01**	**$3,000**
Place riprap.	100	**0.01**	$300,000			
				$300,000	**0.01**	**$3,000**
		0	$300,000			
Total Annual Risk Cost						**$21,000**
Annualized Capital Cost	**Capital Cost**					**$0**
	Disc. rate, i	**0.07125**	**Serv. life, n**	**50**	**CFR**	**0.0736**
	Annualized Capital Cost					**$0**
Total Expected Cost (Annual)						**$21,000**
Summary	Assume 300 feet ($1k/ft) of revetment repair and bank armoring for each flood damage event.					

Notes:

1. Method from HEC-17, April 1981.

Table C1-3. Cost Estimates

Site: **C1 - CMP 3.7 to 4.0 - Bank Stabilization**

Relocate Road

		Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost	LS	1	$	448,000	$	**448,000**
New Road		LF	4,000	$	500	$	**2,000,000**
Hillside Stabilization		LS	1	$	200,000	$	**200,000**
Remove Existing Revetment		LF	2,500	$	200	$	**500,000**
Streambank Reconstruction		LF	1,800	$	1,000	$	**1,800,000**
Streambarbs		EA	10	$	40,000	$	**400,000**
ELJ's		EA	5	$	300,000	$	**1,500,000**
Total Construction Cost without Contingencies						$	**6,848,000**
Contingency	30% of construction cost					$	**2,054,400**
Total Construction Cost						$	**8,902,400**
Compliance	5% of total construction cost					$	**445,120**
Predesign/design (PE)	15% of total construction cost					$	**1,335,360**
Construction Engineering (CE)	15% of total construction cost					$	**1,335,360**
ROW						$	**100,000**
Riprap replacement -	20% replacement every		50	years		$	**80,000**
Wood replacement -	full log replacement every		30	years		$	**1,500,000**
TOTAL Capital Cost		Cost/Foot	**$ 3,425**			$	**13,698,240**
Annualized Capital Cost		Discount rate, i	0.07125			$	**1,008,288**
		Service life, n	50	years			
		CFR	**0.0736071**				

Complex Roughened Large Rock Toe

			Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost		LS	1	$	64,221	$	**64,221**
Remove Existing Revetment			LF	200	$	200	$	**40,000**
Rock	H 12 ft	T 5 ft	CY	**2,356**	$	180	$	**424,000**
	L 1060 ft							
Logs	L 1060 ft	XS 8 ft	EA	**133**	$	2,000	$	**265,000**
Soil	H 12 ft	T 10 ft	CY	**4,711**	$	40	$	**188,444**
	L 1060 ft							
Total Construction Cost without Contingencies							$	**981,666**
Contingency	30% of construction cost						$	**294,500**
Total Construction Cost							$	**1,276,165**
Compliance	5% of total construction cost						$	**63,808**
Predesign/design (PE)	15% of total construction cost						$	**191,425**
Construction Engineering (CE)	15% of total construction cost						$	**191,425**
ROW							$	**-**
Riprap replacement -	20% replacement every			50	years		$	**84,800**
Wood replacement -	full log replacement every			30	years		$	**265,000**
TOTAL Capital Cost			Cost/Foot	**$ 1,955**			$	**2,072,623**
Annualized Capital Cost			Discount rate, i	0.07125			$	**152,560**
			Service life, n	50	years			
			CFR	**0.0736071**				

Table C1-3. Cost Estimates

Complex Log Crib Wall

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost		LS	1	$	80,298	$	**80,298**
Remove Existing Revetment				LF	200	$	200	$	**40,000**
Rock	H 12 ft	T 5 ft		CY	**2,356**	$	120	$	**282,667**
	L 1060 ft								
Logs	L 1060 ft	H 12 ft		EA	**318**	$	2,000	$	**636,000**
	Dia 2 ft	Row 6							
	log l 20 ft	No. 318							
Piles				EA	0	$	-	$	**-**
Soil	H 12 ft	T 10 ft		CY	**4,711**	$	40	$	**188,444**
	L 1060 ft								
Total Construction Cost without Contingencies								$	**1,227,409**
Contingency	30%	of construction cost						$	**368,223**
Total Construction Cost								$	**1,595,632**
Compliance		5%	of total construction cost					$	**79,782**
Predesign/design (PE)		15%	of total construction cost					$	**239,345**
Construction Engineering (CE)		15%	of total construction cost					$	**239,345**
ROW								$	**-**
Riprap replacement -	20%	replacement every			50	years		$	**56,533**
Wood replacement -	full log	replacement every			30	years		$	**636,000**
TOTAL Capital Cost				Cost/Foot	**$ 2,686**			$	**2,846,636**
Annualized Capital Cost			Discount rate, i		0.07125			$	**209,533**
			Service life, n		50	years			
			CFR		**0.0736071**				

Riprap with Roughened Rock Toe, LWD, and Riparian Plantings

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost		LS	1	$	116,337	$	**116,337**
Remove Existing Revetment				LF	200	$	200	$	**40,000**
Riprap	H 13 ft	T 5 ft		CY	**6,674**	$	180	$	**1,201,333**
	L 1060 ft	SS 2 (h):1(v)							
	TW 8 ft	TT 5 ft							
Logs	L 1060 ft	XS 8 ft		EA	**133**	$	2,000	$	**265,000**
Willow	1200 sy	XS 2		EA	**600**	$	10	$	**6,000**
Alder	1200 sy	XS 1		EA	**1,200**	$	20	$	**24,000**
Soil	H 8 ft	T 10 ft		CY	**3,141**	$	40	$	**125,630**
	L 1060 ft								
Total Construction Cost without Contingencies								$	**1,778,300**
Contingency	30%	of construction cost						$	**533,490**
Total Construction Cost								$	**2,311,790**
Compliance		5%	of total construction cost					$	**115,590**
Predesign/design (PE)		15%	of total construction cost					$	**346,769**
Construction Engineering (CE)		15%	of total construction cost					$	**346,769**
ROW								$	**-**
Riprap replacement -	20%	replacement every			50	years		$	**240,267**
Wood replacement -	full log	replacement every			30	years		$	**265,000**
TOTAL Capital Cost				Cost/Foot	**$ 3,421**			$	**3,626,184**
Annualized Capital Cost			Discount rate, i		0.07125			$	**266,913**
			Service life, n		50	years			
			CFR		**0.0736071**				

Table C1-3. Cost Estimates

Riprap with Streambarbs

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost		LS	1	$	116,221	$	**116,221**
Remove Existing Revetment				LF	200	$	200	$	**40,000**
Riprap	H 13 ft	T 5 ft		CY	**5,104**	$	180	$	**918,667**
	L 1060 ft	SS 2 (h):1(v)							
	TW 0 ft	TT 0 ft							
Streambarbs				EA	11	$	40,000	$	**440,000**
Logs	L 1060 ft	XS 20 ft		EA	**53**	$	2,000	$	**106,000**
Willow	1200 sy	XS 2		EA	**600**	$	10	$	**6,000**
Alder	1200 sy	XS 1		EA	**1,200**	$	20	$	**24,000**
Soil	H 8 ft	T 10 ft		CY	**3,141**	$	40	$	**125,630**
	L 1060 ft								
Total Construction Cost without Contingencies								$	**1,776,517**
Contingency	30%	of construction cost						$	**532,955**
Total Construction Cost								$	**2,309,472**
Compliance		5%	of total construction cost					$	**115,474**
Predesign/design (PE)		15%	of total construction cost					$	**346,421**
Construction Engineering (CE)		15%	of total construction cost					$	**346,421**
ROW								$	**-**
Riprap replacement -	20%	replacement every			50	years		$	**271,733**
Wood replacement -	full log	replacement every			30	years		$	**106,000**
TOTAL Capital Cost				Cost/Foot	**$ 3,298**			$	**3,495,521**
Annualized Capital Cost				Discount rate, i	0.07125			$	**257,295**
				Service life, n	50	years			
				CFR	**0.0736071**				

Major River Channel Shift

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost		LS	1	$	266,000	$	**266,000**
Channel Excavation - 100 feet by 5 feet				LF	2,000	$	300	$	**600,000**
Rearing and Resting Habitat Construction				AC	4	$	50,000	$	**200,000**
Remove Existing Revetment				LF	-	$	200	$	**-**
Streambank Reconstruction				LF	-	$	1,000	$	**-**
Streambarbs				EA	-	$	40,000	$	**-**
ELJ's - 20 ft by 60 ft				EA	10	$	300,000	$	**3,000,000**
Total Construction Cost without Contingencies								$	**4,066,000**
Contingency	30%	of construction cost						$	**1,219,800**
Total Construction Cost								$	**5,285,800**
Compliance		5%	of total construction cost					$	**264,290**
Predesign/design (PE)		15%	of total construction cost					$	**792,870**
Construction Engineering (CE)		15%	of total construction cost					$	**792,870**
ROW								$	**-**
Riprap replacement -	20%	replacement every			50	years		$	**-**
Wood replacement -	full log	replacement every			30	years		$	**3,000,000**
TOTAL Capital Cost				Cost/Foot	**$ 5,068**			$	**10,135,830**
Annualized Capital Cost				Discount rate, i	0.07125			$	**746,069**
				Service life, n	50	years			
				CFR	**0.0736071**				

Table C1-3. Cost Estimates

Minor River Channel Shift - ELJ Groins

		Unit	Quantity	Unit Cost	Total Cost
Mobilization	7% of construction cost	LS	1	$ 467,460	**$ 467,460**
Rearing and Resting Habitat Construction		AC	-	$ 50,000	**$ -**
Remove Existing Revetment		LF	-	$ 200	**$ -**
Streambank Reconstruction - fill/plants/fascines		LF	1,700	$ 1,200	**$ 2,040,000**
Large Wood		EA	100	$ 1,500	**$ 150,000**
ELJ groin - 15 ft by 60 ft (3 x 15 ft by 20 ft mod.)		EA	20	$ 224,400	**$ 4,488,000**
Primary logs	50 $ 1,200 $ 60,000				
Pin logs	4 $ 1,200 $ 4,800				
Ballast stone	50 $ 180 $ 9,000				
Cabling	1 $ 1,000 $ 1,000				
	$ 74,800				
No. modules/ ELJ groin	3 $ 224,400				
Total Construction Cost without Contingencies					**$ 7,145,460**
Contingency	30% of construction cost				**$ 2,143,638**
Total Construction Cost					**$ 9,289,098**
Compliance	5% of total construction cost				**$ 464,454.90**
Predesign/design (PE)	15% of total construction cost				**$ 1,393,365**
Construction Engineering (CE)	15% of total construction cost				**$ 1,393,365**
ROW					**$ -**
Riprap replacement -	20% replacement every		50 years		**$ -**
Wood replacement -	full log replacement every		30 years		**$ 4,488,000**
TOTAL Capital Cost		Cost/Foot	**$ 5,464**		**$ 17,028,282**
Annualized Capital Cost		Discount rate, i	0.07125		**$ 1,253,402**
		Service life, n	50 years		
		CFR	**0.0736071**		

Minor River Channel Shift - Stream Barbs

			Unit	Quantity	Unit Cost	Total Cost
Mobilization	7% of construction cost		LS	1	$ 271,740	**$ 271,740**
Rearing and Resting Habitat Construction			AC	-	$ 50,000	**$ -**
Remove Existing Revetment			LF	-	$ 200	**$ -**
Streambank Reconstruction - fill/plants/fascines			LF	1,700	$ 1,200	**$ 2,040,000**
Large Wood			EA	100	$ 1,500	**$ 150,000**
Streambarbs	Length	100 ft	EA	20	$ 84,600	**$ 1,692,000**
	Crest width	8 ft				
	Average bot. width	28 ft				
	Average thickness	7 ft				
	Volume	470 cy				
	Cost/cy	180 $/cy	Cost/barb	$ 84,600		
Total Construction Cost without Contingencies						**$ 4,153,740**
Contingency	30% of construction cost					**$ 1,246,122**
Total Construction Cost						**$ 5,399,862**
Compliance	5% of total construction cost					**$ 269,993**
Predesign/design (PE)	15% of total construction cost					**$ 809,979**
Construction Engineering (CE)	15% of total construction cost					**$ 809,979**
ROW						**$ -**
Riprap replacement -	20% replacement every		50 years			**$ 338,400**
Wood replacement -	full log replacement every		30 years			**$ 150,000**
TOTAL Capital Cost			Cost/Foot	**$ 3,176**		**$ 7,778,214**
Annualized Capital Cost			Discount rate, i	0.07125		**$ 572,532**
			Service life, n	50 years		
			CFR	**0.0736071**		

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C2 - COUNTY MILEPOST 4.4

BANK STABILIZATION



SITE C2 – COUNTY MILEPOST 4.4 BANK STABILIZATION

Site Conditions

The site parallels the outside bank of a river bend (Fig. C2-1). Approximately 3,900 lineal feet of riprap revetment along the apex of the river bend appears to be generally effectively controlling road embankment erosion. Approximately 1,150 feet of the riprap revetment is included with site C1. The 2 to 4 feet diameter riprap comprising the revetment is generally properly graded and placed. Revetments are in two segments. Upstream and downstream segments are approximately 1,400 and 1,350 feet long, respectively. Downstream segment is also the upstream revetment segment for site C1. The segments are densely planted with willow and alder and appear generally stable. Currently, a large portion of the downstream segment is experiencing impinging flood flow. Down-valley translation of the meander channel at the site could eventually erode away a point bar, exposing the entire revetment segment to impinging flood flows.

Distance of stream bank between the upstream and downstream revetment segments is approximately 350 feet. Currently, a point bar directs stream flow towards the bank. Toe erosion and undermining of the stream bank is occurring (Photo C2-1). The stream bank toe is approximately 10 to 20 feet away and 8 feet below the road pavement edge (Photo C2-2).

Cobbles and small boulders naturally armor the lower 3 to 4 feet of the bank. A soft, highly fractured silt-stone was observed at several areas along the bank toe (Photo C2-3 and 4). It and the cobbles and boulders inhibit the toe erosion. The upper 5 to 6 feet of bank is a highly erodible, finer-grained alluvial material. Large trees are and dense vegetation is sparse (Photo C2-2). Where present they have inhibited the bank erosion. Erosion scarps have reached within 10 feet of the pavement edge. The scarps tend to be less than 20 feet long.

An erosion resistant poorly consolidated alluvium terrace deposit has limited river bend migration to the north and south. The terrace deposit represents the historical channel migration zone (HCMZ) right and left (looking downstream) boundaries (Geomorphic Assessment of the Hoh River in Washington State, Bureau of Reclamation, July 2004). Width of the HCMZ is approximately 500 to 1,000 feet. The road embankment coincides with the HCMZ right boundary and valley wall. Based on historical satellite imagery, the active channel has not changed significantly in width and location since 1994 (Fig. C2-2). The point of active flow channel impingement on the right bank has sifted downstream approximately 1,000 feet since 1994.

Continued stream bank erosion could undermine the road. Based on current channel alignment and expected limited channel alignment shifts, the risk of a catastrophic road embankment failure is high. Water depth at typically normal annual low flow conditions is estimated to be 4 to 6 feet.

Considered Options

Continuing maintenance, relocating the road, installing additional bank stabilization, minor active river channel shift, and major active river channel shift were considered. Table C2-1 presents an evaluation and ranking of the options against design selection criteria.

Riprap is expected to be lost during extreme flooding, requiring replenishment for maintaining the riprap installation's effectiveness. Total Capital and Annualized Total Capital Costs provided in Table C2-1 assume 20 percent of the riprap in an installation is replaced every 50 years.

Douglas fir and hemlock are the most commonly available logs in the area. Douglas-fir logs can remain durable in wetting-drying conditions for 25 to 60 years (Tech. Supp. 14J, Use of Large Woody Material for Habitat and Bank Protection, Part 654, National Engineering Handbook, USDA, Natural Resources Conservation Service). Hemlock is the least durable of the conifers. Because the tree quality and species to be used in the structures is not known, Total Capital and Annualized Total Capital Costs provided in Table C2-1 assume wood used in the alternatives is replaced every 30 years.

Continue Maintenance

Continued maintenance involves monitoring the stream bank areas for excessive bank erosion. Stream bank toe erosion could progress to the point that undermining of the road is imminent. Continued maintenance is placing riprap in an emergency action or after flooding as needed for preventing a road closure. Placing riprap as an emergency action may be hazardous or difficult. The emergency-placed riprap may not be effective in controlling the erosion.

A Total Expected Cost analysis (HEC-17, FHWA, April 1981) was completed for estimating total expected cost repairing flood-induced road damage over a 50-year service-life. Based on observed proximity of channel to roadway and resistance of the natural bank armoring, the analysis assumes damage requiring addition of new riprap revetment placed as an emergency action for stabilizing an eroding river bank occurs for floods equal to and larger than the 10-year flood event. Based on review of historical satellite imagery, length of bank typically exposed to impinging flood flow is estimated to be approximately 300 feet. Based on vegetation distribution and age and estimated riprap placement sequencing, the length of past revetment installations ranged from 200 to 500 feet. Assuming 300 feet total for each flood damage event and a cost of $1,000 per foot, the total expected annual cost is $45,000 (Table C2-2, Total Expected Cost).

Relocate Road

Shifting the road at least 100 to 200 feet away from the active river channel edge provides a riparian buffer wide enough for containing a reconstructed stream bank area, eliminating the need for continuous revetment bank stabilization. The 260 feet high terrace slope is immediately adjacent to the roadway. A shift would mean an alignment that crosses the terrace slope. Slumping observed on the terrace slope suggests the terrace slope is not geotechnically stable. A new road alignment located across the terrace slope would experience landslides and debris flows that could potentially bury the road with debris. The road alignment may require significant foundation stabilization for mitigating landslides. Length of reroute is estimated to be 1,200 feet for connecting to existing road segments that are behind stable appearing riprap revetments.

The unprotected stream bank will continue to erode and migrate to the north. Streambarbs, engineered-log-jams (ELJ's), and planted vegetation would inhibit the bank erosion and lateral migration and preserve a riparian buffer between the active river channel and road embankment. The alternative requires monitoring and repair of the streambarbs and ELJ's to remain effective in controlling the bank erosion and lateral migration. Approximately 350 feet of the stream bank is reconstructed.

Estimated construction cost for the new road, existing road removal, three streambarbs, and two ELJ's is summarized in Table C2-3. Stabilizing landslides may require significantly more money. Road construction is expected to occur outside the active flow channel. Streambarb, ELJ, and stream bank construction is expected to occur within the active flow channel. Turbidity released is expected to be limited in extent and duration. Access for construction is assumed from the existing road. Constructing the new road alignment first and then switching the Upper

Hoh Road traffic over before removing the existing road reduces traffic impacts to one-lane closures and short-term delays.

Stabilize Existing Road Embankment

Approximately 350 feet of stream bank is proposed for stabilization.

Alternatives evaluated;

- Complex roughened large rock toe.
- Complex log crib wall.
- Riprap with roughened rock toe, LWD, and riparian plantings.
- Riprap with streambarbs.

Based on field evidence, the site will experience high shear stress, 10 to 12 feet deep flood flows, and abundant floating debris. It is critical that the stabilization methods be properly designed and anchored for maintaining effectiveness and surviving the expected flood conditions.

Construction for all the alternatives is expected to occur entirely within the active flow channel and requires excavating into the streambed and stream bank. Stream work would be accomplished in flowing water. Assuming the work is completed during low flow periods, turbidity released is expected to be limited in extent and duration. Access for construction is assumed down a temporary access route built of riprap and logs. The access route would be removed after construction is completed. Upper Hoh Road traffic impacts are expected to be limited to one-lane closures and short-term delays.

-Complex roughened large rock toe (Appendix A, Sheet 4).

The approach involves placing a rock toe between the expected scour depth and ordinary high water level, approximately 10 to 12 feet high and 5 feet thick. Log bundles spaced 6 to 10 feet are placed at the bottom of the rock toe. Soil placed above the rock toe in overlapping layers of erosion control blanket, approximately 2 to 4 feet. The rock toe and soil ballast the logs and reduce the risk of the logs floating away. Estimated construction cost for the complex roughened large rock toe is summarized in Table C2-3.

-Complex log crib wall (Appendix A, Sheet 5).

The approach involves placing a log crib wall made of rough logs between the expected scour depth and ordinary high water level, approximately 10 to 12 feet high. Stone is placed within the log crib wall for ballast. Logs with attached root wads extending into the stream bank provide roughness and additional wall stability. All logs are cabled together for enhancing stability. Designs typically include piles driven to refusal or minimum depth of 10 feet. The cobble and boulder stream bed material will likely prevent the piles from being cost-effectively driven or excavated. They are assumed eliminated in the proposed design. Approximately 2 to 4 feet of soil is placed above the crib wall and planted. Estimated construction cost for the complex log crib wall is summarized in Table C2-3.

-Riprap with Roughened Rock Toe, LWD, and Riparian Plantings (Appendix A, Sheet 9).

The approach involves placing a riprap revetment between the expected scour depth and 50-year flood event water level, approximately 12 to 15 feet high, 5 feet thick, and 2(h):1(v) slope. A launchable riprap toe 8 feet wide and 5 feet thick reduces the risk of scour and channel incision undermining the revetment and provides additional stability. Logs or log bundles

spaced 6 to 10 feet are placed along the revetment toe for providing roughness and channel complexity. The logs are buried in the road embankment for reducing the risk of them floating away. Willow and alder are planted throughout the revetment and bank area above the revetment. Estimated construction cost is summarized in Table C2-3.

-Riprap with Streambarbs (Appendix A, Sheet 11).

The approach involves placing a riprap revetment between the expected scour depth and 50-year flood event water level, approximately 12 to 15 feet high, 5 feet thick, and 2(h):1(v) slope. Instead of a launchable riprap toe, 10 to 12 - 40 to 50 feet long streambarbs are proposed for reducing shear stress and deflecting the river flow away from the revetment. The streambarbs reduce the risk of scour and channel incision undermining the revetment, promote sediment deposition and retention along the bank toe, and creates channel complexity. The bank, riprap, streambarbs, and channel area between the streambarbs would be augmented with streambed material, large woody debris, and planted with riparian vegetation for establishing a riparian buffer. Estimated construction cost is summarized in Table C2-3.

Minor Active River Channel Shift

An environmentally desirable approach would be to nudge the active river channel over enough from the road to reestablish a riparian buffer. Ideally, the buffer would have the same erosion resistance of a natural, wooded and vegetated river bank. The buffer would need to be wide enough to allow some bank erosion without threatening the roadway. It would be made by placing alluvial material over existing riprap revetment and unstable bank areas. To promote vegetation establishment and soil mass stability, the finished surface of the buffer area should not be steeper than 5(h):1(v). Assuming an 8 feet high bank, the width of the new buffer area would be at least 40 feet. Existing relative stable riparian buffers observed along the river are at least 40 to 50 feet wide and densely vegetated with alder and fir. The new buffer area would be prone to erosion from active channel migration. The erosive forces are expected to be too large for passive and bio-engineering methods to be effective by themselves. Hardened, more erosion resistant components in the buffer system are needed for mitigating the erosive forces.

-Engineered-log-jam Groins.

ELJ's groins constructed perpendicular to the stream bank and extending through the new buffer area would control channel location and deflect river flow away from new buffer area (Appendix A, Sheet 10). An ELJ's buoyancy and sliding analysis (Design Guidelines for Reintroducing Wood in Australian Streams, Abbe/Brooks, 2006) was completed assuming 6 feet design flow depth, 5 feet design scour depth, 8 feet per second average flow velocity, 1.5 velocity correction factor, and 18-inch average trunk diameter. The river bed contains cobbles and small boulders. Piles would need to penetrate the river bottom at least 20 to 30 feet for providing adequate resistance to buoyancy and sliding. Tree trunk piles would likely splinter before reaching the desired design depth. As wood decays, it losses strength and cannot resist the shear stresses created by a sliding ELJ mass. Driving steel piles for pinning the ELJ structure to the river bottom would be expensive and leave a tangle of steel piles protruding from the river bottom. Based on the analysis, an ELJ structure 15 feet wide and ballasted with stone is needed for achieving a minimum sliding factor-of-safety of 2.0, the minimum needed for unknown flow conditions and resisting expected additional woody debris accumulation.

Each ELJ groin would be 40 feet long and constructed of two 15 feet wide by 20 feet long modules. Assuming 2 to 3 feet gaps between logs and 8 layers, approximately 50 logs are needed for each module and 100 for each groin. Based on the stability analysis, 100 cubic yards of ballast stone is needed for each ELJ groin for achieving minimum sliding and buoyancy

factor-of-safeties of 2.0, the minimum needed for unknown flow conditions and resisting expected additional woody debris accumulation. The logs are cabled together for keeping them in place against expected flow depth and velocity and additional woody debris accumulation.

-Riprap Streambarbs.

Streambarbs are an alternative to using ELJ groins for controlling channel location and reducing erosive forces (Appendix A, Sheet 10). Each stream barb would be angled upstream 30 degree relative the bank line and approximately 90 feet long for fitting within the new riparian buffer. Assuming Class 8 riprap, crest width is 8 feet. Barb thickness is 6 feet at base and 6 feet at tip. Barb bottom width is 23 feet at base and 23 feet at tip. Approximately 310 cubic yards of riprap is needed for each stream barb.

Based on review of historical satellite imagery, length of bank typically exposed to impinging flood flow is estimated to be approximately 150 to 200 feet. The radius of curvature for active channel is 200 to 500 feet. To effectively deflect the impinging river flow away from the new bank area, the ELJ groins or stream barbs would need to be spaced every 100 to 150 feet. Assuming the new bank area is placed over the eroding bank, approximately 350 feet of new bank area is created and four ELJ groins or stream barbs are needed.

The existing stream bank is assumed left in place. New stream bank area is constructed between the ELJ groins or stream barbs by placing conserved and imported stream bed and bank material. Willow and cottonwood trees are planted throughout the area. Willow fascines are placed along the lower 3 to 6 feet of the bank toe for controlling erosion. Large wood is incorporated randomly throughout the bank area.

Estimated construction cost is summarized in Table C2-3. Work will be within the active river channel and requires temporarily diverting the river flow. Flow defection is assumed accomplished with large sandbags or water-inflated bladders. Dewatering the work area would be extremely difficult and expensive. Excavation and placing logs, stone, and new stream bank fill material is assumed to take place in the water ponded behind the flow diversion structure. Turbidity released is expected to be limited in extent and duration. Access for construction is assumed down a ramp constructed over the existing riprap revetment. The ramp could provide permanent access for maintenance. Upper Hoh Road traffic impacts are expected to be limited to one-lane closures and short-term delays.

The HCMZ is narrows at the site relative to upstream and downstream reaches. Consequently, it is expected that any active channel relocation would likely induce dramatic bank erosion and stream avulsion, resulting in unnatural changes in the HCMZ boundaries and the likely loss of private property downstream.

Executive Order 11988, Floodplain Management, established federal policies for protecting floodplains and floodways. The intention of the associated regulations is to avoid, to the extent practical, adverse impacts to floodplains; minimize the impact of floods to human safety, health, and welfare; and avoid supporting land use development that is incompatible with the natural and beneficial floodplain values. When avoidance is not possible, the policies require appropriate consideration of methods to assess and minimize adverse impacts. If the option is considered, additional analysis is needed for identifying extent and location of private property impacts. If found violating Executive Order 11988, relocating the active river channel would not be eligible for Federal funds.

Major Active River Channel Shift

Shifting the active river channel away from the road eliminates the current road loss risk from bank erosion occurring between the existing revetments. Shifting the active river channel to flow across the point bar opposite the existing riprap revetment could be accomplished with four to six ELJ's, each at least 20 feet wide and 60 to 100 feet long. All would be constructed within the active river channel. Top of the ELJ's are set equal to 100-year water surface, estimated to be approximately 5 to 6 feet above the point bar surface. Bottom of the ELJ's are set below the active channel thalweg elevation and expected scour depth, approximately 6 feet below the point bar surface. Each engineered-log-jam is ballasted with stone and logs cabled together for keeping them in place against expected flow depth and velocity and additional woody debris accumulation.

The existing revetments are assumed left in place. No stream bank area is reconstructed. Off-channel rearing and resting habitat is created along the toe of the existing road embankment. A new 100 feet wide active flow channel would be constructed across the point bar for diverting stream flow away from the construction area. Alluvial and plant materials from the channel excavation would be used for the habitat reconstruction.

Estimated construction cost is summarized in Table C2-3. Construction requires temporarily diverting the river flow. Turbidity released is expected to be limited in extent and duration. Access for construction is assumed down a ramp constructed over the existing road embankment. The ramp could provide permanent access for maintenance. Upper Hoh Road traffic impacts are expected to be limited to one-lane closures and short-term delays.

The HCMZ is narrows at the site relative to upstream and downstream reaches. Consequently, it is expected that any active channel relocation would likely induce dramatic bank erosion and stream avulsion, resulting in unnatural changes in the HCMZ boundaries and the likely loss of private property downstream.

Executive Order 11988, Floodplain Management, established federal policies for protecting floodplains and floodways. The intention of the associated regulations is to avoid, to the extent practical, adverse impacts to floodplains; minimize the impact of floods to human safety, health, and welfare; and avoid supporting land use development that is incompatible with the natural and beneficial floodplain values. When avoidance is not possible, the policies require appropriate consideration of methods to assess and minimize adverse impacts. If the option is considered, additional analysis is needed for identifying extent and location of private property impacts. If found violating Executive Order 11988, relocating the active river channel would not be eligible for Federal funds.

Environmental Clearance Considerations

This section of the Upper Hoh Road extends through primarily state trust lands. Designated critical marbled murrelet critical habitat is located immediately to the north and designated bull trout critical habitat is in the Hoh River. Designated northern spotted owl critical habitat is located approximately 3 miles to the east. Individuals of both species may be present in the forest immediately north of the road at this location. No wetlands were identified on the National Wetland Inventory Maps. A wetland survey and, if needed, delineation, would need to be conducted to confirm this negative finding.

Except for as described below, environmental clearance considerations for Site C2 are the same as described for Site C1.

Continue Maintenance

Environmental considerations are the same as those described in Site C1.

Relocate Road

The environmental clearance considerations are the same at this site as for Site C1 except for the fact that the existing riprap revetment would not be removed at this site and, therefore, the benefit to aquatic species is not as great.

Stabilize Existing Road Embankment

Environmental considerations are the same as those described in Site C1.

Minor and Major Active River Channel Shift

This could have a dramatic effect on the existing river system. The extent to which the option helps or harms the aquatic habitat would need determined through modeling and formal consultation with the Service, the Hoh Tribe, and the WDFW. This work would require an individual permit from the Corps and 401 Certification from the DOE.

A biological assessment would need to be prepared evaluating short and long term impacts to bull trout and short term construction impacts to the marbled murrelet and the northern spotted owl.

In addition, geomorphic assessments would need to be conducted for assessing effect this option may have on downstream properties.

Due to the scope of work and the limited in-water work window, WDFW would likely need to be petitioned for an extension.

Each ELJ requires a number of trees to be cut down. Approximately 400 and 900 logs are needed for the minor and major active river channel shift options, respectively. Cutting these trees would have a direct impact on some forest's ecosystem and watershed's health.



ACMZ - Active Channel Migration Zone, Geomorphic Assessment of Hoh River in Washington State, USBR, July 2004.

Imagery date 9/25/2011

Figure C2-1. Site Location

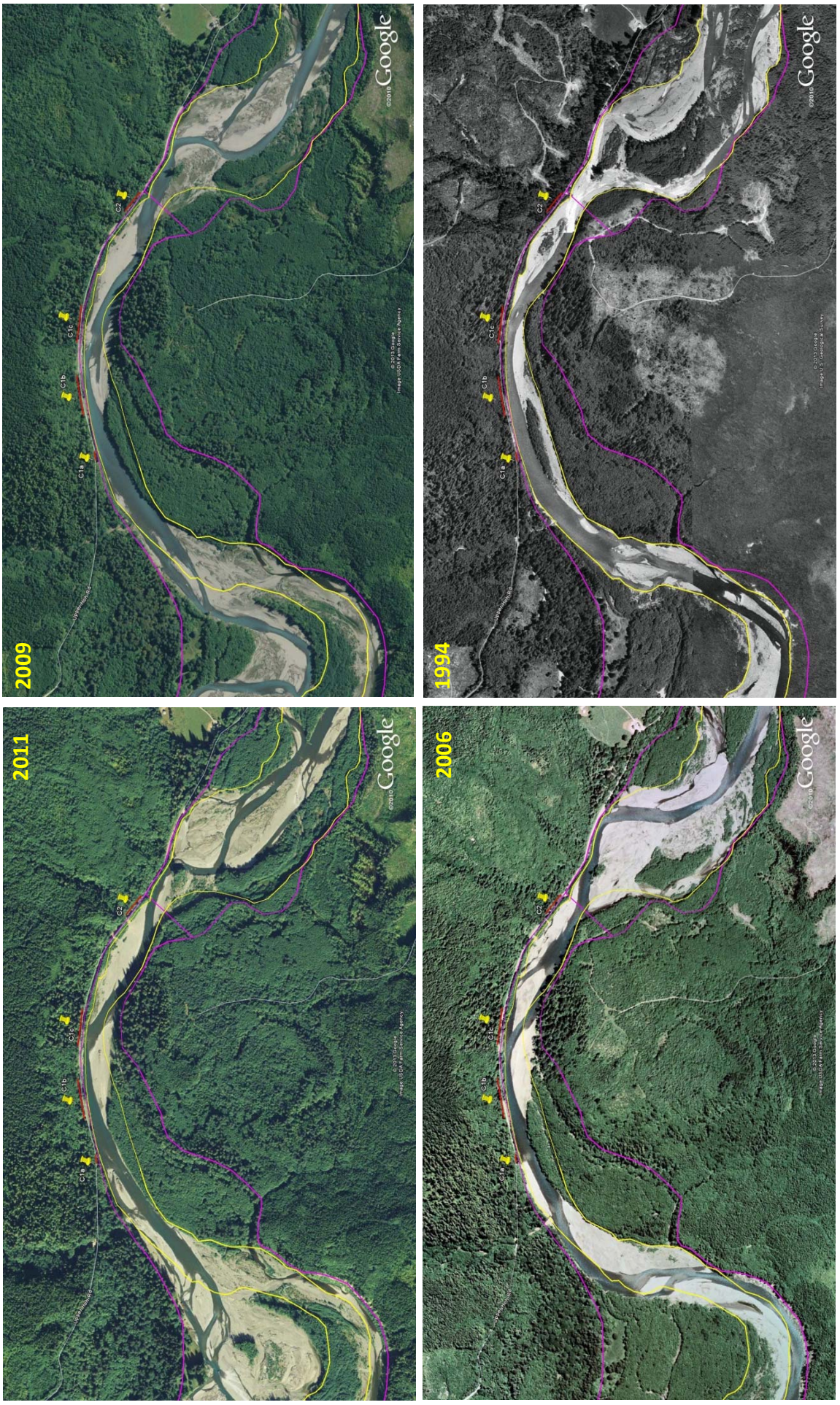


Figure C2-2. Historical Satellite Imagery

Photos

C2 - CMP 4.4 Bank Stabilization



PHOTO C2-1

Upstream end of eroding bank - looking downstream.

Vegetation leaning and bank vertical. Point bar deflects flow towards bank.



PHOTO C2-2

Downstream end of eroding bank - looking upstream.

Road 8 to 20 feet from erosion scarp. Vegetation sparse. Point bar deflects flow towards bank. Bank erosion nearest road at red flagging.



PHOTO C2-3

Typical erosion scarp.

Road 15 to 20 feet from erosion scarp. Soft, fractured silt-stone observed along bank toe. Finer-grained alluvial material in upper bank is highly erodible.

12/12/2012

Photos

C2 - CMP 4.4 Bank Stabilization



PHOTO C2-4

Typical erosion scarp.

Road 15 to 20 feet from erosion scarp. Bottom 2 to 3 feet armored with cobble and small boulder material. Soft, fractured silt-stone observed along bank toe. Finer-grained alluvial material in upper bank is highly erodible.

Table C2-1. Alternative Summary and Ranking.

Upper Hoh River Road Site - C2 - MP 4.4 Bank Stabilization

						Bank Stabilization								Minor Active River Channel Shift				Major Active River Channel Shift	
OPTIONS	**Rank**	**Continued Maintenance**	**Rank**	**Relocate Road**	**Rank**	**Complex Roughened Large Rock Toe**	**Rank**	**Complex Log Crib Wall**	**Rank**	**Riprap with LWD and Plantings**	**Rank**	**Riprap with Streambarbs**	**Rank**	**ELJ Groins**	**Rank**	**Large Stream barbs**	**Rank**	
Road on the edge of the channel migration zone has less of an impact to the total channel zone.		**Place or replace riprap as needed for preventing road closure.**		**Offset Road 200 Feet - install streambarbs and ELJ's for preserving riparian zone.**		**Rock toe with LWD.**		**Log crib wall with roughness elements.**		**Riprap similar to what is commonly used along Upper Hoh River Road embankment.**		**Bank area planted with willow and alder.**		**Construct new stream bank area over unstable and revetment areas.**		**Construct new stream bank area over unstable and revetment areas.**		**Shift active flow channel to flow across point bar away from revetment area.**
Ability to preserve and operate the roadway in a specific location (Most able 5, least able 1)	**3**	Reduces risk of a catastrophic road failure during extreme flood event.	**3**	Better than where it is, but the river may eventually migrate north and impact road again.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.
Roadway sustainability (life of solution) (Longest 5, shortest 1)	**1**	Increased maintenance in the future mitigating climate change or after large flood events.	**3**	Increase road life reduces future risk from river. Road near hillside may experience landslides and debris flows.	**3**	Requires moderate amount of wood replacement and maintenance.	**1**	Requires substantial amount of wood replacement and maintenance.	**3**	Requires moderate amount of wood replacement and maintenance.	**5**	Requires moderate level of maintenance.	**1**	Requires substantial amount of wood replacement and maintenance.	**5**	Requires moderate level of maintenance.	**1**	Requires substantial amount of wood replacement and maintenance.
Impact to hillside stability adjacent to site (Most likely 1; least likely 5)	**5**	No expected additional impacts.	**1**	Road near hillside may experience landslides and debris flows.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.
Potential to reduce erosion of banks adjacent to site (Most 5; Least 1)	**1**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**1**	Likely increase down stream right bank erosion.
Impacts to listed Threatened and Endangered (T&E) terrestrial species and habitat (Least 5; most 1)	**5**	No expected additional impacts.	**1**	Impacts upland areas and potentially T&E.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.
Impacts to listed T&E fish and habitat (Least 5; most 1)	**3**	Riprap placed along bank reduces habitat complexity.	**3**	Material placed in channel.	**3**	Material placed in channel.	**3**	Material placed in channel.	**3**	Material placed in channel.	**1**	Riprap along bank reduces habitat complexity. Barbs require significant excavation into channel bed.	**3**	Considerable temporary impacts from in-stream channel work.	**3**	Considerable temporary impacts from in-stream channel work.	**3**	Considerable temporary impacts from in-stream channel work.
Impact to upland habitat (Least 5; most 1)	**5**	No expected additional impacts.	**1**	Impacts upland areas.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.
Impacts to Wetlands and Waters of the U.S. (Least 5; most 1)	**3**	No expected additional impacts to wetlands; riprap placement in river.	**3**	Riprap placement in river.	**3**	No expected additional impacts to wetlands; riprap placement in river.	**3**	No expected additional impacts to wetlands.	**3**	No expected additional impacts to wetlands; riprap placement in river.	**1**	Riprap along bank reduces habitat complexity. Barbs require significant excavation into channel bed.	**1**	Requires major in stream construction.	**1**	Requires major in stream construction.	**1**	Requires major in stream construction.
Impact to Designated Wilderness area (Least 5; most 1)	**0**	No expected impacts.	**0**	Expected impacts.	**0**	No expected impacts.	**0**	No expected impacts.	**0**	No expected impacts.	**0**	No expected impacts.	**0**	No impacts.	**0**	No impacts.	**0**	No expected impacts.
Potential for Hoh River Enhancement (Greatest 5; Least 1)	**1**	Does not provide river enhancements.	**5**	Provides off-channel/side-channel habitat, allows river to fully access HCMZ.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Moves thalweg away from road, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.
Potential to maintain or improve river process and function (Most 5; Least 1)	**1**	Does not improve river process and function.	**5**	Provides off-channel/side-channel habitat, allows river to fully access HCMZ	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Moves thalweg away from road, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.
Potential for other habitat enhancements (Most 5; Least 1)	**1**	Does not provide other habitat enhancements.	**5**	Opportunity for improving fish access to off-channel habitat	**3**	Provides some woody debris for habitat complexity and biological processes.	**3**	Provides some woody debris for habitat complexity and biological processes.	**3**	Provides some woody debris for habitat complexity and biological processes.	**1**	Does not provide other habitat enhancements.	**5**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides some woody debris for habitat complexity and biological processes.	**5**	Provides woody debris for habitat complexity and biological processes.
Potential private property impacts (Least 5; Most 1)	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**3**	Some impacts expected from bank erosion downstream of site.	**3**	Some impacts expected from bank erosion downstream of site.	**1**	Impacts likely from bank erosion downstream of site.
Safety risk of design to public (Least 5; Most 1)	**5**	No expected increase in safety risk.	**3**	Boaters could become trapped in root wads.	**3**	Boaters could become trapped in root wads.	**1**	Public could fall down wall. Boaters could become trapped in root wads.	**3**	Boaters could become trapped in root wads.	**5**	No expected increase in safety risk.	**1**	Boaters could become trapped in ELJ's.	**3**	Boaters could become trapped in root wads.	**1**	Boaters could become trapped in ELJ's.
Total Construction cost	**5**	**NA**	**1**	**$1,905,670**	**3**	**$338,090**	**3**	**$499,214**	**3**	**$764,664**	**3**	**$673,089**	**1**	**$1,458,324**	**1**	**$936,421**	**1**	**$2,823,730**
Riprap and Wood Replacement (50 years)		**NA**		**$624,000**		**$115,500**		**$228,667**		**$166,833**		**$119,667**		**$598,400**		**$74,640**		**$1,800,000**
Total Capital Cost (50 years)		**NA**		**$3,246,655**		**$571,922**		**$902,606**		**$1,199,129**		**$1,028,337**		**$2,567,138**		**$1,338,809**		**$5,612,036**
Annualized Total Capital Cost (Least 5; Most 1)		**$45,000**		**$238,977**		**$42,098**		**$66,438**		**$88,264**		**$75,693**		**$188,960**		**$98,546**		**$413,086**
SCORE	**44**		**43**		**52**		**48**		**52**		**50**		**48**		**52**		**44**	

Table C2-2. Total Expected Cost

Project: Hoh River Road Bank Erosion Risk Study **Date: 3/14/2013**

Site: C2 - CMP 4.4 Bank Stabilization

Alternative: Continue Maintenance **By: S. Leon**

	Flood Frequency (yr)	Exceedance Probability	Flood Damage	Average Flood Damage	Delta Exceedance Probability	Annual Risk Cost
No damage.	2	**0.5**	$0			
				$0	**0.3**	**$0**
No damage.	5	**0.2**	$0			
				$150,000	**0.1**	**$15,000**
No damage.	10	**0.1**	$300,000			
				$300,000	**0.06**	**$18,000**
Place riprap.	25	**0.04**	$300,000			
				$300,000	**0.02**	**$6,000**
Place riprap.	50	**0.02**	$300,000			
				$300,000	**0.01**	**$3,000**
Place riprap.	100	**0.01**	$300,000			
				$300,000	**0.01**	**$3,000**
		0	$300,000			
Total Annual Risk Cost						**$45,000**
Annualized Capital Cost	**Capital Cost**					**$0**
	Disc. rate, i	**0.07125**	**Serv. life, n**	**50**	**CFR**	**0.0736**
	Annualized Capital Cost					**$0**
Total Expected Cost (Annual)						**$45,000**
Summary	Assume 300 feet ($1k/ft) of revetment repair and bank armoring for each flood damage event.					

Notes:

1. Method from HEC-17, April 1981.

Table C2-3. Cost Estimates

Site: **C2 - CMP 4.4 - Bank Stabilization**

Relocate Road

		Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost	LS	1	$	95,900	$	**95,900**
New Road		LF	1,200	$	500	$	**600,000**
Hillside Stabilization		LS	1	$	50,000	$	**50,000**
Remove Existing Revetment		LF	-	$	200	$	**-**
Streambank Reconstruction		LF	-	$	1,000	$	**-**
Streambarbs		EA	3	$	40,000	$	**120,000**
ELJ's		EA	2	$	300,000	$	**600,000**
Total Construction Cost without Contingencies						$	**1,465,900**
Contingency	30% of construction cost					$	**439,770**
Total Construction Cost						$	**1,905,670**
Compliance	5% of total construction cost					$	**95,284**
Predesign/design (PE)	15% of total construction cost					$	**285,851**
Construction Engineering (CE)	15% of total construction cost					$	**285,851**
ROW						$	**50,000**
Riprap replacement -	20% replacement every		50	years		$	**24,000**
Wood replacement -	full log replacement every		30	years		$	**600,000**
TOTAL Capital Cost		Cost/Foot	**$ 2,706**			$	**3,246,655**
Annualized Capital Cost		Discount rate, i	0.07125			$	**238,977**
		Service life, n	50	years			
		CFR	**0.0736071**				

Complex Roughened Large Rock Toe

			Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost		LS	1	$	17,014	$	**17,014**
Remove Existing Revetment			LF	-	$	200	$	**-**
Rock	H 12 ft	T 5 ft	CY	**778**	$	180	$	**140,000**
	L 350 ft							
Logs	L 350 ft	XS 8 ft	EA	**44**	$	2,000	$	**87,500**
Soil	H 3 ft	T 10 ft	CY	**389**	$	40	$	**15,556**
	L 350 ft							
Total Construction Cost without Contingencies							$	**260,069**
Contingency	30% of construction cost						$	**78,021**
Total Construction Cost							$	**338,090**
Compliance	5% of total construction cost						$	**16,905**
Predesign/design (PE)	15% of total construction cost						$	**50,714**
Construction Engineering (CE)	15% of total construction cost						$	**50,714**
ROW							$	**-**
Riprap replacement -	20% replacement every			50	years		$	**28,000**
Wood replacement -	full log replacement every			30	years		$	**87,500**
TOTAL Capital Cost			Cost/Foot	**$ 1,634**			$	**571,922**
Annualized Capital Cost			Discount rate, i	0.07125			$	**42,098**
			Service life, n	50	years			
			CFR	**0.0736071**				

Table C2-3. Cost Estimates

Complex Log Crib Wall

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost		LS	1	$	25,122	$	**25,122**
Remove Existing Revetment				LF	200	$	200	$	**40,000**
Rock	H 12 ft	T 5 ft		CY	**778**	$	120	$	**93,333**
	L 350 ft								
Logs	L 350 ft	H 12 ft		EA	**105**	$	2,000	$	**210,000**
	Dia 2 ft	Row 6							
	log l 20 ft	No. 105							
Piles				EA	0	$	-	$	**-**
Soil	H 3 ft	T 10 ft		CY	**389**	$	40	$	**15,556**
	L 350 ft								
Total Construction Cost without Contingencies								$	**384,011**
Contingency	30%	of construction cost						$	**115,203**
Total Construction Cost								$	**499,214**
Compliance		5%	of total construction cost					$	**24,961**
Predesign/design (PE)		15%	of total construction cost					$	**74,882**
Construction Engineering (CE)		15%	of total construction cost					$	**74,882**
ROW								$	**-**
Riprap replacement -	20%	replacement every			50	years		$	**18,667**
Wood replacement -	full log	replacement every			30	years		$	**210,000**
TOTAL Capital Cost			Cost/Foot		**$ 2,579**			$	**902,606**
Annualized Capital Cost			Discount rate, i		0.07125			$	**66,438**
			Service life, n		50	years			
			CFR		**0.0736071**				

Riprap with Roughened Rock Toe, LWD, and Riparian Plantings

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost		LS	1	$	38,481	$	**38,481**
Remove Existing Revetment				LF	200	$	200	$	**40,000**
Riprap	H 13 ft	T 5 ft		CY	**2,204**	$	180	$	**396,667**
	L 350 ft	SS 2 (h):1(v)							
	TW 8 ft	TT 5 ft							
Logs	L 350 ft	XS 8 ft		EA	**44**	$	2,000	$	**87,500**
Willow	400 sy	XS 2		EA	**200**	$	10	$	**2,000**
Alder	400 sy	XS 1		EA	**400**	$	20	$	**8,000**
Soil	H 3 ft	T 10 ft		CY	**389**	$	40	$	**15,556**
	L 350 ft								
Total Construction Cost without Contingencies								$	**588,203**
Contingency	30%	of construction cost						$	**176,461**
Total Construction Cost								$	**764,664**
Compliance		5%	of total construction cost					$	**38,233**
Predesign/design (PE)		15%	of total construction cost					$	**114,700**
Construction Engineering (CE)		15%	of total construction cost					$	**114,700**
ROW								$	**-**
Riprap replacement -	20%	replacement every			50	years		$	**79,333**
Wood replacement -	full log	replacement every			30	years		$	**87,500**
TOTAL Capital Cost			Cost/Foot		**$ 3,426**			$	**1,199,129**
Annualized Capital Cost			Discount rate, i		0.07125			$	**88,264**
			Service life, n		50	years			
			CFR		**0.0736071**				

Table C2-3. Cost Estimates

Riprap with Streambarbs

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost		LS	1	$	33,872	$	**33,872**
Remove Existing Revetment				LF	-	$	200	$	**-**
Riprap	H 13 ft	T 5 ft		CY	**1,685**	$	180	$	**303,333**
	L 350 ft	SS 2 (h):1(v)							
	TW 0 ft	TT 0 ft							
Streambarbs				EA	3	$	40,000	$	**120,000**
Logs	L 350 ft	XS 20 ft		EA	**18**	$	2,000	$	**35,000**
Willow	400 sy	XS 2		EA	**200**	$	10	$	**2,000**
Alder	400 sy	XS 1		EA	**400**	$	20	$	**8,000**
Soil	H 3 ft	T 10 ft		CY	**389**	$	40	$	**15,556**
	L 350 ft								
Total Construction Cost without Contingencies								$	**517,761**
Contingency	30%	of construction cost						$	**155,328**
Total Construction Cost								$	**673,089**
Compliance		5%	of total construction cost					$	**33,654**
Predesign/design (PE)		15%	of total construction cost					$	**100,963**
Construction Engineering (CE)		15%	of total construction cost					$	**100,963**
ROW								$	**-**
Riprap replacement -	20%	replacement every			50	years		$	**84,667**
Wood replacement -	full log	replacement every			30	years		$	**35,000**
TOTAL Capital Cost				Cost/Foot	**$ 2,938**			$	**1,028,337**
Annualized Capital Cost			Discount rate, i		0.07125			$	**75,693**
			Service life, n		50	years			
			CFR		**0.0736071**				

Major River Channel Shift

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost		LS	1	$	142,100	$	**142,100**
Channel Excavation - 100 feet by 5 feet				LF	600	$	300	$	**180,000**
Rearing and Resting Habitat Construction				AC	1	$	50,000	$	**50,000**
Remove Existing Revetment				LF	-	$	200	$	**-**
Streambank Reconstruction				LF	-	$	1,000	$	**-**
Streambarbs				EA	-	$	40,000	$	**-**
ELJ's - 20 ft by 60 ft				EA	6	$	300,000	$	**1,800,000**
Total Construction Cost without Contingencies								$	**2,172,100**
Contingency	30%	of construction cost						$	**651,630**
Total Construction Cost								$	**2,823,730**
Compliance		5%	of total construction cost					$	**141,187**
Predesign/design (PE)		15%	of total construction cost					$	**423,560**
Construction Engineering (CE)		15%	of total construction cost					$	**423,560**
ROW								$	**-**
Riprap replacement -	20%	replacement every			50	years		$	**-**
Wood replacement -	full log	replacement every			30	years		$	**1,800,000**
TOTAL Capital Cost				Cost/Foot	**$ 9,353**			$	**5,612,036**
Annualized Capital Cost			Discount rate, i		0.07125			$	**413,086**
			Service life, n		50	years			
			CFR		**0.0736071**				

Table C2-3. Cost Estimates

Minor River Channel Shift - ELJ Groins

		Unit	Quantity	Unit Cost	Total Cost
Mobilization	7% of construction cost	LS	1	$ 73,388	**$ 73,388**
Rearing and Resting Habitat Construction		AC	-	$ 50,000	**$ -**
Remove Existing Revetment		LF	-	$ 200	**$ -**
Streambank Reconstruction - fill/plants/fascines		LF	350	$ 1,200	**$ 420,000**
Large Wood		EA	20	$ 1,500	**$ 30,000**
ELJ groin - 15 ft by 40 ft (2 x 15 ft by 20 ft mod.)		EA	4	$ 149,600	**$ 598,400**
Primary logs	50 $ 1,200 $ 60,000				
Pin logs	4 $ 1,200 $ 4,800				
Ballast stone	50 $ 180 $ 9,000				
Cabling	1 $ 1,000 $ 1,000				
	$ 74,800				
No. modules/ ELJ groin	2 $ 149,600				
Total Construction Cost without Contingencies					**$ 1,121,788**
Contingency	30% of construction cost				**$ 336,536**
Total Construction Cost					**$ 1,458,324**
Compliance	5% of total construction cost				**$ 72,916**
Predesign/design (PE)	15% of total construction cost				**$ 218,749**
Construction Engineering (CE)	15% of total construction cost				**$ 218,749**
ROW					**$ -**
Riprap replacement -	20% replacement every		50 years		**$ -**
Wood replacement -	full log replacement every		30 years		**$ 598,400**
TOTAL Capital Cost		Cost/Foot	**$ 4,167**		**$ 2,567,138**
Annualized Capital Cost		Discount rate, i	0.07125		**$ 188,960**
		Service life, n	50 years		
		CFR	**0.0736071**		

Minor River Channel Shift - Stream Barbs

		Unit	Quantity	Unit Cost	Total Cost
Mobilization	7% of construction cost	LS	1	$ 47,124	**$ 47,124**
Rearing and Resting Habitat Construction		AC	-	$ 50,000	**$ -**
Remove Existing Revetment		LF	-	$ 200	**$ -**
Streambank Reconstruction - fill/plants/fascines		LF	350	$ 1,200	**$ 420,000**
Large Wood		EA	20	$ 1,500	**$ 30,000**
Streambarbs	Length 90 ft	EA	4	$ 55,800	**$ 223,200**
	Crest width 8 ft				
	Average bot. width 23 ft				
	Average thickness 6 ft				
	Volume 310 cy				
	Cost/cy 180 $/cy	Cost/barb	$ 55,800		
Total Construction Cost without Contingencies					**$ 720,324**
Contingency	30% of construction cost				**$ 216,097**
Total Construction Cost					**$ 936,421**
Compliance	5% of total construction cost				**$ 46,821**
Predesign/design (PE)	15% of total construction cost				**$ 140,463**
Construction Engineering (CE)	15% of total construction cost				**$ 140,463**
ROW					**$ -**
Riprap replacement -	20% replacement every		50 years		**$ 44,640**
Wood replacement -	full log replacement every		30 years		**$ 30,000**
TOTAL Capital Cost		Cost/Foot	**$ 2,675**		**$ 1,338,809**
Annualized Capital Cost		Discount rate, i	0.07125		**$ 98,546**
		Service life, n	50 years		
		CFR	**0.0736071**		

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C3 - COUNTY MILEPOST 7.6

TOWER CREEK BRIDGE



SITE C3 - TOWER CREEK BRIDGE

Existing Bridge

The existing bridge is a single span decked bulb-tee girder (5 girders) with thrie-beam guardrail supported on spill-through abutments and founded on pipe piles (4 piles per abutment). The basic geometry of the existing bridge is approximately 70 feet in length, 30 feet in width and 18 feet vertical clearance from stream bed to bottom of girders (Photo C3-1). In general, the bridge is in good condition. There are minor spalls on the decked bulb-tee girders.

Main deficiencies include scour at the abutments with exposed piles and erosion at wingwalls (Photo C3-2). There is significant embankment scour/erosion on the upstream side of west abutment (Photo C3-6). It was observed that the abutment fills have been scoured or eroded and replaced with riprap. The existing riprap was installed at a very steep slope (greater than 1:1 slope). Sheet piling was installed behind the west abutment for retaining the approach road fill. At the wingwalls, it appears that these “elephant-ear” wingwalls were not extended low & long enough to retain the soil.

The active channel width is approximately 20 feet. Ordinary high water flow depth is approximately 3 feet. Stream gradient upstream of the bridge is approximately 7 percent. Stream gradient downstream is approximately 4 percent. Step-pool and cascade are the dominant bed forms. Cobble and small boulders are the dominant bed material. Estimated 2-year and 50-year peak discharges are 231 cfs and 484 cfs, respectively (StreamStats). There is abundant woody debris available for recruitment to the stream from windfall and stream bank erosion. The stream is capable of transporting the woody debris at the more extreme (> 25-year) flood events. Based on satellite imagery and field evidence, the stream is subject to relative frequent debris flows and sediment impulses.

Tower Creek is a tributary of the Hoh River, a braided river with dramatically shifting active channels. Currently, a main active river channel is 300 feet from the bridge (Fig. C3-1 and Photo C3-3). Between 1994 and 2009 the active river channel was within 100 feet of the bridge (Fig. C3-2). Woody debris accumulating on a river point bar beginning in 2006 developed a jam that eventually deflected the river flow away from the north river bank, cutting in 2011 a new active channel across the river point bar. The woody debris jam has largely dissipated, leaving only a small woody debris jam at the head of a small mid-channel gravel bar.

The river channel bottom is lower than the Tower Creek channel bottom. The bottom elevation of the Tower Creek channel will tend to lower until the channel bottoms are nearly the same elevation. Typically, incising or degradation occurs as a nick point migrating upstream from the active river channel edge. A 5-foot high nick point is approximately 80 feet downstream of the bridge (Photos C3-1 and 3). It was likely initiated in 1994 when the active river channel was closer to the bridge. The nick point is expected to migrate upstream to the bridge.

The degradation rate is controlled by the elevation differences between stream bottom and river edge (approximately 8 feet), bed armoring, and an erosion resistant, consolidated alluvial material observed on the stream banks and bottom (Photos C3-4 to 6). Based on projecting the downstream channel gradient and adjusting for the relative coarse bed material, stream degradation at the bridge is not expected to exceed 5 to 6 feet below existing channel bottom elevation. Total scour (degradation and local scour) is estimated to be 10 feet.

Depth of the piles below stream bottom is not known. The bridge rests on the piles. Piles that do not extend far enough into the ground could buckle, causing the bridge foundation to fail. The hardness of the consolidated alluvial material likely prevented the piles being driven to an

adequate depth below estimated total scour. The piles depend on the embankment material around them for support. Scouring of the embankment materials could increase the potential for the piles to buckle and the bridge foundation to fail. The existing riprap beneath the bridge is intended to control the scour. The riprap appears properly sized for expected stream flow velocities, but is overly steep and lacks stabilizing key trenches founded below the estimated total scour depth (Photos C3-2, 4, 5, 7, 8, and 9). Flood events equal to and larger than the 10-year would have enough flow depth and velocity to undermine and displace the existing riprap. To remain effective, the dislodged riprap would need to be repaired or replaced after each major flood event. Flood events equal to and larger than the 100-year would have enough flow depth and velocity to significantly displace the riprap and scour the embankment material from around the piles. Scour from a 100-year flood could also completely undermine the piles. Undermined or buckled piles would require a complete bridge replacement.

Considered Options

Three options were evaluated for mitigating the expected stream degradation and scour; continue maintenance, new concrete walls placed under existing bridge, and new bridge. Table C3-1 presents an evaluation and ranking of the options against design selection criteria.

Continue Maintenance

Riprap will need to be replaced when dislodged from extreme flood flows. Riprap is not easily countersunk and keyed into the consolidated alluvial material. Width of the existing waterway does not allow the riprap to be laid back at a stable slope and layer thickness. A moderate to large debris flow would likely almost completely erode the existing riprap. Replacing riprap as needed after a flood may not prevent an extreme flood from inducing scour that completely undermines piles. Placing riprap as an emergency action may be hazardous or difficult. The emergency-placed riprap may not be effective in controlling the erosion.

A Total Expected Cost analysis (HEC-17, FHWA, April 1981) was completed for estimating total expected cost repairing damage caused by flooding. The analysis assumes a 50-year service-life. Based on observed riprap revetment condition, expected flood flow depths, assumed bridge pile depths, debris flow risk, and scour resistance of the consolidated alluvial material, the extent of damage varies with flooding magnitude.

Assumed flooding magnitude and damage extent:

- 10-year – 60 lineal feet new riprap - $60,000.
- 25-year – 80 lineal feet new riprap - $80,000.
- 50-year – 160 lineal feet new riprap - $160,000.
- 100-year – bridge undermined by scour/debris flow - $2,300,000.
- 500-year – bridge undermined by scour/debris flow - $2,300,000.

Riprap replacement assumes $1,000 per foot. Bridge replacement assumes road is shifted upstream slightly and includes new road construction costs. Total expected annual cost is $40,300 (Table C3-2, Total Expected Cost).

New Concrete Walls under Existing Bridge

New concrete walls are proposed for protecting existing bridge from scour. The new concrete walls are expected to provide at least a 50-year service life, with minimal maintenance. The remaining service life of the existing bridge is expected to be less than 30 years. Foundation, structure, deck, and railing elements could be replaced as needed for providing the remaining

20 years of service life. The approach is believed not cost-effective. A more cost-effective approach is to replace the existing bridge with one designed for a full 50-year service-life when the existing bridge must be replaced. A full replacement costing equivalent to a new 130 feet bridge is assumed.

Set the bottom of the wall below the expected stream degradation, approximately 6 feet below the channel thalweg elevation, measured at the downstream bridge face. Set the top of wall 10 feet above channel thalweg elevation, measured at the upstream bridge face. Terminate the walls into the existing road embankments or stream banks at least 5 feet. Place Class 6 riprap over the concrete wall footings for controlling local scour. Minimum distance between wall faces is 45 feet. Total length of wall is estimated to be 160 feet. Estimated construction costs for excavation, concrete wall, and riprap are summarized in Table C3-3.

New 130 Feet Long Bridge

The new bridge must have an initial waterway that accommodates the expected stream degradation. Assuming 6 feet of degradation, 1.75(h):1(v) side slopes, and 20 feet active channel, the initial waterway width is 44 feet. Assuming 16 feet clearance between initial channel bottom and bridge low chord, 5 feet thick riprap layer, and 1.75(h):1(v) side slopes, the recommended minimum bridge length is 130 feet.

SPAN ARRANGEMENT: The existing structure is single span, and the proposed structure span length suits well with a single span deck bulb tee bridge. Thus, only single span arrangement is considered at this site.

