Henry M. Jackson Hydroelectric Project (FERC No. 2157)

Relicensing Study Plan No. 24

Feasibility of Marsh Creek Slide Modification to Improve Fish Passage

Prepared for

Public Utility District No. 1 of Snohomish County

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EXECUTIVE SUMMARY

On December 11, 2004, a major landslide (classed as a rock fall) occurred along the Sultan River immediately below the confluence with Marsh Creek at RM 7.6. The slide deposited a significant volume of large rock and debris in the river. Subsequent high flow events of up to 3,560 cfs cleared some of the rocks and debris from the channel. However, as documented in annual spawning surveys, passage of Chinook salmon and steelhead trout beyond the slide has been hindered since late 2004 and remains so today. Fish access to 2.1 miles of upstream habitat has been reduced. Given the concern about future fish production in this 2.1-mile reach, the Jackson Project Relicensing Aquatic Resources Work Group requested that the Licensee conduct an additional study of the Marsh Creek slide cascade. The overall objective of this study was to determine the feasibility of modifying the partial passage barrier at Marsh Creek slide cascade to promote improved fish passage. Specific objectives include identifying alternative methods to modify the slide or cascade, assessing their relative feasibility for the site, and providing general cost opinions of each method.

The feasibility assessment for passage improvement at the Marsh Creek slide cascade relied largely on the expertise of a geologist/geotechnical engineer, a contractor with experience working in such environments, and fisheries biologists knowledgeable of fish passage requirements. A site visit took place on January 30, 2009, when stream flow was approximately 200 cfs. On-site activities included inspection of the hillside scarp that created the barrier cascade when it failed in December 2004, the rock debris pile that lies between the scarp and cascade, and the size and configuration of the rocks that contribute to the hydraulic conditions in the cascade. An earlier hydraulic evaluation related to fish passage at the cascade was completed in 2007.

The 150 foot hillside above the Marsh Creek slide cascade remains unstable. The hillside consists mostly of rock that is highly influenced by vertical shear zones and jointing. There is evidence of some continued fall of small rocks since the site was last viewed and photographed in October 2007. The instability of the hillside would create safety concerns for crews working below attempting to modify the cascade, especially for the more intensive efforts that would involve removal of large rocks. The debris fan at the base of the hillside also contains unstable rocks that could fall.

Several alternative construction methods were identified that could be used to modify the configuration of the Marsh Creek slide cascade. These include use of (1) helicopters, (2) high lead cable system, (3) crawler tractor and winch line, (4) hand operated equipment, and (5) blasting / use of expandable grout without rock removal. Most of these methods involve the active removal of rock from the cascade and their placement into other nearby locations in the canyon. In most cases, much of the existing rock would have to be substantially reduced in size, most likely with blasting, to facilitate its movement and removal. Extracting rocks and moving them would be a major undertaking with considerable safety risks, uncertainties, and high cost.

The method of simply reducing the size of apparent problem rocks with blasting or expandable grout and then leaving them in place for natural high-flow dispersal would

be the easiest and safest approach to modify the cascade. However, there is some uncertainty as to whether this approach would be successful at improving fish passage in the short term (before a high flow event rearranges rocks) and perhaps in the long term as well. Eliminating the large rocks that are causing hydraulic turbulence problems for fish passage may also remove needed resting areas in the cascade. Therefore, careful selection of rocks for downsizing and/or removal would be important for success.

Given the uncertainty of fish passage effectiveness associated with the blast–and-leave method (and any method), an adaptive management approach would be necessary to increase the probability of passage success. Best judgment would dictate how many and which individual rocks would be candidates for blasting on the initial effort. This would be followed by a visual inspection of the site, first after blasting and again after a high flow event. If the site “appears” to have been improved, studies would be needed to confirm that passage has been improved. This could be done by monitoring adult escapement to the 2.1-mile reach above the site, visually observing fish passage, and/or tracking radio-tagged fish. The latter approach would provide more detailed information on attempted or successful passage routes at the cascade, thus informing additional modifications to the cascade, if necessary. Recognizing the desire to have a sufficient numbers of spawners pass the site to adequately seed the 2.1-miles of river up to the Diversion Dam, passage monitoring and evaluation should be done for at least two life cycles (8 – 10 years) after the cascade is modified to ensure that enough fish consistently reach the Diversion Dam.

1.0 STUDY OBJECTIVES AND DESCRIPTION

On December 11, 2004, a major landslide (classed as a rock fall) occurred along the Sultan River immediately below the confluence with Marsh Creek at RM 7.6. The slide deposited a significant volume of large rock and debris in the river, temporarily blocking the flow in the river and resulting in a constricted channel with high gradient at the debris location. Two high flow events occurred in the river in November 2006 and March 2007 of up to 3,560 cfs. These high flows cleared some of the rocks and debris from the channel area and all of the exposed woody debris associated with the slide. However, as documented in annual spawning surveys, fish passage beyond the slide has been hindered since late 2004 and remains so today. Fish access to 2.1 miles of upstream habitat has been reduced. Specific conclusions of a 2007 study of fish passage at the Marsh Creek (Ruggerone 2008) are presented below in Section 2.0. That study focused only on the passage of fish and made no specific recommendations for improving passage conditions.

The overall objective of this study is to determine the feasibility of modifying the partial passage barrier at Marsh Creek slide cascade to promote improved fish passage. Specific objectives include identifying alternative methods to modify the cascade, assessing their relative feasibility for the site, and providing general cost opinions of each method.

2.0 BACKGROUND INFORMATION

Prior to the landslide in December 2004, summer and winter-run steelhead, Chinook salmon, and coho salmon utilized the entire Sultan River area downstream of the Diversion Dam (PUD & City of Everett 2005). Steelhead and Chinook salmon redds were regularly enumerated near the Diversion Dam during annual surveys. Regular surveys are not conducted for coho salmon, which enter the river during late fall and winter when flows are typically higher and water clarity is reduced. Chum and pink salmon spawn primarily in the lower three miles of the Sultan River; however, pink salmon have been observed upstream to RM 7.5, i.e., the area just below the Marsh Creek slide cascade. Bull trout (Salvelinus confluentus) have not been observed spawning in the Sultan River; however, they are known to use the lower river as rearing/foraging habitat especially during odd-numbered years when pink salmon eggs are prevalent. Both fall Chinook salmon and steelhead trout using the Sultan River are listed as threatened species under the federal Endangered Species Act.

Phase 1 of Revised Study Plan 20 was conducted as part of the Jackson Project Integrated Licensing Process required by the Federal Energy Regulatory Commission (FERC). The study was conducted to document the extent to which the slide is a fish passage barrier. Specific conclusions of the study were:

- The present configuration of Marsh Creek cascade appears to block the migration of most Chinook salmon even though Chinook are present when flows were low to moderate (105 to 165 cfs and above).

- Summer run steelhead have the greatest opportunity for gaining passage at the Marsh Creek cascade because they encounter the full range of available flows in the Sultan River and because they have long residence in the river prior to spawning. Although the cascade may hinder summer steelhead migration, it is likely that most are able to eventually negotiate the cascade in its present configuration.

- Many winter steelhead are likely able to negotiate the cascade, but additional observations of spawning steelhead during spring are important for further evaluating this statement.

- It is likely that the Marsh Creek cascade is a modest impediment to coho salmon, but some coho do gain access above the cascade.

- Pink and chum salmon would not likely gain passage over the cascade.

- The longevity of the existing Marsh Creek cascade was evaluated. Significant changes occurred following high flow events up to 3,300 cfs. Additional change is possible but it will likely require flows exceeding 3,500 cfs because the remaining substrate consisted of large boulders wedged against each other and between the rock wall on the left and the active slide on the right. During the past 25 years, flows at the Diversion Dam exceeded 3,500 cfs on 16 days during six years, whereas flows exceeded 6,000 cfs on seven days in four years. Maximum flow during the past 25 years was 16,600 cfs.

- The right bank cliff above Marsh Creek cascade, which rises vertically approximately 200 ft, remains highly unstable. Rock debris along the right bank indicated small landslides have continued since 2004. It is highly likely that another large landslide will occur at the site in the future. The high probability of another landslide is supported by the observation of another large landslide and several smaller landslides occurring further upstream in the bypass reach during early 2007.

