Review of Stream Flow Analyses in the USDI Bureau of Land Management (BLM) Draft Environmental Impact Statement (DEIS) for its Western Oregon Plan Revisions (WOPR)

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Jonathan J. Rhodes
Conservation Hydrologist, Planeto Azul Hydrology
P.O. Box 15286 •• Portland, OR 97293-5286

I. INTRODUCTION

Management effects on peakflows are a significant issue within the analysis area of the DEIS for several reasons. Scientific assessments have repeatedly concluded that management effects on watershed-scale hydrology and peakflows affect aquatic conditions that strongly affect salmonid populations (USFS et al., 1993; Murphy, 1995; Spence et al., 1996). Studies have repeatedly demonstrated that logging and roads cumulatively elevate peakflows, especially in smaller watersheds.

Elevated peakflows have numerous negative impacts on stream conditions and processes, including increased sediment transport, bank erosion, channel scour, and sedimentation of downstream salmonid habitats. Elevated peakflows also contribute to channel widening, which contributes to increased summer water temperatures. High summer water temperatures are already a widespread problem for salmonid populations within the DEIS analysis area.

Proposed logging levels vary considerably among the alternatives analyzed in the DEIS. Hence, effects of the alternatives on peakflows will also vary among the alternatives, because logging and associated activities elevate peakflows. However, the DEIS failed to reasonably analyze and disclose the impacts of the alternatives on peakflows due to several defects in the analysis. These deficiencies include the following:

- The DEIS failed to use the results of Grant et al. (2007) which found that forest canopy removal of more than about 20% of watershed area elevated peakflows generated by rain-on-snow.

- The DEIS did not analyze the impacts of the existing conditions and the alternatives at scales where peakflow impacts are most pronounced and ecologically significant.

- The DEIS's analysis narrowly focused on the effects of forest canopy removal on peakflows and ignored other important causes of peakflow elevation, including cumulative soil compaction from roads, logging, and grazing, and the acceleration of runoff routing by roads.

- The DEIS's analysis is fraught with potential error, yet, the DEIS failed to assess and disclose the likely magnitude and implications of potential individual errors, nor of combining or compounding of error in the analysis, although this has long been standard scientific practice.

Each of these defects contributes to underestimation of the magnitude, extent, and significance of existing peakflow elevation within the analysis area under existing conditions. This is significant because impacts to already damaged systems can be considerably different and more ecologically serious than those in systems that have not been impaired (Reid, 1993; Dunne et al., 2001).

Each of the aforementioned deficiencies also contributes to underestimation of peakflow impacts under the alternatives. These defects also have a combined effect that contributes to underestimation of the magnitude, extent, and significance of peakflow impacts under the alternatives. Therefore, the DEIS fails to adequately differentiate among the alternatives in terms of their effects on peakflows. Based on available information, it is highly likely that the action alternatives will elevate peakflows to a significantly greater degree than forecast in the DEIS. Because peakflows influence a host of aquatic conditions, the DEIS's failure to reasonably analyze and disclose peakflow impacts also causes the DEIS to fail to reasonably differentiate among the alternatives with respect to their impacts on aquatic habitat conditions and salmonids.

The foregoing defects in the DEIS's analysis of peakflows need to be rectified. The FEIS must analyze and disclose:

- All cumulative sources of peakflow elevation under existing conditions and the alternatives, including their extent and severity within the analysis area at scales where impacts are likely to be most pronounced;

- The uncertainties and other limitations inherent in the analysis approach, and their implications for accuracy and ecological consequences;

- The potential accuracy of the analysis, including its expected error, and their ramifications.

Low flows can also be reduced by the cumulative effects of management activities on BLM lands throughout the analysis area. Reductions in low flows negatively impact aquatic habitat conditions and salmonids. However, the DEIS is without any reasonable analysis of the cumulative management-induced impacts on low flows under existing conditions or the action alternatives. This significant defect must be rectified by taking a hard look at all sources of impacts to low flows and their cascading effects on aquatic conditions and salmonids.

II. THE DEIS'S ANALYSIS OF PEAKFLOW IMPACTS FAILED TO REASONABLY INCORPORATE AVAILABLE INFORMATION ON THE LEVELS OF FOREST CANOPY REMOVAL THAT INCREASE PEAKFLOWS GENERATED BY RAIN-ON-SNOW

The DEIS notes that "For basins within the rain-on-snow hydroregion, the detection threshold is 20% of a harvested watershed area (Grant et al. 2007)." However, the DEIS's completely fails to use this information to analyze the impacts of management activities on peakflows under existing conditions and the action alternatives. Instead, the DEIS relies on a relatively arcane method of estimating effects on peakflows from rain-on-snow, which has not been empirically verified, and based on assumptions and approximations that are fraught with potential error.

The failure to apply the results of Grant et al. (2007) with respect to logging impacts on peakflows is a significant flaw for several reasons. The results of Grant et al. (2007) are plainly applicable, because the DEIS used the results of Grant et al. (2007) in the DEIS's analysis of peakflow impacts in rain-dominated watersheds (DEIS, pp. 382-388, 1095-1105).

Although the DEIS discloses the findings in Grant et al. (2007) regarding the effects of logged areas on peakflows generated by rain-on-snow, the DEIS provides absolutely no rationale for why these findings were not used in its analysis of peakflow impacts. Therefore, the failure to use the findings of Grant et al. (2007) with respect peakflow elevation in watersheds subject to rain-on-snow is plainly arbitrary.

Second, it is highly likely that many watersheds analyzed in the DEIS have had more than 20% of the watershed area logged, which Grant et al. (2007) indicates would detectably elevate peakflows in watersheds affected by rain-on-snow. Therefore, the failure to apply this information causes the DEIS to underestimate the magnitude and extent of increased peakflow under existing conditions and the action alternatives.

Third, the use of the threshold of detectable peakflow increase in Grant et al. (2007) is eminently tractable analytically. Such an analysis is much less onerous than the approach employed in the DEIS. It could also be easily applied at ecologically relevant scales, including watersheds smaller than those analyzed in the DEIS.

Fourth, peakflow from rain-on-snow events is environmentally significant. Some of the highest peakflows within the analysis area occur in response to rain-on-snow events. These events often act as catalyst for high levels of management-induced erosion and sediment delivery within the analysis area.

The DEIS has plainly ignored relevant scientific information by failing to apply the results of Grant et al. (2007) with respect to the effects of logging on peakflows generated by rain-on-snow. It is highly likely that the failure to incorporate these findings causes the DEIS to greatly underestimate the magnitude and extent of existing peakflow elevation. This failure also causes the DEIS to underestimate the differences among the alternatives with respect to their effects on peakflows generated by rain-on-snow.

III. THE ANALYTICAL SCALE OF THE DEIS'S ANALYIS OF PEAKFLOWS IS INADEQUATE FOR DISCLOSING PEAKFLOW EFFECTS UNDER EXISTING CONDITIONS AND THE ALTERNATIVES

There are several reasons why the DEIS analysis of peakflows at the scale of sixth-field watersheds (DEIS, pp. pp. 382-388, 1095-1105) is inadequate to reasonably analyze and disclose impacts on peakflows and their effects on important aquatic conditions. First, peakflows in smaller watersheds are more prone to elevation by logging (MacDonald and Coe, 2007). Studies have consistently demonstrated that logging activities elevate peakflows in smaller watersheds (MacDonald and Ritland, 1989; Bowling et al., 2000).

Second, smaller watersheds often have a greater percentage of their watershed area that has been recently logged. This higher percentage of watershed disturbance causes proportionately greater peakflow increases in these smaller watersheds. Due to the patchiness in the distribution of logged areas, analysis at larger scales does not capture the more intensive disturbance levels existing in smaller watershed systems that significantly elevate peakflows. Thus, the DEIS's scale of analysis obscures, rather than discloses, the effects of logging on peakflows in headwater systems in watersheds smaller than the sixth-field scale analyzed in the DEIS.

Third, increases in peakflows in smaller watersheds have significant impacts. Some channel types in headwaters are highly vulnerable to increased channel erosion caused by peakflow elevation (Rosgen, 1996). Once degraded, many headwater streams in have very poor prospects for recovery, even after the causes of degradation have been eliminated (Rosgen, 1996). Due to their position in the channel network, elevated erosion in headwater channels increases downstream sediment transport and sedimentation in downstream fish habitats (Montgomery and Buffington, 1998).

For these reasons, the DEIS's analysis of peakflows effects at the scale of sixth-field watersheds is inadequate for assessing and disclosing the impacts on peakflows under existing conditions and the action alternatives. Due to these defects, the DEIS has failed to reasonably differentiate among the alternatives with respect to effects on peakflows and, instead, has underestimated the extent and magnitude of peakflow elevation under existing conditions and the action alternatives.

These scale defects must be rectified in the FEIS by analysis at scales smaller than the 6^{th} field. Such an analysis is tractable, especially using the results of Grant et al. (2007).

IV. THE DEIS UNDERESTIMATES IMPACTS ON PEAKFLOWS BECAUSE IT DOES NOT REASONABLY EVALUATE AND DISCLOSE THE EFFECTS OF ALL SOURCES OF INCREASED PEAKFLOWS DUE TO MANAGEMENT ACTIVITIES

The DEIS does not reasonably examine and disclose the effects of all management activities on peakflows due to several defects which synergistically cause the DEIS to underestimate the extent and magnitude of increases in peakflows under existing conditions and the action alternatives. The DEIS's analysis only narrowly considers some effects of forest vegetation conditions on peakflows, while ignoring other factors that have long been known to affect peakflows. For instance, soil compaction contributes to increased peakflow (Wissmar et al., 1994; USFS et al., 1993; Booth et al., 2002; Booth et al., 2004). Roads alter peakflow through additional mechanisms. However, the DEIS analysis does not reasonably analyze and disclose these impacts on peakflow alteration under existing conditions and the action alternatives. As a result, the DEIS's analysis of peakflow underestimates the extent and intensity of peakflow alteration under existing conditions and the alternatives.

Peakflow elevation by cumulative soil compaction

The DEIS fails to reasonably assess and disclose the effects of soil compaction on peakflows. The methods used in the DEIS to provide some nominal analysis of the extent of peakflow alteration within the analysis area do not explicitly incorporate the effects of soil compaction (DEIS, pp. 382-388, 1095-1105). Instead, the method only narrowly focuses on some impacts of forest canopy conditions (DEIS, pp. 382-388, 1095-1105).

