PART I - ADMINISTRATIVE

Section 1. General administrative information

Title of project

Watershed Scale Response Of Stream Habitat To Abandoned Mine Waste

BPA project number: 9803500
Contract renewal date (mm/yyyy): 10/1999 ☒ **Multiple actions?**

Business name of agency, institution or organization requesting funding
University of Washington, College of Forest Resources, Center of Streamside Studies

Business acronym (if appropriate) U.W.

Proposal contact person or principal investigator:

Name	Donald W. Allen, Director, Grant And Contracts
Mailing Address	3935 University Way, N.E.
City, ST Zip	Seattle, WA 98105-6613
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NPPC Program Measure Number(s) which this project addresses
7.8C Mining: 7.8C1 ". . . ensure that all mining activities comply with state water quality standards . . ."

FWS/NMFS Biological Opinion Number(s) which this project addresses

Other planning document references

Short description
Seasonal fluctuations of mine drainage effects will be analyzed. Heavy metal loading in forest soils, Alder Creek, and the mainstem of the Methow River will be measured. Metal uptake, transfer, and hazards in the stream food web will determined.

Target species
Salmo gairdneri (steelhead/rainbow), Oncorhynchyus tshawtscha (Chinook salmon), bull trout (Salvelinus fontinalis, Salvelinus coufluentus)

Section 2. Sorting and evaluation

Subbasin
Upper Mid-Columbia Subregion. Methow subbasin.

Evaluation Process Sort

CBFWA caucus	Special evaluation process	ISRP project type
Mark one or more caucus	If your project fits either of these processes, mark one or both	Mark one or more categories
☒ Anadromous fish ☒ Resident fish ☐ Wildlife	☐ Multi-year (milestone-based evaluation) ☒ Watershed project evaluation	☒ Watershed councils/model watersheds ☐ Information dissemination ☐ Operation & maintenance ☐ New construction ☒ Research & monitoring ☐ Implementation & management ☐ Wildlife habitat acquisitions

Section 3. Relationships to other Bonneville projects

Umbrella / sub-proposal relationships. List umbrella project first.

Project #	Project title/description

Other dependent or critically-related projects

Project #	Project title/description	Nature of relationship

Section 4. Objectives, tasks and schedules

Past accomplishments

Year	Accomplishment	Met biological objectives?
1998	Identified Mine Waste Problem	Confirmed Effluent and Leachate as Acid Mine Drainage Containing Heavy Metals

1998	Stream Water Chemistry Measured June through September	Heavy Metal Concentration High Relative to Reference Stream, Exceeds WAC Freshwater Criteria
1998	Biological Impact Measured	Biological Function of Stream Impaired: Benthic Index of Biotic Integrity Low Relative to Reference Stream
1998	Terrestrial Impact of Acid Mine Drainage and Waste Rock Leachate on Riparian Vegetation Measured	Percent Cover and Species Composition Reflects Impact
1998	Physical and Chemical Impact on Stream Substrate Measured	Calcite and Heavy Metal Concentration and Precipitation High Relative to Reference Stream
1998	Completed Initial GIS Mapping and Analysis	Base Map for Data Analysis and Reclamation Planning in Place

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task
1	Determine Monthly Fluctuation of Hydrological parameters	a	Measure Current Speed, Flow, Temperature
2	Determine Subsurface Flow	a	Install Piezometers East Side Below Mine (Test), West Side (Reference), and Poorman Creek (Reference)
		b	Sample Subsurface Water Monthly
3	Determine Monthly Fluctuation of Surface and Subsurface Water Chemistry	a	Measure Total and Dissolved Metals, pH, DO, Alkalinity, and Suspended Colloids
4	Determine Heavy Metal Loading in Forest Soils below Mine	a	Measure Total Metals in Forest Soils below Mine Relative to Reference Sites
5	Determine Heavy Metal Uptake by Forest Vegetation below Mine and in Riparian Area	a	Measure Total Metals in Forest and Riparian Area Plant Tissues
6	Measure Monthly Fluctuation in the Index of Biotic Integrity	a	Measure Density and Diversity of Benthic Macroinvertebrates
7	Measure Monthly Fluctuation of Sediment Chemistry	a	Measure Total Metals in Sieved Sediment Samples
8	Confirm Premining Background Chemistry	a	Collect Two Sediment Cores to Supplement 1998 Core Sample
		b	Use Lead Isotopes to Date Core Sections and Associated Metal Concentrations

9	Determine Relationships among Metal Concentrations in Surface and Subsurface Water, Suspended Colloids, Sediment, and Stream Biota	a	Measure Metal Concentrations in Periphyton Samples (Algae, Microorganisms, Mineral Deposits)
10	Characterize the Transfer of Metals among Trophic Levels and Determine the Potential Hazard of Metal Toxity to Fish and Humans	a	Measure Metal Concentrations in Tissues of Invertebrates and Fish, and in the Milk of Lactating Cows that Drink Alder Creek Water
11	Expand GIS Model for Alder Creek Watershed	a	Add data layers for Analysis and Display

