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PRELIMINARY ENVIRONMENTAL IMPACT ASSESSMENT OF THE SUNRISE MINE-MILL PROJECT ON FISH AND WILDLIFE RESOURCES

by

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SUMMARY

This report reviews the available fish and wildlife statistics regarding the Stillaguamish River system with specific emphasis on the South Fork Sunrise Mine site. A review of the recent literature was conducted concerning the toxicity of heavy metal ions to fish and wildlife likely to result from the proposed mining and milling of copper. Since adequate specific comprehensive aquatic and terrestrial ecological baseline data are not available for the site, a study outline detailing the general kinds and scope of studies needed was developed. Detailed review of the revised operational plan at this time is not possible due to the lack of comprehensive ecological data and a need for further specificity in how the mine-mill operation will be designed to prevent water pollution.

INTRODUCTION

The International BrenMac Development Corporation and Century Explorations Inc. have submitted a revised proposal detailing the operational plan for development of the Sunrise Mining Project located in eastern Snohomish County, Washington. The mine site lies on land managed by the U.S. Forest Service and the Washington State Department of Natural Resources at the headwaters of the South Fork of the Stillaguamish River. Both agencies in cooperation with the developer are compiling a draft environmental impact statement for the proposed mine-mill operation. The University of Washington Fisheries Research Institute was contracted to provide technical assistance on the potential effects on fisheries and wildlife resources which may result from this proposed project.

This report responds to four objectives which required the compilation of existing literature and fish and wildlife statistics. The objectives were to:

1. Review the available fisheries and wildlife statistics regarding the Stillaguamish River system with specific emphasis on the South Fork mine site, as far as possible;

2. Review the literature concerning the toxicity of those heavy metal ions likely to occur and their effects on fish and wildlife;

3. Outline the general kinds and scope of the aquatic and terrestrial ecological baseline studies needed in order to obtain the necessary data for completion of an environmental impact assessment of the proposed action; and

4. Review the operational plan from the viewpoint of real or potential impacts on the fish and wildlife resources.

The report is organized by objective, and each is addressed to the extent presently possible.

OBJECTIVE 1: Review of the available fisheries and wildlife statistics regarding the Stillaguamish River with emphasis on the South Fork Sunrise Mine Site.

FISHERIES

Four of the five species of Pacific salmon use the South Fork of the Stillaguamish River as a migratory pathway to their spawning grounds in the upper river reaches or use the river proper for spawning. There are, in addition, three anadromous species of trout which use the river: winter and summer steelhead, sea-run cutthroat and Dolly Varden. Each species generally spawns in a particular region of the river or its tributaries although spawning areas may overlap. Adults of one or more species enter the system every month and upstream migration timing overlaps considerably (Puget Sound Task Force, 1970).

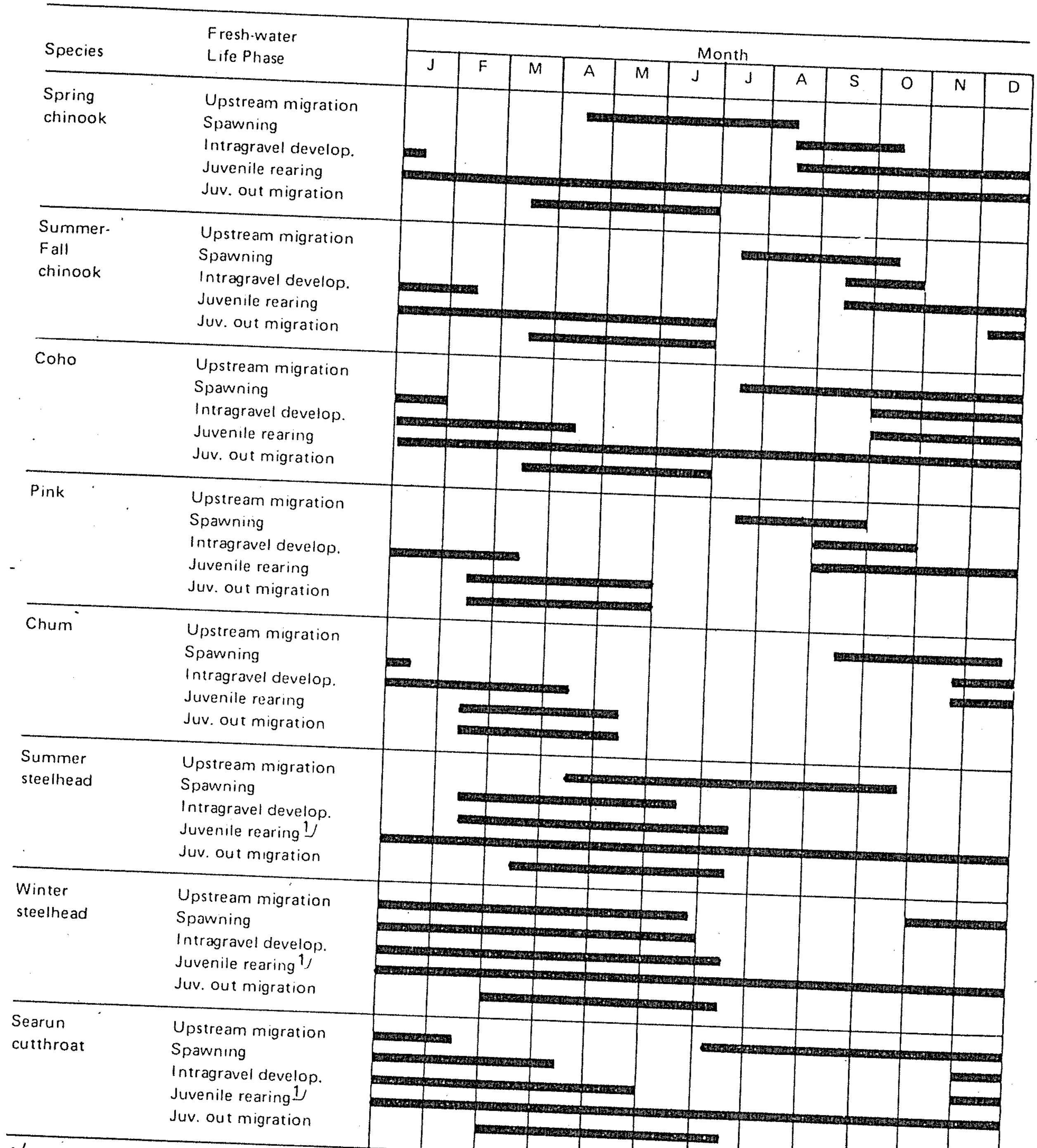
There are many similarities between the life histories of these anadromous salmon and trout. The adult fish migrate in from the sea and spawn in the gravel of a river or stream. The eggs are deposited in nests or "redds" which have been excavated by the adults and then covered up. The eggs develop in the gravel for several months before hatching, and the young remain in the gravel until the yolk sac is fully absorbed. Depending on the species, the fully formed and free-swimming fry emerge from the gravel late in the winter or as late as early summer, and remain in fresh water for a few weeks or up to several years before entering salt water. The fish feed and grow to adult size in the sea and return to fresh water from one to five years later, also depending on the racial stocks and species.

Salmon have access up the South Fork of the Stillaguamish River to River Mile 69, which is upstream of the tributaries flowing down from the Sunrise Mine site (Washington State Department of Fisheries, 1975). A fish ladder was installed near Granite Falls (RM 34.5) in 1954 to provide passage for chinook, coho, and pink salmon which utilize the good spawning and rearing habitat in the upper reaches of the river.

Chinook Salmon.

Stream sections throughout the accessible length of the South Fork of the Stillaguamish, plus portions of the main river downstream from Arlington receive chinook spawners. Canyon and Jim Creeks are important South Fork tributaries supporting chinook populations (Puget Sound Task Force, 1970). Occasional plants of chinook are made in the upper South Fork by the Washington State Department of Fisheries.

