Comment on the Environmental Effects on Bull Trout (*Salvelinus confluentus*)

as Considered in the

Supplemental Draft Environmental Impact Statement for the Montanore Project

Kootenai National Forest and
Montana Department of Environmental Quality

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INTRODUCTION

In this comment letter I critically evaluate the information presented and implications of the Montanore Supplemental Draft Environmental Impact Statement (SDEIS) pertaining to conservation and recovery of the bull trout (*Salvelinus confluentus*), a char native to the project area that listed as a threatened species under the US Endangered Species Act. The Montanore project, in combination with the proposed Rock Creek mine, would adversely impact significant areas of bull trout critical habitat, and the populations of fish supported therein, in key tributaries of the Lower Clark Fork and Kootenai River systems in northwest Montana.

REVIEWER'S QUALIFICATIONS

I am currently employed as a private consultant and as Senior Staff Scientist with the Pacific Rivers Council. I hold Ph.D. and M.S. degrees in Fisheries Science from Oregon State University, I have previously held research faculty posts at Oregon State and The University of Montana's Flathead Lake Biological Station. My research and the work of my students concerns the cumulative effects of human actions on land and water on the ecology of streams and rivers, freshwater ecosystem restoration, role of groundwater in shaping stream ecosystems, climate variability, and the conservation biology of fishes and amphibians. Much of my work bridges scientific and policy arenas; I have led or participated many technical groups of scientists working to inform key policy decisions with the best available scientific knowledge. In the 1990s I served as a member of the Montana Bull Trout Scientific Group, a panel of scientists engaged to inform Montana's interagency bull trout restoration planning, and my research includes studies of bull trout ecology and landscape-level population dynamics. My qualifications are summarized in the attached curriculum vitae (Appendix A).

DOCUMENTS REVIEWED

In preparing this comment letter I primary evaluated relevant sections of the SDEIS (2010) and the DEIS (2009) for the Montanore Project. I also reviewed supporting information, in particular Geomatrix (2011), and additional relevant literature as cited, including published papers and reports on bull trout status and ecology. There is relatively little literature that directly relates bull trout to underground mine impacts, though there is relevant research that ties bull trout ecology to groundwater influence in streams. While this mine project (in particular the SDEIS Alternative 3) makes some effort to reduce or otherwise mitigate some of the adverse effects of surface disturbance, the mine is projected to impact groundwater systems on a large scale.

CONSERVATION IMPORTANCE OF STREAMS AT RISK IN MONTANORE

Bull trout are dependent on groundwater (whether of deep bedrock origin or retained water in shallow alluvial aquifers) to moderate stream temperatures and keep rearing, foraging, and egg incubation habitat ice free in winter, and to buffer streams against low flows and high thermal extremes that could restrict rearing, foraging, and migration space in summer and fall. Throughout their range there is a strong association of robust bull trout populations with streams that show a groundwater-influenced hydrologic signature (Baxter and McPhail 1999, Baxter et al. 2000, Baxter and Hauer 2000). Low road density and a limited extent of disturbance of land and water in the contributing catchment is another signal feature of productive bull trout systems (Baxter et al. 2000, Dunham and Rieman 1999).

East Fork Bull River from its confluence with the Bull River upstream 12.8 km (8.0 mi) and the South Fork Bull River from the confluence upstream 3.6 km (2.2 mi) is designated critical habitat for bull trout, supporting spawning and rearing (USFWS 2010c). AVISTA Corp. (2011) conducts bull trout redd counts in East Fork Bull River every fall, which have ranged over the last decade from 7 to 19 redds--the highest counts of any lower Clark Fork tributary. East Fork Bull River supports good densities of juvenile bull trout, but is subject to incipient invasion form downstream by introduced fish species that can displace or interbreed with bull trout and native westslope cutthroat trout, which has lead to an experimental nonnative fish suppression effort (Moran and Storaasli 2009). The author inspected East Fork Bull River in the field on December 5, 2011 and noted that the stream provided superb bull trout winter rearing and spawning habitat. During sustained subfreezing conditions when nearby streams held extensive ice cover, this stream remained virtually ice-free, testament to a strong influence of groundwater that is strongly characteristic of high-quality bull trout habitat (see citations above).

East Fork Bull River's exceptional degree of ecological integrity and its signature groundwater-influenced hydrology elevate it to globally significant status as a refuge habitat for bull trout. The importance of East Fork Bull River as a conservation habitat is further enhanced by a genetically pure, non-hybridized population of native westslope cutthroat trout (Moran and Storaasli 2009).

Rock Creek and *East Fork Rock Creek* from its confluence with Cabinet Gorge Reservoir upstream 13.5 km (8.4 mi) to a natural barrier provides spawning and rearing habitat (USFWS 2010c). The designated bull trout critical habitat in Rock Creek is listed as impaired on Montana's 303(d) list due to anthropogenic substrate alterations, with the probable source of as silvicultural activities (SDEIS p. 133). In most years, habitat is adversely affected to some degree due to the lack of surface water connectivity in the lower 3.4 miles of Rock Creek during summer and fall base flows, preventing upstream movement of adult migratory bull trout. While the mainstem of Rock Creek is heavily affected by bedload accumulation and continuing sediment inputs from roads and supports only intermittent surface flow at baseflow season in dry water years, the East Fork of Rock Creek at present supports sustained, cool streamflows and complex, less severely impacted riparian and instream habitat that harbors resident bull trout in good numbers and supports spawning of migratory bull trout in some years. East

Fork Rock Creek remains inaccessible to bull trout spawners in years with low summer and fall flows. East Fork Rock Creek supports high densities of juvenile bull trout, and nonnative species that can displace or interbreed with bull trout appear to be absent (Moran no date). Rock Creek bull trout are genetically distinguishable from bull trout born in other Clark Fork basin tributaries (Moran no date, AVISTA Corp. unpublished data). Field inspection by the author on 5 December 2011, during a spell of subfreezing weather in which many nearby streams developed extensive ice cover, showed that the lower miles of East Fork Rock Creek remained largely ice-free, indicative of a strong groundwater influence on water temperature and hydrology, highly favorable to bull trout survival and reproduction. The value of East Fork Rock Creek value as a conservation habitat is further enhanced by it being home (in its middle and lower reaches) to a genetically pure, non-hybridized population of native westslope cutthroat trout (Moran, no date).

Libby Creek, tributary to the Kootenai River, supports migratory or resident (nonmigratory) forms of bull trout in main Libby Creek and its tributaries Ramsay, Poorman, and Bear Creeks. The uppermost reach of Libby Creek, roughly upstream 5.7 km (3.6 mi) from the confluence of Howard Creek and Bear Creek, from its confluence with Libby Creek upstream 13.2 km (8.2 mi) to its headwaters provide known spawning and rearing habitat and are designated critical habitat for bull trout (USFWS 2010a, 2010b). However, these streams have been heavily impaired by historical mining, logging and existing roads, compounded by wildfire (SDEIS pp. 132-133). Although the Libby Creek system is not thoroughly or regularly surveyed for bull trout distribution and abundance, due to historical impact and resulting generally poor habitat conditions, it is not considered as important a contributor to Kootenai River migratory bull trout as some other Kootenai River tributaries. Impact from Montanore project would primarily risk impeding future recovery of bull trout in Libby Creek system. Most segments of designated critical habitat on Libby Creek are on Montana's 303(d) list of water quality-impaired streams with impairment limiting their capacity to support coldwater fisheries (SDEIS p. 132). Libby Creek and its tributaries also support genetically pure populations of native redband rainbow trout.

The East Fork of Bull River, the East Fork of Rock Creek, and Libby Creek are all recognized in the SDEIS as subject to adverse alteration of streamflows from Montanaore Mine (in comobination with nearby Rock Creek Mine) development. In addition, Libby Creek could be further impacted by sediment generated from surface developments including heavily used roads, service facilities, a large waste impoundment and water treatment facility, diversion of flows away from filled natural channels and wetlands, possible contaminated mine runoff, and a new power transmission line. All three streams could be further impacted by possible aggressive mitigation measures identified in the SDEIS, which could include instream structural manipulations supposed to compensate for flow losses.

In addition, small bull trout populations occur in segments of Fisher River, West Fisher River, and Standard Creek that would be impacted by the proposed transmission line alternative corridor (SDEIS p. 132, and Fig. 55). Transmission corridors impact streams primarily by permanent clearance of overstory vegetation and loss of shade at stream crossings, and by sedimentation from service roads that are constructed and maintained to low use standards and are sited to service the line infrastructure, not to minimize potential erosion and sediment delivery.

CONSEQUENCES FOR BULL TROUT RECOVERY OPTIONS

It is extremely difficult to conceive how permanent or sustained harm to East Fork Bull River and East Fork Rock Creek could not materially and permanently impair the recovery of bull trout. East Fork Rock Creek and particularly East Fork Bull River are two primary tributaries supporting recovery of migratory bull trout in the US Fish and Wildlife Service's Lower Clark Fork River Critical Habitat Subunit (USFWS 2010c), and the only critical habitat tributaries designated in the Cabinet Reservoir reach. In its 2006 Rock Creek Biological Opinion, the Fish and Wildlife Service found that harm to bull trout in Rock Creek did not jeopardize recovery because productive habitat was present elsewhere in the unit—most notably, in East Fork Bull River (USFWS 2006, p.B-54 and B-58). The Montanore project now threatens further impact in Rock Creek and essentially permanent harm to East Fork Bull River.