SUPERSTRUCTURE TYPE: Precast prestressed concrete decked bulb tee girders are appropriate girder types for this stream crossing. The decked bulb tee can be lifted into place by cranes located on the banks of the channels and eliminating the needs for deck forming, rebar installation, and concrete casting and curing. Steel girders may also be an effective alternative at this span length; yet it may require cast-in-place concrete deck, be susceptible to corrosion and create maintenance problems over the life of the structure. Thus, only precast prestressed concrete decked bulb tee superstructure is considered at this site.

SUBSTRUCTURE TYPE: Semi-integral abutments supported on deep foundation with cantilevered wing walls are recommended. This type of construction will eliminate the need for any expansion joints on the bridge superstructure eliminating water leakage and long term maintenance associated with expansion joints. Additionally, this type of abutment configuration will help to eliminate design complexity and the uncertainty of the structure and soil movements.

Based on the existing as-built plans and proposed bridge size, it is most likely that the foundation type would be pipe pile.

STRUCTURE ALTERNATIVES AND PRELIMINARY COST ESTIMATES: The study evaluated two structure types for the single span arrangements using precast prestressed concrete deck bulb girders.

Table C3-4. Summary of Bridge Structure Type Alternative

Alt. No.	No. of Spans	Span Length	Girder Type	Girder Spacing	Deck Thickness	Total Cost	Cost per sft
1	1	130	WASHINGTON 53" - DBT	7'-0"	6"	$1,040,000	$220

The single span using Washington 53"-DBT (Deck Bulb-Tee) girders, is the recommended alternative. This recommended bridge provides the best compromise between structure costs, constructability and environmental concerns.

Because the abutments are integral with the superstructure, approach slabs are recommended to ensure ride-ability across the abutments should the approach fill settle. Deck drains are not anticipated due to the longitudinal slope, crowned deck section, and shoulders. Catch basins can be installed in the shoulder approach of the bridge to capture pavement runoff flowing toward the bridge.

Construction Phasing: At this site, a combination of minor shift of alignment, and staged removal and construction of the existing bridge and proposed bridge respectively may provide an adequate one-lane temporary traffic during construction. For the purpose of this study, let us assume that the alignment will be shifted lightly to the south.

The proposed construction phasing for this bridge is described in the following subsections.

Phase 1: Install concrete barrier on the south edge of the third deck bulb tee of the existing bridge. Set up a one-lane traffic on the existing bridge on the north portion of the existing bridge. Construct the south portion of the new bridge with three deck bulb tees. Construct the permanent bridge rail on the south bridge edge, and set a temporary concrete barrier along the north edge of the bridge. This first south portion of the new bridge may have to have a minimum width of 20 feet edge to edge to provide a one-lane 10-foot lane with 2-foot shoulders.

Phase 2: Shift traffic onto the completed south portion of the new structure. Remove the remaining existing bridge. Construct the remaining north portion of the new bridge with two deck bulb tees.

The estimated construction cost for the new bridge, shifting the road alignment, removing the existing bridge, and installing riprap abutment scour countermeasures are summarized in Table C3-3.

Environmental Clearance Considerations

This portion of the road extends through a small parcel of U.S. Forest Service (FS)-managed lands and privately-held trust lands. The existing Tower Creek Bridge is located on the northern edge of designated critical habitat for the northern spotted owl. Marbled murrelet critical habitat is located approximately one mile north of the project in lands managed by the FS. During the December 2012 field review at least one suitable tree believed to be suitable for marbled murrelet nesting was identified just west of the bridge on the north side of the road. WDFW identified Tower Creek as a Priority Habitat area for resident and migratory fish species. The National Wetland Inventory Maps identified no wetlands adjacent to Tower Creek at this

location, though Tower Creek itself is a Water of the US and State. A wetland survey and, if needed, delineation, would need to be conducted to confirm this negative finding.

Project development should be coordinated with the FS in addition to the other project partners.

Continued Maintenance

This work is likely covered under a Nationwide Permit 3 under the Clean Water Act. There may be in-water work windows and timing restrictions to avoid adversely impacting the marbled murrelet, northern spotted owl, and the bull trout.

New Concrete Walls Under Existing Bridge

As described, this alternative will likely require streambed alteration with the placement of riprap below the ordinary high water mark triggering the need for a Section 404 Permit. Depending on the extent of work and volume of fill, the work may qualify for a Nationwide Permit 14. Otherwise, an individual permit will be required.

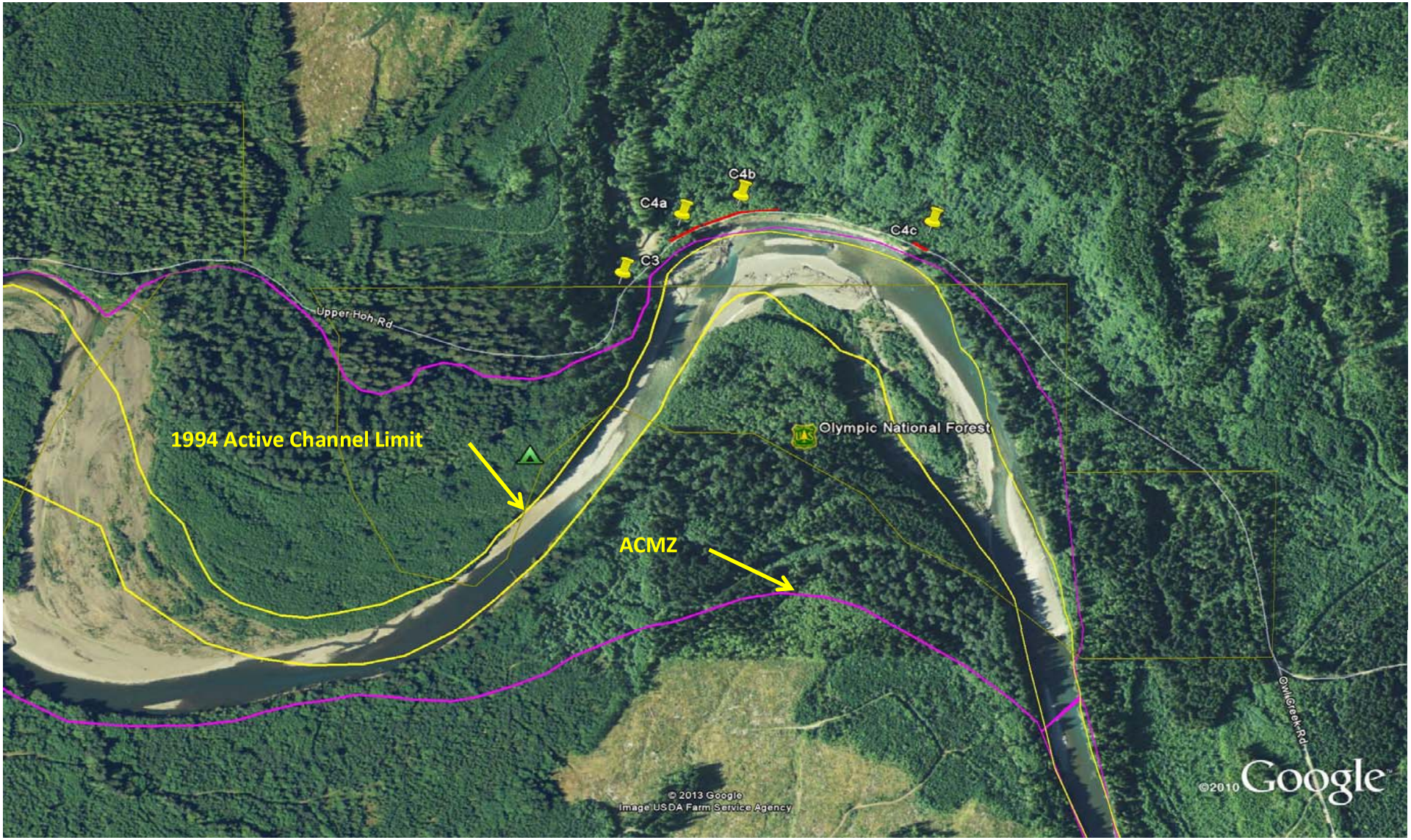
Further coordination is needed to determine if Tower Creek, being a WDFW Priority habitat, will warrant the implementation of bioengineering methods to soften the bank stabilization materials.

A biological assessment will need to be prepared to evaluate impacts to marbled murrelet, northern spotted owl, including designated critical habitat, and bull trout. If no protocol surveys are done for the marbled murrelet or the northern spotted owl, or if protocol surveys are done and species presence is confirmed, construction would have to adhere to noise restrictions, typically no work being permitted 2 hours after sunrise and 2 hours before sunset.

New Bridge

The new bridge as described will require minor realignment to allow for maintenance of single-lane traffic during construction. This minor realignment shift will result in vegetation clearing. The present anticipated shift to the south would result in vegetation clearing of designated critical habitat for the northern spotted owl. It could also impact suitable nesting, roosting, foraging, and dispersal habitat for the marbled murrelet. Also, the proposed construction may generate noise that could adversely affect these bird species as they nest, roost, and forage. As a result, a biological assessment will need to be prepared to analyze these effects and determine if there will be a take of any individuals of these species.

The installation of the new bridge and associated rip-rap will require in-water work, thereby potentially impacting the bull trout. As a result, a biological assessment will need to be prepared to analyze these effects. Also, this work will trigger the need to acquire a Section 404 permit and 401 Certification.



ACMZ - Active Channel Migration Zone, Geomorphic Assessment of Hoh River in Washington State, USBR, July 2004.

Imagery date 11/3/2011

Figure C3-1. Site Location

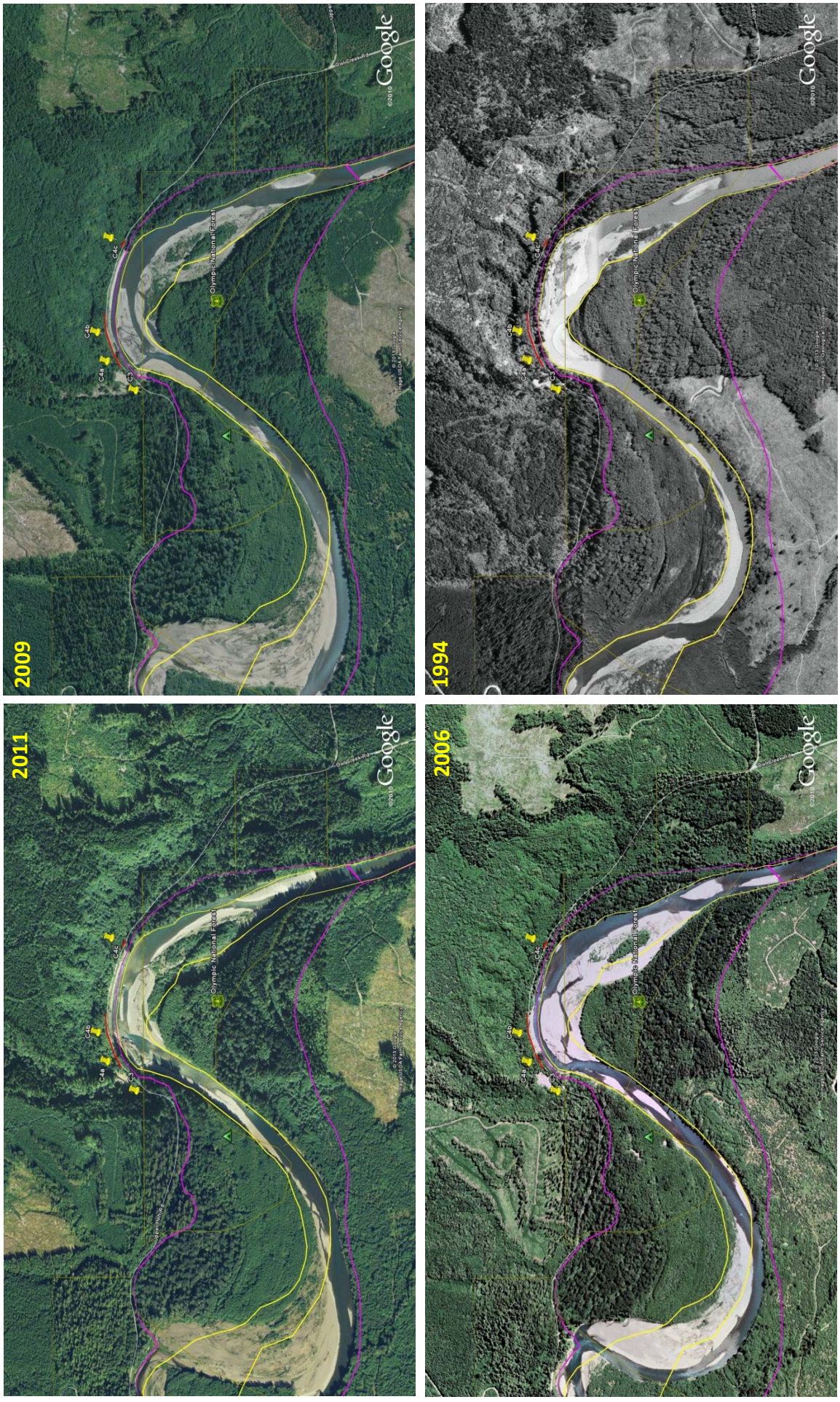


Figure C3-2. Historical Satellite Imagery

Photos

C3 - Tower Creek Bridge



PHOTO C3- 1

Looking upstream at nick point and bridge.

Nick point approximately 4 to 5 feet high and consisting of woody debris and cobbles/boulders. Stream bed is cobble-boulder dominated.



PHOTO C3- 2

Looking upstream at bridge.

Riprap setting on consolidated alluvial material. Stream bed is cobble-boulder dominated. Upstream channel has abundant large woody debris.



PHOTO C3- 3

Looking downstream over nick point towards confluence with river.

Nick point approximately 4 to 5 feet high and consisting of woody debris and cobbles/boulders. Stream bed is cobble-boulder dominated. Active river channel is approx. 300 feet away from bridge.

Photos

C3 - Tower Creek Bridge



PHOTO C3- 4

East abutment riprap scour countermeasure.

Riprap setting on consolidated alluvial material, which is exposed across stream bed. Channel incised into material approx. 3 to 4 feet.



PHOTO C3- 5

East abutment riprap scour countermeasure and consolidated alluvial material.

Riprap setting on consolidated alluvial material, which is exposed across stream bed. Channel incised into material approx. 3 to 4 feet. Consolidated alluvial material is firm, difficult to pick or scratch with rock hammer, and is likely retards erosion.



PHOTO C3- 6

Upstream west abutment.

Bank is vertical and prone to erosion. Woody debris deflects stream flow towards bank. Consolidated alluvial material is exposed on stream bed and dark green vertical bank area in center of photo.

12/12/2012

Photos

C3 - Tower Creek Bridge



PHOTO C3- 7

Upstream east abutment.

Bank reasonably well protected from erosion by riprap. Woody debris deflects stream flow towards bank.



PHOTO C3- 8

Downstream west abutment.

Bank reasonably well protected from erosion by riprap.



PHOTO C3- 9

Downstream east abutment.

Bank reasonably well protected from erosion by riprap.

12/12/2012

Table C3-1. Alternative Summary and Ranking.

Upper Hoh River Road Site - C3 - Tower Creek Bridge

OPTIONS	Rank	Continued Maintenance	Rank	Concrete Wall under Bridge	Rank	Replace Bridge
		Replace riprap when dislodged from extreme flood flows.		**Install new wall in front of existing abutments - existing bridge remains in place.**		**Replace bridge with new 130 feet long bridge - requires new road alignment immediately upstream of existing bridge.**
Ability to preserve and operate the roadway in a specific location (Most able 5, least able 1)	**1**	Large flood event could undermine footings.	**3**	Moderate reduction in scour risk. At least 50-year service-life.	**5**	Mitigates scour risk. At least 50-year service-life.
Roadway sustainability (life of solution) (Longest 5, shortest 1)	**1**	Large flood event could undermine footings.	**3**	Moderate reduction in scour risk. At least 50-year service-life.	**5**	Mitigates scour risk. At least 50-year service-life.
Impact to hillside stability adjacent to site (Most likely 1; least likely 5)	**1**	No impact to geological stability.	**1**	No impact to geological stability.	**3**	Shift in road alignment to construct new bridge may induce hillside instability.
Potential to reduce erosion of banks adjacent to site (Most 5; Least 1)	**1**	Constrained channel increase bank erosion.	**3**	Constrained channel increase bank erosion.	**5**	Channel not constrained.
Impacts to listed Threatened and Endangered (T&E) terrestrial species and habitat (Least 5; most 1)	**5**	None expected.	**3**	No permanent impacts, temporary construction impacts.	**1**	Likely adverse modification of suitable marbled murrelet habitat and temporary construction impacts.
Impacts to listed T&E fish and habitat (Least 5; most 1)	**5**	None expected, assuming no road or bridge failure.	**3**	None expected.	**3**	None expected.
Impact to upland habitat (Least 5; most 1)	**5**	None expected.	**5**	None expected.	**1**	Realignment results in upland habitat loss.
Impacts to Wetlands and Waters of the U.S. (Least 5; most 1)	**1**	Riprap fill placed in channel.	**3**	Riprap fill placed in channel - channel less constrained.	**5**	Riprap fill placed in channel - channel not constrained.
Impact to Designated Wilderness area (Least 5; most 1)	**5**	None expected.	**5**	None expected.	**5**	None expected.
Potential for Hoh River Enhancement (Greatest 5; Least 1)	**5**	Fish access to off-channel habitat not reduced of increased.	**5**	Fish access to off-channel habitat not reduced of increased.	**5**	Fish access to off-channel habitat not reduced of increased.
Potential to maintain or improve river process and function (Most 5; Least 1)	**1**	Constrained channel reduces debris passage.	**3**	Constrained channel reduces debris passage.	**5**	Channel not constrained.
Potential for other habitat enhancements (Most 5; Least 1)	**1**	Constrained channel reduces debris passage.	**3**	Constrained channel reduces debris passage.	**5**	Channel not constrained - debris transported through site.
Potential private property impacts (Least 5; Most 1)	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**1**	Shift in road alignment to construct new bridge may require ROW.
Safety risk of design to public (Least 5; Most 1)	**1**	Large flood event could undermine footings.	**3**	Moderate reduction in scour risk.	**5**	Mitigates scour risk.
Total Construction cost		**NA**		**$782,875**		**$2,342,444**
Total Capital Cost (50 years)	**5**	**NA**	**1**	**$4,239,181**	**1**	**$3,182,299**
Annualized Total Capital Cost (Least 5; Most 1)		**$40,300**		**$312,034**		**$234,240**
SCORE	**43**		**50**		**60**	

Table C3-2. Total Expected Cost

Project: Hoh River Road Bank Erosion Risk Study **Date: 3/14/2013**

Site: C3 - Tower Creek Bridge

Alternative: Continue Maintenance **By: S. Leon**

	Flood Frequency (yr)	Exceedance Probability	Flood Damage	Average Flood Damage	Delta Exceedance Probability	Annual Risk Cost
No damage.	2	**0.5**	$0			
				$0	**0.3**	**$0**
No damage.	5	**0.2**	$0			
				$30,000	**0.1**	**$3,000**
Revetment damaged.	10	**0.1**	$60,000			
				$70,000	**0.06**	**$4,200**
Revetment damaged.	25	**0.04**	$80,000			
				$120,000	**0.02**	**$2,400**
Revetment damaged.	50	**0.02**	$160,000			
				$1,230,000	**0.01**	**$12,300**
Replace bridge.	100	**0.01**	$2,300,000			
				$2,300,000	**0.008**	**$18,400**
Replace bridge.	500	**0.002**	$2,300,000			
Total Annual Risk Cost						**$40,300**
Annualized Capital Cost	**Capital Cost**					**$0**
	Disc. rate, i	**0.07125**	**Serv. life, n**	**50**	**CFR**	**0.0736**
	Annualized Capital Cost					**$0**
Total Expected Cost (Annual)						**$40,300**
Summary	Assume bridge is replaced for 100-year and larger flood events.					

Notes:

1. Method from HEC-17, April 1981.

Table C3-3. Cost Estimate

Site: **C3 - Tower Creek Bridge**

130 Feet Long Bridge

		Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost	LS	1	$	117,880	$	**117,880**
New Road		LF	400	$	500	$	**200,000**
Hillside Stabilization		LS	1	$	30,000	$	**30,000**
Flow Diversion		LS	1	$	20,000	$	**20,000**
Remove Existing Bridge		LS	1	$	250,000	$	**250,000**
130 feet Bridge		LS	1	$	1,040,000	$	**1,040,000**
Riprap	H 12 ft T 5 ft	CY	**800**	$	180	$	**144,000**
	L 160 ft SS 1.75 (h):1(v)						
	TW 6 ft TT 5 ft						
Total Construction Cost without Contingencies						$	**1,801,880**
Contingency	30% of construction cost					$	**540,564**
Total Construction Cost						$	**2,342,444**
Compliance	5% of total construction cost					$	**117,122**
Predesign/design (PE)	15% of total construction cost					$	**351,367**
Construction Engineering (CE)	15% of total construction cost					$	**351,367**
ROW						$	**20,000**
TOTAL Capital Cost		Cost/Foot	**$ 7,956**			$	**3,182,299**
Annualized Capital Cost	Discount rate, i		0.07125			$	**234,240**
	Service life, n		50 years				
	CFR		**0.0736071**				

Concrete Wall Under Existing Bridge

		Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost	LS	1	$	39,397	$	**39,397**
Flow Diversion		LS	1	$	20,000	$	**20,000**
Exc.	H 6 ft T 14 ft	CY	**498**	$	200	$	**99,556**
	L 160 ft						
Wall	H 16 ft T 2 ft	CY	**190**	$	2,000	$	**379,259**
	L 160 ft						
Riprap	H 6 ft T 10 ft	CY	**356**	$	180	$	**64,000**
	L 160 ft						
Total Construction Cost without Contingencies						$	**602,212**
Contingency	30% of construction cost					$	**180,664**
Total Construction Cost						$	**782,875**
Compliance	5% of total construction cost					$	**39,144**
Predesign/design (PE)	15% of total construction cost					$	**117,431**
Construction Engineering (CE)	15% of total construction cost					$	**117,431**
ROW						$	**-**
New 130 feet bridge to replace existing bridge after remaining 30-year service life is over.						$	**3,182,299**
TOTAL Capital Cost		Cost/Foot	**$ 26,495**			$	**4,239,181**
Annualized Capital Cost	Discount rate, i		0.07125			$	**312,034**
	Service life, n		50 years				
	CFR		**0.0736071**				

C4 - COUNTY MILEPOST 7.8

BANK STABILIZATION



SITE C4 – COUNTY MILEPOST 7.8 BANK STABILIZATION

Site Conditions

The site parallels the outside bank of a river bend (Fig. C4-1). Approximately 1,300 lineal feet of riprap revetment along the apex of the river bend appears to be effectively controlling road embankment erosion (Photo C4-1). The 2 to 4 feet diameter riprap comprising the revetment is generally properly graded and placed. The upstream 800 feet long segment, installed in 2007, has a 1.75(h):1(v) finished surface slope and appears stable. The downstream 500 feet long segment, installed in 2004, has a 1.5(h):1(v) steeper finished surface slope and appears less stable (Fig. C4-1, C4b). Some riprap has been dislodged from toe and mid slope areas. The segment is at the maximum point of stream bank curvature and likely experiences high shear stress when floods occur. Continued riprap loss could result in dismantling of the revetment and damage to the road. Based on current channel alignment and expected limited channel alignment shifts, the risk of a catastrophic road embankment failure is low. Water depth at typically normal annual low flow conditions is estimated to be 4 to 6 feet.

Toe erosion and undermining of the stream bank continues immediately upstream and downstream of the riprap revetment (Photos C4-2 and 6). At the upstream location, C4c, the stream bank toe is approximately 50 feet away and 20 feet below the road surface. Cobbles and small boulders naturally armoring the toe and large trees growing in the stream bank have inhibited the bank erosion. A mid-channel gravel bar approximately 50 feet away from and paralleling the stream bank deflects stream flow towards the bank, aggravating the bank erosion. Continued stream bank erosion could undermine the road. Based on current channel alignment and expected limited channel alignment shifts, the risk of a catastrophic road embankment failure is moderate. Water depth at typically normal annual low flow conditions is estimated to be 4 to 5 feet.

At the downstream location, C4a, the stream bank toe is approximately 50 feet away and 20 feet below the road surface. Cobbles and small boulders naturally armoring the toe and large trees growing in the stream bank have inhibited the bank erosion (Photos C4-5 and 6). Currently, the downstream stream bank toe is separated from the active river channel by a gravel bar (Photos C4-3 to 5). The gravel bar is expected to be completely exposed at typically normal annual low flow conditions. Woody debris will likely continue to accumulate on the existing small woody debris jam at the head of the small mid-channel gravel bar (Photos C4-3 to 5). A woody debris jam not completely plugging the 150 feet wide side channel between the small mid-channel gravel bar and stream bank could deflect river flow directly at the stream bank, accelerating the bank erosion and undermining the road. Based on the amount and size of wood available in the river for transport and the width of the side channel, the risk of a woody debris jam building that only partially blocks the side channel is high. With a partial blocking of the side channel, the risk of a catastrophic road embankment failure is high.

The Hoh River is a braided river with dramatically shifting active channels. Between 1994 and 2009 the active river channel flowed along the north bank (Fig. C4-2). Woody debris accumulating on a river point bar beginning in 2006 developed a jam that eventually deflected the river flow away from the north river bank, cutting in 2011 a new active channel across a river point bar. The woody debris jam has largely dissipated, leaving only a small woody debris jam at the head of a small mid-channel gravel bar.

An erosion resistant poorly consolidated alluvium terrace deposit has limited river bend migration to the north. The terrace deposit represents the historical channel migration zone (HCMZ) right (looking downstream) boundary. Width of the HCMZ is approximately 2,500 feet.

The road embankment coincides with the HCMZ right boundary. Wetlands between the terrace toe and existing road have been established due to drainage off the hillside. Terrace deposits have also limited active channel migration to the south. Terrace deposits and Tower Creek debris flow and alluvial material have restricted down-valley migration of the meander bend.

Considered Options

Continuing maintenance, relocating the road, installing additional bank stabilization, minor active river channel shift, and major active river channel shift were considered. Table C4-1 presents an evaluation and ranking of the options against design selection criteria.

Riprap is expected to be lost during extreme flooding, requiring replenishment for maintaining the riprap installation's effectiveness. Total Capital and Annualized Total Capital Costs provided in Table C4-1 assume 20 percent of the riprap in an installation is replaced every 50 years.

Douglas fir and hemlock are the most commonly available logs in the area. Douglas-fir logs can remain durable in wetting-drying conditions for 25 to 60 years (Tech. Supp. 14J, Use of Large Woody Material for Habitat and Bank Protection, Part 654, National Engineering Handbook, USDA, Natural Resources Conservation Service). Hemlock is the least durable of the conifers. Because the tree quality and species to be used in the structures is not known, Total Capital and Annualized Total Capital Costs provided in Table C4-1 assume wood used in the alternatives is replaced every 30 years.

Continue Maintenance

Continued maintenance involves monitoring the riprap revetment and upstream/downstream stream bank areas for excessive riprap loss and bank erosion, respectively. Riprap will need to be replaced when dislodged from extreme flood flows. Stream bank toe erosion upstream and downstream of the existing riprap revetments could progress to the point that undermining of the road is imminent. Continued maintenance is placing riprap in an emergency action or after flooding as needed for preventing a road closure. Placing riprap as an emergency action may be hazardous or difficult. The emergency-placed riprap may not be effective in controlling the erosion.

A Total Expected Cost analysis (HEC-17, FHWA, April 1981) was used for estimating total expected cost repairing flood-induced road damage over a 50-year service-life. Based on observed riprap revetment condition, proximity of channel to roadway, and amount of natural bank armoring, the analysis assumes damage requiring repair of the existing revetments or addition of new riprap revetment placed as an emergency action for stabilizing an eroding river bank occurs for flood events equal to and larger than the 25-year flood event. Based on review of historical satellite imagery, length of bank typically exposed to impinging flood flow is estimated to be approximately 300 feet. Based on vegetation distribution and age and estimated riprap placement sequencing, the length of past revetment installations ranged from 500 to 800 feet. Assuming 300 feet total for each flood damage event and a cost of $1,000 per foot, the total expected annual cost is $21,000 (Table C4-2, Total Expected Cost).

Relocate Road

Shifting the road away from the river eliminates the current riprap revetment failure risk and road loss risk from bank erosion occurring upstream and downstream of the existing revetment. The alternative involves shifting the road 100 to 150 feet north to parallel the valley edge along the toe of a 260 feet high terrace. Length of reroute is 2,000 feet and extends from the existing Tower Creek Bridge to a point on the existing road that is outside of the HCMZ.

Connecting the new alignment to the existing bridge would make the road turn sharply. It would require the posted speed for this location to be reduced. To correct this problem, the Tower Creek Bridge would need to be rebuilt about 100 feet north of the existing one. The option assumes that the new road alignment connects to the existing bridge.

Existing riprap revetment is removed and approximately 80 to 100 feet wide by 1,800 feet long area of the stream bank is reconstructed. An erodible newly reconstructed stream bank would allow lateral bank erosion and migration to the north. Streambarbs constructed from the existing revetment riprap, engineered-log-jams (ELJ's), and planted vegetation control the bank erosion and lateral migration and preserve a riparian buffer between the active river channel and road embankment.

Rerouting the road requires construction in the wetlands established between the terrace toe and existing road. Constructing new wetlands and off-channel rearing and resting habitat within the existing road prism would not fully mitigate the area of wetlands lost realigning the road.

Slumping observed on the terrace slope suggests the terrace slope is not geotechnically stable. A new road alignment located at the terrace toe would likely experience landslides and debris flows that could potentially bury the road with debris. Keeping the road away from terrace toe and elevating it as much as possible would reduce the severity and frequency of landslide-induced damage. The alternative requires monitoring and repair of the streambarbs and ELJ's to remain effective in controlling the bank erosion and lateral migration.

Estimated construction cost for the 2,000 feet of new road, existing road removal, 10 streambarbs, 5 ELJ's, and stream bank reconstruction is summarized in Table C4-3. Construction is expected to occur outside the active flow channel. Turbidity released is expected to be limited in extent and duration. Access for construction is assumed from the existing road. Constructing the new road alignment first and then switching the Upper Hoh Road traffic over before removing the existing road reduces traffic impacts to one-lane closures and short-term delays.

Stabilize Existing Road Embankment

Approximately 100 feet of upstream stream bank (C4c), 200 feet of downstream stream bank (C4a), and 500 feet of the revetment (C4b) are proposed for stabilization.

Alternatives evaluated;

- Complex roughened large rock toe.
- Complex log crib wall.
- Riprap with roughened rock toe, LWD, and riparian plantings.
- Riprap with streambarbs.

Based on field evidence, the sites are expected to experience high shear stress, 10 to 14 feet deep flood flows, and abundant floating debris. It is critical that the stabilization methods be properly designed and anchored for maintaining effectiveness and surviving the expected flood conditions.

Construction for all the alternatives is expected to occur entirely within the active flow channel and requires excavating into the streambed and stream bank. Stream work would be accomplished in flowing water. Assuming the work is completed during low flow periods, turbidity released is expected to be limited in extent and duration. Access for construction is assumed down a temporary access route built of riprap and logs. The access route would be

removed after construction is completed. Upper Hoh Road traffic impacts are expected to be limited to one-lane closures and short-term delays.

-Complex roughened large rock toe (Appendix A, Sheet 4).

The approach involves placing a rock toe between the expected scour depth and ordinary high water level, approximately 10 to 12 feet high and 5 feet thick. Log bundles spaced 6 to 10 feet are placed at the bottom of the rock toe. Soil placed above the rock toe in overlapping layers of erosion control blanket, approximately 6 to 12 feet. The rock toe and soil ballast the logs and reduce the risk of the logs floating away. Estimated construction cost for the complex roughened large rock toe is summarized in Table C4-3.

-Complex log crib wall (Appendix A, Sheet 5).

The approach involves placing a log crib wall made of rough logs between the expected scour depth and ordinary high water level, approximately 10 to 12 feet high. Stone is placed within the log crib wall for ballast. Logs with attached root wads extending into the stream bank provide roughness and additional wall stability. All logs are cabled together for enhancing stability. Designs typically include piles driven to refusal or minimum depth of 10 feet. The cobble and boulder stream bed material will likely prevent the piles from being cost-effectively driven or excavated. They are assumed eliminated in the proposed design. Approximately 6 to 12 feet of soil is placed above the crib wall and planted. Estimated construction cost for the complex log crib wall is summarized in Table C4-3.

-Riprap with Roughened Rock Toe, LWD, and Riparian Plantings (Appendix A, Sheet 9).

The approach involves placing a riprap revetment between the expected scour depth and 50-year flood event water level, approximately 12 to 15 feet high, 5 feet thick, and 2(h):1(v) slope. A launchable riprap toe 8 feet wide and 5 feet thick reduces the risk of scour and channel incision undermining the revetment and provides additional stability. Logs or log bundles spaced 6 to 10 feet are placed along the revetment toe for providing roughness and channel complexity. The logs are buried in the road embankment for reducing the risk of them floating away. Willow and alder are planted throughout the revetment and bank area above the revetment. Estimated construction cost is summarized in Table C4-3.

-Riprap with Streambarbs (Appendix A, Sheet 11).

The approach involves placing a riprap revetment between the expected scour depth and 50-year flood event water level, approximately 12 to 15 feet high, 5 feet thick, and 2(h):1(v) slope. Instead of a launchable riprap toe, 6 to 8 - 40 to 50 feet long streambarbs are proposed for reducing shear stress and deflecting the river flow away from the revetment. The streambarbs reduce the risk of scour and channel incision undermining the revetment, promote sediment deposition and retention along the bank toe, and creates channel complexity. The bank, riprap, streambarbs, and channel area between the streambarbs would be augmented with streambed material, large woody debris, and planted with riparian vegetation for establishing a riparian buffer. Estimated construction cost is summarized in Table C4-3.

<u>Minor Active River Channel Shift</u>

An environmentally desirable approach would be to nudge the active river channel over enough from the road to reestablish a riparian buffer. Ideally, the buffer would have the same erosion resistance of a natural, wooded and vegetated river bank. The buffer would need to be wide enough to allow some bank erosion without threatening the roadway. It would be made by placing alluvial material over existing riprap revetment and unstable bank areas. To promote

vegetation establishment and soil mass stability, the finished surface of the buffer area should not be steeper than 5(h):1(v). Assuming a 10 feet high bank, the width of the new buffer area would be at least 50 feet. Existing relative stable riparian buffers observed along the river are at least 40 to 50 feet wide and densely vegetated with alder and fir. The new buffer area would be prone to erosion from active channel migration. The erosive forces are expected to be too large for passive and bio-engineering methods to be effective by themselves. Hardened, more erosion resistant components in the buffer system are needed for mitigating the erosive forces.

-Engineered-log-jam Groins.

ELJ's groins constructed perpendicular to the stream bank and extending through the new buffer area would control channel location and deflect river flow away from new buffer area (Appendix A, Sheet 10). An ELJ's buoyancy and sliding analysis (Design Guidelines for Reintroducing Wood in Australian Streams, Abbe/Brooks, 2006) was completed assuming 6 feet design flow depth, 5 feet design scour depth, 8 feet per second average flow velocity, 1.5 velocity correction factor, and 18-inch average trunk diameter. The river bed contains cobbles and small boulders. Piles would need to penetrate the river bottom at least 20 to 30 feet for providing adequate resistance to buoyancy and sliding. Tree trunk piles would likely splinter before reaching the desired design depth. As wood decays, it losses strength and cannot resist the shear stresses created by a sliding ELJ mass. Driving steel piles for pinning the ELJ structure to the river bottom would be expensive and leave a tangle of steel piles protruding from the river bottom. Based on the analysis, an ELJ structure 15 feet wide and ballasted with stone is needed for achieving a minimum sliding factor-of-safety of 2.0, the minimum needed for unknown flow conditions and resisting expected additional woody debris accumulation.

Each ELJ groin would be 60 feet long and constructed of three 15 feet wide by 20 feet long modules. Assuming 2 to 3 feet gaps between logs and 8 layers, approximately 50 logs are needed for each module and 150 for each groin. Based on the stability analysis, 150 cubic yards of ballast stone is needed for each ELJ groin for achieving minimum sliding and buoyancy factor-of-safeties of 2.0, the minimum needed for unknown flow conditions and resisting expected additional woody debris accumulation. The logs are cabled together for keeping them in place against expected flow depth and velocity and additional woody debris accumulation.

-Riprap Streambarbs.

Streambarbs are an alternative to using ELJ groins for controlling channel location and reducing erosive forces (Appendix A, Sheet 10). Each stream barb would be angled upstream 30 degree relative the bank line and approximately 100 feet long for fitting within the new riparian buffer. Assuming Class 8 riprap, crest width is 8 feet. Barb thickness is 8 feet at base and 6 feet at tip. Barb bottom width is 32 feet at base and 23 feet at tip. Approximately 470 cubic yards of riprap is needed for each stream barb.

Based on review of historical satellite imagery, length of bank typically exposed to impinging flood flow is estimated to be approximately 300 feet. The radius of curvature for active channel is 500 to 800 feet. To effectively deflect the impinging river flow away from the new bank area, the ELJ groins or stream barbs would need to be spaced every 100 to 150 feet. Assuming 100 feet of upstream stream bank (C4c), 200 feet of downstream stream bank (C4a), and 1,300 feet of the revetment is proposed for covering and stabilization, approximately 13 ELJ groins or stream barbs are needed.

The existing revetment is assumed left in place. Stream bank area is constructed between the ELJ groins or stream barbs by placing conserved and imported stream bed and bank material. Willow and cottonwood trees are planted throughout the area. Willow fascines are placed along

the lower 3 to 6 feet of the bank toe for controlling erosion. Large wood is incorporated randomly throughout the bank area.

Estimated construction cost is summarized in Table C4-3. Work will be within the active river channel and requires temporarily diverting the river flow. Flow defection is assumed accomplished with large sandbags or water-inflated bladders. Dewatering the work area would be extremely difficult and expensive. Excavation and placing logs, stone, and new stream bank fill material is assumed to take place in the water ponded behind the flow diversion structure. Turbidity released is expected to be limited in extent and duration. Access for construction is assumed down a ramp constructed over the existing riprap revetment. The ramp could provide permanent access for maintenance. Upper Hoh Road traffic impacts are expected to be limited to one-lane closures and short-term delays.

Shifting the active river channel 50 feet south is expected to induce moderate erosion of the point bar erosion opposite the site. It also increases the risk of an avulsion across the point bars opposite and immediately downstream of the site. The approach would likely induce minor downstream bank erosion.

Executive Order 11988, Floodplain Management, established federal policies for protecting floodplains and floodways. The intention of the associated regulations is to avoid, to the extent practical, adverse impacts to floodplains; minimize the impact of floods to human safety, health, and welfare; and avoid supporting land use development that is incompatible with the natural and beneficial floodplain values. When avoidance is not possible, the policies require appropriate consideration of methods to assess and minimize adverse impacts. If the option is considered, additional analysis is needed for identifying extent and location of private property impacts. If found violating Executive Order 11988, relocating the active river channel would not be eligible for Federal funds.

Major Active River Channel Shift

Shifting the river 200 to 400 feet away from the road eliminates the current riprap revetment failure risk and road loss risk from bank erosion occurring upstream and downstream of the existing revetment. Shifting the active river channel to flow across the point bar opposite the existing riprap revetment could be accomplished with four to six ELJ's, each at least 20 feet wide and 60 to 100 feet long. Three of the ELJ's would be constructed within the active river channel and two would be constructed within the point bar. Top of the ELJ's are set equal to 100-year water surface, estimated to be approximately 5 to 6 feet above the point bar surface. Bottom of the ELJ's are set below the active channel thalweg elevation and expected scour depth, approximately 6 feet below the point bar surface. Each engineered-log-jam is ballasted with stone and logs cabled together for keeping them in place against expected flow depth and velocity and additional woody debris accumulation.

The existing revetment is assumed left in place. Off-channel rearing and resting habitat is created along the toe of the existing riprap revetment. A new 100 feet wide active flow channel would be constructed across the point bar for diverting stream flow away from the construction area. Alluvial and plant materials from the channel excavation are to be used for the habitat reconstruction.

Estimated construction cost is summarized in Table C4-3. Construction requires temporarily diverting the river flow. Turbidity released is expected to be limited in extent and duration. Access for construction is assumed down a temporary access routes through the Olympic National Forest land, across river point bar, and across the Tower Creek alluvial fan. A ramp constructed over the existing riprap revetment could provide temporary access for construction

and permanent access for maintenance. Upper Hoh Road traffic impacts are expected to be limited to one-lane closures and short-term delays.

Moving the active river channel 400 feet south provides opportunity for creating off-channel rearing and resting habitat along the toe of the existing riprap revetment. Moving the active river channel more than 400 feet south would likely induce dramatic downstream bank erosion and stream avulsion, resulting in unnatural changes in the HCMZ boundaries and loss of private property and Olympic National Forest land.

Executive Order 11988, Floodplain Management, established federal policies for protecting floodplains and floodways. The intention of the associated regulations is to avoid, to the extent practical, adverse impacts to floodplains; minimize the impact of floods to human safety, health, and welfare; and avoid supporting land use development that is incompatible with the natural and beneficial floodplain values. When avoidance is not possible, the policies require appropriate consideration of methods to assess and minimize adverse impacts. If the option is considered, additional analysis is needed for identifying extent and location of private property impacts. If found violating Executive Order 11988, relocating the active river channel would not be eligible for Federal funds.

Environmental Clearance Considerations

This section of the Upper Hoh Road appears to extend through private lands with FS lands to the immediate south. The 1400 linear foot of rip-rap installed after flood events in 2004 and 2007 have created multiple fish barriers, preventing migratory and resident fish from accessing high quality rearing habitat in a forested wetland on the north side of the road. This section of road is adjacent to critical habitat for the bull trout. Northern spotted owl critical habitat is located just south of the project and marbled murrelet critical habitat is located about ¾ of a mile north of the project area in lands managed by the FS. A wetland delineation would need to be conducted to confirm to determine its boundaries.

Except for as described below, environmental clearance considerations for Site C4 are the same as described for Site C1.

Continue Maintenance

Environmental considerations are the same as those described in Site C1.

Relocate Road

The proposed relocation would involve placing fill in an estimated 2 acres of forested wetland. This area appears to be suitable juvenile rearing and resting habitat for various fish species. Removing the riprap revetment and the restoring the natural streambank in conjunction with the installation of more natural streambarbs and engineer-long jams and the reestablishment of wetlands and accessible off-channel rearing and resting habitat, could likely benefit bull trout and resident fish.

This proposed work would require an Individual Permit under Section 404 of the Clean Water Act as well as a 401 certification from the DOE. Due to the impacts to special aquatic sites (wetlands) a full 404(b)(1) analysis is likely required demonstrating that this road relocation is the least environmentally damaging (to wetlands) practicable alternative. Practicable is defined in terms of cost, existing technology, and logistics. This project will also likely require off-site wetland mitigation, using a wetland mitigation bank. Wetland mitigation banks in this area are expensive, costing up to $200K per credit.

A biological assessment will need to be prepared evaluating impacts to bull trout, bull trout designated critical habitat, marbled murrelet, and the northern spotted owl.

Hoh River Trust, owners of the land that would be impacted by the relocation have indicated that there are easement restrictions preventing the Trust from selling the land for development purposes. As a result, condemnation may be required.

Stabilize Existing Road Embankment

Environmental considerations are the same as those described in Site C1.

Minor and Major Active River Channel Shift

This could have a dramatic effect on the existing river system. The extent to which the option helps or harms the aquatic habitat would need determined through modeling and formal consultation with the Service, the Hoh Tribe, and the WDFW. This work would require an individual permit from the Corps and 401 Certification from the DOE.

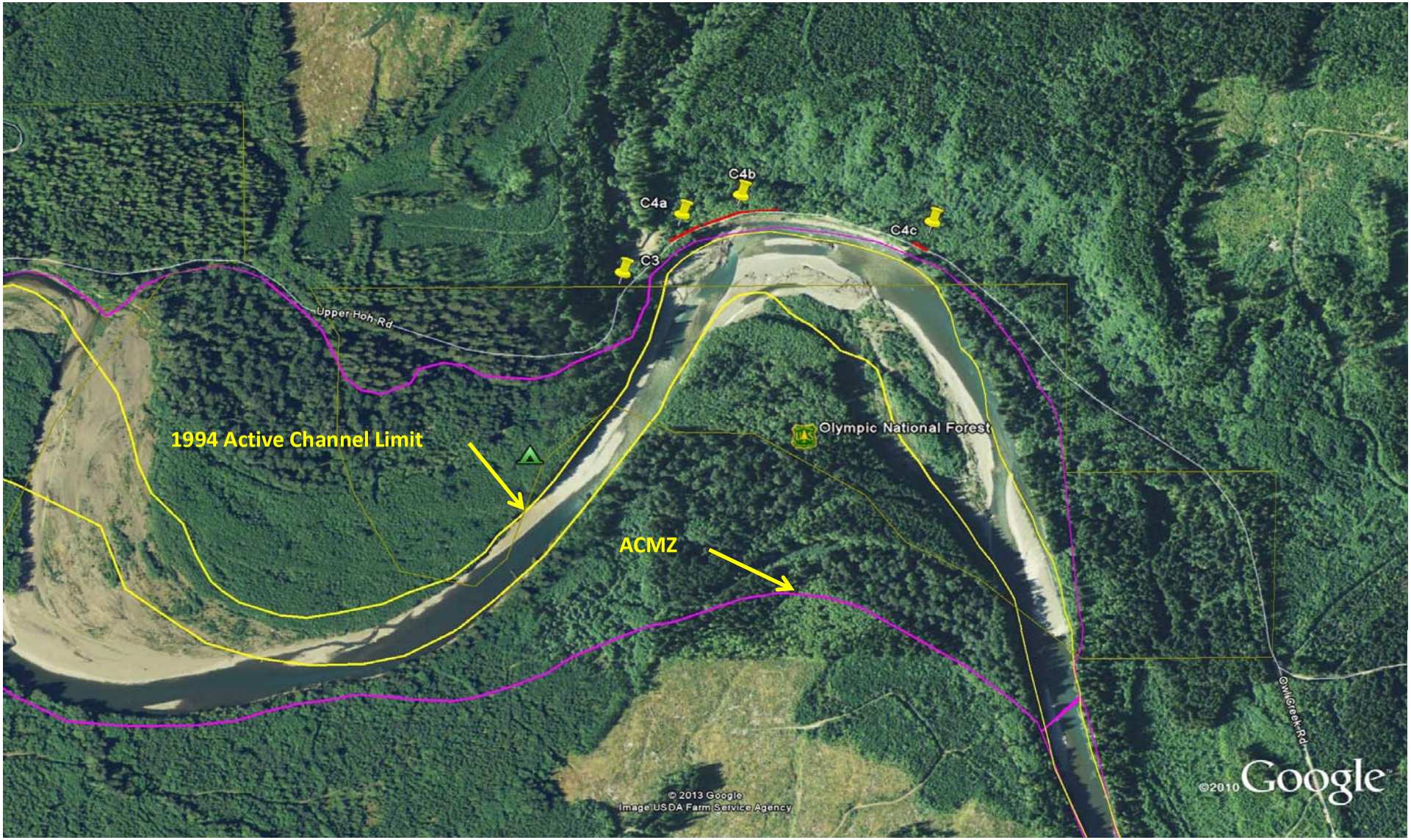
A biological assessment would need to be prepared evaluating short and long term impacts to bull trout and short term construction impacts to the marbled murrelet and the northern spotted owl.

In addition, geomorphic assessments would need to be conducted for assessing effect this option may have on downstream properties.

Due to the scope of work and the limited in-water work window, WDFW would likely need to be petitioned for an extension.

Each ELJ requires a number of trees to be cut down. Approximately 2,000 and 900 logs are needed for the minor and major active river channel shift options, respectively. Cutting these trees would have a direct impact on some forest's ecosystem and watershed's health.

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ACMZ - Active Channel Migration Zone, Geomorphic Assessment of Hoh River in Washington State, USBR, July 2004.

Imagery date 11/3/2011

Figure C4-1. Site Location

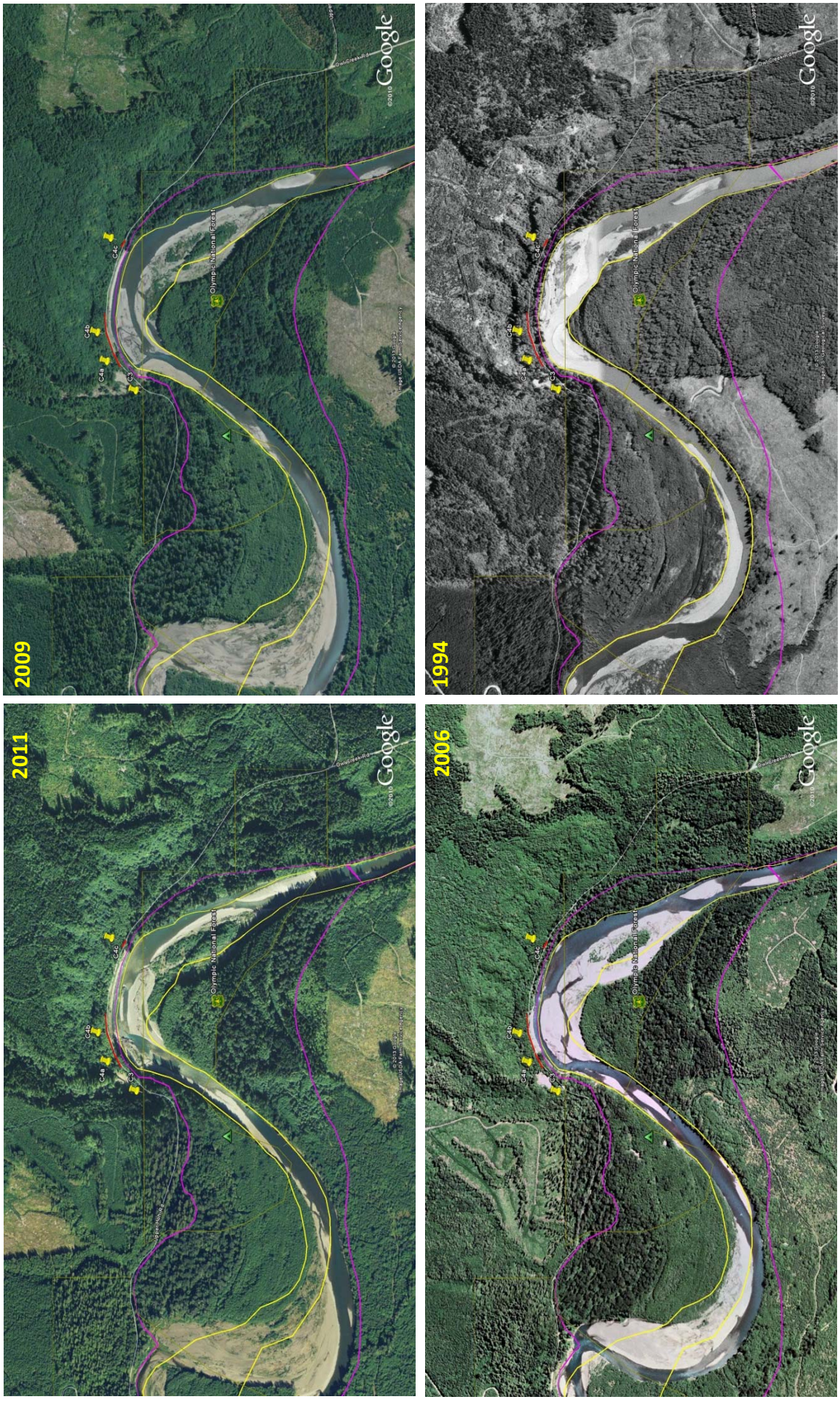


Figure C4-2. Historical Satellite Imagery

Photos

C4 - MP 7.8 Bank Stabilization



PHOTO C4-1

Looking downstream along riprap revetment, upstream segment in foreground.

Finished slope is steep, some riprap has been dislodged from middle slope and toe areas.



PHOTO C4-2

C4c - Steep, undercut, and eroding stream bank immediately upstream of revetment.

Bank 20 feet high. Lower 3 feet of toe naturally armored with cobble/boulder material.



PHOTO C4-3

Steep, undercut, and eroding stream bank immediately downstream of revetment, looking downstream.

Bank 20 feet high. Lower 3 feet of toe naturally armored with cobble/boulder material. Gravel bar between bank and natural woody debris jam at head of small island. Woody debris deflects stream flow towards bank. Distance between bank and woody debris 150 feet.

12/12/2012

Photos

C4 - MP 7.8 Bank Stabilization



PHOTO C4-4

Steep, undercut, and eroding stream bank immediately downstream of revetment, looking upstream.

Bank 20 feet high. Lower 3 feet of toe naturally armored with cobble/boulder material. Gravel bar between bank and natural woody debris jam at head of small island. Woody debris deflects stream flow towards bank. Distance between bank and woody debris 150 feet.



PHOTO C4-5

Looking upstream at riprap revetment, eroding bank, gravel bar, and small woody debris jam/island.

Bank 20 feet high. Lower 3 feet of toe naturally armored with cobble/boulder material. Gravel bar between bank and natural woody debris jam at head of small island. Woody debris deflects stream flow towards bank. Distance between bank and woody debris 150 feet.



PHOTO C4-6

C4a - Tower Creek confluence with Hoh River - upstream along eroding bank.

Bank 20 feet high. Lower 3 feet of toe naturally armored with cobble/boulder material. Debris flow/alluvial material from Tower Creek inhibits down-valley meander bend migration.

12/12/2012

Table C4-1. Alternative Summary and Ranking.

Upper Hoh River Road Site - C4 - MP 7.8 Bank Stabilization

					Bank Stabilization								Minor Active River Channel Shift				Major Active River Channel Shift	
OPTIONS	**Rank**	**Continued Maintenance**	**Rank**	**Relocate Road**	**Rank**	**Complex Roughened Large Rock Toe**	**Rank**	**Complex Log Crib Wall**	**Rank**	**Riprap with LWD and Plantings**	**Rank**	**Riprap with Streambarbs**	**Rank**	**ELJ Groins**	**Rank**	**Large Stream barbs**	**Rank**	
Road on the edge of the channel migration zone has less of an impact to the total channel zone.		**Place or replace riprap as needed for preventing road closure.**		**Offset Road 200 Feet with mitigation of existing roadway slope to riparian zone - install streambarbs and ELJ's for preserving riparian zone.**		**Rock toe with LWD.**		**Log crib wall with roughness elements.**		**Riprap similar to what is commonly used along Upper Hoh River Road embankment.**		**Bank area planted with willow and alder.**		**Construct new stream bank area over unstable and revetment areas.**		**Construct new stream bank area over unstable and revetment areas.**		**Shift active flow channel to flow across point bar away from revetment area.**
Ability to preserve and operate the roadway in a specific location (Most able 5, least able 1)	**3**	Reduces risk of a catastrophic road failure during extreme flood event.	**3**	Better than where it is, but the river may eventually migrate north and impact road again.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.
Roadway sustainability (life of solution) (Longest 5, shortest 1)	**1**	Increased maintenance in the future mitigating climate change or after large flood events.	**3**	Increase road life reduces future risk from river. Road near hillside may experience landslides and debris flows.	**3**	Requires moderate amount of wood replacement and maintenance.	**1**	Requires substantial amount of wood replacement and maintenance.	**3**	Requires moderate amount of wood replacement and maintenance.	**5**	Requires moderate level of maintenance.	**1**	Requires substantial amount of wood replacement and maintenance.	**5**	Requires moderate level of maintenance.	**1**	Requires substantial amount of wood replacement and maintenance.
Impact to hillside stability adjacent to site (Most likely 1; least likely 5)	**5**	No expected additional impacts.	**1**	Road near hillside may experience landslides and debris flows.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.
Potential to reduce erosion of banks adjacent to site (Most 5; Least 1)	**1**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**1**	Likely increase down stream right bank erosion.
Impacts to listed Threatened and Endangered (T&E) terrestrial species and habitat (Least 5; most 1)	**5**	No expected additional impacts.	**1**	Impacts upland areas and potentially T&E.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.
Impacts to listed T&E fish and habitat (Least 5; most 1)	**3**	Riprap placed along bank reduces habitat complexity.	**3**	Material placed in channel.	**3**	Material placed in channel.	**3**	Material placed in channel.	**3**	Material placed in channel.	**1**	Riprap along bank reduces habitat complexity. Barbs require significant excavation into channel bed.	**3**	Considerable temporary impacts from in-stream channel work.	**3**	Considerable temporary impacts from in-stream channel work.	**3**	Considerable temporary impacts from in-stream channel work.
Impact to upland habitat (Least 5; most 1)	**5**	No expected additional impacts.	**1**	Impacts upland areas.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.
Impacts to Wetlands and Waters of the U.S. (Least 5; most 1)	**3**	No expected additional impacts to wetlands; riprap placement in river.	**3**	Riprap placement in river.	**3**	No expected additional impacts to wetlands; riprap placement in river.	**3**	No expected additional impacts to wetlands.	**3**	No expected additional impacts to wetlands; riprap placement in river.	**1**	Riprap along bank reduces habitat complexity. Barbs require significant excavation into channel bed.	**1**	Requires major in stream construction.	**1**	Requires major in stream construction.	**1**	Requires major in stream construction.
Impact to Designated Wilderness area (Least 5; most 1)	**0**	No expected impacts.	**0**	Expected impacts.	**0**	No expected impacts.	**0**	No expected impacts.	**0**	No expected impacts.	**0**	No expected impacts.	**0**	No impacts.	**0**	No impacts.	**0**	No expected impacts.
Potential for Hoh River Enhancement (Greatest 5; Least 1)	**1**	Does not provide river enhancements.	**5**	Provides off-channel/side-channel habitat, allows river to fully access HCMZ.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Moves thalweg away from road, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.
Potential to maintain or improve river process and function (Most 5; Least 1)	**1**	Does not improve river process and function.	**5**	Provides off-channel/side-channel habitat, allows river to fully access HCMZ	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Moves thalweg away from road, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.
Potential for other habitat enhancements (Most 5; Least 1)	**1**	Does not provide other habitat enhancements.	**5**	Opportunity for improving fish access to off-channel habitat	**3**	Provides some woody debris for habitat complexity and biological processes.	**3**	Provides some woody debris for habitat complexity and biological processes.	**3**	Provides some woody debris for habitat complexity and biological processes.	**1**	Does not provide other habitat enhancements.	**5**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides some woody debris for habitat complexity and biological processes.	**5**	Provides woody debris for habitat complexity and biological processes.
Potential private property impacts (Least 5; Most 1)	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**3**	Some impacts expected from bank erosion downstream of site.	**3**	Some impacts expected from bank erosion downstream of site.	**1**	Impacts likely from bank erosion downstream of site.
Safety risk of design to public (Least 5; Most 1)	**5**	No expected increase in safety risk.	**3**	Boaters could become trapped in root wads.	**3**	Boaters could become trapped in root wads.	**1**	Public could fall down wall. Boaters could become trapped in root wads.	**3**	Boaters could become trapped in root wads.	**5**	No expected increase in safety risk.	**1**	Boaters could become trapped in ELJ's.	**3**	Boaters could become trapped in root wads.	**1**	Boaters could become trapped in ELJ's.
Total Construction cost		**NA**		**$7,066,280**		**$855,207**		**$1,151,954**		**$1,724,325**		**$1,650,138**		**$6,394,705**		**$3,866,702**		**$4,033,900**
Riprap and Wood Replacement (50 years)	**5**	**NA**	**1**	**$1,580,000**	**3**	**$264,000**	**3**	**$522,667**	**3**	**$381,333**	**3**	**$282,667**	**1**	**$2,917,200**	**1**	**$339,960**	**1**	**$1,800,000**
Total Capital Cost (50 years)		**NA**		**$11,169,478**		**$1,418,530**		**$2,077,805**		**$2,709,172**		**$2,510,353**		**$11,550,052**		**$5,560,007**		**$7,245,765**
Annualized Total Capital Cost (Least 5; Most 1)		**$21,000**		**$822,153**		**$104,414**		**$152,941**		**$199,414**		**$184,780**		**$850,166**		**$409,256**		**$533,340**
SCORE	**44**		**43**		**52**		**48**		**52**		**50**		**48**		**52**		**44**	

Table C4-2. Total Expected Cost

Project: Hoh River Road Bank Erosion Risk Study **Date: 3/14/2013**

Site: C4 - CMP 7.8 Bank Stabilization

Alternative: Continue Maintenance **By: S. Leon**

	Flood Frequency (yr)	Exceedance Probability	Flood Damage	Average Flood Damage	Delta Exceedance Probability	Annual Risk Cost
No damage.	2	**0.5**	$0			
				$0	**0.3**	**$0**
No damage.	5	**0.2**	$0			
				$0	**0.1**	**$0**
No damage.	10	**0.1**	$0			
				$150,000	**0.06**	**$9,000**
Place riprap.	25	**0.04**	$300,000			
				$300,000	**0.02**	**$6,000**
Place riprap.	50	**0.02**	$300,000			
				$300,000	**0.01**	**$3,000**
Place riprap.	100	**0.01**	$300,000			
				$300,000	**0.01**	**$3,000**
		0	$300,000			
Total Annual Risk Cost						**$21,000**
Annualized Capital Cost	**Capital Cost**					**$0**
	Disc. rate, i	**0.07125**	**Serv. life, n**	**50**	**CFR**	**0.0736**
	Annualized Capital Cost					**$0**
Total Expected Cost (Annual)						**$21,000**
Summary	Assume 300 feet ($1k/ft) of revetment repair and bank armoring for each flood damage event.					