Objective schedules and costs

Obj #	Start date mm/yyyy	End date mm/yyyy	Measureable biological objective(s)	Milestone	FY2000 Cost %
1	10/1999	10/2001	Determine Annual Stream Hydrology Cycle	Measure Monthly Current Speed, Flow and Temperatures	4.00%
2	10/1999	10/2001	Determine Annual Subsurface Hydrology Cycle	Measure Monthly Current Speed, Flow and Temperature	22.00%
3	10/1999	10/2001	Determine Annual Cycle of Surface and Subsurface Water Chemistry	Measure Total, Dissolved Metals, pH, DO, Alkalinity, and Suspended Colloids Monthly	24.00%
4	10/1999	6/2000	Determine Heavy Metal Loading in Forest Soils below Mine	Concentration of Heavy Metals in Soils below Mine relative to Reference Measured	7.00%
5	10/1999	6/2000	Determine Heavy Metal Uptake by Forrest Vegetation below Mine	Heavy Metal Uptake by Vegetation below Mine Measured	6.00%
6	10/1999	10/2001	Determine Annual Cycle of Index of Biotic Integrity	Density and Diversity of Invertebrates Measured	8.00%

7	10/1999	10/2000	Determine Monthly Fluctuation of Sediment Chemistry	Total Metals in Sediments Measured	8.00%
8	6/2000	10/2000	Estimate Premining Background Concentration of Heavy Metals in Water	Measured Total Metal Concentration Monthly	6.00%
9	6/2000	10/2000	Determine Relationship between Physical, Chemical and Biological States of Watershed	Measured Metal Concentrations in Periphyton Samples Monthly	8.00%
10	6/2000	10/2000	Characterize the Transfer of Metals among Trophic Levels and Determine Potential Hazard of Metal Toxity to Fish and Humans	Metal Concentrations in Tissues of Invertebrates and Fish and in Milk of Lactating Cows that Drink Alder Creek Water Measured	6.00%
11	10/1999	10/2001	Expand GIS Model for Alder Creek Watershed	Data Layers Added and Analyzed	1.00%
				Total	100.00%

Schedule constraints
None

Completion date
10/2002

Section 5. Budget

FY99 project budget (BPA obligated): $0

FY2000 budget by line item

Item	**Note**	**% of total**	**FY2000**
Personnel	Research Assistant Salary	%27	14,700
Fringe benefits	@8%	%2	1,176
Supplies, materials, non-expendable property	Piezometers, Sample Bottles and Equipment, Cleaning Agents, Laboratory Supplies	%14	7,560

Operations & maintenance		%0	
Capital acquisitions or improvements (e.g. land, buildings, major equip.)		%0	
NEPA costs		%0	
Construction-related support		%0	
PIT tags	# of tags:	%0	
Travel	Interagency and Professional Mtgs. Mileage for Sampling	%7	3,500
Indirect costs	@26%	%18	9,603
Subcontractor		%0	
Other	Chemical Analysis (7K); Telephone, Copy, Postage, Publication (3K); Graduate Operating Fee (7281)	%32	17,281
		TOTAL BPA FY2000 BUDGET REQUEST	$53,820

Cost sharing

Organization	**Item or service provided**	**% total project cost (incl. BPA)**	**Amount ($)**
Univ. of Washington	Salary (Robert Edmonds, PI)	%6	3,470
	Benefits (Faculty)	%1	729
	Indirect Costs	%2	1092
		%0	
		%0	
		Total project cost (including BPA portion)	$59,111

Outyear costs

	FY2001	**FY02**	**FY03**	**FY04**
Total budget	$55,215	$56,187		

Section 6. References

Watershed?	**Reference**
☐	Alpers, C.N. 1994. Responsibilities and activities of the U.S. Geological Survey related to mining and the environment. Workshop Report-Mine Waste Technical Forum, USGS
☐	Burnet, F.W. 1976. Felsic volcanic rocks and mineral deposits in the Buck Mountain Formation andesites, Okanogan County, washington: University of Washington Master of Science thesis, 26p

☐	Davis, W.S. and T.P. Simon. 1995. Biological Assessment and Criteria. Lewis Publishers. 415 pp.
☐	EPA. 1989. Rapid bioassessment protocols for use in streams and rivers. Benthic macroinvertebrates and fish. (EPA/444/4-89-001). U.S. Environmental Protection Agency, Washington, D.C.
☐	Fuste, L.A. 1978. Effects of Coal Mine Drainage on Wilkeson Creek, a Stream in Western Washington. University of Washington Master of Science thesis. 97 pp.
☐	Griffith, J.S. and T.W. Hillman. 1986. Analysis of Fish Population in the Methow River, Washington: a report to James Mullan, U.S. Fish and Wildlife Service.
☐	Huchton, M., 1995. Washington Department of Ecology Toxic Cleanup Program Initial Investigation Toxic Cleanup Program. Okanogan County Health District. Okanogan, Washington.
☐	Huchton, M., 1997. Summary of Results of Abandoned Mine Land Investigations. Okanogan County Health district. Okanogan, Washington.
☐	Hunting, M.T. 1956. Inventory of Washington Minerals-Part II, Metallic Minerals: Washington Division of Mines and Geology. Bulletin 37, v.1, 428 pp. v.2, 67 pp.
☐	Karr, J.R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6, no. 6:21-27.
☐	Karr, and E. Chu. 1997. Biological monitoring and assessment using multimetric indexes effectively. EPA 235-R97-001.
☐	Lambeth, R.H. 1992. Hydrogeochemical characteristics of an unconsolidated aquifer downgradient from an oxidized, sulfidic mine tailings impoundment. Eastern Washington University Master of Science thesis, 140 pp.
☐	Langmuir, D. 1997. Aqueous Environmental Geochemistry. Prentice Hall. New Jersey.
☐	Margalef, Ramon. 1968. Perspectives in Ecological Theory. The University of Chicago Press, Chicago.
☐	Miller, M.D. and T.W. Hillman. 1987-1998. Chinook salmon spawning ground survey in the Methow and Okanogan River Basins. Chelan County Public Utility District. Chelan, Washington.
☐	Okanogan County Health District. 1995. Washington Department of Ecology Toxic Cleanup Program, Initial Investigation Report/Data Collection. Okanogan, Washington.
☐	Peplow, D. 1998. Effects of Acid Mine Drainage on the Water, Sediments, and Benthic Macroinvertebrates of Alder Creek. Quarterly Reports to B.P.A., 1-2.
☐	Peterson, D.L. and V.T. Parker. 1998. Ecological Scale: Theory and Applications. Columbia University Press. 615 pp.
☐	Plotnikoff, R.W. 1988. the Effects of Mine Drainage on the Macroinvertebrate Insect Community of Blue Creek, spokane Reservation, WA. Eastern Washington University Masters of Science thesis. 194 pp.