Other tributaries accessible to bull trout in the Lower Clark Fork are limited by natural migration barriers (Vermillion River, Graves Creek) and heavily, if not permanently impaired from past alterations and existing developments. Prospect Creek, for example, sees ongoing impact throughout its length from forest roads, a highway, and a transmission line corridor, and is further limited by low base flows, high sediment load, The resulting intermittency of flows and channel instability, hinder bull trout migration and reproduction, and elevated summer water temperature limits rearing. Hence, prospects are poor to nonexistent for reliable off-site mitigation of harm to East Fork Bull River East Fork Rock Creek by the Montanore project.

The Kootenai River Critical Habitat Subunit (USFWS 201c) contains several tributaries that are presently more productive for bull trout than are Libby Creek and Fisher River, and less encumbered by infrastructure developments, hence there might potentially be more opportunity to offset harm to Libby Creek by improved protection and restoration of other Kootenai River tributaries. Nevertheless, potential catastrophic loss of bull trout in Libby Creek stemming from the Montanaore project, e.g., from catastrophic failure of the tailings impoundment (SDEIS p. 136-137), would materially diminish recovery prospects in the Kootenai unit by reducing, perhaps permanently, the spatial range and redundancy of bull trout subpopulations.

PROJECTED IMPACT OF MONTANORE PROJECT ON GROUNDWATER AND STREAMFLOWS

The most widespread and pervasive impact of development of the Montanore project would be its large-scale alteration of a deep montane groundwater system, and the effect of these groundwater changes on surface waters in lakes and streams. The SDEIS reports the results of modeled hydrologic change under the preferred Alternative 3, but states these results would be unchanged for Alternatives 2 and 4 for East Fork Bull River and East Fork Rock Creek, the primary streams of concern for bull trout recovery. Effects on groundwater and stream flow are dynamic, and would span two major phases. The first phase (aggregated Evaluation, Construction, and Operations Phases) would involve dewatering of the rock masses surrounding the ore body and drawdown of the water table to allow mining operations. The operating life of the mine is expected to span about 25 years. The second phase initiates at mine closure, and during this period water groundwater recovers slowly back into to mine void. As a result of this deformation of the deep groundwater system, the SDEIS (p.S-24) predicts the reduction in baseflow in East Fork Rock Creek, Rock Creek, East Fork Bull River (see Figure 71 from SDEIS)

Stream flow reductions would be the greatest about 16 to 30 years after mining ceased. As groundwater levels began to recover after mine closure, the losses of stream baseflow would diminish somewhat, reaching steady state conditions about 1,200 to 1,300 years after mining ended. Groundwater levels would never recover to pre-mining levels, and the baseflow East Fork Rock Creek, Rock Creek, and in East Fork Bull River also would be reduced. The SDEIS also modeled mitigation measures that the authors believe could ameliorate some of the permanent flow reductions on the East Fork of Rock Creek (below Rock Lake) and East Fork Bull River. Libby Creek would show a different flow response to the project; during dewatering of the ore body, Libby Creek receives discharged water and would see increases in streamflow. However, in the much longer time frame during project operations and after closure, baseflow in Libby creek would also be diminished from pre-project levels. Table 2 from Geomatrix (2010) summarizes the streamflow changes projected from modeling, both without and with mitigation measures in the mine void. Note that modeled change in baseflow approaches 100 percent in headwater reaches above bull trout range, and is substantially attenuated, but still significant downstream.

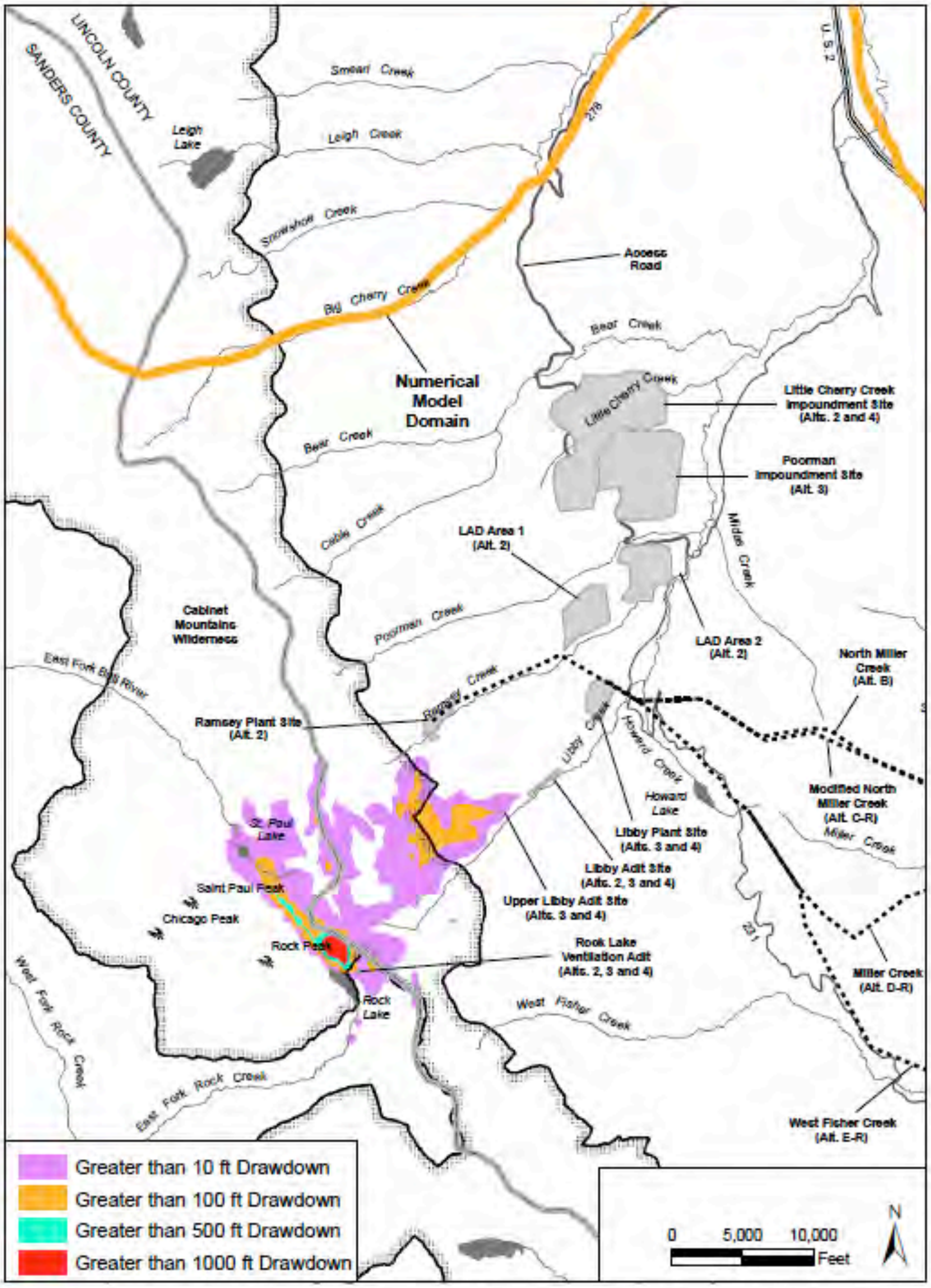

Figure 71. Predicted Area of Groundwater Drawdown Post-Closure Phase (Maximum Baseflow Change)

SDEIS (2011) Fig. 71

Table 2. Predicted Changes to Baseflow from Standard and Mitigation Model Runs Post-Mining