Notes:

1. Method from HEC-17, April 1981.

Table C4-3. Cost Estimates

Site: **C4 - CMP 7.8 Bank Stabilization**

Relocate Road

		Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost	LS	1	$	355,600	$	**355,600**
New Road		LF	2,000	$	500	$	**1,000,000**
Hillside Stabilization		LS	1	$	100,000	$	**100,000**
Remove Existing Revetment		LF	1,400	$	200	$	**280,000**
Streambank Reconstruction		LF	1,800	$	1,000	$	**1,800,000**
Streambarbs		EA	10	$	40,000	$	**400,000**
ELJ's		EA	5	$	300,000	$	**1,500,000**
Total Construction Cost without Contingencies						$	**5,435,600**
Contingency	30% of construction cost					$	**1,630,680**
Total Construction Cost						$	**7,066,280**
Compliance	5% of total construction cost					$	**353,314**
Predesign/design (PE)	15% of total construction cost					$	**1,059,942**
Construction Engineering (CE)	15% of total construction cost					$	**1,059,942**
ROW						$	**50,000**
Riprap replacement -	20% replacement every		50	years		$	**80,000**
Wood replacement -	full log replacement every		30	years		$	**1,500,000**
TOTAL Capital Cost		Cost/Foot	**$ 5,585**			$	**11,169,478**
Annualized Capital Cost		Discount rate, i	0.07125			$	**822,153**
		Service life, n	50	years			
		CFR	**0.0736071**				

Complex Roughened Large Rock Toe

			Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost		LS	1	$	43,037	$	**43,037**
Remove Existing Revetment			LF	-	$	200	$	**-**
Rock	H 12 ft	T 5 ft	CY	**1,778**	$	180	$	**320,000**
	L 800 ft							
Logs	L 800 ft	XS 8 ft	EA	**100**	$	2,000	$	**200,000**
Soil	H 8 ft	T 10 ft	CY	**2,370**	$	40	$	**94,815**
	L 800 ft							
Total Construction Cost without Contingencies							$	**657,852**
Contingency	30% of construction cost						$	**197,356**
Total Construction Cost							$	**855,207**
Compliance	5% of total construction cost						$	**42,760**
Predesign/design (PE)	15% of total construction cost						$	**128,281**
Construction Engineering (CE)	15% of total construction cost						$	**128,281**
ROW							$	**-**
Riprap replacement -	20% replacement every			50	years		$	**64,000**
Wood replacement -	full log replacement every			30	years		$	**200,000**
TOTAL Capital Cost			Cost/Foot	**$ 1,773**			$	**1,418,530**
Annualized Capital Cost			Discount rate, i	0.07125			$	**104,414**
			Service life, n	50	years			
			CFR	**0.0736071**				

Table C4-3. Cost Estimates

Complex Log Crib Wall

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost			LS	1	$	57,970	$	**57,970**
Remove Existing Revetment				LF	200	$	200	$	**40,000**
Rock	H 12 ft	T 5 ft		CY	**1,778**	$	120	$	**213,333**
	L 800 ft								
Logs	L 800 ft	H 12 ft		EA	**240**	$	2,000	$	**480,000**
	Dia 2 ft	Row 6							
	log l 20 ft	No. 240							
Piles				EA	0	$	-	$	**-**
Soil	H 8 ft	T 10 ft		CY	**2,370**	$	40	$	**94,815**
	L 800 ft								
Total Construction Cost without Contingencies								$	**886,119**
Contingency	30% of construction cost							$	**265,836**
Total Construction Cost								$	**1,151,954**
Compliance	5% of total construction cost							$	**57,598**
Predesign/design (PE)	15% of total construction cost							$	**172,793**
Construction Engineering (CE)	15% of total construction cost							$	**172,793**
ROW								$	**-**
Riprap replacement -	20% replacement every				50 years			$	**42,667**
Wood replacement -	full log replacement every				30 years			$	**480,000**
TOTAL Capital Cost			Cost/Foot	$	**2,597**			$	**2,077,805**
Annualized Capital Cost		Discount rate, i			0.07125			$	**152,941**
		Service life, n			50 years				
		CFR			**0.0736071**				

Riprap with Roughened Rock Toe, LWD, and Riparian Plantings

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost			LS	1	$	86,774	$	**86,774**
Remove Existing Revetment				LF	200	$	200	$	**40,000**
Riprap	H 13 ft	T 5 ft		CY	**5,037**	$	180	$	**906,667**
	L 800 ft	SS 2 (h):1(v)							
	TW 8 ft	TT 5 ft							
Logs	L 800 ft	XS 8 ft		EA	**100**	$	2,000	$	**200,000**
Willow	400 sy	XS 2		EA	**200**	$	10	$	**2,000**
Alder	400 sy	XS 1		EA	**400**	$	20	$	**8,000**
Soil	H 7 ft	T 10 ft		CY	**2,074**	$	40	$	**82,963**
	L 800 ft								
Total Construction Cost without Contingencies								$	**1,326,404**
Contingency	30% of construction cost							$	**397,921**
Total Construction Cost								$	**1,724,325**
Compliance	5% of total construction cost							$	**86,216**
Predesign/design (PE)	15% of total construction cost							$	**258,649**
Construction Engineering (CE)	15% of total construction cost							$	**258,649**
ROW								$	**-**
Riprap replacement -	20% replacement every				50 years			$	**181,333**
Wood replacement -	full log replacement every				30 years			$	**200,000**
TOTAL Capital Cost			Cost/Foot	$	**3,386**			$	**2,709,172**
Annualized Capital Cost		Discount rate, i			0.07125			$	**199,414**
		Service life, n			50 years				
		CFR			**0.0736071**				

Table C4-3. Cost Estimates

Riprap with Streambarbs

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost			LS	1	$	83,041	$	**83,041**
Remove Existing Revetment				LF	-	$	200	$	**-**
Riprap	H 13 ft	T 5 ft		CY	**3,852**	$	180	$	**693,333**
	L 800 ft	SS 2 (h):1(v)							
	TW 0 ft	TT 0 ft							
Streambarbs				EA	8	$	40,000	$	**320,000**
Logs	L 800 ft	XS 20 ft		EA	**40**	$	2,000	$	**80,000**
Willow	400 sy	XS 2		EA	**200**	$	10	$	**2,000**
Alder	400 sy	XS 1		EA	**400**	$	20	$	**8,000**
Soil	H 7 ft	T 10 ft		CY	**2,074**	$	40	$	**82,963**
	L 800 ft								
Total Construction Cost without Contingencies								$	**1,269,337**
Contingency	30% of construction cost							$	**380,801**
Total Construction Cost								$	**1,650,138**
Compliance		5% of total construction cost						$	**82,507**
Predesign/design (PE)		15% of total construction cost						$	**247,521**
Construction Engineering (CE)		15% of total construction cost						$	**247,521**
ROW								$	**-**
Riprap replacement -	20% replacement every				50	years		$	**202,667**
Wood replacement -	full log replacement every				30	years		$	**80,000**
TOTAL Capital Cost			Cost/Foot	$	**3,138**			$	**2,510,353**
Annualized Capital Cost			Discount rate, i		0.07125			$	**184,780**
			Service life, n		50	years			
			CFR		**0.0736071**				

Major River Channel Shift

			Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost		LS	1	$	203,000	$	**203,000**
Channel Excavation - 100 feet by 5 feet			LF	2,000	$	300	$	**600,000**
Rearing and Resting Habitat Construction			AC	10	$	50,000	$	**500,000**
Remove Existing Revetment			LF	-	$	200	$	**-**
Streambank Reconstruction			LF	-	$	1,000	$	**-**
Streambarbs			EA	-	$	40,000	$	**-**
ELJ's - 20 ft by 60 ft			EA	6	$	300,000	$	**1,800,000**
Total Construction Cost without Contingencies							$	**3,103,000**
Contingency	30% of construction cost						$	**930,900**
Total Construction Cost							$	**4,033,900**
Compliance		5% of total construction cost					$	**201,695**
Predesign/design (PE)		15% of total construction cost					$	**605,085**
Construction Engineering (CE)		15% of total construction cost					$	**605,085**
ROW							$	**-**
Riprap replacement -	20% replacement every			50	years		$	**-**
Wood replacement -	full log replacement every			30	years		$	**1,800,000**
TOTAL Capital Cost		Cost/Foot	$	**3,623**			$	**7,245,765**
Annualized Capital Cost		Discount rate, i		0.07125			$	**533,340**
		Service life, n		50	years			
		CFR		**0.0736071**				

Table C4-3. Cost Estimates

Minor River Channel Shift - ELJ Groins

		Unit	Quantity	Unit Cost	Total Cost
Mobilization	7% of construction cost	LS	1	$ 321,804	**$ 321,804**
Rearing and Resting Habitat Construction		AC	-	$ 50,000	**$ -**
Remove Existing Revetment		LF	-	$ 200	**$ -**
Streambank Reconstruction - fill/plants/fascines		LF	1,300	$ 1,200	**$ 1,560,000**
Large Wood		EA	80	$ 1,500	**$ 120,000**
ELJ groin - 15 ft by 60 ft (3 x 15 ft by 20 ft mod.)		EA	13	$ 224,400	**$ 2,917,200**
Primary logs	50 $ 1,200 $ 60,000				
Pin logs	4 $ 1,200 $ 4,800				
Ballast stone	50 $ 180 $ 9,000				
Cabling	1 $ 1,000 $ 1,000				
	$ 74,800				
No. modules/ ELJ groin	3 $ 224,400				
Total Construction Cost without Contingencies					**$ 4,919,004**
Contingency	30% of construction cost				**$ 1,475,701**
Total Construction Cost					**$ 6,394,705**
Compliance	5% of total construction cost				**$ 319,735**
Predesign/design (PE)	15% of total construction cost				**$ 959,206**
Construction Engineering (CE)	15% of total construction cost				**$ 959,206**
ROW					**$ -**
Riprap replacement -	20% replacement every	50 years			**$ -**
Wood replacement -	full log replacement every	30 years			**$ 2,917,200**
TOTAL Capital Cost	Cost/Foot	**$ 4,919**			**$ 11,550,052**
Annualized Capital Cost	Discount rate, i	0.07125			**$ 850,166**
	Service life, n	50 years			
	CFR	**0.0736071**			

Minor River Channel Shift - Stream Barbs

		Unit	Quantity	Unit Cost	Total Cost
Mobilization	7% of construction cost	LS	1	$ 194,586	**$ 194,586**
Rearing and Resting Habitat Construction		AC	-	$ 50,000	**$ -**
Remove Existing Revetment		LF	-	$ 200	**$ -**
Streambank Reconstruction - fill/plants/fascines		LF	1,300	$ 1,200	**$ 1,560,000**
Large Wood		EA	80	$ 1,500	**$ 120,000**
Streambarbs	Length 100 ft	EA	13	$ 84,600	**$ 1,099,800**
	Crest width 8 ft				
	Average bot. width 28 ft				
	Average thickness 7 ft				
	Volume 470 cy				
	Cost/cy 180 $/cy	Cost/barb	$ 84,600		
Total Construction Cost without Contingencies					**$ 2,974,386**
Contingency	30% of construction cost				**$ 892,316**
Total Construction Cost					**$ 3,866,702**
Compliance	5% of total construction cost				**$ 193,335**
Predesign/design (PE)	15% of total construction cost				**$ 580,005**
Construction Engineering (CE)	15% of total construction cost				**$ 580,005**
ROW					**$ -**
Riprap replacement -	20% replacement every	50 years			**$ 219,960**
Wood replacement -	full log replacement every	30 years			**$ 120,000**
TOTAL Capital Cost	Cost/Foot	**$ 2,974**			**$ 5,560,007**
Annualized Capital Cost	Discount rate, i	0.07125			**$ 409,256**
	Service life, n	50 years			
	CFR	**0.0736071**			

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C5 - COUNTY MILEPOST 10.2

CANYON CREEK CULVERT



SITE C5 - CANYON CREEK CULVERT

Existing Culvert

The existing drainage is an 8.5 feet diameter corrugated metal pipe, located at a low point of a sag vertical curve and buried under approximately 25 to 30 feet fill. The existing culvert is in fair condition (Photo C5-6). There is damage at the crown and invert of the pipe with some separations at the joints. Offsets at the crown of 6 to 10 inches were observed at three joint locations. The pipe crown damage may have been due to original construction. It has been filled in with grout and appears to be stable. At the inlet the pipe is armored with riprap (Photo C5-3). There is evidence of debris accumulation at the upstream opening. At the outlet, the culvert is protruding approximately 5 feet beyond the road embankment fill and 3 feet above the water surface of a large (30 feet by 30 feet by 4 feet) scour hole (Photos C5-4 and 5). The road embankment material is erodible. Undercutting of the culvert outlet is expected to continue. Water streaming out from under the pipe suggests there is water piping through the culvert bedding material. Possible sources of the water include groundwater, stream water flowing under pipe, and stream water flowing out from the inside of the culvert. The offset crown joint may entangle large woody debris. Removal of the woody debris from inside the culvert would be difficult and hazardous. Based on observed pipe damage and assuming woody debris is not trapped inside the culvert, the culvert could provide another 20 years of service life. Water seeping under the culvert may indicate a potential risk for the bedding material failing. Woody debris trapped inside the culvert could cause water to pond at the inlet, increasing loading and saturation to the point that a catastrophic road embankment failure occurs.

The active channel width is approximately 16 feet. Ordinary high water flow depth is approximately 2.5 feet. Stream gradient upstream of the culvert is approximately 10 percent. Stream gradient downstream of the culvert is approximately 5 percent (Photo C5-2). Step-pool and cascade are the dominant bed forms. Cobble and small boulders are the dominant bed material. Estimated 2-year, 50-year, and 100-year peak discharges are 215 cfs, 450 cfs, and 504 cfs, respectively (StreamStats). Based on a HY-8 hydraulic analysis, the calculated headwater depths for the 2-year, 50-year, and 100-year peak discharges are 5.5 feet, 8.6 feet, and 9.4 feet, respectively. There is abundant woody debris available for recruitment to the stream from windfall and stream bank erosion. The stream is capable of transporting the woody debris at the more extreme (> 25-year) flood events.

Considered Options

In addition to continued maintenance, three options were evaluated. Constructing rock weirs at the existing culvert outlet provides fish passage. Open-bottom arch culvert and a new bridge replace the existing culvert with structures capable of passing fish and expected woody debris. Table C5-1 presents an evaluation and ranking of the options against design selection criteria.

<u>Continue Maintenance</u>

The displaced and offset culvert joints may increase the risk of woody debris hanging up inside the culvert. Debris accumulation at the inlet, joint gaping inside the culvert, debris accumulation inside the culvert, and undercutting at the outlet will need to be monitored. To avoid a catastrophic failure, the inspections should be done annually and after each major flood event. The height of the road embankment makes monitoring difficult. The culvert interior can only be safely accessed during low flow conditions.

A Total Expected Cost analysis (HEC-17, FHWA, April 1981) was completed for estimating total expected cost repairing damage caused by flooding. The analysis assumes a 50-year service-

life. Based on the capacity of the stream and culvert for transporting water and woody debris, debris removal from the inlet area and inside the culvert is expected to be needed for 25-year and larger flood events. Estimated cost for removing debris from the inlet area and inside the culvert is $20,000 per removal event. The analysis assumes the road embankment will be completely washed out for the 500-year flood event. Cost for a new bridge is estimated to be $4,400,000 (Table C5-3). Bridge replacement assumes road is shifted upstream slightly for providing temporary traffic access. Total expected annual cost is $18,880 (Table C5-2, Total Expected Cost).

Rock Weirs at Existing Culvert Outlet

Fish passage could be provided by constructing rock weirs immediately downstream of the existing scour pool that elevate the water surface high enough to eliminate the outlet leap and allow fish to swim directly into the culvert. Four to five rock weirs are needed for effectively reducing the stream gradient enough for fish to easily migrate through the structures. To prevent the stream from cutting around the rock weirs, each rock weir must extend into the valley walls, approximately 40 to 50 feet total length. The rock weirs do not reduce the risk of debris becoming trapped inside the culvert. If ponding backwatering the outlet reduces flow velocities and increases flow depth inside the culvert, the weirs may increase the debris accumulation risk. The rock weirs require rebuilding and are prone to being undermined from downstream degradation.

Access for construction would be difficult. The likely scenario is lowering equipment and stone down the existing road embankment. A temporary wood/rock pad would provide access to the rock weir sites. The temporary pad would be removed and the area reclaimed once construction is completed. Traffic would likely be reduced to one-lane with short-duration interruptions. Estimated construction costs are summarized in Table C5-3.

New Open-bottom Arch Culvert

Based on the field observations, an open-bottom arch with 22 feet span and 11 feet rise is recommended as a culvert alternative. An open-bottom arch constructed over the existing culvert facilitates temporary stream flow diversion. The arch culvert would be placed on a concrete footing founded below expected stream profile degradation and scour, estimated to be 8 feet. Riprap and/or engineered-streambed are placed along the footings for mitigating scour.

Assuming 50 feet road embankment top width and 2(h):1(v) embankment side slopes, the culvert length is 160 feet. Cast-in-place concrete collars provide stiffness for the multi-plate culvert structure. Installing the arch culvert requires a 25 to 30 feet deep excavation. Excavation for the concrete footing would extend down below the arch bottom an additional 10 feet. Width of the excavation at the road surface would be at least 100 feet. Excavating for and installing the culvert would require closing the road to traffic for at least six weeks. Estimated construction costs are summarized in Table C5-3.

New 180 Feet Bridge

Based on the field observation and conceptual hydraulic recommendation, a conceptual bridge length is approximately 160 feet to 180 feet. The conceptual bridge length was based on the following assumptions: 20 feet channel width, 30 feet vertical clearance, 2:1 fill slope, 5 feet of riprap thickness, and approximate abutment and end diaphragm thicknesses.

SPAN ARRANGEMENT: Single span, Two-span & Three-span arrangements were evaluated.

A single clear span structure does not require interior support piers, which eliminates most construction in the channel. This option also eliminates dewatering, temporary cofferdams, and stream temporary work for construction equipment access to the pier locations. Long-term problems with pier scour are also avoided. This option, however, requires approximately 160 to 180-foot long bridge girders, which will have shipping and weight limit issues. The prestressed concrete girders can also be shipped in two pieces and spliced together on the site using post-tensioning. Steel plate girders can be shipped in two or three pieces and field spliced with high strength bolts. The single span structure will have the deepest and heaviest superstructure, which will require larger cranes to set the girders. The analysis included two structural types for the single-span arrangement using prestressed concrete girders, and steel plate girders.

A two-span or three-span structure uses shorter and more cost-effective bridge girders; yet the cost saving from the superstructure may offset by the cost of the additional foundation and pier, and in-water temporary work for the intermediate pier(s). Rolled steel beams or prestressed concrete girders work well for this structure arrangement. These prestressed concrete girders can be shipped in single pieces, do not require field splicing, and can be erected bent to bent. Steel rolled beams will be continuous over the interior pier and shipped in two pieces with a simple bolted splice near one third span points. This multiple span arrangements will help minimize the structural depth and reduce the cost of the bridge superstructure. However, the bridge pier(s) will have to be constructed with this option with all the associated problems of dewatering, cofferdams, and equipment access. The additional pier(s) and shorter spans will combine to catch and retain debris, and provide another mechanism for scour to form under the bridge.

The multiple-span arrangements require intermediate pier(s) and present construction difficulties/concerns such as in-water work, dewatering, cofferdams and equipment access, and potential debris & scour issues. Based on the above discussion and available vertical clearance of the channel, the single span arrangement lends itself well at this site.

SUPERSTRUCTURE TYPE: Precast prestressed concrete girders are appropriate girder types for stream crossings. The precast girders can be lifted into place by cranes located on the banks of the channels, eliminating the need for falsework and minimizing channels disturbances.

Steel girders are also a very practical superstructure type. Steel prices have been volatile in the recent past, but now appear to be stable. As mentioned above the steel girders can be shipped in two or three pieces and field spliced with high strength bolts, and erected by cranes located on the banks of the channels similar to precast prestressed concrete girders.

SUBSTRUCTURE TYPE: Semi-integral abutments supported on deep foundation with cantilevered wing walls are recommended. This type of construction will eliminate the need for any expansion joints on the bridge superstructure eliminating water leakage and long term maintenance associated with expansion joints. Additionally, this type of abutment configuration will help to eliminate design complexity and the uncertainty of the structure and soil movements.

The foundation type cannot be fully determined until the geotechnical investigation is advanced at the later time.

STRUCTURE ALTERNATIVES AND PRELIMINARY COST ESTIMATES: The study evaluated two structure types for the single span arrangements using precast prestressed concrete girders and steel plate girders. Due to the lack of information at this phase, the longer bridge length of 180 feet is selected for this analysis, with centerline bearing to centerline bearing from each abutment to be approximately 172 feet.

Table C5-4. Summary of Bridge Structure Type Alternative

Alt. No.	No. of Spans	Span Length	Girder Type	Girder Spacing	Deck Thickness	Total Cost	Cost per sft
1	1	180	WASHINGTON WF83G	8'-0"	8.5"	$1,550,000	$240
2	1	180	Steel Plant Girder (84" Web)	8'-0"	8.5"	$1,840,000	$285

Alternative 1, the single span using Washington WF83G prestressed bulb-tee girders, is the recommended alternative. This option provides the best compromise between structure costs, constructability and environmental concerns.

Because the abutments are integral with the superstructure, approach slabs are recommended to ensure ride-ability across the abutments should the approach fill settle. Deck drains are not anticipated due to the longitudinal slope, crowned deck section, and shoulders. Catch basins can be installed in the shoulder approach of the bridge to capture pavement runoff flowing toward the bridge.

Construction Phasing: Due to the 30 feet fill on top the existing culvert, it may be very difficult, impractical or costly to stage the new bridge construction on the existing alignment while maintaining traffic during construction. An alignment shift is assumed for this bridge alternative. If a one-lane temporary traffic is an acceptable detour during construction, the alignment shift may be minimized by employing staged construction on the new bridge.

The proposed construction phasing for this bridge is described in the following subsections.

Phase 1: While maintaining traffic in the existing alignment, construction the south portion of the new bridge offset from the existing alignment. Construct the permanent bridge rail on the south bridge edge, and set a temporary concrete barrier along the north edge of the bridge. This first south portion of the new bridge may have to have a minimum width of 20 feet edge to edge to provide a one-lane 10-foot lane with 2-foot shoulders.

Phase 2: Shift traffic onto the completed south portion of the new structure. Remove the existing fill and culvert completely or partially to yield enough space to construct the north portion of the new bridge. Construct the remaining north portion of the new bridge.

The estimated construction cost for the new bridge, shifting the road alignment, removing the existing bridge, and installing riprap abutment scour countermeasures are summarized in Table C5-3.

Environmental Clearance Considerations

This portion of the road appears to extend through Hoh River Trust Lands. The culvert is presently perched and prevents fish passage to upstream habitat for migratory and resident fish. The WDFW have identified this stretch of Canyon Creek as a Priority Habitat for both native and migratory fish. The leap at the culvert outlet is a physical barrier to upstream fish migration. Washington State law requires that, where streams either historically or presently inhabited by native fish, new culverts must provide effective upstream fish migration for all life stages of fish.

National Wetland Inventory maps did not identify any wetlands at this project location. A wetland survey and, if needed, delineation, will need to be conducted to confirm this negative finding. There is no designated critical habitat for marbled murrelet or northern spotted owl, though there may be suitable habitat or individuals of species in the project area. Designated bull trout critical habitat is located downstream in the Hoh River. Because the culvert has a remaining service life of at least 20 years, the primary purpose of this project is to reestablish fish passage

Continue Maintenance

Canyon Creek is a water of the US and State. Monitoring and debris removal activities are typically exempt from permitting and environmental clearance activities. Should the culvert fail, a pulse of sediment will be sent into the Hoh River. If this occurs during the storm event, the increase in turbidity will likely be negligible when compared to the background levels.

Rock Weirs at Existing Culvert Outlet

The proposed work would likely require a Nationwide Permit (#18) provided that the discharged material does not exceed 25 cubic yards below the ordinary high water mark and it does not fill more than 1/10th of an acre of waters of the US. A biological assessment may be needed to evaluate effects construction activities would have on bull trout and its designated critical habitat.

New Open-bottom Arch Culvert

This work would involve work below the ordinary high water mark and would trigger a 404 permit and 401 Certification. Because the primary intent of the work is to reestablish fish passage, the project may qualify for Nationwide Permit 27 – Aquatic Habitat Restoration, Establishment, and Enhancement Activities.

A stream analysis should be done to determine the extent to which the streambed would incise upstream of the new culvert given that incision typically adversely affects fish habitat. This analysis should be coordinated with the WDFW, the Hoh Tribe, and the U.S. Fish and Wildlife Service (Service). It is likely the incision would need to be reduced by installing bed-stabilizing features.

A biological assessment evaluating impacts to bull trout and critical habitat would need to be prepared. Effects to marbled murrelet and northern spotted owl individuals and suitable habitat may also need to be evaluated.

New 180 Feet Bridge

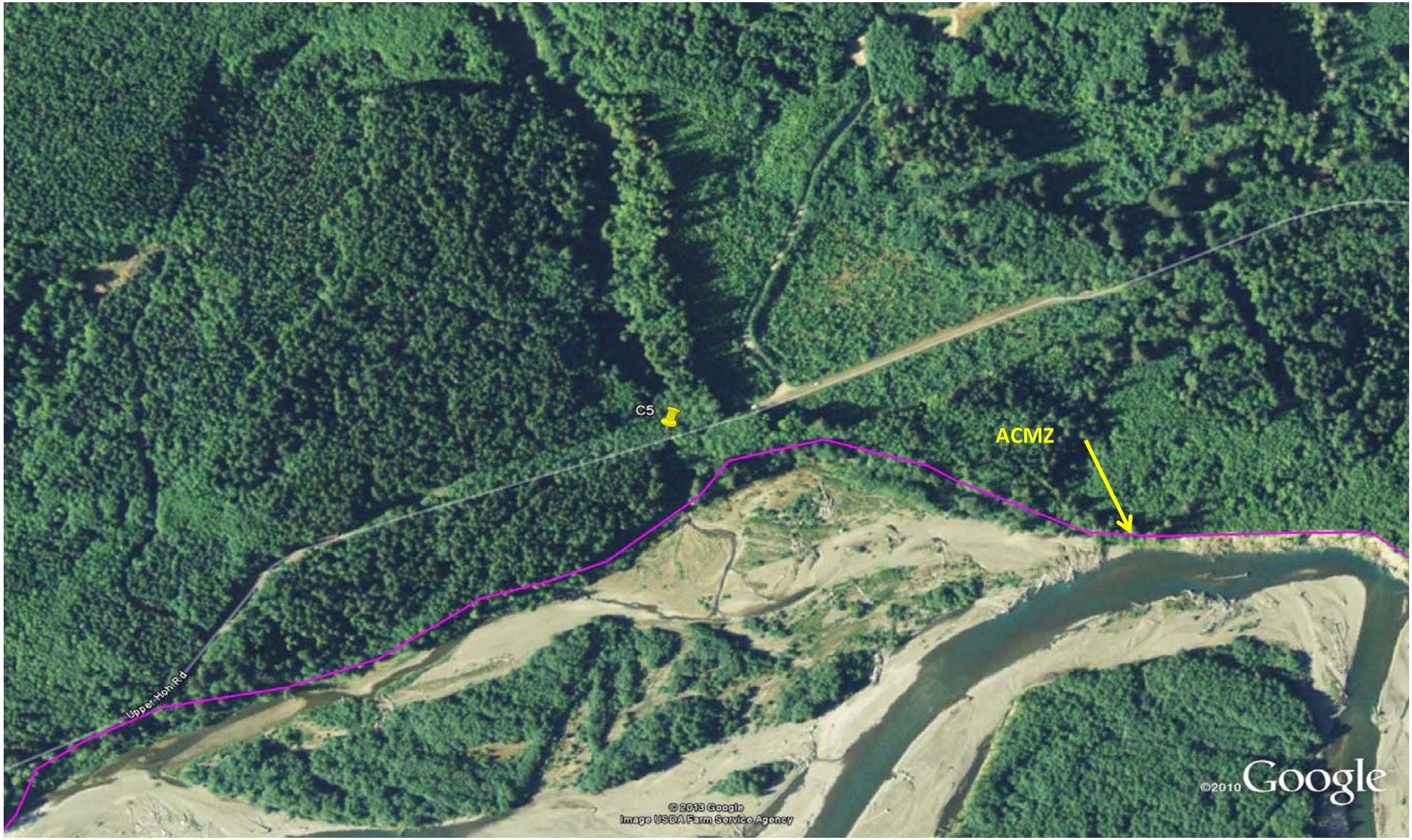
For all bridge proposals removal of the culvert and fill may require a section 404 permit and 401 Certification. For the single-span bridge, the placement of riprap may occur below the ordinary high water mark, thereby triggering the need for a 404 permit/401 Certification.

For multi-span bridges piers should be placed outside of the ordinary high water mark. If this is not feasible, then a 404 permit and 401 Certification would be required.

Regardless of bridge type, a stream analysis should be done to determine the extent to which the streambed would incise upstream of the new culvert given that incision typically adversely affects fish habitat. The analysis should be coordinated with the WDFW, the Hoh Tribe, and the Service.

A biological assessment evaluating short-term impacts culvert removal would have on bull trout and designated critical habitat would need to be prepared. Also, because the bridge alignment would need to be shifted in order to permit one way traffic during construction, clearing and vegetation removal would likely occur. As a result, a biological assessment addressing effects to marbled murrelet and northern spotted owl individuals and suitable habitat would need to be prepared.

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ACMZ - Active Channel Migration Zone, Geomorphic Assessment of Hoh River in Washington State, USBR, July 2004.

Imagery date 9/25/2011.

Figure C5-1. Site Location

Photos

C5 - Canyon Creek Culvert



PHOTO C5-1

Looking upstream from road embankment.

Bankfull width approx. 16 feet, road embankment height 25 feet, stream channel gradient approx. 10 percent.



PHOTO C5-2

Looking downstream from road embankment.

Large (30 feet x30 feet x 4 feet) scour hole at outlet. Stream channel gradient 5 percent.



PHOTO C5-3

8.5 feet dia. culvert inlet.

25 feet high road embankment. Riprap headwall appears stable. Gravel, cobbles and boulders inside culvert. Pipe slope approx. 5 percent. Three joints inside culvert offset 6 to 10 inches at crown.

12/12/2012

Photos

C5 - Canyon Creek Culvert



PHOTO C5-4

Culvert outlet.

3 feet water drop. Culvert undercut approx. 5 feet. Seepage observed under pipe. Large (30 feet x30 feet x 4 feet) scour hole at outlet. Stream channel gradient 5 percent.



PHOTO C5-5

Scour hole downstream of culvert outlet.

Existing riffle at downstream edge of scour hole. Valley bottom width 40 to 50 feet.



PHOTO C5-6

8.5 feet dia. culvert inlet.

Gravel, cobbles, and boulders inside culvert. Pipe slope approx. 5 percent. Three joints inside culvert offset 6 to 10 inches at crown.

12/12/2012

Table C5-1. Alternative Summary and Ranking.

OPTIONS	Rank	Continued Maintenance	Rank	Rock Weirs	Rank	New Open-bottom Culvert	Rank	New Bridge
		Remove debris from culvert inside and inlet.		**Install two rock weirs for backwatering existing culvert and providing fish passage - does nothing for reducing debris jam risk.**		**Install new 22-feet wide open-bottom culvert.**		**Install new 180 feet long bridge - requires new road alignment immediately upstream of existing bridge.**
Ability to preserve and operate the roadway in a specific location (Most able 5, least able 1)	**1**	Large flood event could wash out road embankment.	**1**	Large flood event could wash out road embankment.	**3**	Reduces debris jam risk and opens channel.	**5**	Mitigates debris jam risk and opens channel.
Roadway sustainability (life of solution) (Longest 5, shortest 1)	**1**	Large flood event could wash out road embankment.	**1**	Large flood event could wash out road embankment.	**3**	Reduces debris jam risk and opens channel.	**5**	Mitigates debris jam risk and opens channel.
Impact to hillside stability adjacent to site (Most likely 1; least likely 5)	**1**	No impact to geological stability.	**1**	No impact to geological stability.	**1**	No impact to geological stability.	**3**	Shift in road alignment to construct new bridge may induce hillside instability.
Potential to reduce erosion of banks adjacent to site (Most 5; Least 1)	**1**	Undersized culvert causes bank erosion at outlet.	**3**	Bank erosion at outlet mitigated.	**5**	Channel less constrained.	**5**	Channel not constrained.
Impacts to listed Threatened and Endangered (T&E) terrestrial species and habitat (Least 5; most 1)	**5**	None expected.	**5**	None expected.	**5**	None expected, assuming no temporary traffic bypass.	**1**	Alignment shift results in permanent impact to suitable habitat.
Impacts to listed T&E fish and habitat (Least 5; most 1)	**1**	Fish access not provided.	**3**	Fish access restored, but requires maintenance for ensuring long-term effectiveness.	**5**	Fish access restored.	**5**	Fish access restored.
Impact to upland habitat (Least 5; most 1)	**5**	None expected.	**5**	None expected.	**5**	None expected.	**5**	None expected.
Impacts to Wetlands and Waters of the U.S. (Least 5; most 1)	**3**	Large washout could increase turbidity and sedimentation.	**3**	Large washout could increase turbidity and sedimentation.	**3**	Requires fill below OHW.	**5**	None expected.
Impact to Designated Wilderness area (Least 5; most 1)	**0**	None expected.	**0**	None expected.	**0**	None expected.	**0**	None expected.
Potential for Hoh River Enhancement (Greatest 5; Least 1)	**1**	Fish access not provided.	**3**	Fish access restored, but requires maintenance for ensuring long-term effectiveness.	**5**	Fish access restored.	**5**	Fish access restored.
Potential to maintain or improve river process and function (Most 5; Least 1)	**1**	Constrained channel reduces debris passage.	**3**	Constrained channel reduces debris passage.	**5**	Channel less constrained.	**5**	Channel not constrained.
Potential for other habitat enhancements (Most 5; Least 1)	**1**	Fish access not provided.	**3**	Fish access restored, but requires maintenance.	**5**	Fish access restored.	**5**	Fish access restored.
Potential private property impacts (Least 5; Most 1)	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**3**	Shift in road alignment to construct new culvert may require temporary ROW.	**1**	Shift in road alignment to construct new bridge may require ROW.
Safety risk of design to public (Least 5; Most 1)	**3**	Large flood event could wash out road.	**3**	Large flood event could wash out road.	**5**	Mitigates wash out risk.	**5**	Mitigates wash out risk.
Total Construction cost		**NA**		**$392,571**		**$1,031,751**		**$3,651,839**
Total Capital Cost (50 years)	**5**	**NA**	**5**	**$539,971**	**3**	**$1,392,864**	**1**	**$4,949,982**
Annualized Total Capital Cost (Least 5; Most 1)		**$18,880**		**$39,746**		**$102,525**		**$364,354**
SCORE	**34**		**45**		**61**		**56**	

Table C5-2. Total Expected Cost

Project: Hoh River Road Bank Erosion Risk Study **Date: 3/14/2013**

Site: C5 - Canyon Creek Culvert

Alternative: Continue Maintenance **By: S. Leon**

	Flood Frequency (yr)	Exceedance Probability	Flood Damage	Average Flood Damage	Delta Exceedance Probability	Annual Risk Cost
No debris removal.	2	**0.5**	$0			
				$0	**0.3**	**$0**
No debris removal.	5	**0.2**	$0			
				$0	**0.1**	**$0**
No debris removal.	10	**0.1**	$0			
				$10,000	**0.06**	**$600**
Debris removal.	25	**0.04**	$20,000			
				$20,000	**0.02**	**$400**
Debris removal.	50	**0.02**	$20,000			
				$20,000	**0.01**	**$200**
Debris removal.	100	**0.01**	$20,000			
				$2,210,000	**0.008**	**$17,680**
Replace bridge.	500	**0.002**	$4,400,000			
Total Annual Risk Cost						**$18,880**
Annualized Capital Cost	**Capital Cost**					**$0**
	Disc. rate, i	**0.07125**	**Serv. life, n**	**50**	**CFR**	**0.0736**
	Annualized Capital Cost					**$0**
Total Expected Cost (Annual)						**$18,880**
Summary	Assumes debris removed for flood events larger than 25-year and road embankment is washed out and new bridge installed for 500-year.					

Notes:

1. Method from HEC-17, April 1981.

Table C5-3. Cost Estimates

Site: **C5 - Canyon Creek Culvert**

180 Feet Long Bridge

		Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost	LS	1	$	183,773	$	**183,773**
New Road		LF	1,000	$	500	$	**500,000**
Hillside Stabilization		LS	1	$	50,000	$	**50,000**
Flow Diversion		LS	1	$	20,000	$	**20,000**
Excavation		CY	3,000	$	30	$	**90,000**
180 feet Bridge		LS	1	$	1,840,000	$	**1,840,000**
Riprap	H 10 ft T 5 ft	CY	**696**	$	180	$	**125,333**
	L 160 ft SS 1.75 (h):1(v)						
	TW 6 ft TT 5 ft						
Total Construction Cost without Contingencies						$	**2,809,107**
Contingency	30% of construction cost					$	**842,732**
Total Construction Cost						$	**3,651,839**
Compliance	5% of total construction cost					$	**182,592**
Predesign/design (PE)	15% of total construction cost					$	**547,776**
Construction Engineering (CE)	15% of total construction cost					$	**547,776**
ROW						$	**20,000**
TOTAL Capital Cost		Cost/Foot	**$ 27,500**			$	**4,949,982**
Annualized Capital Cost		Discount rate, i	0.07125			$	**364,354**
		Service life, n	50	years			
		CFR	**0.0736071**				

Rock Weirs at Culvert Outlet

		Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost	LS	1	$	19,756	$	**19,756**
Flow Diversion		LS	1	$	20,000	$	**20,000**
Access pad - place/remove/reclaim		LS	1	$	40,000	$	**40,000**
Weirs	W 8 ft T 6 ft	CY	**444**	$	500	$	**222,222**
	L 250 ft						
Total Construction Cost without Contingencies						$	**301,978**
Contingency	30% of construction cost					$	**90,593**
Total Construction Cost						$	**392,571**
Compliance	5% of total construction cost					$	**19,629**
Predesign/design (PE)	15% of total construction cost					$	**58,886**
Construction Engineering (CE)	15% of total construction cost					$	**58,886**
ROW						$	**10,000**
TOTAL Capital Cost						$	**539,971**
Annualized Capital Cost		Discount rate, i	0.07125			$	**39,746**
		Service life, n	50	years			
		CFR	**0.0736071**				

Table C5-3. Cost Estimates

New Open-bottom Culvert

		Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost	LS	1	$	51,921	$	**51,921**
Flow Diversion		LS	1	$	20,000	$	**20,000**
Excavation/backfill		CY	5,400	$	50	$	**270,000**
Culvert - 22 feet by 11 feet open-bottom arch		LF	160	$	1,800	$	**288,000**
Conc.	H 12 ft T 1 ft	CY	**142**	$	600	$	**85,333**
Foot	L 320 ft						
Concrete headwall/collar		EA	2	$	20,000	$	**40,000**
Riprap	H 6 ft T 6 ft	CY	**213**	$	180	$	**38,400**
	L 160 ft						
Total Construction Cost without Contingencies						$	**793,655**
Contingency	30% of construction cost					$	**238,096**
Total Construction Cost						$	**1,031,751**
Compliance	5% of total construction cost					$	**51,588**
Predesign/design (PE)	15% of total construction cost					$	**154,763**
Construction Engineering (CE)	15% of total construction cost					$	**154,763**
ROW						$	**-**
TOTAL Capital Cost		Cost/Foot	$ **8,705**			$	**1,392,864**
Annualized Capital Cost		Discount rate, i	0.07125			$	**102,525**
		Service life, n	50	years			
		CFR	**0.0736071**				

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P1 - PARK MILEPOST 0.2 to 0.4

BANK STABILIZATION



SITE P1 – PARK MILEPOST 0.2 - 0.4 BANK STABILIZATION

Site Conditions

Approximately 1,300 lineal feet of vegetated riprap revetment has been placed by the Park for controlling bank erosion along a road embankment constructed across the tip of an old river meander bend (Fig. P1-1). Construction created a large (2.5 acre) pond on the north side of the road (Photo P1-8). The road embankment height is approximately 8 feet above the river channel bed and 4 feet above the pond water surface. The lower 4 feet is riprap that appears to be adequately sized and graded for expected flood flow conditions. The upper 4 feet is finer-grained embankment fill soil. Both the soil and the riprap are densely vegetated with 15 to 20 year old willows. Generally, the revetment appears stable (Photo P1-7).

Damage to the revetment was observed at three locations. All locations are on the south side of the road and near the east end of the revetment. The first (going east) damaged area is approximately 180 feet from the east end of the revetment. Riprap has been dislodged from the toe and a minor amount of mid-slope soil slumping was observed (Photos P1-1 and 2). Four to five year old willows growing in the scarp suggest the age of the damage. The damaged area is approximately 20 feet long. The erosion scarp is approximately 10 feet from the road pavement edge. Based on observed conditions and expected flood flow impingement angles, the risk of a catastrophic road failure caused by a single extreme flood is low.

The second (going east) damaged area is approximately 100 feet from the east end of the revetment. Riprap has been dislodged from the toe and a moderate amount of mid-slope soil slumping was observed (Photo P1-3). Four to five year old willows growing in the scarp suggest the age of the damage. The damaged area is approximately 15 feet long. The erosion scarp is approximately 8 feet from the road pavement edge. Based on observed conditions and expected flood flow impingement angles, the risk of a catastrophic road failure caused by a single extreme flood is moderate.

The third (going east) damaged area is approximately 70 feet from the east end of the revetment. Riprap has been dislodged from the toe and a moderate amount of mid-slope soil slumping was observed (Photos P1-4 to 6). Four to five year old willows growing in the scarp suggest the age of the damage. The damaged area is approximately 25 feet long. The erosion scarp is approximately 5 feet from the road pavement edge. Water was observed flowing away from the road embankment in a small pool at the embankment toe, possibly indicating seeping through the embankment from the pond on the north side of the road. Based on observed conditions and expected flood flow impingement angles, the risk of a catastrophic road failure caused by a single extreme flood is high.

The site is at the apex of a river meander bend immediately adjacent to the road, approximately 1,200 feet downstream of the South Fork Hoh River confluence. South Fork Hoh River is believed to contribute more than half the discharge to the main stem Hoh River. Historical channel migration zone (HCMZ) width is approximately 500 feet upstream of the confluence and 1,400 feet at the site. Active channel width at the site is approximately 1,100 feet. Abundant large woody debris jams and mid-channel sediment deposits deflect river flow, causing primary and secondary flow channels to shift dramatically over the entire active channel width. Based on Goggle Earth imagery, the active channel has remained confined against the road embankment since at least 1994 (Fig. P1-2). Currently, the primary active flow channel is along the left (looking downstream) river bank. A secondary back-bar flood channel flows along the right river bank and the project site. Ordinary high water flow depth is approximately 4 feet.

Persistent mid-channel sediment deposits, suggests the eroding bank areas will continue to experience damage-inducing, bank-eroding flood flows.

Erosion resistant, poorly consolidated alluvium terrace deposits limit river bend migration to the south and north. HCMZ boundaries coincide with the terrace deposits. The road is inside the right (looking downstream) boundary.

Considered Options

Continuing maintenance, relocating the road, installing additional bank stabilization, minor active river channel shift, and major active river channel shift were considered. Table P1-1 presents an evaluation and ranking of the options against design selection criteria.

Riprap is expected to be lost during extreme flooding, requiring replenishment for maintaining the riprap installation's effectiveness. Total Capital and Annualized Total Capital Costs provided in Table P1-1 assume 20 percent of the riprap in an installation is replaced every 50 years.

Douglas fir and hemlock are the most commonly available logs in the area. Douglas-fir logs can remain durable in wetting-drying conditions for 25 to 60 years (Tech. Supp. 14J, Use of Large Woody Material for Habitat and Bank Protection, Part 654, National Engineering Handbook, USDA, Natural Resources Conservation Service). Hemlock is the least durable of the conifers. Because the tree quality and species to be used in the structures is not known, Total Capital and Annualized Total Capital Costs provided in Table P1-1 assume wood used in the alternatives is replaced every 30 years.

Continue Maintenance

Continued maintenance involves monitoring the sites for excessive bank erosion. Erosion could progress to the point that undermining of the road is imminent. Placing riprap as an emergency action may be hazardous, difficult, or impossible. The emergency-placed riprap may not be effective in controlling the erosion.

A Total Expected Cost analysis (HEC-17, FHWA, April 1981) was used for estimating total expected cost repairing flood-induced road damage over a 50-year service-life. Based on observed proximity of channel to roadway and amount of natural bank armoring, the analysis assumes damage requiring repair of the existing revetments occurs for flood events equal to and larger than the 10-year flood event. Based on observed vegetated riprap revetment damage, the expected length of future damage is 20 feet. Assuming 20 feet total for each flood damage event and a cost of $1,000 per foot, the total expected annual cost is $3,000 (Table P1-2, Total Expected Cost).

Relocate Road

The road would need to be shifted at least 300 feet away from the active river channel edge to eliminate the need for continuous revetment bank stabilization and to relocate the road around the north side of the pond. A steep terrace slope is immediately adjacent to the pond. A shift would mean an alignment that crosses the terrace slope. Slumping observed on the terrace slope suggests the terrace slope is not geotechnically stable. A new road alignment located across the terrace slope would experience landslides and debris flows that could potentially bury the road with debris. The road alignment may require significant foundation stabilization for mitigating landslides. Length of reroute is estimated to be 1,500 to 2,000 feet.

Existing riprap revetment and road embankment is removed and approximately 60 to 80 feet wide by 700 feet long area of the stream channel is reconstructed. A new stream bank would

be erodible, allowing lateral bank erosion and migration to the north. Streambarbs constructed from the existing revetment riprap, engineered-log-jams (ELJ's), and planted vegetation control the bank erosion and lateral migration and preserve a riparian buffer between the active river channel and road embankment. The alternative requires monitoring and repair of the streambarbs and ELJ's to remain effective in controlling the bank erosion and lateral migration.

Estimated construction cost for the new road, existing road removal, five streambarbs, two ELJ's, and stream bank reconstruction is summarized in Table P1-3. Stabilizing landslides may require significantly more money. Construction is expected to occur outside the active flow channel. Turbidity released is expected to be limited in extent and duration. Access for construction is assumed from the existing road. Constructing the new road alignment first and then switching the Upper Hoh Road traffic over before removing the existing road reduces traffic impacts to one-lane closures and short-term delays.

Stabilize Existing Road Embankment

Approximately 60 feet of stream bank is proposed for stabilization.

Alternatives evaluated;

- Complex roughened large rock toe.
- Complex log crib wall.
- Riprap with roughened rock toe, LWD, and riparian plantings.
- Riprap with streambarbs.

Based on field evidence, the sites are expected to experience high shear stress, 8 to 10 feet deep flood flows, and abundant floating debris. It is critical that the stabilization methods be properly designed and anchored for maintaining effectiveness and surviving the expected flood conditions.

Construction for all the alternatives is expected to occur entirely within the active channel and requires excavating into the streambed and stream bank. Stream work would be accomplished in flowing water. Assuming the work is completed during low flow periods, turbidity released is expected to be limited in extent and duration. Access for construction is assumed down a temporary access route built of riprap and logs. The access route would be removed after construction is completed. Upper Hoh Road traffic impacts are expected to be limited to one-lane closures and short-term delays.

-Complex roughened large rock toe (Appendix A, Sheet 4).

The approach involves placing a rock toe between the expected scour depth and ordinary high water level, approximately 6 to 8 feet high and 5 feet thick. Log bundles spaced 6 to 10 feet apart are placed at the bottom of the rock toe. Soil placed above the rock toe in overlapping layers of erosion control blanket, approximately 1 to 2 feet thick. The rock toe and soil ballast the logs and reduce the risk of the logs floating away. Estimated construction cost for the complex roughened large rock toe is summarized in Table P1-3.

-Complex log crib wall (Appendix A, Sheet 5).

The approach involves placing a log crib wall made of rough logs between the expected scour depth and ordinary high water level, approximately 6 to 8 feet high. Stone is placed within the log crib wall for ballast. Logs with attached root wads extending into the stream bank provide roughness and additional wall stability. All logs are cabled together for enhancing stability. Designs typically include piles driven to refusal or minimum depth of 10 feet. The cobble and

boulder stream bed material will likely prevent the piles from being cost-effectively driven or excavated. They are assumed eliminated in the proposed design. Approximately 1 to 2 feet of soil is placed above the crib wall and planted. Estimated construction cost for the complex log crib wall is summarized in Table P1-3.

-Riprap with Roughened Rock Toe, LWD, and Riparian Plantings (Appendix A, Sheet 9).

The approach involves placing a riprap revetment between the expected scour depth and 50-year flood event water level, approximately 8 to 10 feet high, 5 feet thick, and 2(h):1(v) slope. A launchable riprap toe 8 feet wide and 5 feet thick reduces the risk of scour and channel incision undermining the revetment and provides additional stability. Logs or log bundles spaced 6 to 10 feet apart are placed along the revetment toe for providing roughness and channel complexity. The logs are buried in the road embankment for reducing the risk of them floating away. Willow and alder are planted throughout the revetment and bank area above the revetment. Estimated construction cost is summarized in Table P1-3.

-Riprap with Streambarbs (Appendix A, Sheet 11).

The approach involves placing a riprap revetment between the expected scour depth and 50-year flood event water level, approximately 8 to 10 feet high, 5 feet thick, and 2(h):1(v) slope. Instead of a launchable riprap toe, three (one for each site) - 20 to 30 feet long streambarbs are proposed for reducing shear stress and deflecting the river flow away from the revetment. The streambarbs reduce the risk of scour and channel incision undermining the revetment, promote sediment deposition and retention along the bank toe, and creates channel complexity. The bank, riprap, streambarbs, and channel area between the streambarbs would be augmented with streambed material, large woody debris, and planted with riparian vegetation for establishing a riparian buffer. Estimated construction cost is summarized in Table P1-3.

Minor Active River Channel Shift

An environmentally desirable approach would be to nudge the active river channel over enough from the road to reestablish a riparian buffer. Ideally, the buffer would have the same erosion resistance of a natural, wooded and vegetated river bank. The buffer would need to be wide enough to allow some bank erosion without threatening the roadway. It would be made by placing alluvial material over existing riprap revetment and unstable bank areas. To promote vegetation establishment and soil mass stability, the finished surface of the buffer area should not be steeper than 5(h):1(v). Assuming an 8 feet high bank, the width of the new buffer area would be at least 40 feet. Existing relative stable riparian buffers observed along the river are at least 40 to 50 feet wide and densely vegetated with alder and fir. The new buffer area would be prone to erosion from active channel migration. The erosive forces are expected to be too large for passive and bio-engineering methods to be effective by themselves. Hardened, more erosion resistant components in the buffer system are needed for mitigating the erosive forces.

-Engineered-log-jam Groins.

ELJ's groins constructed perpendicular to the stream bank and extending through the new buffer area would control channel location and deflect river flow away from new buffer area (Appendix A, Sheet 10). An ELJ's buoyancy and sliding analysis (Design Guidelines for Reintroducing Wood in Australian Streams, Abbe/Brooks, 2006) was completed assuming 6 feet design flow depth, 5 feet design scour depth, 8 feet per second average flow velocity, 1.5 velocity correction factor, and 18-inch average trunk diameter. The river bed contains cobbles and small boulders. Piles would need to penetrate the river bottom at least 20 to 30 feet for providing adequate resistance to buoyancy and sliding. Tree trunk piles would likely splinter before reaching the desired design depth. As wood decays, it losses strength and cannot resist

the shear stresses created by a sliding ELJ mass. Driving steel piles for pinning the ELJ structure to the river bottom would be expensive and leave a tangle of steel piles protruding from the river bottom. Based on the analysis, an ELJ structure 15 feet wide and ballasted with stone is needed for achieving a minimum sliding factor-of-safety of 2.0, the minimum needed for unknown flow conditions and resisting expected additional woody debris accumulation.

Each ELJ groin would be 40 feet long and constructed of two 15 feet wide by 20 feet long modules. Assuming 2 to 3 feet gaps between logs and 8 layers, approximately 50 logs are needed for each module and 100 for each groin. Based on the stability analysis, 100 cubic yards of ballast stone is needed for each ELJ groin for achieving minimum sliding and buoyancy factor-of-safeties of 2.0, the minimum needed for unknown flow conditions and resisting expected additional woody debris accumulation. The logs are cabled together for keeping them in place against expected flow depth and velocity and additional woody debris accumulation.

-Riprap Streambarbs.

Streambarbs are an alternative to using ELJ groins for controlling channel location and reducing erosive forces (Appendix A, Sheet 10). Each stream barb would be angled upstream 30 degree relative the bank line and approximately 90 feet long for fitting within the new riparian buffer. Assuming Class 8 riprap, crest width is 8 feet. Barb thickness is 6 feet at base and 6 feet at tip. Barb bottom width is 23 feet at base and 23 feet at tip. Approximately 310 cubic yards of riprap is needed for each stream barb.

Based on review of historical satellite imagery, length of bank typically exposed to impinging flood flow is estimated to be approximately 150 feet. The radius of curvature for active channel is 200 to 500 feet. To effectively deflect the impinging river flow away from the new bank area, the ELJ groins or stream barbs would need to be spaced every 100 to 150 feet. Assuming 200 feet of existing riprap revetment east end is covered with new stream bank; three ELJ groins or stream barbs are needed.

The existing revetment is assumed left in place. Stream bank area is constructed between the ELJ groins or stream barbs by placing conserved and imported stream bed and bank material. Willow and cottonwood trees are planted throughout the area. Willow fascines are placed along the lower 3 to 6 feet of the bank toe for controlling erosion. Large wood is incorporated randomly throughout the bank area.

Estimated construction cost is summarized in Table P1-3. Work will be within the active river channel and requires temporarily diverting the river flow. Flow defection is assumed accomplished with large sandbags or water-inflated bladders. Dewatering the work area would be extremely difficult and expensive. Excavation and placing logs, stone, and new stream bank fill material is assumed to take place in the water ponded behind the flow diversion structure. Turbidity released is expected to be limited in extent and duration. Access for construction is assumed down a ramp constructed over the existing riprap revetment. The ramp could provide permanent access for maintenance. Upper Hoh Road traffic impacts are expected to be limited to one-lane closures and short-term delays.

The site is 1,000 feet upstream of the Park boundary. Private property is found immediately downstream of the Park boundary. Moving the active river channel away from road embankment with ELJ's or groins could induce dramatic bank erosion and stream avulsion, resulting in unnatural changes in the HCMZ boundaries and loss of private property.

Executive Order 11988, Floodplain Management, established federal policies for protecting floodplains and floodways. The intention of the associated regulations is to avoid, to the extent

practical, adverse impacts to floodplains; minimize the impact of floods to human safety, health, and welfare; and avoid supporting land use development that is incompatible with the natural and beneficial floodplain values. When avoidance is not possible, the policies require appropriate consideration of methods to assess and minimize adverse impacts. If the option is considered, additional analysis is needed for identifying extent and location of private property impacts. If found violating Executive Order 11988, relocating the active river channel would not be eligible for Federal funds.

Major Active River Channel Shift

Shifting the primary active flow channel away from the road eliminates the current bank erosion road loss risk. The primary active flow channel can be kept away from the site by placing four to six ELJ's, each at least 20 feet wide and 60 to 100 feet long, in a staggered alignment across the mid-channel sediment deposits, approximately 100 to 200 feet from the road. The ELJ's would be constructed within the active channel. Top of the ELJ's are set equal to 100-year water surface, estimated to be approximately 5 to 6 feet above the mid-channel sediment deposit surface. Bottom of the ELJ's are set below the active channel thalweg elevation and expected scour depth, approximately 6 feet below the mid-channel sediment deposit surface. Each engineered-log-jam is ballasted with stone and logs cabled together for keeping them in place against expected flow depth and velocity and additional woody debris accumulation.

The existing road embankment and revetment are left in place. Off-channel rearing and resting habitat is created along the toe of the existing road embankment. Assuming the primary flow channel remains along the left bank, a temporary channel for diverting stream flow from the construction area is expected not to be needed.

Estimated construction cost is summarized in Table P1-3. Turbidity released is expected to be limited in extent and duration. Ramps constructed over the existing road embankment could provide temporary access for construction and permanent access for maintenance. Upper Hoh Road traffic impacts are expected to be limited to one-lane closures and short-term delays.

The site is immediately adjacent to the Park boundary. Private property is found immediately downstream. Moving the active river channel away from road embankment with ELJ's would likely induce dramatic bank erosion and stream avulsion, resulting in unnatural changes in the HCMZ boundaries and loss of private property.

Executive Order 11988, Floodplain Management, established federal policies for protecting floodplains and floodways. The intention of the associated regulations is to avoid, to the extent practical, adverse impacts to floodplains; minimize the impact of floods to human safety, health, and welfare; and avoid supporting land use development that is incompatible with the natural and beneficial floodplain values. When avoidance is not possible, the policies require appropriate consideration of methods to assess and minimize adverse impacts. If the option is considered, additional analysis is needed for identifying extent and location of private property impacts. If found violating Executive Order 11988, relocating the active river channel would not be eligible for Federal funds.

Environmental Clearance Considerations

This section of the Upper Hoh Road extends through OLYM-managed lands. The roadway is flanked on both sides by water and vegetation species that appear to be primarily alder and willow and, therefore, unsuitable habitat for either the marbled murrelet or the northern spotted owl. The National Wetland Inventory maps identify a wetland on the north side of the road

adjacent to the pond. A wetland delineation would need to be conducted to demarcate the boundaries of this wetland.

Continue Maintenance

Continued maintenance would require periodic replacement of material below the ordinary high water mark where there is currently riprap revetment. The Seattle District of the Corps has indicated that such work is exempt from Section 404 of the Clean Water Act provided that all work occurs within the existing road prism. Consequently no state water quality permitting would be required.

In the event that the embankment should fail during a storm event, the roadway failure would release a large amount of sediment into the river. Assuming the sediment release occurs concurrently with the storm event it is unlikely that this will result in a considerable increase over the background condition.

Repairing the road would likely cause considerable environmental impacts. The need to quickly reestablish access would permit no design time typically needed for more habitat-friendly solutions, thus relying on the use of riprap. Also, work would likely need to occur outside of the in-water work window. The need for rapid response to an emergency situation will result in environmental impacts to sensitive habitats that would likely warrant expensive mitigation. If this option is pursued, OLYM may want to consider developing, in advance, an emergency plan in coordination with the Service, the Hoh Tribe, and the WDFW for developing more habitat friendly designs that can be quickly implemented in the event of a storm. Such a plan may reduce impacts and mitigation costs.

Relocate Road

The proposed 300 shift to the north would likely place the realigned road within a designated wilderness area. This shift into the wilderness area would require Congressional approval.

The relocation of the road would permit the removal of the existing rip-rap revetment and the reconstruction of the riverbank which would likely result in improved habitat for the bull trout and other fish. However, the relocated road would require between 3.5 and 4.5 acres of new physical impact some of which would require the placement of fill into a forested wetland, which likely provides suitable off-channel rearing and resting habitat for bull trout and other resident fish.

This road relocation would likely impact suitable marbled murrelet and northern spotted owl habitat. A biological assessment would need to be prepared evaluating the effects this action would have on these listed species as well as the bull trout.

The in-water work associated with the barbs and the engineered log jams and placing fill in a forested wetland, the relocation of the road will require an individual 404 permit including a full 404(b) (1) analysis to demonstrate to the Corps that the relocation of the road is the least environmentally damaging practicable alternative. Practicable is defined in terms of cost, existing technology, and logistics. This project will also likely require off-site wetland mitigation, using a wetland mitigation bank. Wetland mitigation banks in this area are extremely expensive, costing up to $200K per credit.

Stabilize Existing Road Embankment

Due to lack of design detail, no distinction is made in terms of environmental impacts for each of the four stabilization methods discussed in this report. However, based on conversations with

the Corps, the more natural and softened the stabilization method, the easier it will be to permit the activity. Riprap alone is the most difficult bank stabilization methods to be permitted.

Bank stabilization would likely have no permanent impacts on suitable marbled murrelet or northern spotted owl habitat. Temporary impacts may occur for all three listed species (including bull trout) thereby requiring the preparation of a biological assessment. In addition to complying with the in-water work window, certain construction activities may be limited to certain times of the day or season to minimize disturbing the marbled murrelet and/or the northern spotted owl. Placement of fill will trigger the need for a permit under Section 404 of the Clean Water Act and 401 certification. Whether an individual permit or the simpler nationwide permit is sufficient depends on the design and extent of impacts.

Due to scope of work and the limited in-water work window, the WDFW will likely need to be petitioned for a waiver and extension.

Minor and Major Active River Channel Shift

This could have a dramatic effect on the existing river system. The extent to which the option helps or harms the aquatic habitat would need determined through modeling and formal consultation with the Service, the Hoh Tribe, and the WDFW. This work would require an individual permit from the Corps and 401 Certification from the DOE.

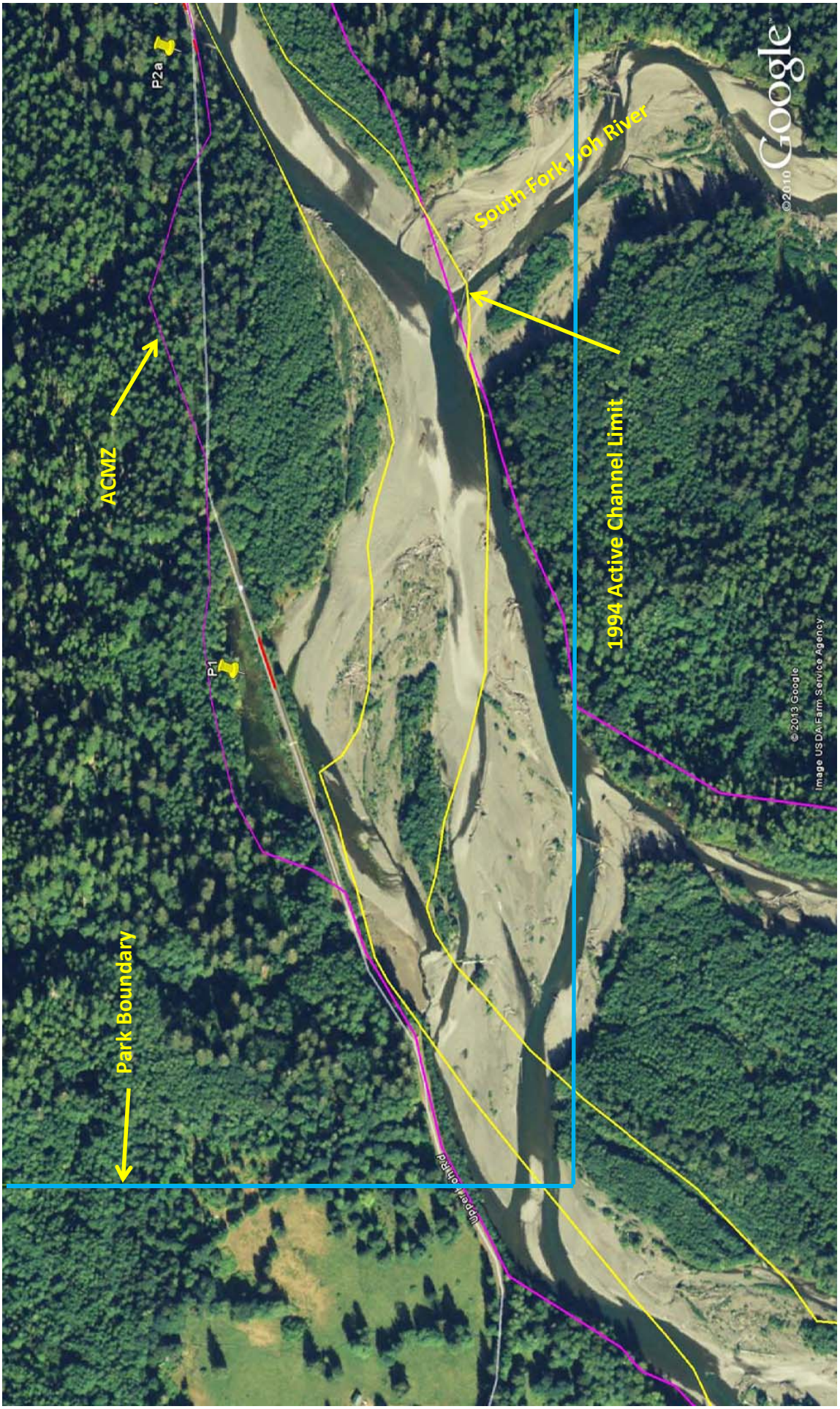
A biological assessment would need to be prepared evaluating short and long term impacts to bull trout and short term construction impacts to the marbled murrelet and the northern spotted owl.