Both spring and fall races of chinook salmon run in the South Fork of the Stillaguamish River. Spring chinook migrate up the river from April to August and spawn from August to October. The eggs develop in the gravel until January. The juveniles spend a year rearing in the river and leave the streams for salt water in May or June of the following year. The fall races of chinook migrate upstream from July to October and spawn in September and October. Eggs develop in the gravel until February, when the juveniles emerge and migrate out of the river between March and July (Figure 1). Chinook adults return to the stream at the age of four or five years and may weigh over 30 pounds.



1/ Normally extends over a two-year period.

Figure 1. Timing of anadromous salmonid freshwater life phases in the Stillaguamish Basin. (From: Comprehensive Study of Water and Related Land Resources, Puget Sound and Adjacent Waters, State of Washington, Appendix XI Fish and Wildlife. By Puget Sound Task Force of the Pacific Northwest River Basins Commission, 1970).

Chinook salmon are the most important fish in the marine sport salmon catch in Puget Sound (Area 8) off the mouth of the Stillaguamish River with an average of 3,468 fish caught by anglers per year from 1964 to 1973 (Table 1). Chinooks also constitute an important element in the commercial catch, averaging 13,220 from 1960 to 1974 (Table 2). Total natural chinook production (harvest plus escapement) for the Stillaguamish River Basin was estimated to have averaged 19,760 chinooks per year for the period 1959 to 1965 (Puget Sound Task Force, 1970).

Table 1. Marine sport salmon catch for the Skagit Bay - Deception Pass area (#8) for the period 1964 to 1973.

Year	Chinook	Coho	Pink	Estimated Total Salmon	Marine Angler Trips	Salmon per Trip
1973	2,556	779	631	3,966	16,650	0.240
1972	2,786	311		3,097	18,273	0.169
1971	2,745	1,986	458	5,189	35,281	0.150
1970	5,368	322		5,690	46,351	0.120
1969	2,556	980	159	3,695	27,267	0.140
1968	2,863	758		3,621	22,948	0.160
1967	3,950	1,123	1,052	6,121	33,942	0.180
1966	3,367	2,293		5,660		
1965	4,912	3,954	1,387	10,253	Not Available-----	
1964	3,577	1,951		5,528		
	$\bar{x}$=3,468	$\bar{x}$=1,446	$\bar{x}$=737	$\bar{x}$=5,282		

From: Washington Salmon Sport Catch Report From Punch Card Returns, by Gene D. Nye and W. Dale Ward. State of Washington, Department of Fisheries. Statistics Section. Reports from each of the following years: 1973, 1972, 1971, 1970, 1969, 1968, and 1967.

Table 2. Commercial marine salmon catch for the Skagit Bay - Deception Pass Area (#8) for the period 1960 to 1974.

Year	Chinook	Coho	Sockeye	Pink	Chum
1974	4,943	19,918	1,095		1,313
1973	8,133	9,904	641	51,334	7,371
1972	5,197	9,468	1,109		2,566
1971	8,121	21,071	340	62,286	9,675
1970	7,797	22,995	30		3,774
1969	8,183	5,600	306	9,070	459
1968	10,869	13,864	448		19,719
1967	8,885	11,639	784	34,710	1,848
1966	19,180	21,053	61		3,022
1965	27,278	16,886	286	42,734	1,462
1964	18,238	21,461	781		9.958
1963	18,076	30,418	3,944	731,240	16,538
1962	12,243	33,259	1,286		11,064
1961	24,102	38,132	300	104,047	12,064
1960	17,055	10,086	578		5,865
	$\bar{x}$=13,220	$\bar{x}$=19,050	$\bar{x}$=799	$\bar{x}$=147,917	$\bar{x}$= 7,113

From: Washington State Department of Fisheries, Annual Report, years 1960 through 1974.

Coho Salmon.

Coho salmon spawn in sections throughout the South Fork of the Stillaguamish River and in many accessible tributaries such as Boardman, Canyon, and Jim Creeks (Puget Sound Task Force, 1970). Coho have also been reported spawning in Perry and Buck Creeks, as well as the upper South Fork of the Stillaguamish River above the mine site. Occasional plants of coho have been made in the upper South Fork by the Washington State Department of Fisheries.

Coho salmon begin migrating into the Stillaguamish River in mid-July and continue through December. Spawning takes place from September through October, and the eggs develop in the gravel through January. The fry rear in pool areas of the river for a year prior to migration to sea from March through June of the following year (Figure 1). The adult fish generally return when they are three years old although a few return at age four.

Coho salmon have traditionally been the most numerous species in the Puget Sound commercial salmon catch of the Stillaguamish River in non-pink salmon years (even years). Cohos are second only to chinooks in the sport fishery, averaging 1,446 per year from 1964 to 1973 (Table 1). Preliminary 1974 figures show that commercial fishermen caught almost 20,000 coho in Area #8 (Table 2). The catch averaged 19,050 per year from 1960 to 1974. Total natural production for the Stillaguamish River Basin was estimated to have averaged as much as 106,000 fish per year for the period 1959 to 1965 (Puget Sound Task Force, 1970).

Pink Salmon.

Pink salmon spawn in the numerous riffle areas of the lower South Fork of the Stillaguamish River mostly downstream from Granite Falls. In addition, they spawn in virtually every tributary of the Stillaguamish and in the main river to within about five miles of its mouth (Puget Sound Task Force, 1970). The upper South Fork also provides good spawning and rearing habitat for pink salmon.

Pink salmon have a two-year life cycle and in Puget Sound waters return almost exclusively in odd-numbered years. They usually begin migrating up the Stillaguamish in mid-July and continue through September. Spawning takes place between September and October. Eggs develop in the gravel until March, and the juveniles migrate down to salt water through May (Figure 1). Juveniles usually form large schools in estuarine areas for several months before migrating out to deeper water.

Pink salmon in odd-numbered years have usually been the largest contributor to the commercial salmon catch off the mouth of the Stillaguamish. The most recent figures indicate that over 51,000 were taken in this area during the 1973 season (Table 2). Pinks also have always formed a significant percentage of the marine sport salmon catch in the past (Table 1). No recent figures on natural productivity of pink salmon in the Stillaguamish River Basin have been made available to us by the Washington State Department of Fisheries.

Chum Salmon.

Considerable chum salmon spawning occurs in the South Fork of the Stillaguamish River downstream from Granite Falls. Few chum salmon have ever been recorded upstream from the falls. They also spawn downstream in the main river to within about five miles of the mouth as well as in most tributary streams (Puget Sound Task Force, 1970).

Chum salmon migrate up the Stillaguamish from September to December and spawn from November through January. The eggs develop in the gravel until as late as April. The juveniles spend a few days to a few weeks in fresh water before migrating to the sea, and return to fresh water as adults in three to five years (Figure 1).

Chum salmon are less valuable per pound than any other salmon species and do not factor heavily in the sport fishery, but do contribute significantly to the commercial catch (Table 2). Total natural chum salmon production for the Stillaguamish River Basin was estimated to have averaged close to 17,000 fish per year for the period 1956 to 1965 (Puget Sound Task Force, 1970).

Steelhead Trout.

Steelhead have been observed in almost every part of the Stillaguamish River system downstream from anadromous fish barriers. Spawning occurs in selected reaches and rearing takes place in all available sheltered sections (Puget Sound Task Force, 1970).

There are both summer and winter runs of steelhead in the Stillaguamish. The summer run is considerably smaller than the winter (Table 3). These fish enter the river June through October and spawn the following February through June. Intragravel development takes place through July. After emerging, the juveniles take up territories in the stream and remain there for one to three years before migrating out to salt water (Figure 1).

The larger runs of winter steelhead enter the river in November and continue through May. Spawning takes place January through June. Eggs develop in the gravel until as late as mid-July (Figure 1).