This is a major defect. Soil compaction is an enduring cumulative impact of management activities. Soil compaction typically persists for many decades before full recovery (Beschta et al., 2004). There are many pervasive sources of soil compaction within the analysis area, including historic and on-going livestock grazing, previous logging, landings, and roads.

Soil compaction contributes to elevated runoff by decreasing infiltration rates and reducing the ability of the soil to store water (Maidment, 1993). The latter increases the duration and extent of saturated soils, increasing the magnitude and duration of surface runoff that contribute to elevated peakflow (O'Laughlin, 1986). Reductions in infiltration rates also contribute to increases in surface runoff that contribute to elevated peakflows.

<u>Peakflow elevation by soil compaction from grazing</u>

Livestock grazing significantly compacts soils (Reid, 1993; CWWR, 1996; Kauffman et al., 2004). The USBLM has estimated that the hooves of a 1,000 pound cow exert more than five times the pressure per square inch on soils and streambanks than that from a bulldozer (Cowley, 2002). Although the DEIS does not reasonably assess and disclose the cumulative impacts of grazing on soil compaction and peakflows, the DEIS concedes that compaction from livestock grazing decreases the ability of soils to absorb water and increases surface runoff (DEIS, p. 796-798).

The impacts of grazing on the hydrologic properties of soils that affect peakflows are far from trivial. Kauffman et al. (2004) documented that cattle grazing persistently reduced infiltration rates by about an average of 85% relative to areas that had not been grazed for more than a decade.

Kauffman et al. (2004) that noted that soil compaction from grazing profoundly reduced the ability of soils to absorb and store water:

> "Based upon the results of this study we calculated that saturated soils of the surface 10 cm of a single hectare of exclosed dry meadow would contain 61000 L more water than an equivalent grazed hectare. Under saturated conditions, a hectare of wet meadows with the pore space measured in the exclosed communities of this study would contain 121000 L more water than those with the pore space of the grazed wet-meadow communities. Our results suggest that if the entire area was excluded from livestock the surface 10 cm of soil in the meadows alone…could potentially store 16.6 X 10^6 L more of water than if the area were grazed by cattle. And, this estimate does not include the entire soil profile. This increase in soil water likely influences ecosystem productivity, soil temperature, biogeochemistry, and streamflows."

Kauffman et al. (2004) concluded that the measured impacts of grazing on the hydrologic properties of soils at the landscape scale had likely had significant effects on stream channel structure, water quality, and the aquatic biota.

CWWR (1996) noted that compaction is pervasive in areas that have been subjected to grazing. In some systems, grazing has rendered more than 80% of soils in compacted state (CWWR, 1996).

These hydrologic impacts of grazing are especially significant because livestock impacts are typically greatest in riparian areas near streams. Due to their proximity, this alteration of soil hydrologic processes in riparian areas causes elevated surface runoff to streams, contributing to elevated peakflows. Grazing has been documented to increase peakflows at the watershed scale (Reid, 1993).

A significant amount of the analysis area has been grazed. Currently, about 560,000 acres, or roughly 22% of the BLM lands in the planning area are subjected to grazing (DEIS, p. 428). However, previous grazing has been more extensive (DEIS, pp. 428-429). Therefore, soils compacted by grazing likely occur over more than 22% of BLM lands covered by the DEIS, because soil compaction is highly persistent (Beschta et al., 2004).

The DEIS fails to reasonably disclose the extent of soils that have been compacted by grazing. This is a significant defect, due to the known impacts of grazing on soil compaction. This defect must be rectified in the FEIS by reasonably estimating the extent and distribution of soil compaction caused by on-going grazing and by grazing over the past several decades.

The DEIS also fails to adequately analyze and disclose how soil compaction from grazing contributes to peakflow increases. The DEIS compounds these problems by failing to clearly disclose that the DEIS's analysis of peakflows does not consider impacts from existing and future soil impacts caused by grazing. The DEIS also fails to reasonably disclose that this defect in the analysis of peakflow impacts in the DEIS results in the underestimation of the extent and intensity of cumulative peakflow alteration within the analysis area under existing conditions and the action alternatives.

Notably, much of the soil compaction caused by grazing occurs in watersheds that have been subjected to past logging and that would be affected by significantly accelerated logging under the action alternatives (DEIS, p. 802). Therefore, soil compaction from grazing is adding to peakflow elevation caused by logging in many watersheds. It will continue to do so, due to the persistence of soil compaction and on-going grazing. Therefore, the DEIS failed to reasonably assess the cumulative impacts on peakflows under the alternatives, because it failed to reasonably assess the contribution of grazing impacts to peakflows in conjunction with the other impacts of action alternatives on peakflows from canopy removal by logging. This defect causes the DEIS to underestimate the cumulative effects of the alternatives on peakflows.

These foregoing defects with respect to grazing, soil compaction, and peakflows, must be rectified in the FEIS. The FEIS must be revamped to ensure that the cumulative impacts of existing conditions and proposed actions on peakflows are analyzed and disclosed, including those from soil compaction caused by grazing.

Peakflow elevation by soil compaction from logging, roads, and landings

Because the DEIS's analysis of peakflows only narrowly focuses on forest canopy conditions, it fails to reasonably analyze and disclose the effects of soil compaction caused by roads, landings and logging. Roads persistently reduce infiltration rates by about 95-99% (Luce, 1997). Due to the extremely low infiltration rates on roads, they generate surface erosion and runoff in response to frequent, low-intensity rainfall and snowmelt events, for as long as the road exists, resulting in persistent and chronic elevation of surface runoff and peakflows. A copious amount of the analysis area is occupied by roads. Although it has long been well-documented that the soil impacts of roads significantly alter runoff and peakflows, the DEIS's analysis of peakflows fails to reasonably disclose the existing effects of roads on peakflows.

Per unit area affected, landings have impacts on soil compaction and infiltration processes that are akin to those from roads in their severity and persistence, as other USFS cumulative methods have acknowledged (Menning et al., 1996). The DEIS analysis fails to reasonably incorporate the cumulative effects of the area affected by landings into the analysis of existing effects on peakflows.

The DEIS fails to disclose the amount of area occupied by existing landings, although the DEIS (p. 795) indicates that this affected area is known.[1] This is a considerable defect because a significant amount of the analysis area has been affected landings due to their association with logging.

Despite the lack of disclosure, the existing extent of compaction from landings can be estimated from the association of landings with logged areas. According to the DEIS, about 46% of the forested area on BLM lands within the planning area has a "management history." It can be reasonably assumed that this management history is from logging. Landings typically occupy about 1-2% of the area logged. Therefore, based on the foregoing, more than 15,000 acres of BLM lands within the analysis area have been severely compacted by landings. This estimated area of landings is roughly equivalent to the area of more than 4,100 miles of road with a mean width of 30 feet. This is clearly significant due to intensity of compaction in areas affected by landings and its effects on runoff and peakflows.

It is highly likely that a significant amount of the soils compacted by landings occur in relatively close proximity to streams. In the recent past, the flatter areas along streams were targeted for landing construction. Landings are usually proximate to ground-based logging operations. The DEIS (p. 345) concedes that many of the riparian areas within the planning area have been logged at least once, so it is likely that a significant amount of these riparian areas have compacted soils from landing construction and use, which contributes to elevated peakflows.

Based on the foregoing, it is obvious that compaction from landings has been significant and is contributing to increases in peakflows. Therefore, the DEIS's failure to reasonably analyze and disclose these effects on peakflows causes the DEIS to underestimate the magnitude and extent of peakflow elevation under existing conditions and the alternatives.

The DEIS (p. 426) concedes that compaction from past logging persists on BLM lands throughout the analysis area. However, the DEIS includes no estimate of the amount of this compaction. Although the DEIS (p. 426) asserts that the amount of compaction from past logging is "not known," it can be reasonably estimated from the information in the DEIS. The DEIS (p. 206) notes that about 42% of the 2.2 million acres of BLM forested lands within the

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[1] It appears that the area occupied by landings is known because the DEIS (p. 795) states "The net effect of road building versus road decommissioning results in a less than 1% increase over current road and landing acreage in Alternatives 2 and 3 and a net decrease in acres in the No Action Alternative and Alternative 1." This statement requires knowledge of current landing acreage, although the total amount is not disclosed in the DEIS.

analysis consists of young stands. These young stands have been logged. It is likely that the majority of this previously logged area was logged by ground-based methods, with some limited amount of skyline. The DEIS (p. 795) estimates that ground-based and skyline logging methods, respectively, cause detrimental soil disturbance on about 15% and 3% of the area logged. Therefore, it is reasonable to assume that about 10%, or more than 92,000 acres, of the previously logged young stands on BLM lands within the analysis have compacted soils, which cumulatively contribute to increases in peakflows.

It is likely that a significant amount of riparian areas have soils compacted by previous logging. The DEIS (p. 345) concedes that many of the riparian areas within the planning area have been logged at least once. Compacted soils in riparian areas are especially likely to increase peakflows due to their proximity to streams, although this is not disclosed in the DEIS.

The foregoing clearly indicates that the DEIS failed to reasonably disclose the likely extent and distribution of existing cumulative soil compaction caused by roads, landings, and past logging. The DEIS also failed to reasonably evaluate and disclose that the soil compaction from these activities contributes to elevated peakflows. Notably, there are numerous tractable methods for estimating the changes in peakflows due the effects of soil compaction.

The DEIS exacerbates these deficiencies by failing to reasonably disclose that the methods used to provide its flawed estimates of management activities on peakflows do not adequately address the effects of soil compaction on peakflows. These manifold defects cause the DEIS to underestimate the extent and magnitude of peakflow alteration under existing conditions and under the activities proposed under the alternatives. In so doing, the DEIS has failed to reasonably disclose cumulative impacts on peakflows and to differentiate among the alternatives with respect to effects on peakflows.

<u>Peakflow elevation due to accelerated topsoil loss from management activities</u>

The DEIS also failed to factor the effects of topsoil loss into the analysis of existing impacts of management on peakflows. This is significant because there are numerous activities and conditions in the analysis area that have cumulatively accelerated topsoil erosion over many decades, including logging, landings, roads, and grazing.

The effects of topsoil loss on the hydrologic properties of soils and streamflows are not trivial. The loss of one inch of soil over one square mile results in the loss of more than 813,120 cubic feet of available water storage in the soil profile. This loss of the ability of soils to store water contributes to peakflow elevation. Topsoil loss also contributes to peakflow elevation by reducing infiltration rates, because the uppermost soil profiles typically have the highest infiltration rates (Maidment, 1993).