☐	Pollard, W.R., G.F. Hartman, C. Groot, P. Edgell. 1997. Field Identifications of Coastal Salmonids. Harbour publishing, Madiera Park, B.C. Canada.
☐	Scott, W.B. and E.J. Grossman. 1973. Freshwater Fishes of Canada. Bulletin 184, Fisheries Board of Canada. Ottawa, Canada.
☐	U.S. E.P.A. 1995. Generic Quality Assurance Project Plan guidance for Programs Using Community Level Biological Assessment in Wadable Streams and Rivers. EPA 841-B-95-004.
☐	U.S. E.P.A, 1998. Guidance for Quality Assurance Project Plans. EPA/600/R-98/018.
☐	U.S. E.P.A., 1996. Biological Criteria: Technical Guidance for Streams and Rivers. EPA 822-B-96-001.
☒	U.S.F.S. 1995. Twisp Watershed Analysis. Okanogan National Forest, Methow Valley Ranger District, United States Department of Agriculture, Washington, D.C.
☐	W.A.C. 1992. Water Quality Standards for Surface Water of the State of Washington. Chapter 173-201-A. WAC.
☐	Ward, J.V. 1992. Aquatic Insect ecology: Biology and Habitat. John Wiley and sons. 438 pp.

PART II - NARRATIVE

Section 7. Abstract

Abandoned hardrock mines have been shown to have devastating impacts on water quality and aquatic life in impacted creeks. Such an impacted creek is Alder Creek in Okanogan County, Washington. We measured the effects of acid mine waste from Alder Mine on the physical, chemical and biological condition of Alder Creek under B.P.A. contract 98BI-09396. This proposal represents an extension of this contract.

Alder Creek provides habitat for juvenile salmonids including native steelhead, chinook salmon and brook trout. At the junction of Alder Creek and the Methow River are spawning grounds monitored by the Yakima and Colville tribes and the Chelan County P.U.D. This project addresses measure 7.8C1 of the CBFW Project which pertains to mining and specifies that,
"… mining activities [shall] comply with state water quality standards".

Our preliminary results indicate that water at sites below Alder Mine exceed Washington's freshwater criteria for heavy metals. Sediment metal concentrations and calcite precipitation were also high. The impact on riparian vegetation was also determined. The benthic index of biotic integrity was less below the mine than above.

While it is clear that Alder Creek has been impaired, the extent of impact has not been determined. The objectives of this project, therefore, are to measure seasonal fluctuations of acid mine waste; measure heavy metal loading in forest soils, in Alder Creek, and in the mainstem of the Methow River; and to measure metal uptake, and

transfer in the stream food web. The results will be used to shape a remediation plan, and when evaluated in the context of larger watersheds, they will assist in a more accurate assessment of other watersheds impacted by toxics.

Section 8. Project description

a. Technical and/or scientific background

Abandoned hardrock mines have been shown to have devastating impacts on water quality and aquatic life in impacted creeks (Plotnikoff 1988, Huchton 1995). Acidic drainage and waste rock leachate containing cadmium, chromium, copper, lead, nickel, silver, and zinc affect the physical, chemical and biological integrity of streams. Historically, exposure to elevated levels of metals has been used to estimate the potential damage to human health and to non-human biota. For regulatory purposes, exposure is usually defined as the concentration of a chemical at the external surface of the affected organism. State and federal water quality standards, written as the maximum allowable concentration of a substance in the water column, reflect this definition (WAC, 1992).

Exposure is usually expressed in terms of the concentrations of the heavy metals in the medium (e.g., water, sediment, and soil). The toxic effect of a given pollutant, however, is a function of the amount of contact between heavy metals and the outer surface of the affected organism. Exposure should, therefore, include an indication of the time and frequency of exposure to the contaminant.

Biological assessment methods that measure changes in the density and diversity of benthic macroinvertebrates have become useful indicators of heavy metal transport and exposure as well as watershed health (Karr 1981, 1997; Davis 1995). Benthic macroinvertebrates are useful because they are long-lived organisms that are affected by impaired water quality and because they integrate the effects of exposure to metals through both aquatic and food-chain transport pathways (Ward 1992).

There are over 150 abandoned hardrock mines in eastern Washington that have been screened to identify sites that have the potential of posing a threat to human health and the environment. An initial investigation of forty-five sites was conducted in 1995 and 1996 (Huchton, 1997). Of those sites, thirty-five (8%) were found to be sufficiently hazardous to warrant soil and water sampling. Ten (22%) were recommended for “No Further Action” either because they were “active” or too insignificant to warrant a full investigation. Of the thirty-five sites sampled, twenty-eight (80%) had at least one contaminant above cleanup levels.