Table 3. Stillaguamish River Steelhead sport catch from 1965 to 1973. (Winter run count includes November and December of previous year.) (From: Washington Steelhead Catch during [1973, 1972, 1971, 1970, 1969, 1968, 1967, and 1966] by the Washington State Department of Game.)

Year	River	Nov	Dec	Jan	Feb	Mar	Apr	May	*June	July	Aug	Sept	Oct	Nov	Dec	Winter	Summer	Calendar Catch
73	S. Fork		89	155	286	141		7	104	81	57	77	37	3	128	678	356	1076
	Main	49	283	484	417	390				40	47	20	13	24	900	1623	120	2335
72	S. Fork	8	549	395	105	89		39	69	158	125	59	76		89	1095	487	1204
	Main	28	1817	1415	572	234				188	72	26	76	49	283	4066	362	2915
71	S. Fork		422	246	260	201		17	68	184	164	133	127	8	349	1146	676	1157
	Main	59	1899	1124	603	328	17	8	25	59	71	37	28	28	1817	4038	220	4145
70	S. Fork	7	339	243	217	126		3	21	41	70	56	67		422	935	255	1266
	Main	7	796	812	366	296		6	15	18	23	21	38	59	1899	2283	115	3553
69	S. Fork	4	152	200	214	61		7		21	11	18		7	339	638	50	878
	Main	36	1035	789	696	303				21	7	21	39	7	796	2859	88	2679
68	S. Fork	3	216	200	253	101			29	40	11	32	14	4	152	873	126	936
	Main	42	1043	1904	1144	496	29	22	29	40	7	29	36	36	1035	4680	141	4807
67	S. Fork	3	300	181	167	206	7	7	38	59	14	28	7	3	216	871	146	933
	Main	48	1608	911	858	673	14	3	38	91	66	31	14	42	1043	4115	240	3784
66	S. Fork		379	718	366	166			19	83	25	3	29	3	300	1629	159	1712
	Main	19	2581	2986	1276	855	13	6	19	54	51	9	13	48	1608	7736	146	6938
65	S. Fork		28	256	79	202			13	35	47	50	50		379	565	195	1111
	Main	18	838	1346	771	774		3	13	120	19	19	22	19	2581	3750	193	5687

*June through October are summer run fish.

Winter steelhead juveniles rear in the river with summer-run juveniles and remain in fresh water for one to three years.

Data from a Washington State Department of Game questionnaire survey showed a steelhead fishing use of 99,200 angler-days on the river. Natural production contributes almost 50 percent of the catch. The total natural production (1959 to 1965) was estimated to have averaged 2,200 summer-run fish and 37,300 winter-run fish (Puget Sound Task Force, 1970).

Since angling in the Stillaguamish for salmon has been poor in recent years (only 14 fish were caught in the entire river in 1973 (Table 4)), steelhead trout are the primary fish sought by sport anglers. In recent years, the freshwater sport catch in the South Fork has ranged from a high of 1,712 fish taken in 1965-66 to a low of 878 in 1968-69. In the main river below the confluence of the two forks, the sport catch has varied from a low of 2,335 fish in 1972-73 to a high of 6,938 in 1965-66 (Table 3)

Table 4. Stillaguamish River sport salmon catch, 1964 to 1973.

Year	Total	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1973	14			3	3			8
1972	105		3	26	29	27	10	10
1971	517		12	419	56	16	14	
1970	291		26	22	125	94	20	4
1969	69	2			14	44	7	2
1968	172		27	11	66	41	25	2
1967	5,539							
1966	259	----------	Not Available	--------------------				
1965	4,741							
1964	156							

From: Washington Salmon Sport Catch from Punch Card Returns, by Gene D. Nye and W. Dale Ward. State of Washington, Department of Fisheries. Statistics Section. Reports from each of the following years: 1973, 1972, 1971, 1969, 1968, and 1967.

Sea-run Cutthroat and Sea-run Dolly Varden.

Sea-run cutthroat trout migrate up the Stillaguamish from June through February and spawn from December to February. The young develop in the gravel until as late as June. The juveniles stay in fresh water for about two years and migrate down to the sea March through mid-July (Figure 1). Total natural production for the Stillaguamish Basin (1959 to 1965) was estimated at 79,000 fish (Puget Sound Task Force, 1970).

Sea-run Dolly Varden spawn in the early to late fall and the fry emerge the next spring (Figure 1). The juveniles remain in the stream an average of two years before migrating out to salt water. Numbers and production of Dolly Varden trout are limited in the Stillaguamish River drainage (Puget Sound Task Force, 1970).

Resident Fish.

Resident fish species live in most of the stream waters of the Stillaguamish Basin and are especially prominent in waters upstream from anadromous fish barriers. Resident rainbow trout, native cutthroat, Dolly Varden, and whitefish inhabit the streams which provide them with an adequate environment and also support a sport fishery (James DeShazo, Regional Fish Biologist, personal communication). Other resident species occurring in relative abundance include threespine sticklebacks, sculpins, dace, redside shiners, suckers, and squawfish (Puget Sound Task Force, 1970).

WILDLIFE

Wildlife species found in the upper Stillaguamish watershed include black-tailed deer, black bear, mountain goat, mountain lion, ruffed and blue grouse, snowshoe rabbit, mink, marten, river otter, raccoon, bobcat, mountain fox, and coyote (Dalquest, 1948).

Estimates of population size for many of the above species (if any) have usually been made over a much broader area than would be desirable for this study. Figures often must be assumed as equally applicable to the study area as to the larger geographical unit, if they are to be of value.

Deer.

Total deer harvests for "game management unit 7E" (an area roughly bounded by U.S. 2, the Glacier Peak Wilderness, and the towns of Darrington and Index, whose boundaries include much of the watershed of the South Fork of the Stillaguamish River) averaged 443 antlered deer per year for the period 1964-72. During this nine-year period, the average kill for the area was about 2.0 deer per square mile (Table 5). Antlerless deer seasons were held in 1964, 1966, 1967, and 1968, and although numbers varied widely between years, these hunts added an average of 257 extra deer to the hunter's bag. In 1972 it was estimated that in over 430 square miles of deer range (in Unit 7E) there were approximately 18.4 deer per square mile for an estimated population of 7,900 animals (Washington State Department of Game, 1973).

For the Stillaguamish River Basin as a whole, for the years 1961 to 1965, it was estimated that there was an average annual production of 1,970 deer over the spring population and an average annual harvest of 800 animals. Deer hunters spent an average of 16,000 hunter-days annually in pursuit of their quarry in the region (Puget Sound Task Force, 1970).

Table 5. Deer harvest in Game Management Unit 7E, 1964 to 1972.

Year	Antlered	Does and Fawns	Total	Does and Fawns Per 100 Bucks	Kill per Square Mile
1972	490		490		1.1
1971	790		790		1.8
1970	745		745		1.7
1969	780		780		1.8
1968	970	580	1,550	60	3.6
1967	590	10	600	2	1.5
1966	860	50	910	6	2.1
1965	680		680		1.6
1964	887	380	1,267	42	2.9

From: Big Game Status Report, Washington State Department of Game, 1972-1973 and 1968-1969.

Mountain Goat.

Mountain goat harvest for the Stillaguamish River drainage from 1948 to 1972 (the season was closed from 1953 to 1959) varied from a low of five animals taken in 1962 and 1963 to a high of 14 in 1971, and averaged about 8 goats per year (Johnson, 1972). About 100 hunter-use days are devoted annually to the pursuit of goats in the area (Puget Sound Task Force, 1970).

During the 1972 season, four goats (three male and one female) were killed in the vicinity of Vesper Peak near the proposed mine site. A good many more were reported sighted (Johnson, 1972) and the region is considered an important wintering area for goats (Mr. Douglas Bellingham, Regional Game Biologist, Department of Game, personal communication).