3.0 METHODS

The feasibility assessment for passage improvement at the Marsh Creek slide cascade relied largely on the expertise of a geologist/geotechnical engineer, a contractor with experience working in such environments, and fisheries biologists knowledgeable of fish passage requirements. To conduct the assessment a site visit took place on January 30, 2009, when stream flow was approximately 200 cfs. The water was somewhat murky as a result of flood flows a few weeks earlier. Those involved in the site visit included:

- Ken Green, Geotechnical Engineer and registered Geologist with CH2M HILL
- Grant Jansen, General Contractor with Jansen Construction of Ferndale, WA
- Forrest Olson, Senior Fisheries Biologist with CH2M HILL
- Greg Ruggerone, Fisheries Biologist with Natural Resource Consultants (study lead for initial fish passage evaluation at Marsh Creek slide)
- Keith Binkley, Senior Environmental Coordinator/Fisheries Biologist with the District
- Bruce Meaker, Project Engineer for the Jackson Hydroelectric Project with the District

Activities during the site visit included an inspection of the landslide (from above and below), debris fan, cascade, and areas immediately upstream and downstream of the cascade. The size of individual larger rocks believed to be contributing to the fish passage problems at the cascade were estimated with the assistance of a measuring tape. Numerous photographs were taken of the landslide, debris fan, and cascade. Alternative means to break apart large rocks and methods to move or remove rocks were discussed on site. Safety issues associated with each method also were identified.

On February 4, 2009, a presentation was made to the Aquatic Resources Work Group (ARWG) in Everett, WA, describing the findings of the site visit and preliminary conclusions by the team regarding the feasibility of modifying the cascade using various alternative approaches. Some of the feedback and suggestions from the stakeholders attending the meeting are incorporated in the results and discussion below.

4.0 RESULTS

4.1 Site Description

4.1.1 General Setting

Figure 1 provides a topographic map of the study area showing the location of the rock fall and cascade. The site is located in a very steep-walled rock canyon having near-vertical side slopes. The canyon drops more than 150 feet from the rim down to the river. The canyon was formed by the Sultan River downcutting through the rock formations of the area. There is evidence that the walls of the canyon in this segment of the river have historically seen rock falls and surficial instability of similar nature to the recent Marsh Creek slide.

4.1.2 Geologic Setting

The site is underlain by consolidated bedrock consisting of Meszoic meta-igneous and marine meta-sedimentary rocks, which have been interpreted to be a mélange. The rock has undergone folding that has warped the formation and altered its composition resulting in a fractured matrix with well-developed foliations in some areas. The Mesozoic mélange consists of a pervasively sheared matrix of argillite, greenstone, amphibolite, metagabbro, meta-andesite, chert, marble, and metatonalite. In some areas the mélange grades into phylite, with well-developed foliation commonly parallel to bedding.

A thin mantel of glacial drift overlies the top of the bedrock at the area of the rock fall slide. The glacial drift consists of a very dense layer of well graded silt, sand, and gravel with cobbles and boulders up to about 24 inches in diameter. These sediments are exposed in the top 20 feet or so of the slide area, and the slide scarp remains in a near vertical configuration.

4.1.3 Geometry and Conditions at the Rock Fall

Figure 2 illustrates the approximate geometry of the slide area. The north rim of the canyon is at an elevation of approximately 600 ft and the river immediately downstream of the slide debris is at elevation 435 ft. The debris pile at the base of the rock fall rests against the rock hillside at a height of about 35 to 40 feet above the river.

During the December 2004 rockslide, the upper portion of the scarp sheared at a near vertical slope, and the scarp appears to be at about the same configuration currently. Photos 1 and 2 show a top looking down and a bottom looking up perspective of the scarp. The downstream portion of the upper scarp appears to have been influenced by a near vertical shear zone that is more planar in surface shape than in other portions of the scarp. The shear planes appear to have been controlled by pre-existing fractures and jointing, and/or foliation in the rock. The upstream two thirds or more of the upper slide scarp is characterized by a very irregular shaped but near vertical fracture surface. The jointing/fracture system or foliated plane of weakness, which may have controlled the stability of the downstream portion of the upper slope, may also extend under a large portion of the rock mass still hanging on the steep upstream portion of the slope. Photo 3 illustrates these conditions.

The lower portion of the rock mass is masked by the debris pile, which rests against the base of the rock slope. It is possible that the debris mass is providing temporary stability to the rock mass of the lower slope, particularly if the steeply inclined shear zone extends down into the lower rock mass.

The stability of the hillside is believed to be controlled by fractures, joints, and planes of weakness that exist in the rock mass. The steep nature of this rock fall further substantiates this assumption. It appears that the rock fall occurred as a result of a build-up of hydrostatic pressure within the joints, fractures, and planes of weakness. The hydrostatic pressure occurs as groundwater drains into the fractures. When the rate of water in the fractures builds at a rate faster than it can drain out of the rock mass, hydrostatic pressure begins to build. Especially during periods of heavy rainfall, the water pressure can lead to instability and slope failure.

Also shown in Figure 2 is the approximated configuration of the slope and river valley prior to the rock fall. It also shows the estimated current configuration and potential rock masses that may become unstable with additional unloading of the debris from the toe of the slide area. The figure also shows about where the slope debris was configured immediately after the slide. A portion of the lower slope has subsequently eroded away approximately as shown. This is further illustrated by Photo 4.

Photo 5 is an image taken from the landslide movie (kayakingsucks.com) that was captured a few minutes after the rockfall occurred. The photo shows the rock and debris pile as it came to rest against the rock hillside on the south side of the river. The river had not yet begun to flow over the debris pile. The slope of the debris pile is evident. A large boulder can be observed on the upper left side of the photo that also shows up in the recent Photo 6. A line has been added to this photo illustrating about where the original debris pile came to rest. This illustrates how much of the debris has eroded away naturally since December 11, 2004. The initial erosion removed much of the “finer” debris leaving the larger rocks that have become wedged and anchored in place.

Photos 7 to 9 show the large boulders that remain in the new channel. The rocks commonly range in size from 3 to 25 feet or more. The erosion has resulted in an over-steepened slopes adjacent to the west side of the river with many large boulders “hanging”in the debris pile, ready to fall into the river with additional erosion or down cutting by the river.

Photos 10 and 11 reveal that rock falls have continued to occur in some portions of the slide area since 2004. Although the entire slide scarp is characterized by a relatively fresh rock surface, a thin mantle of moss covers portions of the slopes. Because moss and small vegetation establishes within a year, the large areas of the scarp observed without moss indicate that substantial rock falls have continued since the original hillside failure in 2004.

4.2 Methods of Channel Modification

A major difficulty in clearing the rock fall debris that forms the cascade is access to the site. It is not possible to get large equipment capable of directly clearing the debris into the cascade area. Furthermore, as discussed above, the hillside areas next to the river are highly unstable, and any disturbance by large equipment is likely to initiate further movement of individual rocks. Rocks and blocks of debris of various sizes continue to fall from the exposed slide scarp. Even during our short period of inspection along the river, rocks up so several inches in diameter became dislodged from the steep slope for no apparent reason, and fell down into the cascade area next to and into the river. Several large rocks 10 to 15 feet in size appear to be highly unstable, as can be noted in the photos of the area.

During the site inspection, alternative methods were identified for moving and removing the rocks. These methods are described below:

4.2.1 Removal by Large Chinook Helicopter

A large Chinook helicopter is capable of lifting weights of up to 14,000 lbs, which is equivalent to a rock size of about 4-ft square. The helicopter would be capable of moving a large number of loads during a short period of time under normal circumstances if all the rocks were separated and harnessed for pickup.

This project site is complicated by the highly unstable and steep configuration of the natural slopes. The helicopter would have to operate from above the canyon and tree level. Still, reaction forces from the heavy lift and weight of the helicopter would generate an equal and opposite downdraft or air wash from the blades of the aircraft. This would likely generate disturbance on the steep slopes thereby causing rocks and debris to fall to the work areas below. The method would require that riggers be stationed at the base of the slope to attached rock loads. It was concluded that the safety issues using this method would be severe and may likely preclude the use of helicopters for this work.

A large Chinook helicopters costs about $5,000 to $6,000/hour when operating. The work would entail daily mobilization and demobilization costs as well. A Chinook helicopter is based relatively close in Darrington, Washington.