<u>Peakflow elevation from the alteration of runoff routing by roads</u>

The DEIS fails to credibly and reasonably analyze the multiple effects of roads on peakflows. This is significant because roads increase peakflows in several ways besides compaction. Roadcuts intercept subsurface flow (Megahan, 1972), converting it to surface flow during wetter periods. The physics of water flow in soils make the interception of subsurface flows by roadcuts unavoidable (Kirkby, 1978).

Roads also contribute to elevating peakflows by concentrating runoff and rapidly shunting it to streams via integration with the stream network (Wemple et al., 1996; Jones and Grant, 1996; Bowling et al., 2000; USFS, 2000; Gucsinski et al., 2001; La Marche and Lettenmaier, 2001; MacDonald and Coe, 2007). The effects of roads alone on peakflows in the Pacific Northwest are estimated to be roughly equivalent to the effect of logging (La Marche and Lettenmaier, 2001). These impacts of roads on peakflows are in addition to those caused by loss of vegetation from logging (La Marche and Lettenmaier, 2001). USFS et al. (1993) noted that much of the massive road network in the area under the aegis of the Northwest Forest Plan, including the DEIS planning area, already had adversely affected peakflows.

It is also well established that a significant fraction of road networks is hydrologically connected to channel networks, elevating peakflows (Wemple et al., 1996; Jones and Grant, 1996; Bowling et al., 2000; La Marche and Lettenmaier, 2001; Gucinski et al., 2001). This is certainly the case for roads on BLM lands within the analysis area, although this is not adequately disclosed in the DEIS. A copious amount of roads occur within 200 feet of stream channels (DEIS, p. 377). Notably, it is likely that roads that are more than 200 feet from streams contribute accelerated runoff to streams. The Clearwater National Forest (2003) noted that roads within 300 feet of streams were likely to have some hydrologic connectivity with streams.

However, the DEIS's analysis of impacts on peakflows does not adequately incorporate and disclose these effects of roads on peakflow elevation. Notably, this failure in the DEIS exists despite the DEIS's (p. 388) acknowledgment that roads elevate peakflows by altering runoff pathways.

Estimating road impacts on peakflows is tractable because models for road impacts, including runoff routing, on peakflows have been developed (La Marche and Lettenmaier, 2001). The DEIS also fails to adequately disclose that its analysis omits these significant effects on peakflows, and therefore underestimates peakflow elevation under existing conditions and the alternatives. Because available scientific information indicates that the effects of roads on peakflows is equivalent and in addition to the impacts of vegetation removal by logging (e.g., Bowling et al., 2000; La Marche and Lettenmaier, 2000), it is likely that actual peakflow alteration within the DEIS analysis area is about double the level estimated by the DEIS's defective analysis. This is an extremely significant magnitude of underestimation.

Peakflow elevation by wildfire

Sporadic wildland fire occurs with some frequency within the analysis area (DEIS, Fig. 19, p. 195). Although patchy, wildland fire can affect a significant fraction of a watershed, and, especially, of smaller watersheds that exhibit the most pronounced increases in peakflows in response to vegetation removal. Depending on the fire severity and extent, the impacts on vegetation and soils can significantly elevate peakflows, as repeatedly documented in many studies.

Although wildfire occurrence at a given location cannot be predicted, the extent of future fire-affected areas over a larger analysis area, such as the DEIS analysis area, can be estimated based on past fire occurrence. However, the DEIS's analysis of effects on peakflows did not take into account the effects of wildfire occurrence. Therefore, the DEIS failed to reasonably analyze and disclose the cumulative effects of the alternatives' direct impacts on peakflows, together with those from wildfire processes.

V. THE DEIS'S ANALYSIS OF THE IMPACTS ON PEAKFLOWS ARE BASED ON ASSUMPTIONS THAT ARE NOT WARRANTED AND FRAUGHT WITH POTENTIAL ERROR, WHICH ARE NOT ADEQUATELY DISCLOSED

The methods used in the DEIS to screen for peakflow impacts rely on assumptions that are not warranted based on available scientific information. For instance, in rain-dominated watersheds, the DEIS arbitrarily assumes that only areas that have less than 30% canopy cover contribute to elevated peakflows. One of the mechanisms by which logging contributes to elevated peakflows is through the reduction of evapotranspiration (ET) and precipitation interception from tree removal (Reid, 1993; Rhodes et al., 1994). Reductions in canopy cover that retain above 30% canopy cover still contribute to elevation in peakflows by decreasing interception and ET. Therefore, the DEIS clearly fails to disclose the lack of scientific basis for its unfounded assumptions.

Similarly, the DEIS's analysis of peakflows assumes that only estimated increases in peakflows in excess of an arbitrary threshold are significant (DEIS, pp. 382-388, 1095-1105). The DEIS fails to examine the veracity of these assumed thresholds based on available scientific information. The DEIS also fails to reasonably disclose scientific information salient to the assumed thresholds of peakflow elevation in the DEIS. For instance, the DEIS does not disclose that Dunne et al. (2001) expressly noted that it cannot be reasonably assumed that relatively small increases in peakflows do not have significant adverse impacts on stream systems, aquatic habitats, and fish populations, because relatively small increases in peakflows exponentially increase sediment transport.

There are many more embedded assumptions in the DEIS analysis of peakflow elevation that cumulatively and synergistically influence the veracity of the results, but are not reasonably assessed for their veracity within the context of available scientific information. These include assumed differences in snowpack accumulation and snowmelt rates as a function of canopy conditions, assumed flow-frequency relationships in the watersheds analyzed, and the size of storms analyzed. Although these assumptions strongly influence the veracity of the results and are fraught with sources of cumulative error, the DEIS fails to reasonably assess and disclose how tenable the assumed approximations are, based on available scientific information.

The DEIS compounds these defects by failing to reasonably assess and disclose the likely magnitude of error inherent in these individual assumed approximations, in order to estimate the total potential error inherent in the DEIS's aggregate estimates of the magnitude and extent of peakflow elevation in the analysis area. Such an analysis is essential to reasonably disclosing the potential accuracy of the results and has long been a standard part of hydrologic analyses (Maidment, 1993). This is a very significant defect, because it is highly likely that the aggregate potential for error in the DEIS's analysis of impacts on peakflow elevation is relatively large, which undermines the veracity of the DEIS's analysis.

The foregoing aspects of the DEIS's analysis of peakflow elevation are central to assessing its potential accuracy. Therefore, these existing defects must be rectified. The FEIS must reasonably examine the veracity of the assumptions in the analysis, based on available scientific information. The FEIS must also credibly assess and disclose the potential for error in the analysis.

VI. THE DEIS's USE OF ASSUMED THRESHOLDS OF DETECTABILITY IS NOT ADEQUATE TO REASONABLY DISCLOSE THE LIKELY IMPACTS OF MANAGEMENT-INDUCED PEAKFLOW ELEVATION

The DEIS's discussion of variability, detectability, and significance of peakflow elevation compounds the defects in its analysis of peakflow impacts. For instance, the DEIS asserts that variability in streamflow is likely greater than the level of elevation of peakflows caused by management activities. However, currently-increased peakflows caused by existing conditions are *in addition* to natural variation. This overlaying of management-induced impacts causes altered peakflows to be outside of the range of natural variability. Management-induced peakflow elevation increases not only the magnitude of peakflows, but also the frequency of peakflows of a given magnitude. Because sediment transport is strongly affected by peakflows, peakflow elevation inexorably increases channel erosion and sediment transport. This occurs whether or not peakflow increases are less than the detection thresholds assumed in the DEIS.

Similarly, the DEIS erroneously conflates detectability with ecological significance. Impacts that are manifest at levels below the threshold of detectability of peakflow increases can have nonetheless profound ecological impacts. Dunne et al. (2001) noted that peakflow elevation by logging and roads is an important concern because even minor changes in peakflow magnitude and frequency can have major effects on salmonids by triggering significant changes in channel erosion and sediment transport.

Further, the DEIS failed to reasonably assess the considerable error associated with its methods for analyzing peakflow impacts. It is highly likely that if the error in the methods were reasonably assessed, that it would more than bound the DEIS's assumed thresholds of detectability in peakflow increases. Thus, the magnitude of the expected error in the DEIS's peakflow analyses is likely so large that if expected errors are taken into account, peakflows may be elevated beyond the assumed detection limits, even where the DEIS's methods – which disclose only the point estimates – indicate that peakflows have not been elevated. This is undisclosed in the DEIS.

VII. THE DEIS'S FAILURE TO REASONABLY DISCLOSE IMPACTS ON PEAKFLOWS RENDERS THE ANALYSIS OF AQUATIC IMPACTS INADEQUATE.

These DEIS defects regarding peakflows are significant because peakflow strongly affects a host of aquatic resources and processes, including sediment delivery to streams, sediment transport, channel form, turbidity, fish habitat conditions, levels of fine sediment in streams, and downstream flooding (USFS et al., 1993; Reid, 1993; Wissmar et al., 1994; Spence et al., 1996), although this is inadequately disclosed in the DEIS.

For instance, the DEIS fails to adequately disclose that increased peakflows inexorably widen stream channels as documented by Dose and Roper (1994) in logged watersheds in Oregon. The DEIS also inadequately considers and discloses that it is well-known that increases in stream channel width increase water temperature, even in the absence of shade loss (Rhodes et al., 1994; McCullough, 1999; Bartholow, 2000). This is a significant defect because elevated summer water temperatures are already a widespread aquatic problem within the analysis area.

Increased peakflows increase the downstream transport of sediment from headwater streams to the depositional reaches where salmonids spawn and rear. They can also trigger elevated channel erosion, adding to downstream sedimentation. Due to their characteristics, some headwater streams are extremely vulnerable to channel erosion caused by peakflow elevation (Rosgen, 1996); due to their position in the channel network, this increases downstream sedimentation in fish habitats (Montgomery and Buffington, 1998). Increases in peakflows can also increase bedload movement, reducing the survival of salmonid eggs and alevins (USFS et al., 1993). Peakflow elevation by logging and roads is an important concern because even minor changes in peakflow magnitude and frequency can have major effects on salmonids by triggering significant changes in channel erosion and sediment transport (Dunne et al., 2001).

Turbidity and temperature, which are both strongly affected by peakflow elevation, are set as state water quality standards. Because the DEIS failed to reasonably estimate cumulative elevation of peakflows and its resulting effects on turbidity and water temperature, the DEIS's analysis of compliance with water quality standards is defective.