Black Bear.

A black bear population of about 750 was estimated for the forested areas of the Stillaguamish watershed. Limited harvest data available indicate an average annual harvest of 150 bears. The annual reproductive rate is estimated to be about 25 to 30 percent, which would result in 150 to 200 cubs annually. An estimated 1,180 hunter-use days are devoted to the pursuit of black bear in the drainage (Puget Sound Task Force, 1970).

A spring bear season was held in the area of the upper South Fork of the Stillaguamish River for 1976. This season was a result of significant bear damage to the commercial timber of the region (Washington Forest Protection Association, 1975).

Mountain Lion.

The small population of mountain lion in the Stillaguamish River drainage results in only an occasional animal taken annually, although about 100 hunter-use days per year have been expended by sportsmen in the past (Puget Sound Task Force, 1970).

Ruffed Grouse and Blue Grouse.

Based on density studies, population estimates of 33,000 ruffed grouse and 22,000 blue grouse were made for the entire area of the Stillaguamish River Basin. Annual production is estimated at 20,000 ruffed grouse and 13,000 blue grouse annually. Hunters take about 4,300 ruffed grouse and 1,100 blue grouse in 7,200 hunter-days annually (Puget Sound Task Force, 1970).

Snowshoe Rabbit.

Snowshoe rabbits are confined to the evergreen-hardwood forest area. Population densities fluctuate widely over time, and the average annual hunter take is not large.

Mink.

Snohomish County, which contains the bulk of the Stillaguamish River Basin, ranks third in the state in the harvest of mink. The basin has been estimated to have roughly 750 mink with an annual production of 250 to 350. The annual harvest averages about 300 animals (Washington State Department of Game, 1974).

Marten.

The marten population of the Stillaguamish River drainage is estimated to be low, and only an occasional animal is taken.

River Otter.

Small numbers of river otter are taken annually in the basin including a few from the South Fork drainage (Washington State Department of Game, 1974).

Raccoon.

Trappers yearly take raccoons from the Basin. A 1973 report notes ten taken in the vicinity of the South Fork, nine in the vicinity of Granite Falls, and 21 in the area of the main river (Washington State Department of Game, 1974).

Bobcat.

Between five and fifteen bobcats are taken in the South Fork Stillaguamish drainage annually (Washington State Department of Game, 1974).

Coyote and Mountain Fox.

Significant numbers of coyote and mountain fox are harvested yearly (Washington State Department of Game, 1974).

CONCLUSIONS

Clearly, the available data show that the South Fork of the Stillaguamish River is an important salmon and trout stream from the river mouth to the Sunrise Mine site. The area also supports important wildlife populations. However, data on both fish and wildlife are of a very general nature and leave much to be desired in the determination of potential impact assessment on terrestrial and aquatic habitats important to the major species occurring in the drainage.

An aquatic and terrestrial baseline study program will be required to obtain the basic data needed before any useful impact assessment can be made.

OBJECTIVE 2: Review of literature concerning selected heavy metal toxicity to fish and wildlife.

Dissolved metals are common pollutants in fresh waters receiving wastes from industrial mining operations. Many studies have proven the often fatal effects these metals can have on aquatic resources and wildlife. Some investigators have attributed the death of fish in waters containing heavy metal cations to the coagulation or precipitation of mucus secreted by the gills, or damage to gill tissues. Insoluble metal-protein compounds formed are believed to interfere with the respiratory function of the gills and thus bring about death by suffocation.

Mount (1967) suggested that there is a threshold concentration of heavy metal ions on the gills and that death occurred when this concentration was exceeded. The tendency of heavy metals to accumulate within fish (other than on the gills) has been noted and it has been suggested that metal ions in any given concentration may become toxic over very long periods of time. Water containing heavy metals in concentrations causing chronic toxicity to fish has resulted in histological changes suggesting cardiac damage, blood cell destruction, degeneration of organs, and retardation of sexual maturity.

The toxicity of all heavy metals to fish and wildlife resources varies with concentration, state of the metal, and the buffering effect of the chemical properties of the water.

Two broad categories of toxic effects may be distinguished: acute toxicity which is usually lethal, and chronic toxicity, which may be lethal or sublethal. Chronic toxicity can affect such things as growth, reproduction, respiration, swimming speed and various physiological functions.

Most of the available recent toxicity data have been reported as the median tolerance limit (TLm or TL50) or median lethal concentration (LC50). Either symbol signifies the concentration that kills 50 percent of the test organisms within a specific time span, usually 96 hours.

Copper.

Aquatic organisms are known to be very sensitive to copper and its compounds. Sprague (1964 a) found that young salmon in soft water avoided concentrations as low as .0023 mg/l and were killed by only 0.48 mg/l of copper.

The toxicity of copper to freshwater organisms varies significantly not only with the species, but also with the physical and chemical characteristics of the water, such as its alkalinity, pH, turbidity, and temperature (McKee and Wolf, 1963). Stiff (1971 a) found that in hard, moderately polluted water much (43 to 88 percent) of the copper present was associated with suspended solids and concluded that it was effectively unavailable to fish in this form. More recent work (Pagenkopf, Russo, and Thursten, 1974) indicates that copper (II) is the chemical species that is toxic to fishes and that alkalinity is the most important factor controlling copper (II) concentration. It was determined that $CuOH^+$ may also be an important toxic species, but less so than Cu^{++}.

Since copper (II) ions are the primary toxic form of copper, then the non-toxic copper carbonate complex formed by copper in alkaline waters accounts for the differences in toxicities of copper to aquatic organisms in hard and soft water. The differences are related not to the differences in hardness *per se* but to the different alkalinities which they accompany (Stiff, 1971 b).

Rainbow trout (Brown, 1968) had the following 48-hour LC50 values for copper at 3 different water hardnesses: .035 mg/l Cu at 10 ppm hardness; 0.12 mg/l Cu at 50 ppm hardness; and 0.20 mg/l Cu at 100 ppm hardness.

Water runoff from copper mine wastes in Idaho has eliminated entire runs of steelhead trout and salmon from Panther Creek, a tributary of the Salmon River (Platts, 1972).

With copper concentrations as low as 0.02 mg/l in soft water Grande (1967) observed that Atlantic salmon fingerlings became unwilling to eat the food given to them. It was also noted that some of the experimental fish acquired a darkened integument compared to the controls. On being disturbed they made characteristic horizontal wiggling movements. However, they seemed to recover and to acclimatize to some extent, but those in the control aquaria were in better condition at the end of the experiment.

Recently Shaw and Brown (1974) exposed rainbow trout to copper at pH values from 6.5 to 7.5 and found that the variation in toxicity was only slightly affected by this small change. At pH 7.5 the 48-hour LC50 was 0.11 mg/l while at pH 6.5 it was 0.12 mg/l.

Precipitation or coagulation of mucus on the surface of the gills in the presence of this metal is believed to interfere with the respiratory function of the gills. This adverse effect was shown (Morgan and Kuhn, 1974) by the sudden increase in opercular activity of largemouth bass when the fish were subjected to high concentrations of copper (5.0 and 1.0 mg/l). A response was also recognized at a concentration of 0.1 mg/l Cu^{++}, although somewhat more delayed. O'Hara (1971) found a large increase in oxygen consumption by bluegills between 3 and 6 hours after first exposed to high concentrations of copper. After producing their maximum respiratory response, the fish entered a phase of declining oxygen consumption which continued until death.

Brungs, Leonard, and McKim (1973) reported a distinct increase and accumulation of copper in the gill tissue and liver of brown bullheads (*Ictalurus nebulosus*) when exposed to concentrations of .027 mg/l Cu and above. Beyond this copper level they postulated that the copper excretory mechanism was probably overloaded and copper accumulated within the body, which contributed to later toxic effects.