In addition, geomorphic assessments would need to be conducted for assessing effect this option may have on downstream properties.

Due to the scope of work and the limited in-water work window, the WDFW would likely need to be petitioned for an extension.

Each ELJ requires a number of trees to be cut down. Approximately 300 logs and 900 logs are needed for the minor and major active river channel shift options, respectively. Cutting these trees would have a direct impact on some forest’s ecosystem and watershed’s health.

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ACMZ - Active Channel Migration Zone, Geomorphic Assessment of Hoh River in Washington State, USBR, July 2004.

Imagery date 9/25/2011

Figure P1-1. Site Location

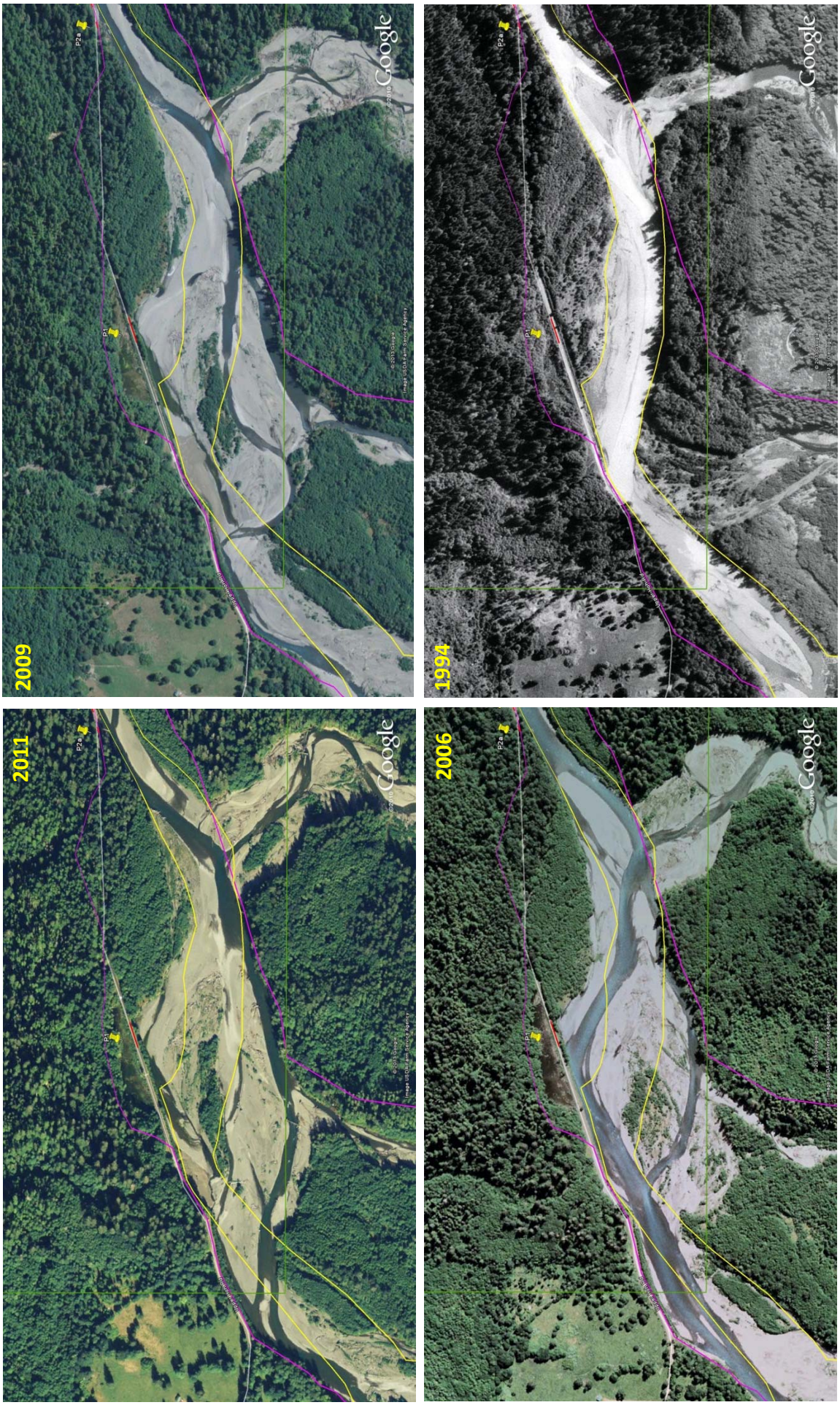


Figure P1-2. Historical Satellite Imagery

Photos

P1 - PMP 0.4 Bank Stabilization



PHOTO P1-1

1st damaged revetment area - looking upstream.

Riprap dislodged from toe. Minor amount of mid-slope slumping. 4 to 5 year old willows growing in scarp indicates age of damage. Scarp 10 feet from road pavement edge.



PHOTO P1-2

1st damaged revetment area - looking downstream.

Riprap dislodged from toe. Minor amount of mid-slope slumping. 4 to 5 year old willows growing in scarp indicates age of damage. Scarp 10 feet from road pavement edge.



PHOTO P1-3

2nd damaged revetment area - looking downstream.

Riprap dislodged from toe. Moderate amount of mid-slope slumping. 4 to 5 year old willows growing in scarp indicates age of damage. Scarp 8 feet from road pavement edge.

12/12/2012

Photos

P1 - PMP 0.4 Bank Stabilization



PHOTO P1-4

3rd damaged revetment area - looking upstream.

Riprap dislodged from toe. Severe amount of mid-slope slumping. 4 to 5 year old willows growing in scarp indicates age of damage. Scarp 5 feet from road pavement edge.



PHOTO P1-5

3rd damaged revetment area - looking downstream.

Riprap dislodged from toe. Severe amount of mid-slope slumping. 4 to 5 year old willows growing in scarp indicates age of damage. Scarp 5 feet from road pavement edge.



PHOTO P1-6

3rd damaged revetment area - looking downstream.

Riprap dislodged from toe. Severe amount of mid-slope slumping. 4 to 5 year old willows growing in scarp indicates age of damage. Scarp 5 feet from road pavement edge. Water flowing away from road embankment in small pool at toe suggests water may be seeping through embankment from pond side.

12/12/2012

Photos

P1 - PMP 0.4 Bank Stabilization



PHOTO P1-7

Typical moderately stable vegetated revetment - looking upstream.

Vegetation relatively dense and riprap toe in place.



PHOTO P1-8

Pond on north side of road embankment - looking west/downstream.

Embankment height approximately 4 feet above water surface. Hoh River side, water surface 8 feet below embankment crest.

Table P1-1. Alternative Summary and Ranking.

Upper Hoh River Road Site - P1 - PMP 0.2 - 0.4 Bank Stabilization

					Bank Stabilization									Minor Active River Channel Shift				Major Active River Channel Shift	
OPTIONS	**Rank**	**Continued Maintenance**	**Rank**	**Relocate Road**	**Rank**	**Complex Roughened Large Rock Toe**	**Rank**	**Complex Log Crib Wall**	**Rank**	**Riprap with LWD and Plantings**	**Rank**	**Riprap with Streambarbs**	**Rank**	**ELJ Groins**	**Rank**	**Large Stream barbs**	**Rank**	
Road on the edge of the channel migration zone has less of an impact to the total channel zone.		**Place or replace riprap as needed for preventing road closure.**		**Offset Road around pond, remove existing roadway - install streambarbs and ELJ's for preserving riparian zone.**		**Rock toe with LWD.**		**Log crib wall with roughness elements.**		**Riprap similar to what is commonly used along Upper Hoh River Road embankment.**		**Bank area planted with willow and alder.**		**Construct new stream bank area over unstable and revetment areas.**		**Construct new stream bank area over unstable and revetment areas.**		**Shift active flow channel to flow across point bar away from revetment area.**
Ability to preserve and operate the roadway in a specific location (Most able 5, least able 1)	**3**	Reduces risk of a catastrophic road failure during extreme flood event.	**3**	Better than where it is, but the river may eventually migrate north and impact road again.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.
Roadway sustainability (life of solution) (Longest 5, shortest 1)	**1**	Increased maintenance in the future mitigating climate change or after large flood events.	**3**	Increase road life reduces future risk from river. Road near hillside may experience landslides and debris flows.	**3**	Requires moderate amount of wood replacement and maintenance.	**1**	Requires substantial amount of wood replacement and maintenance.	**3**	Requires moderate amount of wood replacement and maintenance.	**5**	Requires moderate level of maintenance.	**1**	Requires substantial amount of wood replacement and maintenance.	**5**	Requires moderate level of maintenance.	**1**	Requires substantial amount of wood replacement and maintenance.
Impact to hillside stability adjacent to site (Most likely 1; least likely 5)	**5**	No expected additional impacts.	**1**	Road near hillside may experience landslides and debris flows.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.
Potential to reduce erosion of banks adjacent to site (Most 5; Least 1)	**1**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**1**	Likely increase down stream right bank erosion.
Impacts to listed Threatened and Endangered (T&E) terrestrial species and habitat (Least 5; most 1)	**5**	No expected additional impacts.	**1**	Impacts upland areas and potentially T&E.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.
Impacts to listed T&E fish and habitat (Least 5; most 1)	**3**	Riprap placed along bank reduces habitat complexity.	**1**	Likely impacts to suitable habitat.	**3**	Material placed in channel.	**3**	Material placed in channel.	**3**	Material placed in channel.	**1**	Riprap along bank reduces habitat complexity. Barbs require significant excavation into channel bed.	**3**	Considerable temporary impacts from in-stream channel work.	**3**	Considerable temporary impacts from in-stream channel work.	**3**	Considerable temporary impacts from in-stream channel work.
Impact to upland habitat (Least 5; most 1)	**5**	No expected additional impacts.	**1**	Impacts upland areas.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.
Impacts to Wetlands and Waters of the U.S. (Least 5; most 1)	**3**	No expected additional impacts to wetlands; riprap placement in river.	**1**	Impacts forested wetland area; riprap placement in river.	**3**	No expected additional impacts to wetlands; riprap placement in river.	**3**	No expected additional impacts to wetlands.	**3**	No expected additional impacts to wetlands; riprap placement in river.	**1**	Riprap along bank reduces habitat complexity. Barbs require significant excavation into channel bed.	**1**	Requires major in stream construction.	**1**	Requires major in stream construction.	**1**	Requires major in stream construction.
Impact to Designated Wilderness area (Least 5; most 1)	**5**	No expected impacts.	**1**	Expected impacts.	**5**	No expected impacts.	**5**	No expected impacts.	**5**	No expected impacts.	**5**	No expected impacts.	**5**	No expected impacts.	**5**	No expected impacts.	**5**	No expected impacts.
Potential for Hoh River Enhancement (Greatest 5; Least 1)	**1**	Does not provide river enhancements.	**5**	Provides off-channel/side-channel habitat, allows river to fully access HCMZ.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Moves thalweg away from road, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.
Potential to maintain or improve river process and function (Most 5; Least 1)	**1**	Does not improve river process and function.	**5**	Provides off-channel/side-channel habitat, allows river to fully access HCMZ	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Moves thalweg away from road, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.
Potential for other habitat enhancements (Most 5; Least 1)	**1**	Does not provide other habitat enhancements.	**5**	Opportunity for improving fish access to off-channel habitat	**3**	Provides some woody debris for habitat complexity and biological processes.	**3**	Provides some woody debris for habitat complexity and biological processes.	**3**	Provides some woody debris for habitat complexity and biological processes.	**1**	Does not provide other habitat enhancements.	**5**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides some woody debris for habitat complexity and biological processes.	**5**	Provides woody debris for habitat complexity and biological processes.
Potential private property impacts (Least 5; Most 1)	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**3**	Some impacts expected from bank erosion downstream of site.	**3**	Some impacts expected from bank erosion downstream of site.	**1**	Impacts likely from bank erosion downstream of site.
Safety risk of design to public (Least 5; Most 1)	**5**	No expected increase in safety risk.	**3**	Boaters could become trapped in root wads.	**3**	Boaters could become trapped in root wads.	**1**	Public could fall down wall. Boaters could become trapped in root wads.	**3**	Boaters could become trapped in root wads.	**5**	No expected increase in safety risk.	**1**	Boaters could become trapped in ELJ's.	**3**	Boaters could become trapped in root wads.	**1**	Boaters could become trapped in ELJ's.
Total Construction cost	**5**	**NA**	**1**	**$3,741,790**	**3**	**$45,594**	**3**	**$123,026**	**3**	**$160,351**	**3**	**$195,126**	**1**	**$999,851**	**1**	**$608,423**	**1**	**$2,538,575**
Riprap and Wood Replacement (50 years)		**NA**		**$640,000**		**$18,200**		**$38,133**		**$26,200**		**$32,000**		**$448,800**		**$63,480**		**$1,800,000**
Total Capital Cost (50 years)		**NA**		**$5,691,417**		**$79,752**		**$204,219**		**$242,674**		**$295,421**		**$1,798,599**		**$884,852**		**$5,227,076**
Annualized Total Capital Cost (Least 5; Most 1)		**$3,000**		**$418,929**		**$5,870**		**$15,032**		**$17,863**		**$21,745**		**$132,390**		**$65,131**		**$384,750**
SCORE	**49**		**40**		**57**		**53**		**57**		**55**		**53**		**57**		**49**	

Table P1-2. Total Expected Cost

Project: Hoh River Road Bank Erosion Risk Study **Date: 3/14/2013**

Site: P1 - PMP 0.2 - 0.4 Bank Stabilization

Alternative: Continue Maintenance **By: S. Leon**

	Flood Frequency (yr)	Exceedance Probability	Flood Damage	Average Flood Damage	Delta Exceedance Probability	Annual Risk Cost
No damage.	2	**0.5**	$0			
				$0	**0.3**	**$0**
No damage.	5	**0.2**	$0			
				$10,000	**0.1**	**$1,000**
Place riprap.	10	**0.1**	$20,000			
				$20,000	**0.06**	**$1,200**
Place riprap.	25	**0.04**	$20,000			
				$20,000	**0.02**	**$400**
Place riprap.	50	**0.02**	$20,000			
				$20,000	**0.01**	**$200**
Place riprap.	100	**0.01**	$20,000			
				$20,000	**0.01**	**$200**
		0	$20,000			
Total Annual Risk Cost						**$3,000**
Annualized Capital Cost	**Capital Cost**					**$0**
	Disc. rate, i	**0.07125**	**Serv. life, n**	**50**	**CFR**	**0.0736**
	Annualized Capital Cost					**$0**
Total Expected Cost (Annual)						**$3,000**
Summary	Assume 20 feet ($1k/ft) of revetment repair and bank armoring for each flood damage event.					

Notes:

1. Method from HEC-17, April 1981.

Table P1-3. Cost Estimates

Site: **P1 - PMP 0.2 - 0.4 Bank Stabilization**

Relocate Road

		Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost	LS	1	$	188,300	$	**188,300**
New Road		LF	2,000	$	500	$	**1,000,000**
Hillside Stabilization		LS	1	$	50,000	$	**50,000**
Remove Existing Revetment		LF	700	$	200	$	**140,000**
Streambank Reconstruction		LF	700	$	1,000	$	**700,000**
Streambarbs		EA	5	$	40,000	$	**200,000**
ELJ's		EA	2	$	300,000	$	**600,000**
Total Construction Cost without Contingencies						$	**2,878,300**
Contingency	30% of construction cost					$	**863,490**
Total Construction Cost						$	**3,741,790**
Compliance	5% of total construction cost					$	**187,090**
Predesign/design (PE)	15% of total construction cost					$	**561,269**
Construction Engineering (CE)	15% of total construction cost					$	**561,269**
ROW						$	**-**
Riprap replacement -	20% replacement every		50	years		$	**40,000**
Wood replacement -	full log replacement every		30	years		$	**600,000**
TOTAL Capital Cost		Cost/Foot	**$ 2,846**			$	**5,691,417**
Annualized Capital Cost		Discount rate, i	0.07125			$	**418,929**
		Service life, n	50	years			
		CFR	**0.0736071**				

Complex Roughened Large Rock Toe

			Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost		LS	1	$	2,294	$	**2,294**
Remove Existing Revetment			LF	-	$	200	$	**-**
Rock	H 8 ft	T 5 ft	CY	**89**	$	180	$	**16,000**
	L 60 ft							
Logs	L 60 ft	XS 8 ft	EA	**8**	$	2,000	$	**15,000**
Soil	H 2 ft	T 10 ft	CY	**44**	$	40	$	**1,778**
	L 60 ft							
Total Construction Cost without Contingencies							$	**35,072**
Contingency	30% of construction cost						$	**10,522**
Total Construction Cost							$	**45,594**
Compliance	5% of total construction cost						$	**2,280**
Predesign/design (PE)	15% of total construction cost						$	**6,839**
Construction Engineering (CE)	15% of total construction cost						$	**6,839**
ROW							$	**-**
Riprap replacement -	20% replacement every			50	years		$	**3,200**
Wood replacement -	full log replacement every			30	years		$	**15,000**
TOTAL Capital Cost			Cost/Foot	**$ 1,329**			$	**79,752**
Annualized Capital Cost			Discount rate, i	0.07125			$	**5,870**
			Service life, n	50	years			
			CFR	**0.0736071**				

Table P1-3. Cost Estimates

Complex Log Crib Wall

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost		LS	1	$	6,191	$	6,191
Remove Existing Revetment				LF	200	$	200	$	40,000
Rock	H 8 ft	T 5 ft		CY	89	$	120	$	10,667
	L 60 ft								
Logs	L 60 ft	H 12 ft		EA	18	$	2,000	$	36,000
	Dia 2 ft	Row 6							
	log l 20 ft	No. 18							
Piles				EA	0	$	-	$	-
Soil	H 2 ft	T 10 ft		CY	44	$	40	$	1,778
	L 60 ft								
Total Construction Cost without Contingencies								$	94,636
Contingency	30%	of construction cost						$	28,391
Total Construction Cost								$	123,026
Compliance		5%	of total construction cost					$	6,151
Predesign/design (PE)		15%	of total construction cost					$	18,454
Construction Engineering (CE)		15%	of total construction cost					$	18,454
ROW								$	-
Riprap replacement -	20%	replacement every			50	years		$	2,133
Wood replacement -	full log	replacement every			30	years		$	36,000
TOTAL Capital Cost			Cost/Foot		$ 3,404			$	204,219
Annualized Capital Cost			Discount rate, i		0.07125			$	15,032
			Service life, n		50	years			
			CFR		0.0736071				

Riprap with Roughened Rock Toe, LWD, and Riparian Plantings

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost		LS	1	$	8,069	$	8,069
Remove Existing Revetment				LF	200	$	200	$	40,000
Riprap	H 10 ft	T 5 ft		CY	311	$	180	$	56,000
	L 60 ft	SS 2 (h):1(v)							
	TW 8 ft	TT 5 ft							
Logs	L 60 ft	XS 8 ft		EA	8	$	2,000	$	15,000
Willow	100 sy	XS 2		EA	50	$	10	$	500
Alder	100 sy	XS 1		EA	100	$	20	$	2,000
Soil	H 2 ft	T 10 ft		CY	44	$	40	$	1,778
	L 60 ft								
Total Construction Cost without Contingencies								$	123,347
Contingency	30%	of construction cost						$	37,004
Total Construction Cost								$	160,351
Compliance		5%	of total construction cost					$	8,018
Predesign/design (PE)		15%	of total construction cost					$	24,053
Construction Engineering (CE)		15%	of total construction cost					$	24,053
ROW								$	-
Riprap replacement -	20%	replacement every			50	years		$	11,200
Wood replacement -	full log	replacement every			30	years		$	15,000
TOTAL Capital Cost			Cost/Foot		$ 4,045			$	242,674
Annualized Capital Cost			Discount rate, i		0.07125			$	17,863
			Service life, n		50	years			
			CFR		0.0736071				

Table P1-3. Cost Estimates

Riprap with Streambarbs

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost		LS	1	$	9,819	$	**9,819**
Remove Existing Revetment				LF	-	$	200	$	**-**
Riprap	H 10 ft	T 5 ft		CY	**222**	$	180	$	**40,000**
	L 60 ft	SS 2 (h):1(v)							
	TW 0 ft	TT 0 ft							
Streambarbs				EA	3	$	30,000	$	**90,000**
Logs	L 60 ft	XS 20 ft		EA	**3**	$	2,000	$	**6,000**
Willow	100 sy	XS 2		EA	**50**	$	10	$	**500**
Alder	100 sy	XS 1		EA	**100**	$	20	$	**2,000**
Soil	H 2 ft	T 10 ft		CY	**44**	$	40	$	**1,778**
	L 60 ft								
Total Construction Cost without Contingencies								$	**150,097**
Contingency	30%	of construction cost						$	**45,029**
Total Construction Cost								$	**195,126**
Compliance		5%	of total construction cost					$	**9,756**
Predesign/design (PE)		15%	of total construction cost					$	**29,269**
Construction Engineering (CE)		15%	of total construction cost					$	**29,269**
ROW								$	**-**
Riprap replacement -	20%	replacement every			50	years		$	**26,000**
Wood replacement -	full log	replacement every			30	years		$	**6,000**
TOTAL Capital Cost				Cost/Foot	**$ 4,924**			$	**295,421**
Annualized Capital Cost			Discount rate, i		0.07125			$	**21,745**
			Service life, n		50	years			
			CFR		**0.0736071**				

Major Active River Channel Shift

			Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost	LS	1	$	127,750	$	**127,750**
Channel Excavation - 100 feet by 5 feet			LF	-	$	300	$	**-**
Rearing and Resting Habitat Construction			AC	0.5	$	50,000	$	**25,000**
Remove Existing Revetment			LF	-	$	200	$	**-**
Streambank Reconstruction			LF	-	$	1,000	$	**-**
Streambarbs			EA	-	$	40,000	$	**-**
ELJ's - 20 ft by 60 ft			EA	6	$	300,000	$	**1,800,000**
Total Construction Cost without Contingencies							$	**1,952,750**
Contingency	30%	of construction cost					$	**585,825**
Total Construction Cost							$	**2,538,575**
Compliance		5%	of total construction cost				$	**126,929**
Predesign/design (PE)		15%	of total construction cost				$	**380,786**
Construction Engineering (CE)		15%	of total construction cost				$	**380,786**
ROW							$	**-**
Riprap replacement -	20%	replacement every		50	years		$	**-**
Wood replacement -	full log	replacement every		30	years		$	**1,800,000**
TOTAL Capital Cost							$	**5,227,076**
Annualized Capital Cost			Discount rate, i	0.07125			$	**384,750**
			Service life, n	50	years			
			CFR	**0.0736071**				

Table P1-3. Cost Estimates

Minor River Channel Shift - ELJ Groins

			Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost	LS	1	$	50,316	$	**50,316**
Rearing and Resting Habitat Construction			AC	-	$	50,000	$	**-**
Remove Existing Revetment			LF	-	$	200	$	**-**
Streambank Reconstruction - fill/plants/fascines			LF	200	$	1,200	$	**240,000**
Large Wood			EA	20	$	1,500	$	**30,000**
ELJ groin - 15 ft by 40 ft (2 x 15 ft by 20 ft mod.)			EA	3	$	149,600	$	**448,800**
Primary logs	50	$ 1,200 $ 60,000						
Pin logs	4	$ 1,200 $ 4,800						
Ballast stone	50	$ 180 $ 9,000						
Cabling	1	$ 1,000 $ 1,000						
		$ 74,800						
No. modules/ ELJ groin		2 $ 149,600						
Total Construction Cost without Contingencies							$	**769,116**
Contingency	30%	of construction cost					$	**230,735**
Total Construction Cost							$	**999,851**
Compliance	5%	of total construction cost					$	**49,993**
Predesign/design (PE)	15%	of total construction cost					$	**149,978**
Construction Engineering (CE)	15%	of total construction cost					$	**149,978**
ROW							$	**-**
Riprap replacement -	20%	replacement every	50	years			$	**-**
Wood replacement -		full log replacement every	30	years			$	**448,800**
TOTAL Capital Cost		Cost/Foot	**$ 4,999**				$	**1,798,599**
Annualized Capital Cost		Discount rate, i	0.07125				$	**132,390**
		Service life, n	50	years				
		CFR	**0.0736071**					

Minor River Channel Shift - Stream Barbs

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost		LS	1	$	30,618	$	**30,618**
Rearing and Resting Habitat Construction				AC	-	$	50,000	$	**-**
Remove Existing Revetment				LF	-	$	200	$	**-**
Streambank Reconstruction - fill/plants/fascines				LF	200	$	1,200	$	**240,000**
Large Wood				EA	20	$	1,500	$	**30,000**
Streambarbs	Length	90	ft	EA	3	$	55,800	$	**167,400**
	Crest width	8	ft						
	Average bot. width	23	ft						
	Average thickness	6	ft						
	Volume	310	cy						
	Cost/cy	180	$/cy	Cost/barb	$ 55,800				
Total Construction Cost without Contingencies								$	**468,018**
Contingency	30%	of construction cost						$	**140,405**
Total Construction Cost								$	**608,423**
Compliance	5%	of total construction cost						$	**30,421**
Predesign/design (PE)	15%	of total construction cost						$	**91,264**
Construction Engineering (CE)	15%	of total construction cost						$	**91,264**
ROW								$	**-**
Riprap replacement -	20%	replacement every		50	years			$	**33,480**
Wood replacement -		full log replacement every		30	years			$	**30,000**
TOTAL Capital Cost			Cost/Foot	**$ 3,042**				$	**884,852**
Annualized Capital Cost			Discount rate, i	0.07125				$	**65,131**
			Service life, n	50	years				
			CFR	**0.0736071**					

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P2 - PARK MILEPOST 0.8

BANK STABILIZATION



SITE P2 – PARK MILEPOST 0.8 BANK STABILIZATION

Site Conditions

Approximately 100 lineal feet of complex roughened large rock toe was placed by the Park for controlling bank erosion (Fig. P2-1 and Photo P2-1). Logs in the toe are 18 to 24 inches diameter and extend 10 to 15 feet into the embankment under the road surface and adjacent shoulder. Approximately 4 feet of stone fill ballasts the logs. Bank height is approximately 6 feet. Assuming no additional large woody debris entangles on the toe logs, the ballast is sufficient for keeping the toe logs in place. A large accumulation of woody debris may pull out the toe logs during an extreme flood event.

-P2a

Immediately downstream of the complex roughened large rock toe, 30 lineal feet of a sparsely vegetated, steeply-sloping road embankment is experiencing erosion and soil slumping (Fig. P2-1, P2a and Photo P2-2). Bank height is approximately 8 feet. The bank toe is approximately 10 to 15 feet from the road edge. A large root wad and tree trunk deflects river flow towards the bank. Continued erosion could eventually undermine the road.

-P2b

Immediately upstream between a riprap revetment (Site P3) and the complex roughened large rock toe, 150 lineal feet of a sparsely vegetated, steeply-sloping road embankment is experiencing erosion and soil slumping (Fig. P2-1, P2b and Photos P2-3 and 4). Bank height is approximately 8 feet. The bank toe is approximately 15 to 20 feet from the road edge. Boulder-cobble toe armoring, root mass of a large tree, and smaller vegetation reduce the bank erosion rate. Continued erosion and undermining of the bank could result in loss of the large tree and eventual undermining of the road.

The site is at the apex of a river meander bend immediately adjacent to the road. Mid-channel sediment deposits deflect ordinary and extreme flood flow towards the stream bank, inducing bank erosion and lateral migration. Erosion resistant, poorly consolidated alluvium terrace deposits limit river bend migration to the south and north. Historical channel migration zone (HCMZ) boundaries coincide with the terrace deposits. The road is immediately outside the right (looking downstream) boundary. The river bend apex is at the right HCMZ boundary. Width of the HCMZ is approximately 400 feet upstream and downstream of the site. Active channel width is 200 feet at the site and 400 feet upstream and downstream of the site. Ordinary high water flow depth is approximately 4 feet.

Based on Goggle Earth imagery (1994, 2009, and 2011), the active flow channel has remained confined against the road embankment (Fig. P2-2). Further migration is prevented by the riprap bank stabilization and terrace deposits. Down valley translation of the meander bend is limited by the terrace deposits, large trees lining the bank, and a low ridge behind the point bar on the opposite river bank.

The relatively limited down-valley river bend migration, narrowness of the HCMZ, and persistent mid-channel sediment deposits, suggests the eroding bank areas will continue to experience damage-inducing, bank-eroding flood flows. The risk of a catastrophic road failure caused by a single extreme flood is moderately-high.

Considered Options

Continuing maintenance, relocating the road, installing additional bank stabilization, minor active river channel shift, and major active river channel shift were considered. Table P2-1 presents an evaluation and ranking of the options against design selection criteria.

Riprap is expected to be lost during extreme flooding, requiring replenishment for maintaining the riprap installation's effectiveness. Total Capital and Annualized Total Capital Costs provided in Table P2-1 assume 20 percent of the riprap in an installation is replaced every 50 years.

Douglas fir and hemlock are the most commonly available logs in the area. Douglas-fir logs can remain durable in wetting-drying conditions for 25 to 60 years (Tech. Supp. 14J, Use of Large Woody Material for Habitat and Bank Protection, Part 654, National Engineering Handbook, USDA, Natural Resources Conservation Service). Hemlock is the least durable of the conifers. Because the tree quality and species to be used in the structures is not known, Total Capital and Annualized Total Capital Costs provided in Table P2-1 assume wood used in the alternatives is replaced every 30 years.

Continue Maintenance

Continued maintenance involves monitoring the upstream (P2b) and downstream (P2a) stream bank areas and complex roughened large rock toe area for excessive bank erosion. Stream bank toe erosion upstream and downstream of the complex roughened large rock toe could progress to the point that undermining of the road is imminent. Continued maintenance is placing riprap in an emergency action as needed for preventing a road closure. Placing riprap as an emergency action may be hazardous, difficult, or impossible. The emergency-placed riprap may not be effective in controlling the erosion.

A Total Expected Cost analysis (HEC-17, FHWA, April 1981) was used for estimating total expected cost repairing flood-induced road damage over a 50-year service-life. Based on observed proximity of channel to roadway, and amount of natural bank armoring, the analysis assumes damage requiring new riprap revetment placed as an emergency action for stabilizing an eroding river bank occurs for flood events equal to and larger than the 25-year flood event. Based on review of historical satellite imagery, length of bank typically exposed to impinging flood flow is estimated to be approximately 100 feet. Based on vegetation distribution and age and estimated riprap placement sequencing, the length of past revetment installations ranged from 100 to 200 feet. Assuming 100 feet total for each flood damage event and a cost of $1,000 per foot, the total expected annual cost is $7,000 (Table P2-2, Total Expected Cost).

Relocate Road (Common to P2 and P3)

The road would need to be shifted at least 100 to 200 feet away from the active river channel edge to eliminate the need for continuous revetment bank stabilization. The steep terrace slope is immediately adjacent to the roadway. A shift would mean an alignment that crosses the terrace slope. Slumping observed on the terrace slope suggests the terrace slope is not geotechnically stable. A new road alignment located across the terrace slope would experience landslides and debris flows that could potentially bury the road with debris. The road alignment may require significant foundation stabilization for mitigating landslides. Length of reroute is estimated to be 1,100 to 1,300 feet.

Existing riprap revetment and complex roughened large rock toe is removed and approximately 80 to 100 feet wide by 400 feet long area of the stream bank is reconstructed. A new stream bank would be erodible, allowing lateral bank erosion and migration to the north. Streambarbs

constructed from the existing revetment riprap, engineered-log-jams (ELJ's), and planted vegetation control the bank erosion and lateral migration and preserve a riparian buffer between the active river channel and road embankment. The alternative requires monitoring and repair of the streambarbs and ELJ's to remain effective in controlling the bank erosion and lateral migration.

Estimated construction cost for the new road, existing road removal, five streambarbs, two ELJ's, and stream bank reconstruction is summarized in Table P2-3. Stabilizing landslides may require significantly more money. Construction is expected to occur outside the active flow channel. Turbidity released is expected to be limited in extent and duration. Access for construction is assumed from the existing road. Constructing the new road alignment first and then switching the Upper Hoh Road traffic over before removing the existing road reduces traffic impacts to one-lane closures and short-term delays.

Stabilize Existing Road Embankment

Approximately 180 feet of stream bank is proposed for stabilization (P2a - 30 feet, P2b - 150 feet).

Alternatives evaluated;

- Complex roughened large rock toe.
- Complex log crib wall.
- Riprap with roughened rock toe, LWD, and riparian plantings.
- Riprap with streambarbs.

Based on field evidence, the sites are expected to experience high shear stress, 8 to 12 feet deep flood flows, and abundant floating debris. It is critical that the stabilization methods be properly designed and anchored for maintaining effectiveness and surviving the expected flood conditions.

Construction for all the alternatives is expected to occur entirely within the active flow channel and requires excavating into the streambed and stream bank. Stream work would be accomplished in flowing water. Assuming the work is completed during low flow periods, turbidity released is expected to be limited in extent and duration. Access for construction is assumed down a temporary access route built of riprap and logs. The access route would be removed after construction is completed. Upper Hoh Road traffic impacts are expected to be limited to one-lane closures and short-term delays.

-Complex roughened large rock toe (Appendix A, Sheet 4).

The approach involves placing a rock toe between the expected scour depth and ordinary high water level, approximately 8 to 10 feet high and 5 feet thick. Log bundles spaced 6 to 10 feet are placed at the bottom of the rock toe. Soil placed above the rock toe in overlapping layers of erosion control blanket, approximately 1 to 2 feet. The rock toe and soil ballast the logs and reduce the risk of the logs floating away. Estimated construction cost for the complex roughened large rock toe is summarized in Table P2-3.

-Complex log crib wall (Appendix A, Sheet 5).

The approach involves placing a log crib wall made of rough logs between the expected scour depth and ordinary high water level, approximately 8 to 10 feet high. Stone is placed within the log crib wall for ballast. Logs with attached root wads extending into the stream bank provide roughness and additional wall stability. All logs are cabled together for enhancing stability.

Designs typically include piles driven to refusal or minimum depth of 10 feet. The cobble and boulder stream bed material will likely prevent the piles from being cost-effectively driven or excavated. They are assumed eliminated in the proposed design. Approximately 1 to 2 feet of soil is placed above the crib wall and planted. Estimated construction cost for the complex log crib wall is summarized in Table P2-3.

-Riprap with Roughened Rock Toe, LWD, and Riparian Plantings (Appendix A, Sheet 9).

The approach involves placing a riprap revetment between the expected scour depth and 50-year flood event water level, approximately 10 to 12 feet high, 5 feet thick, and 2(h):1(v) slope. A launchable riprap toe 8 feet wide and 5 feet thick reduces the risk of scour and channel incision undermining the revetment and provides additional stability. Logs or log bundles spaced 6 to 10 feet are placed along the revetment toe for providing roughness and channel complexity. The logs are buried in the road embankment for reducing the risk of them floating away. Willow and alder are planted throughout the revetment and bank area above the revetment. Estimated construction cost is summarized in Table P2-3.

-Riprap with Streambarbs (Appendix A, Sheet 11).

The approach involves placing a riprap revetment between the expected scour depth and 50-year flood event water level, approximately 10 to 12 feet high, 5 feet thick, and 2(h):1(v) slope. Instead of a launchable riprap toe, three to four - 40 to 50 feet long streambarbs are proposed for reducing shear stress and deflecting the river flow away from the revetment. The streambarbs reduce the risk of scour and channel incision undermining the revetment, promote sediment deposition and retention along the bank toe, and creates channel complexity. The bank, riprap, streambarbs, and channel area between the streambarbs would be augmented with streambed material, large woody debris, and planted with riparian vegetation for establishing a riparian buffer. Estimated construction cost is summarized in Table P2-3.

<u>Minor Active River Channel Shift (Common to P2 and P3)</u>

An environmentally desirable approach would be to nudge the active river channel over enough from the road to reestablish a riparian buffer. Ideally, the buffer would have the same erosion resistance of a natural, wooded and vegetated river bank. The buffer would need to be wide enough to allow some bank erosion without threatening the roadway. It would be made by placing alluvial material over existing riprap revetment and unstable bank areas. To promote vegetation establishment and soil mass stability, the finished surface of the buffer area should not be steeper than 5(h):1(v). Assuming an 8 feet high bank, the width of the new buffer area would be at least 40 feet. Existing relative stable riparian buffers observed along the river are at least 40 to 50 feet wide and densely vegetated with alder and fir. The new buffer area would be prone to erosion from active channel migration. The erosive forces are expected to be too large for passive and bio-engineering methods to be effective by themselves. Hardened, more erosion resistant components in the buffer system are needed for mitigating the erosive forces.

-Engineered-log-jam Groins.

ELJ's groins constructed perpendicular to the stream bank and extending through the new buffer area would control channel location and deflect river flow away from new buffer area (Appendix A, Sheet 10). An ELJ's buoyancy and sliding analysis (Design Guidelines for Reintroducing Wood in Australian Streams, Abbe/Brooks, 2006) was completed assuming 6 feet design flow depth, 5 feet design scour depth, 8 feet per second average flow velocity, 1.5 velocity correction factor, and 18-inch average trunk diameter. The river bed contains cobbles and small boulders. Piles would need to penetrate the river bottom at least 20 to 30 feet for providing adequate resistance to buoyancy and sliding. Tree trunk piles would likely splinter

before reaching the desired design depth. As wood decays, it losses strength and cannot resist the shear stresses created by a sliding ELJ mass. Driving steel piles for pinning the ELJ structure to the river bottom would be expensive and leave a tangle of steel piles protruding from the river bottom. Based on the analysis, an ELJ structure 15 feet wide and ballasted with stone is needed for achieving a minimum sliding factor-of-safety of 2.0, the minimum needed for unknown flow conditions and resisting expected additional woody debris accumulation.

Each ELJ groin would be 40 feet long and constructed of two 15 feet wide by 20 feet long modules. Assuming 2 to 3 feet gaps between logs and 8 layers, approximately 50 logs are needed for each module and 100 for each groin. Based on the stability analysis, 100 cubic yards of ballast stone is needed for each ELJ groin for achieving minimum sliding and buoyancy factor-of-safeties of 2.0, the minimum needed for unknown flow conditions and resisting expected additional woody debris accumulation. The logs are cabled together for keeping them in place against expected flow depth and velocity and additional woody debris accumulation.

-Riprap Streambarbs.

Streambarbs are an alternative to using ELJ groins for controlling channel location and reducing erosive forces (Appendix A, Sheet 10). Each stream barb would be angled upstream 30 degree relative the bank line and approximately 90 feet long for fitting within the new riparian buffer. Assuming Class 8 riprap, crest width is 8 feet. Barb thickness is 6 feet at base and 6 feet at tip. Barb bottom width is 23 feet at base and 23 feet at tip. Approximately 310 cubic yards of riprap is needed for each stream barb.

Based on review of historical satellite imagery, length of bank typically exposed to impinging flood flow is estimated to be approximately 150 to 200 feet. The radius of curvature for active channel is 200 to 500 feet. To effectively deflect the impinging river flow away from the new bank area, the ELJ groins or stream barbs would need to be spaced every 100 to 150 feet. Assuming the new bank area is placed over the site P2a, site P2b, the existing complex roughened large rock toe, and site P3, approximately 400 feet of new bank area is created and four ELJ groins or stream barbs are needed.

The existing revetment is assumed left in place. Stream bank area is constructed between the ELJ groins or stream barbs by placing conserved and imported stream bed and bank material. Willow and cottonwood trees are planted throughout the area. Willow fascines are placed along the lower 3 to 6 feet of the bank toe for controlling erosion. Large wood is incorporated randomly throughout the bank area.

Estimated construction cost is summarized in Table P2-3. Work will be within the active river channel and requires temporarily diverting the river flow. Flow defection is assumed accomplished with large sandbags or water-inflated bladders. Dewatering the work area would be extremely difficult and expensive. Excavation and placing logs, stone, and new stream bank fill material is assumed to take place in the water ponded behind the flow diversion structure. Turbidity released is expected to be limited in extent and duration. Access for construction is assumed down a ramp constructed over the existing riprap revetment. The ramp could provide permanent access for maintenance. Upper Hoh Road traffic impacts are expected to be limited to one-lane closures and short-term delays.

The site is 3,000 feet upstream of the Park boundary. Private property is found immediately downstream of the Park boundary. Moving the active river channel away from road embankment with ELJ’s or groins could induce dramatic bank erosion and stream avulsion, resulting in unnatural changes in the HCMZ boundaries and loss of private property.

Executive Order 11988, Floodplain Management, established federal policies for protecting floodplains and floodways. The intention of the associated regulations is to avoid, to the extent practical, adverse impacts to floodplains; minimize the impact of floods to human safety, health, and welfare; and avoid supporting land use development that is incompatible with the natural and beneficial floodplain values. When avoidance is not possible, the policies require appropriate consideration of methods to assess and minimize adverse impacts. If the option is considered, additional analysis is needed for identifying extent and location of private property impacts. If found violating Executive Order 11988, relocating the active river channel would not be eligible for Federal funds.

Major Active River Channel Shift (Common to P2 and P3)

Shifting the river away 100 to 200 feet from the road eliminates the current riprap revetment failure risk and road loss risk from bank erosion occurring between and downstream of the existing revetments. Shifting the active river channel to flow across the point bar opposite the existing riprap revetment could be accomplished with four to six ELJ's, each at least 20 feet wide and 60 to 100 feet long. All would be constructed within the active river channel. Top of the ELJ's are set equal to 100-year water surface, estimated to be approximately 5 to 6 feet above the point bar surface. Bottom of the ELJ's are set below the active channel thalweg elevation and expected scour depth, approximately 6 feet below the point bar surface. Each engineered-log-jam is ballasted with stone and logs cabled together for keeping them in place against expected flow depth and velocity and additional woody debris accumulation.

The existing complex roughened large rock toe and revetment (P3) are left in place. Off-channel rearing and resting habitat is created along the toe of the existing road embankment. A new 100 feet wide active flow channel would be constructed across the point bar for diverting stream flow away from the construction area. Alluvial and plant materials from the channel excavation are to be used for the habitat reconstruction.

Estimated construction cost is summarized in Table P2-3. Construction requires temporarily diverting the river flow. Turbidity released is expected to be limited in extent and duration. Ramps constructed over the existing road embankment could provide temporary access for construction and permanent access for maintenance. Upper Hoh Road traffic impacts are expected to be limited to one-lane closures and short-term delays.

The HCMZ is relatively narrow at the site. Moving the active river channel 100 to 200 feet south provides opportunity for creating off-channel rearing and resting habitat along the toe of the existing road embankment. It is not expected to have a direct negative impact on private property adjacent to and downstream of the Park. Moving the active river channel more than 200 feet south would likely induce dramatic downstream bank erosion and stream avulsion, resulting in unnatural changes in the HCMZ boundaries and loss of private property and Olympic National Forest land. A channel relocation project would include a detailed geomorphic analysis for verifying the no-direct-impact assumption.

Executive Order 11988, Floodplain Management, established federal policies for protecting floodplains and floodways. The intention of the associated regulations is to avoid, to the extent practical, adverse impacts to floodplains; minimize the impact of floods to human safety, health, and welfare; and avoid supporting land use development that is incompatible with the natural and beneficial floodplain values. When avoidance is not possible, the policies require appropriate consideration of methods to assess and minimize adverse impacts. If the option is considered, additional analysis is needed for identifying extent and location of private property

impacts. If found violating Executive Order 11988, relocating the active river channel would not be eligible for Federal funds.

Environmental Clearance Considerations

This section of the Upper Hoh Road extends through OLYM-managed lands. The road is bordered on the south by the Hoh River and on the north by primarily conifer trees. Based on a review of the National Wetland Inventory maps no wetlands were identified within the project corridor though this negative determination needs to be verified by a field survey. Except for as described below, environmental clearance considerations are the same as described for Site P1.

Continue Maintenance

Environmental considerations are the same as those described in Site P1.

Relocate Road

The proposed 100 to 200 feet shift to the north may place the realigned road within designated wilderness area. This action would require Congressional approval.

The relocation of the road would permit the removal of the existing rip-rap revetment and the reconstruction of the riverbank which would likely result in improved habitat for the bull trout and other fish. However, the relocated road would require between 2.5 and 3 acres of new impact through conifer forest which likely provide suitable habitat for the northern spotted owl and the marbled murrelet. A biological assessment would need to be prepared evaluating the effects this action would have on these listed species.

Installation of the stream barbs and the ELJ's would require a 404 permit and 401 Water Quality Certification.

Stabilize Existing Road Embankment

Environmental considerations are the same as those described in Site P1.

Minor and Major Active River Channel Shift

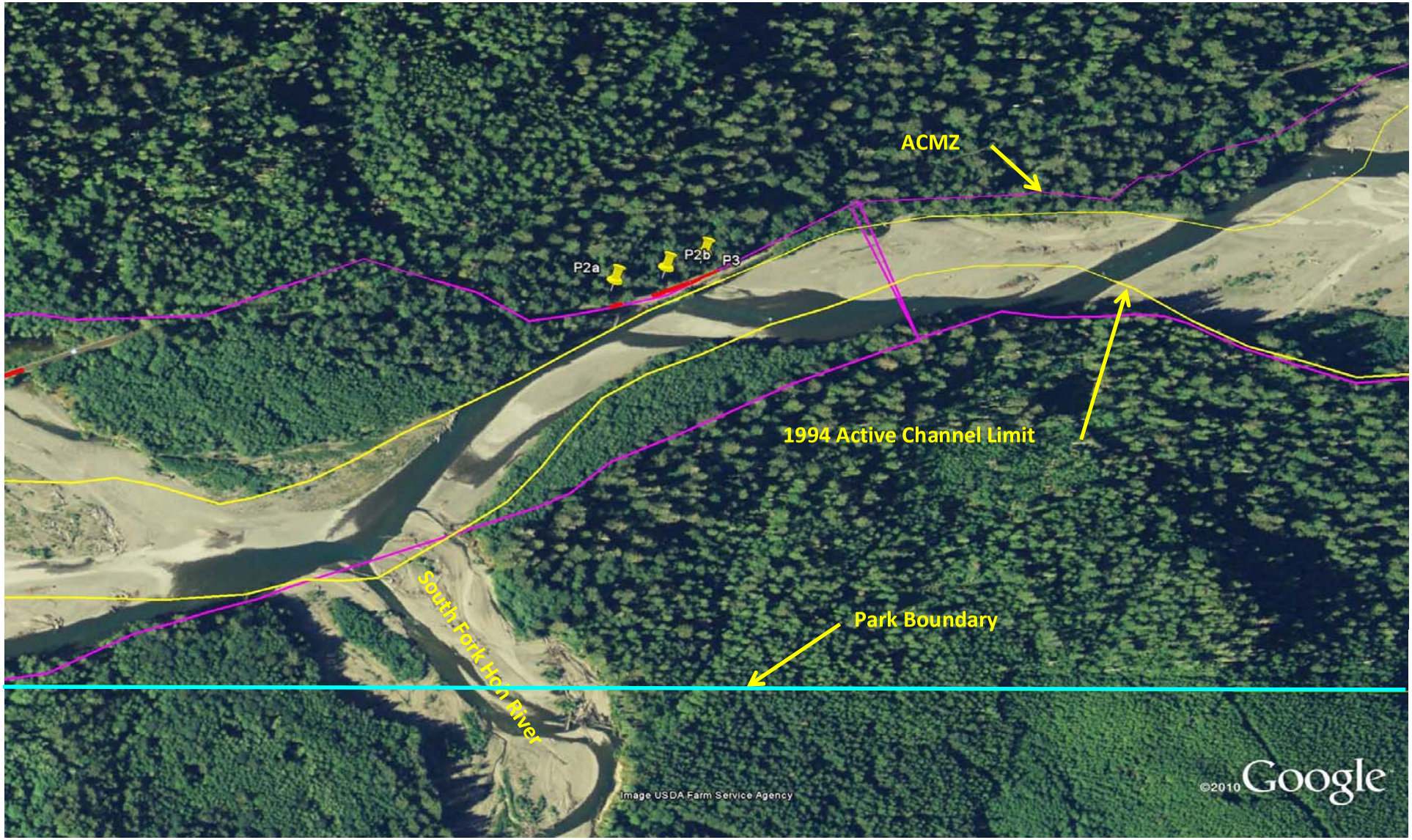
This could have a dramatic effect on the existing river system. The extent to which the option helps or harms the aquatic habitat would need determined through modeling and formal consultation with the Service, the Hoh Tribe, and the WDFW. This work would require an individual permit from the Corps and 401 Certification from the DOE.

A biological assessment would need to be prepared evaluating short and long term impacts to bull trout and short term construction impacts to the marbled murrelet and the northern spotted owl.

In addition, geomorphic assessments would need to be conducted for assessing effect this option may have on downstream properties.

Due to the scope of work and the limited in-water work window, the WDFW would likely need to be petitioned for an extension.

Each ELJ requires a number of trees to be cut down. Approximately 400 logs and 900 logs are needed for the minor and major active river channel shift options, respectively. Cutting these trees would have a direct impact on a forest's ecosystem and watershed's health.



ACMZ - Active Channel Migration Zone, Geomorphic Assessment of Hoh River in Washington State, USBR, July 2004.

Imagery date 9/25/2011

Figure P2-1. Site Location

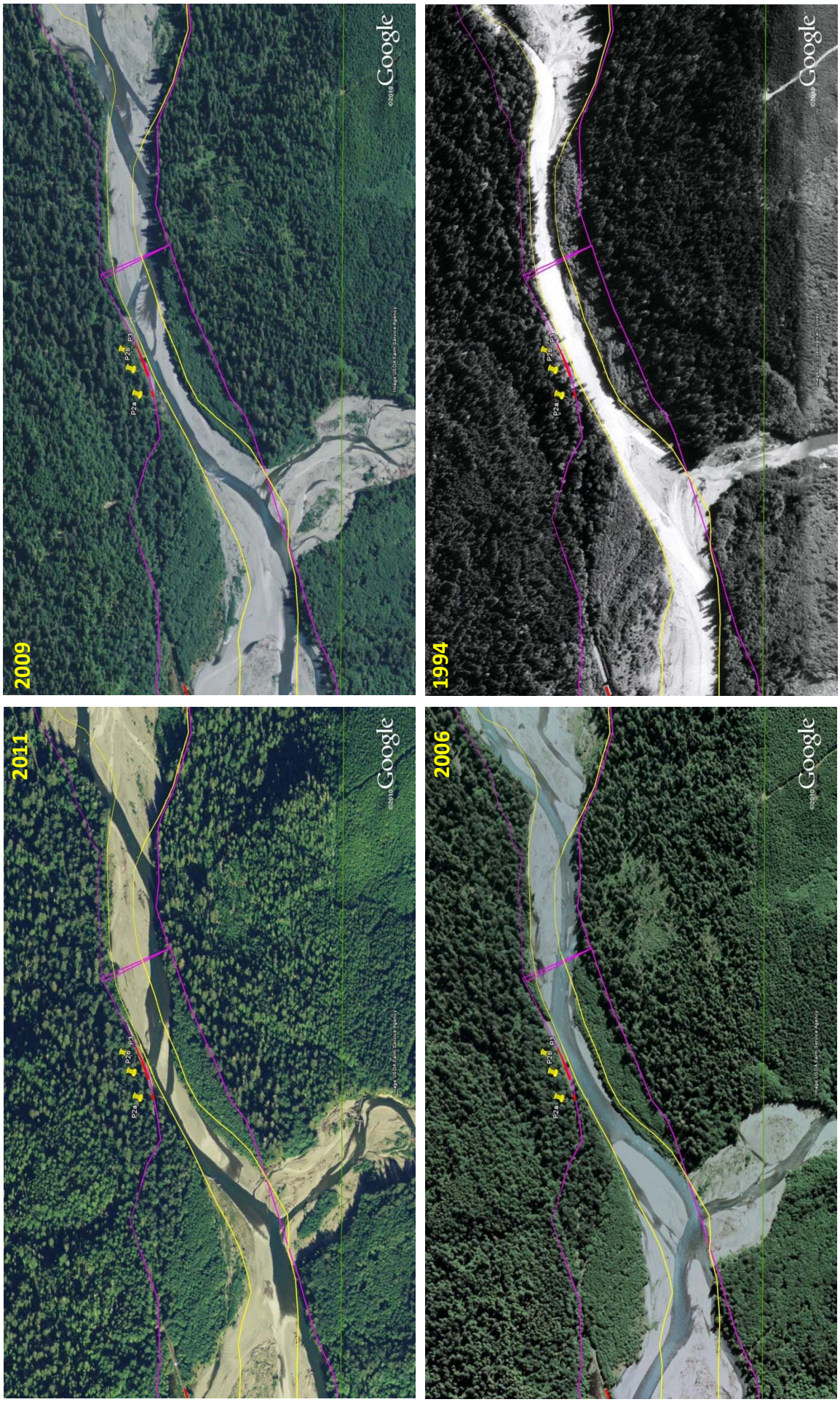


Figure P2-2. Historical Satellite Imagery

Photos

P2 - PMP 0.8 Bank Stabilization



PHOTO P2-1

Looking upstream along complex roughened large rock toe armoring.

Large logs capturing small floating woody debris. Structure appears stable. Bank height provides 4 feet of ballast material over logs.



PHOTO P2-2

P2a - Looking downstream of complex roughened large rock toe armoring.

Large root wad deflect river flow towards bank, inducing erosion. Bank area not well vegetated. Erosion scarp 10 feet from road pavement edge.



PHOTO P2-3

P2b - Looking upstream from upstream end of complex roughened large rock toe armoring.

Bank steep, cobble-boulder toe armoring and vegetation reduce bank erosion rate. Flow depth approximately 3 to 4 feet next to bank. Erosion scarp 15 to 20 feet from road pavement edge.

12/12/2012

Photos



P2 - PMP 0.8 Bank Stabilization

PHOTO P2-4

P2b - Looking downstream from upstream revetment. Revetment part of Site P3.

Bank steep, cobble-boulder toe armoring and vegetation reduce bank erosion rate. Flow depth approximately 3 to 4 feet next to bank. Erosion scarp 15 to 20 feet from road pavement edge.

Table P2-1. Alternative Summary and Ranking.

Upper Hoh River Road Site - P2 - PMP 0.8 Bank Stabilization

					Bank Stabilization									Minor Active River Channel Shift				Major Active River Channel Shift	
OPTIONS	**Rank**	**Continued Maintenance**	**Rank**	**Relocate Road**	**Rank**	**Complex Roughened Large Rock Toe**	**Rank**	**Complex Log Crib Wall**	**Rank**	**Riprap with LWD and Plantings**	**Rank**	**Riprap with Streambarbs**	**Rank**	**ELJ Groins**	**Rank**	**Large Stream barbs**	**Rank**	
Road on the edge of the channel migration zone has less of an impact to the total channel zone.		**Place or replace riprap as needed for preventing road closure.**		**Offset Road 200 Feet with mitigation of existing roadway slope to riparian zone - install streambarbs and ELJ's for preserving riparian zone.**		**Rock toe with LWD.**		**Log crib wall with roughness elements.**		**Riprap similar to what is commonly used along Upper Hoh River Road embankment.**		**Bank area planted with willow and alder.**		**Construct new stream bank area over unstable and revetment areas.**		**Construct new stream bank area over unstable and revetment areas.**		**Shift active flow channel to flow across point bar away from revetment area.**
Ability to preserve and operate the roadway in a specific location (Most able 5, least able 1)	**3**	Reduces risk of a catastrophic road failure during extreme flood event.	**3**	Better than where it is, but the river may eventually migrate north and impact road again.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.
Roadway sustainability (life of solution) (Longest 5, shortest 1)	**1**	Increased maintenance in the future mitigating climate change or after large flood events.	**3**	Increase road life reduces future risk from river. Road near hillside may experience landslides and debris flows.	**3**	Requires moderate amount of wood replacement and maintenance.	**1**	Requires substantial amount of wood replacement and maintenance.	**3**	Requires moderate amount of wood replacement and maintenance.	**5**	Requires moderate level of maintenance.	**1**	Requires substantial amount of wood replacement and maintenance.	**5**	Requires moderate level of maintenance.	**1**	Requires substantial amount of wood replacement and maintenance.
Impact to hillside stability adjacent to site (Most likely 1; least likely 5)	**5**	No expected additional impacts.	**1**	Road near hillside may experience landslides and debris flows.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.
Potential to reduce erosion of banks adjacent to site (Most 5; Least 1)	**1**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**1**	Likely increase down stream right bank erosion.
Impacts to listed Threatened and Endangered (T&E) terrestrial species and habitat (Least 5; most 1)	**5**	No expected additional impacts.	**1**	Impacts upland areas and potentially T&E.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.
Impacts to listed T&E fish and habitat (Least 5; most 1)	**3**	Riprap placed along bank reduces habitat complexity.	**3**	Material placed in channel.	**3**	Material placed in channel.	**3**	Material placed in channel.	**3**	Material placed in channel.	**1**	Riprap along bank reduces habitat complexity. Barbs require significant excavation into channel bed.	**3**	Considerable temporary impacts from in-stream channel work.	**3**	Considerable temporary impacts from in-stream channel work.	**3**	Considerable temporary impacts from in-stream channel work.
Impact to upland habitat (Least 5; most 1)	**5**	No expected additional impacts.	**1**	Impacts upland areas.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.
Impacts to Wetlands and Waters of the U.S. (Least 5; most 1)	**3**	No expected additional impacts to wetlands; riprap placement in river.	**5**	Riprap placement in river.	**3**	No expected additional impacts to wetlands; riprap placement in river.	**3**	No expected additional impacts to wetlands.	**3**	No expected additional impacts to wetlands; riprap placement in river.	**1**	Riprap along bank reduces habitat complexity. Barbs require significant excavation into channel bed.	**1**	Requires major in stream construction.	**1**	Requires major in stream construction.	**1**	Requires major in stream construction.
Impact to Designated Wilderness area (Least 5; most 1)	**5**	No expected impacts.	**1**	Expected impacts.	**5**	No expected impacts.	**5**	No expected impacts.	**5**	No expected impacts.	**5**	No expected impacts.	**5**	No impacts.	**5**	No impacts.	**5**	No expected impacts.
Potential for Hoh River Enhancement (Greatest 5; Least 1)	**1**	Does not provide river enhancements.	**5**	Provides off-channel/side-channel habitat, allows river to fully access HCMZ.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Moves thalweg away from road, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.
Potential to maintain or improve river process and function (Most 5; Least 1)	**1**	Does not improve river process and function.	**5**	Provides off-channel/side-channel habitat, allows river to fully access HCMZ	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Moves thalweg away from road, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.
Potential for other habitat enhancements (Most 5; Least 1)	**1**	Does not provide other habitat enhancements.	**5**	Opportunity for improving fish access to off-channel habitat	**3**	Provides some woody debris for habitat complexity and biological processes.	**3**	Provides some woody debris for habitat complexity and biological processes.	**3**	Provides some woody debris for habitat complexity and biological processes.	**1**	Does not provide other habitat enhancements.	**5**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides some woody debris for habitat complexity and biological processes.	**5**	Provides woody debris for habitat complexity and biological processes.
Potential private property impacts (Least 5; Most 1)	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**3**	Some impacts expected from bank erosion downstream of site.	**3**	Some impacts expected from bank erosion downstream of site.	**1**	Impacts likely from bank erosion downstream of site.
Safety risk of design to public (Least 5; Most 1)	**5**	No expected increase in safety risk.	**3**	Boaters could become trapped in root wads.	**3**	Boaters could become trapped in root wads.	**1**	Public could fall down wall. Boaters could become trapped in root wads.	**3**	Boaters could become trapped in root wads.	**5**	No expected increase in safety risk.	**1**	Boaters could become trapped in ELJ's.	**3**	Boaters could become trapped in root wads.	**1**	Boaters could become trapped in ELJ's.
Total Construction cost		**NA**		**$2,726,360**		**$153,474**		**$268,927**		**$399,681**		**$462,276**		**$1,541,784**		**$1,019,881**		**$3,039,335**
Riprap and Wood Replacement (50 years)	**5**	**NA**	**1**	**$640,000**	**3**	**$57,000**	**3**	**$116,000**	**3**	**$83,400**	**3**	**$78,800**	**1**	**$598,400**	**1**	**$74,640**	**1**	**$1,800,000**
Total Capital Cost (50 years)		**NA**		**$4,320,586**		**$264,189**		**$479,051**		**$622,969**		**$702,872**		**$2,679,809**		**$1,451,480**		**$5,903,102**
Annualized Total Capital Cost (Least 5; Most 1)		**$7,000**		**$318,026**		**$19,446**		**$35,262**		**$45,855**		**$51,736**		**$197,253**		**$106,839**		**$434,510**
SCORE	**49**		**46**		**57**		**53**		**57**		**55**		**53**		**57**		**49**	

Table P2-2. Total Expected Cost

Project: Hoh River Road Bank Erosion Risk Study **Date: 3/14/2013**

Site: P2 - PMP 0.8 Bank Stabilization

Alternative: Continue Maintenance **By: S. Leon**

	Flood Frequency (yr)	Exceedance Probability	Flood Damage	Average Flood Damage	Delta Exceedance Probability	Annual Risk Cost
No damage.	2	**0.5**	$0			
				$0	**0.3**	**$0**
No damage.	5	**0.2**	$0			
				$0	**0.1**	**$0**
No damage.	10	**0.1**	$0			
				$50,000	**0.06**	**$3,000**
Place riprap.	25	**0.04**	$100,000			
				$100,000	**0.02**	**$2,000**
Place riprap.	50	**0.02**	$100,000			
				$100,000	**0.01**	**$1,000**
Place riprap.	100	**0.01**	$100,000			
				$100,000	**0.01**	**$1,000**
		0	$100,000			
Total Annual Risk Cost						**$7,000**
Annualized Capital Cost	**Capital Cost**					**$0**
	Disc. rate, i	**0.07125**	**Serv. life, n**	**50**	**CFR**	**0.0736**
	Annualized Capital Cost					**$0**
Total Expected Cost (Annual)						**$7,000**
Summary	Assume 100 feet ($1k/ft) of revetment repair and bank armoring for each flood damage event.					