	Pre-Mine	STANDARD MODEL RUN									MITIGATION MODEL RUN (bulk heads and grouting)								
	Base-flow (cfs)	Simulated baseflow (cfs)			Change in baseflow (cfs)			Percent change in baseflow			Simulated baseflow (cfs)			Change in baseflow (cfs)			Percent change in baseflow		
	0 yr	38 yrs*	25 yrs	1172 yrs	38 yrs*	25 yrs	1172 yrs	38 yrs*	25 yrs	1172 yrs	38 yrs	25 yrs*	1322 yrs	38 yrs	25 yrs*	1322 yrs	38 yrs	25 yrs*	1322 yrs
E.Fk. Bull River at Mouth	11.34	11.08	11.22	11.39	-0.26	-0.12	+0.05	-2.3%	-1.1%	+0.4%	11.09	11.25	11.33	-0.25	-0.09	-0.01	-2.2%	-0.8%	-0.1%
E.Fk. Bull River at Wilderness Bndry	4.36	3.98	4.20	4.35	-0.38	-0.16	-0.01	-8.7%	-3.7%	-0.2%	3.99	4.21	4.35	-0.37	-0.15	-0.01	-8.5%	-3.4%	-0.2%
E.Fk. Bull River at EFBR-300	0.29	0.02	0.17	0.27	-0.27	-0.12	-0.02	-93%	-41.4%	-7%	0.03	0.18	0.27	-0.26	-0.11	-0.02	-90%	-37%	-7%
Rock Creek at Mouth	7.70	7.05	7.51	7.67	-0.65	-0.19	-0.03	-8.4%	-2.5%	-0.4%	7.55	7.54	7.71	-0.15	-0.16	+0.01	-1.9%	-2.1%	+0.1%
Rock Creek (E. Fork) below Rock Lake at Wilderness Bndry	0.29	-0.15	0.11	0.26	-0.44	-0.18	-0.03	>100%[1]	-62.1%	-10%	0.12	0.14	0.29	-0.17	-0.15	0.00	-59%	-51%	0%
E.Fk. Rock Creek at EFRC-50 (above lake)	0.04	0.00	0.00	0.02	-0.04	-0.04	-0.02	-100%	-100%	-50%	0.00	0.00	0.03	-0.04	-0.04	-0.01	-100%	-100%	-25%
Libby Creek at Mouth	19.83	19.72	19.58	19.83	-0.11	-0.25	0.00	-0.6%	-1.3%	0%	19.73	19.58	19.83	-0.10	-0.25	0.00	-0.5%	-1.3%	0%
Libby Creek at LB-300	1.22	1.10	1.03	1.22	-0.12	-0.19	0.00	-10.2%	-15.6%	0%	1.10	1.04	1.22	-0.12	-0.18	0.00	-9.8%	-14.8%	0%
Libby Creek at Wilderness Bndry	0.54	0.47	0.44	0.54	-0.07	-0.10	0.00	-12.2%	-18.5%	0%	0.48	0.44	0.54	-0.06	-0.10	0.00	-11.1%	-18.5%	0%
Libby Creek at LB-50 (inside Wilderness Bndry)	0.28	0.24	0.24	0.28	-0.04	-0.04	0.00	-13.8%	-14.3%	0%	0.25	0.25	0.28	-0.03	-0.03	0.00	-10.7%	-10.7%	0%
Ramsey Creek at Wilderness Bndry	0.38	0.36	0.35	0.38	-0.01	-0.03	0.00	-3.8%	-6.7%	0%	0.36	0.35	0.38	-0.02	-0.02	0.00	-4.0%	-6.7%	0%
Poorman Creek at Wilderness Bndry	0.12	0.12	0.12	0.12	0.00	0.00	0.00	-3.7%	0.0%	0%	0.12	0.12	0.12	0.00	0.00	0.00	0.0%	0%	0%

Note: cfs = cubic feet per second. Shaded cells show >20% change predicted in baseflow. * Time period with an asterisk is when maximum groundwater drawdown occurs over model Block 18.

[1] Percent change greater than 100% for East Fork Rock Creek below Rock Lake at Wilderness Boundary indicates there is a net flow of lake water (recharge) contributing to groundwater at this site (assuming lake is well-connected to groundwater system).

Geomatrix (2010) Appendix G

Note that Geomatrix (2010) in Appendix H, developed at the request of the lead agencies, simulates the bedrock porosity around fault zones differently. In model runs approximately doubled baseflow losses in East Fork Bull River and East Fork Rock Creek (See Geomatrix Appendix H Table 5 below).

Table 5. Predicted Impacts to Streams from Calibrated and Adjusted Model Parameterizations

Drainage	Calibrated Model			Adjusted Parameterization		
	Modeled Groundwater Contributing to Surface Water		Modeled Baseflow Change	Modeled Groundwater Contributing to Surface Water		Modeled Baseflow Change
	Pre-Exploration (ft³/sec)	Stage 3 (ft³/sec)	(ft³/sec)	Pre-Exploration (ft³/sec)	Stage 3 (ft³/sec)	(ft³/sec)
East Fork Bull River	11.34	11.25	-0.09	11.36	11.17	-0.19
East Fork Bull River at Wilderness Boundary	4.36	4.29	-0.07	4.37	4.22	-0.15
Rock Creek	7.70	7.64	-0.06	7.70	7.57	-0.13
Rock Creek at Wilderness Boundary (below lake)	0.29	0.23	-0.06	0.29	0.16	-0.13
Libby Creek	19.83	19.56	-0.27	19.87	19.48	-0.4
Libby Creek at Wilderness boundary	0.54	0.43	-0.12	0.56	0.39	-0.17
Ramsey Creek at Wilderness Boundary	0.375	0.34	-0.04	0.38	0.34	-0.04
Poorman Creek At Wilderness Boundary	0.12	0.11	-0.01	0.12	0.11	-0.01

Geomatrix (2010) Appendix H

The SEIS (Pp. 229-230) summarizes information from Geomatrix (2010) to explain what is known about the connectivity of the deep groundwater system and the streams of concern as follows:

> The observation that streams become perennial and bedrock springs occur consistently at an elevation of about 5,400 to 5,600 feet indicates that a water table has developed within interconnected fractures and the water table appears to intersect the ground surface at an elevation of about 5,400 to 5,600 feet. The water table most likely slopes upward beneath areas above 5,600 feet, subparallel to topography and may be 500 feet or more deep beneath the highest areas in the range (Figure 68). Springs exist above and below 5,400 to 5,600 feet elevation range. Those springs above this elevation range are part of the shallow flow path and those below this elevation range are connected to both flow systems. Below an elevation of between 5,400 and 5,600 feet, there are two distinct groundwater flow paths due to very different hydraulic conductivities, but the two flow paths are hydraulically connected. Shallow groundwater flows through shallow weathered and fractured bedrock and surficial material where present, and deeper groundwater flows through fractures in unweathered bedrock…
> …These observations are consistent with the conceptual model that

deeper bedrock groundwater is connected to shallow groundwater and surface water at elevations below about 5,600 feet.

Projected changes in the large-scale water table are illustrated in Fig. 2, excerpted from Geomatrix (2010).

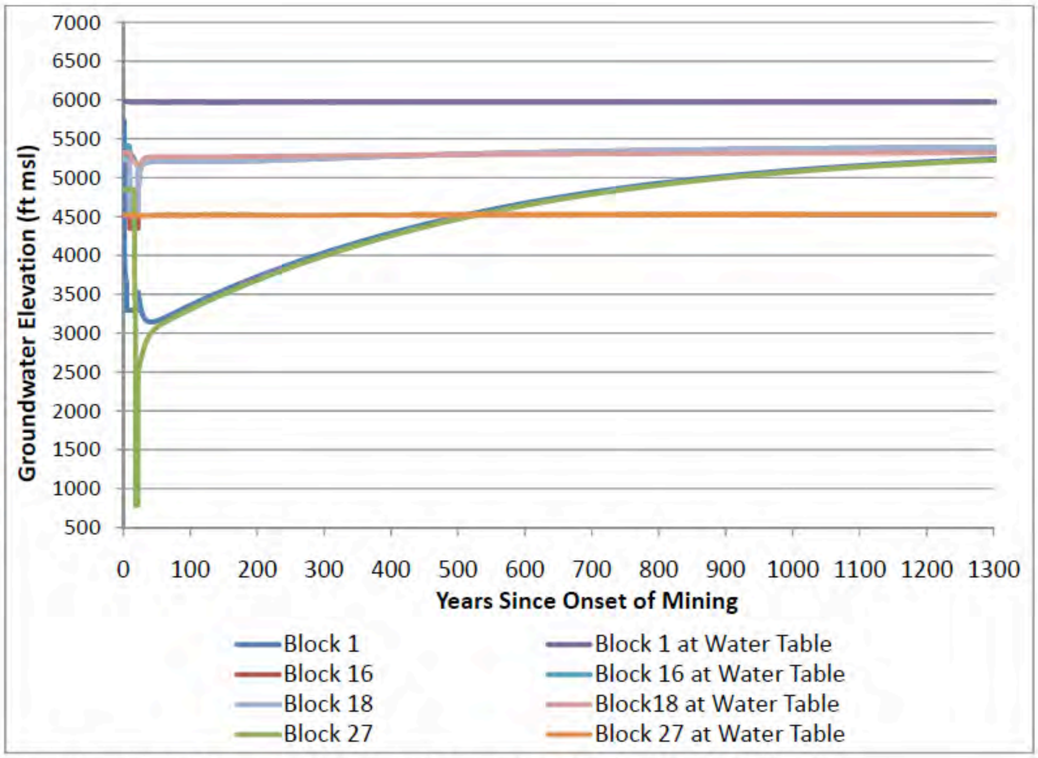

Figure 2. Predicted Groundwater Elevations During and After Mining with Mitigation

Geomatrix (2010) Appendix G

CRITICAL UNCERTAINTIES ABOUT GROUNDWATER-SURFACE WATER CONNECTIVITY

The conceptual model of flow effect in the SDEIS and Geomatrix (2010) implies, but does not specify the implications of, three points of linkage between the deep groundwater system affected by the mine and surface waters in streams: First, headwater spring sources at high elevation that originate in bedrock fractures or fissures; second, potential subsurface flow contributions of deep groundwater volume to shallow groundwater systems in the glacial and allucial valley fill surrounding the streams (i.e., buried springs); and third, the potential influence of the slope or regional water table on valley fill water table and resultant connectivity of valley fill shallow aquifers to surface waters thought hyporheic flows. While the descriptions of this analysis in the SDEIS suffer from vagueness, it appears that in evaluating the potential effects of mine dewatering post-closure infilling, the SDEIS only explicitly accounts for the first category of flow impact—direct effects on surface spring discharge.