Brook trout (*Salvelinus fontinalis*) exposed to low levels of copper (0.067 to 0.069 and 0.038 to 0.039 mg/l Cu) for 6 to 21 days showed complex physiological changes (McKim, Christensen and Hunt, 1970). There were significant increases in red blood cell count, hemoglobin, plasma glutamic oxalacetic transaminase (PGOT), and total protein, while plasma chloride and osmolarity increased during the same periods. At even lower concentrations (0.003 to 0.032 mg/l Cu) for a long term 337-day exposure, no changes were observed in the blood except for a measurable decrease in PGOT values. Such transaminases are reported to be indicators of degradation in salmonids (Bell, 1968), and in this case, were an indicator of cellular degradation by Cu (II), perhaps in the liver or heart muscle.

A "no effect" concentration of 0.0094 mg/l copper and less was reported for brook trout (McKim and Benoit, 1974). At this concentration no adverse effects were observed in either first or second generation fish exposed in the laboratory through a cycle from eggs to spawning. This confirmed the previous findings of McKim and Benoit (1971) on exposure of brook trout to similar and higher copper concentrations, which indicated no adverse effect of exposure from yearlings through spawning to 3-month juveniles at 0.0094 mg/l. At this level and below, apparently the copper excretory mechanism was able to prevent the accumulation of metal in the tissues.

Eggs of rainbow trout exposed to 0.05 mg/l copper in very soft water (8 ppm hardness) experienced a 50 percent mortality during development from the eyed stage to hatching (Grande, 1967). For chinook salmon eggs in water with an alkalinity and hardness of 21 mg/l and 44 mg/l $CaCO_3$, respectively, short term exposures to copper concentrations greater than 0.10 mg/l may have acutely toxic effects (Hazel and Meith, 1970). Chinook sac fry, it seems, are even less resistant than eggs, and copper concentrations greater than 0.02 mg/l have detrimental effects.

The toxicity of copper to various invertebrates varies widely. In water with a hardness of 45.3 mg/l, the cladoceran *Daphnia magna* had a 48-hour LC50 of 0.06 mg/l Cu, a chronic 3-week LC50 of 0.044 mg/l Cu, and experienced some reproductive impairment at concentrations as low as 0.022 mg/l Cu.

Aquatic insects seem less affected by copper toxicities than many fish that have been tested. For the stonefly, *Acroneuria lycorias*, in water with an alkalinity of 54 mg/l, the 96-hour TLm was 8.3 mg/l Cu (Warnick and Bell, 1969). For the mayfly, *Ephemerella subvaria*, with an alkalinity of 42 mg/l, the 48-hour TLm was 0.32 mg/l Cu.

The amphipod *Grammarus pseudolimnaeris* was much more sensitive. The 96-hour TLm in water with an alkalinity of 43 mg/l was 0.020 mg/l Cu (Arthur and Leonard, 1970). The 96-hour TLm values for the snails *Campeloma decisum* and *Physa integra* were 1.7 and 0.039 mg/l Cu, respectively. In general, the operculum of *Campeloma* was tightly closed within the shell aperture in total copper concentrations greater than 1.0 mg/l, but motility about the tank after 24 hours was observed only with concentrations less than 0.03 mg/l. *Physa integra* was not motile in tanks of total copper concentrations greater than 0.03 mg/l. The amphipod *Gammarus*, when placed in total concentrations of more than 0.02 mg/l, immediately exhibited increased locomotor activity but lost its power of motility prior to death. The total copper concentration having no effect after 6 weeks' exposure for all three species was between 0.008 and 0.148 mg/l. These results indicate that these three test species were extremely sensitive to copper, and safe levels approached those already existing naturally in soft water.

Hubschman (1967) studied crayfish (*Oronectes rusticus*) survival to copper under continuous flow conditions and observed that age markedly influenced the acute toxicity level. Newly hatched young were about 15 times more sensitive to copper than adults. A calculated concentration of 0.015 mg/l affected growth of these young after 30 days.

The 120-hour TLm for Cu^{++} ion to the diatom *Nitzschia linearis* in water with an alkalinity of 100 mg/l was between 0.795 and 0.815 mg/l Cu (Patrick, Cairns, and Scheier, 1968). The use of $CuSO_4$ as an algicide and for chemical control of rooted aquatic plants is well known.

Evidence indicates that the effects of copper on aquatic organisms can be magnified considerably by its synergistic association with zinc. Solutions containing mixtures of the two metal ions appeared to be much more toxic to aquatic organisms than would be expected if their effects were only additive (Bell, 1973).

Copper is not considered to be a cumulative systemic poison to mammals as are lead or mercury. Most of the copper ingested is excreted and very little is retained (McKee and Wolf, 1963). Daily copper doses of 6 to 9 mg per day have been harmful; doses amounting to more than 1 mg/kg of body weight are definitely injurious to growth (Anon., 1950).

Hale (1942) has reported that one gram daily of soluble copper salts is safe for dogs, and that all sheep died when given 18 to 182.5 grams of copper in quantities as high as 2 grams daily. Cartwright (1950) found that among cattle, toxicity develops at one gram of copper sulfate per pound of live weight per day; the symptoms of poisoning include loss of appetite, copper accumulation in the liver, jaundice, and yellow discoloration of the entire animal. Laboratory animals fed copper sulfates in excessive quantities developed intense inflammation of the gastro-intestinal tract among other symptoms (Browning, 1969).

The only reference found concerning the effect on wildlife of copper in water states that 630 mg/l or more of copper sulfate in water caused turkeys to drink other water if given a chance, and 2500 mg/l $CuSO_4 \cdot 5H_2O$ in water was harmful to the birds when this was the only water available (Hinshaw and Lloyd, 1931).

Copper and its compounds are extremely toxic and are a hazardous potential threat to the aquatic and wildlife resource of the Stillaguamish River Basin. Its introduction from mining wastes into a stream in Idaho caused the complete elimination of the anadromous runs of salmon and steelhead trout (Platts, 1972). Copper ions entered into the system from mine portal discharge waters and from the tailings pond. Concentrations as high as 1,200 mg/l were reported in the water, and these eliminated all fish and aquatic life completely. All efforts should be made to minimize any potential for accidental introduction of copper or its compounds into the Stillaguamish River System.

Iron and Iron-Sulphur Compounds

The toxicity of iron is complicated by the fact that aqueous solutions of its salts, such as chlorides, nitrates, and sulfates, are markedly acidic because of partial hydrolysis. When one of these iron salts is added to alkaline receiving water, a nearly insoluble hydroxide may precipitate out onto the bottom of the stream (Doudoroff and Katz, 1953).

Fish and aquatic life may be adversely affected by dissolved iron, although the amount of iron actually in solution will be extremely small in well-aerated streams (Bell, 1973).

The mineral pyrite (which is found at the mine site) is nearly insoluble, and as long as it remains in the soil, without access to air, it will remain unchanged. When exposed to the atmosphere, however, pyrite is oxidized, causing the formation of sulfuric acid and iron salts, predominantly iron (II) sulfate. The water is often acidified to the point where it becomes unlivable for different species of aquatic life.

When the pH is below 3.0, iron (II) sulfate will remain in solution. When the pH increases above 3.0, hydrolysis results in the formation of insoluble iron (III) hydroxide and sulfuric acid.

In water in which the pH has been brought below 3.0 by sulfuric acid and iron (II) sulfate, fish will be killed immediately by the acid action alone. Low pH values have been found to kill or delay the emergence of many species of aquatic insects (Bell, 1971). The 30-day TL50 pH values for a number of insects were as follows: *Brachycentrus americanus* at 2.45, *Hydropsyche betteri* at 3.38, *Taeniopteryx maura* at 3.71, *Acroneuria lycorias* at 3.85, *Ophiogomphus rupinsulensis* at 4.30, *Boyeria vinosa* at 4.42, *Isogenus frontalis* at 4.50, *Pteronarcys dorsata* at 5.00 and *Ephemerella subvaria* at 5.38.