Notes:

1. Method from HEC-17, April 1981.

Table P2-3. Cost Estimates

Site: **P2 - PMP 0.8 Bank Stabilization**

Relocate Road (Common to P2 and P3)

		Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost	LS	1	$	137,200	$	**137,200**
New Road		LF	1,300	$	500	$	**650,000**
Hillside Stabilization		LS	1	$	50,000	$	**50,000**
Remove Existing Revetment		LF	300	$	200	$	**60,000**
Streambank Reconstruction		LF	400	$	1,000	$	**400,000**
Streambarbs		EA	5	$	40,000	$	**200,000**
ELJ's		EA	2	$	300,000	$	**600,000**
Total Construction Cost without Contingencies						$	**2,097,200**
Contingency	30% of construction cost					$	**629,160**
Total Construction Cost						$	**2,726,360**
Compliance	5% of total construction cost					$	**136,318**
Predesign/design (PE)	15% of total construction cost					$	**408,954**
Construction Engineering (CE)	15% of total construction cost					$	**408,954**
ROW						$	**-**
Riprap replacement -	20% replacement every	50	years			$	**40,000**
Wood replacement -	full log replacement every	30	years			$	**600,000**
TOTAL Capital Cost	Cost/Foot	**$ 3,324**				$	**4,320,586**
Annualized Capital Cost	Discount rate, i	0.07125				$	**318,026**
	Service life, n	50	years				
	CFR	**0.0736071**					

Complex Roughened Large Rock Toe

			Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost		LS	1	$	7,723	$	**7,723**
Remove Existing Revetment			LF	-	$	200	$	**-**
Rock	H 10 ft	T 5 ft	CY	**333**	$	180	$	**60,000**
	L 180 ft							
Logs	L 180 ft	XS 8 ft	EA	**23**	$	2,000	$	**45,000**
Soil	H 2 ft	T 10 ft	CY	**133**	$	40	$	**5,333**
	L 180 ft							
Total Construction Cost without Contingencies							$	**118,057**
Contingency	30% of construction cost						$	**35,417**
Total Construction Cost							$	**153,474**
Compliance	5% of total construction cost						$	**7,674**
Predesign/design (PE)	15% of total construction cost						$	**23,021**
Construction Engineering (CE)	15% of total construction cost						$	**23,021**
ROW							$	**-**
Riprap replacement -	20% replacement every		50	years			$	**12,000**
Wood replacement -	full log replacement every		30	years			$	**45,000**
TOTAL Capital Cost		Cost/Foot	**$ 1,468**				$	**264,189**
Annualized Capital Cost		Discount rate, i	0.07125				$	**19,446**
		Service life, n	50	years				
		CFR	**0.0736071**					

Table P2-3. Cost Estimates

Complex Log Crib Wall

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost		LS	1	$	13,533	$	**13,533**
Remove Existing Revetment				LF	200	$	200	$	**40,000**
Rock	H 10 ft	T 5 ft		CY	**333**	$	120	$	**40,000**
	L 180 ft								
Logs	L 180 ft	H 12 ft		EA	**54**	$	2,000	$	**108,000**
	Dia 2 ft	Row 6							
	log l 20 ft	No. 54							
Piles				EA	0	$	-	$	**-**
Soil	H 2 ft	T 10 ft		CY	**133**	$	40	$	**5,333**
	L 180 ft								
Total Construction Cost without Contingencies								$	**206,867**
Contingency	30%	of construction cost						$	**62,060**
Total Construction Cost								$	**268,927**
Compliance		5%	of total construction cost					$	**13,446**
Predesign/design (PE)		15%	of total construction cost					$	**40,339**
Construction Engineering (CE)		15%	of total construction cost					$	**40,339**
ROW								$	**-**
Riprap replacement -	20%	replacement every			50	years		$	**8,000**
Wood replacement -	full log	replacement every			30	years		$	**108,000**
TOTAL Capital Cost				Cost/Foot	**$ 2,661**			$	**479,051**
Annualized Capital Cost			Discount rate, i		0.07125			$	**35,262**
			Service life, n		50	years			
			CFR		**0.0736071**				

Riprap with Roughened Rock Toe, LWD, and Riparian Plantings

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost		LS	1	$	20,113	$	**20,113**
Remove Existing Revetment				LF	200	$	200	$	**40,000**
Riprap	H 12 ft	T 5 ft		CY	**1,067**	$	180	$	**192,000**
	L 180 ft	SS 2 (h):1(v)							
	TW 8 ft	TT 5 ft							
Logs	L 180 ft	XS 8 ft		EA	**23**	$	2,000	$	**45,000**
Willow	200 sy	XS 2		EA	**100**	$	10	$	**1,000**
Alder	200 sy	XS 1		EA	**200**	$	20	$	**4,000**
Soil	H 2 ft	T 10 ft		CY	**133**	$	40	$	**5,333**
	L 180 ft								
Total Construction Cost without Contingencies								$	**307,447**
Contingency	30%	of construction cost						$	**92,234**
Total Construction Cost								$	**399,681**
Compliance		5%	of total construction cost					$	**19,984**
Predesign/design (PE)		15%	of total construction cost					$	**59,952**
Construction Engineering (CE)		15%	of total construction cost					$	**59,952**
ROW								$	**-**
Riprap replacement -	20%	replacement every			50	years		$	**38,400**
Wood replacement -	full log	replacement every			30	years		$	**45,000**
TOTAL Capital Cost				Cost/Foot	**$ 3,461**			$	**622,969**
Annualized Capital Cost			Discount rate, i		0.07125			$	**45,855**
			Service life, n		50	years			
			CFR		**0.0736071**				

Table P2-3. Cost Estimates

Riprap with Streambarbs

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost		LS	1	$	23,263	$	**23,263**
Remove Existing Revetment				LF	-	$	200	$	**-**
Riprap	H 12 ft	T 5 ft		CY	**800**	$	180	$	**144,000**
	L 180 ft	SS 2 (h):1(v)							
	TW 0 ft	TT 0 ft							
Streambarbs				EA	4	$	40,000	$	**160,000**
Logs	L 180 ft	XS 20 ft		EA	**9**	$	2,000	$	**18,000**
Willow	200 sy	XS 2		EA	**100**	$	10	$	**1,000**
Alder	200 sy	XS 1		EA	**200**	$	20	$	**4,000**
Soil	H 2 ft	T 10 ft		CY	**133**	$	40	$	**5,333**
	L 180 ft								
Total Construction Cost without Contingencies								$	**355,597**
Contingency	30%	of construction cost						$	**106,679**
Total Construction Cost								$	**462,276**
Compliance		5%	of total construction cost					$	**23,114**
Predesign/design (PE)		15%	of total construction cost					$	**69,341**
Construction Engineering (CE)		15%	of total construction cost					$	**69,341**
ROW								$	**-**
Riprap replacement -	20%	replacement every			50	years		$	**60,800**
Wood replacement -	full log	replacement every			30	years		$	**18,000**
TOTAL Capital Cost				Cost/Foot	**$ 3,905**			$	**702,872**
Annualized Capital Cost			Discount rate, i		0.07125			$	**51,736**
			Service life, n		50	years			
			CFR		**0.0736071**				

Major Active River Channel Shift (Common to P2 and P3)

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost		LS	1	$	152,950	$	**152,950**
Channel Excavation - 100 feet by 5 feet				LF	1,200	$	300	$	**360,000**
Rearing and Resting Habitat Construction				AC	0.5	$	50,000	$	**25,000**
Remove Existing Revetment				LF	-	$	200	$	**-**
Streambank Reconstruction				LF	-	$	1,000	$	**-**
Streambarbs				EA	-	$	40,000	$	**-**
ELJ's - 20 ft by 60 ft				EA	6	$	300,000	$	**1,800,000**
Total Construction Cost without Contingencies								$	**2,337,950**
Contingency	30%	of construction cost						$	**701,385**
Total Construction Cost								$	**3,039,335**
Compliance		5%	of total construction cost					$	**151,967**
Predesign/design (PE)		15%	of total construction cost					$	**455,900**
Construction Engineering (CE)		15%	of total construction cost					$	**455,900**
ROW								$	**-**
Riprap replacement -	20%	replacement every			50	years		$	**-**
Wood replacement -	full log	replacement every			30	years		$	**1,800,000**
TOTAL Capital Cost				Cost/Foot	**$ 4,919**			$	**5,903,102**
Annualized Capital Cost			Discount rate, i		0.07125			$	**434,510**
			Service life, n		50	years			
			CFR		**0.0736071**				

Table P2-3. Cost Estimates

Minor River Channel Shift - ELJ Groins (Common to P2 and P3)

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost		LS	1	$	77,588	$	**77,588**
Rearing and Resting Habitat Construction				AC	-	$	50,000	$	**-**
Remove Existing Revetment				LF	-	$	200	$	**-**
Streambank Reconstruction - fill/plants/fascines				LF	400	$	1,200	$	**480,000**
Large Wood				EA	20	$	1,500	$	**30,000**
ELJ groin - 15 ft by 40 ft (2 x 15 ft by 20 ft mod.)				EA	4	$	149,600	$	**598,400**
Primary logs	50	$ 1,200	$ 60,000						
Pin logs	4	$ 1,200	$ 4,800						
Ballast stone	50	$ 180	$ 9,000						
Cabling	1	$ 1,000	$ 1,000						
			$ 74,800						
No. modules/ ELJ groin		2	$ 149,600						
Total Construction Cost without Contingencies								$	**1,185,988**
Contingency	30%	of construction cost						$	**355,796**
Total Construction Cost								$	**1,541,784**
Compliance	5%	of total construction cost						$	**77,089**
Predesign/design (PE)	15%	of total construction cost						$	**231,268**
Construction Engineering (CE)	15%	of total construction cost						$	**231,268**
ROW								$	**-**
Riprap replacement -	20%	replacement every	50 years					$	**-**
Wood replacement -		full log replacement every	30 years					$	**598,400**
TOTAL Capital Cost			Cost/Foot **$ 3,854**					$	**2,679,809**
Annualized Capital Cost			Discount rate, i 0.07125					$	**197,253**
			Service life, n 50 years						
			CFR **0.0736071**						

Minor River Channel Shift - Stream Barbs (Common to P2 and P3)

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost		LS	1	$	51,324	$	**51,324**
Rearing and Resting Habitat Construction				AC	-	$	50,000	$	**-**
Remove Existing Revetment				LF	-	$	200	$	**-**
Streambank Reconstruction - fill/plants/fascines				LF	400	$	1,200	$	**480,000**
Large Wood				EA	20	$	1,500	$	**30,000**
Streambarbs	Length	90 ft		EA	4	$	55,800	$	**223,200**
	Crest width	8 ft							
	Average bot. width	23 ft							
	Average thickness	6 ft							
	Volume	310 cy							
	Cost/cy	180 $/cy	Cost/barb $ 55,800						
Total Construction Cost without Contingencies								$	**784,524**
Contingency	30%	of construction cost						$	**235,357**
Total Construction Cost								$	**1,019,881**
Compliance	5%	of total construction cost						$	**50,994**
Predesign/design (PE)	15%	of total construction cost						$	**152,982**
Construction Engineering (CE)	15%	of total construction cost						$	**152,982**
ROW								$	**-**
Riprap replacement -	20%	replacement every	50 years					$	**44,640**
Wood replacement -		full log replacement every	30 years					$	**30,000**
TOTAL Capital Cost			Cost/Foot **$ 2,550**					$	**1,451,480**
Annualized Capital Cost			Discount rate, i 0.07125					$	**106,839**
			Service life, n 50 years						
			CFR **0.0736071**						

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P3 - PARK MILEPOST 0.9

BANK STABILIZATION



SITE P3 – PARK MILEPOST 0.9 BANK STABILIZATION

Site Conditions

The site is a riprap armored river bank 300 feet upstream of Site P2, approximately 300 feet long and 10 feet high (Fig. P3-1). Toe of the riprap is approximately 15 to 20 feet from the edge of the Upper Hoh Road. The riprap generally appears to be adequately sized and graded for controlling the bank erosion. The finished slope is 1.5(h):1(v) and steeper. The upstream 200 feet is densely-vegetated with willows and appears moderately stable (Photo P3-3). Currently, mid-channel sediment deposits deflect flood flow away the revetment segment. The downstream 100 feet is not vegetated and appears moderately unstable. Currently, mid-channel sediment deposits deflect flood flow towards the revetment segment. Based on photographs of the site taken for the Flood Prone Facility Assessment report by the NPS (ENTRIX, July 29, 2009), a moderate amount of riprap along the toe and mid-slope area appears to have been dislodged (Photos P3-1 and 2). Continued riprap loss could allow embankment erosion that eventually undermines the road. The site is Priority Number 8 in the Flood Prone Facility Assessment report.

The site is at the apex of a river meander bend immediately adjacent to the road. Mid-channel sediment deposits deflect ordinary and extreme flood flow towards the stream bank, inducing bank erosion and lateral migration. Erosion resistant, poorly consolidated alluvium terrace deposits limit river bend migration to the south and north. Historical channel migration zone (HCMZ) boundaries coincide with the terrace deposits. The road is immediately outside the right (looking downstream) boundary. The river bend apex is at the right HCMZ boundary. Width of the HCMZ is approximately 400 feet upstream and downstream of the site. Active channel width is 200 feet at the site and 400 feet upstream and downstream of the site. Ordinary high water flow depth is approximately 4 feet.

Based on Goggle Earth imagery (1994, 2009, and 2011), the active flow channel has remained confined against the road embankment (Fig. P3-2). Further migration is prevented by the riprap bank stabilization and terrace deposits. Down valley translation of the meander bend is limited by the terrace deposits, large trees lining the bank, and a low ridge behind the point bar on the opposite river bank.

The relatively limited down-valley river bend migration, narrowness of the HCMZ, and persistent mid-channel sediment deposits, suggests the eroding bank areas will continue to experience damage-inducing, bank-eroding flood flows.

Assuming riprap dislodged during flooding is replaced, the risk of a catastrophic road failure caused by a single extreme flood is moderately low. Assuming riprap dislodged during flooding is not replaced, the risk of a catastrophic road failure caused by a single extreme flood is moderate.

Considered Options

Continuing maintenance, relocating the road, installing additional bank stabilization, minor active river channel shift, and major active river channel shift were considered. Table P3-1 presents an evaluation and ranking of the options against design selection criteria.

Riprap is expected to be lost during extreme flooding, requiring replenishment for maintaining the riprap installation's effectiveness. Total Capital and Annualized Total Capital Costs provided in Table P3-1 assume 20 percent of the riprap in an installation is replaced every 50 years.

Douglas fir and hemlock are the most commonly available logs in the area. Douglas-fir logs can remain durable in wetting-drying conditions for 25 to 60 years (Tech. Supp. 14J, Use of Large Woody Material for Habitat and Bank Protection, Part 654, National Engineering Handbook, USDA, Natural Resources Conservation Service). Hemlock is the least durable of the conifers. Because the tree quality and species to be used in the structures is not known, Total Capital and Annualized Total Capital Costs provided in Table P3-1 assume wood used in the alternatives is replaced every 30 years.

Continue Maintenance

Continued maintenance involves monitoring the riprap revetment for excessive riprap loss. Riprap will need to be replaced when dislodged from extreme flood flows. Erosion could progress to the point that undermining of the road is imminent. Continued maintenance is placing riprap in an emergency action as needed for preventing a road closure. Placing riprap as an emergency action may be hazardous, difficult, or impossible. The emergency-placed riprap may not be effective in controlling the erosion.

A Total Expected Cost analysis (HEC-17, FHWA, April 1981) was used for estimating total expected cost repairing flood-induced road damage over a 50-year service-life. Based on observed riprap revetment condition, proximity of channel to roadway, and amount of natural bank armoring, the analysis assumes damage requiring repair of the existing revetment occurs for flood events equal to and larger than the 25-year flood event. Based on review of historical satellite imagery, length of bank typically exposed to impinging flood flow is estimated to be approximately 100 feet. Based on vegetation distribution and age and estimated riprap placement sequencing, the length of past revetment installations ranged from 100 to 200 feet. Assuming 100 feet total for each flood damage event and a cost of $1,000 per foot, the total expected annual cost is $7,000 (Table P3-2, Total Expected Cost).

Relocate Road (Common to P2 and P3)

The road would need to be shifted at least 100 to 200 feet away from the active river channel edge to eliminate the need for continuous revetment bank stabilization. The steep terrace slope is immediately adjacent to the roadway. A shift would mean an alignment that crosses the terrace slope. Slumping observed on the terrace slope suggests the terrace slope is not geotechnically stable. A new road alignment located across the terrace slope would experience landslides and debris flows that could potentially bury the road with debris. The road alignment may require significant foundation stabilization for mitigating landslides. Length of reroute is estimated to be 1,100 to 1,300 feet.

Existing riprap revetment and complex roughened large rock toe is removed and approximately 80 to 100 feet wide by 400 feet long area of the stream bank is reconstructed. A new stream bank would be erodible, allowing lateral bank erosion and migration to the north. Streambarbs constructed from the existing revetment riprap, engineered-log-jams (ELJ's), and planted vegetation control the bank erosion and lateral migration and preserve a riparian buffer between the active river channel and road embankment. The alternative requires monitoring and repair of the streambarbs and ELJ's to remain effective in controlling the bank erosion and lateral migration.

Estimated construction cost for the new road, existing road removal, five streambarbs, two ELJ's, and stream bank reconstruction is summarized in Table P3-3. Stabilizing landslides may require significantly more money. Construction is expected to occur outside the active flow channel. Turbidity released is expected to be limited in extent and duration. Access for construction is assumed from the existing road. Constructing the new road alignment first and

then switching the Upper Hoh Road traffic over before removing the existing road reduces traffic impacts to one-lane closures and short-term delays.

Stabilize Existing Road Embankment

Approximately 100 feet of stream bank is proposed for stabilization.

Alternatives evaluated;

- Complex roughened large rock toe.
- Complex log crib wall.
- Riprap with roughened rock toe, LWD, and riparian plantings.
- Riprap with streambarbs.

Based on field evidence, the site is expected to experience high shear stress, 8 to 12 feet deep flood flows, and abundant floating debris. It is critical that the stabilization methods be properly designed and anchored for maintaining effectiveness and surviving the expected flood conditions.

The existing unstable 100 feet riprap revetment is removed. Construction for all the alternatives is expected to occur entirely within the active flow channel and requires excavating into the streambed and stream bank. Stream work would be accomplished in flowing water. Assuming the work is completed during low flow periods, turbidity released is expected to be limited in extent and duration. Access for construction is assumed down a temporary access route built of riprap and logs. The access route would be removed after construction is completed. Upper Hoh Road traffic impacts are expected to be limited to one-lane closures and short-term delays.

-Complex roughened large rock toe (Appendix A, Sheet 4).

The approach involves placing a rock toe between the expected scour depth and ordinary high water level, approximately 8 to 10 feet high and 5 feet thick. Log bundles spaced 6 to 10 feet are placed at the bottom of the rock toe. Soil placed above the rock toe in overlapping layers of erosion control blanket, approximately 1 to 2 feet. The rock toe and soil ballast the logs and reduce the risk of the logs floating away. Estimated construction cost for the complex roughened large rock toe is summarized in Table P3-3.

-Complex log crib wall (Appendix A, Sheet 5).

The approach involves placing a log crib wall made of rough logs between the expected scour depth and ordinary high water level, approximately 8 to 10 feet high. Stone is placed within the log crib wall for ballast. Logs with attached root wads extending into the stream bank provide roughness and additional wall stability. All logs are cabled together for enhancing stability. Designs typically include piles driven to refusal or minimum depth of 10 feet. The cobble and boulder stream bed material will likely prevent the piles from being cost-effectively driven or excavated. They are assumed eliminated in the proposed design. Approximately 1 to 2 feet of soil is placed above the crib wall and planted. Estimated construction cost for the complex log crib wall is summarized in Table P3-3.

-Riprap with Roughened Rock Toe, LWD, and Riparian Plantings (Appendix A, Sheet 9).

The approach involves placing a riprap revetment between the expected scour depth and 50-year flood event water level, approximately 10 to 12 feet high, 5 feet thick, and 2(h):1(v) slope. A launchable riprap toe 8 feet wide and 5 feet thick reduces the risk of scour and channel incision undermining the revetment and provides additional stability. Logs or log bundles

spaced 6 to 10 feet are placed along the revetment toe for providing roughness and channel complexity. The logs are buried in the road embankment for reducing the risk of them floating away. Willow and alder are planted throughout the revetment and bank area above the revetment. Estimated construction cost is summarized in Table P3-3.

-Riprap with Streambarbs (Appendix A, Sheet 11).

The approach involves placing a riprap revetment between the expected scour depth and 50-year flood event water level, approximately 10 to 12 feet high, 5 feet thick, and 2(h):1(v) slope. Instead of a launchable riprap toe, two to three - 40 to 50 feet long streambarbs are proposed for reducing shear stress and deflecting the river flow away from the revetment. The streambarbs reduce the risk of scour and channel incision undermining the revetment, promote sediment deposition and retention along the bank toe, and creates channel complexity. The bank, riprap, streambarbs, and channel area between the streambarbs would be augmented with streambed material, large woody debris, and planted with riparian vegetation for establishing a riparian buffer. Estimated construction cost is summarized in Table P3-3.

Minor Active River Channel Shift (Common to P2 and P3)

An environmentally desirable approach would be to nudge the active river channel over enough from the road to reestablish a riparian buffer. Ideally, the buffer would have the same erosion resistance of a natural, wooded and vegetated river bank. The buffer would need to be wide enough to allow some bank erosion without threatening the roadway. It would be made by placing alluvial material over existing riprap revetment and unstable bank areas. To promote vegetation establishment and soil mass stability, the finished surface of the buffer area should not be steeper than 5(h):1(v). Assuming an 8 feet high bank, the width of the new buffer area would be at least 40 feet. Existing relative stable riparian buffers observed along the river are at least 40 to 50 feet wide and densely vegetated with alder and fir. The new buffer area would be prone to erosion from active channel migration. The erosive forces are expected to be too large for passive and bio-engineering methods to be effective by themselves. Hardened, more erosion resistant components in the buffer system are needed for mitigating the erosive forces.

-Engineered-log-jam Groins.

ELJ's groins constructed perpendicular to the stream bank and extending through the new buffer area would control channel location and deflect river flow away from new buffer area (Appendix A, Sheet 10). An ELJ's buoyancy and sliding analysis (Design Guidelines for Reintroducing Wood in Australian Streams, Abbe/Brooks, 2006) was completed assuming 6 feet design flow depth, 5 feet design scour depth, 8 feet per second average flow velocity, 1.5 velocity correction factor, and 18-inch average trunk diameter. The river bed contains cobbles and small boulders. Piles would need to penetrate the river bottom at least 20 to 30 feet for providing adequate resistance to buoyancy and sliding. Tree trunk piles would likely splinter before reaching the desired design depth. As wood decays, it losses strength and cannot resist the shear stresses created by a sliding ELJ mass. Driving steel piles for pinning the ELJ structure to the river bottom would be expensive and leave a tangle of steel piles protruding from the river bottom. Based on the analysis, an ELJ structure 15 feet wide and ballasted with stone is needed for achieving a minimum sliding factor-of-safety of 2.0, the minimum needed for unknown flow conditions and resisting expected additional woody debris accumulation.

Each ELJ groin would be 40 feet long and constructed of two 15 feet wide by 20 feet long modules. Assuming 2 to 3 feet gaps between logs and 8 layers, approximately 50 logs are needed for each module and 100 for each groin. Based on the stability analysis, 100 cubic yards of ballast stone is needed for each ELJ groin for achieving minimum sliding and buoyancy

factor-of-safeties of 2.0, the minimum needed for unknown flow conditions and resisting expected additional woody debris accumulation. The logs are cabled together for keeping them in place against expected flow depth and velocity and additional woody debris accumulation.

-Riprap Streambarbs.

Streambarbs are an alternative to using ELJ groins for controlling channel location and reducing erosive forces (Appendix A, Sheet 10). Each stream barb would be angled upstream 30 degree relative the bank line and approximately 90 feet long for fitting within the new riparian buffer. Assuming Class 8 riprap, crest width is 8 feet. Barb thickness is 6 feet at base and 6 feet at tip. Barb bottom width is 23 feet at base and 23 feet at tip. Approximately 310 cubic yards of riprap is needed for each stream barb.

Based on review of historical satellite imagery, length of bank typically exposed to impinging flood flow is estimated to be approximately 150 to 200 feet. The radius of curvature for active channel is 200 to 500 feet. To effectively deflect the impinging river flow away from the new bank area, the ELJ groins or stream barbs would need to be spaced every 100 to 150 feet. Assuming the new bank area is placed over the site P2a, site P2b, the existing complex roughened large rock toe, and site P3, approximately 400 feet of new bank area is created and four ELJ groins or stream barbs are needed.

The existing revetment is assumed left in place. Stream bank area is constructed between the ELJ groins or stream barbs by placing conserved and imported stream bed and bank material. Willow and cottonwood trees are planted throughout the area. Willow fascines are placed along the lower 3 to 6 feet of the bank toe for controlling erosion. Large wood is incorporated randomly throughout the bank area.

Estimated construction cost is summarized in Table P3-3. Work will be within the active river channel and requires temporarily diverting the river flow. Flow defection is assumed accomplished with large sandbags or water-inflated bladders. Dewatering the work area would be extremely difficult and expensive. Excavation and placing logs, stone, and new stream bank fill material is assumed to take place in the water ponded behind the flow diversion structure. Turbidity released is expected to be limited in extent and duration. Access for construction is assumed down a ramp constructed over the existing riprap revetment. The ramp could provide permanent access for maintenance. Upper Hoh Road traffic impacts are expected to be limited to one-lane closures and short-term delays.

The site is 3,000 feet upstream of the Park boundary. Private property is found immediately downstream of the Park boundary. Moving the active river channel away from road embankment with ELJ’s or groins could induce dramatic bank erosion and stream avulsion, resulting in unnatural changes in the HCMZ boundaries and loss of private property.

Executive Order 11988, Floodplain Management, established federal policies for protecting floodplains and floodways. The intention of the associated regulations is to avoid, to the extent practical, adverse impacts to floodplains; minimize the impact of floods to human safety, health, and welfare; and avoid supporting land use development that is incompatible with the natural and beneficial floodplain values. When avoidance is not possible, the policies require appropriate consideration of methods to assess and minimize adverse impacts. If the option is considered, additional analysis is needed for identifying extent and location of private property impacts. If found violating Executive Order 11988, relocating the active river channel would not be eligible for Federal funds.

Major Active River Channel Shift (Common to P2 and P3)

Shifting the river away 100 to 200 feet from the road eliminates the current riprap revetment failure risk and road loss risk from bank erosion occurring between and downstream of the existing revetments. Shifting the active river channel to flow across the point bar opposite the existing riprap revetment could be accomplished with four to six ELJ's, each at least 20 feet wide and 60 to 100 feet long. All would be constructed within the active river channel. Top of the ELJ's are set equal to 100-year water surface, estimated to be approximately 5 to 6 feet above the point bar surface. Bottom of the ELJ's are set below the active channel thalweg elevation and expected scour depth, approximately 6 feet below the point bar surface. Each engineered-log-jam is ballasted with stone and logs cabled together for keeping them in place against expected flow depth and velocity and additional woody debris accumulation.

The existing complex roughened large rock toe and revetment (P3) are left in place. Off-channel rearing and resting habitat is created along the toe of the existing road embankment. A new 100 feet wide active flow channel would be constructed across the point bar for diverting stream flow away from the construction area. Alluvial and plant materials from the channel excavation are to be used for the habitat reconstruction.

Estimated construction cost is summarized in Table P3-3. Construction requires temporarily diverting the river flow. Turbidity released is expected to be limited in extent and duration. Ramps constructed over the existing road embankment could provide temporary access for construction and permanent access for maintenance. Upper Hoh Road traffic impacts are expected to be limited to one-lane closures and short-term delays.

The HCMZ is relatively narrow at the site. Moving the active river channel 100 to 200 feet south provides opportunity for creating off-channel rearing and resting habitat along the toe of the existing road embankment. It is not expected to have a direct negative impact on private property adjacent to and downstream of the Park. Moving the active river channel more than 200 feet south would likely induce dramatic downstream bank erosion and stream avulsion, resulting in unnatural changes in the HCMZ boundaries and loss of private property and Olympic National Forest land. A channel relocation project would include a detailed geomorphic analysis for verifying the no-direct-impact assumption.

Executive Order 11988, Floodplain Management, established federal policies for protecting floodplains and floodways. The intention of the associated regulations is to avoid, to the extent practical, adverse impacts to floodplains; minimize the impact of floods to human safety, health, and welfare; and avoid supporting land use development that is incompatible with the natural and beneficial floodplain values. When avoidance is not possible, the policies require appropriate consideration of methods to assess and minimize adverse impacts. If the option is considered, additional analysis is needed for identifying extent and location of private property impacts. If found violating Executive Order 11988, relocating the active river channel would not be eligible for Federal funds.

Environmental Clearance Considerations

This section of the Upper Hoh Road extends through OLYM-managed lands. The road is bordered on the south by the Hoh River and on the north by primarily conifer trees. Based on a review of the National Wetland Inventory maps no wetlands were identified within the project corridor though this negative determination needs to be verified by a field survey. Except for as described below, environmental clearance considerations for Site P1 are the same as described for Site C1.

Continue Maintenance

Environmental considerations are the same as those described in Site P1.

Relocate Road

The proposed 100 to 200 foot shift to the north may place the realigned road within a designated wilderness area. This action would likely require Congressional approval.

The relocation of the road would permit the removal of the existing rip-rap revetment and the reconstruction of the riverbank which would likely result in improved habitat for the bull trout and other fish. However, the relocated road would require between 2.5 and 3 acres of new impact through conifer forest which likely provide suitable habitat for the northern spotted owl and the marbled murrelet. A biological assessment would need to be prepared evaluating the effects this action would have on these listed species.

Installation of the stream barbs and the ELJ's would require a 404 permit and 401 Water Quality Certification.

Stabilize Existing Road Embankment

Environmental considerations are the same as those described in Site P1.

Minor and Major Active River Channel Shift

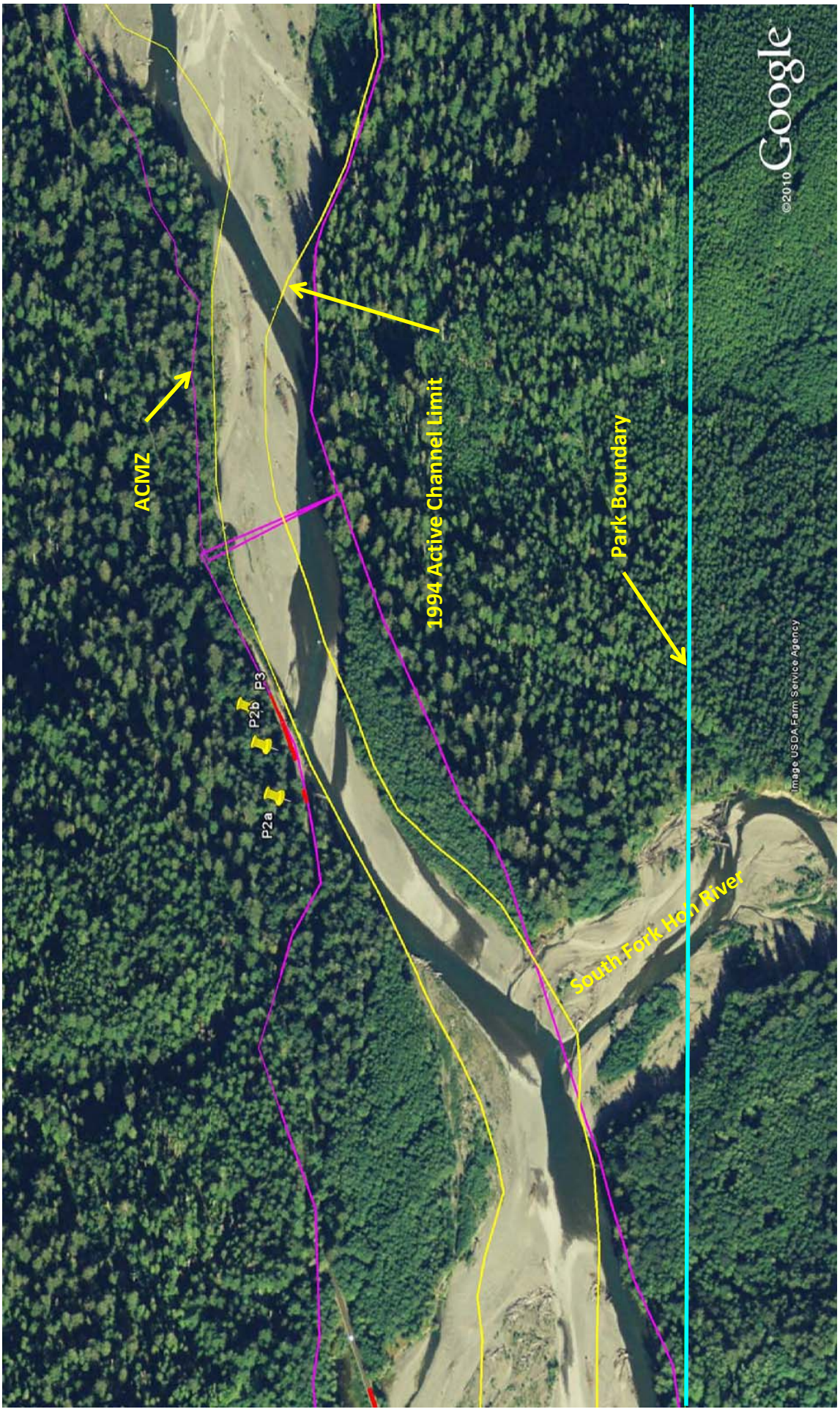
This could have a dramatic effect on the existing river system. The extent to which the option helps or harms the aquatic habitat would need determined through modeling and formal consultation with the Service, the Hoh Tribe, and the WDFW. This work would require an individual permit from the Corps and 401 Certification from the DOE.

A biological assessment would need to be prepared evaluating short and long term impacts to bull trout and short term construction impacts to the marbled murrelet and the northern spotted owl.

In addition, geomorphic assessments would need to be conducted for assessing effect this option may have on downstream properties.

Due to the scope of work and the limited in-water work window, the WDFW would likely need to be petitioned for an extension.

Each ELJ requires a number of trees to be cut down. Approximately 400 logs and 900 logs are needed for the minor and major active river channel shift options, respectively. Cutting these trees would have a direct impact on a forest's ecosystem and watershed's health.



ACMZ - Active Channel Migration Zone, Geomorphic Assessment of Hoh River in Washington State, USBR, July 2004.

Imagery date 9/25/2011

Figure P3-1. Site Location

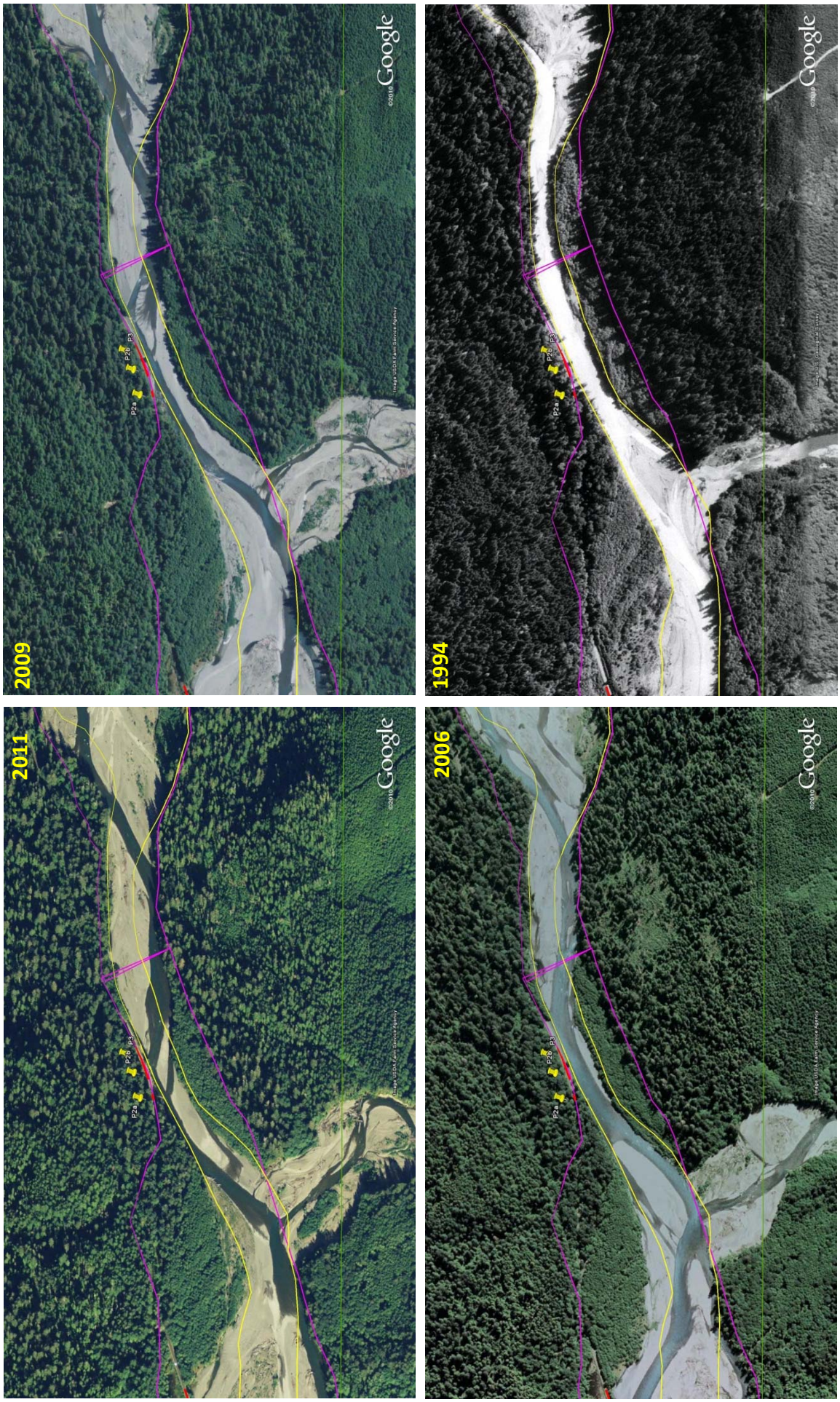


Figure P3-2. Historical Satellite Imagery

Photos

P3 - PMP 0.9 Bank Stabilization



PHOTO P3-1

Downstream end of riprap looking upstream along bank.

Riprap steep. Stone dislodged from toe and mid-slope areas. Mid-channel gravel bars deflect river flow at bank. Vegetated riprap appears relatively more stable.



PHOTO P3-2

Middle of riprap looking downstream along bank.

Riprap steep. Stone dislodged from toe and mid-slope areas. Mid-channel gravel bars deflect river flow at bank. P2 starts at downstream end of riprap.



PHOTO P3-3

Middle of riprap looking upstream along bank.

Riprap steep. Stone dislodged from toe and mid-slope areas. Area not currently experiencing impinging river flow. Vegetated riprap appears relatively more stable.

12/12/2012

Table P3-1. Alternative Summary and Ranking.

Upper Hoh River Road Site - P3 - PMP 0.9 Bank Stabilization

					Bank Stabilization									Minor Active River Channel Shift					Major Active River Channel Shift	
OPTIONS	**Rank**	**Continued Maintenance**	**Rank**	**Relocate Road**	**Rank**	**Complex Roughened Large Rock Toe**	**Rank**	**Complex Log Crib Wall**	**Rank**	**Riprap with LWD and Plantings**	**Rank**	**Riprap with Streambarbs**	**Rank**	**ELJ Groins**	**Rank**	**Large Stream barbs**	**Rank**	
Road on the edge of the channel migration zone has less of an impact to the total channel zone.		**Place or replace riprap as needed for preventing road closure.**		**Offset Road 200 Feet with mitigation of existing roadway slope to riparian zone - install streambarbs and ELJ's for preserving riparian zone.**		**Rock toe with LWD.**		**Log crib wall with roughness elements.**		**Riprap similar to what is commonly used along Upper Hoh River Road embankment.**		**Bank area planted with willow and alder.**		**Construct new stream bank area over unstable and revetment areas.**		**Construct new stream bank area over unstable and revetment areas.**		**Shift active flow channel to flow across point bar away from revetment area.**
Ability to preserve and operate the roadway in a specific location (Most able 5, least able 1)	**3**	Reduces risk of a catastrophic road failure during extreme flood event.	**3**	Better than where it is, but the river may eventually migrate north and impact road again.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.
Roadway sustainability (life of solution) (Longest 5, shortest 1)	**1**	Increased maintenance in the future mitigating climate change or after large flood events.	**3**	Increase road life reduces future risk from river. Road near hillside may experience landslides and debris flows.	**3**	Requires moderate amount of wood replacement and maintenance.	**1**	Requires substantial amount of wood replacement and maintenance.	**3**	Requires moderate amount of wood replacement and maintenance.	**5**	Requires moderate level of maintenance.	**1**	Requires substantial amount of wood replacement and maintenance.	**5**	Requires moderate level of maintenance.	**1**	Requires substantial amount of wood replacement and maintenance.
Impact to hillside stability adjacent to site (Most likely 1; least likely 5)	**5**	No expected additional impacts.	**1**	Road near hillside may experience landslides and debris flows.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.
Potential to reduce erosion of banks adjacent to site (Most 5; Least 1)	**1**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**1**	Likely increase down stream right bank erosion.
Impacts to listed Threatened and Endangered (T&E) terrestrial species and habitat (Least 5; most 1)	**5**	No expected additional impacts.	**1**	Impacts upland areas and potentially T&E.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.
Impacts to listed T&E fish and habitat (Least 5; most 1)	**3**	Riprap placed along bank reduces habitat complexity.	**3**	Material placed in channel.	**3**	Material placed in channel.	**3**	Material placed in channel.	**3**	Material placed in channel.	**1**	Riprap along bank reduces habitat complexity. Barbs require significant excavation into channel bed.	**3**	Considerable temporary impacts from in-stream channel work.	**3**	Considerable temporary impacts from in-stream channel work.	**3**	Considerable temporary impacts from in-stream channel work.
Impact to upland habitat (Least 5; most 1)	**5**	No expected additional impacts.	**1**	Impacts upland areas.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.
Impacts to Wetlands and Waters of the U.S. (Least 5; most 1)	**3**	No expected additional impacts to wetlands; riprap placement in river.	**5**	Riprap placement in river.	**3**	No expected additional impacts to wetlands; riprap placement in river.	**3**	No expected additional impacts to wetlands.	**3**	No expected additional impacts to wetlands; riprap placement in river.	**1**	Riprap along bank reduces habitat complexity. Barbs require significant excavation into channel bed.	**1**	Requires major in stream construction.	**1**	Requires major in stream construction.	**1**	Requires major in stream construction.
Impact to Designated Wilderness area (Least 5; most 1)	**5**	No expected impacts.	**1**	Expected impacts.	**5**	No expected impacts.	**5**	No expected impacts.	**5**	No expected impacts.	**5**	No expected impacts.	**5**	No impacts.	**5**	No impacts.	**5**	No expected impacts.
Potential for Hoh River Enhancement (Greatest 5; Least 1)	**1**	Does not provide river enhancements.	**5**	Provides off-channel/side-channel habitat, allows river to fully access HCMZ.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Moves thalweg away from road, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.
Potential to maintain or improve river process and function (Most 5; Least 1)	**1**	Does not improve river process and function.	**5**	Provides off-channel/side-channel habitat, allows river to fully access HCMZ	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Moves thalweg away from road, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.
Potential for other habitat enhancements (Most 5; Least 1)	**1**	Does not provide other habitat enhancements.	**5**	Opportunity for improving fish access to off-channel habitat	**3**	Provides some woody debris for habitat complexity and biological processes.	**3**	Provides some woody debris for habitat complexity and biological processes.	**3**	Provides some woody debris for habitat complexity and biological processes.	**1**	Does not provide other habitat enhancements.	**5**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides some woody debris for habitat complexity and biological processes.	**5**	Provides woody debris for habitat complexity and biological processes.
Potential private property impacts (Least 5; Most 1)	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**3**	Some impacts expected from bank erosion downstream of site.	**3**	Some impacts expected from bank erosion downstream of site.	**1**	Impacts likely from bank erosion downstream of site.
Safety risk of design to public (Least 5; Most 1)	**5**	No expected increase in safety risk.	**3**	Boaters could become trapped in root wads.	**3**	Boaters could become trapped in root wads.	**1**	Public could fall down wall. Boaters could become trapped in root wads.	**3**	Boaters could become trapped in root wads.	**5**	No expected increase in safety risk.	**1**	Boaters could become trapped in ELJ's.	**3**	Boaters could become trapped in root wads.	**1**	Boaters could become trapped in ELJ's.
Total Construction cost	**5**	**NA**	**1**	**$2,726,360**	**3**	**$116,380**	**3**	**$146,313**	**3**	**$246,387**	**3**	**$355,349**	**1**	**$1,541,784**	**1**	**$1,019,881**	**1**	**$3,039,335**
Riprap and Wood Replacement (50 years)		**NA**		**$640,000**		**$31,667**		**$64,444**		**$46,333**		**$50,000**		**$598,400**		**$74,640**		**$1,800,000**
Total Capital Cost (50 years)		**NA**		**$4,320,586**		**$188,780**		**$261,966**		**$378,956**		**$529,721**		**$2,679,809**		**$1,451,480**		**$5,903,102**
Annualized Total Capital Cost (Least 5; Most 1)		**$7,000**		**$318,026**		**$13,896**		**$19,283**		**$27,894**		**$38,991**		**$197,253**		**$106,839**		**$434,510**
SCORE	**49**		**46**		**57**		**53**		**57**		**55**		**53**		**57**		**49**	

Table P3-2. Total Expected Cost

Project: Hoh River Road Bank Erosion Risk Study **Date: 3/14/2013**

Site: P3 - PMP 0.9 Bank Stabilization

Alternative: Continue Maintenance **By: S. Leon**

	Flood Frequency (yr)	Exceedance Probability	Flood Damage	Average Flood Damage	Delta Exceedance Probability	Annual Risk Cost
No damage.	2	**0.5**	$0			
				$0	**0.3**	**$0**
No damage.	5	**0.2**	$0			
				$0	**0.1**	**$0**
No damage.	10	**0.1**	$0			
				$50,000	**0.06**	**$3,000**
Place riprap.	25	**0.04**	$100,000			
				$100,000	**0.02**	**$2,000**
Place riprap.	50	**0.02**	$100,000			
				$100,000	**0.01**	**$1,000**
Place riprap.	100	**0.01**	$100,000			
				$100,000	**0.01**	**$1,000**
		0	$100,000			
Total Annual Risk Cost						**$7,000**

Annualized Capital Cost	**Capital Cost**					**$0**
	Disc. rate, i	**0.07125**	**Serv. life, n**	**50**	**CFR**	**0.0736**
	Annualized Capital Cost					**$0**
Total Expected Cost (Annual)						**$7,000**

Summary	Assume 100 feet ($1k/ft) of revetment repair and bank armoring for each flood damage event.

Notes:

1. Method from HEC-17, April 1981.

Table P3-3. Cost Estimates

Site: **P3 - PMP 0.9 Bank Stabilization**

Relocate Road (Common to P2 and P3)

		Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost	LS	1	$	137,200	$	**137,200**
New Road		LF	1,300	$	500	$	**650,000**
Hillside Stabilization		LS	1	$	50,000	$	**50,000**
Remove Existing Revetment		LF	300	$	200	$	**60,000**
Streambank Reconstruction		LF	400	$	1,000	$	**400,000**
Streambarbs		EA	5	$	40,000	$	**200,000**
ELJ's		EA	2	$	300,000	$	**600,000**
Total Construction Cost without Contingencies						$	**2,097,200**
Contingency	30% of construction cost					$	**629,160**
Total Construction Cost						$	**2,726,360**
Compliance	5% of total construction cost					$	**136,318**
Predesign/design (PE)	15% of total construction cost					$	**408,954**
Construction Engineering (CE)	15% of total construction cost					$	**408,954**
ROW						$	**-**
Riprap replacement -	20% replacement every		50	years		$	**40,000**
Wood replacement -	full log replacement every		30	years		$	**600,000**
TOTAL Capital Cost		Cost/Foot	**$ 3,324**			$	**4,320,586**
Annualized Capital Cost		Discount rate, i	0.07125			$	**318,026**
		Service life, n	50	years			
		CFR	**0.0736071**				

Complex Roughened Large Rock Toe

			Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost		LS	1	$	5,857	$	**5,857**
Remove Existing Revetment			LF	100	$	200	$	**20,000**
Rock	H 10 ft	T 5 ft	CY	**185**	$	180	$	**33,333**
	L 100 ft							
Logs	L 100 ft	XS 8 ft	EA	**13**	$	2,000	$	**25,000**
Soil	H 2 ft	T 10 ft	CY	**133**	$	40	$	**5,333**
	L 180 ft							
Total Construction Cost without Contingencies							$	**89,523**
Contingency	30% of construction cost						$	**26,857**
Total Construction Cost							$	**116,380**
Compliance	5% of total construction cost						$	**5,819**
Predesign/design (PE)	15% of total construction cost						$	**17,457**
Construction Engineering (CE)	15% of total construction cost						$	**17,457**
ROW							$	**-**
Riprap replacement -	20% replacement every			50	years		$	**6,667**
Wood replacement -	full log replacement every			30	years		$	**25,000**
TOTAL Capital Cost			Cost/Foot	**$ 1,888**			$	**188,780**
Annualized Capital Cost			Discount rate, i	0.07125			$	**13,896**
			Service life, n	50	years			
			CFR	**0.0736071**				

Table P3-3. Cost Estimates

Complex Log Crib Wall

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost		LS	1	$	7,363	$	**7,363**
Remove Existing Revetment				LF	100	$	200	$	**20,000**
Rock	H 10 ft	T 5 ft		CY	**185**	$	120	$	**22,222**
	L 100 ft								
Logs	L 100 ft	H 12 ft		EA	**30**	$	2,000	$	**60,000**
	Dia 2 ft	Row 6							
	log l 20 ft	No. 30							
Piles				EA	0	$	-	$	**-**
Soil	H 2 ft	T 10 ft		CY	**74**	$	40	$	**2,963**
	L 100 ft								
Total Construction Cost without Contingencies								$	**112,548**
Contingency	30%	of construction cost						$	**33,764**
Total Construction Cost								$	**146,313**
Compliance		5%	of total construction cost					$	**7,316**
Predesign/design (PE)		15%	of total construction cost					$	**21,947**
Construction Engineering (CE)		15%	of total construction cost					$	**21,947**
ROW								$	**-**
Riprap replacement -	20%	replacement every			50	years		$	**4,444**
Wood replacement -	full log	replacement every			30	years		$	**60,000**
TOTAL Capital Cost			Cost/Foot		**$ 2,620**			$	**261,966**
Annualized Capital Cost			Discount rate, i		0.07125			$	**19,283**
			Service life, n		50	years			
			CFR		**0.0736071**				

Riprap with Roughened Rock Toe, LWD, and Riparian Plantings

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost		LS	1	$	12,399	$	**12,399**
Remove Existing Revetment				LF	200	$	200	$	**40,000**
Riprap	H 12 ft	T 5 ft		CY	**593**	$	180	$	**106,667**
	L 100 ft	SS 2 (h):1(v)							
	TW 8 ft	TT 5 ft							
Logs	L 100 ft	XS 8 ft		EA	**13**	$	2,000	$	**25,000**
Willow	100 sy	XS 2		EA	**50**	$	10	$	**500**
Alder	100 sy	XS 1		EA	**100**	$	20	$	**2,000**
Soil	H 2 ft	T 10 ft		CY	**74**	$	40	$	**2,963**
	L 100 ft								
Total Construction Cost without Contingencies								$	**189,529**
Contingency	30%	of construction cost						$	**56,859**
Total Construction Cost								$	**246,387**
Compliance		5%	of total construction cost					$	**12,319**
Predesign/design (PE)		15%	of total construction cost					$	**36,958**
Construction Engineering (CE)		15%	of total construction cost					$	**36,958**
ROW								$	**-**
Riprap replacement -	20%	replacement every			50	years		$	**21,333**
Wood replacement -	full log	replacement every			30	years		$	**25,000**
TOTAL Capital Cost			Cost/Foot		**$ 3,790**			$	**378,956**
Annualized Capital Cost			Discount rate, i		0.07125			$	**27,894**
			Service life, n		50	years			
			CFR		**0.0736071**				

Table P3-3. Cost Estimates

Riprap with Streambarbs

		Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost	LS	1	$	17,882	$	**17,882**
Remove Existing Revetment		LF	200	$	200	$	**40,000**
Riprap	H 12 ft T 5 ft	CY	**444**	$	180	$	**80,000**
	L 100 ft SS 2 (h):1(v)						
	TW 0 ft TT 0 ft						
Streambarbs		EA	3	$	40,000	$	**120,000**
Logs	L 100 ft XS 20 ft	EA	**5**	$	2,000	$	**10,000**
Willow	100 sy XS 2	EA	**50**	$	10	$	**500**
Alder	100 sy XS 1	EA	**100**	$	20	$	**2,000**
Soil	H 2 ft T 10 ft	CY	**74**	$	40	$	**2,963**
	L 100 ft						
Total Construction Cost without Contingencies						$	**273,345**
Contingency	30% of construction cost					$	**82,004**
Total Construction Cost						$	**355,349**
Compliance	5% of total construction cost					$	**17,767**
Predesign/design (PE)	15% of total construction cost					$	**53,302**
Construction Engineering (CE)	15% of total construction cost					$	**53,302**
ROW						$	**-**
Riprap replacement -	20% replacement every		50	years		$	**40,000**
Wood replacement -	full log replacement every		30	years		$	**10,000**
TOTAL Capital Cost		Cost/Foot	**$ 5,297**			$	**529,721**
Annualized Capital Cost		Discount rate, i	0.07125			$	**38,991**
		Service life, n	50	years			
		CFR	**0.0736071**				

Major Active River Channel Shift (Common to P2 and P3)

		Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost	LS	1	$	152,950	$	**152,950**
Channel Excavation - 100 feet by 5 feet		LF	1,200	$	300	$	**360,000**
Rearing and Resting Habitat Construction		AC	0.5	$	50,000	$	**25,000**
Remove Existing Revetment		LF	-	$	200	$	**-**
Streambank Reconstruction		LF	-	$	1,000	$	**-**
Streambarbs		EA	-	$	40,000	$	**-**
ELJ's - 20 ft by 60 ft		EA	6	$	300,000	$	**1,800,000**
Total Construction Cost without Contingencies						$	**2,337,950**
Contingency	30% of construction cost					$	**701,385**
Total Construction Cost						$	**3,039,335**
Compliance	5% of total construction cost					$	**151,967**
Predesign/design (PE)	15% of total construction cost					$	**455,900**
Construction Engineering (CE)	15% of total construction cost					$	**455,900**
ROW						$	**-**
Riprap replacement -	20% replacement every		50	years		$	**-**
Wood replacement -	full log replacement every		30	years		$	**1,800,000**
TOTAL Capital Cost		Cost/Foot	**$ 4,919**			$	**5,903,102**
Annualized Capital Cost		Discount rate, i	0.07125			$	**434,510**
		Service life, n	50	years			
		CFR	**0.0736071**				

Table P3-3. Cost Estimates

Minor River Channel Shift - ELJ Groins (Common to P2 and P3)

			Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost	LS	1	$	77,588	$	**77,588**
Rearing and Resting Habitat Construction			AC	-	$	50,000	$	**-**
Remove Existing Revetment			LF	-	$	200	$	**-**
Streambank Reconstruction - fill/plants/fascines			LF	400	$	1,200	$	**480,000**
Large Wood			EA	20	$	1,500	$	**30,000**
ELJ groin - 15 ft by 40 ft (2 x 15 ft by 20 ft mod.)			EA	4	$	149,600	$	**598,400**
Primary logs	50	$ 1,200 $ 60,000						
Pin logs	4	$ 1,200 $ 4,800						
Ballast stone	50	$ 180 $ 9,000						
Cabling	1	$ 1,000 $ 1,000						
		$ 74,800						
No. modules/ ELJ groin	2	$ 149,600						
Total Construction Cost without Contingencies							$	**1,185,988**
Contingency	30%	of construction cost					$	**355,796**
Total Construction Cost							$	**1,541,784**
Compliance	5%	of total construction cost					$	**77,089**
Predesign/design (PE)	15%	of total construction cost					$	**231,268**
Construction Engineering (CE)	15%	of total construction cost					$	**231,268**
ROW							$	**-**
Riprap replacement -	20%	replacement every		50	years		$	**-**
Wood replacement -		full log replacement every		30	years		$	**598,400**
TOTAL Capital Cost			Cost/Foot	**$ 3,854**			$	**2,679,809**
Annualized Capital Cost			Discount rate, i	0.07125			$	**197,253**
			Service life, n	50	years			
			CFR	**0.0736071**				

Minor River Channel Shift - Stream Barbs (Common to P2 and P3)

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost		LS	1	$	51,324	$	**51,324**
Rearing and Resting Habitat Construction				AC	-	$	50,000	$	**-**
Remove Existing Revetment				LF	-	$	200	$	**-**
Streambank Reconstruction - fill/plants/fascines				LF	400	$	1,200	$	**480,000**
Large Wood				EA	20	$	1,500	$	**30,000**
Streambarbs	Length	90	ft	EA	4	$	55,800	$	**223,200**
	Crest width	8	ft						
	Average bot. width	23	ft						
	Average thickness	6	ft						
	Volume	310	cy						
	Cost/cy	180	$/cy	Cost/barb	$ 55,800				
Total Construction Cost without Contingencies								$	**784,524**
Contingency	30%	of construction cost						$	**235,357**
Total Construction Cost								$	**1,019,881**
Compliance	5%	of total construction cost						$	**50,994**
Predesign/design (PE)	15%	of total construction cost						$	**152,982**
Construction Engineering (CE)	15%	of total construction cost						$	**152,982**
ROW								$	**-**
Riprap replacement -	20%	replacement every			50	years		$	**44,640**
Wood replacement -		full log replacement every			30	years		$	**30,000**
TOTAL Capital Cost				Cost/Foot	**$ 2,550**			$	**1,451,480**
Annualized Capital Cost				Discount rate, i	0.07125			$	**106,839**
				Service life, n	50	years			
				CFR	**0.0736071**				

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P4 - PARK MILEPOST 3.0

EAST TWIN CREEK CULVERT



SITE P4 – PARK MILEPOST 3 EAST TWIN CREEK CULVERT

Site Conditions

The stream flows under the road through a 48-inch diameter galvanized corrugated metal pipe (CMP) culvert. A second 48-inch diameter CMP culvert is immediately north of the main culvert at a higher elevation and conveys flood overflow. A large scour pool is below the culvert outlets (Photo P4-3). The primary culvert is 101 feet long and has a 1.1 percent slope. The fill height over the culvert is approximately 22 feet. The outlet is perched approximately 6 feet above the stream bottom (elevation measured immediately downstream of the scour pool). The difference between the stream bottom elevation immediately upstream of the culvert and immediately downstream of the scour pool is approximately 7 feet. The culvert appears in good condition. It has no streambed material or baffles, and appears to be a velocity and leap barrier to adult salmon. Several large logs are immediately upstream of the inlet.

Based on observed pipe condition and assuming woody debris is not trapped inside the culvert or at the inlet, the culvert could provide another 20 to 30 years of service life. Woody debris trapped inside the culvert or at the inlet could cause water to pond at the inlet, increasing loading and saturation to the point that a catastrophic road embankment failure occurs. The overflow culvert reduces the risk of a catastrophic embankment failure. There is abundant woody debris available for recruitment to the stream from windfall and stream bank erosion. The stream is capable of transporting the woody debris at the more extreme (> 25-year) flood events. Assuming debris is routinely removed from inside the culvert or inlet area, the risk catastrophic embankment failure is moderately low. Work is being proposed of this site for improving fish passage and reducing risk of woody debris being trapped within the culvert.

The road crossing is skewed approximately 6 degrees relative to the stream. Immediately upstream of the crossing two equally sized stream channels merge. Both streams are moderately sloped (approx. 2%), entrenched (entrenchment ratio < 1.4), and have low sinuosity (Photo P4-1). The stream downstream is moderately sloped, slightly more entrenched, and less sinuous (Photo P4-2). Bankfull width is approximately 14 feet. Bankfull depth is approximately 2 feet. The stream lies in a narrow colluvial valley with flood prone area widths between 14 and 20 feet. Floodplains are poorly developed. The crossing is approximately 800 feet upstream from the confluence with the Hoh River and 20 feet higher in elevation. The stream is perennial. Spring and storm flow are the dominant stream-flow control.

Steps and pools are the dominant channel bed morphology. Steps in the channel coincide with large woody debris sills. Bed load material observed both upstream and downstream of the crossing appears to be predominantly sand and gravel. A grain size analysis completed on a bedload sample collected immediately downstream of the crossing site indicated a D50 of 10 millimeters (mm). The largest particle size measured was 30 mm. Bank materials appear predominantly silt and sand. Riparian vegetation is predominantly large conifer trees and dense underbrush. No bedrock was observed in the stream banks or bottom near the crossing.

Large woody debris in the channel and floodway indicate an abundant debris supply. The large woody debris is more abundant upstream of the crossing. Based on the estimated 50-year flood width and depth, the potential of the stream transporting large woody debris is small. Abundant vegetation, moss, and organic soil established on the woody debris indicate it may remain stationary for long periods of time. Eroding banks, sediment stored upstream of woody debris sills, and pools refilled with bedload suggest a high sediment supply. Downstream of the culvert stream banks are generally undercut and thinly vegetated, and appear unstable (Photo P4-4). Upstream the banks are vegetated and generally not undercut, and appear moderately

stable. Based on the surveyed stream profile, the deeper entrenchment, and the undercut and unstable banks, the stream below the crossing appears to be degrading. The stream above appears moderately stable.