The Alder Mine, an abandoned gold, silver, copper and zinc production mine located east of Alder Creek near its source in Okanogan County, Washington was listed as a site with a high likelihood of releasing hazardous waste based on size, commodity, and status (Huchton, 1997). The initial investigation and pre-screening study prioritized the potential hazards of the Alder Mine but was not adequate to estimate the presence or absence of a problem (Huchton, 1997).

Preliminary results indicate that water from Alder Creek below the mine exceed Washington State's acute freshwater criteria for cadmium, copper, and zinc (Peplow, 1998). The concentrations of these elements also appear to vary between high and low flow periods. The density and diversity of benthic macorinvertebrates was also found to be less below the mine than above indicating the biological integrity of the stream ecosystem has been compromised. These results establish the existence of a problem. The next phase of this study will determine the extent of the problem and will be used at a later time to help shape a remediation proposal.

This proposal addresses four important questions related to habitat condition in the Alder Creek watershed: 1) what is the nature and extent of current metal contamination including mass loading measurements, 2) what was the estimated premining background level of metals in stream water and sediments, 3) is the contamination bioavailable and migrating into the foodweb, and 4) what is the extent of biological impairment. When paired with the neighboring unimpacted Poorman Creek watershed, we have a model system for studying the watershed scale effects of acid mine drainage. The final results, when evaluated in the context of larger watersheds, will also assist in a more accurate assessment of watersheds impacted by toxics.

b. Rationale and significance to Regional Programs

The abandoned Alder Mine is located in an environmentally sensitive mountain watershed that discharges water in to the Methow River at historic spawning grounds for chinook salmon, steelhead, and bull trout. The significance of Alder Mine as a source of heavy metal contamination depends, however, on the toxicity of the particular metals, the quantity of metals entering the stream, and whether or not the metals remain in the stream in toxic form. The amount of metal entering a stream is called mass loading and it is calculated as the product of metal concentration and stream discharge. The overall effect of high metal concentrations on Alder Creek, the Methow River and on aquatic organisms is unclear without mass loading measurements. This project will account for the quantity of trace metals entering Alder Creek and how much stays in the creek, enters the Methow River, as well as the amount of contaminating metals entering the foodweb.

c. Relationships to other projects

This project is consistent with the Methow subbasin goals to improve water quality as well as in-stream flow. This project also will include the transfer of technical information regarding the impact of mines on watershed health including the physical, chemical and biological condition of streams and riparian habitats impacted by acid mine drainage and waste-rock leachate. Results from this project will be provided to managers and regulatory agency representatives. Principal contacts include the following:

Kate Terrell, USFWS, Moses Lake, WA
Lynda Hoffman, WDFW, Twisp, WA
Bob Raforth, WA DOE, Yakima, WA
Nick Ceto, US EPA, Seattle, WA
Dave Norman, WA DNR, Olympia, WA
Rod Lentz, USFS, Okanogan, WA
Ken Williams, WA DFW, Malott, WA
Richard Smith, USFW, Moses Lake, WA
Jennifer Molesworth, USFS Winthrop, WA
Greg Knott, USFS Winthrop, WA
Robert Plotnikof, WA DOE, Olympia, WA
Rick Roeder, WA DOE, Yakima, WA

Letters of consistency (support letters) will accompany the Statement of Work and can be furnished upon request.

d. Project history (for ongoing projects)

The key personnel working on this project are Dan Peplow and Robert Edmonds. Professor Edmonds is principal investigator and chairman of Dan Peplow’s graduate committee. Dan Peplow is a graduate student in the College of Forest Resources at the University of Washington and is affiliated with the Center for Streamside Studies.

Preliminary results from the first year of this Bonneville Power Administration project, contract number 98BI-09396, indicate that acid mine drainage and waste-rock leachate impact the water, substrates and benthic macroinvertebrates of Alder Creek and show that the chemical, biological, and physical characteristics of Alder Creek have been altered. The in-stream concentration of copper, cadmium, chromium and zinc exceed Washington State’s acute freshwater criteria. The benthic macroinvertebrate community responded with a reduction in both the population density and taxonomic diversity. The infiltration of subsurface acid mine drainage supersaturated with calcite into the stream resulted in a calcite precipitation gradient that increased with distance away from the mine. It appears that the impact from the acid mine drainage and waste-rock leachate has been significant and has transformed the Alder Creek watershed.

Chemical Impacts

Drainage from two adits and soils affected by waste-rock leachate were sampled and tested. The first adit was acidic (pH < 3.0). Data presented in Table 1 indicate that cadmium, copper, and zinc were above acute freshwater criteria (Chapter 173-201A WAC). Lead was above chronic freshwater criteria. The second adit was not acidic (pH = 7.2). Cadmium, copper, selenium, and zinc were above acute freshwater criteria. Paste pH of waste-rock averaged 3.74. Forest soil between the waste-rock and the creek averaged 5.51. Forest control soil not affected by waste-rock leachate was 6.44.

Table 1. Metal concentrations in acid mine drainage from the Alder Mine.