Other issues include:

- Most boulders are large and must be split into smaller rocks in order to move.
- Many of the boulders would undoubtedly be wedged together making them impossible to remove with the helicopter.

4.2.2 Use of Smaller Huey Helicopter

A smaller “Huey-type” helicopter has a lifting limit of only about 1,500 lbs. This is equivalent to a rock size of about 2-ft square. The hourly operating cost for a small helicopter is about $1800/hour. These helicopters would not be large enough to economically move the size and numbers of rock required at the site but could be used to bring equipment and tools into the work area.

4.2.3 High Lead Cable System

This system would require setup in the canyon using anchor poles and blocks/rigging located both upstream and downstream of the rockfall area. Blocks, anchorage, drums and rigging would be setup on the west side of the canyon where access could be achieved. The system would consist of a mainline and haulback lines. The Contractor believed that it would be possible to anchor some of the blocks into the exposed rock mass in selected areas of the canyon.

For this method, the rocks would also have to be broken into substantially smaller rock sizes. Each rock would then have to be configured with lifting eyes or a harness. The mainline lead from the cable system would be connected in order to lift/drag a suitable downstream boulder disposal location. The haulback line is used to return the line to pick another boulder. Issues/limitations with this method include:

- Limited lifting capacity (limited to about 1500 lb in size)
- Time consuming and costly to set up and demobilize
- Difficult access for set up
- Limited access alignment once set up

4.2.4 Crawler Tractor with Winch Line

This approach would require access trails be opened through the trees to appropriate areas near the top rim of the canyon. Multiple locations may be required. A large crawler tractor (D8 or D9) with a heavy winch would be used. The dozer would be anchored in position from a pull location. One or more cable blocks would be user to support the cable route. Long lengths of cable would be required to reach from the cascade area to the pulling location. The setup would most likely be downstream of the cascade perhaps as much as 2,000 ft away. The pulling cable from downstream would have to be routed along the river in a way that avoided unnecessary disturbance to trees and vegetation and existing slopes in the canyon. Pulling from directly above the cascade would be another option, but there is no place to dispose of the boulders.

This method is has the advantage of easier set up, and it provides flexible access by cable to the cascade area. The equipment set up might include anchorage of cable blocks into competent bedrock of the canyon walls. Extraction of boulders would result from direct pull from the cable winch on crawler tractor. A large dozer is capable of pulling a load of about 50,000 lbs. This method also could be used to help extract wedged boulders by applying greater extraction force from an advantage point above the slide.

Issues with this method include:

- Pulling from top of canyon may lead to increased instability of the upper canyon wall because of the large reaction loads imposed by blocks set near the edge of the slope.

- This approach focuses only on extraction/dragging of the boulders from the cascade and slide area and is limited for access to specific disposal locations.
- The method would require the use of very heavy and very long lead cables to get to the cascade area and would require the use of a helicopter or other equipment to pull the line into the canyon.
- A pull-back system would be required to return the cable to the cascade area after each boulder is removed.
- Dragging boulders along the stream may result in some disturbance to the hillside vegetation or river environment.
- The work would occur in a dangerous setting and would require working with large equipment and associated hazards. Workers would have to move to safe areas outside the cascade area while each of the boulders is moved. However, the steep canyon walls on both sides of the river at the cascade site limit access to safe areas.
- This method also would require clearing, grubbing, and road building in the uplands forested area which would require additional permits.

4.2.5 Use of Hand Operated Equipment

Use of hand operated winches was briefly discussed during the site visit. The method consists of anchoring a small winch system in canyon walls upstream or downstream of the cascade area. Individual boulders would be winched by hand. This method would require a small crew working with jack hammers, compressors, and blasting materials to reduce boulders to a workable size. The method could be used in combination with other alternatives for moving the boulders.

The most practical use of this method would be for making minor readjustment of a few individual boulders as necessary to improve the flow conditions in a particular area.

Issues with this method include:

- Too slow and underpowered to move large boulders very far.
- The method is labor intensive and would probably not be cost effective in moving large numbers or boulders or moving rocks very far.
- The workers would be subject to rockfall hazards.
- Access to anchorage points along the rock wall of the river would be difficult because of the fast flowing water.
- Access would still require mobilization of many specialized tools and equipment.

4.2.6 Blasting without Rock Removal

The approach of simple blasting apart the large rocks in the cascade that appear to be most contributing to the fish passage problems would be the easiest and safest way to modify the cascade. With this approach rocks would not be physically removed from the immediate site, but some movement and redistribution of the rocks would occur naturally over time during high flow events. Compared to the rock removal approaches described above this approach would have more uncertain results regarding physical and hydraulic changes to the cascade and its fish barrier conditions.

With this alternative, different blasting techniques may be desirable compared to the other alternatives that focus on rock removal. Depending on site-specific conditions a greater number of holes may be used with small charges or a fewer number of well-distributed holes with heavier charges. This type of blasting would take advantage of hairline fractures in the rock by imparting enough gas and energy into the boulders to break along the minor fractures that probably already exist in much of the rock mass.

Blasting methods may benefit from a trial and error approach. The effectiveness of the blasting could be monitored after initial blasts, and the methods altered for subsequent blasts as necessary to achieve the most efficient breakage of rock. Also, it may be possible to break up large boulders that are buried well below the debris and water line using blasting methods. Water or wet conditions would not preclude this option. Blasting methods have the advantage of being flexible in approach and location, relatively low cost compared to other methods, require mobilization of only minor hand operated equipment, can be accomplished in stages as the conditions warrant, and equipment can be remobilized if necessary.

4.2.7 Additional Considerations

Rock sizes and numbers. All of the boulder removal options would require the reduction in size of most rocks prior to their moving or removal. Photos 12 and 13 show some of the more prominent boulders in the cascade reach. Each boulder is numbered and approximate dimensions were determined by measuring the size of the rocks in the field. The rock numbers and dimensions are shown in Table 1. This information was used to estimate the number of rocks that would result if the large boulders were to be broken into small pieces having the maximum rock sizes shown. The table illustrates that for the 22 surficial boulders selected for measuring, reduction in size would result in a range of 160 to 1120 boulders for the respective 14,000 and 2,000 maximum lifting weights.

The table suggests that the number of boulders to be moved could be significant. To substantially improve fish passage conditions in the cascade, many more boulders may need to be reduced in size and removed. Many of the boulders needing removal are ones that rest deeper in the channel, under the water, or tightly wedged between other boulders.

Use of blasting or expandable grout to break up boulders. As noted above, all of the boulder removal methods would first require that the rock size be reduced. Available methods for reducing the size of the boulders include blasting, mechanical means (jack hammers), or expandable grout. Small hand operated jack hammers would be slow and inefficient in accomplishing the work. Use of expandable grout would be difficult and slow to achieve results. Many of the boulders are in or under the water, which would preclude the use of the expanding grout products. Therefore, we believe that it would have only limited utility at the site.

Blasting is the most practical solution for rock size reduction. Blasting could be accomplished in a relatively short period of time compared to the other methods. Carefully selected drilling positions and a limited number and sequenced charges would be required to blast the rocks into desired sizes.

Several issues associated with blasting include:

- Blasting in or near the water to achieve mass reduction of boulders could harm fish and require an ESA incidental take permit.
- Blasting could lead to minor vibration, fly rock, and air blast that might dislodge additional rocks or debris from the adjacent hillside and debris fan.
- No complete assurance that fish passage can be improved. This would require a trial and error approach to see if the combination of blasting and hydraulic removal of debris by the river is effective. It may require multiple mobilizations for the work before desired improvement could be realized.

4.2.8 Cost Considerations

The project team discussed a range of costs for the methods of rock removal identified above. In summary, we felt that the large Chinook helicopter approach would not be feasible because of the severe safety concerns associated with rocks and debris falling from the steep cliffs above the work areas. The method would require access into dangerous areas while the disturbance was occurring. It may be possible to use a longer lead line to minimize the issue, but there would still be other safety concerns.

A smaller Huey Helicopter is considered to be too small to be effective for the work of moving boulders. It could be used for mobilization of smaller equipment and tools to the work area, however.