Failure in the SDEIS and supporting analyses to fully address the second and third sources of potential impact on stream flow could result in a serious underestimation and mischaracterization of the potential consequences of the Montanore project for bull trout and stream habitat. For example, reduction of water table elevation in the valley fill of either East Fork Rock Creek or East Fork Bull River (at elevations below 5,600 ft) could result in partial decoupling of surface water and shallow subsurface aquifers well downstream, leading directly to loss of water depth, intermittent flow through riffles that blocks bull trout migration, and stress and death of riparian vegetation that shades the stream and provides bank stability and instream structural complexity. The latter could contribute indirectly to channel widening and sedimentation that further harm stream habitat, and loss of vertical flow exchange would result in greatly increased heating of that surface water which did remain. The effects of local water table lowering could potentially far outstrip the impact of spring source depletion on streamflows throughout the lengths of East Fork Bull River and East Fork Rock Creek. It appears quite conceivable that if water table lowering produces such a hydrologic tipping point, the result could be catastrophic transformation of these now-productive streams into systems that are ill-suited to support bull trout. The keystone to this possible transformation is not the volume of water issuing from bedrock springheads, but rather the loss of vertical (hyporheic) flow connectivity along the stream length associated with drawdown of valley fill water tables.

Cold, clear streams that are best suited to bull trout reproduction and growth are generally characterized by a combination of summer-cool, deep groundwater sources and an extensive alluvial aquifer and hyporheic flow exhange that serves to buffer the bulk of downvalley flow from atmospheric and solar heating. (Notably, the shallow alluvial aquifer also stores and slowly discharges cold water generated locally from spring snowmelt.) These stream types not only are the most productive for bull trout today, they are the most likely to retain relatively cold, clearwater signatures through future decades of climate warming, hence they are the only likely long-term refugia for bull trout. It is very important that analysis of the Montanore project thoroughly elucidate the potential effects on both the spring sources and the tributary water tables and hyprheic flow exchange.

Adequately evaluating the quantitative effect of large-scale water table alteration on the second and third components of streamflow will require a greater base of empirical field data for the streams in question, including data that could be gained from synoptic flow measurements of surface waters, piezometric measurements across and along valley gradients, and stable isotope characterization of water sources and their seasonal flux. Although not trivial to conduct, such a study is feasible and would lend some semblance of certainty about the possible range of flow effects on the affected streams. Considering the critical importance of the streams in question to bull trout conservation, such a study absolutely should be conducted before a decision about permitting this project is made.

Short of such an informed evaluation of the hydrologic basis of stream flow and its relation to water tables in the streams of concern, the SDEIS's characterization of the magnitude of loss of fish habitat based on a simple baseflow discharge assumption could seriously underestimate the potential effects on bull trout, westslope cutthroat trout, and other aquatic life. Note that once they occur, these effects are expected to last for centuries after mine closure and because they stem from large-scale alteration of the groundwater system, they are fundamentally irreversible, once they occur.

Even if the SDEIS projections of incremental flow depletion in the range of 3 to 10 percent post-closure in the mid-reaches of East Fork Bull River and East Fork Rock Creek are correct, without any fundamental alteration of local flow exchange, this magnitude of baseflow loss is biologically significant. In streams of this size and bed configuration, any depletion of baseflow tends to produce proportionally large reductions in usable habitat area (see EES 2005), primarily because of loss of depth in shallow glides, pool tails, and pocket pools within riffles and rapids makes these areas less suited, or in some cases completely unsuitable, for juvenile, subadult, and adult bull trout foraging. In headwater streams many presently used habitats are at the margin of depth for suitability for bull trout. More formalized analysis of instream flow response, including possible PHABSIM analysis, would be needed to understand the biological magnitude of potential harm to bull trout. Simply because the percentage magnitude of sustained base flow loss is within the margin of interannual variability does not mean it can be tolerated by a fish population without substantial cumulative impact. The effect of the loss will be to aggravate and extend adverse conditions in periods of drought, and to blunt survival and growth benefits in relatively average water years, rendering populations increasingly dependent on occasional high-precipitation, high-flow years for their survival. Far from a slight proportional change in quantity, this represents a major qualititative conversion of high-quality habitat into low-quality habitat.

MITIGATION MEASURES IN THE DEIS AND SDEIS

Considering the potential importance of simulated underground mitigation measures (grouting of mine void walls and construction of bulkheads after mining is completed) for water table and streamflow response in the post-closure period (Geomatrix, Appendix G, and see Geomatrix Table 2 and Figure 2 above), it seems critical that a clear formal appraisal of these mitigation measures be included in the SDEIS. At present, key questions are left unresolved. How feasible are the measures given the mine and rock characteristics? What is the record of success for similar installations in other projects? What is their cost? What is the functional life span of these structures relative to the duration of the impact they are intended to mitigate? How vulnerable are these structures to compromise by seismic activity? Finally, it appears these modeled mitigation measures reduce streamflow impact by slowing the rate of inflow into some parts of the mine void. While this may reduce the most dramatic streamflow response in the initial years after closure, does not the procedure actually reallocate the absolute impact by spreading it into future years? Is the temporal spreading truly so extended that the effect actually vanishes? What might be the outcome in the event of failure—for example, catastrophic failure from a seismic event-- of the mitigation structures, which not be amenable to maintenance or repair after the mine void is sealed and water reaccumulates?

In section 2.5.7.2.2 of the DEIS (p.1129-1130), in-channel mitigation measures were proposed to compensate for losses of streamflow on streams including Rock Creek and East Fork Bull River. The primary action identified is:

> …a stream improvement plan to increase productivity and carrying capacity" of the streams in question. "A component of the plan would be installation and maintenance of instream structures to form pool and deep water habitat, provide cover for subadults, and secure habitat for spawning adults. These would be built and maintained using appropriate-sized rock and large wood according to accepted methodologies……
> Another component of the plan would be grade control structures to improve bedload transport, decrease width to depth ratios, and reduce fine sediment accumulation. These components would be modified as appropriate following the habitat survey.

What literature supports the notion that losses of stream flow can be biologically compensated by instream structural manipulations? Specifically, what studies show that bull trout can so benefit? I submit the literature is rather clear that this tradeoff is not feasible. As a rule, instream structures cannot compensate for loss of streamflow, nor for increases of sediment (Frissell and Nawa 1992). There is no structural substitute for water. East Fork Bull River and East Fork Rock Creek have flashy peakflows caused by snowmelt and rain-on snow runoff, resulting in channels that are actively and annual self-formed and rearranged primarily via movement of wood debris accumulations and by lateral channel avulsion. This degree of stream energy and extant complexity and channel dynamic are well-recognized to hinder the effectiveness artificial instream structures. Morever, these streams already possess good to excellent habitat structure through much of their lengths, with an abundance of boulders, large wood, and connected side channels and spring brooks; sediment loads are limited by their being well-buffered from roads, the limited extent of logging, and Wilderness protection in the headwaters of their catchments. Structural alterations are not likely to produce any more optimum configuration. When flow is limited, deepening pools would simply reallocate water, likely causing a shallowing of riffle habitats that could impair mobility and migration during the fall bull trout spawning season. Additionally, in both streams existing roads are distant from the channel and do not provide ready equipment access for construction. The channels are separated from hillslopes by wet, spring-channeled valley floor that is highly vulnerable to disturbance by ground-based equipment. Given this setting, construction activity necessary to install instream structures would risk far more harm to stream habitat than any marginal benefit that structures could bring.

The SDEIS in 2.5.6.1 (p. 54, elaborated in Appendix C) proposes a monitoring of "Groundwater Dependent Ecosystem Inventory and Monitoring" in upper Libby Creek and East Fork Rock Creek. The text defines "Groundwater dependent ecosystems (GDE)" as "ecosystems that depend solely or partially on groundwater for their existence." While I have advocated extended *pre-project study* to improve understanding of groundwater-surface water conductivity in bull trout streams to help inform any future decision about the Montanore project, the SDEIS does not make clear what the purpose of "GDE monitoring" is when executed *during* project operations. Are there elements of groundwater impact that can be mitigated during construction or operations if the monitoring information calls them out? There may be some opportunity for adaptive adjustment in Libby Creek and Little Cherry Creek, where surface infrastructure will alter shallow groundwater flow paths, but in East Rock Rock Creek, where the impact stems from large-scale groundwater distortion caused by the mine dewatering, excavation, and refilling, no mitigation opportunity is apparent. Simply monitoring the effect of the mine on an ecosystem does not protect that ecosystem from harm.

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Baxter, C.V. & F.R. Hauer. 2000. Geomorphology, hyporheic exchange, and selection of spawning habitat by bull trout (*Salvelinus confluentus*). Can. J. Fish. Aquat. Sci. 57: 1470-1481.

Baxter, C.V., C.A. Frissell, and F.R. Hauer. 1999. Geomorphology, logging roads and the distribution of bull trout *(Salvelinus confluentus)* spawning in a forested river basin: implications for management and conservation. Transactions of the American Fisheries Society 128:854-867.

Baxter, J.S. & J.D. McPhail. 1999. The influence of redd site selection, groundwater upwelling, and over-winter incubation temperature on survival of bull trout *Salvelinus confluentus* from egg to alevins. Can. J. Zool. 77:1233-1239.

DEIS. 2009. Draft Environmental Impact Statement for the Montanore Project. Kootenai National Forest, Libby, MT, and Montana Department of Environmental Quality, Helena, MT.

Dunham, J.S., and B.E. Rieman. 1999. Metapopulation structure of bull trout: influences of physical, biotic, and geothermal landscape characteristics. Ecological Applications 9:642-655.

EES Consulting, 2005. Bull trout habitat index suitability data from upper Wenatchee River basin. Prepared for Chelan County Natural Resources Department and WRIA 45 Watershed Planning Unit. Bellingham, WA. 39 pp.