	Cd (µg/L)	Cu (µg/L)	Se (µg/L)	Pb (µg/L)	Zn (µg/L)
Adit pH < 3.0	4,760	21,680	<67	560	331,170
WAC Criteria	67	1808	*N.A.	64	982
Adit pH = 7.2	180	950	270	<24	12,610
WAC Criteria	19	66	20	Not	390

* (NA=Not Applicable).

Dissolved oxygen, alkalinity, pH, and temperature were measured in-situ in Alder Creek (test site) and in Poorman Creek (reference site).. Water samples were assayed for total metals and the samples from sites below the mine exceeded the acute freshwater criteria for cadmium, copper, and zinc. Respiration chambers were used to estimate perilithic photosynthsis and indicate relative algal densities on stream substrate.

Table 2. Metal concentrations and ancillary measurements of water samples from Alder Creek and the reference stream compared to Washington freshwater criteria (entered where applicable in parenthesis).

	Poorman Creek Reference	Above Mine Impact Site	Below Mine Impact Site	Down-stream 1 Km	Down-stream 2 Km
Cd (µg/L)	<9 (NA*)	<9 (NA)	110 (16)	33 (14)	<9 (NA)
Cu (µg/L)	<4 (NA)	<4 (NA)	140 (55)	20 (30)	<4 (NA)
Zn (µg/L)	<106 (NA)	<106 (NA)	6,360 (328)	1,040 (309)	720 (313)
B-IBI**	15	12	9	9	10
PH	8.3	8.6	8.2	8.4	8.5
Temperature (°C)	8.8	9.5	9.4	9.2	9.4
Alkalinity (ppm CaCO)	223	194	242	276	265
Dissolved Oxygen (mg/L)	9.5	9.0	9.2	9.1	9.0
Algae (2-hr Delta DO) ppm O_2	+ 0.75	+ 0.45	+ 5.9	+3.6	+ 2.3
Sediment Calcite (%)	5%	4%	2%	14%	38%

*(NA=Not Applicable) **Benthic Index of Biological Integrity (Karr 1997)

Calcite, present in soil and stream sediment, appears to dominate the chemistry of soil and ground water (Table 2). Acid digestion of substrate was conducted to estimate calcite composition. It has been observed that precipitates of calcite increase with distance downstream from the mine impact site. This feature may be extremely important if one is concerned about their ability to neutralize acid mine waters.

Calcite solubility is a function of pH and CO2 pressure (Langmuir, 1997). According to Langmuir, at atmospheric CO2 pressure, the saturation pH is 8.3 which is approximately equal to the pH of Alder and Poorman Creeks. Surface water, infiltrating and percolating through soils and sediments, picks up additional CO2 making them less saturated with respect to calcite when compared to stream water. Following the mixture of ground water and stream water, stream turbulence causes CO2 loss making the stream water over-saturated with respect to calcite. This is followed by calcite precipitation under atmospheric CO2 pressures. This process was also observed to occur at low levels in the reference stream.

The carbonates of Fe, Mn, Zn, Cd, Co, and Pb are less soluble than calcite (Langmuir 1997) and so these metal carbonates are expected to precipitate out. It has been observed that the calcite precipitate in Alder Creek is significantly higher in metals than the carbonate mineral layers formed in the nearby arid soils as caliche.

Biological Impacts

Invertebrate data from surber samples (Table 2) were used to evaluate the biological condition of Alder Creek. A preliminary analysis of the data using a 5 metric benthic index of biotic integrity (B-IBI) was compared to the results from a reference stream. The impact of mine waste on the biotic condition of Alder Creek appears to be most severe immediately below the mine and increases slightly with distance downstream from the mine. The index scores is a composite of five metrics expressed as a number out of a possible 25 that include taxa diversity, pollution intolerance, and percent of dominant taxa. Also, algal densities appear greatest immediately below the mine and decrease with distance downstream.

Trend Analysis

Water samples from the Alder Creek sample site immediately below the mine were collected weekly to measure trends in the concentration of cadmium, zinc, chromium and copper (Table 3). Cadmium and zinc exceeded Washington's criteria for freshwater and declined to near criteria levels approximately 4 weeks after peak high flow following spring runoff. The concentration of metals, however, rose within two weeks to previous levels and remained high until the end of the study period. Chromium was several times the acute criteria limit and remained constantly high throughout the course of the study. Copper was found to be several times higher than the acute freshwater criteria during high flow but declined steadily and within five weeks it had dropped to the detection limit of the assay method.

Table 3. **Trends of heavy metal concentrations (µg/L) in stream water over time between high and low flow.**

	Month 1	Week 2	3	4	Month 2	Week 6	7	8	Month 3	Month 4
Cadmium	107	80	70	18	88	99	102	102	94	112
Zinc	6397	3505	3205	593	4320	4845	4870	4730	4135	4789
Chromium	73	70	74	65	72	77	77	75	71	71
Copper	112	50	19	12	7.2	4	4	4	4	4

Sediment samples were also collected in triplicate, sieved to 2 mm and analyzed for total metals. The concentration of zinc in the sediments immediately below the mine site (59 mg/Kg) was approximately 70 times higher than in the reference stream (0.846 mg/Kg) and 42 times higher than in the reference tributary of Alder Creek (1.4 mg/Kg) not impacted by the mine. Similar results were obtained for cadmium and copper.