The drainage area was determined using a U.S.G.S. quadrangle map and StreamStats to be approximately 0.6 square miles. The drainage area is mountainous, with elevations from 500 to 2,600 feet (msl). The entire drainage area is heavily timbered. According to StreamStats mean annual rainfall exceeds 140 inches. Peak flood discharges at the crossing site were estimated using drainage-area based statewide regression equations (U.S.G.S. Report 97-4277, 1998). The 2-year, 50-year, and 100-year peak discharge is 97, 204, and 228 cubic feet per second (cfs).

Considered Options

In addition to continued maintenance, three alternatives were evaluated. One alternative, constructing rock weirs at the existing culvert outlet, provide fish passage. Two alternatives, structural-plate culvert and a new bridge, replace the existing culvert with a structure capable of passing fish and expected woody debris. Table P4-1 presents an evaluation and ranking of the alternatives against design selection criteria.

Continue Maintenance

Continued maintenance involves monitoring the site for excessive woody debris accumulation at the inlet and removing the debris as needed for preventing flood water overtopping the road and causing a catastrophic road failure. Removing woody debris as an emergency action may be hazardous, difficult, or impossible. To avoid a catastrophic failure, inspections should be done annually and after each major flood event. The height of the road embankment makes monitoring difficult. The culvert interior can only be safely accessed during low flow conditions.

A Total Expected Cost analysis (HEC-17, FHWA, April 1981) was completed for estimating total expected cost repairing damage caused by flooding. The analysis assumes a 50-year service-life. Based on the capacity of the stream and culvert for transporting water and woody debris, debris removal from the inlet area and inside the culvert is expected to be needed for 25-year and larger flood events. Estimated cost for removing debris from the inlet area and inside the culvert is $20,000 per removal event. The analysis assumes the road embankment will be completely washed out for the 500-year flood event. Cost for a new structural-plate culvert is estimated to be $1,250,000 (Table P4-3). Total expected annual cost is $5,880 (Table P4-2, Total Expected Cost).

Rock Weirs at Existing Culvert Outlet

Fish passage could be provided by constructing rock weirs immediately downstream of the existing scour pool that elevate the water surface high enough to eliminate the outlet leap and allow fish to swim directly into the culvert. Six to eight rock weirs are needed for effectively reducing the stream gradient enough for fish to easily migrate through the structures. To prevent the stream from cutting around the rock weirs, each rock weir must extend into the valley walls, approximately 15 to 20 feet total length. The rock weirs do not reduce the risk of debris becoming trapped inside the culvert. If ponding backwatering the outlet reduces flow velocities and increases flow depth inside the culvert, the weirs may increase the debris accumulation risk. The rock weirs require repair for maintaining effectiveness and are susceptible to undermining from downstream channel incision.

Access for construction would be difficult. The likely scenario is lowering equipment and stone down the existing road embankment. A temporary wood/rock pad would provide access to the rock weir sites. The temporary pad would be removed and the area reclaimed once construction is completed. Traffic would likely be reduced to one-lane with short-duration interruptions. Estimated construction costs are summarized in Table P4-3.

New 20 Feet Diameter Culvert

The alternative proposes replacing the primary culvert with a new 124 feet long, structural-plate galvanized corrugated metal pipe culvert. Based on WDFW fish passage culvert design guidelines, the new culvert should have a minimum 20 feet diameter. The culvert will be sloped at approximately 6 percent and countersunk 40 percent. Stream degradation downstream is expected to continue. Countersinking at least 40 percent accommodates the expected channel profile adjustments and ensures continued effective fish passage. Streambed material placed inside the countersunk culvert will provide channel roughness for fish passage. Additional stone roughness features placed inside and immediately downstream of the culvert reduce the channel incision rate. The north culvert will not be needed to provide additional flood conveyance capacity, and will be removed.

Do to the depth of the fill it is not possible to maintain one-way traffic along the existing alignment. Unless the road can be closed for two months, a temporary detour road is needed for diverting traffic around the construction. To reduce cost and habitat impact, a single lane, 12 feet wide road with traffic signal control is proposed. Constructing a bypass channel adjacent to the new culvert temporarily conveys the stream flow through the construction site. Culvert installation requires extensive shoring or trench-benching when excavating into the deep road fill. Once the culvert is complete, the temporary detour road will be completely removed. Estimated construction cost, including culvert, temporary detour road, culvert infill, and site grading is summarized in Table P4-3. Estimated construction time for the proposed culvert is two months.

44 Feet Long Bridge with Sheet Pile Wall Abutments

The site was evaluated for receiving a new bridge in 2002 through 2004. Bedrock depth and geotechnical foundation conditions influence foundation design and bridge length. Geotechnical exploration completed for the site in 2002 and 2003 identified a weak silty-clay layer persisting for significant depth and not adequate for supporting a bridge with spill-through abutments founded on driven piles. The proposed bridge design included a 44 feet long bridge supported on spread footings bearing on fill placed behind sheet pile walls. The sheet pile walls need to be at least 50 feet long for penetrating the weak soil layer and include deadman tie-backs for supporting the bridge structure.

A bridge with pre-stressed concrete girders and cast-in-place deck was proposed. The bridge is located on a road segment with a 220 feet radius. A 29 feet wide bridge is needed for accommodating the road radius. Setting the sheet pile walls at least 20 feet apart provides a waterway that spans the natural channel bankfull width and conveys the estimated 50 and 100-year peak discharges. The proposed design provides approximately 18 feet of clearance between the bridge low chord and stream bottom, and is adequate for flood/debris conveyance and maintenance access.

The crossing is located on a sag vertical curve. Road grades approaching the sag are approximately 2 percent. Based on existing road topography, the bridge deck will have approximately a 1 percent grade. Runoff conveyed in the gutter lines and then discharged down the embankment provides adequate bridge deck drainage.

Overall stream degradation is likely to continue at a reduced rate after the existing culvert is removed. Based on the preliminary hydraulic analysis, extensive streambed scours and aggressive stream lateral migration is not expected. A 3-percent grade transition is proposed between the upstream and downstream channel bottom elevations. The transition will start immediately upstream of the existing culvert and slope downstream until the existing streambed is encountered. To reconstruct the floodway, appropriately sized streambed material will be placed in the scour pool and downstream channel. Because the natural stream gradient above and below the crossing is approximately 2 percent, a nick zone will form at the upstream end of the 3-percent grade transition and migrate upstream. The natural accumulation of large woody debris and the placement of large woody debris in the newly constructed waterway are expected to limit the size and advancement of the nick zone. A stabilized-bed design would reduce the incision extent and rate.

A temporary detour road is needed for diverting traffic around the construction. To minimize habitat impact and cost, a single lane, 12 feet wide road with traffic signal control is proposed. Extending the existing culvert temporarily conveys the stream flow through the construction site. Once the bridge is complete, the temporary detour road will be used for removing the existing culvert, road embankment, and reconstructing the stream. The temporary detour road will be completely removed after the stream work is complete. Estimated construction cost, including bridge, sheet pile walls, temporary detour road, culvert removal, site grading, and installing riprap abutment scour countermeasures are summarized in Table P4-3. Estimated construction time for the proposed bridge is six months.

Environmental Clearance Considerations

This portion of the road extends OLYM-managed lands. As currently proposed, none of the options would impact designated wilderness areas.

The culvert is presently perched and prevents fish passage to upstream habitat for migratory and resident fish.

National Wetland Inventory maps are inconclusive regarding the presence of wetlands in the project area. Due to incision downstream, it is unlikely that any wetlands would be present at this location. A wetland survey will need to be conducted to determine the presence of wetlands.

The forest in the vicinity of the project area is dominated by large conifers, including Douglas fir, Sitka spruce, western hemlock, and red cedar. Willow and alder trees occupy the riparian areas. This vegetation provides suitable habitat for the marbled murrelet and northern spotted owl. Designated bull trout critical habitat is located downstream in the Hoh River.

In the 2006 Park Environmental Assessment prepared for the installation of bridge at West Twin Creek in 2007-2008, it was determined that the proposed project was located on a deposition terrace of less than 1,000 years old in the Hoh River floodplain. Surveys identified no cultural resources. It is likely that the same conditions will be found at the East Twin Creek Culvert, though surveys will be needed to confirm this.

<u>Continue Maintenance</u>

East Twin Creek is a water of the State and US. Monitoring and debris removal activities are typically exempt from permitting and environmental clearance activities. Should the culvert fail in a 500-year event, a pulse of sediment will be sent into the Hoh River. If this occurs, the

turbidity increase to the river is expected to be negligible, compared to the background levels found in the flooding river.

Rock Weirs at Existing Culvert Outlet

The proposed work would likely need a Nationwide Permit (#18) provided that the discharged material does not exceed 25 cubic yards below the ordinary high water mark and it does not fill more than 1/10th of an acre of waters of the US. Work should occur during the in-water work window. A biological assessment may be needed to evaluate temporary effects construction activities would have on bull trout and its critical habitat.

New 20 Feet Diameter Culvert

This work would involve excavation below the ordinary high water mark triggering the need for a 404 permit and 401 Water Quality Certification. Because the primary intent of the work is to reestablish fish passage, the project may qualify for Nationwide Permit 27 – Aquatic Habitat Restoration, Establishment, and Enhancement Activities.

A stream analysis should be done to determine the extent to which the streambed would incise upstream of the new culvert given that incision typically adversely affects fish habitat. This analysis should be coordinated with the WDFW, the Hoh Tribe, and the Service.

A biological assessment evaluating impacts to bull trout and critical habitat would need to be prepared. The biological assessment would also need to evaluate the effects that vegetation removal necessitated by the temporary bypass would have on the marbled murrelet and the northern spotted owl suitable habitat as well as the effect construction noise would have on individuals.

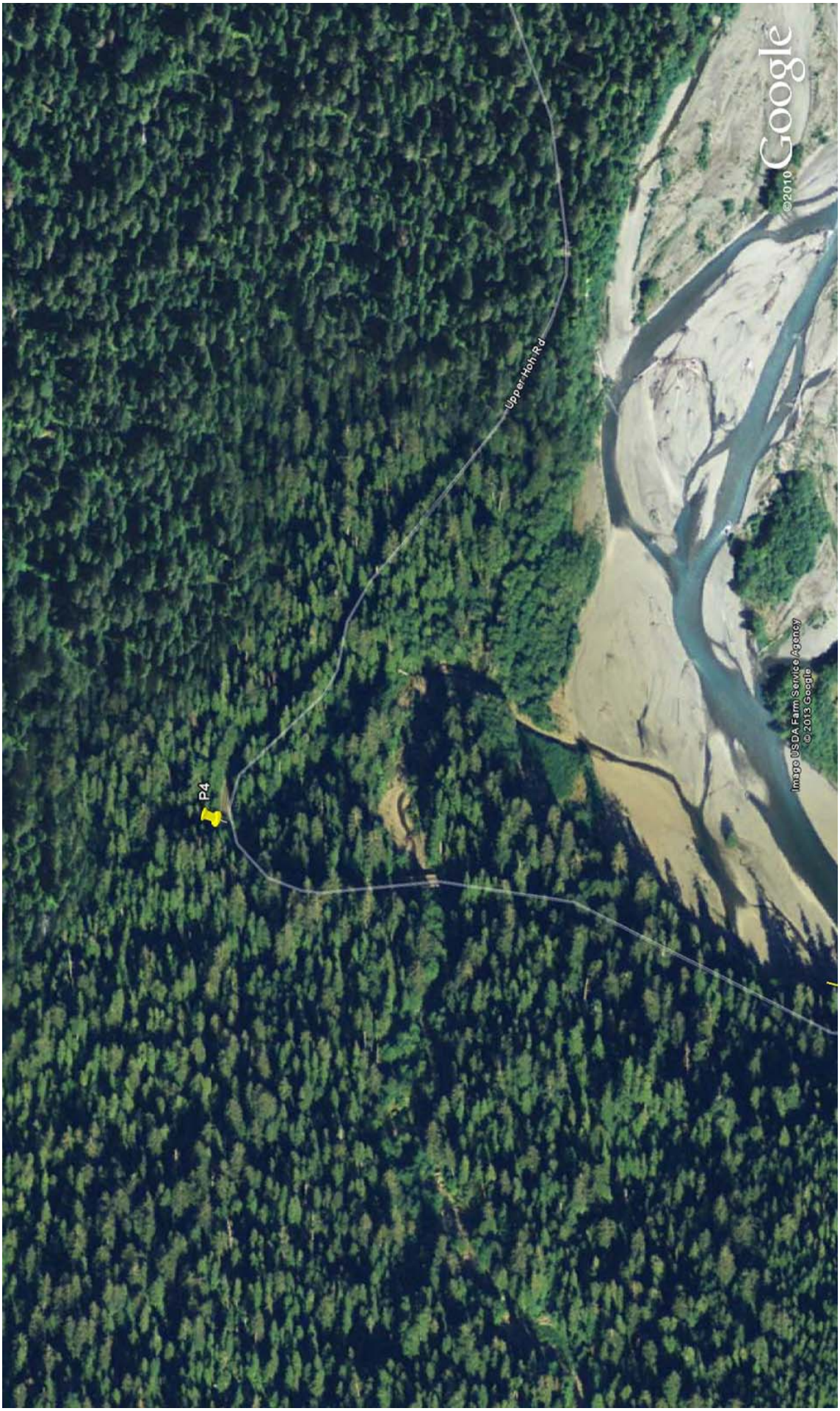
As noted in the description, a stream bypass would need to be installed during construction to minimize the potential for sedimentation. Because the length for construction is to last longer than the in-water work window (August 1- August 15), a waiver application will need to be submitted.

44 Feet Long Bridge with Sheet Pile Wall Abutments

Removal of the culvert and fill for the bridge proposal may require a section 404 permit and 401 Water Quality Certification. As a single-span bridge, no placement of any permanent structures below ordinary high water mark is expected. Consequently, no 404 permit/401 certification would be required unless temporary structures or construction activities need to occur in the stream channel. If a single-span bridge is used, restrictions regarding in-water work would likely not apply, provided there is no in-water work.

A stream analysis should be done to determine the extent to which the streambed would incise upstream of the new bridge, given that incision typically adversely affects fish habitat. The analysis should be coordinated with the WDFW, the Hoh Tribe, and the Service. It is likely a stabilized-bed design will be needed for reducing upstream incision and habitat degradation.

A biological assessment evaluating short-term impacts culvert removal would have on bull trout and designated critical habitat would need to be prepared. Also, the biological assessment would also need to evaluate the effects that vegetation removal necessitated by the temporary bypass construction would have on the suitable habitats for marbled murrelet and the northern spotted owl as well as the effect construction noise would have on individuals.



Imagery date 9/25/2011

Figure P4-1. Site Location

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Photos

P4 - East Twin Creek Culvert



PHOTO P4-1

Looking upstream from road.

Abundant vegetation near inlet. Inlet area difficult to access for maintenance.



PHOTO P4-2

Looking downstream from road.

Abundant vegetation near outlet. Outlet area difficult to access for maintenance.



PHOTO P4-3

Scour hole at outlet.

Bank steep and unstable. Soil on top of bank undercut and slumping.

12/12/2012

Photos



P4 - East Twin Creek Culvert

PHOTO P4-4

Bank erosion downstream of culvert.

Bank steep and unstable. Soil on top of bank undercut and slumping. Weak soils outcropping along bank. Stream bed material predominantly sand and gravel.

Table P4-1. Alternative Summary and Ranking.
Upper Hoh River Road Site - P4 - East Twin Creek Culvert

OPTIONS	Rank	Continued Maintenance	Rank	Rock Weirs at Existing Culvert Outlet	Rank	New 20 feet dia. Culvert	Rank	New Bridge
		Remove debris from culvert inside and inlet.		**Install two rock weirs for backwatering existing culvert and providing fish passage - does nothing for reducing debris jam risk.**		**Install new 20-feet dia. structural-plate culvert.**		**Install new 44 feet long bridge with 50 feet high sheet pile wall abutments.**
Ability to preserve and operate the roadway in a specific location. (Most able 5, least able 1)	**1**	Large flood event could wash out road embankment.	**1**	Large flood event could wash out road embankment.	**3**	Reduces debris jam risk and opens channel.	**5**	Mitigates debris jam risk and opens channel.
Roadway sustainability (life of solution) (Longest 5, shortest 1)	**1**	Large flood event could wash out road embankment.	**1**	Large flood event could wash out road embankment.	**3**	Reduces debris jam risk and opens channel.	**5**	Mitigates debris jam risk and opens channel.
Impact to hillside stability adjacent to site (Most likely 1; least likely 5)	**1**	No impact to geological stability.	**1**	No impact to geological stability.	**1**	No impact to geological stability.	**3**	Shift in road alignment to construct new bridge may induce hillside instability.
Potential to reduce erosion of banks adjacent to site (Most 5; Least 1)	**1**	Undersized culvert causes bank erosion at outlet.	**3**	Bank erosion at outlet mitigated.	**5**	Channel less constrained.	**5**	Channel not constrained.
Impacts to listed Threatened and Endangered (T&E) terrestrial species and habitat (Least 5; most 1)	**5**	None expected.	**5**	None expected.	**1**	Temporary bypass road.	**1**	Temporary bypass road.
Impacts to listed T&E fish and habitat (Least 5; most 1)	**1**	Fish access not provided.	**3**	Fish access restored, but requires maintenance.	**3**	In-water work.	**5**	Fish access restored.
Impact to upland habitat (Least 5; most 1)	**5**	None expected.	**3**	Impacts from access road.	**3**	Temporary bypass road.	**3**	Temporary bypass road.
Impacts to Wetlands and Waters of the U.S. (Least 5; most 1)	**3**	Large washout could increase turbidity and sedimentation.	**3**	Large washout could increase turbidity and sedimentation.	**3**	In-water work.	**3**	In-water work.
Impact to Designated Wilderness area (Least 5; most 1)	**5**	None expected.	**5**	None expected.	**5**	None expected.	**5**	None expected.
Potential for Hoh River Enhancement (Greatest 5; Least 1)	**1**	Fish access not provided.	**3**	Fish access restored, but requires maintenance to ensure long-term effectiveness.	**5**	Fish access restored.	**5**	Fish access restored.
Potential to maintain or improve river process and function (Most 5; Least 1)	**1**	Constrained channel reduces debris passage.	**1**	Constrained channel reduces debris passage.	**3**	Channel less constrained.	**5**	Channel not constrained.
Potential for other habitat enhancements (Most 5; Least 1)	**1**	Fish access not provided.	**3**	Fish access restored, but requires maintenance.	**5**	Fish access restored.	**5**	Fish access restored.
Potential private property impacts (Least 5; Most 1)	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.
Safety risk of design to public (Least 5; Most 1)	**3**	Large flood event could wash out road.	**3**	Large flood event could wash out road.	**5**	Mitigates wash out risk.	**5**	Mitigates wash out risk.
Total Construction cost		**NA**		**$267,381**		**$884,676**		**$1,655,290**
Total Capital Cost	**5**	**NA**	**5**	**$360,965**	**3**	**$1,194,313**	**1**	**$2,234,642**
Annualized Total Capital Cost (Least 5; Most 1)		**$5,880**		**$26,570**		**$87,910**		**$164,485**
SCORE	**39**		**46**		**58**		**61**	

Table P4-2. Total Expected Cost

Project: Hoh River Road Bank Erosion Risk Study **Date: 3/14/2013**

Site: P4 - East Twin Creek Culvert

Alternative: Continue Maintenance **By: S. Leon**

	Flood Frequency (yr)	Exceedance Probability	Flood Damage	Average Flood Damage	Delta Exceedance Probability	Annual Risk Cost
No debris removal.	2	**0.5**	$0			
				$0	**0.3**	**$0**
No debris removal.	5	**0.2**	$0			
				$0	**0.1**	**$0**
No debris removal.	10	**0.1**	$0			
				$10,000	**0.06**	**$600**
Debris removal.	25	**0.04**	$20,000			
				$20,000	**0.02**	**$400**
Debris removal.	50	**0.02**	$20,000			
				$20,000	**0.01**	**$200**
Debris removal.	100	**0.01**	$20,000			
				$585,000	**0.008**	**$4,680**
Install 20' dia. culvert.	500	**0.002**	$1,150,000			
Total Annual Risk Cost						**$5,880**
Annualized Capital Cost	**Capital Cost**					**$0**
	Disc. rate, i	**0.07125**	**Serv. life, n**	**50**	**CFR**	**0.0736**
	Annualized Capital Cost					**$0**
Total Expected Cost (Annual)						**$5,880**
Summary	Assumes debris removed for flood events larger than 25-year and road embankment is washed out and new 20 feet dia. culvert installed for 500-year.					

Notes:

1. Method from HEC-17, April 1981.

Table P4-3. Cost Estimates

Site: **P4 - East Twin Creek Culvert**

44 Feet Long Bridge with Sheet Pile Wall Abutments

		Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost	LS	1	$	83,300	$	**83,300**
New Road		LF	300	$	500	$	**150,000**
Hillside Stabilization		LS	1	$	50,000	$	**50,000**
Flow Diversion		LS	1	$	20,000	$	**20,000**
Excavation		CY	3,000	$	30	$	**90,000**
44 ft Bridge/50 ft high sheet pile wall abutments		LS	1	$	800,000	$	**800,000**
Riprap	H 8 ft T 5 ft	CY	**444**	$	180	$	**80,000**
	L 120 ft SS 1.75 (h):1(v)						
	TW 6 ft TT 5 ft						
Total Construction Cost without Contingencies						$	**1,273,300**
Contingency	30% of construction cost					$	**381,990**
Total Construction Cost						$	**1,655,290**
Compliance	5% of total construction cost					$	**82,764.50**
Predesign/design (PE)	15% of total construction cost					$	**248,293.50**
Construction Engineering (CE)	15% of total construction cost					$	**248,293.50**
ROW						$	**-**
TOTAL Capital Cost		Cost/Foot	**$ 12,415**			$	**2,234,642**
Annualized Capital Cost		Discount rate, i	0.07125			$	**164,485**
		Service life, n	50	years			
		CFR	**0.0736071**				

Rock Weirs at Existing Culvert Outlet

		Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost	LS	1	$	13,456	$	**13,456**
Flow Diversion		LS	1	$	20,000	$	**20,000**
Access pad - place/remove/reclaim		LS	1	$	30,000	$	**30,000**
Weirs	W 8 ft T 6 ft	CY	**284**	$	500	$	**142,222**
	L 160 ft						
Total Construction Cost without Contingencies						$	**205,678**
Contingency	30% of construction cost					$	**61,703**
Total Construction Cost						$	**267,381**
Compliance	5% of total construction cost					$	**13,369.06**
Predesign/design (PE)	15% of total construction cost					$	**40,107.17**
Construction Engineering (CE)	15% of total construction cost					$	**40,107.17**
ROW						$	**-**
TOTAL Capital Cost						$	**360,965**
Annualized Capital Cost		Discount rate, i	0.07125			$	**26,570**
		Service life, n	50	years			
		CFR	**0.0736071**				

Table P4-3. Cost Estimates

New 20 feet dia. Culvert

		Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost	LS	1	$	44,520	**$**	**44,520**
Flow Diversion		LS	1	$	20,000	**$**	**20,000**
Excavation/backfill		CY	4,000	$	50	**$**	**200,000**
Culvert - 20 feet dia.		LF	124	$	2,000	**$**	**248,000**
Culvert Infill		CY	500	$	120	**$**	**60,000**
Traffic Detour Road		LF	300	$	200	**$**	**60,000**
Concrete headwall/collar		EA	2	$	20,000	**$**	**40,000**
Riprap	H 6 ft T 5 ft L 40 ft	CY	**44**	$	180	**$**	**8,000**
Total Construction Cost without Contingencies						**$**	**680,520**
Contingency	30% of construction cost					**$**	**204,156**
Total Construction Cost						**$**	**884,676**
Compliance	5% of total construction cost					**$**	**44,233.80**
Predesign/design (PE)	15% of total construction cost					**$**	**132,701.40**
Construction Engineering (CE)	15% of total construction cost					**$**	**132,701.40**
ROW						**$**	**-**
TOTAL Capital Cost		Cost/Foot	**$ 29,858**			**$**	**1,194,313**
Annualized Capital Cost		Discount rate, i	0.07125			**$**	**87,910**
		Service life, n	50	years			
		CFR	**0.0736071**				

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P5 - PARK MILEPOST 5.8

BANK STABILIZATION



SITE P5 – PARK MILEPOST 5.8 BANK STABILIZATION

Site Conditions

The site is an unprotected river bank, approximately 50 feet long, 12 feet high, and 40 feet from the edge of the Upper Hoh Road (Fig. P5-1 and Photo P5-2). The bank is experiencing toe erosion and moderate slumping that could eventually undermine the road and utilities located in the road shoulder. The site is part of the Priority Number 5 site in the Flood Prone Facility Assessment report by the NPS (ENTRIX, July 29, 2009).

The site is at the apex of a river meander bend immediately adjacent to the road. Mid-channel sediment deposits deflect ordinary and extreme flood flow towards the stream bank, inducing bank erosion and lateral migration. To prevent loss of the road, the Park has installed approximately 400 lineal feet of riprap bank stabilization. Total length of bank line along meander bend (between inflection points) is 2,400 feet. The riprap is well-vegetated with willows and generally appears adequately sized and placed for controlling the bank erosion (Photo P5-1).

The site is between a debris cone at the mouth of Taft Creek and the riprap bank stabilization. Coarse material in the debris cone inhibits bank erosion along the cone perimeter. Some of the toe erosion experienced at the site may be caused by back-eddy flow from Taft Creek.

Erosion resistant, poorly consolidated alluvium terrace deposits limit river bend migration to the south and north. Historical channel migration zone (HCMZ) boundaries coincide with the terrace deposits. The road is immediately outside the right (looking downstream) boundary. The river bend apex is at the right HCMZ boundary. Width of the HCMZ is approximately 1,000 to 1,200 feet. Active channel width is 400 to 1,000 feet. Ordinary high water flow depth is approximately 4 feet.

Based on Goggle Earth imagery, between 1990 and 2011 the outside bank (bank nearest the road) of the river bend has migrated north 400 feet (Fig. P5-2). Further migration is prevented by the riprap bank stabilization and the Taft Creek debris cone. Down valley translation of the meander bend is limited by the terrace deposits, the Taft Creek debris cone, large trees lining the bank, and a low ridge behind the point bar on the opposite river bank.

The relatively limited down-valley river bend migration, narrowness of the HCMZ, and persistent mid-channel sediment deposits, suggests the site will continue to experience damage-inducing, bank-eroding flood flows. The risk of a catastrophic road failure caused by a single extreme flood is moderately low.

A shallow active flow channel parallels the stream bank (Photo P5-3). Flow discharged from Taft Pond, a water body considered by the Park as critical habitat, is conveyed by the active flow channel. Bank stabilization should not block the channel or induce sediment deposition that blocks the channel.

Considered Options

Continuing maintenance, relocating the road, installing additional bank stabilization, and relocating the river channel were considered. The side channel discharging flow from Taft Pond would potentially be blocked by structures and bank area placed for a minor active river channel shift. A minor active river channel shift was not considered. Table P5-1 presents an evaluation and ranking of the options against design selection criteria.

Riprap is expected to be lost during extreme flooding, requiring replenishment for maintaining the riprap installation's effectiveness. Total Capital and Annualized Total Capital Costs provided in Table P5-1 assume 20 percent of the riprap in an installation is replaced every 50 years.

Douglas fir and hemlock are the most commonly available logs in the area. Douglas-fir logs can remain durable in wetting-drying conditions for 25 to 60 years (Tech. Supp. 14J, Use of Large Woody Material for Habitat and Bank Protection, Part 654, National Engineering Handbook, USDA, Natural Resources Conservation Service). Hemlock is the least durable of the conifers. Because the tree quality and species to be used in the structures is not known, Total Capital and Annualized Total Capital Costs provided in Table P5-1 assume wood used in the alternatives is replaced every 30 years.

Continue Maintenance

Continued maintenance involves monitoring the stream bank areas for excessive bank erosion. Stream bank toe erosion could progress to the point that undermining of the road is imminent. Continued maintenance is placing riprap in an emergency action as needed for preventing a road closure. Placing riprap as an emergency action may be hazardous, difficult, or impossible. The emergency-placed riprap may not be effective in controlling the erosion.

A Total Expected Cost analysis (HEC-17, FHWA, April 1981) was used for estimating total expected cost repairing flood-induced road damage over a 50-year service-life. Based on observed proximity of channel to roadway, and amount of natural bank armoring, the analysis assumes damage requiring new riprap revetment placed as an emergency action for stabilizing an eroding river bank occurs for flood events equal to and larger than the 25-year flood event. The length of unprotected bank area is 50 feet. Assuming 50 feet total for each flood damage event and a cost of $1,000 per foot, the total expected annual cost is $3,500 (Total Expected Cost).

Relocate Road

The steep terrace slope is immediately adjacent to the roadway. The steep hillside and Taft Pond limit a shift in the road alignment to less than 100 feet. The shift would mean an alignment that crosses the terrace slope. Slumping observed on the terrace slope suggests the terrace slope is not geotechnically stable. A new road alignment located across the terrace slope would experience landslides and debris flows that could potentially bury the road with debris. The road alignment may require significant foundation stabilization for mitigating landslides. Length of reroute is estimated to be approximately 300 feet.

Existing riprap revetment is left in place. No stream bank is reconstructed. An unprotected stream bank would be erodible. Lateral bank erosion and migration is expected to be limited and would not undermine the road. A new culvert is assumed for the Taft Pond outlet channel.

Estimated construction cost for the new road is summarized in Table P5-3. Stabilizing landslides may require significantly more money. Construction is expected to occur outside the active flow channel. Turbidity released is expected to be limited in extent and duration. Access for construction is assumed from the existing road. Constructing the new road alignment first and then switching the Upper Hoh Road traffic over before removing the existing road reduces traffic impacts to one-lane closures and short-term delays.

Stabilize Existing Road Embankment

Approximately 50 feet of stream bank is proposed for stabilization.

Alternatives evaluated;

- Complex roughened large rock toe.
- Complex log crib wall.
- Riprap with roughened rock toe, LWD, and riparian plantings.
- Riprap with streambarbs.

Based on field evidence, the site is expected to experience high shear stress, 8 to 12 feet deep flood flows, and abundant floating debris. It is critical that the stabilization methods be properly designed and anchored for maintaining effectiveness and surviving the expected flood conditions.

Construction for all the alternatives is expected to occur entirely within the active flow channel and requires excavating into the streambed and stream bank. Stream work would be accomplished in flowing water. Assuming the work is completed during low flow periods, turbidity released is expected to be limited in extent and duration. Access for construction is assumed down a temporary access route built of riprap and logs. The access route would be removed after construction is completed. Upper Hoh Road traffic impacts are expected to be limited to one-lane closures and short-term delays.

-Complex roughened large rock toe (Appendix A, Sheet 4).

The approach involves placing a rock toe between the expected scour depth and ordinary high water level, approximately 8 to 10 feet high and 5 feet thick. Log bundles spaced 6 to 10 feet apart are placed at the bottom of the rock toe. Soil is placed above the rock toe in overlapping layers of erosion control blanket, approximately 2 to 4 feet high. The rock toe and soil ballast the logs and reduce the risk of the logs floating away. Estimated construction cost for the complex roughened large rock toe is summarized in Table P5-3.

-Complex log crib wall (Appendix A, Sheet 5).

The approach involves placing a log crib wall made of rough logs between the expected scour depth and ordinary high water level, approximately 8 to 10 feet high. Stone is placed within the log crib wall for ballast. Logs with attached root wads extending into the stream bank provide roughness and additional wall stability. All logs are cabled together for enhancing stability. Designs typically include piles driven to refusal or minimum depth of 10 feet. The cobble and boulder stream bed material will likely prevent the piles from being cost-effectively driven or excavated. They are assumed eliminated in the proposed design. Approximately 2 to 4 feet of soil is placed above the crib wall and planted. Estimated construction cost for the complex log crib wall is summarized in Table P5-3.

-Riprap with Roughened Rock Toe, LWD, and Riparian Plantings (Appendix A, Sheet 9).

The approach involves placing a riprap revetment between the expected scour depth and 50-year flood event water level, approximately 10 to 12 feet high, 5 feet thick, and 2(h):1(v) slope. A launchable riprap toe 8 feet wide and 5 feet thick reduces the risk of scour and channel incision undermining the revetment and provides additional stability. Logs or log bundles spaced 6 to 10 feet apart are placed along the revetment toe for providing roughness and channel complexity. The logs are buried in the road embankment for reducing the risk of them floating away. Willow and alder are planted throughout the revetment and bank area above the revetment. Estimated construction cost is summarized in Table P5-3.

-Riprap with Streambarbs (Appendix A, Sheet 11).

The approach involves placing a riprap revetment between the expected scour depth and 50-year flood event water level, approximately 10 to 12 feet high, 5 feet thick, and 2(h):1(v) slope. Instead of a launchable riprap toe, two - 20 to 30 feet long streambarbs are proposed for reducing shear stress and deflecting the river flow away from the revetment. The streambarbs reduce the risk of scour and channel incision undermining the revetment, promote sediment deposition and retention along the bank toe, and creates channel complexity. The bank, riprap, streambarbs, and channel area between the streambarbs would be augmented with streambed material, large woody debris, and planted with riparian vegetation for establishing a riparian buffer. Estimated construction cost is summarized in Table P5-3.

Relocate River Channel

The primary active flow channel can be kept away from the site by placing four to six ELJ's, each at least 60 feet by 100 feet, in a staggered alignment across the mid-channel sediment deposits, approximately 200 feet from the road. Keeping the primary active flow channel away from the road eliminates the current bank erosion road loss risk.

The engineered-log-jams (ELJ's) would be constructed within the active river channel. Top of the ELJ's are set equal to 100-year water surface, estimated to be approximately 5 to 6 feet above the mid-channel sediment deposit surface. Bottom of the ELJ's are set below the active channel thalweg elevation and expected scour depth, approximately 6 feet below the mid-channel sediment deposit surface. Each ELJ is ballasted with stone and logs cabled together for keeping them in place against expected flow depth and velocity and additional woody debris accumulation.

The existing revetment is left in place. Off-channel rearing and resting habitat is created along the toe of the existing road embankment. Assuming the primary flow channel remains along the left bank, a temporary channel for diverting stream flow from the construction area is expected not to be needed.

Estimated construction cost is summarized in Table P5-3. Turbidity released is expected to be limited in extent and duration. Ramps constructed over the existing road embankment could provide temporary access for construction and permanent access for maintenance. Upper Hoh Road traffic impacts are expected to be limited to one-lane closures and short-term delays.

Executive Order 11988, Floodplain Management, established federal policies for protecting floodplains and floodways. The intention of the associated regulations is to avoid, to the extent practical, adverse impacts to floodplains; minimize the impact of floods to human safety, health, and welfare; and avoid supporting land use development that is incompatible with the natural and beneficial floodplain values. When avoidance is not possible, the policies require appropriate consideration of methods to minimize adverse impacts.

Keeping the primary active flow channel 200 feet south provides opportunity for creating off-channel rearing and resting habitat along the toe of the existing road embankment. It is not expected to have a direct negative impact on private property adjacent to and downstream of the Park. Keeping the primary active flow channel more than 200 feet south would likely induce dramatic downstream bank erosion and stream avulsion, resulting in unnatural changes in the HCMZ boundaries. A channel relocation project would include a detailed geomorphic analysis for verifying the no-direct-impact assumption.

Environmental Clearance Considerations

This section of road extends through OLYM-managed lands and is situated just prior to the entrance to the Hoh Rain Forest Visitor Center and Campground to the east. To the west of this site, Taft Creek crosses the road via a large culvert. Underground utilities are located on both sides of the road. To the immediate east, a stream was constructed to provide salmon migrating in the Hoh River, access to spawning grounds on the north side of the road. The Hoh Tribe has considerable interest in these spawning grounds. Possible adverse effects to the spawning grounds by sedimentation, unintentional drainage of the spawning grounds, or cutting off access to the spawning grounds from the Hoh River are of considerable concern.

As currently proposed, none of the options would impact designated wilderness areas.

The culvert at Taft Creek is perched. However, it is not believed that the creek was historically inhabited by fish given the steep grade. As a result, fish passage is not a concern at this location.

National Wetland Inventory maps indicate that the area of concern does not appear to have wetlands, but valuable wetlands are located to the east in the form of the salmon spawning grounds.

There is a forested area immediately to the north of the project area, dominated by large conifers, including Douglas fir, Sitka spruce, western hemlock, and red cedar. Willow and alder trees occupy the riparian areas on the south side of the road. The coniferous forest provides suitable habitat for the marbled murrelet and northern spotted owl. Designated bull trout critical habitat is located in the Hoh River.

Continue Maintenance

Environmental Clearance Considerations under this alternative are the same as those described for Site P1. In addition, failure of the road at this location during a storm event could very likely result in permanent loss of the valuable salmon spawning grounds to the northeast of the road.

Relocate Road

Road relocation would provide little to no additional benefit to the aquatic species, including bull trout given that the existing revetment would need to stay in place. Relocating the road would also likely involve tree removal and have the potential to adversely impact the salmon spawning grounds. This option would require the preparation of a biological assessment to evaluate impacts to marbled murrelet, northern spotted owl, and bull trout individuals and critical habitat.

If wetlands are present, then a 404 permit and 401 Water Quality Certification would be required.

Stabilize Existing Road Embankment

Environmental Clearance Considerations under this alternative are the same as those described for Site P1.

Relocate Active River Channel

Environmental Clearance Considerations under this alternative are the same as those described for Site P1.

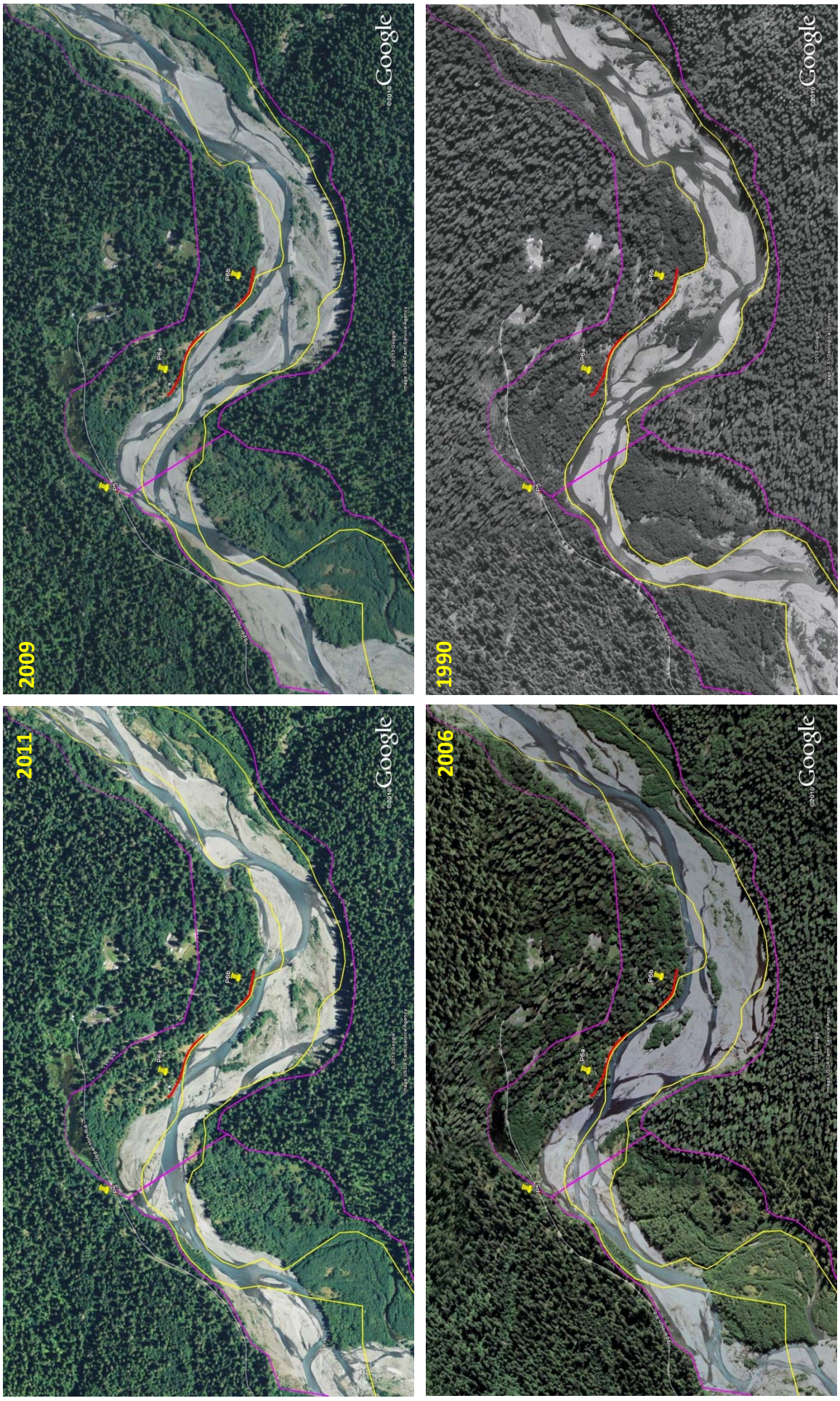
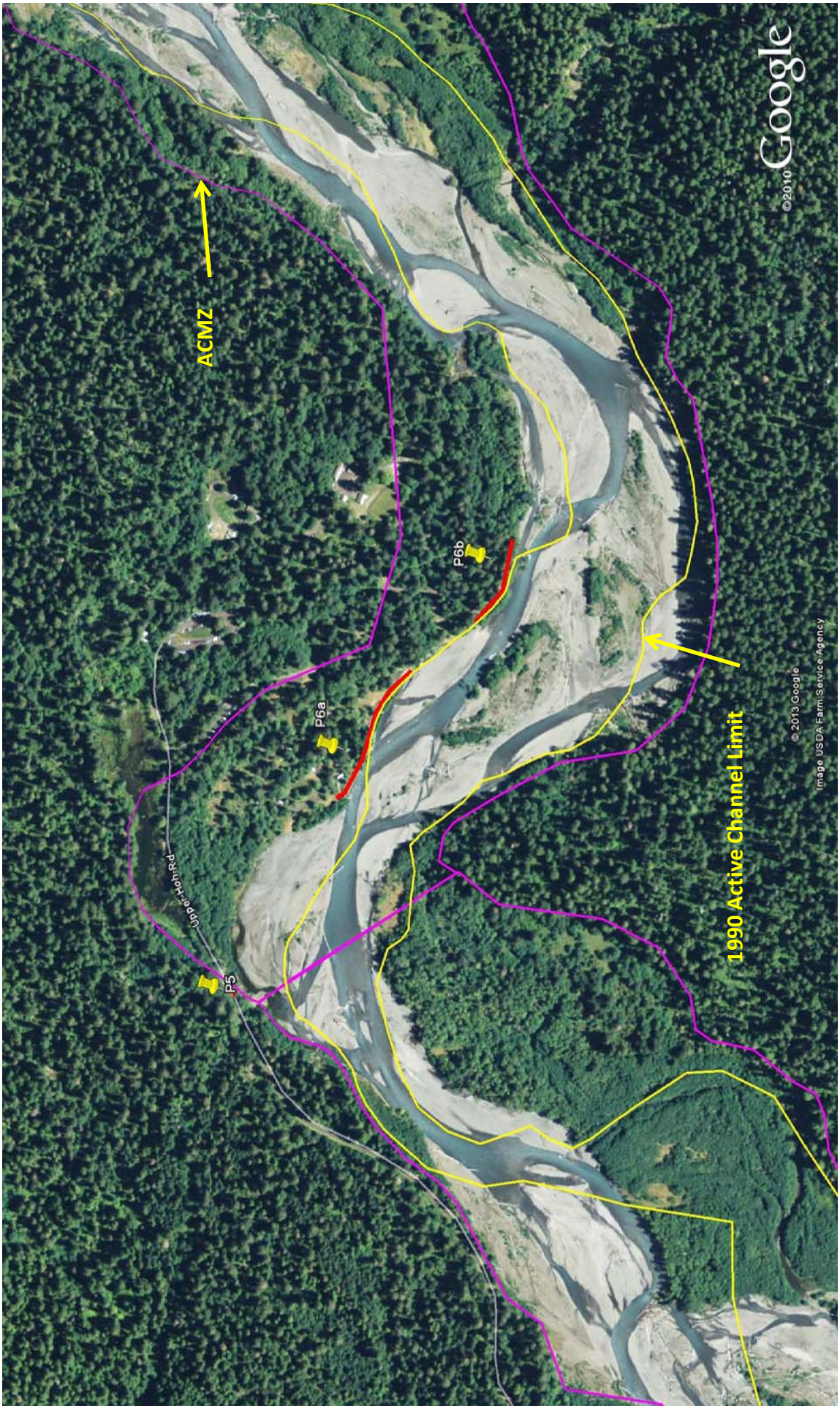


Figure P5-2. Historical Satellite Imagery



ACMZ - Active Channel Migration Zone, Geomorphic Assessment of Hoh River in Washington State, USBR, July 2004.

Imagery date 9/25/2011

Figure P5-1. Site Location

Photos

P5 - PMP 5.8 Bank Stabilization



PHOTO P5-1

Looking downstream along bank.

Riprap ends downstream side of willows. Taft Creek debris cone downstream of site.



PHOTO P5-2

Looking upstream along bank.

Riprap ends downstream side of willows. Taft Creek debris cone downstream of site.



PHOTO P5-3

Looking upstream along bank.

Active flow channel conveys water discharged from Taft Pond.

12/12/2012

Table P5-1. Alternative Summary and Ranking.

Upper Hoh River Road Site - P5 - PMP 5.8 Bank Stabilization

						Bank Stabilization									
OPTIONS	**Rank**	**Continued Maintenance**	**Rank**	**Relocate Road**	**Rank**	**Complex Roughened Large Rock Toe**	**Rank**	**Complex Log Crib Wall**	**Rank**	**Riprap with LWD and Plantings**	**Rank**	**Riprap with Streambarbs**	**Rank**	**ELJ's to shift active river channel**
Road on the edge of the channel migration zone has less of an impact to the total channel zone.		**Place or replace riprap as needed for preventing road closure.**		**Offset Road 100 Feet with no mitigation of existing roadway slope to riparian zone.**		**Rock toe with LWD.**		**Log crib wall with roughness elements.**		**Riprap similar to what is commonly used along Upper Hoh River Road embankment.**		**Bank area planted with willow and alder.**		**Shift active flow channel to flow across gravel bar away from revetment area.**
Ability to preserve and operate the roadway in a specific location (Most able 5, least able 1)	**3**	Reduces risk of a catastrophic road failure during extreme flood event.	**3**	Better than where it is, but the river may eventually migrate north and impact road again.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic road failure during extreme flood event.
Roadway sustainability (life of solution) (Longest 5, shortest 1)	**1**	Increased maintenance in the future mitigating climate change or after large flood events.	**3**	Increase road life reduces future risk from river. Road near hillside may experience landslides and debris flows.	**3**	Requires moderate amount of wood replacement and maintenance.	**1**	Requires substantial amount of wood replacement and maintenance.	**3**	Requires moderate amount of wood replacement and maintenance.	**5**	Requires moderate level of maintenance.	**1**	Requires substantial amount of wood replacement and maintenance.
Impact to hillside stability adjacent to site (Most likely 1; least likely 5)	**5**	No expected additional impacts.	**1**	Road near hillside may experience landslides and debris flows.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.
Potential to reduce erosion of banks adjacent to site (Most 5; Least 1)	**1**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**1**	Likely increase down stream right bank erosion.
Impacts to listed Threatened and Endangered (T&E) terrestrial species and habitat (Least 5; most 1)	**5**	No expected additional impacts.	**1**	Impacts upland areas and potentially T&E.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.
Impacts to listed T&E fish and habitat (Least 5; most 1)	**3**	Placed riprap reduces habitat complexity.	**3**	Existing riprap remains.	**3**	Material placed in channel.	**3**	Material placed in channel.	**3**	Material placed in channel.	**1**	Riprap along bank reduces habitat complexity. Barbs require significant excavation into channel bed.	**3**	Considerable temporary impacts from in-stream channel work.
Impact to upland habitat (Least 5; most 1)	**5**	No expected additional impacts.	**1**	Impacts upland areas.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.
Impacts to Wetlands and Waters of the U.S. (Least 5; most 1)	**3**	No expected additional impacts to wetlands; riprap placement in river.	**1**	May impact sensitive wetlands.	**3**	No expected additional impacts to wetlands; riprap placement in river.	**3**	Material placed in channel.	**3**	No expected additional impacts to wetlands; riprap placement in river.	**1**	Riprap along bank reduces habitat complexity. Barbs require significant excavation into channel bed.	**1**	Requires major in stream construction.
Impact to Designated Wilderness area (Least 5; most 1)	**5**	No expected impacts.	**5**	No expected impacts.	**5**	No expected impacts.	**5**	No expected impacts.	**5**	No expected impacts.	**5**	No expected impacts.	**5**	No expected impacts.
Potential for Hoh River Enhancement (Greatest 5; Least 1)	**1**	Does not provide river enhancements.	**1**	Does not provide river enhancements.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Moves thalweg away from road, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.
Potential to maintain or improve river process and function (Most 5; Least 1)	**1**	Does not improve river process and function.	**5**	Allows river to fully access HCMZ	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Moves thalweg away from road, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from road, adds bank area, improves sediment transport and habitat complexity.
Potential for other habitat enhancements (Most 5; Least 1)	**1**	Does not provide other habitat enhancements.	**1**	Does not provide other habitat enhancements.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**1**	Does not provide other habitat enhancements.	**5**	Provides woody debris for habitat complexity and biological processes.
Potential private property impacts (Least 5; Most 1)	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**1**	Impacts likely from bank erosion downstream of site.
Safety risk of design to public (Least 5; Most 1)	**5**	No expected increase in safety risk.	**3**	Boaters could become trapped in root wads.	**3**	Boaters could become trapped in root wads.	**1**	Public could fall down wall. Boaters could become trapped in root wads.	**3**	Boaters could become trapped in root wads.	**5**	No expected increase in safety risk.	**1**	Boaters could become trapped in ELJ's.
Total Construction cost	**5**	**NA**	**1**	**$695,500**	**3**	**$43,662**	**3**	**$115,917**	**3**	**$152,752**	**3**	**$151,593**	**1**	**$2,573,350**
Riprap and Wood Replacement (50 years)		**NA**		**$0**		**$15,833**		**$32,222**		**$23,167**		**$25,000**		**$1,800,000**
Total Capital Cost (50 years)		**NA**		**$938,925**		**$74,777**		**$188,710**		**$229,382**		**$229,651**		**$5,274,023**
Annualized Total Capital Cost (Least 5; Most 1)		**$3,500**		**$69,112**		**$5,504**		**$13,890**		**$16,884**		**$16,904**		**$388,206**
SCORE	**49**		**38**		**57**		**53**		**57**		**55**		**49**	

Table P5-2. Total Expected Cost

Project: Hoh River Road Bank Erosion Risk Study **Date: 3/14/2013**

Site: P5 - PMP 5.8 Bank Stabilization

Alternative: Continue Maintenance **By: S. Leon**

	Flood Frequency (yr)	Exceedance Probability	Flood Damage	Average Flood Damage	Delta Exceedance Probability	Annual Risk Cost
No damage.	2	**0.5**	$0			
				$0	**0.3**	**$0**
No damage.	5	**0.2**	$0			
				$0	**0.1**	**$0**
No damage.	10	**0.1**	$0			
				$25,000	**0.06**	**$1,500**
Place riprap.	25	**0.04**	$50,000			
				$50,000	**0.02**	**$1,000**
Place riprap.	50	**0.02**	$50,000			
				$50,000	**0.01**	**$500**
Place riprap.	100	**0.01**	$50,000			
				$50,000	**0.01**	**$500**
		0	$50,000			
Total Annual Risk Cost						**$3,500**
Annualized Capital Cost	**Capital Cost**					**$0**
	Disc. rate, i	**0.07125**	**Serv. life, n**	**50**	**CFR**	**0.0736**
	Annualized Capital Cost					**$0**
Total Expected Cost (Annual)						**$3,500**
Summary	Assume 50 feet ($1k/ft) of bank armoring for each flood damage event.					

Notes:

1. Method from HEC-17, April 1981.

Table P5-3. Cost Estimates

Site: **P5 - PMP 5.8 Bank Stabilization**

Relocate Road

		Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost	LS	1	$	35,000	$	**35,000**
New Road		LF	300	$	500	$	**150,000**
Hillside Stabilization		LS	1	$	50,000	$	**50,000**
Remove Existing Revetment		LF	-	$	200	$	**-**
Streambank Reconstruction		LF	-	$	1,000	$	**-**
Streambarbs		EA	-	$	40,000	$	**-**
Concrete Box Culvert		EA	1	$	300,000	$	**300,000**
Total Construction Cost without Contingencies						$	**535,000**
Contingency	30% of construction cost					$	**160,500**
Total Construction Cost						$	**695,500**
Compliance	5% of total construction cost					$	**34,775**
Predesign/design (PE)	15% of total construction cost					$	**104,325**
Construction Engineering (CE)	15% of total construction cost					$	**104,325**
ROW						$	**-**
Riprap replacement -	20% replacement every		50	years		$	**-**
Wood replacement -	full log replacement every		30	years			
TOTAL Capital Cost		Cost/Foot	**$ 3,130**			$	**938,925**
Annualized Capital Cost		Discount rate, i	0.07125			$	**69,112**
		Service life, n	50	years			
		CFR	**0.0736071**				

Complex Roughened Large Rock Toe

			Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost		LS	1	$	2,197	$	**2,197**
Remove Existing Revetment			LF	-	$	200	$	**-**
Rock	H 10 ft	T 5 ft	CY	**93**	$	180	$	**16,667**
	L 50 ft							
Logs	L 50 ft	XS 8 ft	EA	**6**	$	2,000	$	**12,500**
Soil	H 3 ft	T 10 ft	CY	**56**	$	40	$	**2,222**
	L 50 ft							
Total Construction Cost without Contingencies							$	**33,586**
Contingency	30% of construction cost						$	**10,076**
Total Construction Cost							$	**43,662**
Compliance	5% of total construction cost						$	**2,183**
Predesign/design (PE)	15% of total construction cost						$	**6,549**
Construction Engineering (CE)	15% of total construction cost						$	**6,549**
ROW							$	**-**
Riprap replacement -	20% replacement every			50	years		$	**3,333**
Wood replacement -	full log replacement every			30	years		$	**12,500**
TOTAL Capital Cost			Cost/Foot	**$ 1,496**			$	**74,777**
Annualized Capital Cost			Discount rate, i	0.07125			$	**5,504**
			Service life, n	50	years			
			CFR	**0.0736071**				

Table P5-3. Cost Estimates

Complex Log Crib Wall

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost			LS	1	$	5,833	$	5,833
Remove Existing Revetment				LF	200	$	200	$	40,000
Rock	H 10 ft	T 5 ft		CY	93	$	120	$	11,111
	L 50 ft								
Logs	L 50 ft	H 12 ft		EA	15	$	2,000	$	30,000
	Dia 2 ft	Row 6							
	log l 20 ft	No. 15							
Piles				EA	0	$	-	$	-
Soil	H 3 ft	T 10 ft		CY	56	$	40	$	2,222
	L 50 ft								
Total Construction Cost without Contingencies								$	89,167
Contingency	30% of construction cost							$	26,750
Total Construction Cost								$	115,917
Compliance		5% of total construction cost						$	5,796
Predesign/design (PE)		15% of total construction cost						$	17,388
Construction Engineering (CE)		15% of total construction cost						$	17,388
ROW								$	-
Riprap replacement -	20% replacement every				50 years			$	2,222
Wood replacement -	full log replacement every				30 years			$	30,000
TOTAL Capital Cost			Cost/Foot	$ 3,774				$	188,710
Annualized Capital Cost			Discount rate, i	0.07125				$	13,890
			Service life, n	50 years					
			CFR	0.0736071					

Riprap with Roughened Rock Toe, LWD, and Riparian Plantings

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost			LS	1	$	7,687	$	7,687
Remove Existing Revetment				LF	200	$	200	$	40,000
Riprap	H 12 ft	T 5 ft		CY	296	$	180	$	53,333
	L 50 ft	SS 2 (h):1(v)							
	TW 8 ft	TT 5 ft							
Logs	L 50 ft	XS 8 ft		EA	6	$	2,000	$	12,500
Willow	100 sy	XS 2		EA	50	$	10	$	500
Alder	100 sy	XS 1		EA	100	$	20	$	2,000
Soil	H 2 ft	T 10 ft		CY	37	$	40	$	1,481
	L 50 ft								
Total Construction Cost without Contingencies								$	117,502
Contingency	30% of construction cost							$	35,251
Total Construction Cost								$	152,752
Compliance		5% of total construction cost						$	7,638
Predesign/design (PE)		15% of total construction cost						$	22,913
Construction Engineering (CE)		15% of total construction cost						$	22,913
ROW								$	-
Riprap replacement -	20% replacement every				50 years			$	10,667
Wood replacement -	full log replacement every				30 years			$	12,500
TOTAL Capital Cost			Cost/Foot	$ 4,588				$	229,382
Annualized Capital Cost			Discount rate, i	0.07125				$	16,884
			Service life, n	50 years					
			CFR	0.0736071					

Table P5-3. Cost Estimates

Riprap with Streambarbs

			Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost		LS	1	$	7,629	$	**7,629**
Remove Existing Revetment			LF	-	$	200	$	**-**
Riprap	H 12 ft	T 5 ft	CY	**222**	$	180	$	**40,000**
	L 50 ft	SS 2 (h):1(v)						
	TW 0 ft	TT 0 ft						
Streambarbs			EA	2	$	30,000	$	**60,000**
Logs	L 50 ft	XS 20 ft	EA	**3**	$	2,000	$	**5,000**
Willow	100 sy	XS 2	EA	**50**	$	10	$	**500**
Alder	100 sy	XS 1	EA	**100**	$	20	$	**2,000**
Soil	H 2 ft	T 10 ft	CY	**37**	$	40	$	**1,481**
	L 50 ft							
Total Construction Cost without Contingencies							$	**116,610**
Contingency	30% of construction cost						$	**34,983**
Total Construction Cost							$	**151,593**
Compliance	5% of total construction cost						$	**7,580**
Predesign/design (PE)	15% of total construction cost						$	**22,739**
Construction Engineering (CE)	15% of total construction cost						$	**22,739**
ROW							$	**-**
Riprap replacement -	20% replacement every			50	years		$	**20,000**
Wood replacement -	full log replacement every			30	years		$	**5,000**
TOTAL Capital Cost			Cost/Foot	**$ 4,593**			$	**229,651**
Annualized Capital Cost		Discount rate, i		0.07125			$	**16,904**
		Service life, n		50	years			
		CFR		**0.0736071**				

Relocate River Channel

		Unit	Quantity		Unit Cost		Total Cost
Mobilization	7% of construction cost	LS	1	$	129,500	$	**129,500**
Channel Excavation - 100 feet by 5 feet		LF	-	$	300	$	**-**
Rearing and Resting Habitat Construction		AC	1.0	$	50,000	$	**50,000**
Remove Existing Revetment		LF	-	$	200	$	**-**
Streambank Reconstruction		LF	-	$	1,000	$	**-**
Streambarbs		EA	-	$	40,000	$	**-**
ELJ's - 20 ft by 60 ft		EA	6	$	300,000	$	**1,800,000**
Total Construction Cost without Contingencies						$	**1,979,500**
Contingency	30% of construction cost					$	**593,850**
Total Construction Cost						$	**2,573,350**
Compliance	5% of total construction cost					$	**128,668**
Predesign/design (PE)	15% of total construction cost					$	**386,003**
Construction Engineering (CE)	15% of total construction cost					$	**386,003**
ROW						$	**-**
Riprap replacement -	20% replacement every		50	years		$	**-**
Wood replacement -	full log replacement every		30	years		$	**1,800,000**
TOTAL Capital Cost		Cost/Foot	**#DIV/0!**			$	**5,274,023**
Annualized Capital Cost		Discount rate, i	0.07125			$	**388,206**
		Service life, n	50	years			
		CFR	**0.0736071**				

P6 - PARK MILEPOST 7.0

HOH RIVER CAMPGROUND BANK STABILIZATION



SITE P6 – PARK MILEPOST 7.0 CAMPGROUND BANK STABILIZATION

Site Conditions

Park campground facilities lie within the inside bank line of a river meander bend (Fig. P6-1). A mid-channel island deflects ordinary and extreme flood flows towards the stream bank on the south, southwest, and west side of the campground. Coarse boulder and cobble overlain by cobble-gravel-sand comprise the stream bank material. The bank is approximately 6 feet high, nearly devoid of erosion-limiting vegetation, and is generally highly erodible.

The Park has installed approximately 1,200 lineal feet of riprap armoring along the bank southwest of the campground facilities for controlling bank erosion. Total length of bank line along meander bend (between inflection points) is 2,500 feet. Except where noted below, the riprap armoring generally appears adequate for controlling erosion under current active flow channel locations. The stable appearing armoring consists of predominantly two sizes of riprap, a smaller 1 to 2 feet diameter and a larger 3 to 4 feet diameter. Proportions of the two sizes are approximately equal. Finished slope of the riprap is 1(h):5(v) or flatter. Riprap thickness is observed to be 3 to 4 feet. A geotextile underlayment was observed at the upstream end of the bank armoring and was assumed to be present under all the placed riprap (Photo P6b-1). The stable armoring is densely planted with willow and/or alder (Photos P6b-8 and 9).

Two areas of excessive erosion that threatens campground facilities were observed; P6a and P6b (Fig. P6-1).

-P6a (total 600 lineal feet bank area at risk)

The stream bank for approximately 300 feet immediately downstream of the riprap armoring is actively eroding (Fig. P6-1, P6a, Photos P6a-3 and 4). Top of bank is within 10 feet of some campground units and have required closure of the sites due to safety concerns. An active flow channel is immediately adjacent to and impinging on the eroding bank. Continued bank erosion could result in loss of campground units and access roads.

Approximately 300 feet of the downstream end of the riprap armoring is failing (Photos P6a-1 and 2). Numerous stones were observed dislodged from the bank. Finished slope of the riprap is 1(h):1(v) or steeper. Riprap thickness is observed to be 3 to 4 feet. Upper bank areas where not stabilized with rock show evidence of undercutting by the stream and slumping. An active back bar flow channel is immediately adjacent to the bank line. Continued loss of the riprap armoring could result in loss of campground units and access roads.