Frissell, C.A., and R.K. Nawa. 1992. Incidence and causes of failure of artificial habitat structures in streams of western Oregon and Washington. North American Journal of Fisheries Management 12:182-197.

Geomatrix. 2011. Numerical Groundwater Model Development, Calibration, and Predictions, Montanore Mine Project, Sanders and Lincoln Counties, Montana. Report prepared for the Montanore Minerals Corp., Libby, MT. 196 pp.

Moran, S., and J. Storaasli. 2009. Non-Native Fish Suppression Project in the East Fork Bull River Drainage, Montana: 2007 – 2013, Annual Progress Report – 2009, Fish Passage/Native Salmonid Program, Appendix C. Avista Corporation Natural Resources Field Office, Noxon, MT. 84 pp.

Moran, S. No date. Rock Creek Fisheries Summary. Avista Corporation Natural Resources Field Office, Noxon, MT. 7 pp.

SDEIS. 2012. Supplemental Draft Environmental Impact Statement for the Montanore Project. Kootenai National Forest, Libby, MT, and Montana Department of Environmental Quality, Helena, MT.

USFWS. 2010a. Endangered and Threatened Wildlife and Plants; Revising Critical Habitat for Bull Trout: A Rule by the Fish and Wildlife Service on 10/18/2010. C Federal Register pp. 63898-64070. http://federalregister.gov/a/2010-25028

USFWS. 2010b. Bull Trout Final Critical Habitat Justification. Chapter 30. Columbia Headwaters Recovery Unit—Kootenai River Basin Critical Habitat Unit U. S. Fish and Wildlife Service, September 2010. Pp. 813-823.

USFWS. 2010c. Bull Trout Final Critical Habitat Justification. Chapter 31. Columbia Headwaters Recovery Unit—Clark Fork River Basin Critical Habitat Unit U. S. Fish and Wildlife Service, September 2010. Pp. 825-913.

USFWS. 2006. Rock Creek Mine Biological Opinion, Part B – Bull Trout. 120 pp. http://www.fws.gov/mountain-prairie/species/mammals/grizzly/cabinet.htm

APPENDIX A

20 March 2007 *Curriculum Vitae*

CHRISTOPHER A. FRISSELL

Senior Staff Scientist
The Pacific Rivers Council
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Birth: 1 December 1960, Chehalis, Washington

Education: Ph.D. in Fisheries Science, Oregon State University, 1992
M.S. in Fisheries Science, Oregon State University, 1986
B.A. with High Honors in Zoology, University of Montana, 1982

Appointments:

Senior Staff Scientist, The Pacific Rivers Council, 2000-present.
Research Associate Professor, The University of Montana, Flathead Lake Biological Station, 1998-2000 (presently Affiliate Faculty status)
Research Assistant Professor, The University of Montana, Flathead Lake Biological Station, 1993-1998
Research Assistant Professor, Department of Fisheries and Wildlife, Oregon State University, 1994-1997
Postdoctoral Research Associate (Faculty), Department of Fisheries and Wildlife, Oregon State University, 1992-1994
Research Assistant (Faculty), Oak Creek Laboratory of Biology, Department of Fisheries and Wildlife, Oregon State University, 1985-1992

Fields of Interest:

Cumulative impacts of human activities and natural processes on stream habitat and stream biota
Ecology, biogeography, and conservation biology of fishes and aquatic biota in relation to landscape change
Aquatic ecosystem conservation and restoration strategies
Geomorphology and landscape ecology in design of integrated conservation reserves
Restoration and recovery planning and design

Professional Societies:
Society for Conservation Biology, 1991-present
American Fisheries Society, 1985-present
Ecological Society of America, 1987-present
North American Benthological Society, 1983-present

Graduate Students Mentored

Cavallo, B.J. M.S. in Organismal Biology and Ecology, The University of Montana, 1997. Thesis title: Floodplain habitat heterogeneity and the distribution, abundance, and behavior of fishes and amphibians in the Middle Fork Flathead River Basin, Montana.

Adams, S. B. Ph.D.in Organismal Biology and Ecology, The University of Montana, 1999. Dissertation title: Mechanisms Limiting a Vertebrate Invasion: Brook Trout in Mountain Streams of the Northwestern USA.

Hitt, N.P., M.S. in Organismal Biology and Ecology, The University of Montana, 2002, Distribution and potential invasion of introduced rainbow trout in the upper Flathead River drainage.

Carnefix, G. M.S. in Organismal Biology and Ecology, The University of Montana, 2002. Thesis title: Movements and ecology of bull trout in Rock Creek, MT.

Hastings, K. Ph.D.in Organismal Biology and Ecology, The University of Montana, 2005. Dissertation title: Long-term persistence of isolated fish populations in the Alexander Archipelago.

Appointments to Peer Review Panels and Scientific Advisory Committees:

Landscape Pattern Task Group, *State of the Nation's Ecosystems* report. 2003-2007. H. John Heinz III Center For Science, Economics and the Environment. Washington, DC. http://www.heinzctr.org/Programs/Reporting/Working%20Groups/Fragmentation/index.shtml

Science Review Team, King County Normative Flow Studies Project. 2002-2005, Seattle, WA. http://dnr.metrokc.gov/wlr/BASINS/flows/science-review-team.htm

Science Advisory Panel, Westside. Governor's Salmon Restoration Funding Board, Washington State, February 2000.

Ecological Work Group, Multi-species Framework Process and Subbasin Assessment Process, Northwest Power Planning Council 1998-2000.

Peer review panelist for U.S. Environmental Protection Agency/National Science Foundation Water and Watersheds Grants Program for 1997. 7-9 May 1997.

Scientific Group for the Governor's Bull Trout Restoration Team, State of Montana, 1994-present

Oregon Department of Environmental Quality, 1992-95: Temperature Standards Review Subcommittee of the Technical Advisory Committee, Triennial Water Quality Standards Review

Scientific Assessment Panel for amphibian species, Eastside Oregon-Washington and Upper Columbia Basin EIS, US BLM and US Forest Service, 1994

Oregon Department of Forestry, 1990-93: Technical Advisory Group for the Forest Practices Monitoring Program; Wetlands Technical Group; Stream Protection Advisory Panel

Theses and Dissertations:

Frissell, C.A. 1992. Cumulative effects of land use on salmon habitat in southwest Oregon coastal streams. Doctoral dissertation, Oregon State University, Corvallis.
Frissell, C. A. 1986. A hierarchical stream habitat classification system: development and demonstration. M.S. thesis, Oregon State University, Corvallis.
Frissell. C. A. 1982. Colonization and development of community structure in coexisting Ephemerellid mayflies (Ephemeroptera, Ephemerellidae). Senior Thesis, Watkins Scholarship Program, The University of Montana, Missoula.

Member of Board of Editors for Journals:

Conservation Biology, 1996-2000

Reviewer for Journals and Agency Publications:

Canadian Journal of Fisheries and Aquatic Sciences, Conservation Biology, Ecological Applications, Environmental Management, Fisheries, Freshwater Biology, North American Journal of Fisheries Management, Oikos, Transactions of the American Fisheries Society, Fundamental and Applied Limnology, USDA Forest Service General Technical Reports

Articles Published in Scientific Journals:

Olson, D.H., P.D. Anderson, C.A. Frissell, H. H. Welsh, Jr., and D. F. Bradford. 2007. Biodiversity management approaches for stream-riparian areas: perspectives for Pacific Northwest headwater forests, microclimates, and amphibians. *Forest Ecology and Management,* In Press.
Poole, G.C., J.A. Stanford, S.W. Running, and C.A. Frissell. 2006. Multiscale geomorphic drivers of groundwater flow paths: subsurface hydrologic dynamics and hyporheic habitat diversity *Journal of the North American Benthological Society*. 25(2): 288-303.
Poole, G. C., J. A. Stanford, S. W. Running, C. A. Frissell, W. W. Woessner, and B. K. Ellis. 2004. A patch hierarchy approach to modeling surface and sub-surface hydrology in complex flood-plain environments. *Earth Surface Processes and Landforms* 29**:** 1259–1284.
Karr, J. R., J. J. Rhodes, G. W. Minshall, F. R. Hauer, R. L. Beschta, C. A. Frissell, and D. A. Perry. 2004. The effects of postfire salvage logging on aquatic ecosystems in the American West. *BioScience* 54:1029-1033.
Hitt, N.P., and C.A. Frissell. 2004. A case study of surrogate species in aquatic conservation planning. *Aquatic Conservation: Marine and Freshwater Ecosystems*. 14:625–633.
Beschta, ,R.L., J. J. Rhodes, J. B. Kauffman, R. E. Gresswell, G. W. Minshall, J. R. Karr, D.A. Perry, F.R. Hauer, C. A. Frissell. 2004. Postfire Management on Forested Public Lands of the Western United States. *Conservation Biology* 18: 957–967.

Articles Published in Scientific Journals, continued

Hitt, N.P., Frissell, C.A., Muhlfeld, C.C. and F.W. Allendorf. 2003. Spread of hybridization between native westslope cutthroat trout, *Oncorhynchus clarki lewisi*, and non-native rainbow trout, *O. mykiss*. *Canadian Journal of Fisheries and Aquatic Sciences* 60: 1440-1451.Ebersole. J.T., W.J. Liss, and C.A. Frissell. 2003. Thermal heterogeneity, stream channel morphology and salmonid abundance in northeast Oregon streams. *Canadian Journal of Fisheries and Aquatic Sciences* 60:1266-1280.