These impacts all strongly affect the survival and production of salmonids that inhabit the streams that will be affected by action alternatives (Meehan, 1991; USFS et al., 1993). Therefore, it is clear that DEIS's analysis of the action alternatives' impacts on ESA listed fish, fish habitat condition, and fish populations is fatally flawed because it fails to adequately incorporate the likely cumulative impacts of the action alternatives on peakflows and resulting aquatic impacts.

VIII. THE DEIS FAILS TO REASONABLY ANALYZE AND DISCLOSE THE CUMULATIVE IMPACTS ON LOW FLOWS AND SUBSURFACE-SURFACE WATER INTERACTIONS

There are numerous activities and conditions in the analysis area that individually and cumulatively reduce low flows and negatively impact subsurface-surface water interactions. These include: soil compaction and loss caused by grazing, roads, landings, and logging; alterations in surface and subsurface runoff timing and routing caused by roads; and impacts on riparian vegetation and channel form caused by grazing. Reductions in low flows are a critically important factor for native aquatic species (e.g., salmonids, amphibians) survival and persistence. The DEIS fails to reasonably analyze and disclose these impacts.

Soil compaction contributes to reduced low flows by increasing surface runoff and reducing the amount of water stored in the soil profile that can supply streamflow during low flow periods. Grazing, roads, logging, and landings all increase soil compaction and surface runoff, while decreasing available water storage in the soil profile which can ultimately be supplied to streams during low flow periods. Kauffman et al. (2004) documented that grazing caused a significant loss of water storage capacity in soils due to compaction.

However, both grazing and roads have additional impacts on runoff that can reduce low flows. Grazing often causes channel incisement, which lowers near-stream water tables and xerifies adjacent riparian areas (Platts, 1991; Rhodes et al., 1994; CWWR, 1996; USFS, 2001). These impacts reduce low flows. Beschta et al. (1991) and Beschta et al. (1993) noted that channel incisement caused by grazing likely reduced baseflow contributions during the low flow period in damaged riparian systems. The cumulative effects of grazing in damaged systems have likely caused some perennial streams to become intermittent (Rhodes et al., 1994). Elimination of grazing in damaged riparian areas has increased low flows (Meehan, 1991), indicating that grazing had decreased low flows.

Seasonally-saturated and perennially-saturated riparian areas, wetlands and springs are vital to the maintenance of low flows and summer water temperatures. Many of these features are particularly vulnerable to significant damage from livestock grazing and, hence, are often pervasively degraded in areas subjected to livestock grazing (Rhodes et al., 1994; CWWR, 1996; USFS, 2001), contributing to the loss of instream flows derived from subsurface flows.

Reductions in subsurface flow caused by soil compaction, and subsurface flow interruption by roads, grazing, and logging negatively affect aquatic resources, because these impacts reduce hyporheic flows (Hancock, 2002). Cumulative soil compaction contributes to reductions in low flows (Booth et al., 2002; Booth et al., 2004).

Roadcuts inexorably interrupt subsurface flow. This interception by roadcuts is likely to reduce downslope soil moisture levels and subsurface flow contributions to affected streams, contributing to reduced baseflows (Tague and Band, 2001). Hancock (2002) noted that logging and roads reduced subsurface flows to hyporheic areas by reducing subsurface percolation and baseflow contributions to streams. Hicks et al. (1991) documented that watersheds in Oregon had statistically significant decreases in low flows after logging relative to an unlogged control watershed.

Subsurface flow interception by roads likely increases water temperatures via a two-pronged effect. Reductions in subsurface flows to streams reduce low flow volumes, which, alone, increase summer water temperatures (Beschta et al., 1987; Rhodes et al., 1994). However, subsurface flows entering streams are also typically far cooler than surface flows, aiding in the thermal regulation of streams during low flows (Beschta et al., 1987), so the loss of this cooler water also contributes to stream warming (Rhodes et al., 1994). Increases in summer water temperature have negative effects on native salmonids. Elevated summer water temperature is a widespread water-quality problem afflicting salmonids within the analysis area (USFS et al., 1993; DEIS, p. 359).

Despite this information, the DEIS is without any adequate analysis and disclosure of cumulative impacts of management activities on low flows and surface-subsurface hydrologic interactions. The defects on this front must be rectified in the FEIS by fully analyzing and disclosing all of the impacts of existing conditions and proposed activities on low flows and subsurface-surface water interactions based on available scientific information.

IX. CONCLUSION

The DEIS's analysis of the cumulative impacts of management activities on the stability of streamflow is wholly inadequate due to several significant defects. The DEIS failed to reasonably examine and disclose the impacts of logging on peakflows generated by rain-on-snow based on information in Grant et al. (2007) on the level of forest removal that generates detectable increases in these peakflows.

The DEIS also failed to examine the peakflow impacts of existing conditions and the proposed activities in the action alternatives on smaller watersheds where peakflow increases are likely to be most commonly manifest and pronounced. The DEIS failed to analyze and disclose the impacts of roads, cumulative soil compaction, topsoil loss, and future wildfire on peakflows. These foregoing defects cause the DEIS to significantly underestimate the magnitude and prevalence of peakflow elevation across the analysis area under existing conditions and the action alternatives. They also cause the DEIS to underestimate the differences among the alternatives with respect to peakflows. The DEIS compounds the foregoing defects by failing to reasonably disclose the limitations of its analysis and its likely degree of error. These are serious failures, because the action alternatives will significantly increase impacts on peakflows with negative consequences for aquatic conditions and salmonid populations. For these combined reasons, the DEIS has failed to adequately disclose the aquatic impacts of the alternatives.

Existing conditions and activities under the alternatives also affect low flows and surface-subsurface water interactions. These impacts affect aquatic conditions, but are not disclosed in the DEIS.

For these reasons, the DEIS fails to adequately disclose the cumulative impacts on streamflow stability. It also fails to adequately differentiate among the alternatives with respect to impacts on streamflow stability and its aquatic consequences.

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Curriculum Vitae: <u>Jonathan J. Rhodes</u>

Hydrologist
P.O. Box 15286 •• Portland, OR 97293-5286

EDUCATION

1989: Doctoral candidacy degree in forest hydrology at the Univ. of Wash. Completed all requirements but dissertation.

1985: M.S. in Hydrology and Hydrogeology at the Univ. of Nev.-Reno. Thesis topic: The influence of seasonal stream runoff patterns on water quality.

1981: B.S. in Hydrology and Water Resources at the Univ. of Ariz.

PROFESSIONAL HISTORY

Sept. 2001 – present. Hydrologist. Main duties: Analysis of effects of water and land use on streams and other aquatic resources, including native salmonids and their habitats; diagnosis of watershed and stream conditions; stream monitoring; development of programmatic and site-specific watershed and stream protection measures; project management. Recent projects (and clients): Analysis of potential effects of groundwater pumping on streamflow (Conf. Tribes of the Umatilla Indian Reservation, OR); diagnosis of watershed and stream conditions in an urbanized watershed (West Multnomah Soil and Water Conservation District, OR); diagnosis of effects of grazing on watershed and stream conditions in forested watersheds in N. California (Center for Biological Diversity (CBD)) and Oregon (Or. Natural Desert Assoc.); Coordinator and Aquatic Scientist for the Western Native Trout Campaign (CBD, Pacific Rivers Council (PRC), Biodiversity Conservation Alliance, Trout Unlimited).

Aug. 1990 – Sept. 2001. Consulting hydrologist for non-profit organizations. Past projects (and clients): hydrologic characterization of remnant marsh proposed as urban wildlife refuge/greenspace (Multnomah County Parks Department, OR); review of aquatic effects of: quarry expansion (Friends of Forest Park, OR), urban construction (homeowners consortium, W. Linn, OR); forest manipulations on streamflow (PRC).

Apr. 1989 – Sept. 2001. Senior Scientist-Hydrologist, Columbia River Inter-Tribal Fish Commission. Main duties: Administration and implementation of projects monitoring channel change from land management in Columbia River basin; development of programmatic and site-specific land management plans to ensure protection of watershed integrity, water quality and aquatic resources; development of restoration plans for watersheds degraded by grazing, roads, logging and mining; design of plans for monitoring watershed and stream erosion, sedimentation, water quality, and habitat conditions; review of land management plans for adequacy of protection of aquatic resources; field evaluation of watershed and channel conditions throughout the Columbia Basin; expert witness testimony; development of technical recommendations for policy staff for protection of natal habitat for anadromous fish; review of state and federal aquatic resource monitoring plans; report and proposal writing; and, participation in various state and federal technical work groups.

Aug. '84 -- Apr. '89. Research assistant, College of Forestry, Univ. of Wash. Main duties: analysis and interpretation of water quality-quantity data; technical report writing; design and maintenance of water chemistry and quantity monitoring network in a coastal forested watershed; training in data acquisition techniques; public presentation of findings.

July -- Oct. 1987 and May -- Oct. 1988. Consulting hydrologist, Tahoe Regional Planning Association, CA and NV. Main duties: field delineation and mapping of riparian zones, wetlands, and erosion-prone areas.

June -- Sept. 1985 and July 1986. Research assistant, Dept. of Geophysics, Univ of Wash. Main duties: operation of field station for glacier research on Mt. Olympus, Wash.; measurement of snow and glacier melt rates; mapping of supra- and extra- glacial streams contributing to basal sub-glacial flow rates on surging and non-surging glaciers in the Alaska Range, Alaska.

Jan. 1984. Consultant with C.M. Skau, Reno, NV. Main duties: field evaluation of logging roads for erosion potential and sedimentation risk; recommendations for placement of future roads to minimize erosion and sediment delivery to fish-bearing streams in coastal Northern California; report preparation.

Oct. 1983 -- June 1984. Hydrologic Tech., USGS, Carson City, NV. Main duties: aid in development and calibration of predictive water quality model for the Truckee River; statistical analysis of water quality data; identification and quantification of non-point sources of nutrients to Truckee River, NV.

Aug. 1981 -- Sept. 1983. Research Assistant, Univ. of Nev.-Reno. Main duties: design and installation of instrument network to monitor water chemistry and quantity in a small, forested alpine watershed in the Sierra Nevada; water quality sampling; data interpretation and management; preparation of reports, grant proposals, and publications, computer programming for data reduction and storage; mapping of geology, soils and runoff-producing areas; and, training of field technicians.

