POTENTIAL FOR SUBMARINE TAILINGS DISPOSAL TO AFFECT THE AVAILABILITY OF MINERALS FROM UNITED STATES COASTAL AREAS

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CONTENTS

ILLUSTRATIONS

TABLES

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

dpy	days per year	mt	metric ton
g	gram	mtpd	metric tons per day
g/mt	gram per metric ton	mtpy	metric tons per year
kg	kilogram	mtu	metric ton unit
lb	pound	st	short ton
ltu	long ton unit	tr oz	troy ounce
Mmt	million metric tons	yrs	years

POTENTIAL FOR SUBMARINE TAILINGS DISPOSAL TO AFFECT THE AVAILABILITY OF MINERALS FROM UNITED STATES COASTAL AREAS

by James R. Coldwell[1] and Edward C. Gensler[1]

ABSTRACT

The Bureau of Mines investigated submarine tailings disposal (STD) as an alternative to on-land tailings disposal. This report evaluates coastal metal deposits in the United States that may be amenable to STD. A pre-feasibility economic analysis comparing the two methods for twenty deposits in Alaska was completed. Environmental aspects of the deposits and potential effects of STD on minerals availability were evaluated.

On average, Net Present Values (NPV) were 22.3% larger for STD than for on-land disposal, due to a 17.0% reduction in capital costs, a 1.6% increase in operating costs, and a 7.1% reduction in breakeven prices.

Although STD has substantial promise for Alaska, a policy change would have little effect on minerals availability. Only three projects could benefit from STD in the near term. These deposits with a Gross Metal Value of $9.75 billion would provide 1,835 jobs. Four deposits may benefit in the longer term. These four marginally economic projects with a Gross Metal Value of $19.5 billion would provide 1,180 jobs. Thirteen would not benefit, as STD alone didn't overcome other economic factors.

None of the deposits had oceanographic or environmental constraints preventing STD use. Bathymetry, nearshore slope, profile, threatened and endangered species, and fisheries were considered for this preliminary report.

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INTRODUCTION

Present Environmental Protection Agency (EPA) policy precludes the use of Submarine Tailings Disposal (STD) (10)[2]. However, because of unique opportunities in Alaska, the Bureau of Mines (Bureau) has spent three years investigating STD and evaluating its application. This work has resulted in a series of publications providing an overview and bibliography, two volumes of case studies of STD worldwide, and analysis of implications of current United States policy (10,11,40,46). The conclusion of this work is a well designed STD system in some coastal areas can be an environmentally acceptable alternative to on-land disposal of mill tailings in a tailings impoundment (11).

In comparison, the on-land tailings disposal option generally involves the construction of a dam in a drainage, or an embankment on sloping or level terrain, which is used to impound the tailings. These structures are often the largest surface feature of a mine and can be quite massive, flooding hundreds of acres and permanently changing the terrestrial environment. Tailings impoundments are generally left in place after mining has ceased, and often require perpetual inspection, rebuilding, and maintenance.

The long-term stability of a dam and impounded mine tailings is dependent on the site's climate and seismicity, and on how well the facility was designed, constructed, and operated. In some coastal areas, long after decommissioning of the structure, extreme precipitation and/or seismic events could bring about an unexpected catastrophic failure. In spite of these detriments, current EPA regulations consider tailings impoundments to be the best available technology for all tailings disposal. As will be illustrated in this study, in the majority of cases, on-land disposal will continue to be accepted practice regardless of a change in EPA policy toward STD.

On the other hand, the marine environment is inherently stable and unaffected by extreme climatic or seismic events and will not need long-term inspection, rebuilding or maintenance. STD may cause a change in the bathymetry, and make some of the seafloor, where active deposition is taking place, uninhabitable by marine biota.