Poole, G. C., J. A. Stanford, C. A. Frissell and S. W. Running. 2002. Three-dimensional mapping of geomorphic controls on flood-plain hydrology and connectivity from aerial photos. *Geomorphology* 48(4):329-347.

Adams, S.B., and C.A. Frissell. 2002. Changes in distribution of nonnative brook trout in an Idaho drainage over two decades. *Transactions of the American Fisheries Society*, 131:561-568.

Adams, S.B.,and C.A. Frissell. 2001. Thermal habitat use and evidence of seasonal migration by tailed frogs, *Ascaphus truei*, in Montana. *Canadian Field-Naturalist* 115: 251-256.

Adams, S.B., C.A. Frissell, and B.E. Rieman. 2001. Geography of invasion in mountain streams: consequences of headwater lake fish introductions. *Ecosystems* 296-307.

Ebersole, J.L., W.J. Liss, and C. A. Frissell. 2001. Relationship between stream temperature, thermal refugia, and rainbow trout *Oncorhynchus mykiss* abundance in arid-land streams in the northwestern United States. *Ecology of Freshwater Fish* 10:1-10.

Adams, S.A., C.A. Frissell, and B.E. Rieman. 2000. Movements of non-native brook trout in relation to stream channel slope. *Transactions of the American Fisheries Society* 129:623-638

Trombulak, S.C., and C.A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. *Conservation Biology* 14:18-30.

Baxter, C.V., C.A. Frissell, and F.R. Hauer. 1999. Geomorphology, logging roads and the distribution of bull trout *(Salvelinus confluentus)* spawning in a forested river basin: implications for management and conservation. *Transactions of the American Fisheries Society,* 128:854-867.

Independent Scientific Group. 1999. Scientific issues in the restoration of salmonid fishes in the Columbia River. *Fisheries* 24(3):10-19.

Currens, K.P., F.W. Allendorf, D. Bayles, D.L. Bottom,. C.A. Frissell, D. Hankin, J.A. Lichatowich, P.C. Trotter, and T.A. Williams. 1998. Conservation of Pacific salmon: response to Wainwright and Waples. *Conservation Biology* 12:1148-1149.

Poole, G.C., C.A. Frissell, and S.C. Ralph. 1997. In-stream habitat unit classification: inadequacies for monitoring and some consequences for management. *Journal of the American Water Resources Association* 33:879-896.

Ebersole, J.L., W.J. Liss, and C.A. Frissell. 1997. Restoration of stream habitats in the western United States: restoration as re-expression of habitat capacity. *Environmental Management*. 21:1-14.

Articles Published in Scientific Journals, continued

Allendorf, F.W., D. Bayles, D.L. Bottom, K.P. Currens, C.A. Frissell, D. Hankin, J.A. Lichatowich, W. Nehlsen, P.C. Trotter, and T.H. Williams. 1997. Prioritizing Pacific salmon stocks for conservation. *Conservation Biology* 11:140-152.

Frissell, C.A., and D. Bayles. 1996. Ecosystem management and the conservation of aquatic biodiversity and ecological integrity. *Water Resources Bulletin* 32:229-240.

Stanford, J.A., J.V. Ward, W.J. Liss, C.A. Frissell, R.N. Williams, J.A. Lichatowich, and C.C. Coutant. 1996. A general protocol for restoration of regulated rivers. *Regulated Rivers: Research and Management* 12:391-413.

Nawa, R., and C.A. Frissell. 1994. Measuring scour and fill of gravel streambeds with scour chains and sliding bead monitors. *North American Journal of Fisheries Management* 13:634-639.

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Frissell, C.A., and R.K. Nawa. 1992. Incidence and causes of failure of artificial habitat structures in streams of western Oregon and Washington. *North American Journal of Fisheries Management* 12:182-197.

Frissell, C.A., W.J. Liss, C.E. Warren, and M.D. Hurley. 1986. A hierarchical framework for stream habitat classification: viewing streams in a watershed context. *Environmental Management* 10:199-214.

Symposium Articles Published:

Poole, G.C., J.A. Stanford, S.W. Running, and C.A. Frissell. 2000. A Linked GIS/modeling approach to assessing the influence of flood-plain structure on surface- and ground-water routing in rivers. *Proceedings of the 4th International Conference on Integrating Geographic Information Systems (GIS) and Environmental Modeling*. Held 2-8 September 2000, Banff, Alberta. B. Parks, editor.

Clancy, C., C. Frissell, and T. Weaver. 1998. Removal or suppression of introduced fish to aid bull trout recovery. *Proceedings of the Wild Trout XI Conference*, held August, 1997 in Bozeman, MT.

Li, H.W., K. Currens, D. Bottom, S. Clarke, J. Dambacher, C. Frissell, P. Harris, R.M. Hughes, D. McCullough, A. McGie, K. Moore, R. Nawa, and S. Thiele. 1995. Safe havens: refuges and evolutionarily significant units. *American Fisheries Society Symposium* 17:371-380.

Frissell, C.A., W.J. Liss, and D. Bayles. 1993. An integrated, biophysical strategy for ecological restoration of large watersheds. In D.F. Potts ed., *Changing Roles in Water Resources Management and Policy*. Proceedings of a symposium of the American Water Resources Association, held 27-30 June, 1993, Bellevue, WA.

Symposium Articles Published, continued

Frissell, C.A., and R.K. Nawa. 1989. Cumulative impacts of timber harvest on fisheries: "All the King's horses and all the King's men..." In C. Toole, (ed.), *Proceedings of the Seventh California Salmon, Steelhead and Trout Restoration Conference*. February 24-26, Arcata, CA. California Sea Grant Publication UCSGEP-89-02.

Frissell, C.A., and T. Hirai. 1988. Life history patterns, habitat change, and productivity of fall chinook stocks of southwest Oregon. In B. Sheperd (ed.) *Proceedings of the Northeast Pacific Chinook and Coho Workshop*, Bellingham, Washington, 3-4 October 1988. North Pacific International Chapter, American Fisheries Society.

Books and Book Chapters Published:

Frissell, C.A., N.L. Poff, and M.E. Jensen. 2001. Assessment of biotic patterns in freshwater ecosystems. Chapter 27 in Bourgeron, P., M. Jensen, and G. Lessard (eds.) *A Guidebook for Integrated Ecological Assessments*. Springer-Verlag, NY.

Jensen, M.E., I. Goodman, and C.A. Frissell. 2001. Design and use of aquatic biophysical classifications and maps. Chapter 26 in Bourgeron, P., M. Jensen, and G. Lessard (eds). *A Guidebook for Integrated Ecological Assessments.* Springer-Verlag, NY.

Welsh, H.H., T.D. Roelofs, and C.A. Frissell. 2000. Aquatic ecosystems of the redwood region. Pages 165-199 in R. Noss (ed.) *The Redwood Forest: History, Ecology, and Conservation of the Coast Redwoods.* Island Press, Washington, DC.

Frissell, C.A., and S.C. Ralph. 1998. Stream and watershed restoration. Pages 599-624 in R.J. Naiman and R.E. Bilby (eds.) *Ecology and Management of Streams and Rivers in the Pacific Northwest Coastal Ecoregion*. Springer-Verlag, NY.

Frissell, C.A. 1997. Ecological principles. Pages 96-115 in J.E. Williams, M.P. Dombeck, and C.A. Wood (eds.) *Watershed Restoration: Principles and Practices.* The American Fisheries Society, Bethesda, MD.

Frissell, C.A., W.J. Liss, R.K. Nawa, R.E. Gresswell, and J.L. Ebersole. 1997. Measuring the failure of salmon management. Pages 411-444 in D.J. Stouder, P.A. Bisson,and R.J. Naiman (eds.) *Pacific Salmon and their Ecosystems: Status and Future Options*. Chapman and Hall, New York, NY.

Frissell, C.A. 1996. A new strategy for watershed protection, restoration and recovery of wild native fish in the Pacific Northwest. Pages 1-24 in B. Doppelt (ed.) *Healing the Watershed: A Guide to the Restoration of Watersheds and Native Fish in the West*. The Pacific Rivers Council, Eugene, OR.

Books and Book Chapters Published, continued

Frissell, C.A., and D.G. Lonzarich. 1996. Habitat use and competition among stream fishes. Pages 493-510 in F.R. Hauer and G.A. Lamberti (eds.) *Methods in Stream Ecology*. Academic Press, San Diego, CA.

Doppelt, B., M. Scurlock, C. Frissell, and J. Karr. 1993. *Entering the Watershed: A New Aproach to Save America's River Ecosystems* . Island Press, Washington, DC.

Final Research Reports and Miscellaneous Publications since 1993:

Frissell, C.A., P. H. Morrison, S.B. Adams, L. H. Swope, and N.P. Hitt. 2000. Conservation Priorities: an Assessment of Freshwater Habitat for Puget Sound Salmon. Trust for Public Land, Northwest Regional Office, 1011 Western Suite 605, Seattle, WA. http://www.tpl.org/tier3_cd.cfm?content_item_id=9280&folder_id=262.

Frissell, C.A. 1999. An ecosystem approach for habitat conservation for bull trout: groundwater and surface water protection. Flathead Lake Biological Station, Open File Report 156-99, The Univ.of Montana, Polson, MT

Hitt, N.P. and C.A. Frissell. 1999. Wilderness in a landscape context: a quantitative approach to ranking aquatic diversity areas in western Montana. Paper presented at the Wilderness Science Conference, 23-27 May, Missoula, MT.