Feb. -- May 1981. Water Quality Intern, Pima Assoc. of Gov'ts., Tucson, AZ. Main duties: water quality sampling of agricultural production wells; mapping of groundwater levels; and, coordination of sampling efforts.

PROFESSIONAL SERVICE

Mar. 2007. Invited Panel Speaker, International Environmental Law Conference: "Fuel Treatments & Thinning: Its Impacts and Low Priority Relative to Other Needed Restoration Measures," Univ. of OR, Eugene, OR.

Mar. 2007. Invited Panel Speaker, International Environmental Law Conference: "The Impacts of Livestock Grazing on Water Quality and Trout Habitats," Univ. of OR, Eugene, OR.

Feb. 2005. Invited Guest Lecturer, Lewis and Clark School of Law course on public lands law: "Postfire Watershed Management on Western Public Lands" Portland, OR.

Mar. 2004. Invited Panel Speaker, International Environmental Law Conference: "Postfire Watershed Restoration," Univ. of OR, Eugene, OR.

April 2002. Invited Speaker, Restoring Public Lands: Reclaiming the Concept of Forest Restoration, "Watersheds and Fisheries: Restoration Needs for Trout Habitats," Univ. of CO, Boulder, CO

Mar 2002. Invited Panel Speaker, International Environmental Law Conference: "Soils Impacts and Effects on Trout Habitat," Univ. of OR, Eugene, OR

Mar. 2001. Invited Panel Speaker, International Environmental Law Conference: "NFMA and Salmon Habitat Protection," Univ. of OR, Eugene, OR.

May 2000. Invited speaker, 5th National Tribal Conf. on Environmental Management: "Federal Land Management's Effects on Critical Habitat for Endangered Salmon," Lincoln City, OR

July 1998-2000. Peer Reviewer for N. Amer. J. Fish for papers related to the sedimentation of fish habitat in response to erosion from land uses and fire.

Feb. 1998. Invited Speaker, Oregon AFS Annual meeting: "Adaptive management: Is it really adaptive?" Sunriver, OR

May 1996-2000. Guest lecturer, Oregon State Univ. graduate course on riparian and wetland ecology, Corvallis, OR

Apr.-May 1996. Peer-reviewer for Proceedings of Forest-Fish Conference: Land Management Affecting Aquatic Ecosystems, Proc. Forest-Fish Conf., May 1-4, 1996, Calgary, Alberta, Canada. Nat. Resour. Can., Can. For. Serv. Nort. For. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-356.

Apr. 1995. Invited speaker, Pacific Rivers Council Workshop on Watershed Analysis and Salvage Logging, Wenatchee, Wash.

Apr. 1995. Invited speaker, Oregon State Univ. Dept of Fisheries and Wildlife Seminar, Corvallis, OR

Apr. 1995. Invited speaker, American Fisheries Society North Pacific International Chapter, Annual Meeting, Vancouver B.C., Can.

Mar. 1995. Invited speaker, American Fisheries Society Idaho Chapter Annual Meeting, Boise, ID.

Nov. 1994. Invited speaker, President's Council on Sustainable Development Workshop, Yakima, WA.

Sept. 1994. Invited speaker, Oregon Water Resources Research Institute Streambank Restoration Conference: "Biological Methods to Stabilize Streambanks--From Theory to Practice," Portland, OR.

Mar.-April, 1994. Peer-reviewer for Henjum et al., 1994. Interim Protection for Late Successional Forests, Fisheries, and Watersheds: National Forests East of The Cascade Crest, Oregon and Washington. The Wildlife Soc., Bethesda, MD.

Jan. 1993-Sept. 1995. Member, Oregon Department of Environmental Quality's (ODEQ) Technical Advisory Committee for Triennial Review of the State Water Temperature Standard.

Mar. 1993. Invited speaker, Northwest Scientific Association Symposium: "Cumulative Effects of Land Management Practices on Anadromous Salmonids," La Grande, OR.

Aug. 1992 -- Sept. 1992. Member, Ad Hoc Consultant Selection Committee for Portland Water Bureau Study of Future Water Supply Needs.

May 1992. Invited Speaker, US Forest Service, Pacific Northwest Region, Regional Workshop on Monitoring Soil and Water Resources, Bend, OR.

May 1992. Invited Speaker, Northern Arizona University, School of Forestry, Graduate Seminar Series, Flagstaff, AZ.

Jan. 1991 -- Mar. 1995. Member, Technical Work Group: Upper Grande Ronde River Anadromous Fish Habitat Protection, Restoration and Monitoring Plan.

Aug. 1989 -- Feb. 1990. Member, Technical Advisory Committee to ODEQ for development of definitions for level of beneficial use impairment by nonpoint sources.

May 1989 -- Jan. 1991. Member, Nonpoint Source Technical Advisory Committee to Idaho Department of Environmental Quality: Coordinated Nonpoint Source Monitoring Program For Idaho.

PUBLICATIONS

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1999. Annual Project Report: Watershed Evaluation and Aquatic Habitat Response to Recent Storms. Bonneville Power Administration (BPA), Portland, OR. (Co-author: C. Huntington)

1999. Annual Project Report: Monitoring Fine Sediment in Salmon Habitat in John Day and Grande Ronde Rivers. BPA, Portland, OR (Co-author: M. Purser)

2000. Annual Project Report: Watershed Evaluation and Aquatic Habitat Response to Recent Storms. BPA, Portland, OR. (Co-author: C. Huntington)

2000. Annual Project Report: Monitoring Fine Sediment in Salmon Habitat in John Day and Grande Ronde Rivers. (Co-author: M. J. Greene)

2001. Annual Project Report: Monitoring Fine Sediment in Salmon Habitat in John Day and Grande Ronde Rivers. BPA, Portland, OR. (Co-author: M. J. Greene)

2001. Imperiled Western Trout and the Importance of Roadless Areas. Western Native Trout Campaign, Center for Biological Diversity, Tucson, Az. (Co-authors: J. Kessler, C. Bradley, and J. Wood)

2002. Tryon Creek Watershed: Overview of Existing Conditions, Data Gaps, and Recommendations for the Protection and Restoration of Aquatic Resources. West Multnomah Soil and Water Conservation District, Portland, OR

2002. An Analysis of Trout and Salmon Status and Conservation Values of Potential Wilderness Candidates in Idaho and Eastern Washington. Western Native Trout Campaign, Center for Biological Diversity, Tucson, AZ. (Co-authors: C. Bradley, J. Kessler, C. Frissell)

2003. Stream and Fish Habitat Conditions in Tryon Creek: Their Likely Causes and Ramifications for Salmonids. Proceedings of Urban Ecology and Conservation Symposium, January 24, 2003, Portland, OR. Portland State University, Environmental Sciences and Resources, Portland, OR

Semi-Technical Publications:

1993. Dam the analysis--heal streams instead. The Assoc. of Forest Service Employees for Env. Ethics Inner Voice, **5**(6): 1, 4-5.

1994. Invited Preface to Northwest Science Special Issue--Environmental History of River Basins in Eastern Oregon and Washington. Northwest Sci., **68**.

PROJECT MANAGEMENT

1993-1996. Technical Assistance Contract with NMFS to produce technical guidance for ESA consultations for effects of land management on critical habitat for listed Columbia basin salmon. Main duties: Co-Primary Investigator; primary author of peer-reviewed reports including proposed ESA consultation guidelines for effects on salmon habitat (Rhodes et al., 1994), evaluation and comparison of compatibility of land management plans with protection of critical salmon habitat (Rhodes, 1995), and evaluation of models for estimating land management effects on salmon habitat (Rhodes, 1996); review and synthesis of available scientific literature; budget preparation and tracking; coordination with subcontractors and grantor representatives. Total budget: $230,000

1998-2000. Watershed Evaluation and Aquatic Habitat Response to Recent Storms. Main duties: Primary Investigator; design and implementation of monitoring methods (erosion, runoff, etc.), coordination with subcontracting fish biologists in 10 watersheds with differing levels of grazing and logging within 3 subbasins in Idaho, Washington, and Oregon; training of field technicians; data analysis and synthesis; subcontract administration; proposal development; technical and progress report preparation; budget development and tracking; coordination with grantor representatives. Total budget: $164,000.

1998-2000. Evaluation of Effects of Grazing on Rate of Salmon Habitat Recovery. Main duties: Primary Investigator; design and implementation of monitoring methods, training of field technician; data analysis and synthesis; proposal development; preparation of progress reports; budget development and tracking; coordination with grantor representatives. Total budget: $73,000

1998-2001. Monitoring Fine Sediment Levels in Salmon Habitat in Grande Ronde and John Day Rivers. Main duties: Primary Investigator; design and implementation of methods for monitoring fine sediment levels in four rivers; field technician training; data analysis and synthesis; subcontract administration; proposal development; progress and technical report preparation; budget development and tracking; coordination with grantor representatives. Total budget: $128,000.

2001-2002. Western Native Trout Campaign, Aquatic Scientist and Coordinator. Main duties: Provide oversight and assure scientific integrity of all reports and work products; coordinate conservation efforts among campaign member organizations; coordinate campaign efforts with other groups working to protect and restore trout habitats and populations; budget tracking; technical and progress report preparation.

HONORS AND AWARDS

1996. Leadership and Excellence. Col. River Inter-Tribal Fish Comm., Portland, OR

1991. Employee of the Year. Col. River Inter-Tribal Fish Comm., Portland, OR

1984. Academic Recruitment Scholarship for Outstanding Graduate Prospect. Univ. of Wash, Seattle, Wash.

1982. Maxey Award for Outstanding Graduate Student Paper in Hydrology. Univ. of Nev.-Reno.

1980. Winslow and Myron Reuben Scholarship for Outstanding Undergraduate in the Earth Sciences. Univ. of Ariz., Tucson, Az.