There may also be a long-term change in the seafloor habitat from whatever was there originally to a perhaps shallower, smooth, sandy bottom. Deep, rocky fjords are gradually filled with sand naturally in Alaska coastal waters, where sediment-laden, glacially-fed rivers empty into fjords. However, studies indicate that these new habitats are rapidly recolonized and become highly productive once tailings deposition ceases (46). Submarine disposal of tailings limits the potential for reprocessing of tailings for additional mineral extraction in the future.

This report summarizes an evaluation of the effect a change in policy to allow STD would have on the availability of minerals to the United States (U.S.). The entire coastline of the U.S. was screened for metallic mineral deposits which might be amenable to STD methods. The following criteria were used to screen deposits which might be able to use STD as a tailings disposal method. The deposits had to contain metallic minerals, near (less than 16 km from) a coastline, have suitable bathymetry nearshore (nearshore depth greater than 100 meters), and

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[2] Underlined numbers in parentheses refer to references at the end of this report.

a mixing chamber to outfall slope greater than 5%. The Bureau's Minerals Availability System (MAS) database and geological inference were used for the initial screening of metallic deposits found near the U.S. coastline.

The only sites found within the U.S. and its territories that satisfied the screening criteria were twenty deposits located in Alaska and two in Puerto Rico. The twenty Alaskan deposits were selected for economic modelling. The two Puerto Rican deposits and ten other Alaskan deposits were not evaluated in this report due to problems affecting their development potential, such as size, land status, and unfavorable offshore conditions. See Appendix A for a discussion of selection criteria.

Economic models were developed for twenty known deposits with STD potential using existing cost estimates, published information, permitting document disclosures, and the Bureau's PREVAL and Cost Estimation System (CES). These models were used to compare the costs of on-land and STD (54,68). Environmental information was collected and evaluated for the twenty sites to determine if there were any obvious environmental reasons for not using the sites for STD.

ECONOMIC METHODOLOGY

Initially, a list of thirty-two deposits located in the U.S. and its territories resulted from querying the MAS database. The Gross Metal Value (GMV) of all of the deposits was calculated for ranking purposes using long-term average commodity prices. Based on various screening criteria, twenty of these deposits were selected as potentially viable and used as the basis on which to build economic models. The remaining twelve were not evaluated in this report largely because they were too small to be viable. See Appendix A and B for selection criteria and further details.

Twenty cash flow models were developed to compare the economic effects of alternative tailings disposal methods. Capital and operating costs for the majority of the models were determined using simplified cost models for pre-feasibility mineral evaluations (14,18,54). The Bureau's Cost Estimation System (CES) was used to estimate costs for the on-land and STD alternatives (14,54,68). Cost estimates for submarine tailings disposal are listed in Appendix F. All costs were escalated by factors which reflect the higher cost of labor, transportation, and electricity in Alaska (12,14). Published cost information drawn from permitting documents and environmental impact statements was also used (20,22,42,45,70). All cost estimates were expressed in 1992 dollars.

Using long-term average commodity-prices and the estimated capital and operating costs, economic models were developed using cash flow analysis techniques. Net Present Value (NPV), Discounted Cash-Flow Rate-of-Return (DCFROR), and breakeven prices were computed. Comparisons between on-land and STD were made using the results. See Appendix B for the economic assumptions and Appendix C for detailed results of the calculations. Metal prices used are the inflation adjusted twenty and thirty year averages found in Appendix B.

RESULTS OF ECONOMIC EVALUATION

It is important to emphasize that the mine models described in this report are based on hypothetical mining and milling scenarios. The models are not meant to represent a feasibility analysis of specific deposits. This would be inappropriate since such an analysis requires a data base greater in size than that available for this report. The models can be considered a preliminary estimate at a pre-feasibility level.

A number of factors control the feasibility of mineral development and STD use including physical attributes of the deposit, oceanographic considerations, metal markets, infrastructure availability, political climate, environmental constraints, and corporate policy. Any forecast of the development potential should weigh all of the factors. Results presented here are preliminary.

Bureau policy prohibits issuing any report as to the value of any mine or other private mineral property. The models were arbitrarily assigned the letters A through T to disguise their actual identity. The models are based on published resource and grade data and do not include proprietary data which, if available, would probably change the outcome of the evaluation. When applicable, cost information from developing or producing mines in Alaska was used in constructing the models.