The other approaches were not costed out other than to develop a general understanding of the types of equipment, personnel, and time required to complete the work. The most effective of the boulder removal methods (other than blasting) would be the crawler tractor with winch line option. It would require a period of 1.5 to 3 months to reduce the rock sizes and move a minimum number of boulders (estimated to be less than 25 modest sized boulders). The contractor believed that very few bids would be received because of the difficult access and high safety risks associated with the work. He opined that the actual cost of this approach could easily range from $250,000 to $500,000 and that contractors would likely double that cost for bidding to take into account uncertainty and safety issues. This estimate would not account for the studies, permitting, engineering, and project management required for the effort and thus is only a rough estimate by a contractor.

As stated above, we concluded that the most practical opportunity of improving the condition in the channel would be the use of blasting methods. This method offers significant advantages over the other options including better access to the rocks that are restricting the flow. The method takes advantage of the energy of the river for rock removal. Blasting to remove selected rocks may also help train more of the energy of the river into the toe of the remaining rock fall debris pile. Widening of the river channel would help to distribute the flow to a wider area and may provide lower turbulence and velocity in the stream.

The work associated with blasting would require mobilization of jack hammers and other compressed air operated equipment. Sizable compressors, air lines, and tools would be required. The equipment might be positioned above the work area and small hand operated tools dropped by helicopter into the work areas. There would still be safety concerns for falling rocks. It is likely that 10 to 25 rocks might be targeted for blasting and size reduction during the first attempt at blasting. Blasting for these rocks would likely occur in 3 or more blast sets. The number of holes required in each rock would be determined by the size of charges to be set and size of the rocks. A hole spacing of 3 to 6 feet might be attempted initially in the larger rocks. The effectiveness of each blast would be monitored and drilling patterns and charges would be altered as needed for subsequent blasts.

It is possible that this work might require 2 to 4 weeks to complete using a crew of 4 to 6 people. It is roughly estimated that the blasting work would cost in the range of $50,000 to $100,000 to complete. This estimate does not account for any studies, permitting, engineering, or project management. The effectiveness of the rock size reduction and resulting changes to the slide debris would not be known until after a high flow event.

Following the presentation of the site visit findings to the ARWG on February 4, 2009, the US Forest Service submitted to the District two alternative ideas for modifying the Marsh Creek slide cascade (Attachment A). The ideas were developed based on their review of the photographs of the cascade. Their approach appears to be a reasonable option for improving fish passage at the site but would require additional evaluation with an on-site visit by experts in barrier removal and stream restoration.

5.0 DISCUSSION AND CONCLUSIONS

5.1 Technical Feasibility

Of the methods identified to modify the Marsh Creek slide cascade, all but one involves the physical movement or removal of large quantities of rock to other locations in the canyon. Extracting rocks and moving them would be a major undertaking with considerable risks, uncertainties, and high cost. The approach of using a large helicopter seems particularly challenging because of the concern of extracting rocks that may be wedged together. This concern also would pertain to the high lead cable method but less so for the crawler tractor method. While these approaches are technically feasible, they all would require a major field effort under very challenging and risky conditions and would still have high uncertainty regarding effectiveness.

The method of simply reducing the size of apparent problem rocks with blasting and then leaving them in place for natural dispersal would be the easiest and safest approach to modify the cascade. However, there is some uncertainty as to whether this approach would be successful at improving fish passage in the short term (before a high flow event rearranges rocks) and perhaps in the long term as well, as discussed below.

5.2 Effectiveness

Even if the larger boulders in the neck of the cascade (where fish passage is most impaired) are removed or broken into smaller pieces, it is still uncertain whether this will help fish passage. The site still is confined totally on the left bank by a bedrock cliff and on the right bank by a large boulder/rubble pile that constitutes the “fan” of the landslide. The upper half of the cascade has a 10.5 ft drop over a distance of 51 ft (21% gradient). At its narrowest point the cascade drops 7.3 ft over a distance 16 ft (46 % gradient). Considerable turbulence and air entrainment, both which hinder fish movement, exists at this site even at low flows (~100 cfs) and increasingly at higher flows. Powers and Orsborn (1985) ranked turbulent cascades as the most difficult type of barrier for fish passage, independent of barrier height and velocity. Removing one boulder to eliminate a problem chute may just create another problem chute.

Another uncertainty affecting any modification of the cascade is the effect that high flow events would have on the configuration. The current materials and configuration of the cascade are reflective of the highest flow event, 3,560 cfs, which has occurred since the side happened. Flows as high as 19,000 cfs have occurred since 1990 when Spada Lake has operated under current guidelines. This event occurred during one of the largest peak flow events ever recorded in the Snohomish basin. An event of nearly similar magnitude in the Snohomish basin occurred recently in January 2009, and yet Spada Lake was able to capture all inflow without over-spilling at Culmback Dam. Flows measured below the Diversion Dam only reached 1,820 cfs. Thus, a flow that could substantially alter the Marsh Creek slide cascade may be long in coming. Furthermore, as noted in Ruggerone (2008), it is possible that alteration of the cascades resulting from an exceptionally high flow could cause fish passage to become even more difficult at the site.

The Phase 1 report (Ruggerone 2008) concluded that under existing conditions fish passage at the Marsh Creek slide cascade was possible at lower flows, up to ~250 cfs, and less likely at flows above that. Observations in the fall 2008 found that four adult Chinook salmon passed the site when flows were approximately 100 cfs, but none passed when flows (released for spawning) increased to 155 cfs. This points out how sensitive fish passage at the site is to flow. Even though modifications of the site presumably could make it more passable, there would likely be ranges of flow, probably higher flows, that would still impede passage. Given the 10% gradient over 100 ft, coupled with the confined nature of the site, water velocities and turbulence will always increase rapidly with flow at the site.

During discussions with stakeholders on Feb 4, 2009, concerns were raised with all of the alternative methods to remove rocks from the site. However, there was interest expressed in the more simple approach of merely blasting apart those rocks that appear to be creating the passage problems (high velocities and turbulence), and waiting for a high flow event to carry away and/or rearrange the rocks, hopefully leaving better passage conditions. While such an approach may work, there still would be uncertainty as to its effectiveness. One of the key features of a passable cascade is the presence of large boulders that can provide resting areas for fish as they make their way through the site (Powers and Orsborn 1985). Thus, simply making the problem rocks smaller to reduce velocities in chutes may not necessarily reduce excessive turbulence or leave large rocks in strategic positions to provide needed resting spots.

Given the uncertainty of fish passage effectiveness associated with the blast–and-leave method (or any method), an adaptive management approach may be necessary to increase the probably of passage success. Best judgment would dictate how many and which individual rocks would be candidates for blasting on the initial effort. This would be followed by a visual inspection of the site, first after blasting and again after a high flow event. If the site “appears” to have been improved, studies would be needed to confirm the passage improvement. This could be done by monitoring adult escapement to the 2.2-mile reach above the site, visually observing fish passing the slide cascade, and/or tracking radio-tagged fish. The latter approach would provide more detailed information on attempted or successful passage routes at the cascade, thus informing additional modifications to the cascade, if necessary. Recognizing the desire to have a sufficient numbers of spawners pass the site to adequately seed the 2.2-miles of river up to the Diversion Dam, passage monitoring and evaluation should be done for at least two life cycles (8 – 10 years) after the slide cascade is modified to ensure that enough fish consistently reach the Diversion Dam.

5.3 Permanence

The most significant factor regarding the permanence of any modification to the Marsh Creek slide cascade is the obvious instability of the hillside above the site. Large rocks will continue to periodically break off of the hillside as a result of normal erosion and sloughing. Most of the rocks would undoubtedly end up in the river at or near where it is now most constricted. In addition, it is likely that there will be another major landslide event at the site some time in the future.

The most permanent means for making the site passable over a larger range of flows (but still low) would be to remove most of the material constituting the hydraulic control. This would lower the gradient of the cascade. However, this would be challenging because the area of the hydraulic control extends entirely across the channel as well as downstream about 30 feet. It would probably require at least two layers of rock be removed. The rocks would have to be moved away from the site. Simply blasting rocks in the hydraulic control would not be an obvious solution and may make passage conditions worse by eliminating what now appear to be good resting spots. Very large rocks up to about 20 feet in diameter occur in the right-bank tailout of the pool just above the cascade, and these tend to deflect the force of high flows to the bedrock face on the opposite (left) side of the river where it would be less effective at removing rocks from the hydraulic control.