Endangered Species

To identify salmonids in Alder Creek a survey was conducted by direct underwater observation (snorkeling) on Friday, September 4, 1998. The study area included three pools. The pools contain cover from undercut banks, overhanging riparian vegetation, stumps, roots, coarse woody debris, and submerged aquatic vegetation. All three pools contained fish, less than 100-125 mm in length, that were too numerous to count (TNTC) precisely. Pool number 2 was chosen for snorkeling due to access, lighting, and visibility. The species observed and identified as present were:

	Common Name	Latin Name	Number Observed
1.	Steelhead/Rainbow (native)	*Salmo gairdneri*	1
2.	Chinook Salmon	*Oncorhynchyus tshawytscha*	4
3.	Cutthroat Trout	*Salmo clarki*	1
4.	Sucker	*Catostomus sp*	3
5.	Mountain Whitefish (presumptive)	*Prosopium williamsoni* (presumptive)	4
6.	Unidentified		TNTC

Methods, notes and observations were reviewed with Heather Bartlett, Fish Biologist, Washington Department of Fish and Wildlife, who concurred with the identifications that were made. The steelhead/rainbow was identified as a native based on the presence of its adipose fin. The identification of fish as “presumptive mountain whitefish” was made based on parr mark patterns and body morphology according to Pollard et al. (1997) and Scott (1973).

Premining Metal Concentrations

As part of this research, stratigraphic techniques were used to analyze a sediment core and estimate the pre-mining background levels of the components found in acid mine drainage. These estimates will be used to establish target criteria for restoration. It is not clear, however, what the extent of heavy metal loading on an annual basis is and whether the biology of a watershed will return to a premining state when stream water chemistry has been restored. The premining biological condition can be estimated by measuring the benthic index of biological integrity in selected reference streams that have not been impacted by acid mine drainage.

e. Proposal objectives

The purpose of this study is to understand the biological consequences of acid mine drainage from the abandoned Alder Mine in Okanogan County, eastern Washington. In this study, analyses will be made to determine the seasonal fluctuations of acid mine drainage and waste-rock leachate; measure heavy metal loading in forest soils, Alder Creek, and the mainstem of the Methow River; and estimate metal uptake, transfer and potential hazards in the stream food web.

The specific objectives of this study are to determine: 1) the monthly fluctuations of surface and subsurface current speed, flow, and temperature; 2) the annual cycle of water (surface and subsurface) and sediment chemistry, and fluctuations in the benthic index of biotic integrity based on monthly samples; 3) premining background levels of metals in the water and sediments of Alder Creek based on a stratigraphic analysis of sediment cores using lead isotope dating methods; 4) relationships among metal concentrations in surface and subsurface water, suspended colloids, sediment, and stream biota based on the measurement of metal concentrations in periphyton samples (algae, microorganisms, and mineral deposits); 5) uptake of heavy metals by forest and riparian vegetation and the transfer of metals among trophic levels and the potential hazard of metal toxicity to fish based on measurements of metal concentrations in the tissues of invertebrates and amphibians; and 6) heavy metal loading in forest soils below the mine. A GIS model of the Alder Creek Watershed will also be completed and used for data analysis and mapping.

<u>Anticipated Results</u>

The results from this study will be used to test the following three hypotheses:

1) The impact of metals on biotic indices increases as a function of increasing mass loading and exposure. Biological impact, therefore, will be explained better by exposure and mass loading than by metal concentration alone.
2) The presence or absence of certain species relative to specified reference sites is an indicator of metal contamination or, conversely, ecosystem health.
3) Metal contamination by acid mine drainage reduces biodiversity and changes species composition resulting in a short-link, closed loop food chain.

Sampling and Analysis Plan (SAP)

A *Quality Assurance Program Plan* will be prepared that meets the Washington State Department of Ecology's and the U.S. E.P.A.'s guidelines and specifications. The Quality Assurance Project Plan, which will include the 16 elements described in the EPA's guidelines, will be completed and submitted for review prior to initiation of fieldwork. Standard methods that comply with Washington Department of Ecology and U.S. Environmental Protection Agency guidelines will be used.

Surface water and sediment samples for chemical analysis and concurrent Surber samples for analysis of benthic macroinvertebrate analysis will be collected to determine annual cycles at predetermined sample sites. Replicate samples will be collected to add power to the statistical analysis. Triplicate Surber samples will be collected at each site. Triplicate surface water, sediment, and Surber sample will be collected monthly for 15-24 months.

Triplicate core samples will also be taken at a depositional pool downstream from the mine as recommended by the Assistant State Geologist, Regulatory Section, Division of Geology and Earth Sciences at the Washington State Department of Natural Resources. Geochronological measurements of core fractions will be performed to determine the pre-mining concentration of metals.

Data Evaluation and Management

The chemical model will be analyzed in terms of the biological model. The impact of metal concentration on benthic fauna diversity will be considered. Results will be analyzed using analysis of variance procedures (ANOVA, $P<0.05$) for significant differences in metric scores between stations. A regression analyses will be conducted to determine whether or not there is a correlation between variables and to describe the shape of the response curve. Metal concentration in water and sediment samples and diversity values for benthic fauna at each of the ten sampling sites will be evaluated by regression analysis. Residual plots will be used to evaluate linearity and normality. Standard methods for data transformation will be used to approximate a linear model if necessary. The impact of metals on indicator taxa and functional feeding groups and the potential influence of insect drift from upstream areas will be considered.