With one exception, overall capital costs for STD models were less expensive than on-land disposal capital costs. Figure 1 displays the amount of savings provided by STD use, expressed as a percentage of the total on-land capital cost. The average reduction in total capital costs for the twenty models was 17%. In one extreme case, capital cost was reduced by 76%. In the other extreme, capital cost increased by 2%. These cost savings are due to the fact that tailings dams are much more expensive than STD systems.

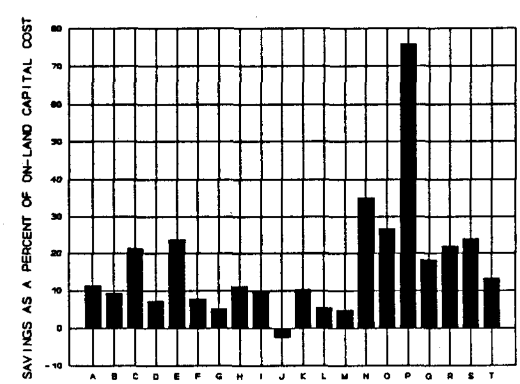

Figure 1. - STD Capital Cost Savings

Model J has negative savings because it assumes production has already begun. An investment in a tailings disposal system has already been made and converting to STD will be an additional cost. The other nineteen models have not begun production and the choice between on-land and STD can still be made.

For the twenty models, savings in operating cost was mixed. Figure 2 displays the amount of savings provided by STD use, expressed as a percentage of on-land operating cost. A positive percentage indicates savings; STD operating costs are less expensive than on-land operating costs.

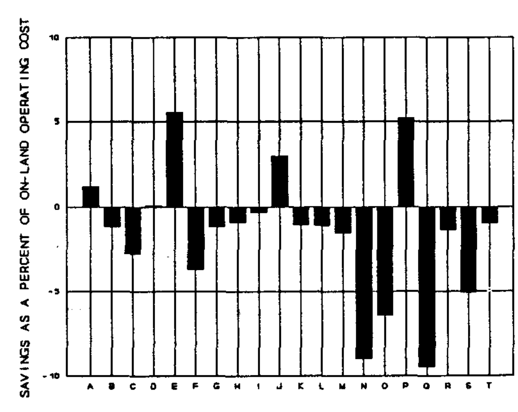

Figure 2. - STD Operating Cost Savings

A negative percentage indicates increased costs; STD operating costs were more expensive than on-land disposal operating costs. Average STD operating costs were 1.6% higher (ranging from -9.5% to +5.5%) than on-land operating costs. The longer pumping distances required for many STD operations resulted in higher operating costs.

Initially, breakeven metal prices using the two disposal methods were calculated. Prices needed to make a 15 percent rate of return were then calculated. The results of these calculations showed that at 15% DCFROR, average STD breakeven prices were 7.1% lower (ranging from 0.5% to 42.8%) than the on-land breakeven prices (Appendix C).

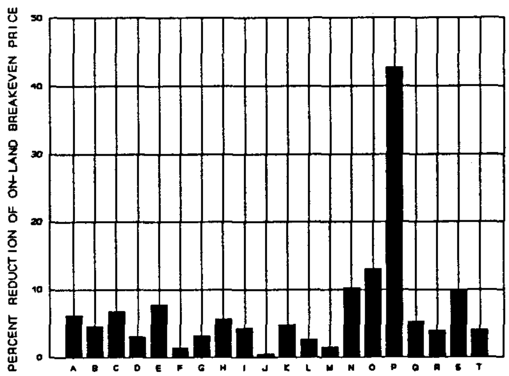

Figure 3. - STD Breakeven Price Reductions

Figure 3 displays the price reduction as a percent of the on-land breakeven price for 15% DCFROR. Models N, O, and P had the largest reductions in breakeven price. All three models are based on large scale surface mining scenarios with large production rates and relatively long mine lives. These models gain the largest benefit from using STD. This is due almost entirely to capital cost savings from not building tailings impoundment structures.