ADDITIONAL TRAINING

1993. USFWS Water Temperature Modeling via SNTEMP

1991. USFWS Introduction to IFIM Investigations

Review of LWD recruitment model used within NEPA Draft Environmental Impact Statement (DEIS) for the Revision of Resource Management Plans of the Western Oregon Bureau of Land Management Districts

Technical Memorandum

Prepared for
Pacific Rivers Council
PMB 219, 48901 Highway 93, Suite A
Polson, MT 59860

Prepared by
Stillwater Sciences
1314 NE 43rd St., Suite 210
Seattle, WA 98115

January 2008

Stillwater Sciences

1 BACKGROUND

This memo addresses a request by the Pacific Rivers Council to review the NEPA Draft Environmental Impact Statement (DEIS) for the Revision of Resource Management Plans of the Western Oregon Bureau of Land Management Districts (BLM 2007) with specific emphasis on the application of a large woody debris (LWD) recruitment model described therein. The application of this model by the BLM is intended to demonstrate the long-term outcome of riparian and hillslope harvest restrictions on the sustainable input of large wood into streams within their managed landscapes. The objectives of this review were to:

1. Review sections of the DEIS that discuss LWD and its recruitment to stream channels within the plan area

2. Review assumptions regarding the current condition of large wood in the standing stock of riparian zones, riparian disturbance and response to logging, recruitment and persistence of large wood in channels and floodplains, and whether all sources of landslide-derived large wood have been accounted for within the model assumptions

This review is structured around the description of the woody debris recruitment model as presented within Chapter 3 (pp. 340-355), Chapter 4 (pp. 723-740) and Appendix H (pp. 1082-1092) of the DEIS. When appropriate, or possible, background reference material was reviewed to gain insight into ideas, concepts, and assumptions presented within the report. Unreferenced, but relevant, material was also consulted and incorporated in this review where considered appropriate. While this particular review is narrowly focused on LWD in streams, interpretation of the expected outcomes of proposed management alternatives on stream habitat and physical processes that shape ecological values requires a more integrated analysis than was done here. The authors' professional credentials are referenced in their CVs, attached as Appendix A.

2 TOOLS USED FOR LONG-RANGE FORECAST OF LWD LOADING IN STREAMS

We did not evaluate the merits of each land management alternative on input rates of LWD, but rather focused on the analytical tools and approach used by the BLM and applied equally to all four alternatives. We made particular note of the assumptions and evidence of prior applications of these models. The effects analysis of the DEIS relies upon the application of two models, one a spatially explicit, Geographic Information System (GIS)-based wood recruitment model to determine potential large wood contributions to fish-bearing streams, and a second model that accounts for predictions of the relationship between watershed and channel attributes, LWD and pool habitats, referred to as *intrinsic potential*. The intrinsic potential for each stream reach was also coupled with a fish productivity index to make predictions of assessing the effects of wood recruitment on fish habitat and productive potential. This was done independently for juvenile steelhead, coho, and Chinook salmon. In our review, we could find no actual data on current conditions of instream habitats or LWD loading provided by BLM to support the model outputs under each alternative.

The LWD recruitment model considers wood input from three recruitment sources: tree fall, channel migration, and debris flows, calculating average annual wood recruitment (# of pieces

>20" diameter/year) over a 100-year planning horizon, broken into twenty-year intervals from 2006 to 2106. In recognition of inter-annual spatial and temporal variability in wood recruitment, the model output is a long-term (20-year) average rate, rather than an annual recruitment rate calculated for each year. The GIS-based nature of the model allows for spatial identification of potential wood source areas, different weighting of recruitment processes, and examination of spatial patterns in recruitment rates.

The LWD input model uses mean annual stream flow, valley constraint, and channel gradient as determinant features to predict input rates and sources. The model determines the theoretical input of large wood from each recruitment source: riparian tree fall, channel migration, and debris flow. The model is based upon US Geological Survey 10 m Digital Elevation Models (DEMs) of the planning area, upon which the stream and road networks were digitized. Stream segments were buffered by a horizontal distance equal to their estimated active channel width, and for each DEM point within one potential tree height of the active channel, the model calculated the probability that a tree originating from that point will intersect an active channel segment. The probability is based upon random tree fall direction, the angle subtended by the falling tree, distance to the active channel, and the slope at the point where the tree originated. Each DEM point is associated with a 10 by 10 m DEM pixel that is associated with forest cover types, from growth model (Organon) and yield models that are comprised of trees size classes incorporating stem density, diameter at breast height, average tree height, and mortality rate. Using these data, the model determines a probability that a probability that a fallen tree actually intersects a stream segment, thus adding to a rate of input over time.

As described in the DEIS, the output from the LWD model is linked to a fish productivity index, which is used to assess the potential fish habitat and resulting fish production output within the planning area. The index incorporates species-specific intrinsic habitat potential of individual channel segments and estimated large wood recruitment from the large wood model. The intrinsic potential calculated for each reach is scaled by a large wood index value, which is the ratio of the maximum # of pools expected in a reach that is fully seeded with LWD (based upon an empirical value from Beechie and Sibley 1997), and the number of pools expected based upon the model-predicted LWD input. This nexus gets a bit obtuse in that the reader is required to make a leap of faith that these aggregated model assumptions and input values will truly reflect a reasonable expectation of the net outcome of alternative land management actions across this diverse landscape.

3 DIFFERENCES IN LWD INPUT RATES BY PHYSIOGRAPHIC PROVINCE

Potential differences in riparian growth and LWD input process rates between physiographic provinces are not explicitly accounted for in the model, but are implied within the DEIS. For purposes of the application of the model, the DEIS identifies and treats as one, all provinces within the plan area, including: Coast Range, Western Cascades, Eastern Cascades, Klamath Mountains, and Willamette Valley. It is not clear, however, how the model input values are adjusted to reflect inherent differences in landscape determinant features such as bedrock geology (e.g. volcanic vs. metamorphic), soils, vegetative potential, and climate, all of which influence erosion rates, potential wood recruitment, and riparian stand dynamics. Variable sedimentation and erosion rates among physiographic provinces may be expressed as differences in LWD recruitment rates and mechanisms (Fox et al. 2003), differences in longitudinal and cross-sectional channel form (Buffington et al. 2003), and differences in LWD storage and the role it plays in habitat formation and maintenance (Buffington et al. 2002). Chapter 3 (p.372) states that "natural rates of sediment yield within the planning area vary greatly depending on physiographic area, topography, vegetation, and climate," and then describes differences in sediment yield between the Coast Range and Western Cascades, but the reader is not directed to where the details are provided. Figure 103 (p. 374) shows landscape level differences in erosion rates based upon underlying parent material, which when compared to Figure 10 (p. 183) indicates differences between provinces. Yet it is hard for the reader to see how these differences are actually accounted for in the model output, and to what degree they determine a given outcome. They may be there, we just can't see them.

Additionally, parent rock type through which stream channels flow can have a significant deterministic influence on the nature of channel gradients, instream habitats, and the fish populations they support. Hick and Hall (2003), in their studies of salmonid populations in Oregon's Coast Range, found that sandstone-bedded streams supported four times more coho juveniles than age-0 trout, while basalt-bedded streams supporting age-0 trout outnumbered coho juveniles by a factor of five. It is not clear if and how these inherent geomorphic differences are dealt with in the application of these two integrated models to management decisions applied to such diverse landscapes and stream channels.

Within the LWD model, debris flow inputs are based upon the assumptions of Miller and Burnett (2007), who concluded that debris flow run-out (i.e. potential wood recruitment from hillslopes) could be calibrated for different geologies and soils. Their results are likely reasonable for low-order channels within the Coast Range province, but further research may be required to assess potential influence of other rock types. Figure 258 (p. 735) shows large differences in maximum large wood recruitment to five representative basins, and Figure 259 (p. 736) shows differences in recruitment source from three representative basins without detailed explanation of these differences. Yet a sensitivity analysis of the model predictions is not represented in the documents we reviewed.

4 MODEL ASSUMPTIONS, CONSTRUCTION, AND VALIDATION

Further, however elegant and comprehensive the LWD recruitment model is, the DEIS does not present evidence that the model predictions might actually fairly represent reality. If real-world applications of the model have been done, it would help bolster confidence in the model if these calibration experiences were presented. One simple way this could be done is to apply the model to several basins for which LWD loading data currently exists, and see how well the predictions comport to actual data. Such a sensitivity analysis would go a long way towards building confidence in the utility of the model predictions.

A significant shortcoming of the LWD input model predictions is that there is no basis to judge the current riparian stand conditions or in-stream LWD loading in these streams because information on existing baseline conditions is not provided. Given the extensive investments made to date in stream habitat surveys, including LWD frequency assessments, it seems curious why this information was not at least summarized for the reader. If they were all actually "equal" in condition, there would be no concern, but what does not compute is how a calculated LWD input rate applied to *all* streams can result in essentially the same outcome, if the streams already exhibit wildly different existing conditions. They seem to assume that existing conditions do not really matter because the riparian prescriptions will, in the long run, equalize whatever discrepancies currently exist. The same is true of the intrinsic potential (aka fish productivity vs. habitat capacity) model. These assumptions are fundamental and cry out for validation through monitoring. Initial in-channel wood stocking may influence the short- and long-term wood storage potential, thus affecting habitat formation and abundance, and assumptions regarding habitat availability. A lack of key-pieces, which are large and stable enough to form jams, may result in reaches with persistent low wood loading because of low storage potential (due to lack of storage opportunities) and high transport potential (due to smaller initial size of LWD input) (Bilby and Ward 1991, Braudrick and Grant 2000, Fox et al. 2003).

It is unclear from Chapters 3 and 4, or Appendix H, whether the source area of debris flow-recruited wood is one site potential tree height from the edge of a stream segment, or extends farther upslope. If debris flows are assumed to originate exclusively within a one site potential tree height zone, the model certainly underestimates current and future wood recruitment, particularly from intermittent, non-fish-bearing streams. McDade et al. (1990) and Murphy and Koski (1989) found that most wood in alluvial channels came from within 30 m (~100 ft) of the channel margin, but, May and Gresswell (2003a) (as cited on p. 750) found that in small, low-order streams, 80% of large wood came from within 50 m (~150 ft) of the channel. Because the model may underestimate wood input to non-fish-bearing streams under current conditions, it may thus underestimate the loss of wood recruitment via landslides under the three action alternatives, which call for 8-30 m (25-100 ft) retention (no- or selective-harvest) zones. May and Gresswell (2003b) found wood recruitment from low-order channels can diminish if managed for intensive timber harvest, which the alternatives may encourage. Further, if wood volume is depleted, the sediment storage capacity of low-order channels diminishes, leading to physical habitat and water quality concerns downstream. This bias in the model would, of course, obscure differences among the alternatives that are in fact real, and could be consequential to the survival and productivity of fish and other aquatic life.