Under other conditions where a certain amount of buffer is present in the water and the hydrolysis of iron (II) sulfate starts, possibly accelerated by iron bacteria (*Thiobacillus* sp.), the fish are killed by the precipitation of ferric hydroxide on their gills (Dahl, 1963).

Larsen and Olson (1948) found that fish kills occurred in a trout hatchery when the pH value of the water was 6.2 to 7.0, and the water contained from 1.5 to 20 ppm Fe; the cause of death was attributed to the precipitation of iron (III) hydroxide on the gills, since the pH value of the water was higher than the lethal value.

Pyrite ore entering water systems of the Salmon River in Idaho made the waters very acidic (Platts, 1972), and water draining pyrite wastes into Spring Creek, California, lowered the pH to 2.3. Benthic macroinvertebrates and diatom standing crop was reduced, while young chinook tested in the water died (Benoit, Cairns, and Reiner, 1967).

Cruz (Ashley, 1969) exposed goldfish to iron (II) chlorides and sulfates, and to iron (III) chlorides and sulfates at concentrations from 5 to 100 mg/l. Gills of the affected fish had epithelial edema, hypersecretion of mucus, inflammation, capillary congestion, destruction of respiratory epithelium, blockage of gill filaments and lamellae by mucoferruginous hydroxide precipitates in epithelial cells and in lumens of renal tubules. Fish responded similarly to exposure to the four iron salts tested.

Much of the data in the literature on iron toxicities to fish is difficult to compare because of the strong complicating effects of pH and alkalinity. Jones (1939) reported fish deaths from $FeCl_3$ concentrations as low as 1.0 mg/l, and Minkira (1946) reported deaths of several fresh water fish at 0.2 mg/l $FeCl_3$. On the other hand, for *Gambusia*, Wallen *et al.* (1957) reported the 96-hour TLm for $FeCl_3$ as 73 mg/l and for $Fe_2(SO_4)_3$ as 133 mg/l.

Anderson (1948) found that for *Daphnia magna* the median 64-hour threshold limit was less than 6.2 mg/l Fe. More recently Biesinger and Christensen (1972) reported the 3-week LC50 to be 5.9 mg/l. Some reproduction was impaired at a still lower concentration of 4.3 mg/l Fe.

The 96-hour TLm for the mayfly *Ephemerella subvaria* for iron from $FeSO_4$ was as low as 0.32 mg/l (Warnick and Bell, 1969). A stonefly, *Acroneuria lycorias* and a caddisfly, *Hydropsyche betteri*, were also exposed to 16 mg/l of $FeSO_4$ until a 50 percent mortality resulted. This mortality occurred after 9 days for *Acroneuria* and after 7 days for *Hydropsyche*.

Iron compounds often give water a noxious taste and some mammals will not drink the water if it is high in dissolved iron (Taylor, 1935).

In general, iron compounds in the ore used by the proposed mine, and in the tailings waste produced by it, are a significant potential hazard to the aquatic biota of the area if not properly contained.

Zinc.

Fish are strongly affected by zinc. Concentrations as low as 0.01 mg/l have been observed to be lethal (Bell, 1973). The toxicity of zinc compounds is modified by several environmental factors. Lloyd (1960) found the survival times of rainbow trout to zinc at three water hardness levels: 320 ppm, 50 ppm, and 12 ppm. He observed that the effect of hardness increased with increase in survival until there was a ten-fold difference between the toxicities of zinc in the hardest and softest water over 2-1/2 days' exposure.

There was a reduction in reproduction of *Daphnia magna* at a zinc concentration of 0.10 mg/l using soft water (45 mg/l as $CaCO_3$) (Beisinger and Christensen, 1972). No effect was observed at 0.07 mg/l, which indicated that *D. magna* was more resistant to zinc than most fish.

An incipient lethal level of 0.6 mg/l Zn was reported for young Atlantic salmon by Sprague (1964 b). For rainbow trout Lloyd (1960) showed an incipient lethal level for zinc of 0.7 mg/l in water of 20 mg/l hardness. The 24-hour LC50 for rainbow trout was reduced only 20 percent when the fish were forced to swim at 85 percent of their maximum sustainable swimming speed (Herbert and Shurben, 1964).

Mixtures of zinc and copper cut survival times of salmon in half (Sprague, 1964). This strong synergism makes these mixtures up to 5 times more toxic than either of the metal ions alone (Skidmore, 1964; Doudoroff and Katz, 1953). Both an increase in temperature and a reduction in dissolved oxygen concentration can increase the toxicity of zinc.

Sprague (1964) reported that salmon can detect dissolved zinc down to 10 mg/l and avoid it if possible. At acutely toxic concentrations zinc kills adult and juvenile fish by destroying the gill tissues. At chronically toxic levels it may induce stress that results in death (Skidmore, 1964).

Patrick, Cairns and Scheier (1968) found the 96-hour TLm for the snail *Physa heterostropha* to be from 0.79 to 1.27 mg/l $ZnCl_2$. They also reported the 120-hour TLm for a diatom, *Nitzschia linearia*, to be 4.3 mg/l $ZnCl_2$.

Water Quality Criteria (1972) suggests that once a 96-hour LC50 has been determined using the receiving water in question and the most sensitive important species in the locality as the test organism, a concentration of zinc safe to aquatic life in that water can be estimated by multiplying the 96-hour LC50 by an application factor of 0.005.

Rats fed zinc in their food at concentrations ranging from 0.4 to 1.0 % showed reduced growth, anemia, poorer reproduction, and decreases in bone calcium (Prasid, 1966). Rats, cats, frogs, and snails all showed a reduction in arterial blood pressure when subjected to different concentrations of zinc (Chanh, Suong, Silve-mamy and Plancade, 1969).

In general biological organisms seem highly affected by even small quantities of zinc and its compounds. Therefore it seems necessary that all possible efforts be made to prevent or minimize their actual exposure to it.

Silver.

The toxicity of silver ions was documented by Jones (1939). He stated that "they precipitate the gill secretions and bring about asphyxiation with extreme rapidity". In soft water the lethal concentration limit for sticklebacks was as low as .003 mg/l Ag. With different concentrations of silver the average survival times of the fish were as follows: one week at 0.004 mg/l, four days at 0.01 mg/l, and only one day at 0.1 mg/l of silver.

Earlier, Marsh and Robinson (1908) reported that 0.04 mg/l $AgNO_3$ (0.025 mg/l Ag) killed some, but not all, chinook salmon fry within 48 hours; 0.044 mg/l $AgNO_3$ proved decidedly toxic; and 0.033 mg/l did not prove fatal in 48 hours.

Anderson (1948) reported the threshold concentrations of $AgNO_3$ to be 0.0051 mg/l for the immobilization of *Daphnia magna* in Lake Erie water which agreed well with Jones' (1939) data for sticklebacks. Bringman and Kuhn (1959) studied the threshold effects of silver, added as silver nitrate on various species during a 4-day exposure at 23 to 27 C. For *Daphnia* and *Microregma* the median threshold effect occurred at 0.03 mg/l of silver, for a common bacterium, *E. coli*, at 0.04 mg/l, and for the algae *Scenedesmus* at 0.05 mg/l. Silver ions were found to be among the most toxic of several tested to the fungus *Alternaria tenuis* (Somers, 1959).

Shaw and Grushkin (1957) found silver at a concentration of 0.01 mg/l killed fish and at 0.1 mg/l tadpoles of the toad *Bufo valliceps*. Bell (1973) suggested 0.003 mg/l Ag as a desirable maximum limit concentration for fresh water aquatic life.