Another way to help achieve permanence of fish passage at the site would be to totally remove the debris fan at the base of the slide. However, that option is not technically feasible without some herculean and costly effort. Many large boulders are present in the depositional fan, but are buried under dirt and smaller rocks. An extremely high flow event would be required to clear out the smaller material to expose the larger rocks for potential breakup and removal. Also, removal of the debris fan would act to destabilize the hillside above, thus making it more prone to failure.

5.4 Safety

In addition to the technical difficulties with moving large rocks, safety of work crews is of concern. The active slide on the canyon wall contains many large fractured rocks as well as smaller material that could become unstable from air wash from helicopter blades, rock drilling, and blasting. This could present a difficult safety concern with riggers in the canyon below. The approach of simply drilling and blasting the rocks and leaving them in place would be the safest approach because crews would move a safe distance away during blasting.

5.5 Permits

Any of the methods presented above to modify the Marsh Creek slide cascade would require a Hydraulic Project Approval (HPA permit) from Washington State Department of Fish and Wildlife. In addition, an Incidental Take Statement under the Endangered Species Act would be required from National Marine Fisheries Service. Measures to reduce potential impacts on fish would likely include restricting any major disruption activities, especially blasting, to periods when adult fish are least likely to be present (July and early August for Chinook) and when smolts are not migrating through the area. Measures to remove or frighten away juvenile fish from the potential impact area during blasting also may be required. Additional permits required for this type of activity would include a Snohomish County shoreline permit and Army Corp of Engineers permit.

6.0 REFERENCES

Powers, P.D. and J.F. Orsborn. 1985. Analysis of Barriers to Upstream Migration. An Investigation of the Physical and Biological Conditions Affecting Fish Passage Success at Culverts and Waterfalls. Final Project Report. Part 4 of 4. Submitted to the Bonneville Power Administration, Portland, OR. Project No. 82-14. August 1985.

Ruggerone, G.T. January 2008. Evaluation of Salmon and Steelhead Migration after a Landslide on the Sultan River. Phase 1: Fish Passage Assessment. Prepared for Public Utility District No. 1 of Snohomish County, WA.

FIGURES

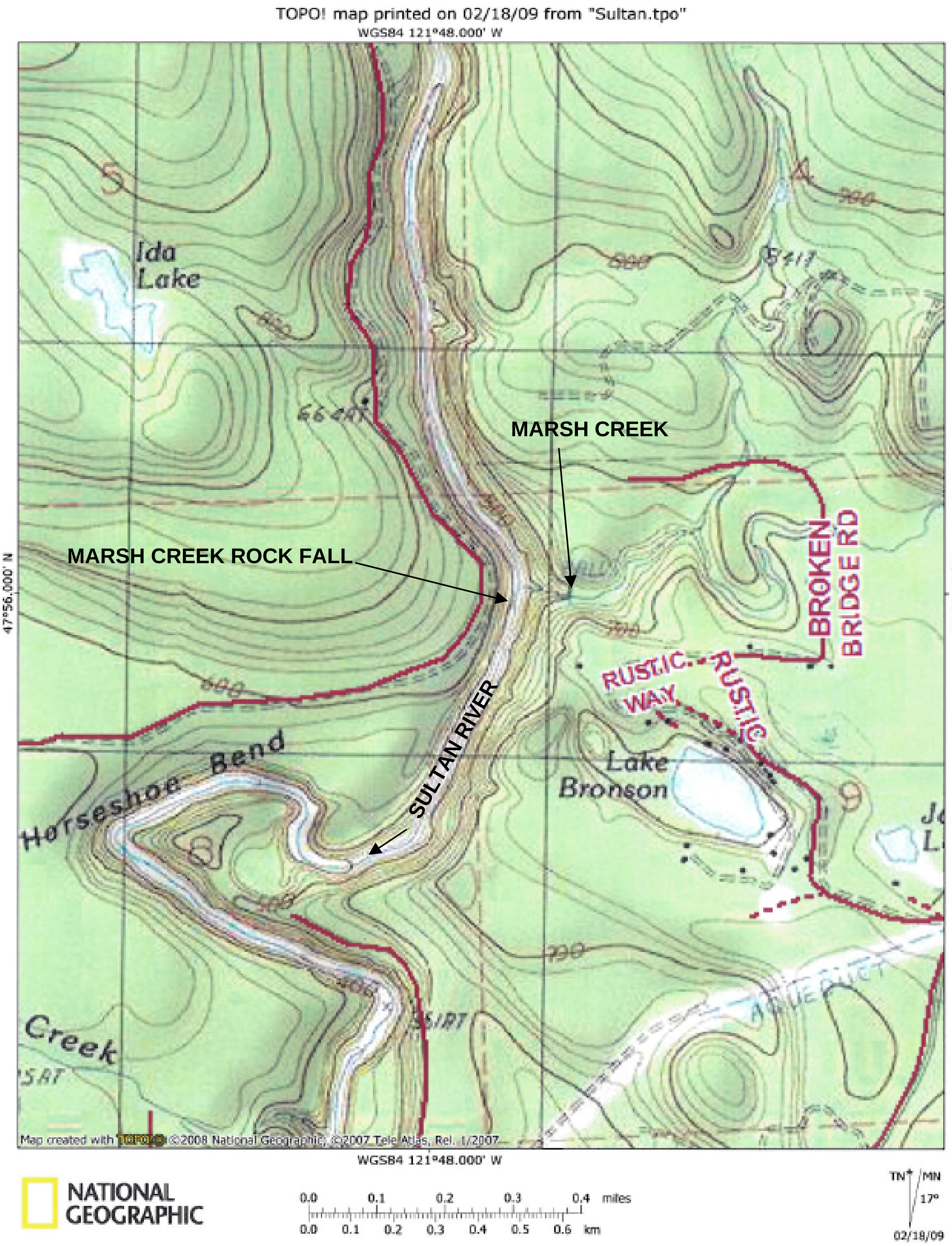
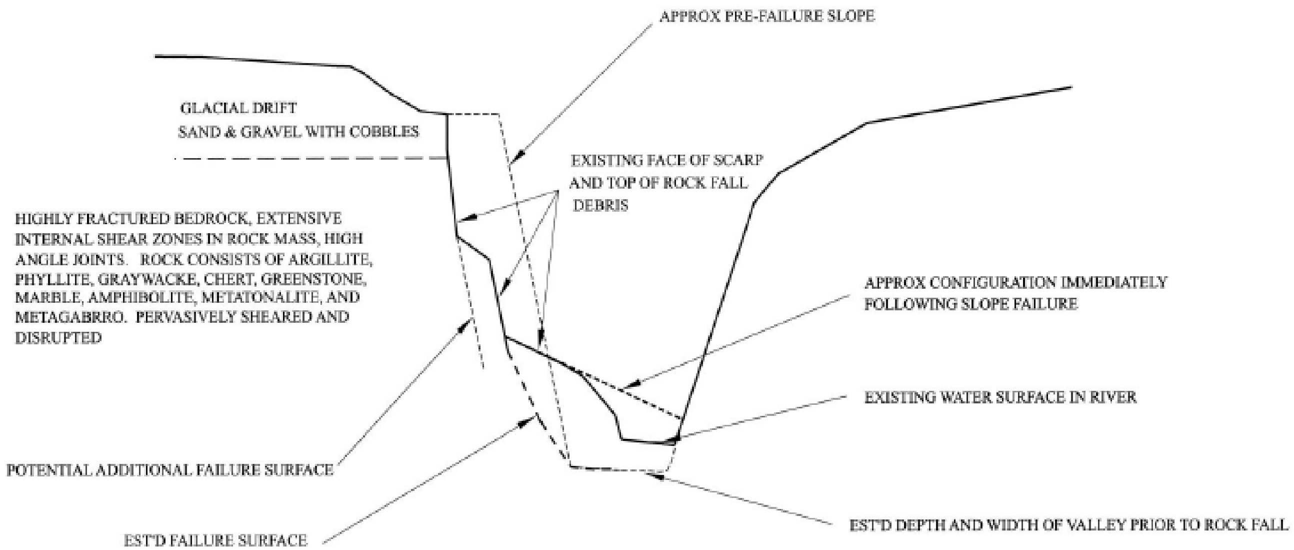


FIGURE 1
SITE MAP



MARSH CREEK ROCK FALL

NTS

FIGURE 2
SECTION

JAN 2009

TABLES

TABLE 1

Estimated Size and Number of Prominent Boulders Presently Exposed in the River Channel