A final point has to do with the incorporation of a monitoring component for evaluating performance of the riparian prescriptions through an adaptive management system. As described in the DEIS, the BLM seems only to commit to compliance monitoring for the riparian prescriptions and does not feel the need to include an effectiveness or validation monitoring component to systematically judge the outcomes predicted by the various models used in this analysis. Without these other monitoring components, there is no opportunity to recognize any errors with the modeling predictions for LWD recruitment and the adequacy of the riparian management approach. The application of models to predict environmental outcomes is only as good as the assumptions and input values used in their construction. The science to support them is never perfect, but they can provide important insights. However, these model predictions, should be corroborated with disciplined field observation from well designed experiments. But, in this application, what if the model predictions are substantially incorrect? Without a robust monitoring component there is no way to detect this, or even to modestly calibrate other model assumptions or input values. The commitment to adaptive management—which entails careful and robust monitoring, learning from the results of these focused studies, and making changes in management practices—is nowhere to be found in this DEIS. What exists is a vaguely described commitment to work out the details at some later, yet undefined date, with no specified process or responsibility in order to track performance measures and predicted ecological endpoints.

In conclusion, based upon a review of the assumptions and outputs, the model supports the conclusions presented in the alternatives, but the analysis and subsequent discussion do not address the following, potentially important, items:

1. LWD recruitment process rates likely differ by physiographic province, and this could affect the magnitude of the effects, including differences among the alternatives, both physically and biologically, in ways that are not addressed in the DEIS.

2. Critical model assumptions, construction, and validation are not addressed specifically:

    a. Current large wood condition, riparian characteristics, and stocking data across streams within the managed districts are poorly described or altogether absent.

    b. Delivery of large wood via debris flows may underestimate wood input under current and future conditions.

    c. Sensitivity analysis of model parameters (e.g., fish productivity vs. habitat relationships) is not presented, nor evaluated systematically through monitoring.

    d. There appears to be no sensitivity analysis of the numeric values chosen for any of the various key model parameters. This information is critical to understanding the merits and consequences of model predictions, even more so when several models are used together in ways that can compound their strengths and weaknesses. The choice of assigning a single value to a metric can have significant consequences on the reliability of their predictions. For example, which of the metrics within each model had the most influence on the predictions? How were values chosen for each of these metrics? Were model runs made using alternative values, or range of values, that represent natural variability? Are these results available and do they predict markedly different model predictions for the alternatives considered? A case in point: the range of values for habitat vs. coho smolt production observed throughout their distribution is highly variable both geographically and from year to year. If geometric mean values alone were used as model input values it might result in erroneous assumptions of key relationships and ecological outcomes. Mean values alone do not adequately account for natural variability in the expression of key metrics, and may introduce error in to model predictions that simply are not realistic or conservative from a resource protection standpoint. Using alternative statistical tools, such as the coefficient of variation as alternatives for these metrics, would add to a sense of the statistical rigor of the model predictions (see Conquest 1983).

3. As described in the DEIS, and elaborated on above, future provisions for monitoring and adaptive management appear wholly inadequate to justify blind application of these models.

5 STATEMENT OF QUALIFICATIONS

Dr. Neil Lassettre has a background in aquatic and riparian ecology and fluvial geomorphology (See Appendix for CV). Much of Dr. Lassettre's work has focused on large woody debris (LWD) dynamics along the North and Central Coast of California, and more recently has focused on Central Oregon and a large gravel-bedded river in southeastern France. Additionally, Dr. Lassettre conducted a comprehensive literature review on the ecological and geomorphic influence of woody debris in rivers and streams for the California Department of Forestry and Fire Protection.

Contact Neil Lassettre, Ph.D., Ecologist/Geomorphologist:
neil@stillwatersci.com
(510) 848-8098 ext. 148

With a background in aquatic and terrestrial ecology (see Appendix for CV), Stephen Ralph has over 29 years of experience in forestry and aquatic habitat assessments throughout Washington, Oregon, Alaska, and Idaho. While with the University of Washington's Center for Streamside Studies, Mr. Ralph was program manager for a statewide evaluation of the effects of industrial scale forestry on aquatic habitats. For 10 years Mr. Ralph was the regional salmon ecologist for the Environmental Protection Agency Region 10. He has co-authored numerous articles on aquatic habitat assessments, water quality metrics, the design of large scale aquatic monitoring, and adaptive management.

Contact Stephen Ralph, M.S., Senior Aquatic Ecologist:
ralph@stillwatersci.com
(206) 632-0107

6 LITERATURE CITED

Beechie, T. J. and T. H. Sibley. 1997. Relationships between channel characteristics, woody debris and fish habitat in northwestern Washington streams. Transactions of the American Fisheries Society 126:217-229.

Bilby, R. E. and J. W. Ward. 1991. Characteristics and function of large woody debris in streams draining old growth, clear-cut, and second-growth forests in southwestern Washington. Canadian Journal of Fisheries and Aquatic Sciences 48: 2499-2508.

Braudrick, C. A. and G. E. Grant. 2000. When do logs move in rivers? Water Resources Research 36: 571-584.

Buffingon, J.M, T.E. Lisle, and R.D. Woodsmith. 2002. Controls on grain size and occurrence of pools in coarse grained forest rivers. River Research and Applications 18: 507-531.

Buffington, J.M., R.D. Woodsmith, D.B. Booth, and D.R. Montgomery. 2003. Fluvial Processes in Puget Sound Rivers. In: Restoration of Puget Sound Rivers, Montgomery, D.R., S. Bolton, D.B. Booth, and L. Wall, editors. Center for Water and Watershed Studies, University of Washington Press, Seattle, WA, USA.

Conquest, L.L. 1983. Assessing the statistical effectiveness of ecological experiments: utility of the coefficient of variation. Intern. J. Environmental Studies 20: 209-221.

Fox, M., S. Bolton, L. Conquest. 2003. Reference Conditions for Instream Wood in Western Washington. In: Restoration of Puget Sound Rivers, Montgomery, D.R., S. Bolton, D.B. Booth, and L. Wall, editors. Center for Water and Watershed Studies, University of Washington Press, Seattle, WA, USA.

Hick, B. J. and J. D. Hall. 2003. Rock type and channel gradient structure salmonid populations in the Oregon Coast Range. Transactions of the American Fisheries Society 132:468-482.

May, C.L. and R.E. Gresswell. 2003a. Large wood recruitment and redistribution in headwater streams of the Oregon Coast Range, U.S.A. Can. J. of Forest Res. 33: 1352-1362.

May, C. L., and R. E. Gresswell. 2003b. Processes and rates of sediment and wood accumulation in headwater streams of the Oregon Coast Range, USA. Earth Surface Processes and Landforms 28: 409-424.

McDade, M. H., F. J. Swanson, W. A. McKee, J. F. Franklin, and J. Van Sickle. 1990. Source distances for coarse woody debris entering small streams in western Oregon and Washington [USA]. Canadian Journal of Forest Research 20: 326-330.

Murphy, M. L., and K. V. Koski. 1989. Input and depletion of woody debris in Alaska streams and implications for streamside management. North American Journal of Fisheries Management 9: 427-436.

Appendix

Stillwater Sciences

Neil Lassettre, PhD

Ecologist/Geomorphologist

EDUCATION

- **Ph.D.,** *Environmental Planning*, University of California, Berkeley, 2003
- **M.S.,** *Environmental Studies*, San Jose State University, 1997
- **B.A.,** *Biology*, University of California, Santa Cruz, 1993

AREAS OF EXPERTISE

- Aquatic ecology
- Fluvial geomorphology
- Large woody debris dynamics
- Watershed planning

PROFESSIONAL AFFILIATIONS

- American Geophysical Union
- Society for Ecological Restoration

AWARDS

- Fulbright Fellowship 2003-2004, Centre National de la Recherche Scientifique, UMR 5600, Lyon, France

SELECTED PUBLICATIONS

- Lassettre, N.S., H. Piegay, S. DuFour, A.J. Rollet. 2007. Temporal changes of large woody debris distribution and abundance in a large river, the Ain River, France (Accepted to Earth Surface Processes and Landforms).
- Lassettre, N.S. and G.M. Kondolf. 2007. The wood-passing approach to managing large woody debris in rivers and streams (In preparation).
- Lassettre, N.S., J.K. Wooster, and J.D. Stallman. 2007. Large woody debris dynamics in a large basin bisected by geomorphic terrains with contrasting process rates (In preparation).

OVERVIEW

Dr. Lassettre has a background in aquatic and riparian ecology, and fluvial geomorphology. He has experience in river restoration, watershed scale planning, and anadromous fisheries habitat restoration, and has worked on projects throughout northern California, and more recently in Oregon and southeastern France. Dr. Lassettre was recently project manager on a Limiting Factors Analysis (LFA) within the Gualala River basin that assessed the current conditions of the Buckeye Creek and Wheatfield Fork sub-basins and identified factors limiting the production of steelhead (*Oncorhynchus mykiss*). The analysis focused on geomorphic processes influencing the creation and maintenance of life-stage specific habitat and found winter rearing habitat as the primary factor limiting steelhead production. Dr. Lassettre's previous work has also focused on large woody debris (LWD) dynamics along the California Central Coast (Soquel Creek, Santa Cruz County) and within a large gravel-bedded river in southeastern France (the Ain River, and tributary to the Rhone). His work in Soquel Creek focused on the basin-scale input, storage, and transport of LWD, evaluating the effect of infrastructure and flood control related management on LWD processes. In southeastern France, he examined the temporal changes in LWD dynamics along a 36 km reach and three individual meanders over several decades (using aerial photography and prior surveys) in response to land use changes, forest succession, and flooding. Additionally, Dr. Lassettre has evaluated the effectiveness of instream structures intended to create habitat for steelhead, and conducted a comprehensive literature review on the ecological and geomorphic influence of woody debris in rivers and streams for the California Department of Forestry and Fire Protection. .

PROJECT EXPERIENCE

Preservation Ranch Limiting Factors Analysis *(Client: Buckeye Ranch LLC)*: Project Manager and lead geomorphologist on a project to identify physical factors limiting the production of Northern California Coast steelhead within Buckeye Creek and Wheatfield Fork sub-basins of the Gualala River. The project identified limiting factors based upon the results of focused studies targeted on the linkage between physical processes and aquatic habitat, and recommended future studies to reduce uncertainty related to steelhead population dynamics. Unique research within the project explored the usage of cobble/boulder substrates as winter (hydraulic) and summer (thermal) refugia by steelhead.