Montana Bull Trout Scientific Group. 1998. The relationship between land management activities and habitat requirements of bull trout. Report prepared for the Montana Bull Trout Restoration Team, Office of the Governor, Helena, MT.

Frissell, C.A. 1998. Landscape refugia for conservation of Pacific salmon in selected river basins of the Olympic Peninsula and Hood Canal, Washington. Flathead Lake Biological Station, Open File Report 147-98, The Univ.of Montana, Polson, MT.

Frissell, C.A. 1997. Ecological benefits of wildland reserves: The proposed Copper Salmon Wilderness in southwest Oregon. Flathead Lake Biological Station, Open File Report 150-97, The University of Montana, Polson, MT.

Huntington, C.W., and C.A. Frissell. 1997. Aquatic conservation and salmon recovery in the North Coast Basin of Oregon: A crucial role for the Tillamook and Clatsop State Forests. Report prepared for Oregon Trout, Portland, OR.

Williams, R.N., L.D. Calvin, C.C. Coutant, M.W. Erho, Jr., J.A. Lichatowich, W.J. Liss, W. E. McConnaha, P.R. Mundy, J.A. Stanford, R.R. Whitney, D.L. Bottom, and C.A. Frissell. In press. *Return to the River: Restoration of Salmonid Fishes in the Columbia River Ecosystem.* Independent Scientific Group, Northwest Power Planning Council, Portland, OR.

C.A. Frissell, J.L. Ebersole, W.J. Liss, B.J. Cavallo, and G.C. Poole. 1996. Potential effects of climate change on thermal complexity and biotic integrity of streams: seasonal intrusion of non-native fishes. Final Report for USEPA Environmental Research Laboratory, Duluth, MN. Oak Creek Laboratory of Biology, Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR.

Final Research Reports and Miscellaneous Publications since 1993, continued

Bottom, D.L., J.A. Lichatowich, and C.A. Frissell. 1996. Variability of marine ecosystems and relation to salmon production. Report prepared for Theme 2 of the Pacific Northwest Coastal Ecosystem Region Study Workshop, Troutdale, OR, 12-14 August.

Clancy, C., C. Frissell, and T. Weaver. 1996. Assessment of methods for removal or suppression of introduced fish to aid bull trout recovery. Report prepared by the Montana Bull Trout Scientific Group for the Montana Bull Trout Restoration Team. Montana Fish, Wildlife and Parks, Helena, MT.

Frissell, C.A., J. Doskocil, J. Gangemi, and J. Stanford. 1995. Identifying priority areas for protection and restoration of riverine biodiversity: a case study in the Swan River basin, Montana, USA. Flathead Lake Biological Station, Open File Report 136-95, The University of Montana, Polson, MT.

Beschta, R.L., C.A. Frissell, R. Gresswell, R. Hauer, J.R. Karr, G.W. Minshall, D.A. Perry, and J.J. Rhodes. 1995. Wildfire and salvage logging: recommenda-tions for ecologically sound post-fire salvage logging and other post-fire treatments on federal lands in the West. The Pacific Rivers Council, Eugene, OR.

Frissell, C.A. 1993. The shrinking range of the Pacific Salmon. Report and status and range maps prepared for the Pacific Northwest Salmon Study, The Wilderness Society, Washington, DC.

Frissell, C.A., and W.J. Liss. 1993. Valley segment classification for the streams of Great Basin National Park, Nevada. Report prepared for the Cooperative Park Studies Unit, College of Forestry, Oregon State University, Corvallis, OR.

Frissell, C.A. 1993. Panacea or placebo? An ecologist's view of captive breeding. *Wild Fish* July/August 1993:7-12. The Wilderness Society, Portland, OR.

Frissell, C.A. 1993. A new strategy for watershed restoration and recovery of Pacific salmon in the Pacific Northwest. Report prepared for The Pacific Rivers Council, Eugene, Oregon. Oak Creek Laboratory of Biology, Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR.

Selected Papers and Seminars Presented Since 1993 (__=presenter):

Frissell, C.A. 2007. Setting regional priorities for watershed restoration. 25th Salmonid Restoration Conference, Salmonid Restoration Federation, 9-10, Santa Rosa, CA.

Frissell, C.A., and G, Carnefix. 2007. (Abstract) Spawning abundance of bull trout (*Salvelinus confluentus*) in relation to geomorphology, temperature and roads in tributaries of Rock Creek Basin (Missoula and Granite Counties), Montana, US. Annual Meeting of the Montana Chapter of the American Fisheries Society, 13-16 February, Missoula, MT. http://www.fisheries.org/units/AFSmontana/2007%20MCAFS%20Annual%20Meeting%20Program.pdf

Selected Papers and Seminars Presented Since 1993, continued

Frissell, C.A. 2006. Post-fire management effects on streams. NCSSF Disturbance, Management, and Biodiversity Symposium, National Commission for Science and Sustainable Forestry, 26-27 April, Denver, CO.

Frissell, C.A., and G. Carnefix. 2005. (Abstract) Indicators of landscape pattern for freshwater ecosystems. 20th Annual Symposium of the US-International Association for Landscape Ecology, 12-16 March, Syracuse, NY.

Frissell, C.A. 2004. Managing risk and uncertainty: National Forest management and freshwater conservation. Regional Centennial Forum: The Forest Service In the Pacific Southwest Region. US Forest Service, 5-6 November, Sacramento, CA.

Frissell, C.A. 2001. (Abstract) What to do first with limited time, money, and staff. Watershed Restoration Workshop: Integrating Practical Approaches. Oregon Chapter of the American Fisheries Society, 13-15 November, Eugene, OR.

Ebersole, J.L., Colden V. Baxter, Hiram W. Li, and William J. Liss, and Frissell, C.A. 2001. (Extended abstract) Detecting temporal dynamics and ecological effects of smallmouth bass invasion in northeast Oregon streams. *In*: Proceedings, American Fisheries Society Special Symposium: Practical Approaches for Conserving Native Inland Fishes of the West. Montana Chapter and Western Division of the American Fisheries Society, 6-8 June, The University of Montana, Missoula, MT.

Carnefix, G., C. Frissell, and E. Reiland. 2001. (Extended abstract) Complexity and stability of bull trout (*Salvelinus confluentus*) movement patterns in the Rock Creek drainage, Missoula and Granite counties, Montana. *In*: Proceedings, American Fisheries Society Special Symposium: Practical Approaches for Conserving Native Inland Fishes of the West. Montana Chapter and Western Division of the American Fisheries Society, 6-8 June, The University of Montana, Missoula, MT.

Frissell, C.A. 1999. (Abstract) Groundwater processes and stream classification in the montane West. Invited paper, Symposium #7: Aquatic Classification Schemes for Ecosystem Management: Making the Transition from Methods Development to Application and Validation. Annual Meeting of the Ecological Society of America 7-12 August, Spokane, WA.

Frissell, C.A. 1999. Fisheries and watershed processes: strategies for protection and restoration. Invited paper, Annual Meeting of the Cal-Neva Chapter of the American Fisheries Society, 24-27 March, Redding, CA.

Frissell, C.A. 1999. Surface-subsurface flow linkages in rivers and their importance for river flow conservation. Invited paper, Symposium on Water Quality and Hydropower Re-licensing, Annual Meeting of the Cal-Neva Chapter of the American Fisheries Society, 24-27 March, Redding, CA.

Frissell, C.A. 1999. Dams, uncertainty, and the salmon ecosystem. Keynote Address, Annual Meeting of the Idaho Chapter of the American Fisheries Society and The Wildlife Society, 4-6 March, Boise, ID

Frissell, C.A. 1998. Climate forcing of thermal habitat in Pacific Northwest rivers: Buffering effects of floodplain forests and hyporheic processes. (Abstract)

Symposium on Climate Change Impacts to Freshwater Fish Habitats, Annual Meeting of the American Fisheries Society, 23-27 August, Hartford, CT.

Selected Papers and Seminars Presented Since 1993, continued:

Frissell, C.A. 1998. Ecosystem concepts in large-scale restoration. (Abstract). Montana Chapter of the American Fisheries Society, 3-5 February, Helena, MT.

Frissell, C.A. and B.J. Cavallo 1997. Aquatic habitats used by larval western toads (*Bufo boreas*) on an intermontane river floodplain and some landscape conservation implications (Abstract). Annual Meeting of the Ecological Society of America, 10-14 August, Albuquerque, NM.

Stanford, J.A. (presented by C.A. Frissell). 1997. Conservation and enhancement of alluvial rivers: the importance of hyporheic linkages. (Abstract). Symposium on Ecological Effects of Roads, Society for Conservation Biology, 7-10 June, Victoria, British Columbia, Canada.

Frissell, C.A., and G.C. Poole . 1997 Management of Riparian Zones in Western Montana: Present Issues and Emerging Challenges. (Abstract). Annual Meeting of the American Fisheries Society, 23-28 August, Monterey, CA.

Frissell, C.A., and J.T. Gangemi. 1997. Roads and the conservation of aquatic biodiversity and ecological integrity. (Abstract). Society for Conservation Biology, Victoria, British Columbia, Canada, 7-10 June.

Frissell, C.A. 1997. Spatial assessment of biological status and biodiversity loss. Invited seminar, National Research Center for Statistics and the Environment, University of Washington, Seattle, WA, 14 January.