Marsh Creek Slide, Sultan River

kgreen 2/1/2009

Boulder No.	Length ft	Width ft	Height ft	Vol cf	Est'd Wt lbs	Resulting No. of Boulders if Limited to Size Listed 14,000	12,000	10,000	8,000	6,000	4,000	2,000
1	5	5	2.5	62.5	10,000	1	1	1	1	2	3	5
2	7	6	4	168	26,880	2	2	3	3	4	7	13
3	5	5	3	75	12,000	1	1	1	2	2	3	6
4	5	5	3	75	12,000	1	1	1	2	2	3	6
5	5	6	3	90	14,400	1	1	1	2	2	4	7
6	6	6	3	108	17,280	1	1	2	2	3	4	9
7	8	6	4	192	30,720	2	3	3	4	5	8	15
8	18	10	10	1800	288,000	21	24	29	36	48	72	144
9	10	6	4	240	38,400	3	3	4	5	6	10	19
10	10	8	4	320	51,200	4	4	5	6	9	13	26
11	5	5	3	75	12,000	1	1	1	2	2	3	6
12	12	10	5	600	96,000	7	8	10	12	16	24	48
13	10	7	3	210	33,600	2	3	3	4	6	8	17
14	6	4	3	72	11,520	1	1	1	1	2	3	6
15	10	8	8	640	102,400	7	9	10	13	17	26	51
16	8	10	12	960	153,600	11	13	15	19	26	38	77
17	10	10	6	600	96,000	7	8	10	12	16	24	48
18	6	5	4	120	19,200	1	2	2	2	3	5	10
19	6	4	5	120	19,200	1	2	2	2	3	5	10
20	18	12	10	2160	345,600	25	29	35	43	58	86	173
21	13	11	12	1716	274,560	20	23	27	34	46	69	137
22	20	12	15	3600	576,000	41	48	58	72	96	144	288
					No. Boulders	**160**	**187**	**224**	**280**	**373**	**560**	**1120**