Time Schedule

A detailed schedule that includes major tasks, milestones and decision points will be included in the Statement of Work (SOW). The proposed date of field sampling is October 1999. Major tasks include field sampling, chemical and biological sample analysis, data analysis and report preparation. Decision points include review and approval of the sampling and Analysis Plan (SAP), review and approval of preliminary results and quarterly reports, review and approval of second quarterly report by 12/1, review and approval of draft report by 2/1/98 and approval of a final report by 10/2001.

f. Methods

Site Description

The Alder Creek Mine is located in forest land on the western slope of McClure Mountain at an elevation of 3600 feet and approximately 0.2 miles east of Alder Creek (Huchton, 1995). The mine is on privately owned property surrounded by U.S. Forest Service property (and partially on USFS property) approximately 3 miles southeast of Twisp in Okanogan County, WA (Twn. 33N, Rng. 21 E, Sec. 25, 26, 35, and 36).

The Alder Mine was a gold, silver, copper, and zinc production mine from before 1937 to 1953. The owner granted the author permission to access their property for the purpose of conducting the proposed study in a letter dated September 3, 1997.

Vegetation at the site is characterized by Douglas-fir and ponderosa pine, which dominate the overstory. Pinegrass dominates the understory to the extent that other species are inconspicuous. Shrubs are normally a minor component of the stand. Soil texture is sandy loam to sand and the parent material is granitic rock. Slope position is mid to lower 1/3 at approximately 30% with a western aspect.

Sample sites along the mainstem of Alder Creek basin have been selected for study based on habitat comparability. Additional sites will be studied on a tributary of Alder Creek that is distal to the mine and in the adjacent Poorman Creek drainage, which will serve as references for the Alder Creek study.

Biological Condition

Benthic macroinvertebrates will be quantitatively sampled at each sample site using the Surber method. All benthic macroinvertebrates will be keyed microscopically to genus except for Diptera which will be keyed to family. At each of the sample sites, Surber samples will be collected and sorted following standard procedures for the analysis of benthic macroinvertebrates. Samples will be sorted and specimens will be identified and used in metrics analyses. In addition to the benthic index of biotic integrity (B-IBI), the following ten indices will be calculated from the Surber data: 1) Total Taxa Richness, 2) Ephemeroptera-Plecoptera-Tricoptera (EPT) Index, 3) Ratio of EPT to EPT-plus-Chironomidae, 4) Percent contribution of the dominant taxon, 5) Ratio of shredders to all other individuals collected, 6) Ratio of collectors-filterers to all other individuals collected, 7) Ratio of scrapers to scrapers-plus-filterers/collectors, 9) Forest Service Biotic Index (FSBI), 10) Hilsenhoff Biotic Index (HBI).

Chemical Analysis

Sampling and sample preservation protocols recommended by the EPA will be used. All chemical analyses for heavy metals will be performed using assays for total metals by ICP atomic emission. Chemical assays will be performed in the DOE certified Analytical Services Laboratory at the UW College of Forest Resources. Geochronological measurements of sediment core fractions will be performed to determine the pre-mining concentrations of metals using ICP analysis methods for total metals and Pb isotope dating techniques.

Surface current speed will be measured at the specific sampling locations by timing floating objects over a fixed distance. Current speed should be between 30 and 150 cm/second. The minimum current speed should be greater than or equal to 50% of the maximum current speed unless it is within 20 cm/sec.

Temperature, pH, flow, dissolved oxygen, and conductivity will be measured in situ at each sample site. Preserved samples of water and sediment will be transported to Seattle for analysis at the University of Washington, College of Forest Resources laboratory. All samples will be analyzed for total metals.

Chemical results will be analyzed in terms of aquatic life criteria. Benthic community data will be summarized and statistically analyzed using organism density, taxa richness, Ephemeroptera-Plecoptera-Tricoptera (EPT) richness, and metals tolerance indices. The impact of metals on indicator taxa and functional feeding groups identified in the creek and the potential influence of insect drift from upstream areas will be considered.

Monitoring Well Installation

The controlling assumption concerning the effects of mine drainage and waste rock leachate is that dissolved metals enter and mix with ground water, move from an upgradient source and flow downgradient into Alder Creek according to the normal laws of ground water flow. In order to verify ground water flow and the migration of heavy metal contaminants, piezometers will be installed to permit sampling for total metals in the subsurface water.

Hydrology

Discharge from the Alder mine will be measured by adding Rhodamine-WT dye to the tunnel effluent. The fluorometric procedure (Wilson, 1968) will be used to measure the concentration of the tracer downstream from the injection point. The results will be used to define hydrologic properties such as the velocity of subsurface drainage migration, travel time, mixing of solutes, the quantity of inflow from groundwater, and the transient storage in streambed cobbles. Piezometers will be installed to verify subsurface flow and the aquatic transport of heavy metals.

g. Facilities and equipment

The University of Washington College of Forest Resources in Seattle, Washington, will provide field equipment and laboratory space. Chemical analysis of water samples for total metals will be performed by the Analytical Services Laboratory at the University of Washington, College of Forest Resources.

h. Budget

The total FY2000 budget requested for this project is $53,820 plus cost sharing contributions from the University of Washington to cover salary and benefits for Robert Edmonds, PI. Indirect costs are 18% ($9603) of total. Total direct costs are 69% ($36,936) of total. Total salaries and benefits are 30% ($15,876) of total. Supplies and materials are 15% ($7560). Other items include chemical analyses ($7,000, 13%), piezometers ($7,281, 14%), printing/telephone/office ($3,000, 6%), laboratory supplies ($4,036, 8%), field sampling mileage and travel to meetings ($3,500, 7%).