- Lassettre, N.S. and G.M. Kondolf. 2003. Process-based woody material management of the basin scale: Soquel Creek, California. Report presented to the California Department of Forestry and Fire Protection, and Soquel Demonstration State Forest, Soquel, CA. 150pp.
- Lassettre, N.S. and R.R Harris. 2000. The geomorphic and ecological significance of large woody debris in rivers and streams. Report prepared for the University of California Center for Forestry at UC Berkeley and submitted to California Department of Forestry, Fire Resource and Assessment Program (FRAP). 68pp.
- Kondolf G.M., M. Smeltzer, J.G. Williams, and N. Lassettre. 1999. Geomorphic Study of Mill Creek, Tehama County, California. Report submitted to US Fish and Wildlife Service.
- Smeltzer, M. and N. Lassettre. 1999. Use of Geomorphic Analysis to Characterize Pre-dam Flow Regimes in Ecologically Meaningful Terms. USDA Forest Service Stream Systems Technology Center, Stream Notes July: 5-7.

TEACHING EXPERIENCE

- Graduate Student Instructor, University of California, Berkeley, Fall 1998: Introduction to Environmental Sciences
- Teaching Assistant, University of California, Berkeley, Spring 1999: Hydrology for Planners
- Guest Lecturer, University of California, Berkeley, Restoration of Rivers and Streams: 1998-2001

Large Woody Debris Modeling within Salmon and Clearwater Basins, Idaho *(Client: National Marine Fisheries Service, Idaho State Habitat Office, Boise, ID)*: Critically review sections of Idaho Forest Program Document relating to large woody debris (LWD) recruitment and storage within Salmon and Clearwater basins. Provide technical assistance to interpret results from LWD growth and yield models, evaluate efficacy of predictions, and suggest revised assumptions and parameter inputs for future modeling exercises.

Upper Penitencia Creek Sediment Source Assessment *(Client: Santa Clara Valley Urban Runoff Pollution Prevention Program)*: Project Manager on investigation of sediment sources within the Upper Penitencia Creek basin (Santa Clara County, CA) focused on addressing management questions related to sediment production, identifying priority concerns and locations for controlling anthropogenic sediment supply and deposition, and developing and prioritizing recommendations for erosion and sedimentation management actions.

Upper Penitencia Creek Limiting Factors Analysis *(Client: Santa Clara Valley Urban Runoff Pollution Prevention Program)*: Lead geomorphologist on a basin-scale limiting factors analysis for federally threatened Central California Coast steelhead as part of a regional effort to identify anthropogenic impacts and prepare management recommendations to enhance aquatic resources. Responsibilities include a geomorphic characterization of current and historic basin conditions identifying potential anthropogenic influences on sediment dynamics, development and testing of hypotheses, implementation of focused studies on spawning gravel permeability and pool filling, data analysis, and technical report preparation.

Upper McKenzie River Basin Large Woody Debris Dynamics *(Client: Eugene Water and Electric Board)*: Task lead in analyzing and describing large woody debris dynamics in the Upper McKenzie River Basin, Oregon as part of the Carmen-Smith Hydroelectric Project (FERC No. 2242) license application. The technical report describes the characteristics of LWD, and uses a wood budget and conceptual models based on geomorphic terrain and stream network position to describe effects of the Project, other land uses, and natural processes on recruitment, storage, and transport of wood.

Mendocino Redwood Company EIS/EIR *(Client: Mendocino Redwood Company)*: Lead geomorphologist analyzing current geologic and geomorphic setting and impact analysis of proposed harvest scenarios within Mendocino and Sonoma County forestlands held by Mendocino Redwood Company.

Environmental Water Program *(Client: California Bay-Delta Authority)*: The purpose of the Environmental Water Program is to acquire flows from willing sellers on a set of priority basins within the Central Valley with the goal of providing a measurable environmental benefit to native aquatic and terrestrial species. Project Manager and technical lead in developing testable scientific hypotheses and experiment-based monitoring programs to measure geomorphic changes that result from planned flow acquisitions. Flows are intended to provide proven restoration benefits (with a focus on fisheries), and hypotheses and monitoring are subject to academic and agency peer-review, and adhere to adaptive management principles.

Chili Bar Reservoir Sedimentation Technical Report (*Client: Pacific Gas and Electric)*: Estimated deposition of fine and coarse sediment within Pacific Gas and Electric's Chili Bar Reservoir for FERC project no. 2155 through field surveys of sediment characteristics and empirical relationships of dam trap efficiency. The report estimated the trap efficiency of the dam and the volume of coarse and fine sediment stored the reservoir since the start of the Project (1964).

Stephen C. Ralph
Senior Aquatic Ecologist

Stillwater Sciences

EDUCATION

- **M.S.,** Wildlife Biology, College of Forest Resources, University of Washington, Seattle WA, 1978
- **B.S.,** Biology, George Mason University, Fairfax VA, 1973

AREAS OF EXPERTISE

- Hydroelectric Project Experience
- Water Rights and Instream Flow Studies & Negotiations
- Salmon Conservation
- Water Quality, Monitoring, and Habitat Criteria
- Adaptive management of natural resource decision making
- Watershed assessment and restoration

SELECTED PUBLICATIONS

- Ralph, S. C. and G. C. Poole. 2002. Putting monitoring first: Designing accountable ecosystem restoration and management plans. Montgomery D.R., S. Bolton and D. B. Booth (eds.) *Restoration of Puget Sound Rivers*. University of Washington Press, Seattle, WA.

- Bauer, S. and S. Ralph. 2001. Strengthening the use of aquatic habitat indicators in Clean Water Act Programs. *Fisheries* 26:14-25.

- Conquest, L. L. and S. C. Ralph. 1998. Design considerations for large scale aquatic monitoring efforts. In: Naiman, R. J., R. E. Bilby (eds.), *River Ecology and Management: Lessons from the Pacific Coastal Ecoregion.* Springer-Verlag, New York.

- Frissell, C. A. and S. C. Ralph. 1998. Stream and Watershed Restoration. *In:* Naiman, R. J., R. E. Bilby (eds.), *River Ecology and Management: Lessons from the Pacific Coastal Ecoregion.* Springer-Verlag, New York.

OVERVIEW

Mr. Ralph has over twenty-five years experience in natural resource management in Washington State, concentrating on the effects of water and land use on freshwater and marine ecosystems. Prior to joining Stillwater Sciences to head the Seattle Office in 2004, he worked for a variety of federal, state, tribal, city, and county governments engaged in resolving natural resource management decisions with environmental protection. Mr. Ralph has been involved in watershed assessments, design and implementation of monitoring programs at multiple scales, and has co-authored several publications on monitoring and adaptive management. His expertise includes hydropower relicensing, timberland management for protection of fish and wildlife, water rights and hydrology.

PROJECT EXPERIENCE

***Hydropower Licensing & Re-licensing*:** Working initially as an avian ecologist, Mr. Ralph shifted his emphasis to aquatic ecology to focus on the issues surrounding salmon conservation after joining Seattle City Light's environmental office in the early 1980s. While with City Light, he was involved in all of the City's major and minor hydropower licensing and relicensing issues of the day. He was environmental project manager for the proposed High Ross project, and among other tasks, was chairman of the citizens advisory committee formed to hear and respond to citizen concerns about the project. High Ross was a proposal to increase the height of the existing Ross Dam by 125 feet, creating more generating capacity, but flooding an additional 4,000 acres of shoreline and tributary habitats. Mr. Ralph was the principal analyst for reviewing over 50 proposed small hydropower projects, some initiated by City Light but most proposed by third parties interested in power sales contracts with the City. He evaluated the environmental effects of each project in light of their associated fish and wildlife resources, and sensitivities of tribes having a priority interest. He also was involved in reconciling the mitigation obligations associated with the Boundary Project, and made many field visits to the site in 1983 and 1984. On behalf of the Elwha Tribe, and as part of the licensing proceedings, Mr. Ralph co-authored the 1986 motion to FERC for removal of the two dams on the Elwha River in order to restore the river and its native salmon runs to its historical condition.

***Water Quality*:** While representing the Treaty Tribes, Mr. Ralph served as an expert witness for the State of Washington in their dispute before the Water Pollution Control Hearings Board involving the State assertion of 401 Water Quality Certification in setting instream flows for a pending FERC license application for the Elkhorn Hydroelectric Project on the Dosewallips River. This dispute was eventually settled in the U.S. Supreme Court in their ruling on Jefferson Co. PUD No. 1 vs. Washington.

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For many years, Mr. Ralph has worked on reviews of federal, state and private forestry practices, and refinement of the regulatory schemes in pursuit of appropriate protection of habitats for native salmon and trout. Prior to joining Stillwater Sciences, Mr. Ralph worked for the U.S. Environmental Protection Agency as their regional salmon ecologist concentrating on efforts and policy development to more directly affect salmon conservation and restoration efforts. He is intimately familiar with requirements of the National Environmental Policy Act, Endangered Species Act, and the Clean Water Act. His responsibilities at the EPA included providing technical and policy support within the EPA, and working with sister federal agencies on development of regional salmon policies, habitat protection and restoration, water quality standards, TMDLs (total maximum daily loads), and habitat conservation plans. Mr. Ralph has co-authored numerous publications regarding aquatic habitat protection, watershed restoration, and broad-scale monitoring design.

***Watershed Processes and Aquatic Habitat* Monitoring:** Mr. Ralph has developed considerable experience in watershed assessment and understanding the role of habitats in limiting salmon populations. This experience includes development of comprehensive monitoring programs for assessment of instream aquatic habitats, including experience in methods, evaluation, and interpretation of monitoring data. Mr. Ralph participated on the salmon technical recovery teams for the Stillaguamish and Snohomish basin working groups, developing both a watershed assessment and identification of priorities for restoration actions.

***Habitat Conservation* Planning:** Mr. Ralph has been involved with several high profile Habitat Conservation Plans. One of these focused on a quarter million acres of private forest land in which the applicant sought both ESA coverage as well as compliance certification with the Clean Water Act. Mr. Ralph served as the principal technical negotiator for EPA during the 5 years it took to reach agreement with Simpson Timber Co. Today, it remains the only successful example of the integration of the ESA and the CWA under the Habitat Conservation Plan process.

Since joining Stillwater Sciences, Mr. Ralph has provided a variety of consultant services to Seattle Public Utilities. He was retained by the Utility and Washington Trout to serve as an independent science advisor for the two parties as they jointly developed a series of three public workshops to explore the role of adaptive management in resolving natural resource issues associated with the Cedar River Habitat Conservation Plan. Subsequently, he has been retained to help develop a status and trends monitoring program for the Cedar River Watershed, done as part of the overall commitments the City made in their HCP.