Rabbits fed between 0.25 and 0.025 mg/kg per day for 11 months exhibited a marked decrease in immunological capacity, histopathological changes in the vascular, nervous, and neuroglial tissues of the brain, and certain changes in conditioned reflexes (Barkov and El'piner, 1968). No effect or changes were noticed in the hemoglobin, red blood cells, or differential white blood cells. A concentration of 0.0025 mg/kg was proposed as the maximum ineffective dose to the rabbits.

The high toxicity of silver cations makes them a significant threat to aquatic resources and a potential for environmental damage exists were they to find their way into the aquatic ecosystem of the Stillaguamish River Basin. The potential threat to wildlife is not thought to be as great.

Molybdenum.

Molybdenum occurs at the mine site in the natural mineral molybdenite, MoS_2. In very low concentrations the element has been found to be an essential trace element necessary for a number of plants and mammals (Underwood, 1971; Marston, 1952).

In larger quantities Tarzwell and Henderson (1960) found that the toxicity of molybdic anydride (MoO_3) to fathead minnows varied with the water hardness. In water with a hardness of 400 ppm, total alkalinity of 360 ppm and a pH of 8.2, the 96-hour TLm was 370 mg/l of MoO_3. But, when the water hardness was lowered to 20 ppm the 96-hour TLm decreased dramatically to only 70 mg/l MoO_3. Water hardness in the proposed mine area is expected to more closely approximate this lower hardness value.

A more recent study by Ward (1973) examined molybdenum concentrations in the tissues of rainbow trout from waters of varying molybdenum content. He found that concentrations in the tissues increased only slightly with increased molybdenum concentrations in the water. Fish from high (300 ppb) molybdenum water had mean concentrations of 13 to 372 ppb on a wet weight basis; those from low (6 ppb) molybdenum water had 10 to 146 ppb; those from trace molybdenum water had 5 to 118 ppb. Molybdenum concentrations in fish analyzed were considerably less than those found by other workers with mammals (Higgins *et al.*, 1956; Underwood, 1971) which may relate to the well developed osmoregulatory system of salmonids. It is suggested that the similar concentrations in tissues of fish from the three waters suggests a threshold beyond which excess molybdenum is efficiently excreted.

Laboratory animals fed 10 mg/l molybdenum for life showed no changes in growth rate or longevity (Schroeder, 1970), but at very high concentrations (350 mg/l) cattle suffered diarrhea, anemia, loss of weight, and discoloring of the hides (Farnsworth, 1970).

Molybdenum as MoS_2 is insoluble in water in the range of pH expected around the mine site. In the small quantities present, it will probably have no significant toxic effect on the biota in the area.

Tungsten.

Only a limited amount of research has been done on the effects of this element to aquatic life and terrestrial organisms.

Using water from the River Havel, from which the test organisms were obtained, Bringman and Kuhn (1959) studied the median threshold effects of tungsten added as sodium tungstate. For *Daphnia* the median threshold effect during 48-hour exposure at 23 C occurred at 350 mg/l of tungsten; for the alga *Scenedesimus* at 24 C for 4 days the median threshold level was 110 mg/l of tungsten; for *Microregma* it was 502 mg/l of tungsten; and for the bacterium *E. coli* at 27 C it was 167 mg/l of tungsten.

According to Kinard and Van De Erve (1941) complete mortality of rats was produced by 2% of tungsten in sodium tungstate and 5% of tungsten in ammonium partungstate in the diet. On the other hand, 1000 to 5000 mg/l (150 to 730 mg/kg per day) was not acutely toxic to rabbits but did retard growth.

WO_3 is the naturally occurring tungsten compound in the mineral wolframite at the proposed mine site. It is attacked only slightly by mineral acids and is insoluble in water at the pH values likely to be encountered at the mine site.

Other than its possible physical effects as a fine particle sediment, WO_3, in the small quantities present would not be expected to have a significant effect on the fish and wildlife resources of the area.

<u>Magnesium and Calcium</u> (as MgO and CaO)

Neither of these elements is thought to be toxic to aquatic life except at extremely high concentrations. Moderate amounts of both Ca and Mg ions in fresh water even tend to reduce the toxicity of many chemical compounds to fish and aquatic organisms. These differences in toxicity are apparently caused by the chemical complexation of toxic ions to non-toxic carbonate complexes (Stiff, 1971 b).

Wallen, Greer, and Lasater (1957) reported that laboratory fishes in $CaCO_3$ and $CaSO_4$ concentrations from 10 to 56,000 ppm remained in good condition. The 96-hour TLm was greater than 56,000 ppm, and for $CaCl_2$ the 96-hour TLm was 13,400 ppm. Values for two magnesium compounds were as follows: $MgCL_2$, 16,500 ppm; $MgSO_4$, 15,500 ppm, for 96 hours.

Anderson (1948) found the threshold levels for immobilization of *Daphnia magna* by $CaCl_2$ and $MgCl_2$ to be 920 mg/l and 740 mg/l, respectively. Biesinger and Christensen's (1972) 96-hour TLm values for $CaCl_2$ and $MgCl_2$ for *D. magna* compared nicely: 914 mg/l and 743 mg/l, respectively. Some reproductive impairment occurred for $CaCl_2$ at 321 mg/l and for $MgCl_2$ at 320 mg/l. Patrick, Cairns, and Scheier (1968) reported a 120-hour TLm for $CaCl_2$ for the diatom *Nitzschia linearia* as 3,130 mg/l and for $CaSO_4$ as 3,200 mg/l.

Birds and mammals appear not to be affected by MgO or CaO except in extremely high concentrations (McKee and Wolf, 1963).

Aluminum Oxide

Aluminum oxide, an amorphous white powder readily absorbs water but is insoluble in it (McKee and Wolf, 1963). The most recent research by Freeman and Everhart (1971) indicated that aluminum salts were slightly soluble at neutral pH, and 0.05 mg/l dissolved and had no sublethal effects on fish. At pH 9, and relatively higher concentrations (5 mg/l) of aluminum, fingerling rainbow trout were killed in 48 hours. However, the suspended precipitate of ionized aluminum is toxic. In most natural waters the ionized or potentially ionizable aluminum would be in the form of anionic or neutral precipitates, and anything greater than 0.1 mg/l of this would be detrimental to growth and survival of fish (Water Quality Criteria, 1972).

Rabbits fed 10 to 20 mg/kg per day of aluminum for 6 months showed no change in growth, hemoglobin content, or white and red blood cells (Petina, 1965). Maynard (1947) reported much higher levels of aluminum than those found in food or water have been fed continuously to rats, dogs, pigs and man without observable harm. Since then, however, (Browning, 1969) excessive amounts of Al (1,400 ppm) have been shown capable of lowering the level of inorganic phosphorus in the bones of mammals.

Gold.

The pure metal is extremely inactive, and insoluble in water. A few gold salts are soluble in water, but owing to the fact that the hydroxide, monochloride, monoxide, and several other combinations are insoluble, gold ions are not likely to be found in natural waters (McKee and Wolf, 1963).

Jones (1939) used chlorauric acid ($HAuCl_4$) to examine the toxic effects of gold on sticklebacks. The gold solutions were slightly acid and at concentrations of 3 mg/l the pH reached 5.0 and death was attributed to acidity rather than to the gold cation. With further dilution the solutions rapidly approximated a neutral pH, but a definite toxic effect was evident down to 0.4 mg/l, which represents the lethal concentration limit for gold. Average survival times at other concentrations were as follows: one week at 0.6 mg/l, 4 days at 1.0 mg/l, and less than 12 hours at 3 mg/l. All solutions used had to be kept in darkness due to the decomposing action of light upon them. Of the few other experiments using gold, data obtained are suspect (Iwao, 1936) due to poor technique and complexation and with other anions.