-P6b (total 450 lineal feet bank area at risk)

Approximately 450 feet of the upstream end of the riprap armoring is severely eroding (Fig. P6-1, P6b). Numerous stones were observed dislodged from the bank (Photos P6b-1 and 2). Finished slope of the riprap is 1(h):1(v) or steeper. Riprap thickness is observed to be 3 to 4 feet. Upper bank areas where not stabilized with rock show evidence of undercutting by the stream and slumping. Approximately 180 feet of the armoring has lost all of the riprap, leaving only a steep, eroding bank (Photos P6b-3 and 4). Top of bank is 10 to 20 feet from campground and picnic units. An active flow channel is immediately adjacent to and impinging on the eroding bank (Photo P6b-5). Continued bank erosion could result in loss of campground units and access roads. The upstream end of the riprap armoring terminates behind a point bar sediment deposit and is not currently experiencing excessive erosion damage (Photo P6b-7). River flow is deflected towards the bank area from mid-channel sediment deposits and large woody debris (Photos P6b-5 and 6). Erosion of the point bar and eventual damage to or loss of the riprap armoring is expected.

Erosion resistant, poorly consolidated alluvium terrace deposits limit river bend migration to the south and north. Historical channel migration zone (HCMZ) boundaries coincide with the terrace deposits. Campground facilities are both within and outside of the right (looking downstream) boundary (Fig. P6-1). The river bend apex is at the left HCMZ boundary. Width of the HCMZ is approximately 1,400 to 2,000 feet. Active channel width is 400 to 1,000 feet. Ordinary high water flow depth is approximately 4 to 5 feet.

Based on Goggle Earth imagery, between 1990 and 2011 the outside bank (bank opposite the campground) of the river bend immediately downstream of the bend apex has migrated southwest 180 feet (Fig. P6-2). This bank area will likely continue to migrate to the southwest in a down-valley direction. Migration will be limited by a low ridge and abundant large trees found on the bank and floodplain. Formation of a cutoff channel is unlikely. The bank area immediately downstream of this point has not experienced noticeable migration and appears relatively stable, likely a result of the erosion-resistant low ridge and abundant large trees. The bank at the apex has migrated south 70 feet. The terrace deposits and large trees lining the bank have limited the erosion and bank migration rate. Additional substantial migration into the south valley wall is not expected.

The inside bank (adjacent to the campground) at the bend apex has migrated north approximately 300 feet since 1990. Large woody debris and mid-channel sediment deposits have likely significantly influenced active channel migration and subsequent bank erosion (Photos P6a-5 and 6, Photos P6b-5 and 6).

The relatively limited down-valley river bend migration, narrowness of the HCMZ, and persistent mid-channel sediment deposits, suggest the riprap armoring and eroding stream bank areas will continue to experience damage-inducing, bank-eroding flood flows. The risk of a catastrophic camp site or access road loss caused by a single extreme flood is high. Bank heights and floodplain roughness is adequate for greatly reducing the risk of a river channel avulsion through the facilities.

Considered Options

Continuing maintenance, installing additional bank stabilization, minor active river channel shift, and major active river channel shift were considered. Relocating the campground facility was beyond the report scope and was not considered. Table P6-1 presents an evaluation and ranking of the options against design selection criteria.

Riprap is expected to be lost during extreme flooding, requiring replenishment for maintaining the riprap installation's effectiveness. Total Capital and Annualized Total Capital Costs provided in Table P6-1 assume 20 percent of the riprap in an installation is replaced every 50 years.

Douglas fir and hemlock are the most commonly available logs in the area. Douglas-fir logs can remain durable in wetting-drying conditions for 25 to 60 years (Tech. Supp. 14J, Use of Large Woody Material for Habitat and Bank Protection, Part 654, National Engineering Handbook, USDA, Natural Resources Conservation Service). Hemlock is the least durable of the conifers. Because the tree quality and species to be used in the structures is not known, Total Capital and Annualized Total Capital Costs provided in Table P6-1 assume wood used in the alternatives is replaced every 30 years.

<u>Continue Maintenance</u>

Continued maintenance involves monitoring the stream bank and riprap armoring areas for excessive bank erosion. Bank erosion could progress to the point that undermining of campground facilities is imminent. Continued maintenance is placing riprap in an emergency action as needed for preventing a safety hazard or campground facility closure. Placing riprap

as an emergency action may be hazardous or difficult. The emergency-placed riprap may not be effective in controlling the erosion.

A Total Expected Cost analysis (HEC-17, FHWA, April 1981) was used for estimating total expected cost repairing flood-induced bank stabilization damage over a 50-year service-life. Based on observed proximity of channel to the campground facilities, condition of riprap armoring, and amount of natural bank armoring, the analysis assumes damage requiring new riprap armoring placed as an emergency action for stabilizing an eroding river bank occurs for flood events equal to and larger than the 10-year flood event. Based on review of historical satellite imagery, length of bank typically exposed to impinging flood flow is estimated to be approximately 300 to 400 feet. Based on vegetation distribution and age and estimated riprap placement sequencing, the length of past armoring installations ranged from 300 to 500 feet. Assuming 300 feet total for each flood damage event and a cost of $1,000 per foot, the total expected annual cost is $45,000 (Table P6-2, Total Expected Cost).

Stabilize Existing Streambank

Approximately 1,050 feet of stream bank is proposed for stabilization.

Alternatives evaluated;

- Complex roughened large rock toe.
- Complex log crib wall.
- Riprap with roughened rock toe, LWD, and riparian plantings.
- Riprap with streambarbs.

Based on field evidence, the site is expected to experience high shear stress, 8 to 12 feet deep flood flows, and abundant floating debris. It is critical that the stabilization methods be properly designed and anchored for maintaining effectiveness and surviving the expected flood conditions.

Construction for all the alternatives is expected to occur entirely within the active flow channel and requires excavating into the streambed and stream bank. Stream work would be accomplished in flowing water. Assuming the work is completed during low flow periods, turbidity released is expected to be limited in extent and duration. Access for construction is assumed down temporary access routes built of riprap, soil, and logs. The access route would be removed after construction is completed. Campground traffic and use impacts are expected to be limited to unit closures and short-term use delays.

-Complex roughened large rock toe (Appendix A, Sheet 4).

The approach involves placing a rock toe between the expected scour depth and ordinary high water level, approximately 8 to 10 feet high and 5 feet thick. Log bundles spaced 6 to 10 feet are placed at the bottom of the rock toe. Soil is placed above the rock toe in overlapping layers of erosion control blanket, approximately 1 to 2 feet. The rock toe and soil ballast the logs and reduce the risk of the logs floating away. Approximately 300 feet of the failing riprap armoring is removed. Construction will occur along the existing bank line. Estimated construction cost for the complex roughened large rock toe is summarized in Table P6-3.

-Complex log crib wall (Appendix A, Sheet 5).

The approach involves placing a log crib wall made of rough logs between the expected scour depth and ordinary high water level, approximately 8 to 10 feet high. Stone is placed within the log crib wall for ballast. Logs with attached root wads extending into the stream bank provide roughness and additional wall stability. All logs are cabled together for enhancing stability. Designs typically include piles driven to refusal or minimum depth of 10 feet. The cobble and

boulder stream bed material will likely prevent the piles from being cost-effectively driven or excavated. They are assumed eliminated in the proposed design. Approximately 1 to 2 feet of soil is placed above the crib wall and planted. Approximately 300 feet of the failing riprap armoring is removed. Construction will occur along the existing bank line. Estimated construction cost for the complex log crib wall is summarized in Table P6-3.

-Riprap with Roughened Rock Toe, LWD, and Riparian Plantings (Appendix A, Sheet 9).

The approach involves placing a riprap revetment between the expected scour depth and 50-year flood event water level, approximately 10 to 12 feet high, 5 feet thick, and 2(h):1(v) slope. A launchable riprap toe 8 feet wide and 5 feet thick reduces the risk of scour and channel incision undermining the revetment and provides additional stability. Logs or log bundles spaced 6 to 10 feet are placed along the revetment toe for providing roughness and channel complexity. The logs are buried in the streambank for reducing the risk of them floating away. Willow and alder are planted throughout the revetment and bank area above the revetment. Approximately 300 feet of the failing riprap armoring is removed. Construction will occur along the existing bank line. Estimated construction cost is summarized in Table P6-3.

-Riprap with Streambarbs (Appendix A, Sheet 11).

The approach involves placing a riprap revetment between the expected scour depth and 50-year flood event water level, approximately 10 to 12 feet high, 5 feet thick, and 2(h):1(v) slope. Instead of a launchable riprap toe, two - 20 to 30 feet long streambarbs are proposed for reducing shear stress and deflecting the river flow away from the revetment. The streambarbs reduce the risk of scour and channel incision undermining the revetment, promote sediment deposition and retention along the bank toe, and creates channel complexity. The bank, riprap, streambarbs, and channel area between the streambarbs would be augmented with streambed material, large woody debris, and planted with riparian vegetation for establishing a riparian buffer. Approximately 300 feet of the failing riprap armoring is removed. Construction will occur along the existing bank line. Estimated construction cost is summarized in Table P6-3.

Minor Active River Channel Shift

An environmentally desirable approach would be to nudge the active river channel over enough from the campground facility to reestablish a riparian buffer. Ideally, the buffer would have the same erosion resistance of a natural, wooded and vegetated river bank. The buffer would need to be wide enough to allow some bank erosion without threatening the campground facility. It would be made by placing alluvial material over existing riprap armoring and unstable bank areas. To promote vegetation establishment and soil mass stability, the finished surface of the buffer area should not be steeper than 5(h):1(v). Assuming an 8 feet high bank, the width of the new buffer area would be at least 40 feet. Existing relative stable riparian buffers observed along the river are at least 40 to 50 feet wide and densely vegetated with alder and fir. The new buffer area would be prone to erosion from active channel migration. Erosive forces are expected to be too large for passive and bio-engineering methods to be effective by themselves. Hardened, more erosion resistant components in the buffer system are needed for mitigating the erosive forces.

-Engineered-log-jam Groins.

ELJ's groins constructed perpendicular to the stream bank and extending through the new buffer area would control channel location and deflect river flow away from new buffer area (Appendix A, Sheet 10). An ELJ's buoyancy and sliding analysis (Design Guidelines for Reintroducing Wood in Australian Streams, Abbe/Brooks, 2006) was completed assuming 6 feet design flow depth, 5 feet design scour depth, 8 feet per second average flow velocity, 1.5 velocity correction factor, and 18-inch average trunk diameter. The river bed contains cobbles

and small boulders. Piles would need to penetrate the river bottom at least 20 to 30 feet for providing adequate resistance to buoyancy and sliding. Tree trunk piles would likely splinter before reaching the desired design depth. As wood decays, it losses strength and cannot resist the shear stresses created by a sliding ELJ mass. Driving steel piles for pinning the ELJ structure to the river bottom would be expensive and leave a tangle of steel piles protruding from the river bottom. Based on the analysis, an ELJ structure 15 feet wide and ballasted with stone is needed for achieving a minimum sliding factor-of-safety of 2.0, the minimum needed for unknown flow conditions and resisting expected additional woody debris accumulation.

Each ELJ groin would be 40 feet long and constructed of two 15 feet wide by 20 feet long modules. Assuming 2 to 3 feet gaps between logs and 8 layers, approximately 50 logs are needed for each module and 100 for each groin. Based on the stability analysis, 100 cubic yards of ballast stone is needed for each ELJ groin for achieving minimum sliding and buoyancy factor-of-safeties of 2.0, the minimum needed for unknown flow conditions and resisting expected additional woody debris accumulation. The logs are cabled together for keeping them in place against expected flow depth and velocity and additional woody debris accumulation.

-Riprap Streambarbs.

Streambarbs are an alternative to using ELJ groins for controlling channel location and reducing erosive forces (Appendix A, Sheet 10). Each stream barb would be angled upstream 30 degree relative the bank line and approximately 90 feet long for fitting within the new riparian buffer. Assuming Class 8 riprap, crest width is 8 feet. Barb thickness is 6 feet at base and 6 feet at tip. Barb bottom width is 23 feet at base and 23 feet at tip. Approximately 310 cubic yards of riprap is needed for each stream barb.

Based on review of historical satellite imagery, length of bank typically exposed to impinging flood flow is estimated to be approximately 150 to 200 feet. The radius of curvature for active channel is 200 to 500 feet. To effectively deflect the impinging river flow away from the new bank area, the ELJ groins or stream barbs would need to be spaced every 100 to 150 feet. Assuming the new bank area is placed over sites P6a and P6b, approximately 1,050 feet of new bank area is created and ten ELJ groins or stream barbs are needed.

The existing riprap armoring is assumed left in place. Stream bank area is constructed between the ELJ groins or stream barbs by placing conserved and imported stream bed and bank material. Willow and cottonwood trees are planted throughout the area. Willow fascines are placed along the lower 3 to 6 feet of the bank toe for controlling erosion. Large wood is incorporated randomly throughout the bank area.

Estimated construction cost is summarized in Table P6-3. Work will be within the active river channel and requires temporarily diverting the river flow. Flow defection is assumed accomplished with large sandbags or water-inflated bladders. Dewatering the work area would be extremely difficult and expensive. Excavation and placing logs, stone, and new stream bank fill material is assumed to take place in the water ponded behind the flow diversion structure. Turbidity released is expected to be limited in extent and duration. Access for construction is assumed down a ramp constructed over the existing riprap armoring. The ramp could provide permanent access for maintenance. Campground traffic impacts are expected to be limited to one-lane closures and short-term delays.

Executive Order 11988, Floodplain Management, established federal policies for protecting floodplains and floodways. The intention of the associated regulations is to avoid, to the extent practical, adverse impacts to floodplains; minimize the impact of floods to human safety, health, and welfare; and avoid supporting land use development that is incompatible with the natural

and beneficial floodplain values. When avoidance is not possible, the policies require appropriate consideration of methods to assess and minimize adverse impacts.

The site is 5.3 river miles upstream of the Park boundary. Moving the active river channel away from campground facilities with ELJ's or groins could induce dramatic bank erosion and stream avulsion, resulting in unnatural changes in the HCMZ boundaries. A minor active river channel shift is not expected to have a direct negative impact on private property adjacent to and downstream of the Park. A channel relocation project would include a detailed geomorphic analysis for verifying the no-direct-impact assumption.

Major Active River Channel Shift

The primary active flow channel can be kept away from the bank adjacent to the campground by placing four to six engineered-log-jams (ELJ's), each at least 20 feet wide and 60 to 100 feet long, in a staggered alignment across the mid-channel sediment deposits, approximately 100 to 200 feet from the south and west of the bank. Keeping the primary active flow channel away from the bank reduces the campground facility loss risk.

The ELJ's would be constructed within the active river channel. Top of the ELJ's are set equal to 100-year water surface, estimated to be approximately 5 to 6 feet above the mid-channel sediment deposit surface. Bottom of the ELJ's are set below the active channel thalweg elevation and expected scour depth, approximately 6 feet below the mid-channel sediment deposit surface. Each ELJ is ballasted with stone and logs cabled together for keeping them in place against expected flow depth and velocity and additional woody debris accumulation.

Existing riprap armoring is assumed left in place. Off-channel rearing and resting habitat is created along the toe of the existing riprap armoring. The existing bank area is reshaped and graded for providing a more natural appearing bank, typical of a river meander bend inside bank.

A right (looking downstream) primary flow channel goes through the construction area. A left primary flow channel goes around the west side of the island. One of the new ELJ's would be placed across the right primary flow channel for diverting the stream flow into the left primary flow channel. No other temporary stream diversion channels are expected to be needed for construction.

Estimated construction cost is summarized in Table P6-3. Turbidity released is expected to be limited in extent and duration. Ramps constructed over the existing bank could provide temporary access for construction and permanent access for maintenance. Campground traffic and use impacts are expected to be limited to unit closures and short-term use delays.

Executive Order 11988, Floodplain Management, established federal policies for protecting floodplains and floodways. The intention of the associated regulations is to avoid, to the extent practical, adverse impacts to floodplains; minimize the impact of floods to human safety, health, and welfare; and avoid supporting land use development that is incompatible with the natural and beneficial floodplain values. When avoidance is not possible, the policies require appropriate consideration of methods to minimize adverse impacts.

Keeping the primary active flow channel 200 feet south and west provides opportunity for creating off-channel rearing and resting habitat along the bank. It is not expected to have a direct negative impact on private property adjacent to and downstream of the Park. Keeping the primary active flow channel more than 200 feet south would likely induce dramatic downstream bank erosion and stream avulsion, resulting in unnatural changes in the HCMZ boundaries. A

channel relocation project would include a detailed geomorphic analysis for verifying the no-direct-impact assumption.

Environmental Clearance Considerations

This area of concern is located in OLYM-lands managed for recreational purposes including camping, fishing, trails, and interpretation. Year 2004 visitation statistics reported in the Final Environmental Impact Statement (EIS) for the March 2008 General Management Plan (GMP) indicated the area received over 148,000 recreational visits. The visitor center received almost 262,000 visitor contacts, over 100,000 more visits than Hurricane Ridge (the next most). Hoh visitor center is open year round.

The project area and proposed options as presently described would not impact designated wilderness areas.

Due to map scale, it is unclear whether wetlands are located in the vicinity of the project site. Based on the photos there appear to be none, but this would need to be confirmed by a wetland survey.

Due to the presence of recreational activities, it is not likely that this area provides suitable habitat for the marbled murrelet or the northern spotted owl. This needs to be confirmed in consultation with the Service. Designated bull trout habitat is located in the adjacent Hoh River.

No known cultural resources are within the project area though a literature search and, possibly, surveys would need to be conducted to confirm this negative finding.

Continue Maintenance

Environmental clearance considerations are similar to those described for Site P1 though in this case there is no road to be repaired in the event of a storm event.

Given the high risk of a catastrophic loss of campsites and the access road, careful consideration must be given to managing the safety of park visitors and staff under this option. It was noted in the Record of Decision (ROD) to the above referenced EIS, signed in August 2008, for OLYM's most recent GMP, that flooding generally occurs in the park during winter months in periods of low visitation. Also flooding is usually a result of prolonged rainfall or rainfall over snowfields making warning and evacuation a practical option for ensuring human safety.

Stabilize Existing Streambank

Environmental clearance considerations are similar to those described for Site P1.

Minor and Major Active River Channel Shift

This could have a dramatic effect on the existing river system. The extent to which the option helps or harms the aquatic habitat would need determined through modeling and formal consultation with the Service, the Hoh Tribe, and the WDFW. This work would require an individual permit from the Corps and 401 Certification from the DOE.

A biological assessment would need to be prepared evaluating short and long term impacts to bull trout and short term construction impacts to the marbled murrelet and the northern spotted owl.

In addition, geomorphic assessments would need to be conducted for assessing effect this option may have on downstream properties.

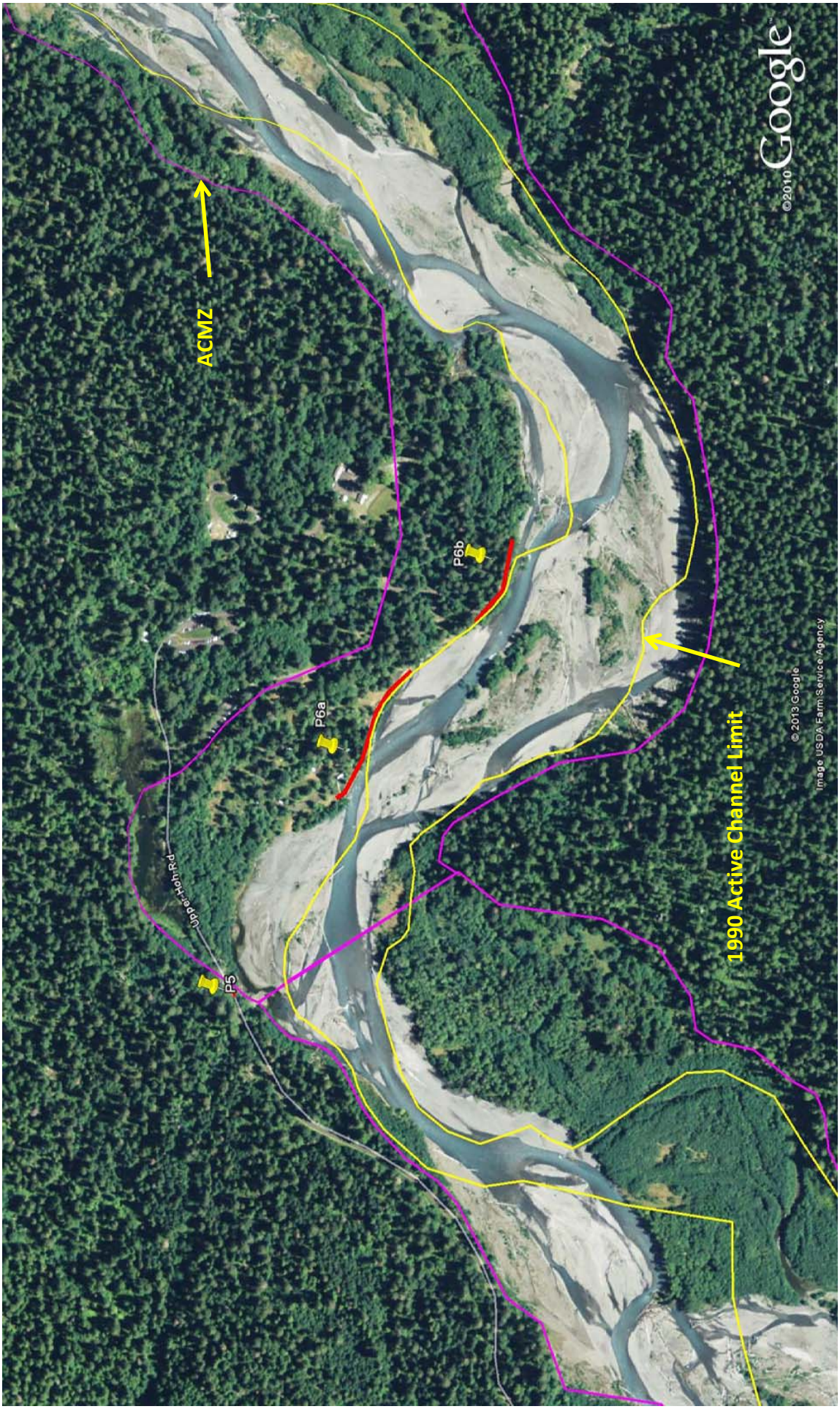
Due to the scope of work and the limited in-water work window, the WDFW would likely need to be petitioned for an extension.

Each ELJ requires a number of trees to be cut down. Approximately 1,000 logs and 900 logs are needed for the minor and major active river channel shift options, respectively. Cutting these trees would have a direct impact on a forest's ecosystem and watershed's health.

Relocate Campground

In the March 2008 GMP EIS, OLYM evaluated various management alternatives at this location, including one that would permit natural stream dynamics to be restored or allowed to recover in areas including the Hoh River Corridor. Under this alternative, park facilities presently situated in floodplains, including those along the Hoh River would be removed. In its ROD, OLYM selected an alternative that favored keeping the campground in its current position for the time being, though it did indicate that individual campsites may be relocated or modified based on river movements.

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ACMZ - Active Channel Migration Zone, Geomorphic Assessment of Hoh River in Washington State, USBR, July 2004.

Imagery date 9/25/2011

Figure P6-1. Site Location

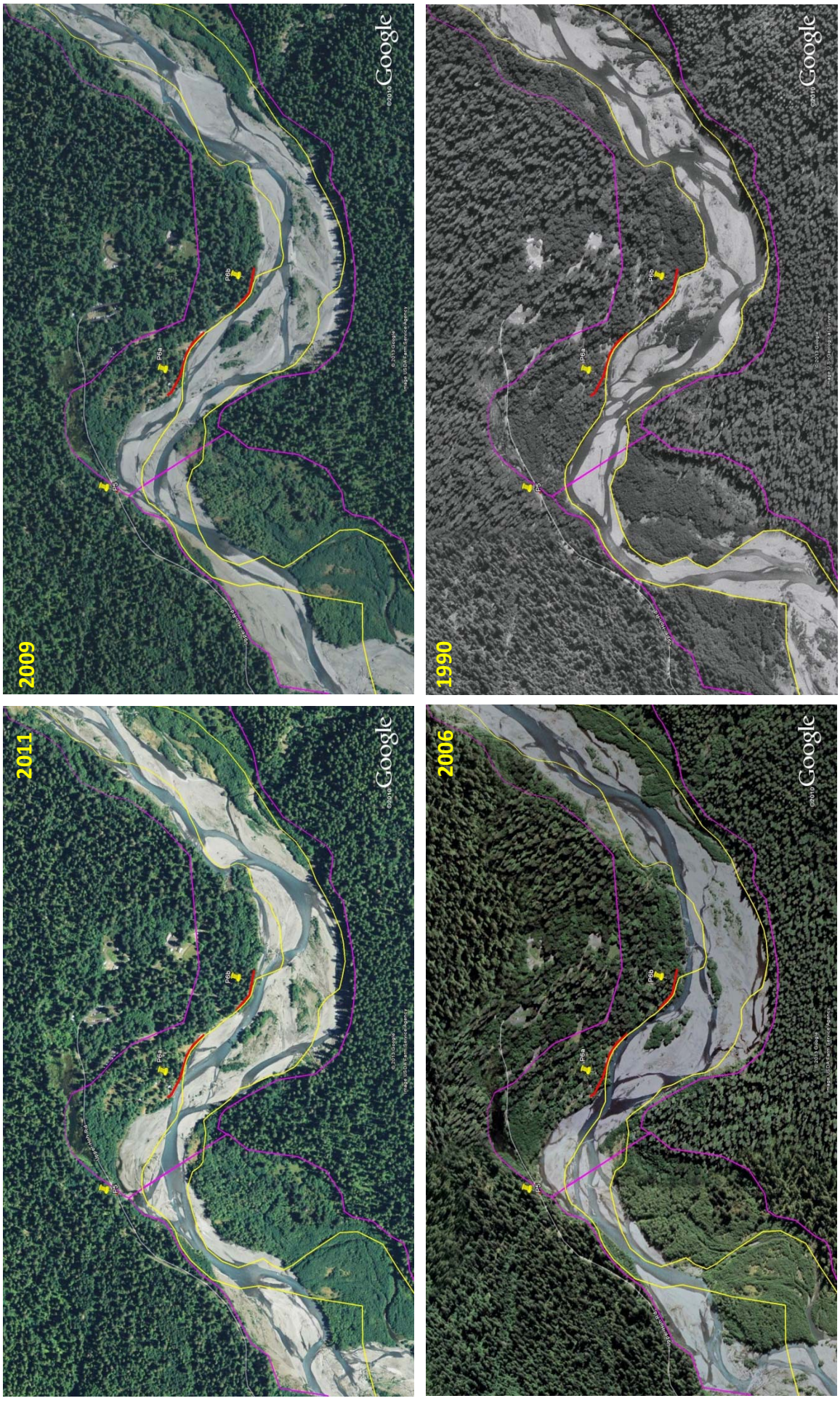


Figure P6-2. Historical Satellite Imagery

Photos

P6a - Hoh River Campground



PHOTO P6a-1

Downstream end of riprap armoring - looking downstream.

Riprap steep, thin, and unstable. Numerous stones dislodged. Soil on top of bank undercut and slumping.



PHOTO P6a-2

Near downstream end of riprap armoring - looking from channel towards campground.

Riprap steep, thin, and unstable. Numerous stones dislodged. Soil on top of bank undercut and slumping.



PHOTO P6a-3

Bank erosion downstream of riprap armoring - looking upstream.

Bank steep and unstable. Soil at top of bank undercut and slumping.

Photos

P6a - Hoh River Campground



PHOTO P6a-4

Bank erosion downstream of riprap - looking downstream.

Bank steep and unstable. Soil at top of bank undercut and slumping. Large woody debris collecting floating debris.



PHOTO P6a-5

Island and mid-channel gravel bar opposite eroding bank.

Mid-channel gravel bar, woody debris, and island deflects flood flow towards bank. Woody debris spread throughout bar and collecting at head of island.



PHOTO P6a-6

Campground area from Upper Hoh Road.

Campground in tree area, center of photo. Bank erosion occurring along active channel edge.

12/12/2012

Photos

P6b - Hoh River Campground



PHOTO P6b-1

Downstream end failing riprap armoring - looking downstream.

Riprap steep, thin, and unstable. Numerous stones dislodged. Soil at top of bank undercut and slumping. Geotextile observed under riprap.



PHOTO P6b-2

Downstream end of failing riprap armoring - looking upstream.

Riprap steep, thin, and unstable. Numerous stones dislodged. Soil at top of bank undercut and slumping. Mid-channel deposits and woody debris deflect river flow towards bank.



PHOTO P6b-3

Bank erosion upstream of failing riprap armoring - looking upstream.

No riprap. Bank steep and unstable. Soil at top of bank undercut and slumping. Mid-channel deposits and woody debris deflect river flow towards bank.

12/12/2012

Photos

P6b - Hoh River Campground



PHOTO P6b-4

Upstream end failing riprap armoring and eroding bank - looking downstream.

Bank steep and unstable. Soil at top of bank undercut and slumping. Mid-channel deposits and woody debris deflect river flow towards bank.



PHOTO P6b-5

Upstream end failing riprap armoring and eroding bank - looking upstream.

Point bar upper left photo. Mid-channel gravel bar and island deflects flood flow towards bank. Woody debris spread throughout bar and collecting at head of island.



PHOTO P6b-6

Downstream end failing riprap armoring and eroding bank - looking upstream across active channel.

Mid-channel gravel bar and island deflects flood flow towards bank. Woody debris spread throughout bar and collecting at head of island.

12/12/2012

Photos

P6b - Hoh River Campground



PHOTO P6b-7

Upstream end failing riprap armoring and eroding bank - looking downstream.

Riprap terminates behind point bar deposits. Riprap and bank currently not experiencing excessive erosion damage. Point bar at risk of eroding, exposing bank area to impinging flows.



PHOTO P6b-8

Downstream end failing riprap armoring and eroding bank - looking downstream.

Riprap densely planted with Alder. Riprap and bank currently not experiencing excessive erosion damage.



PHOTO P6b-9

Riprap armoring between P6a and P6b - looking upstream.

Riprap densely planted with Alder. Riprap and bank currently not experiencing excessive erosion damage.

12/12/2012

Table P6-1. Alternative Summary and Ranking.

Upper Hoh River CG Site - P6 - PMP 7.0 Camp Ground Bank Stabilization

					Bank Stabilization								Minor Active River Channel Shift				Major Active River Channel Shift	
OPTIONS	**Rank**	**Continued Maintenance**	**Rank**	**Relocate Camp Ground**	**Rank**	**Complex Roughened Large Rock Toe**	**Rank**	**Complex Log Crib Wall**	**Rank**	**Riprap with LWD and Plantings**	**Rank**	**Riprap with Streambarbs**	**Rank**	**ELJ Groins**	**Rank**	**Large Stream barbs**	**Rank**	
		Place or replace riprap as needed for preventing safety hazard or facility closure.		**Not Evaluated.**		**Rock toe with LWD.**		**Log crib wall with roughness elements.**		**Riprap similar to what is commonly used along Upper Hoh River CG embankment.**		**Bank area planted with willow and alder.**		**Construct new stream bank area over unstable and revetment areas.**		**Construct new stream bank area over unstable and revetment areas.**		**Shift active flow channel to flow across gravel bar away from revetment area.**
Ability to preserve and operate the CG in a specific location (Most able 5, least able 1)	**3**	Reduces risk of a catastrophic CG failure during extreme flood event.			**5**	Greatly reduces risk of a catastrophic CG failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic CG failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic CG failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic CG failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic CG failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic CG failure during extreme flood event.	**5**	Greatly reduces risk of a catastrophic CG failure during extreme flood event.
CG sustainability (life of solution) (Longest 5, shortest 1)	**1**	Increased maintenance in the future mitigating climate change or after large flood events.			**3**	Requires moderate amount of wood replacement and maintenance.	**1**	Requires substantial amount of wood replacement and maintenance.	**3**	Requires moderate amount of wood replacement and maintenance.	**5**	Requires moderate level of maintenance.	**1**	Requires substantial amount of wood replacement and maintenance.	**5**	Requires moderate level of maintenance.	**1**	Requires substantial amount of wood replacement and maintenance.
Impact to hillside stability adjacent to CG (Most likely 1; least likely 5)	**5**	No expected additional impacts.			**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.
Potential to reduce erosion of banks adjacent to site (Most 5; Least 1)	**1**	Adjacent bank erosion will continue with no effort to soften riprap.			**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**3**	Adjacent bank erosion will continue.	**1**	Likely increase down stream right bank erosion.
Impacts to listed Threatened and Endangered (T&E) terrestrial species and habitat (Least 5; most 1)	**5**	No expected additional impacts.			**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.
Impacts to listed T&E fish and habitat (Least 5; most 1)	**3**	Riprap placed along bank reduces habitat complexity.			**3**	Material placed in channel.	**3**	Material placed in channel.	**3**	Material placed in channel.	**1**	Riprap along bank reduces habitat complexity. Barbs require significant excavation into channel bed.	**3**	Considerable temporary impacts from in-stream channel work.	**3**	Considerable temporary impacts from in-stream channel work.	**3**	Considerable temporary impacts from in-stream channel work.
Impact to upland habitat (Least 5; most 1)	**5**	No expected additional impacts.			**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.
Impacts to Wetlands and Waters of the U.S. (Least 5; most 1)	**3**	No expected additional impacts to wetlands; riprap placement in river.			**3**	No expected additional impacts to wetlands; riprap placement in river.	**3**	No expected additional impacts to wetlands.	**3**	No expected additional impacts to wetlands; riprap placement in river.	**1**	Riprap along bank reduces habitat complexity. Barbs require significant excavation into channel bed.	**1**	Requires major in stream construction.	**1**	Requires major in stream construction.	**1**	Requires major in stream construction.
Impact to Designated Wilderness area (Least 5; most 1)	**5**	No expected impacts.			**5**	No expected impacts.	**5**	No expected impacts.	**5**	No expected impacts.	**5**	No expected impacts.	**5**	No expected impacts.	**5**	No expected impacts.	**5**	No expected impacts.
Potential for Hoh River Enhancement (Greatest 5; Least 1)	**1**	Does not provide river enhancements.			**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Moves thalweg away from CG, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from CG, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from CG, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from CG, adds bank area, improves sediment transport and habitat complexity.
Potential to maintain or improve river process and function (Most 5; Least 1)	**1**	Does not improve river process and function.			**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides woody debris for habitat complexity and biological processes.	**3**	Moves thalweg away from CG, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from CG, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from CG, adds bank area, improves sediment transport and habitat complexity.	**5**	Moves thalweg away from CG, adds bank area, improves sediment transport and habitat complexity.
Potential for other habitat enhancements (Most 5; Least 1)	**1**	Does not provide other habitat enhancements.			**3**	Provides some woody debris for habitat complexity and biological processes.	**3**	Provides some woody debris for habitat complexity and biological processes.	**3**	Provides some woody debris for habitat complexity and biological processes.	**1**	Does not provide other habitat enhancements.	**5**	Provides woody debris for habitat complexity and biological processes.	**3**	Provides some woody debris for habitat complexity and biological processes.	**5**	Provides woody debris for habitat complexity and biological processes.
Potential private property impacts (Least 5; Most 1)	**5**	No expected additional impacts.			**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.	**5**	No expected additional impacts.
Safety risk of design to public (Least 5; Most 1)	**5**	No expected increase in safety risk.			**3**	Boaters could become trapped in root wads.	**1**	Public could fall down wall. Boaters could become trapped in root wads.	**3**	Boaters could become trapped in root wads.	**5**	No expected increase in safety risk.	**1**	Boaters could become trapped in ELJ's.	**3**	Boaters could become trapped in root wads.	**1**	Boaters could become trapped in ELJ's.
Total Construction cost		**NA**				**$895,263**		**$1,327,632**		**$2,069,885**		**$1,461,323**		**$3,958,786**		**$2,654,028**		**$3,157,570**
Riprap and Wood Replacement (50 years)	**5**	**NA**			**3**	**$332,500**	**3**	**$676,667**	**3**	**$486,500**	**3**	**$285,000**	**1**	**$1,496,000**	**1**	**$261,600**	**1**	**$1,800,000**
Total Capital Cost (50 years)		**NA**				**$1,541,105**		**$2,468,970**		**$3,280,845**		**$2,257,786**		**$6,840,361**		**$3,844,538**		**$6,062,720**
Annualized Total Capital Cost (Least 5; Most 1)		**$45,000**				**$113,436**		**$181,734**		**$241,493**		**$166,189**		**$503,499**		**$282,985**		**$446,259**
SCORE	**49**				**57**		**53**		**57**		**55**		**55**		**59**		**53**	

Table P6-2. Total Expected Cost

Project: Hoh River Road Bank Erosion Risk Study **Date: 3/14/2013**

Site: P6 - Campground Bank Stabilization

Alternative: Continue Maintenance **By: S. Leon**

	Flood Frequency (yr)	Exceedance Probability	Flood Damage	Average Flood Damage	Delta Exceedance Probability	Annual Risk Cost
No damage.	2	**0.5**	$0			
				$0	**0.3**	**$0**
No damage.	5	**0.2**	$0			
				$150,000	**0.1**	**$15,000**
Install bank armoring.	10	**0.1**	$300,000			
				$300,000	**0.06**	**$18,000**
Install bank armoring.	25	**0.04**	$300,000			
				$300,000	**0.02**	**$6,000**
Install bank armoring.	50	**0.02**	$300,000			
				$300,000	**0.01**	**$3,000**
Install bank armoring.	100	**0.01**	$300,000			
				$300,000	**0.01**	**$3,000**
		0	$300,000			
Total Annual Risk Cost						**$45,000**
Annualized Capital Cost	**Capital Cost**					**$0**
	Disc. rate, i	**0.07125**	**Serv. life, n**	**50**	**CFR**	**0.0736**
	Annualized Capital Cost					**$0**
Total Expected Cost (Annual)						**$45,000**
Summary	Assume 300 feet ($1k/ft) of bank armoring for each flood damage event.					

Notes:

1. Method from HEC-17, April 1981.

Table P6-3. Cost Estimates

Site: **P6 - Campground Bank Stabilization**

Relocate Facilities - Not evaluated

			Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost	LS	-	$	-	$	-
New Road			LF	-	$	500	$	-
Hillside Stabilization			LS	-	$	50,000	$	-
Remove Existing Revetment			LF	-	$	200	$	-
Streambank Reconstruction			LF	-	$	1,000	$	-
Streambarbs			EA	-	$	40,000	$	-
Concrete Box Culvert			EA	-	$	300,000	$	-
Total Construction Cost without Contingencies							$	-
Contingency	30%	of construction cost					$	-
Total Construction Cost							$	-
Compliance	5%	of total construction cost					$	-
Predesign/design (PE)	15%	of total construction cost					$	-
Construction Engineering (CE)	15%	of total construction cost					$	-
ROW							$	-
Riprap replacement -	20%	replacement every	50	years			$	-
Wood replacement -	full log	replacement every	30	years			$	-
TOTAL Capital Cost		Cost/Foot					$	-
Annualized Capital Cost		Discount rate, i	0.07125				$	-
		Service life, n	50	years				
		CFR	**0.0736071**					

Complex Roughened Large Rock Toe

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost		LS	1	$	45,053	$	**45,053**
Remove Existing Revetment				LF	-	$	300	$	**-**
Rock	H 10 ft	T 5 ft	L 1050 ft	CY	**1,944**	$	180	$	**350,000**
Logs	L 1050 ft	XS 8 ft		EA	**131**	$	2,000	$	**262,500**
Soil	H 2 ft	T 10 ft	L 1050 ft	CY	**778**	$	40	$	**31,111**
Total Construction Cost without Contingencies								$	**688,664**
Contingency	30%	of construction cost						$	**206,599**
Total Construction Cost								$	**895,263**
Compliance	5%	of total construction cost						$	**44,763**
Predesign/design (PE)	15%	of total construction cost						$	**134,289**
Construction Engineering (CE)	15%	of total construction cost						$	**134,289**
ROW								$	**-**
Riprap replacement -	20%	replacement every		50	years			$	**70,000**
Wood replacement -	full log	replacement every		30	years			$	**262,500**
TOTAL Capital Cost			Cost/Foot	**$ 1,468**				$	**1,541,105**
Annualized Capital Cost			Discount rate, i	0.07125				$	**113,436**
			Service life, n	50	years				
			CFR	**0.0736071**					

Table P6-3. Cost Estimates

Complex Log Crib Wall

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost		LS	1	$	66,811	$	**66,811**
Remove Existing Revetment				LF	300	$	200	$	**60,000**
Rock	H 10 ft	T 5 ft		CY	**1,944**	$	120	$	**233,333**
	L 1050 ft								
Logs	L 1050 ft	H 12 ft		EA	**315**	$	2,000	$	**630,000**
	Dia 2 ft	Row 6							
	log l 20 ft	No. 315							
Piles				EA	0	$	-	$	**-**
Soil	H 2 ft	T 10 ft		CY	**778**	$	40	$	**31,111**
	L 1050 ft								
Total Construction Cost without Contingencies								$	**1,021,256**
Contingency	30%	of construction cost						$	**306,377**
Total Construction Cost								$	**1,327,632**
Compliance		5%	of total construction cost					$	**66,382**
Predesign/design (PE)		15%	of total construction cost					$	**199,145**
Construction Engineering (CE)		15%	of total construction cost					$	**199,145**
ROW								$	**-**
Riprap replacement -	20%	replacement every			50	years		$	**46,667**
Wood replacement -	full log	replacement every			30	years		$	**630,000**
TOTAL Capital Cost				Cost/Foot	**$ 2,351**			$	**2,468,970**
Annualized Capital Cost				Discount rate, i	0.07125			$	**181,734**
				Service life, n	50	years			
				CFR	**0.0736071**				

Riprap with Roughened Rock Toe, LWD, and Riparian Plantings

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost		LS	1	$	104,164	$	**104,164**
Remove Existing Revetment				LF	300	$	200	$	**60,000**
Riprap	H 12 ft	T 5 ft		CY	**6,222**	$	180	$	**1,120,000**
	L 1050 ft	SS 2 (h):1(v)							
	TW 8 ft	TT 5 ft							
Logs	L 1050 ft	XS 8 ft		EA	**131**	$	2,000	$	**262,500**
Willow	1200 sy	XS 2		EA	**600**	$	10	$	**6,000**
Alder	1200 sy	XS 1		EA	**1,200**	$	20	$	**24,000**
Soil	H 1 ft	T 10 ft		CY	**389**	$	40	$	**15,556**
	L 1050 ft								
Total Construction Cost without Contingencies								$	**1,592,219**
Contingency	30%	of construction cost						$	**477,666**
Total Construction Cost								$	**2,069,885**
Compliance		5%	of total construction cost					$	**103,494**
Predesign/design (PE)		15%	of total construction cost					$	**310,483**
Construction Engineering (CE)		15%	of total construction cost					$	**310,483**
ROW								$	**-**
Riprap replacement -	20%	replacement every			50	years		$	**224,000**
Wood replacement -	full log	replacement every			30	years		$	**262,500**
TOTAL Capital Cost				Cost/Foot	**$ 3,125**			$	**3,280,845**
Annualized Capital Cost				Discount rate, i	0.07125			$	**241,493**
				Service life, n	50	years			
				CFR	**0.0736071**				

Table P6-3. Cost Estimates

Riprap with Streambarbs

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost		LS	1	$	73,539	$	**73,539**
Remove Existing Revetment				LF	-	$	200	$	**-**
Riprap	H 12 ft	T 5 ft		CY	**4,667**	$	180	$	**840,000**
	L 1050 ft	SS 2 (h):1(v)							
	TW 0 ft	TT 0 ft							
Streambarbs				EA	2	$	30,000	$	**60,000**
Logs	L 1050 ft	XS 20 ft		EA	**53**	$	2,000	$	**105,000**
Willow	1200 sy	XS 2		EA	**600**	$	10	$	**6,000**
Alder	1200 sy	XS 1		EA	**1,200**	$	20	$	**24,000**
Soil	H 1 ft	T 10 ft		CY	**389**	$	40	$	**15,556**
	L 1050 ft								
Total Construction Cost without Contingencies								$	**1,124,094**
Contingency	30%	of construction cost						$	**337,228**
Total Construction Cost								$	**1,461,323**
Compliance		5%	of total construction cost					$	**73,066**
Predesign/design (PE)		15%	of total construction cost					$	**219,198**
Construction Engineering (CE)		15%	of total construction cost					$	**219,198**
ROW								$	**-**
Riprap replacement -	20%	replacement every			50	years		$	**180,000**
Wood replacement -	full log	replacement every			30	years		$	**105,000**
TOTAL Capital Cost				Cost/Foot	**$ 2,150**			$	**2,257,786**
Annualized Capital Cost			Discount rate, i		0.07125			$	**166,189**
			Service life, n		50	years			
			CFR		**0.0736071**				

Major Active River Channel Shift

				Unit	Quantity		Unit Cost		Total Cost
Mobilization	7%	of construction cost		LS	1	$	158,900	$	**158,900**
Channel Excavation - 100 feet by 5 feet				LF	100	$	300	$	**30,000**
Rearing and Resting Habitat Construction				AC	2.5	$	50,000	$	**125,000**
Remove Existing Revetment				LF	-	$	200	$	**-**
Streambank Reconstruction				LF	1,050	$	300	$	**315,000**
Streambarbs				EA	-	$	40,000	$	**-**
ELJ's - 20 ft by 60 ft				EA	6	$	300,000	$	**1,800,000**
Total Construction Cost without Contingencies								$	**2,428,900**
Contingency	30%	of construction cost						$	**728,670**
Total Construction Cost								$	**3,157,570**
Compliance		5%	of total construction cost					$	**157,879**
Predesign/design (PE)		15%	of total construction cost					$	**473,636**
Construction Engineering (CE)		15%	of total construction cost					$	**473,636**
ROW								$	**-**
Riprap replacement -	20%	replacement every			50	years		$	**-**
Wood replacement -	full log	replacement every			30	years		$	**1,800,000**
TOTAL Capital Cost				Cost/Foot	**$ 60,627**			$	**6,062,720**
Annualized Capital Cost			Discount rate, i		0.07125			$	**446,259**
			Service life, n		50	years			
			CFR		**0.0736071**				

Table P6-3. Cost Estimates

Minor River Channel Shift - ELJ Groins

		Unit	Quantity	Unit Cost	Total Cost
Mobilization	7% of construction cost	LS	1	$ 199,220	**$ 199,220**
Rearing and Resting Habitat Construction		AC	-	$ 50,000	**$ -**
Remove Existing Revetment		LF	-	$ 200	**$ -**
Streambank Reconstruction - fill/plants/fascines		LF	1,000	$ 1,200	**$ 1,200,000**
Large Wood		EA	100	$ 1,500	**$ 150,000**
ELJ groin - 15 ft by 40 ft (2 x 15 ft by 20 ft mod.)		EA	10	$ 149,600	**$ 1,496,000**
Primary logs	50 $ 1,200 $ 60,000				
Pin logs	4 $ 1,200 $ 4,800				
Ballast stone	50 $ 180 $ 9,000				
Cabling	1 $ 1,000 $ 1,000				
	$ 74,800				
No. modules/ ELJ groin	2 $ 149,600				
Total Construction Cost without Contingencies					**$ 3,045,220**
Contingency	30% of construction cost				**$ 913,566**
Total Construction Cost					**$ 3,958,786**
Compliance	5% of total construction cost				**$ 197,939**
Predesign/design (PE)	15% of total construction cost				**$ 593,818**
Construction Engineering (CE)	15% of total construction cost				**$ 593,818**
ROW					**$ -**
Riprap replacement -	20% replacement every		50 years		**$ -**
Wood replacement -	full log replacement every		30 years		**$ 1,496,000**
TOTAL Capital Cost		Cost/Foot	**$ 3,959**		**$ 6,840,361**
Annualized Capital Cost		Discount rate, i	0.07125		**$ 503,499**
		Service life, n	50 years		
		CFR	**0.0736071**		

Minor River Channel Shift - Stream Barbs

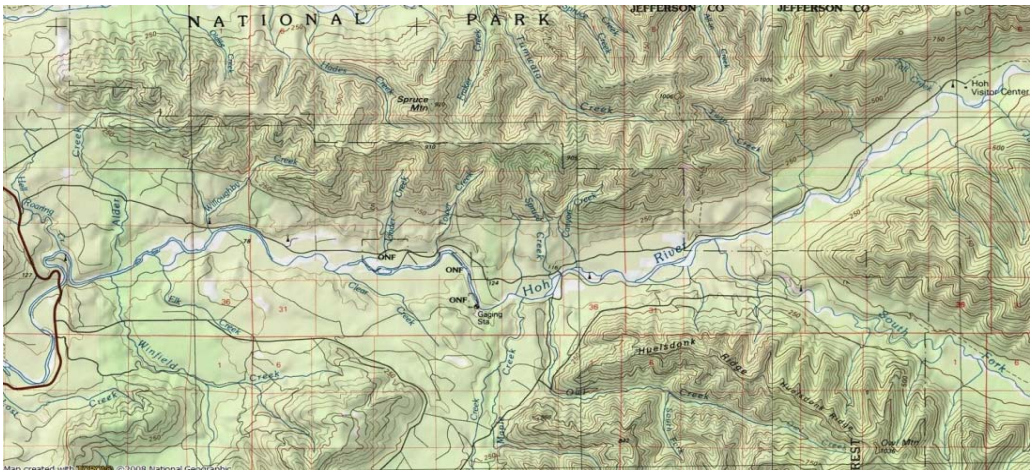
		Unit	Quantity	Unit Cost	Total Cost
Mobilization	7% of construction cost	LS	1	$ 133,560	**$ 133,560**
Rearing and Resting Habitat Construction		AC	-	$ 50,000	**$ -**
Remove Existing Revetment		LF	-	$ 200	**$ -**
Streambank Reconstruction - fill/plants/fascines		LF	1,000	$ 1,200	**$ 1,200,000**
Large Wood		EA	100	$ 1,500	**$ 150,000**
Streambarbs	Length 90 ft	EA	10	$ 55,800	**$ 558,000**
	Crest width 8 ft				
	Average bot. width 23 ft				
	Average thickness 6 ft				
	Volume 310 cy				
	Cost/cy 180 $/cy	Cost/barb	$ 55,800		
Total Construction Cost without Contingencies					**$ 2,041,560**
Contingency	30% of construction cost				**$ 612,468**
Total Construction Cost					**$ 2,654,028**
Compliance	5% of total construction cost				**$ 132,701**
Predesign/design (PE)	15% of total construction cost				**$ 398,104**
Construction Engineering (CE)	15% of total construction cost				**$ 398,104**
ROW					**$ -**
Riprap replacement -	20% replacement every		50 years		**$ 111,600**
Wood replacement -	full log replacement every		30 years		**$ 150,000**
TOTAL Capital Cost		Cost/Foot	**$ 2,654**		**$ 3,844,538**
Annualized Capital Cost		Discount rate, i	0.07125		**$ 282,985**
		Service life, n	50 years		
		CFR	**0.0736071**		

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Upper Hoh Road Bank Failure Risk Reduction Study

Section 3

System Wide Proposals



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Relocating the Hoh River Road Outside of the Channel Migration Zone

In an effort to eliminate the threat the Hoh River poses to the Hoh River Road, the steering committee asked WFLHD to perform a high level, preliminary analysis of the feasibility, cost, and benefits associated with relocating portions of the Hoh River Road. These options looked at relocating the road in areas most susceptible to erosion and washout, outside of the Hoh River channel migration zone.

The general concepts for these options were developed during the stakeholder meetings with further information developed by WLFHD. The road relocation options described below are based on USGS topographic maps which provide limited information. There are many unknowns on the condition of the existing road (if any), slope stability, major and minor stream crossing among other items. If it is determined that any of these options warrant further evaluation then a significant effort would be required to layout the new road, review the conditions of the existing roads (if any), and review the stability of the slopes and other items in the general vicinity of the new roads.

These options were not ranked due to the high cost associated with these options, the limited benefit and the potential for significant environmental impacts. One other major item that needs to be resolved is determining which agency would take over the jurisdiction and maintenance of these new roads. These options could only advance after it is determined which agency would be responsible for designing, building, constructing and maintain these new roads.

Relocating Hoh River Road from CMP 1.4 to CMP 6.9

Description

To address the problematic area at Sites C1 and C2 (County milepost (CMP) 4), WFL considered the possibility of relocating the Hoh River Road from CMP 1.4 to CMP 6.9 to an existing, unimproved gravel road north of the Hoh River Road. See Figure 3-1 for topographic map and alignment information. The roadway typical can be configured in many different ways. If the roadway management agencies prefer to maintain a level of service comparable to the existing Hoh River Road, the new road would be 26 feet wide, consisting of 11-foot travel lanes and two foot shoulders. Assuming the existing gravel road is 16 feet wide; the new road would add 10 feet to the existing roadway prism. This type of roadway construction usually impacts about 30 feet beyond the road way shoulder on each side. Total impact width of the new road would be about 86 feet. The total length of the new corridor is 6.3 miles. Judging from the topographic map, constructing the road is feasible from an engineering point of view. An in-depth geotechnical investigation would need to be done for determining what methods would be needed for ensuring roadway stability. Based on USGS topographic mapping, the proposed relocation corridor crosses numerous drainages, requiring the installation of new culverts, and, in some cases, likely fish passage culverts.

The proposed roadway corridor extends through forest, the majority of which is owned by the state. A small section at the eastern end of the relocation corridor, about 1/3 of a mile where it connects with the existing Upper Hoh Road, extends through FS-managed lands. The entire 6.3 miles extends through designated marbled murrelet critical habitat. The portion that extends through FS-managed lands is also located within northern spotted owl designated critical habitat. There is no designated bull trout critical habitat in the streams crossed by the corridor, but there is critical habitat in the Hoh River to the south. Wetland and cultural resource surveys would need to be conducted to identify any such resources within the corridor. Coordination with the State and the FS would be required given that a portion of the relocation corridor is located on these lands.

Impacts on marbled murrelet and northern spotted owl critical habitat and the addition of impervious paved roadway which could adversely affect water quality through stormwater runoff require formal consultation with the Service. Also, given the potential significant impacts the proposed project may have on threatened and endangered species and critical habitat, and Environmental Impact Statement (EIS) would likely need to be prepared.

Cost Estimate

The cost for building a road is variable. Based on the available information, it is estimated the cost of this road ranges from $2.5 to $3.5 million per mile. This of course depends on many items including the amount of earthwork quantities and type of in-situ materials encountered. In addition, figure 3-1 shows four large drainage crossings. A review of these streams has not been conducted, but it is assumed that these creeks carry a high volume of water during significant flow events. These creeks likely provide suitable fish habitat, therefore, the hydraulics structures would need to provide adequate passage for all life stages of the target fish species. Cost for these structures varies depending on actual site conditions. For this estimate purpose, they are assumed to range from $100,000 to $600,000.

The following additional costs are included to provide a total cost estimate for the projects. Project development or Preliminary Engineering (PE) cost is estimated at 15% of construction cost. Construction administration or Construction Engineering (CE) cost is estimated at 15% of construction cost. A NEPA Compliance cost or cost to mitigate and comply with environmental impacts is assumed to be 5% of the construction cost. A contingency of 30% was added to the cost to cover the unknowns at this time such as ROW costs, and other unforeseen costs. See Table 3-1 below for cost estimate.

Potential Benefits/Drawbacks

This relocation would reduce the County's maintenance costs associated with stabilizing and reconstructing this section of road after severe storm events. Also, abandonment of the existing portion of the road would permit the Hoh River to make fuller use of the channel migration zone as well as the restoration of the stream banks, providing better habitat to the threatened bull trout.

However, due to the need to maintain access to private residences between CMP 4.5 and CMP 5.8 and assuming that access to Willoughby Creek Campground at CMP 3.6 and Minnie Peterson Campground at CMP 4.8 is to be maintained, a majority of the existing road would need to be maintained by the County, though likely at a lower level of service. Under these conditions, only 1.1 miles of road could be abandoned. If the Willoughby Creek Campground could be closed, then an additional two miles of the existing road could be abandoned, assuming no residential access is needed. If Willoughby Campground were to be closed an impact analysis would need to be performed in accordance with Section 4(f) of the U.S. Department of Transportation Act of 1966 to ascertain impacts to recreational resources.

Assuming that access to all residences and campgrounds is to be preserved, this option would almost double the miles of road to be maintained. Though the problematic area at CMP 4 would no longer be maintained, the relocated road may pose different maintenance costs and challenges. It has not been determined which agency would take over the ownership and maintenance responsibility of this new road which could be a considerable commitment. Depending on the nature of the soils and geology, slumping and landslides along the new alignment may be a concern. Also, because the road is located further up the drainage, more culverts are needed to traverse the tributaries to the larger streams crossed by the existing road downstream.

Relocating Hoh River Road from CMP 6.9 to CMP 8.2

Description

This relocation is intended to avoid the problematic area at Site C3 and C4 (CMP 8). This section of road would be relocated to the north using a gravel and more primitive two track road. See Figure 3-2 for topographic map and alignment information. The proposed design is the same as what was described for the CMP 1.4 to CMP 6.9 relocation and the length of the relocation would be 2.8 miles. An in-depth geotechnical investigation would be required to ensure adequate roadway stability. The relocation crosses four streams including Tower and Pole Creeks, requiring the replacement of culverts and, likely, the installation of fish passage culverts at some of these locations.

The proposed relocation extends through forested lands. Two miles of this reroute is on public lands managed by either the FS or the State and the remaining 0.8 miles of the reroute is located on privately held lands. Assuming similar type section with 26 feet wide road, an 86-foot wide impact corridor (including the 16 feet for the existing gravel and two-track road) would result. Where the reroute extends through publicly held lands, it is situated within marbled murrelet habitat or both marbled murrelet and northern spotted owl habitat. No designated bull trout habitat would be directly affected though there is critical habitat found within the Hoh River downstream. Wetland and cultural resource surveys would need to be conducted to identify any such resources within the corridor. Coordination with the State Department of Natural Resources and the FS would be required given that a portion of the relocation corridor is located on these lands.

Due to the impacts to marbled murrelet and northern spotted owl critical habitat and the addition of almost nine acres of impervious paved roadway which could adversely affect water quality through stormwater runoff, formal consultation with the Service would be required. Also, at a minimum an Environmental Assessment would need to be prepared in to determine whether any of the possible physical impacts would have a significant effect on the biological, cultural and social economic environment.

Cost Estimate

Assumptions for estimate are similar to the “Relocation Hoh River Road from CMP 1.4 to CMP 6.9” segment. Two large stream crossing structures permitting fish passage for all life stages of the target fish are assumed for this segment. See Table 3-2 below for cost estimate.

Potential Benefits/Drawbacks

This relocation would likely reduce the County’s maintenance costs associated with stabilizing and reconstructing this section of the existing Hoh River road at CMP 8 after severe storm events. Also, abandonment of the existing portion of the road would permit the Hoh River to make fuller use of the channel migration zone as well as the restoration of the stream banks, providing better habitat to the threatened bull trout.

Access to Morgan’s Crossing Campsite CMP 7.2 would need to be maintained by the County. Approximately 0.9 miles of the existing road could be abandoned. The remaining road segment could be maintained at a lower service level. If the Morgan’s Crossing Campsite could be closed, then the entire 1.3 miles of the existing road might be abandoned, assuming no residential access is needed. If Mogen’s Crossing Campsite were to be closed, an impact analysis would need to be performed in accordance with Section 4(f) of the U.S. Department of Transportation Act of 1966 to ascertain impacts to recreational resources.

Assuming that access to campsite is to be preserved, this option would more than double the miles of road to be maintained with the relocation of this road. Though the problematic area at CMP 8 would no longer be maintained, the relocated road may pose different maintenance costs and challenges. Similar to the previous option, finding an agency that will take over the ownership and maintenance responsibility of this new road has not been determined. Depending on the nature of the soils and geology, slumping and landslides may be a concern. Also, additional culverts would need to be maintained.

Building Bypass Bridge from CMP 7.5 to CMP 8.0

Description

Another option for addressing the problematic area between CMP 7.5 to CMP 8.0 is to build a bridge spanning the river at this location. See Figure 3-3 for topographic and alignment information.

Numerous alternatives and bridge types can be considered. For the sake of simplicity and cost estimate purposes, it is assumed that this option would consider a 2,300 feet long multi-span bridge, 40 feet wide with spans assumed to be 100 feet apart. In-depth geotechnical investigation, hydraulic modeling would have to be done in order to design the bridge properly.

The bridge would require the placement of up to 24 piers in designated bull trout habitat. The abutments would likely impact designated critical habitat for the marbled murrelet and northern spotted owl. Formal consultation with the Service would be required and a Biological Assessment would need to be prepared evaluating the impacts the construction of the piers and their presence within the Hoh River would have on bull trout. The Biological Assessment would also need to address impacts construction would have on marbled murrelet and northern spotted owl and their designated critical habitat. An individual 404 permit from the Corps and 401 Water Quality Certification from DOC would be required for work below the ordinary high water mark and in wetlands, if any are present. Cultural resource surveys would need to be conducted at the bridge abutments to determine whether any historic properties might be affected. Coordination with the FS would be required given that the bridge would be located on FS-managed lands.

Cost Estimate

See Table 3-3 below for cost estimate for the bridge.

Potential Benefits/Drawbacks

Building this bridge would permit the County to abandon the 0.5 mile of road susceptible to river erosion and washout and eliminate its maintenance needs. Also, abandonment of the existing portion of the road would permit the Hoh River to make fuller use of the channel migration zone as well as the restoration of the stream banks, providing better habitat to the threatened bull trout.

Additional consideration should be given for bridge maintenance costs over the life of the bridge and how it compares to the maintenance cost of the abandoned road section.

Building Bridge across the River at CMP 9.9

Description

One final alternative WFL explored to eliminate the need for Jefferson County to maintain the problematic portions of the Hoh River Road in its current location, is to establish access using

existing roads on the south side of the river and then to connect into the existing Hoh River Road via a bridge at CMP 9.9. See Figure 3-4 for topographic and alignment information. Historically there was a bridge at this location but it was washed out due to high flows.

Numerous alternatives and bridge types can be considered. For simplicity and cost estimate purposes, the bridge is assumed to be a 1,300 feet long and 40 feet wide, multi-span, bridge with spans 100 feet apart. In depth geotechnical investigation, hydraulic modeling would have to be done in order to design the bridge properly.