PHOTOGRAPHS

PHOTO 1. SOIL AND ROCK MATERIALS EXPOSED IN TOP OF ROCK FALL SCAR

PHOTO 2. ROCK FALL SCARP AND DEBRIS FAN

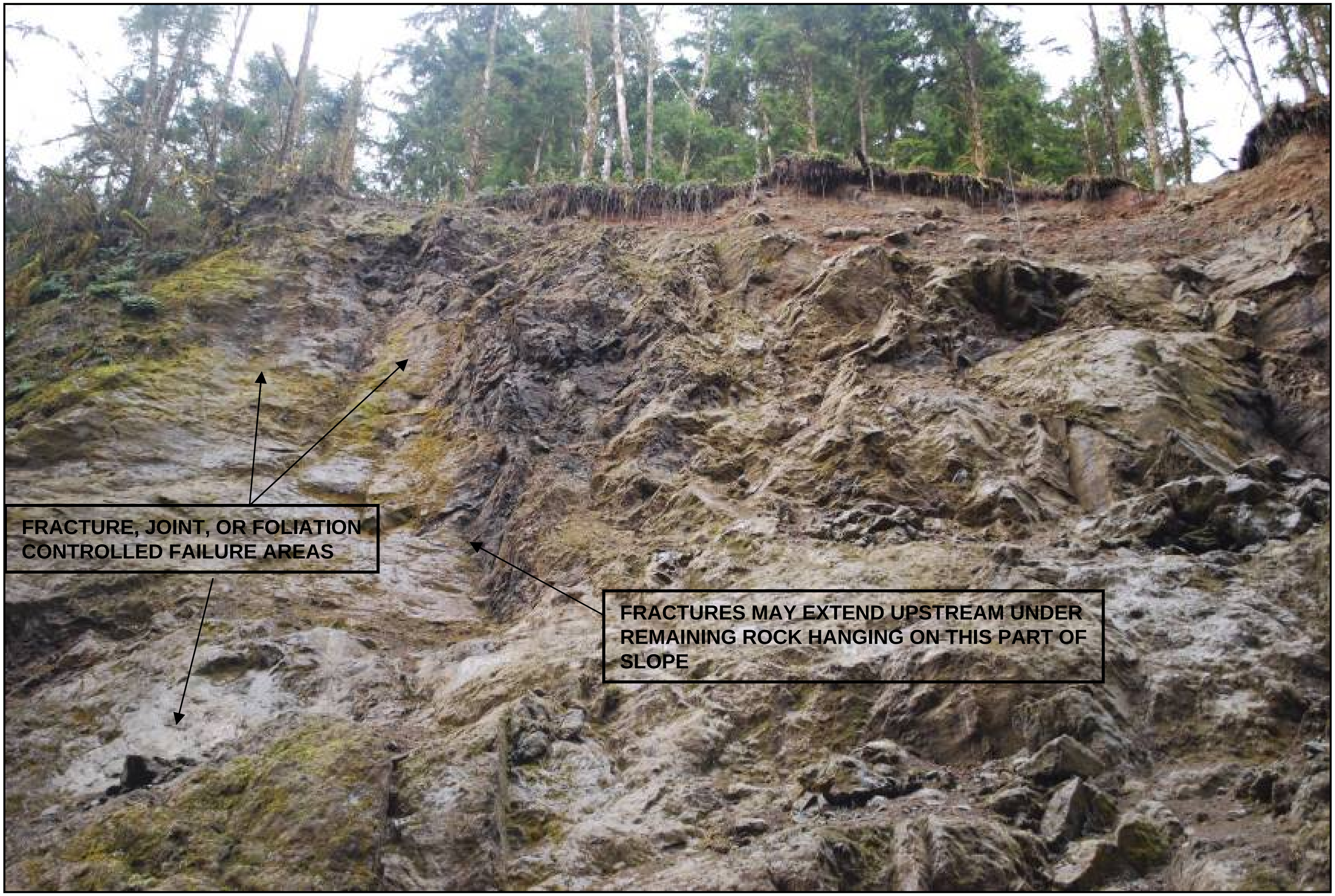


PHOTO 3. ROCK FALL SCARP

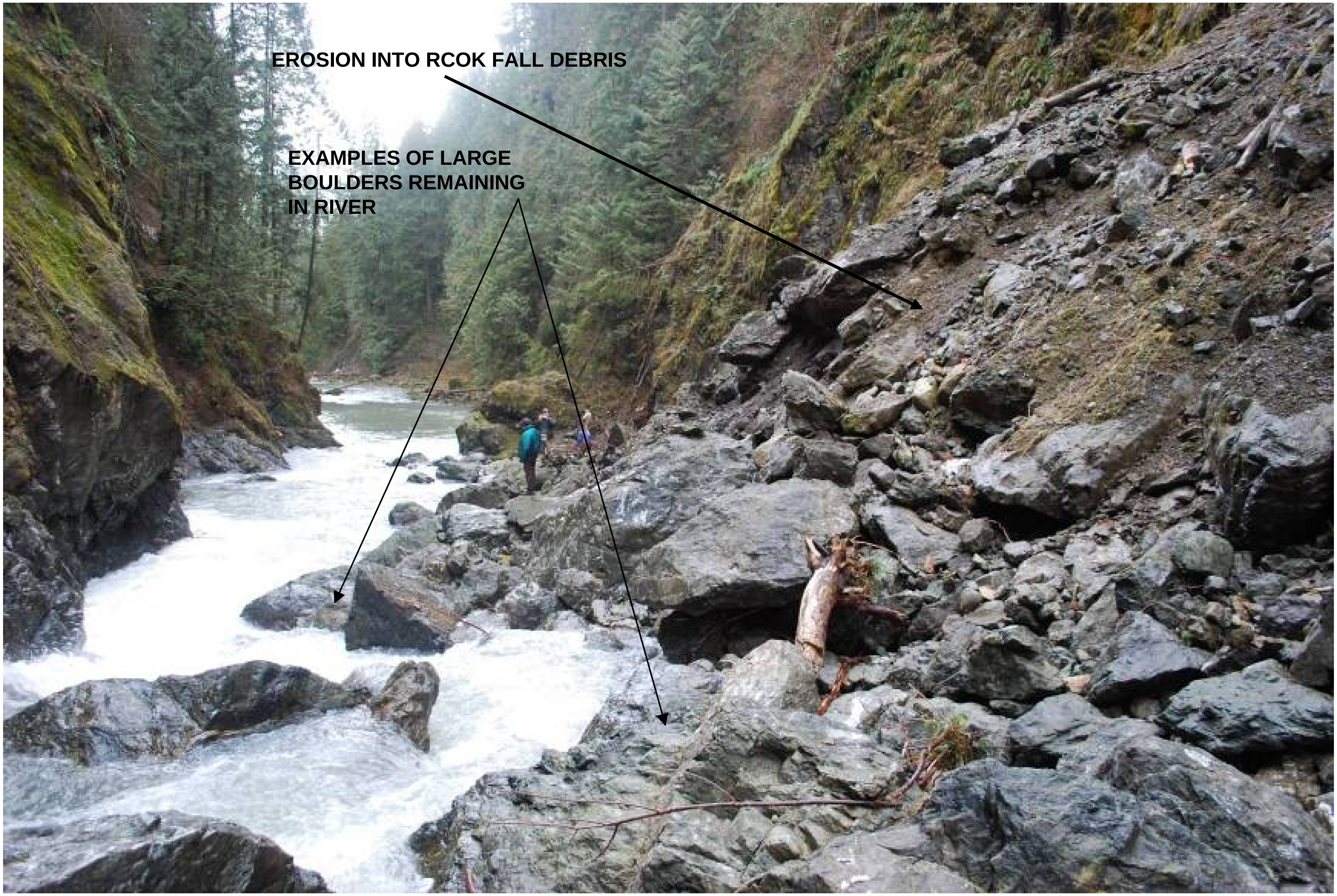


PHOTO 4. LOOKING DOWNSTREAM THROUGH CASCADE

PHOTO 5. ROCK FALL SHORTLY AFTER THE SLIDE OCCURRED

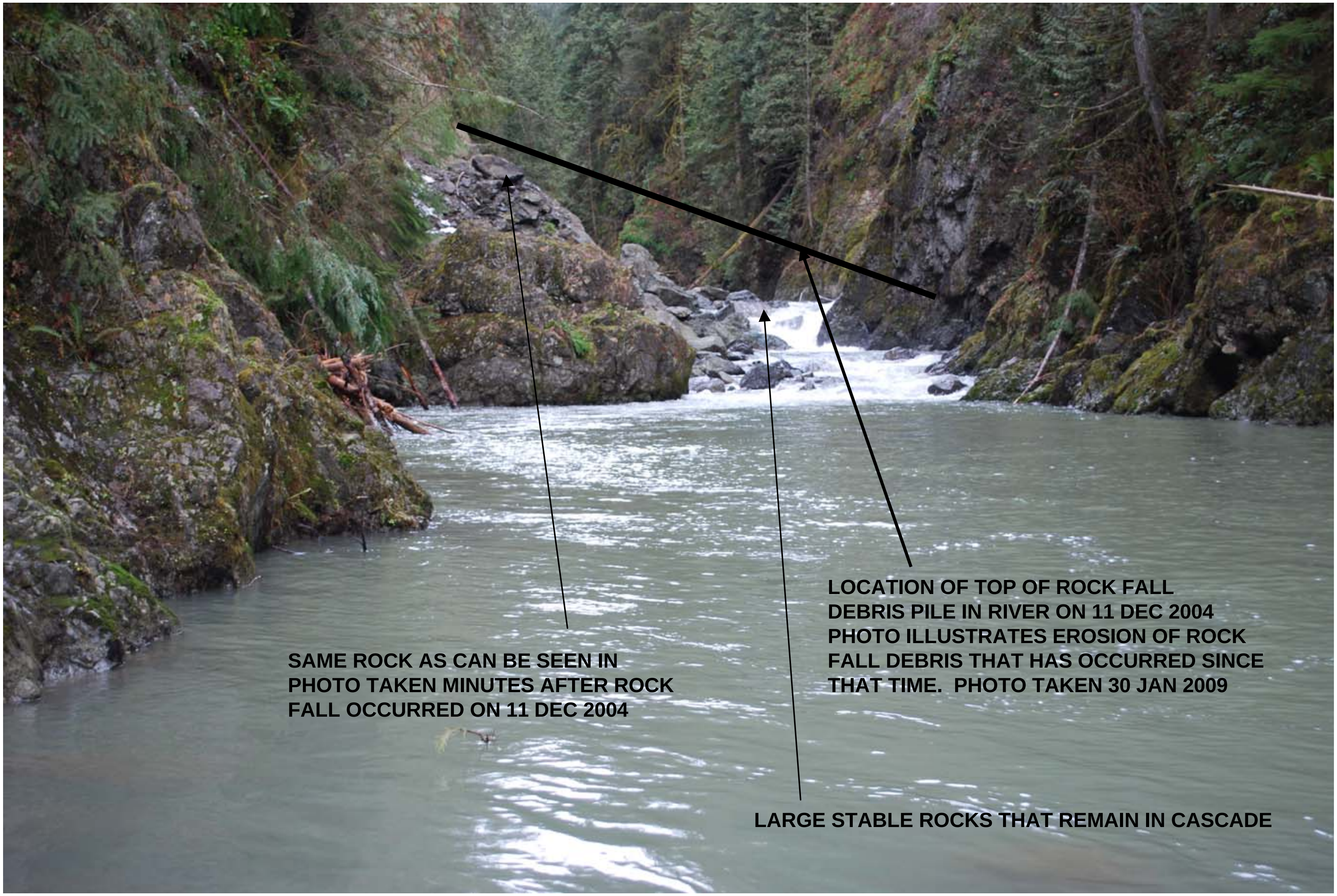


PHOTO 6. ROCK FALL DEBRIS AREA LOOKING UPSTREAM

PHOTO 7. TELEPHOTO VIEW OF UPSTREAM AREA OF CASCADE

PHOTO 8. **TELEPHOTO VIEW OF MIDDLE AREA OF CASCADE**

PHOTO 9. TELEPHOTO VIEW OF DOWNSTREAM AREA OF CASCADE

PHOTO 10. SLIDE SCARP SHOWING STILL-ACTIVE ROCK FALL AREAS

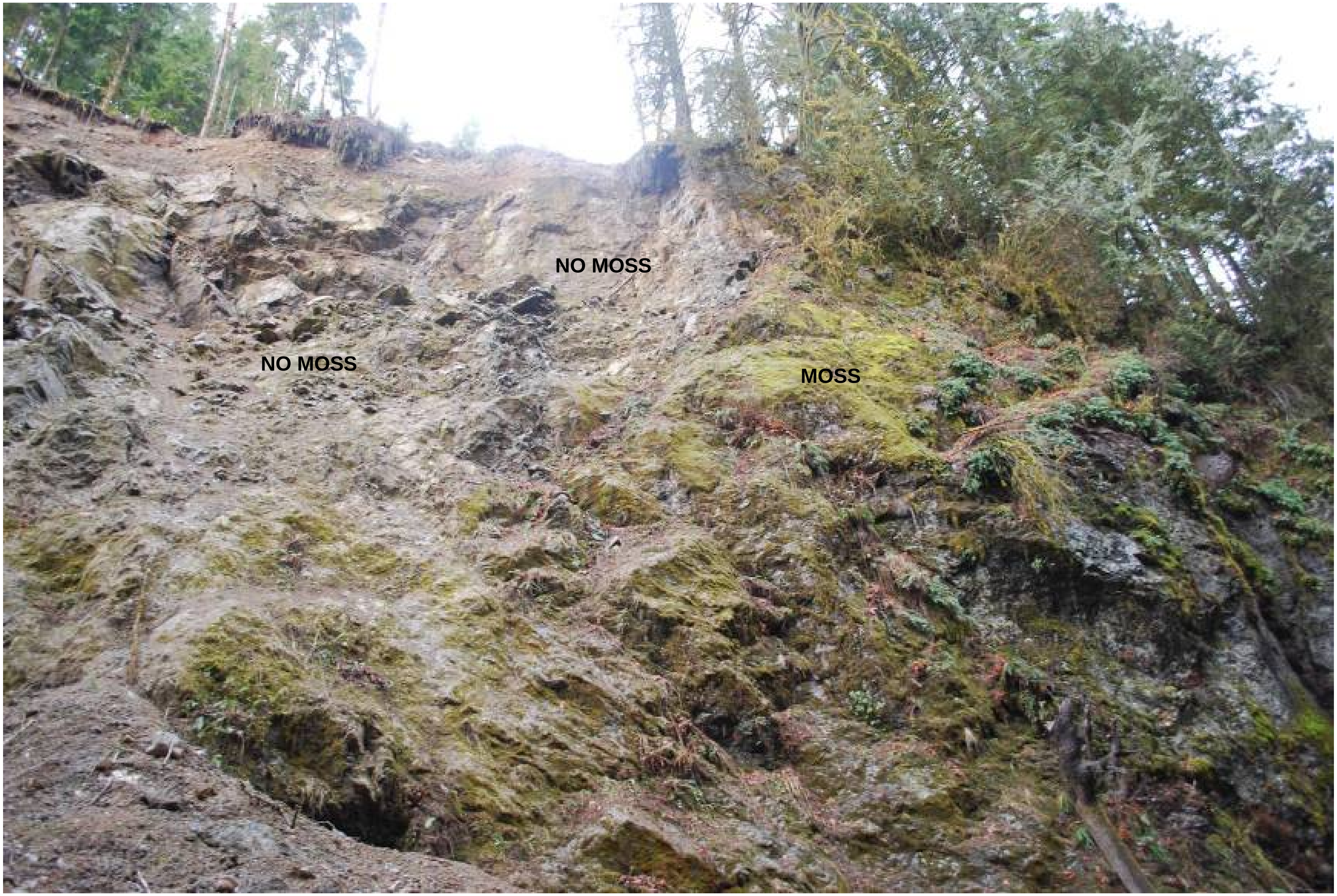


PHOTO 11. **NOTE AREAS OF MOSS AND AREAS OF NO MOSS**
AREAS WITH LITTLE OR NO MOSS MAY REPRESENT AREAS THAT HAVE EXPERIENCED RECENT ROCK FALLS

PHOTO 12. NUMBERED ROCKS IN UPPER CASCADE CORRESPONDING TO TABLE 1

PHOTO 13. NUMBERED ROCKS IN LOWER CASCADE CORRESPONDING TO TABLE 1

ATTACHMENT A
FOREST SERVICE CONCEPTS

Figure 1 “Wet” Alternative for routing flow near right bank (looking downstream) to create bypass channel around thalweg passage impediment.

Figure 2. “Dry” Alternative for routing flow near right bank (looking downstream) to create bypass channel around thalweg passage impediment.

Figure 3. Background picture of slide area. Main passage impediments are found in channel between rocks #4 and #18

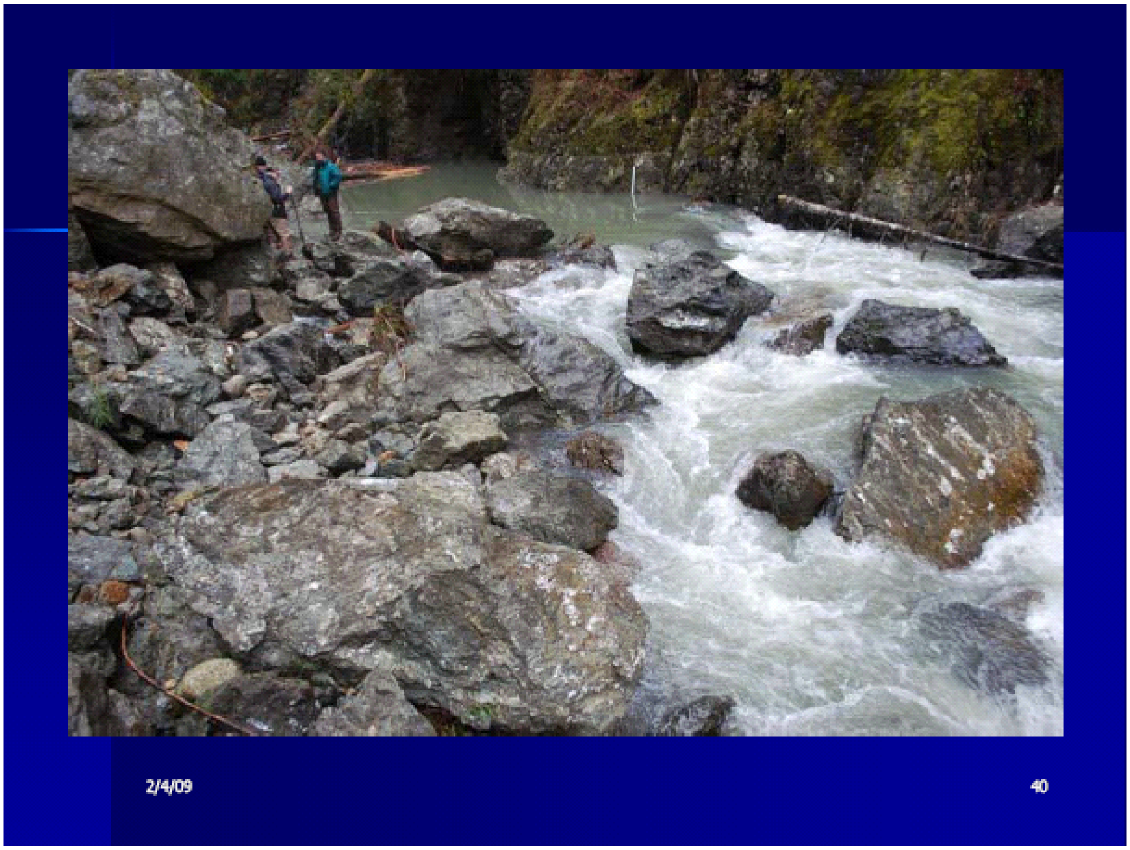


Figure 4. Alternative view of Right bank of slide area. Rock #12 on right of picture?

These are a couple of variations on an option that both Keith Binkley and myself mentioned at the last meeting (2.12). The basic premise is to reduce the amount of flow moving down the left side of the channel (looking downstream) by creating or enlarging some gaps between the rocks on the right bank of the channel. This would not only reduce turbulence and velocity in the main channel thalweg that is currently restricting fish passage but also open up the potential for passage along the right bank near the toe of the slide area. The intent is to redirect flow from the pool tailout area around rock #17 downstream and routing it back into the main channel below rock # 4. The arrows show some of the flow routing options that might be available.