Biesinger and Christensen (1972) examined the chronic toxicity of $HAuCl_4 \cdot 3H_2$) to *Daphnia magna* in water with a total hardness of 45.3 mg/l, an alkalinity of 42.3 mg/l, and a pH of 7.74. In terms of the gold ions only, the 3-week LC50 was 1.05 mg/l, and reproduction was reduced by 16 percent at only 0.06 mg/l gold in solution.

The relative insolubility of gold and its compounds, and the small quantities in which it is present in both the ore and tailings, will serve to minimize its potential effect on the biota of the area. Nevertheless, it is still a possible significant source of toxicity to aquatic life should it get into a stream or river course.

CONCLUSIONS

Although the alkalinity and hardness of the water in the South Fork of the Stillaguamish River is not precisely known, it is generally expected to be low. This expectation is based on experience in other streams draining the west slope of the Cascade mountains which have been measured and which are low in total alkalinity and hardness. The literature clearly indicates that the toxicity of copper and some other heavy metals increases with low or decreasing alkalinity and hardness. Therefore, the toxicity of copper ions, if allowed to enter the South Fork or its tributaries, will result in detrimental impacts on aquatic life and fishes. These impacts can be expected to be more severe to aquatic life than those observed in waters flowing from other copper mine-mill operations where the alkalinity and hardness of the receiving waters are substantially greater, as for example, the mining regions in the Rocky Mountains.

OBJECTIVE 3: Brief outline of the general kinds and scope of the aquatic and terrestrial ecological baseline studies needed to obtain the necessary data required for an environmental impact analysis.

Existing data on the ecology of the Sunrise Mine project area and its fishery and wildlife resources is minimal. The following abbreviated outline defines investigations which should be conducted to establish a comprehensive ecological baseline for the site. Data are needed to assess the possible impact of the proposed mining and milling operation on the biota of the area. Studies should include: (1) a determination of the physical and chemical characteristics of all the water courses in the affected region, (2) their primary productivity, including natural input of organic terrestrial detritus to the streams, (3) abundance and diversity of the benthic organisms, (4) relative abundance, distribution, and timing of each life history stage for each of the fish populations, (5) terrestrial vegetative mapping of the affected areas as well as any critical summer or winter range, and (6) distribution and abundance of the game and non-game animals and birds in association with each habitat, and a determination of the seasonal, spatial, and temporal changes occurring. A minimum study period prior to initiation of any mining activity should include two full years since pink and chum salmon occur in alternate years. These data will provide a basis for assessment of impacts due to mining and provide the developer with data on which to evaluate claims for mitigation which may be blamed on the mining development as well as meet the requirements for an Environmental Impact Statement.

AQUATIC STUDIES (FISHERIES)

1.0 Water Quality

1.1 Sampling Scheme

Nine sampling stations should be established: four on the South Fork of the Stillaguamish River, two upstream from the mining activity and two below it, and one below the confluence of the North Fork on the main stem. In addition, two stations each should be established on Perry and Palmer Creeks. On Palmer Creek one station should be established above the pumping station and another below it. On Perry Creek one station should be established upstream from the tailings disposal sites and one below them.

1.2 Physical and Chemical Parameters to be monitored at each station, general method and minimum sampling frequency.

1.2.1 Discharge: U.S.G.S. gages or array of gages on upstream tributaries, continuously.

1.2.2 Temperature Records: thermographs, continuously.

1.2.3 Water Transparency: turbidity meter, monthly and weekly during runoff periods.

1.2.4 Dissolved Oxygen: modified Winkler method, monthly.

1.2.5 pH: meter, monthly.

1.2.6 Alkalinity and Hardness: Hach water analysis kit, monthly.

1.2.7 Conductivity: samples collected and analyzed with laboratory conductivity meter.

1.2.8 Biological Oxygen Demand (BOD): laboratory measurement of the amount of oxygen remaining in a sample of water held in the dark at 20 C for 5 days, monthly.

1.2.9 Chemical Oxygen Demand (COD): digestion of water samples with $K_2Cr_2O_2$, monthly.

1.2.10 Reduced Carbon: laboratory determination of the amount of organically reduced carbon in a water sample as per <u>Standard Methods</u> (1974), monthly.

1.2.11 Total Nitrates and Phosphates: preserved in field and analyzed in the laboratory per <u>Standard Methods</u> (1974), monthly.

1.2.12 Metals: magnesium, calcium, copper, iron, zinc, silver, aluminum, by atomic absorbtion spectrophotometry, monthly.

1.2.13 Sulfate: laboratory determination by gravimetric method with ignition of residue, monthly.

1.2.14 Cyanide: cyanide-ion-selective electrode method, monthly.

1.3 Biological Parameters

1.3.1 Periphyton standing crop and primary production with artifical substrates, bimonthly.

1.3.2 Detritus input: detritus samples collected with drift nets, bimonthly.

1.3.3 Secondary Producers: benthos, standing crop and diversity, bimonthly.

1.3.4 Relative abundance and distribution of anadromous and resident fishes (juvenile and adult).

1.3.5 Escapement: (Washington Department of Fisheries Records).

1.3.6 Time of spawning and determination of extent of upstream spawning.

1.3.7 Incubation, emergence, and condition factors of juveniles; electroshocking at the stations, winter and spring.

1.3.8 Population estimates of resident fishes: Lincoln-Peterson mark-recapture method, annually.

1.3.9 Species diversity: species richness, electroshocking and identification, annually.

1.3.10 Condition factors: electroshocking and laboratory measurements, annually.

TERRESTRIAL STUDIES (WILDLIFE)

1.0 Habitat Studies

1.1 Sampling Scheme: systematically spaced transects throughout the affected areas.

1.2 Objectives: to index the distribution and abundance of the vegetational complex of the study area and to determine the seasonal, spatial, and temporal changes.

1.3 Habitat Typing: from aerial photographs, habitats typed, mapped, and quantified.

1.4 Vegetative Sampling

1.4.1 Trees and Shrubs: species presence, frequency of occurrence, density, percentage cover, and standing biomass: line intercept technique, annually.

1.4.2 Forbs and Grasses: species presence, frequency of occurrence, density, percentage cover, and standing biomass: microplot technique, annually.

1.4.3 Tree and shrub forage production and utilization: measurement of growth increment (fall) and utilization (spring).

2.0 Wildllife Studies

2.1 Sampling Scheme: sampling stations will of necessity be highly variable as assessment procedures will vary for the many wildlife forms being assessed. Insofar as possible, sampling should center on the same transects utilized in the habitat analysis, thus making possible greater correlation of the habitat data with the faunal data.

2.2 Sampling methods

2.2.1 Pellet Group Transects: population indices of deer, goats, bear, rabbits, major predators and furbearers will be conducted along the vegetational transects, bi-annually (spring and fall).

2.2.2 Car Route Surveys: wildlife censuses along existing logging roads in or near the study area. The route should be established insofar as possible along an altitudinal rise to assess spatial shifts in the area's prominent wildlife, monthly, in spring, summer, and fall.

2.2.3 Small Mammals: systematic snap-trapping along the vegetational transects, bi-annually on three consecutive nights during spring and fall.

2.2.4 Terrestrial Birds: visual and auditory counts along the transects by the Emlen technique, spring, summer, and fall, three times each season.

2.2.5 Amphibians and Reptiles: collected and logged incidentally as observed on transects.

2.2.6 Bats and Coyotes: these species should be assessed for relative abundance at special night stations, monthly.

2.2.7 Endangered Species: a specific attempt should be made to document presence, numbers, and status of all endangered species in the area.

2.2.8 Deer: abundance and distribution, movements, and food habits visually surveyed along transects over the different seasons, specimens for rumen samples collected, monthly.

2.2.9 Goats: abundance, distribution, movements, censused by hunter-kill and radio tagging as well as direct observations, bi-weekly in fall, winter and spring.

2.2.10 Bear: surveys along transects of pellets, hunter-kill and track surveys on logging roads, monthly, in spring, summer and fall.