Eleven miles of roadway connecting the new bridge to US 101 would need to be upgraded for access. See Figure 3-5. Roads that would be upgraded include the Hoh Mainline Road, Maple Creek Road and Owl Road. These roads are owned by the Department of Natural Resource (DNR). The county provides limited maintenance by agreements. To provide a level of service comparable to what is presently provided by the Hoh River Road, these roads would be upgraded to a 26 foot width consisting of 11-foot lanes and two-foot shoulders. Judging from the topographic map, constructing the road is feasible from an engineering point of view. However, an in-depth geotechnical investigation would need to be done to determine what methods, if any, would be needed to ensure roadway stability. The proposed upgrade crosses numerous drainages, many of which would likely require the installation of new culverts, some of which would most likely be fish passage culverts.

The upgraded road extends though forested lands managed by the State of Washington, except for one small parcel. The bridge location appears to be on privately held lands. Approximately 7.8 miles of the 11.3 mile upgrade extends through designated marbled murrelet habitat. The bridge would impact designated bull trout critical habitat. Though there is no designated northern spotted owl habitat in the corridor or bridge site, there is likely suitable habitat for the species. Wetland and cultural resource surveys would need to be conducted to identify any such resources within the corridor. In order to abandon the more problematic areas along the existing Hoh River Road from CMP 4 to CMP 8, relocation or closure of recreational facilities that would no longer be accessible would need to be evaluated. Coordination with the State would be required given that a portion of the relocation corridor is located on these lands.

The county has indicated that it does not have the ability to finance construction and maintain the 1300-foot bridge and the new road. If this alternative is selected for further evaluation, funding from other sources will need to be explored. Because the use of the bridge is dependent on this upgrade, WFL would need to evaluate the impacts of the upgrade in a National Environmental Policy Act (NEPA) document. Given the scope and possible significant effects, and Environmental Impact Statement would like need to be prepared. Formal consultation would be required with the U.S. Fish and Wildlife regarding impacts to bull trout, marbled murrelet and northern spotted owls.

Cost Estimate

See Table 3-4 below for cost estimate for the bridge.

Potential Benefits/Drawbacks

One benefit of this alternative is that park visitors and staff will be provided more reliable access to OLYM through roads located outside of the Hoh River channel migration zone on the south side of the Hoh River. Another benefit of this option is that if the portion of the existing road could be abandoned, it would likely permit the restoration of the stream banks and provide better habitat to the threatened bull trout.

This option is only beneficial if the County is able to abandon the Hoh River Road from CMP 4 to CMP 8, the area most susceptible to erosion and washout by the Hoh River, it will have eliminated a couple of the highest maintenance cost generators on this road system. The impacts to residences, businesses and the existing campsite along this route would have to be reviewed and analyzed. It appears unlikely that this section of road could be abandoned; however, further analysis of impacts would be required. If campsites along this section were to be closed, an impact analysis would need to be performed in accordance with Section 4(f) of the U.S. Department of Transportation Act of 1966 to ascertain impacts to recreational resources.

Even with the abandonment of this 4-mile section of existing Hoh River Road, the option will have increased the maintenance requirements due to the new 11.3 mile access road and new bridge. The new 11.3 mile access road would also likely require upgrading which could result in additional environmental impacts.

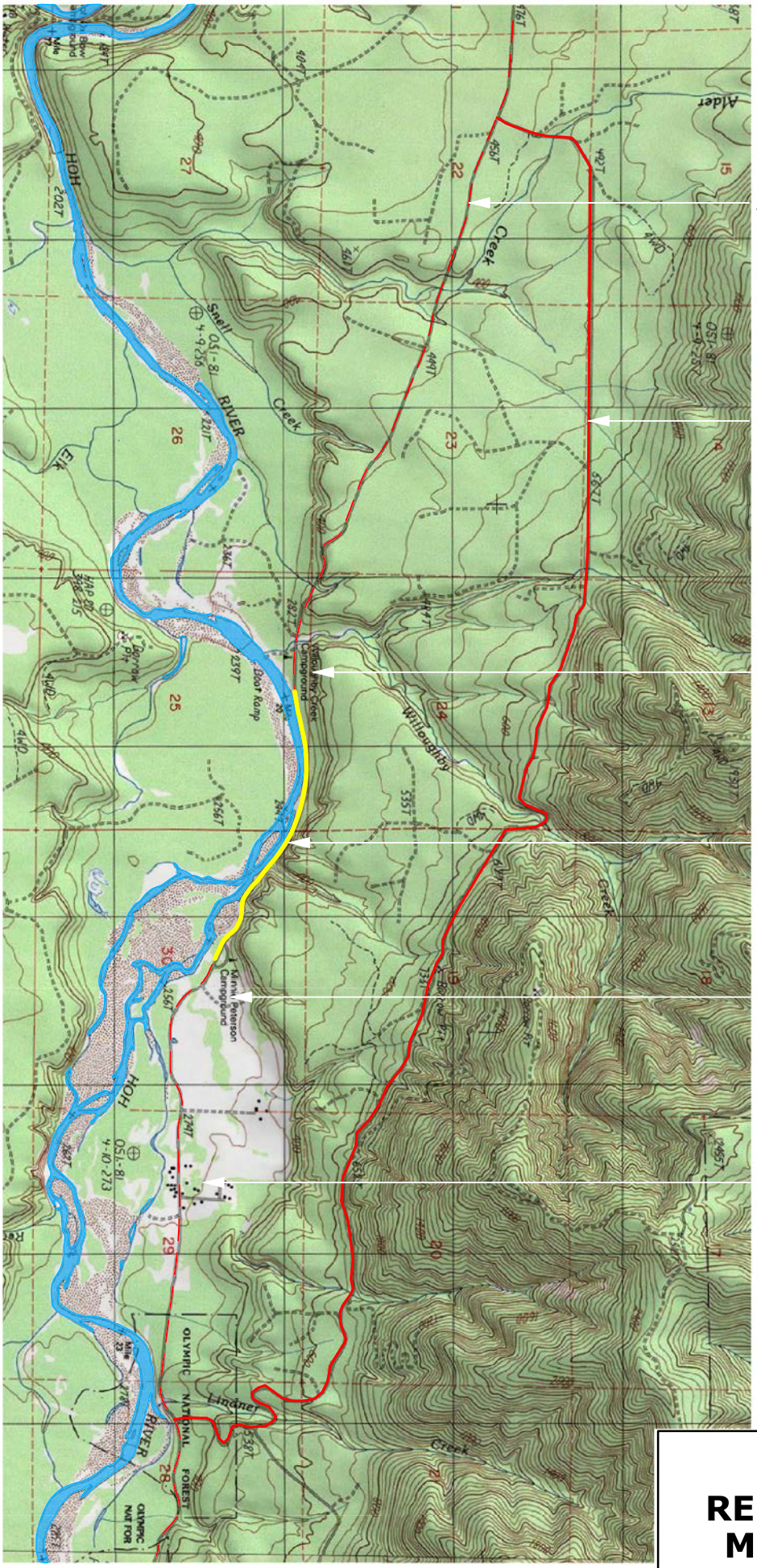


FIGURE 3-1
RELOCATING ROAD
MP 1.4 TO MP 6.9

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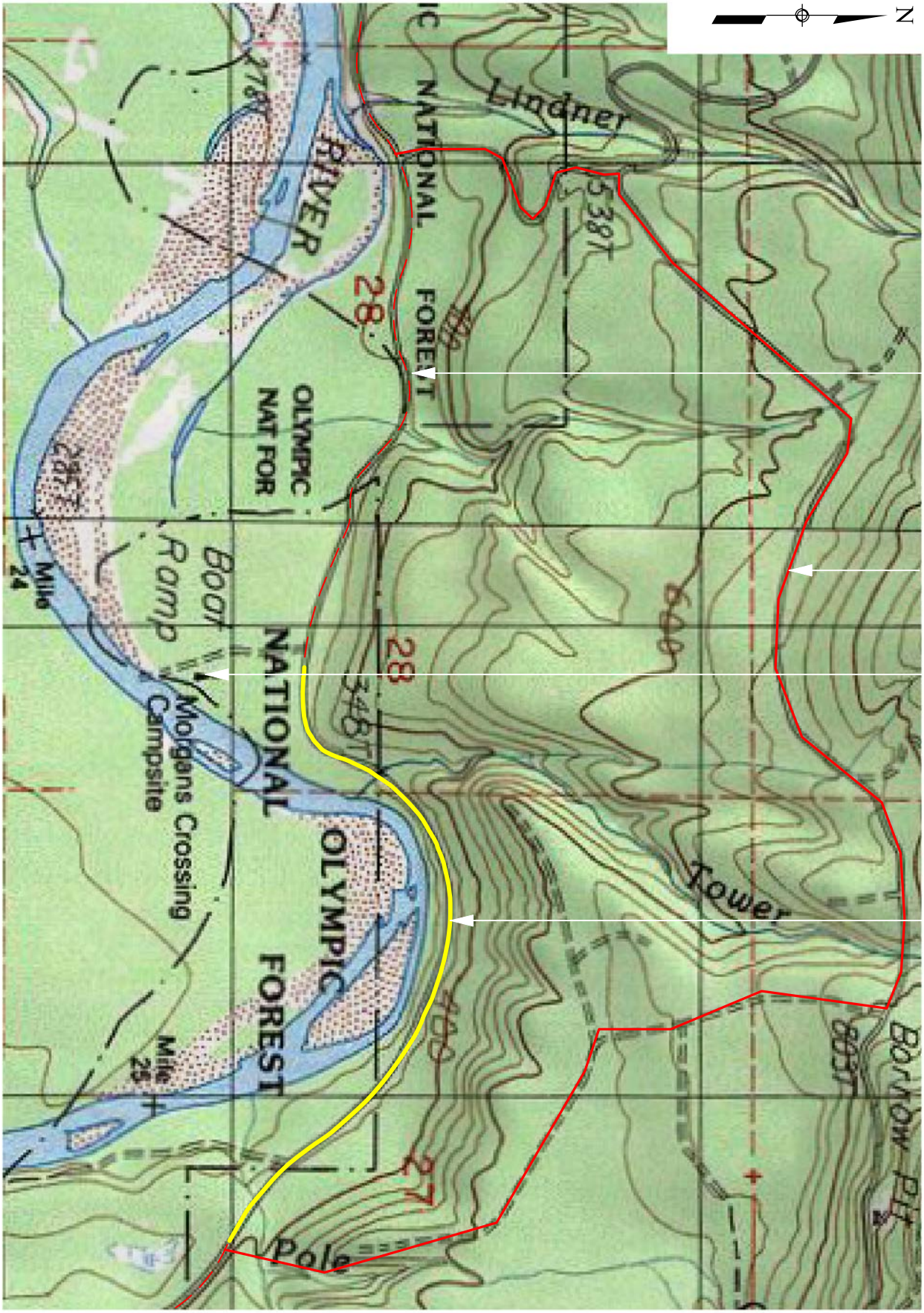


FIGURE 3-2
RELOCATING ROAD
MP 6.9 TO MP 8.2

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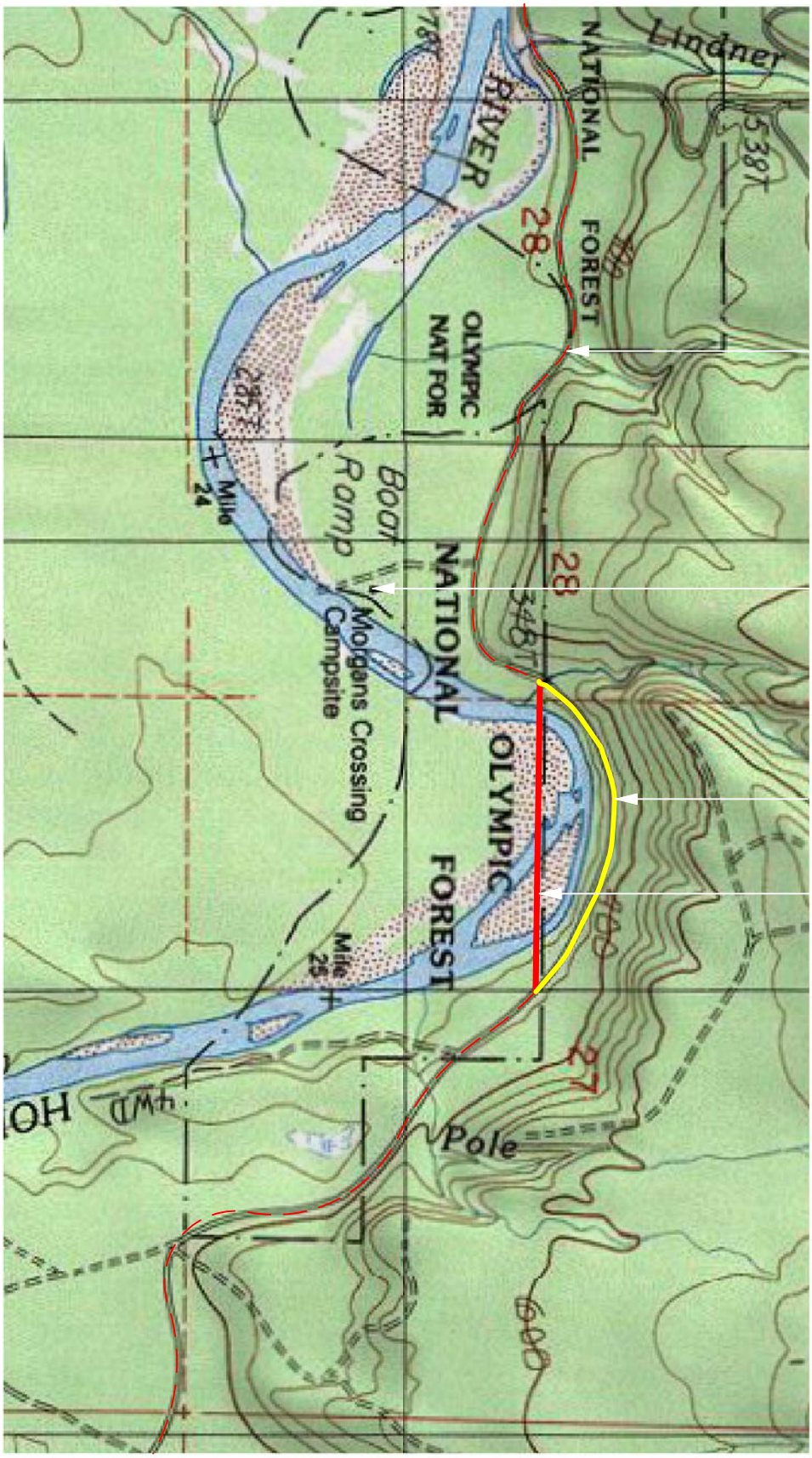


FIGURE 3-3
BYPASS BRIDGE
MP 7.5 TO MP 8.0

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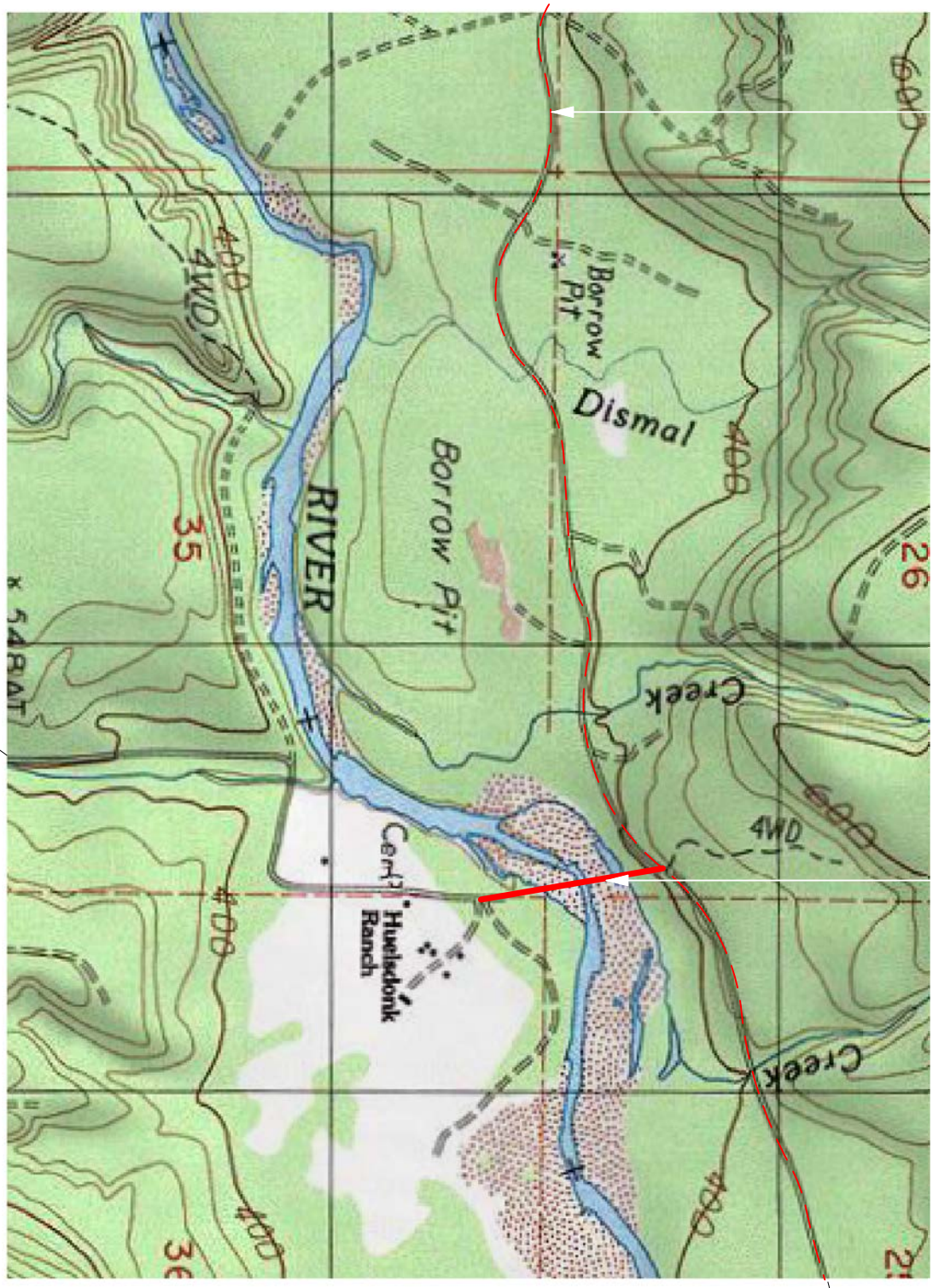


FIGURE 3-4
NEW BRIDGE ACROSS RIVER AT MP 9.9

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Table 3-1. Relocating Road North, CMP 1.4 to CMP 6.9

Description	Quantity	Unit	Low Unit Price ($million)	High Unit Price ($million)	Price Range ($million)
Road construction Cost	6.3	mile	2.5	3.5	15.8 to 22.1
Stream crossing structures	4	each	0.1	0.6	0.4 to 2.4
				Subtotal	**16.2 to 24.5**
NEPA compliance (5%)					0.8 to 1.2
30% contingency					4.8 to 7.3
PE cost (15%)					2.4 to 3.7
CE Cost 15%)					2.4 to 3.7
				Total	**26.6 to 40.3**

Table 3-2. Relocating Road North, CMP 6.9 to CMP 8.2

Description	Quantity	Unit	Low Unit Price ($million)	High Unit Price ($million)	Price Range ($million)
Road construction Cost	2.8	mile	2.5	3.5	7.0 to 9.8
Stream crossing structures	2	each	0.1	0.6	0.2 to 1.2
				Subtotal	**7.2 to 11.0**
NEPA compliance (5%)					0.4 to 0.6
30% contingency					2.2 to 3.3
PE cost (15%)					1.1 to 1.7
CE Cost 15%)					1.1 to 1.7
				Total	**11.9 to 18.2**

Table 3-3. Building Bypass Bridge from CMP 7.5 to CMP 8.0

Description	Quantity	Unit	Low Unit Price ($)	High Unit Price ($)	Price Range ($million)
Bridge area	92,000	Sqft	225	300	20.7 to 27.6
Bridge approach road construction	2	each	250,000	400,000	0.5 to 0.8
				Subtotal	**21.2 to 28.4**
NEPA compliance (5%)					1.1 to 1.4
30% contingency					6.4 to 8.5
PE cost (15%)					3.2 to 4.3
CE Cost 15%)					3.2 to 4.3
				Total	**35.0 to 46.9**

Table 3-4. Building Bridge Across the River at CMP 9.9

Description	Quantity	Unit	Low Unit Price ($)	High Unit Price ($)	Price Range ($million)
Bridge area	52,000	sqft	225	300	11.7 to 15.6
Bridge approach road construction	2	each	250,000	400,000	0.5 to 0.8
				Subtotal	**12.2 to 16.4**
NEPA compliance (5%)					0.6 to 0.8
30% contingency					3.7 to 4.9
PE cost (15%)					1.8 to 2.5
CE Cost 15%)					1.8 to 2.5
				Total	**20.1 to 27.1**

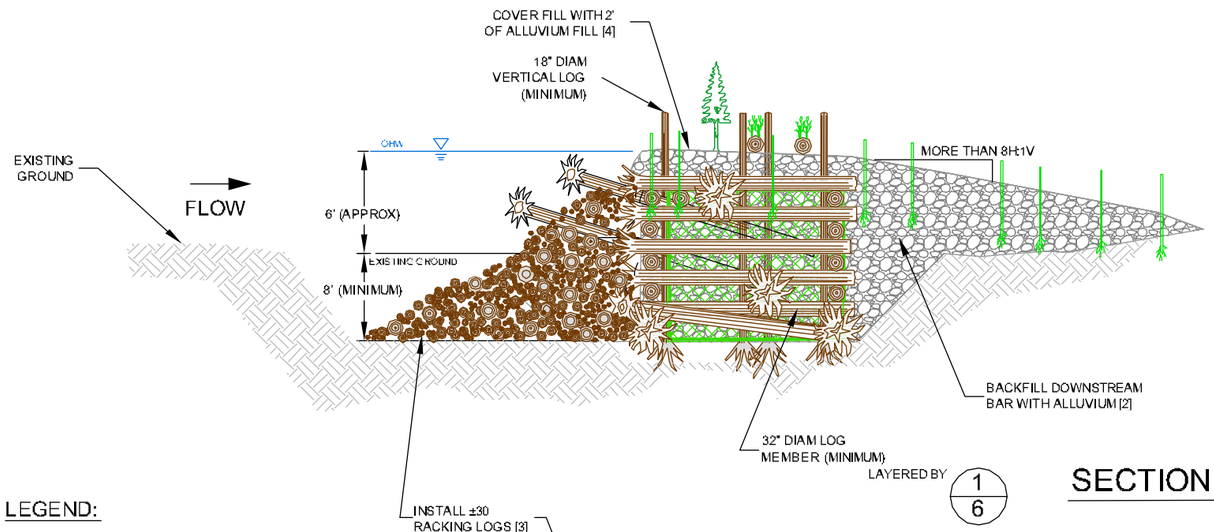
Upper Hoh Road Bank Failure Risk Reduction Study

Appendix A
Bank Stabilization Typical Details



Park Milepost 0.8 Bank Stabilization.

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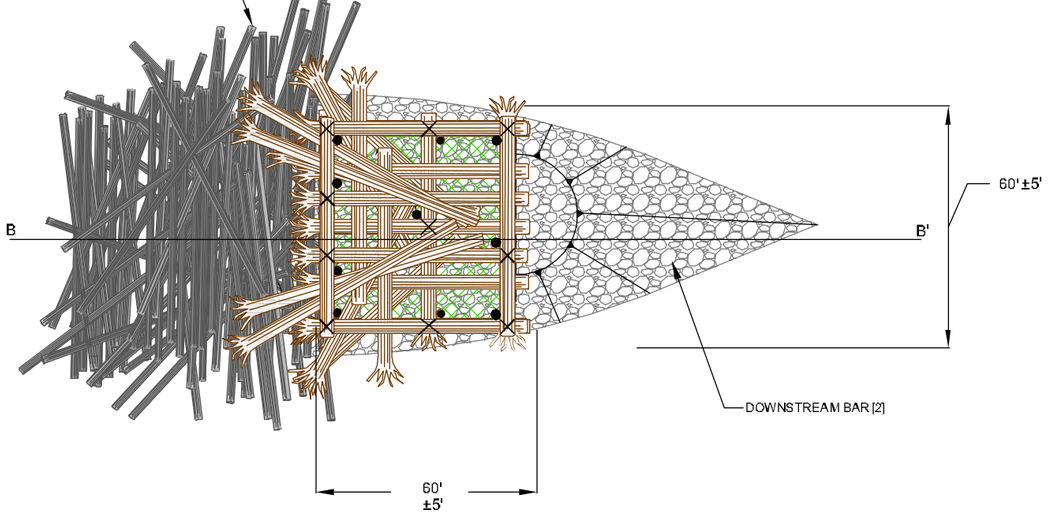
SECTION VIEW B-B'



PHOTO 2004 - CISPUS RIVER ELJ

LEGEND:

- NATIVE ALLUVIUM COBBLE, GRAVEL, SAND
- RACKING MATERIAL
- LOG MEMBER
- BRUSH MATTRESS
- LIVE COTTONWOOD OR WILLOW
- SALVAGED NURSE LOG
- BLACK COTTONWOOD POST, WESTERN RED CEDAR, SITKA SPRUCE, OR DOUGLAS FIR
- 18" UNTREATED DOUGLAS FIR VERTICAL LOG
- CABLE



PLAN VIEW

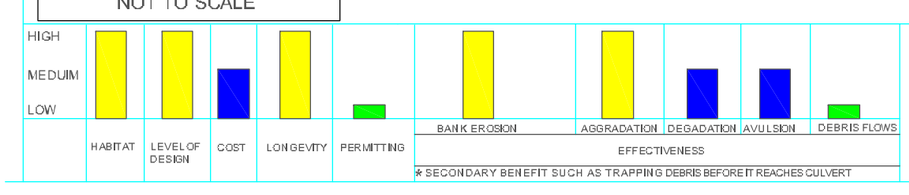
ENGINEERED LOG JAM

1/1

NOTES:

1. ADD LOG MEMBERS TO ACHIEVE ELJ TOP ELEVATION OF APPROXIMATELY ORDINARY HIGH WATER.
2. DOWNSTREAM BAR, A MIXTURE OF COBBLE, GRAVEL, AND FINES, TO BE PLANTED WITH A MIXTURE OF BLACK COTTONWOOD POSTS, RED CEDAR, SITKA SPRUCE, AND/OR DOUGLAS FIRS, WILLOW BUNDLES, BRUSH, AND LIVE STAKING GRAVEL BAR SO THAT THEIR ENDS ARE BELOW THE BASE FLOW ELEVATION.
3. LOGS USED FOR RACKING MATERIAL SHALL BE 10"-16" DIAM. (MINIMUM), AND 35' IN LENGTH. (MINIMUM).
4. ENGINEERED LOG JAM SHALL BE CAPPED WITH 2' OF ALLUVIUM FILL. ALLUVIUM FILL SHALL CONSIST OF COBBLE, GRAVEL, AND SAND MIXTURE FROM SITE.
5. EXCAVATED SPOILS SHALL BE STOCKPILED ON SITE AND USED TO FILL ELJ BARS AND RIVER POINT BARS.
6. FINAL VERTICAL LOG LOCATIONS AND NUMBER TO BE DETERMINED WITH CONTRACTOR BASED ON VERTICAL LOG DRIVING EQUIPMENT.VERTICAL LOGS ARE TO BE SHARPENED ON BOTTOM END AND DRIVEN PAST EXCAVATION DEPTH, IF ROOTWADS ARE NOT ATTACHED.
7. CABLE SQUARE BOX MEMBERS TO VERTICAL VERTICAL LOGS WITH 5/8 INCH GALVANIZED STEEL CABLE AND CLAMPS.
8. LINE BOTTOM, INSIDES OF CORE BOX AND FRONT WITH SLASH BRUSHMATTING. SLASH BRUSHMATTING SHALL CONSIST OF BRUSH AND BRANCHES THAT ARE 1"-4" DIAMETER AND 3'-10' LONG.

SCHEMATIC DESIGN DETAILS
NOT FOR CONSTRUCTION
NOT TO SCALE



ENTRIX
200 FIRST AVE WEST
SUITE 500
SEATTLE WA, 98119
206-269-0104
FAX 206-269-0098

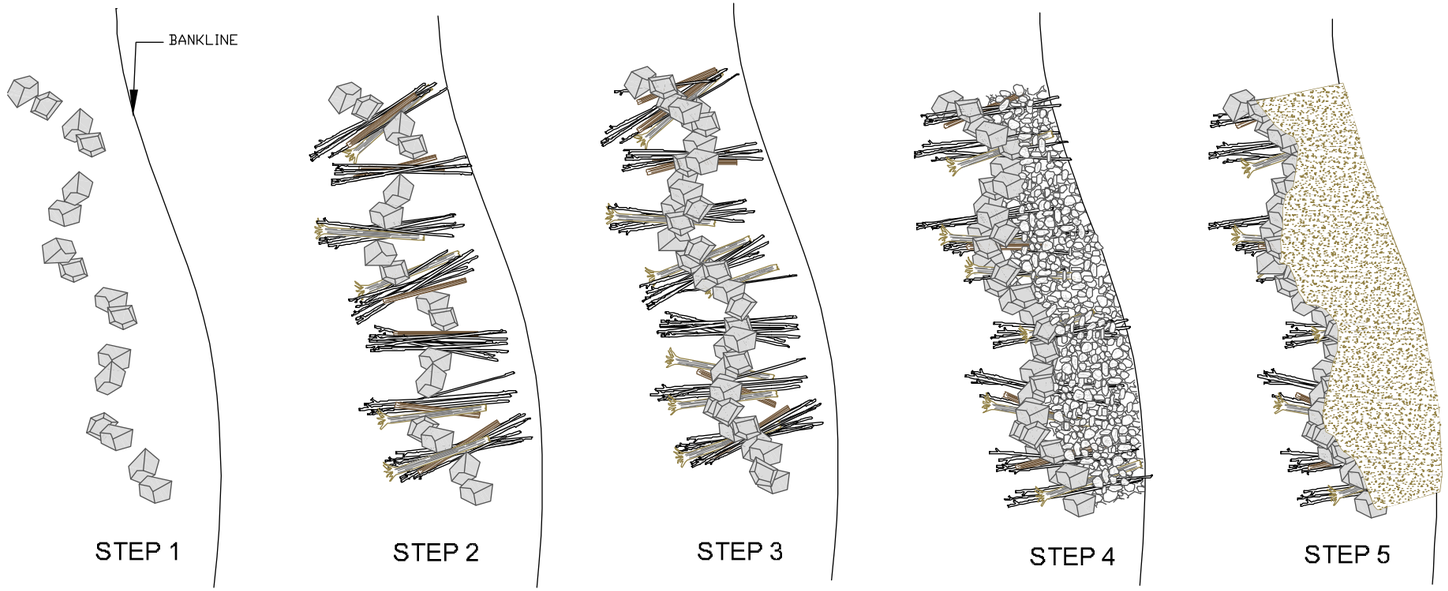
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DSGN	TA
DWN	SK,MM
CHKD	TA
SUPV	
APVD	
DATE	07/01/09

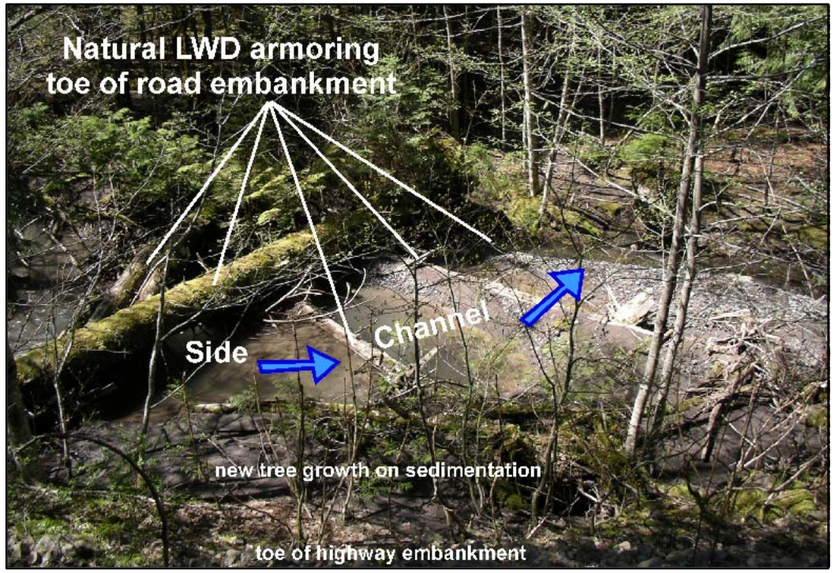
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CADD: AK, MM
TECH. REVIEW:
DATE: 07/01/09
SUB SHEET NO.

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DRAWING NO.
PMIS/PKG NO.
SHEET 1 OF 11

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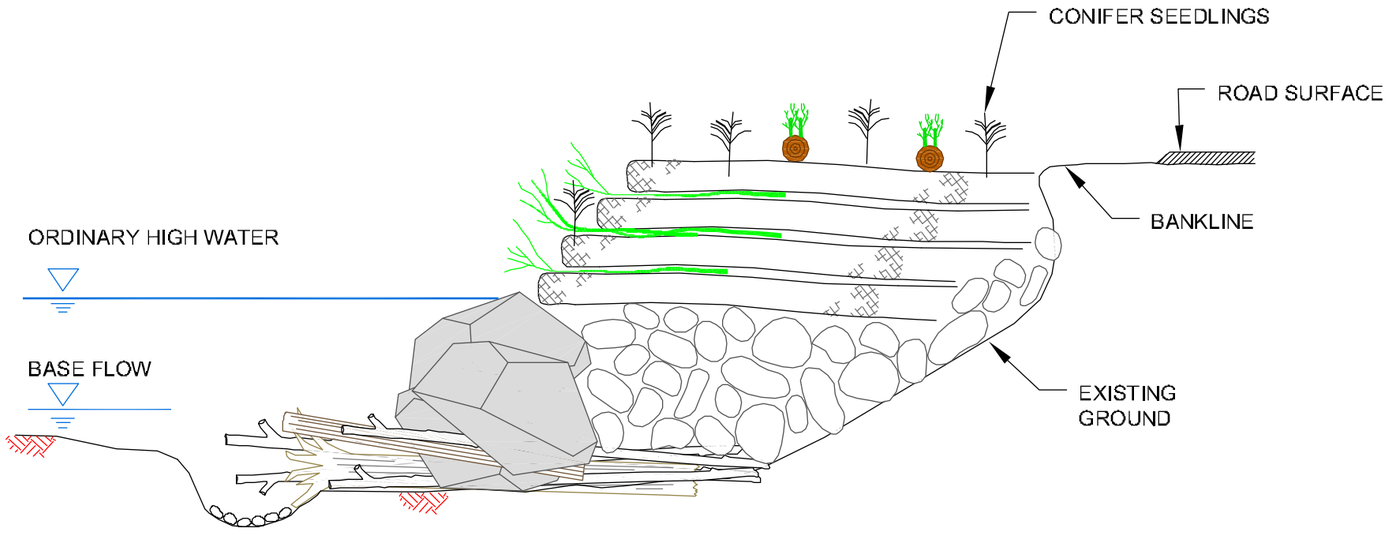




LOG AND ROCK LAYERING PLAN

SCALE: NTS

2
4



SECTION (TYP)

1
4

NOTES:

1. FINAL GEOMETRY TO BE DETERMINED ON SITE SPECIFIC DESIGNS
2. NATIVE SUBSTRATE LIFTS TO BE ENCASED IN OVERLAPPING LAYERS OF EROSION CONTROL BLANKET.
3. SIZING OF ROCK AND LOGS SCALED TO RIVER SIZE AND DISCHARGE BY PROFESSIONAL GEOLOGIST OR ENGINEER.
4. SCOUR POOL DEPTH AND WIDTH WILL VARY BY PROJECT SITE.
5. LARGE ROCKS HAVE A DIAMETER GREATER THAN LARGEST PARTICLES MOVING DOWNSTREAM.

LEGEND

- NATIVE CONIFER SEEDLINGS
- NURSE LOG
- WILLOW & COTTON FASCINES/STAKES
- LOG BUNDLES
- HEAVY LOOSE RIPRAP
- NATIVE SUBSTRATE
- LARGE ROCKS KEYED INTO TOE

SCHEMATIC DESIGN DETAILS
NOT FOR CONSTRUCTION
NOT TO SCALE

	HABITAT	LEVEL OF DESIGN	COST	LONGEVITY	PERMITTING	BANK EROSION	AGGRADATION	DEGADATION	AVULSION	DEBRIS FLOW
HIGH		■		■		■				
MEDUIM	■		■		■				N/A	
LOW							■	■		■
	EFFECTIVENESS									

* SECONDARY BENEFIT SUCH AS TRAPPING DEBRIS BEFORE IT REACHES CULVERT

ENTRIX
200 FIRST AVE WEST
SUITE 500
SEATTLE WA, 98119
206-269-0104
FAX 206-269-0098

REVISION 01	
JOB NO	4194802
DSGN	TA
DWN	SK,MM
CHKD	TA
SUPV	
APVD	
DATE	07/01/09

NATIONAL PARK SERVICE

DESIGNED: TA
CADD: AK, MM
TECH. REVIEW:
DATE: 07/01/09

SUB SHEET NO.

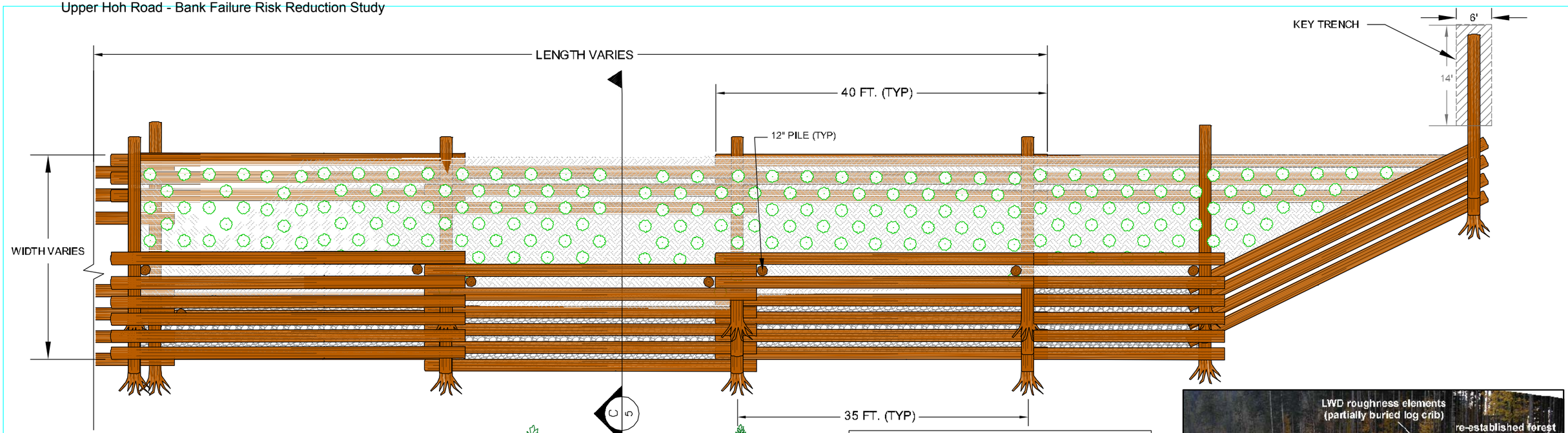
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NATIONAL PARK ROADS

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PMIS/PKG NO.

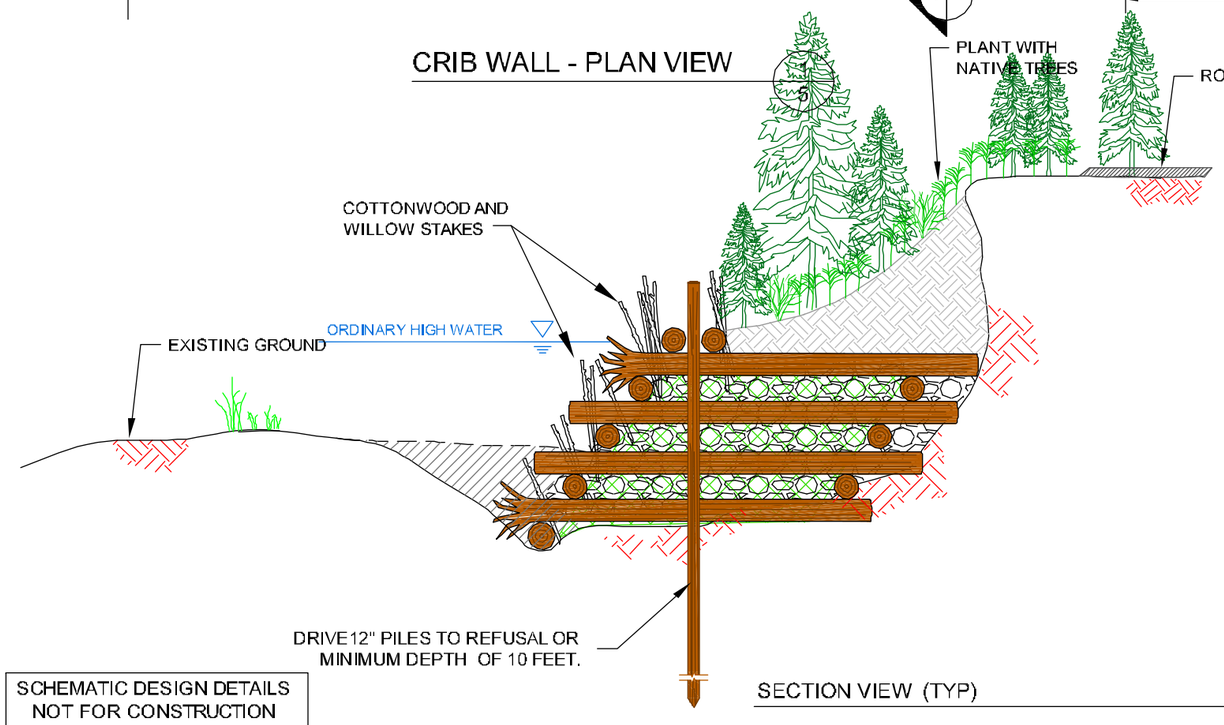
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CRIB WALL - PLAN VIEW

C 5

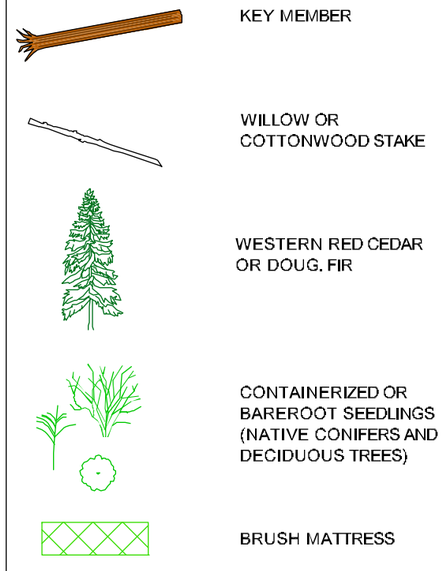


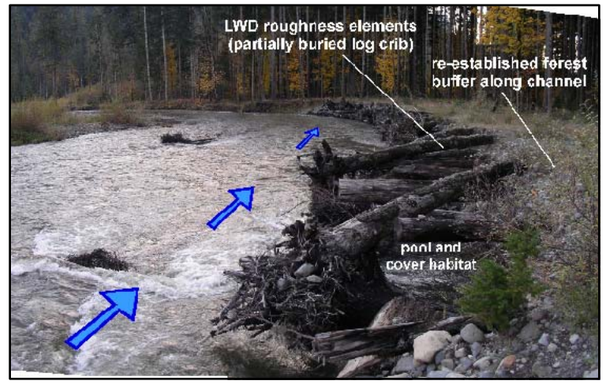
SECTION VIEW (TYP)

C 5

SCHEMATIC DESIGN DETAILS
NOT FOR CONSTRUCTION
NOT TO SCALE

LEGEND:





NOTES:

1. INTERIOR OF ELJ CRIB SHOULD BE LINED WITH CEDAR BRUSH AND LOCAL NATIVE CUTTINGS AS DETERMINED BY PROJECT ENGINEER. CONSTRUCT
2. BRUSH MATTING BY FILLING BOTTOM OF CRIB STRUCTURE AFTER 2 LOG LAYERS. PACK BRUSH MATTING INTO SIDES OF CRIB STRUCTURE EVERY 2 OR 3 LOG LAYERS UNTIL COMPLETION OF THE CRIB STRUCTURE. AFTER EACH PLACEMENT OF PLANT MATTER, SECURE IT BY PLACING AND COMPACTING NATIVE ALLUVIUM FILL.
3. ROCK AND FILL BACKFILL SIZE TO BE DETERMINED BY GEOLOGIST OR ENGINEER FOR SITE SPECIFIC CONDITIONS.
4. CRIB WALL MEMBERS SHOULD BE CHAINED OR CABLED TOGETHER. PILES SHOULD NOT BE CABLED TO ALLOW FOR POSSIBLE SETTLEMENT OF CRIB WALL.
5. KEY IN UPSTREAM CRIBWALL FLANK TO EXISTING GROUND.

	HABITAT	LEVEL OF DESIGN	COST	LONGEVITY	PERMITTING	BANK EROSION	AGGRADATION	DEGADATION	AVULSION	DEBRIS FLOW
HIGH									N/A	
MEDIUM										*
LOW										

EFFECTIVENESS

* SECONDARY BENEFIT SUCH AS TRAPPING DEBRIS BEFORE IT REACHES CULVERT

ENTRIX
200 FIRST AVE WEST
SUITE 500
SEATTLE WA, 98119
206-269-0104
FAX 206-269-0098

REVISION 01	
JOB NO	4194802
DSGN	TA
DWN	SK,MM
CHKD	TA
SUPV	
APVD	
DATE	07/01/09

DESIGNED:	TA
CADD	AK, MM
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TITLE OF SHEET
COMPLEX LOG CRIB WALL NATIONAL PARK ROADS

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PMIS/PKG NO.

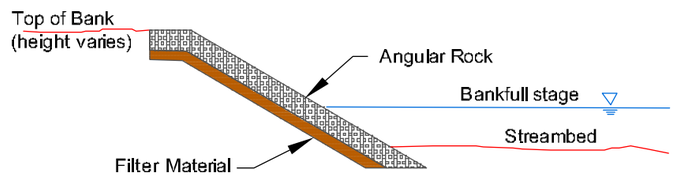
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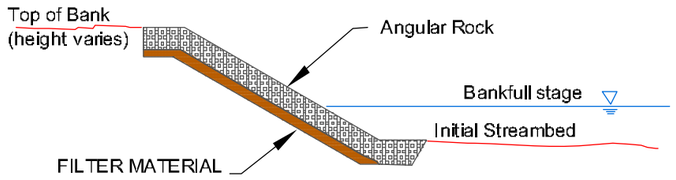


B. NOOKSACK RIVER (EXAMPLE)

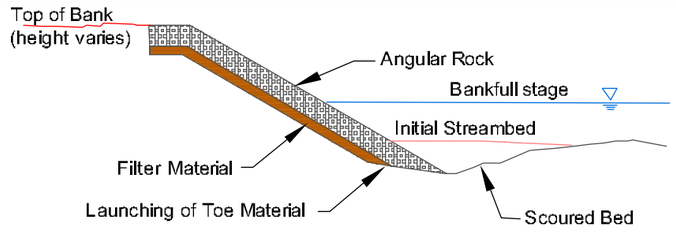
INTEGRATED STREAMBANK PROTECTION GUIDELINES
WASHINGTON STATE AQUATIC HABITAT GUIDELINES
PROGRAM 2003 CHAPTER 6



TYPICAL RIPRAP WITH EXCAVATED TOE



LAUNCHABLE TOE (Before toe is launched into scour hole)



LAUNCHED TOE (after toe has launched into scour hole)

TYPICAL RIPRAP WITH LAUNCHABLE TOE (BEFORE AND AFTER)

NOT TO SCALE

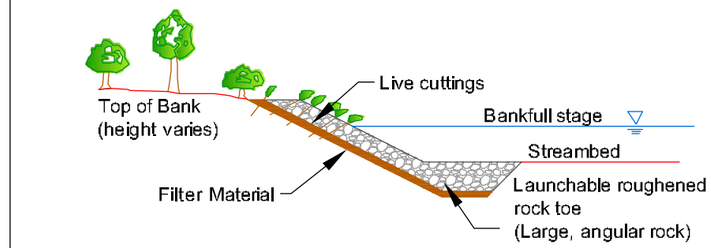
FIGURE 6-22

INTEGRATED STREAMBANK PROTECTION GUIDLINES
www.wa.gov/wdfw/hab/salguide/stmbank.htm

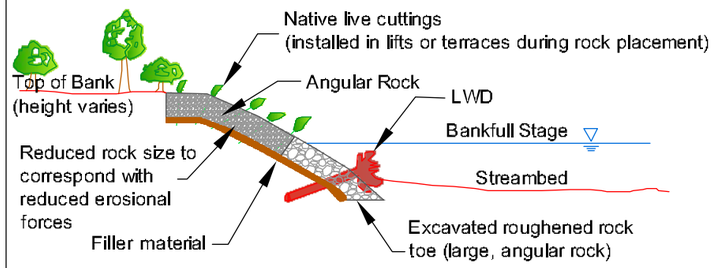
RIPRAP (CONVENTIONAL) CONCEPTUAL DESIGN

RIPRAP (CONVENTIONAL) CONCEPTUAL DESIGN

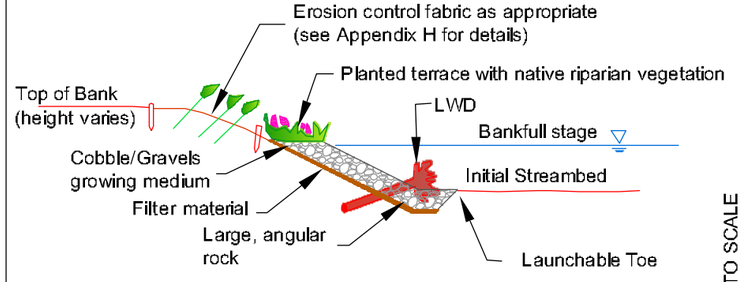
INTEGRATED STREAMBANK PROTECTION GUIDELINES
WASHINGTON STATE AQUATIC HABITAT GUIDELINES
PROGRAM 2003 CHAPTER 6 FIGURE 6-22



RIPRAP ENHANCED WITH RIPARIAN PLANTINGS



RIPRAP WITH ROUGHENED TOE, LWD, AND WILLOW PLANTINGS



RIPRAP TERRACED WITH ROUGHENED ROCK TOE, LWD, RIPARIAN PLANTINGS, AND FABRIC COVERED UPPER BANK

NOT TO SCALE

FIGURE 6-23

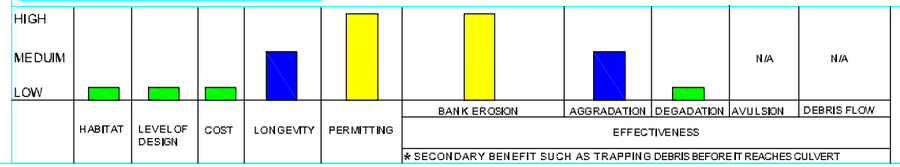
INTEGRATED STREAMBANK PROTECTION GUIDLINES
www.wa.gov/wdfw/hab/salguide/stmbank.htm

RIPRAP (NON-CONVENTIONAL) CONCEPTUAL DESIGN

RIPRAP (NON-CONVENTIONAL) CONCEPTUAL DESIGN

INTEGRATED STREAMBANK PROTECTION GUIDELINES
WASHINGTON STATE AQUATIC HABITAT GUIDELINES
PROGRAM 2003 CHAPTER 6 FIGURE 6-23

SCHEMATIC DESIGN DETAILS
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DATE: 07/01/09

SUB SHEET NO.

TITLE OF SHEET
RIPRAP
NATIONAL PARK ROADS

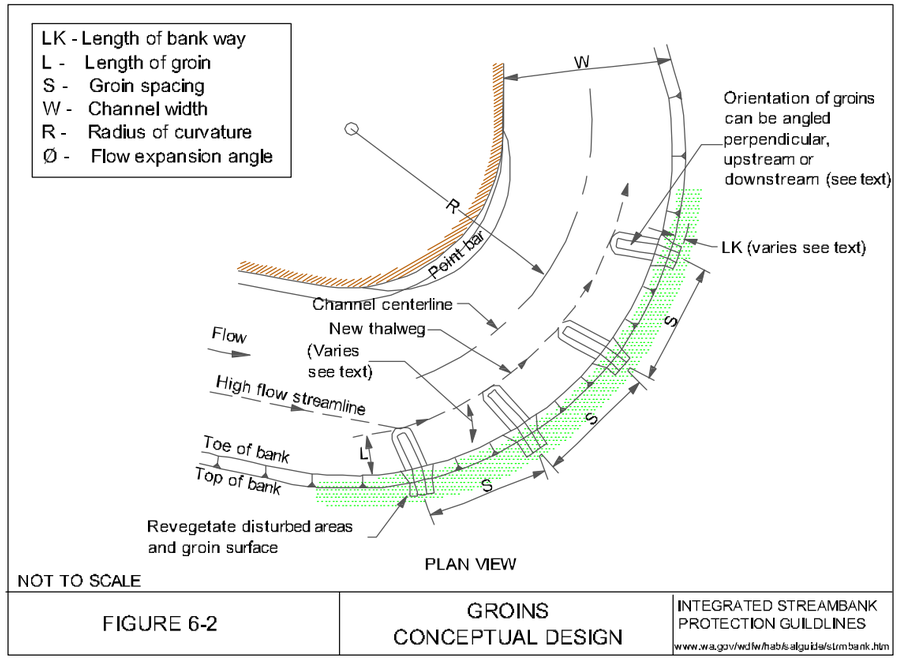
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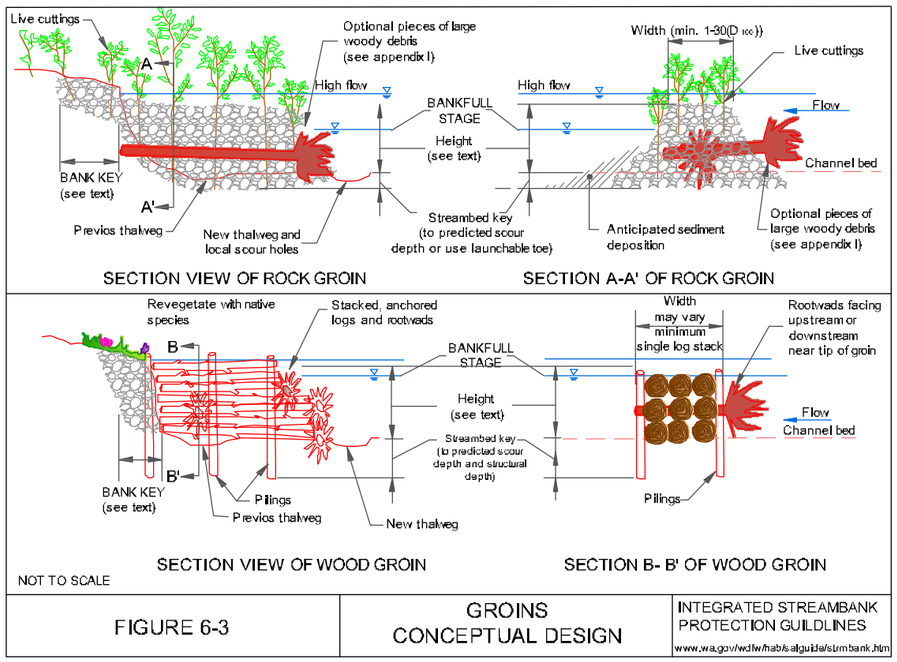
F. WOOD GROINS. NOOKSACK RIVER. (1998).
(EXAMPLE)

INTEGRATED STREAMBANK PROTECTION GUIDELINES
WASHINGTON STATE AQUATIC HABITAT GUIDELINES
PROGRAM 2003 CHAPTER 6 FIGURE 6-1



GROINS CONCEPTUAL DESIGN

INTEGRATED STREAMBANK
PROTECTION GUIDELINES
WASHINGTON STATE AQUATIC
HABITAT GUIDELINES PROGRAM
2003 CHAPTER 6 FIGURE 6-2



GROINS CONCEPTUAL DESIGN

INTEGRATED STREAMBANK
PROTECTION GUIDELINES
WASHINGTON STATE AQUATIC
HABITAT GUIDELINES PROGRAM
2003 CHAPTER 6 FIGURE 6-3

SCHEMATIC DESIGN DETAILS
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	HABITAT	LEVEL OF DESIGN	COST	LONGEVITY	PERMITTING	BANK EROSION	AGGRADATION	DEGADATION	AVULSION	DEBRIS FLOW
HIGH									N/A	N/A
MEDUIM										
LOW										
						EFFECTIVENESS				

*SECONDARY BENEFIT SUCH AS TRAPPING DEBRIS BEFOREIT REACHES CULVERT

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NATIONAL PARK ROADS

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B. COWLITZ RIVER, NEAR TOLEDO, WA. (EXAMPLE)

INTEGRATED STREAMBANK PROTECTION GUIDELINES
WASHINGTON STATE AQUATIC HABITAT GUIDELINES
PROGRAM 2003 CHAPTER 6 FIGURE 6-6

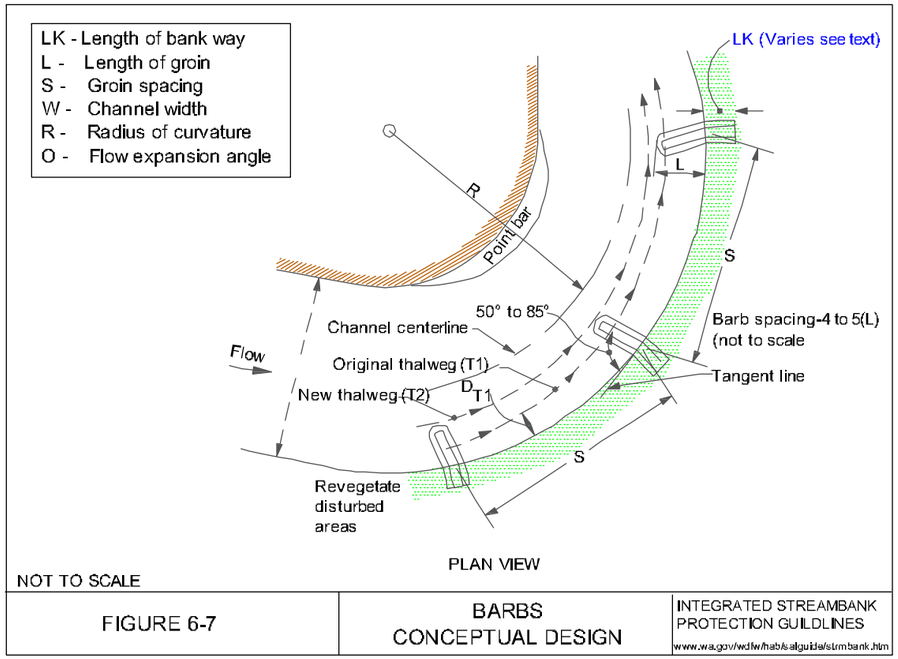


FIGURE 6-7	BARBS CONCEPTUAL DESIGN	INTEGRATED STREAMBANK PROTECTION GUILDLINES www.wa.gov/wdfw/hab/slaguide/strmbank.htm

BARBS CONCEPTUAL DESIGN

INTEGRATED STREAMBANK
PROTECTION GUIDELINES
WASHINGTON STATE AQUATIC
HABITAT GUIDELINES PROGRAM
2003 CHAPTER 6 FIGURE 6-7

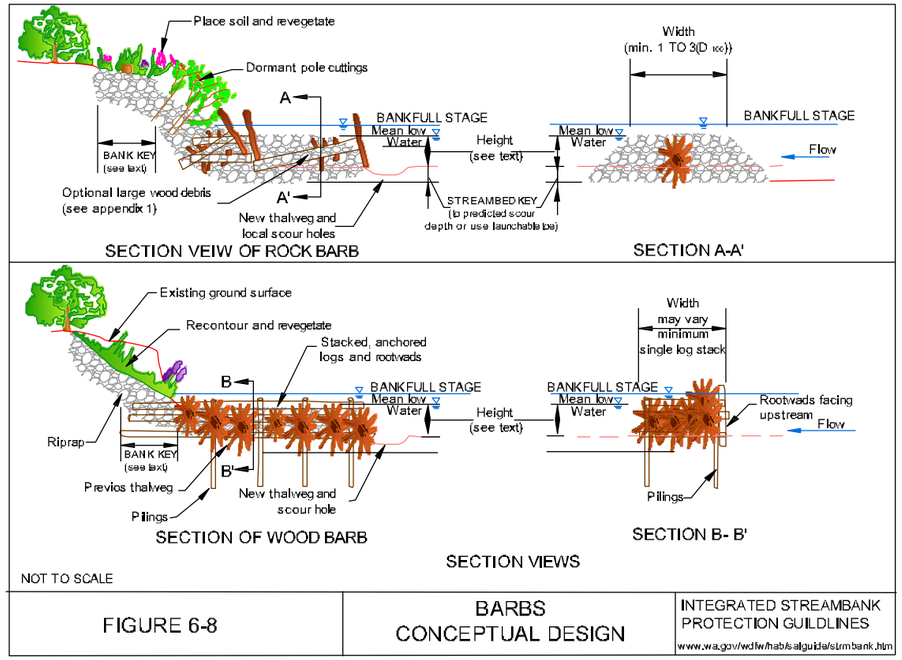
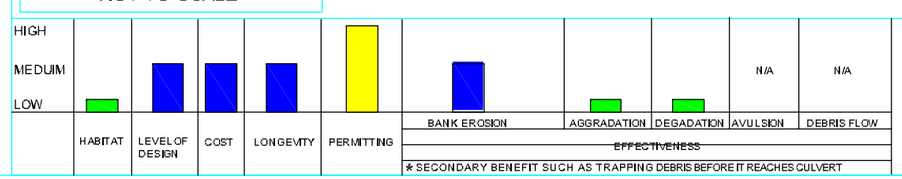


FIGURE 6-8	BARBS CONCEPTUAL DESIGN	INTEGRATED STREAMBANK PROTECTION GUILDLINES www.wa.gov/wdfw/hab/slaguide/strmbank.htm

BARBS CONCEPTUAL DESIGN

INTEGRATED STREAMBANK
PROTECTION GUIDELINES
WASHINGTON STATE AQUATIC
HABITAT GUIDELINES PROGRAM
2003 CHAPTER 6 FIGURE 6-8

SCHEMATIC DESIGN DETAILS
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