Not having been on the site I do not know the feasibility of these alternatives but it appears that these options might be implemented with a relatively small amount of modification of the existing rocks in place and "clean-out" of smaller material in the desired flow paths.

FYI - At past ARSG meetings some parties have expressed an interest in having additional experts at barrier removal/stream restoration look at the site to evaluate the feasibility of improving passage. The Forest Service has an "Enterprise Team" made up Geotechnical Engineers, Hydrologists and Fisheries Biologists who specialize in restoration work of this type. We have used this team to design and/or evaluate projects in several other relicensings that we have worked on. I checked with a member of the team and they are interested and available if that is something the group wants to pursue.

Dean Grover
USFS

ATTACHMENT B
COMMENTS ON DRAFT REPORT

Note: no comments received on the draft report

SNOHOMISH COUNTY PUD PUBLIC UTILITY DISTRICT NO. 1 *Providing quality water, power and service at a competitive price that our customers value*

March 30, 2009

Subject: Henry M. Jackson Hydroelectric Project (FERC No. 2157) –
Revised Study Plan 24: Marsh Creek Slide Modification Draft Technical Report
for Review and Comment

Dear Aquatic Resources Work Group:

The Jackson Project Relicensing Team is pleased to announce that the draft technical report for *RSP24: Feasibility of Marsh Creek Slide Modification to Improve Fish Passage* is available for your review and comment. The draft report is attached. We hope that you will take this opportunity to review the draft report over the next 30-days and provide us with any comments or suggestions you might have. Please submit written comments, if any, by Wednesday, April 29, 2009. Email comments to DJPresler@snopud.com or send via mail to:

Dawn Presler, E2
Snohomish County PUD
PO Box 1107
Everett, WA 98206-1107

Questions regarding the draft report can be directed to Keith Binkley, Senior Environmental Coordinator, at (425) 783-1769 or KMBinkley@snopud.com .

Thank you for your continued interest in the Jackson Project relicensing.

Sincerely,

DJPresler

Dawn Presler
Relicensing Specialist
Jackson Hydroelectric Project
Phone: (425) 783-1709

cc: Relicensing files