Section 9. Key personnel

1. Dan Peplow
   Masters student, University of Washington, College of Forest Resources, Division of Ecosystem Sciences.

2. Robert L. Edmonds
   Professor, College of Forest Resources, Graduate Committee Chairman

Resume´

Robert L. Edmonds
Professor, College of Forest Resources
University of Washington, Seattle, 98195

Ph.D.	1971	University of Washington (Forest Pathology)
M.S.	1968	University of Washington (Forest Pathology)
B.S.	1964	Sydney University, Australia (Forestry)

1993 – 1997	Chairman, Ecosystem Science and Conservation Division, University of Washington
1984 – 1986	Vice Chairman, Forest Resources Management Division, University of Washington
1982 – Present	Professor, University of Washington

1979 – 1982 Associate Professor, University of Washington

1976 – 1979 Assistant Professor and Director Pack Forest, University of Washington

1973 – 1976 Associate Director, US/IBP Coniferous Forest Biome Program and Research Assistant Professor

1971 – 1973 Program Coordinator to Director, US/IBP Aerobiology Program, Botany Department, University of Michigan

1966 – 1970 Research Assistant, College of Forest Resources, University of Washington

1965 – 1966 Research Assistant, Department of Forestry, Australian National University, Canberra, Australia

1964 – 1965 Research Forestry Officer, Forest Research Institute, Canberra, Australia

Robert Edmonds has 35 years experience conducting research in forest biology, nutrient cycling, soil microbiology and ecosystem and watershed studies. He has expertise in stream chemistry and has been involved with students and postocs in invertebrate studies. Four pertinent publications are listed below from a list of 135 publications.

Edmonds, R.L. and R.D. Blew. 1997. Trends in Precipitation and Stream Chemistry in a Pristine Old-Growth forest Watershed, Olympic National Park, Washington. J. Am. Water Res. Assoc. 33:781-793.

Edmonds, R.L., T.B. Thomas, and R.D. Blew. 1995. Biogeochemistry of an Old-Growth forested Watershed, Olympic National Park, Washington. Water Res. Bull. 31:409-419.

Edmonds, R.L., D. Brinkley, M.C. Feller, P. Sollins, A. Abee, and D.D. Myrold. 1989. Nutrient Cycling:Effects on Productivity of Northwest Forests, pages 17-35. In: D.A. Perry, R. Neurisse, B. Thomas, r. Miller, J. Boyle, J. Means, C.R. Perry, and R.F. Powers. (Eds.) Maintaining the Long-Term Productivity of Pacific Northwest forest Ecosystems. Timber Press, Portland, OR.

Edmonds, R.L. (Ed.) 1982. Analysis of Coniferous Forest Ecosystems in the Western United States. US/IBP Synthesis Series. Hutchinson Ross, Stoudsburg, Pennsylvania. 419 P.

Dan Peplow
Bachelor of Science, Zoology, University of Washington, 1997
Bachelor of Science, Bacteriology and Public Health, Washington State University, 1977

1997 to Present	Masters Student, University of Washington, College of Forest Resources, Division of Ecosystem Science and Conservation, Seattle, Washington.
1996 to 1997	Undergraduate, University of Washington, Zoology Department, Seattle, Washington.
1984 to 1996	Manager, Vertebrate Cell Culture Process Development and Manufacture of Recombinant Human Therapeutics, Amgen Inc., Thousand Oaks, California.
1981 to 1984	Research Associate, Invertebrate Cell Culture Process Development, Southwest Foundation for Biomedical Research, San Anotonio, Texas.
1978 to 1981	Parasitologist, National Institute for Agricultural Research (Peace Corps), Ecuador, South America.

Dan Peplow has approximately 17 years experience in biology. Three years as a Peace Corps volunteer participating in public health projects and conducting basic research on the incidence of parasitosis in people and cattle in Ecuador. Three years were spent as a research associate developing process for the large-scale production of insect cells and baculoviruses and the expression of heterologous proteins in culture. Eleven years were dedicated to vertebrate cell culture process development and manufacturing of recombinant human therapeutics. The last two years have been dedicated to the completion of a second degree in zoology and the beginning of graduate studies in forestry focusing on the effects of acid mine drainage and waste rock leachate on watershed ecology.

Peplow, D, D. Carillo, C. Pereria, V. Pimentel, E. Tupman, M. Vanetsky (1990). Modified CUSUM Control Chart: A Statistical procedure for analysis of cell growth data. *In Vitro Cellular and Developmental Biology*, 26(3, part 2): 56A.

Weiss, S.A., D. Peplow, G. C. Smith, R.H. Goodwin (1984). Replication of *Heliothis zea* baculovirus in insect cells grown in serum-free media. *Journal of the Tissue Culture Association*, 20(3):271.

Weiss, S.A., D. Peplow. S.S. Kalter, J.L. Vaughn (1982). Dissociation of insect cell cultures by pancreatin. *In Vitro*, 18(3):298.

Peplow, D. (1982). Intestinal parasites in the people of various regions of Ecuador. *Bulletin of the Pan American Health Organization (WHO)*. 16(4):401-403.

Section 10. Information/technology transfer

A final watershed analysis report will be developed to provide pertinent project findings to the Pacific Power Planning Council (the Bonneville Power Administration), to state and to federal water quality management officials, as well as industry, in an effort to better understand mine site impacts on water quality and biological receptors. A summary report will be prepared to summarize initial findings in early 1999.

Congratulations!