Frissell, C.A., and B.J. Cavallo 1996. Thermal and hydrologic diversity of aquatic habitats mediated by floodplain complexity and hyporheic flow exchange in an alluvial segment of the Middle Fork Flathead River, Montana, USA. (Abstract). Annual Meeting of the N. Am. Benthological Society, Kalispell, MT, 3-8 June.

Frissell, C.A. 1995. Ecological principles for watershed restoration. (Abstract). Invited paper for Workshop on Watershed Restoration: Principles and Practices, Annual Meeting of the American Fisheries Society, Tampa, FL, 27-31 August.

Frissell, C.A. 1995. Managing native fish and their ecosystems: let's get (spatially) explicit! (Abstract). Invited panel presentation at Montana Chapter of the American Fisheries Society, Chico Hot Springs, MT, 6-10 February.

Frissell, C.A. 1995. Birth in the fast lane: sediment transport, human disturbance, and reproductive strategies of salmonid fishes in Pacific Northwest streams. (Abstract). Invited paper for Symposium on Influence of Geomorphic Processes on Terrestrial and Aquatic Ecosystem patterns and Processes, Annual meeting of the Ecological Society of America, Snowbird, UT, 31 July-3 August .

Frissell, C.A. 1995. Resource management impacts on bull trout populations. Invited panel presentation for Searching for Solutions: Solving the Bull Trout Puzzle Science and Policy Conference, Andrus Center for Public Policy, Boise State University, Boise, ID, 1-2 June.

Frissell, C.A. 1995. Watershed dynamics: natural pattern and process and some consequences for ecosystem management. Invited presentations at Managing

Terrestrial Ecosystems Relative to Past and Present Disturbances: A Workshop Integrating Fire, Range, Fish and Wildlife Habitat and the Practice of Silviculture in the Northern Region. U.S. Forest Service, Missoula, MT, 14-16 March.

Selected Papers and Seminars Presented Since 1993, continued:

Ebersole, J.L., C.A. Frissell, and W.J. Liss (Ebersole and Frissell, co-presenters). 1995. Invasion of non-native fishes in northeast Oregon and western Montana streams: potential impacts of climate change. (Abstract). Oregon Chapter of the American Fisheries Society, Ashland, OR, 15-17 February.

Frissell, C.A. 1994. Watershed restoration strategies. (Invited presenter and session convenor) Watersheds '94 Expo, US Environmental Protection Agency and Center for Streamside Studies, University of Washington. Bellevue, WA, 27-30 September.

Frissell, C.A. 1994. A hierarchical approach to restoration of riverine ecosystems. Invited paper at Symposium on Aquatic Habitat Restoration in Northern Ecosystems, Alaska Chapter of the American Fisheries Society, Girdwood, AK, 20-22 September.

Frissell, C.A. 1994. An integrated, biophysical strategy for ecological restoration of large watersheds (Abstract). Annual Conference of The Universities Council on Water Resources, Big Sky, MT, 3-5 August .

Frissell, C.A., and J. A. Stanford. 1994. Designing a watershed reserve network to protect and restore aquatic biodiversity in the northern Rocky Mountains (Abstract). Annual meeting of the Montana Chapter of the American Fisheries Society, Billings, Montana, Billings, MT, 9 February.

Frissell, C.A. 1994. The Endangered Species Act: principles for the protection and recovery of fishes. Invited panel presentation, annual meeting of the Idaho Chapter of the American Fisheries Society, McCall, ID, 24-26 February.

Frissell, C.A., W.J. Liss, B. Doppelt, and D. Bayles. 1993. A new, ecologically based restoration strategy for Pacific salmon in the Pacific Northwest (Abstract). Annual meeting of the American Fisheries Society, Portland, OR, 29 August-2 September.

Technical Workshops Organized:

Organizer and coordinator of Science Panel on Roads and Watersheds, sponsored by Pacific Rivers Council, 10-11 November 2006, Forest Grove, OR.

Organizer and coordinator of the Recovery Science Panel for the Western Native Trout Campaign. Sponsored by Pacific Rivers Council, meeting 2-3 March 2002, Portland, OR.

Organizer and coordinator of Biodiversity Workshop, Consortium for the Study of North Temperate Montane Ecosystems. A cooperative research venture of The University of Montana and Montana State University, supported by the NSF EPSCoR program. 4 February, 1997 Missoula, MT.

Scientific Workshop on Large Basin Restoration: South Umpqua River. 16-18 September 1992, Roseburg, Oregon. Sponsored by The Pacific Rivers Council.

Scientific Workshop on Large Basin Restoration: Lower Rogue River. 21-23 October 1992, Gold Beach, OR. Sponsored by The Pacific Rivers Council.

Other Workshops Attended by Invitation (since 1994):

(With E. Bishop) Scientific Workshop on Large Basin Restoration: Grande Ronde River (co-organizer). 21-22 March 1993, La Grande, OR. Sponsored by The Pacific Rivers Council.

(With W.J. Liss and R.K. Nawa) Stream Classification Workshop for staff of Oregon Department of Fish and Wildlife, 6-7 February 1990, Portland, OR.

Invited Review Panelist, Workshop on Linking Habitat Characteristics to Salmon Data. 29-30 September 1999, National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, WA.

Invited participant, Yellowstone to Yukon Aquatic Conservation Science Workshop. 20-22 August 1999, Flathead Lake Biological Station, The University of Montana, Polson, MT.

Invited Panelist, Workshop on Options for Restoring Salmon Habitat in the Mainstem Snake and Columbia Rivers. Pacific Northwest National Laboratory-Battelle, 19 August 1999, Kennewick, WA

Panelist at State of Oregon/National Marine Fisheries Service Memorandum of Agreement Committee Workshop: Cumulative Effects of State and Private Forest Practices on Salmon Habitat. 21 April 1998, Salem, OR.

Invited participant in a scientific workshop, Multiple Stressors in Ecological Risk Management. Sponsored by the Society for Environmental Chemistry and Toxicology and the USEPA, 13-18 September 1997, Pellston, MI.

Society for Conservation Biology Workshop: Communicating with the Media (panel member). 9 June 1997, Victoria, British Columbia, Canada.

Invited speaker for a workshop, Continuing Education in Ecosystem Management. Sponsored by the University of Idaho. Catchment scale processes and linkages between landscape and stream conditions. 31 January 1997, Moscow, ID.

The Nature Conservancy, Aquatic Classification Workshop (invited presenter). 9-11 April 1996, Cedar Creek Farm, MO.

Kenai River Community Forum (keynote speaker and panelist). The Nature Conservancy of Alaska, USEPA and USFWS, 19-21 April, Soldotna, AK.

Conservation Biology and Management of Interior Salmonids (invited presenter and session co-moderator). USDA Forest Service Intermountain Research Station and Utah State University, 4-5 October 1995, Logan, UT.

Eastside Ecosystem Planning Workshop. Sierra Club Legal Defense Fund, 16 December 1994, Portland, OR.

Co-instructor at workshop series on Watershed Restoration and the "Rapid Biotic Response Strategy" for Riverine Ecosystem Restoration, sponsored by The Pacific Rivers Council, 1993-95, California, Oregon, and Washington.

Fire/Salvage and Aquatic Ecosystems Policy Workshop. The Pacific Rivers Council, 15 December 1994, Portland, OR.

Panel on Forest Health Issues, Native Forest Network annual conference, 13 November 1994, Missoula, MT.

Other Workshops Attended by Invitation (since 1994), (continued)

Workshop on Watershed/Fisheries Cumulative Effects Analysis, sponsored by Headwaters, The Pacific Rivers Council, USDA Forest Service, and Bureau of Land Management. 29 September-2 October, 1994, Ruch, OR.

Boise Funders' Scoping Meeting, sponsored by Bullit, Harder, and Lazar Foundations, 30-31 August 1994, Boise, Idaho. Workshop for a statewide process to prioritize restoration of watersheds and salmon populations, by invitation of Oregon Senate President Bill Bradbury, 18 May 1994, Salem, OR.

Scientific Task Force on Conservation Strategies for Protection of Proposed Wild and Scenic Rivers in California, The Pacific Rivers Council, 22 Feb. 1994, Davis, CA

Other Presentations (Selected):

Scientists Briefing for U.S. Senate staff on post-fire logging and forest management and freshwater resources. Washington, D.C., 18-19 September 2006.

Invited testimony on federal land management and the future of salmon and aquatic biodiversity in the Pacific Northwest, to the U.S. House of Representatives, Subcommittee on National Parks and Public Lands, Washington, D.C., 11 March 1993.

Briefing for Congressional representatives and staff on federal lands management and conservation and recovery of salmonid fishes and riverine ecosystems, Washington, D.C., 22 January 1993.

Invited testimony to the 1991 Oregon State Legislature, on panel representing the Oregon Chapter of the American Fisheries Society, on the status of native fishes, impacts of forest practices on fish habitat, and the need or changes in environmental regulation.

Invited testimony to the Oregon Board of Forestry Forest Issues Forum, December 1990, on cumulative impacts of forest practices on native aquatic species and the need for changes in forest management.

Worked with Oregon Public Broadcasting to describe our research project and its significance in a 15-minute segment of the television program, Oregon Field Guide, first aired in June 1990.

Presented seminars, informal presentations, lectures, and discussions at research review meetings, as guest speaker in classrooms and public interest groups, at state board meetings, at workshops, and on field trips with foresters, geotechnical personnel, fishery and watershed managers, and conservationists.