Net Present Values (NPV) for the twenty models were computed and the results are presented in Table 1 on the following page. At a 15 percent discount rate, all NPVs for STD are higher than NPVs for on-land disposal. Three models are economically viable (all columns positive), denoted by a DCFROR greater than 15% (last column - E). Four models are marginally economic (0% columns - positive, 15% columns - negative), denoted by a DCFROR greater than 0% and less than 15% (last column - M). Thirteen of the models are sub-economic (all columns negative), denoted by a DCFROR less than 0% (last column - S).

ENVIRONMENTAL METHODOLOGY AND EVALUATION

Brief environmental summaries were prepared for the twenty STD sites using charts and data supplied by the U.S. Coast Guard and the National Oceanic and Atmospheric Administration (NOAA) (44,69). Bathymetry, offshore slope and profile, coastline type and sensitivity, critical habitats, and human use including fisheries were examined. See Appendix D and E for further details.

Among the most useful references were those prepared by NOAA entitled "Sensitivity of Coastal Environments and Wildlife to Spilled Oil". These documents identified coastline types, sensitive animal species, and human use of marine resources.

Use of STD would result in a change in the seafloor environment, just as there would be a change in the environment where on-land tailings disposal occurs. Specifically, the seafloor would be raised and made sandy.

Table 1. - Net Present Value ($ million)

Model	On-land NPV 0% DCFROR	STD NPV 0% DCFROR	On-land NPV 15% DCFROR	STD NPV 15% DCFROR	Economic Category
A	551	582	42	67	E
B	2	3	-6	-4	M
C	-78	-79	-135	-113	S
D	-116	-111	-90	-85	S
E	-225	-221	-121	-106	S
F	-231	-245	-328	-315	S
G	-19	-17	-24	-23	S
H	-74	-72	-49	-47	S
I	-36	-34	-30	-28	S
J	263	266	137	141	E
K	-38	-35	-41	-37	S
L	195	200	26	32	E
M	-116	-111	-75	-72	S
N	1,187	1,078	-177	-64	M
O	1,159	1,165	-101	-20	M
P	-2,481	-570	-1,421	-544	S
Q	51	46	-18	-13	M
R	-388	-383	-178	-167	S
S	-172	-164	-114	-100	S
T	-40	-35	-54	-47	S

During the period of active mining when constant tailings deposition is occurring, there would be burial of immobile life forms and loss of habitat for mobile life forms. Upon completion of mining and reestablishment of a stable sea bottom, there would be a relatively rapid re-colonization by life forms adapted to that particular environment (23).

At this time, there is nothing to indicate that there would be any significant effect on anadromous fisheries, seabirds or sea mammals as long as the STD system was properly designed and operated (23).

Impacts on humans would probably be limited to reduction of available crab and shrimp fisheries during deposition with a return to a pre-mining production level in one to five years after cessation of deposition (23). Of the twenty sites evaluated, 7 had crab fisheries that might be affected (crab fisheries did not have exact locations). None of the tidal flats near the twenty STD sites were denoted as known shellfish collection areas. Nothing was found in the environmental evaluation that would preclude use of the sites for STD, although without much more definitive information the results can only be considered preliminary. Each site will require a much more detailed evaluation prior to any actual mining; and it may be discovered that sensitive species exist in these areas.

ECOSYSTEMS VALUES

One of the most important aspects of STD evaluation is one that is almost impossible to place a value on. The consequences of loss or gain of one ecosystem versus another is frequently purely subjective and cannot be uniformly evaluated to everyone's satisfaction.

Some comparisons can be made however. Generally, on-land ecosystems are populated by many plant and animal species which can be long-lived (trees that are dozens or hundreds of years old), reproduce in small numbers (mammals and birds producing only a few offspring per year) and which are absolutely dependent on a narrowly defined niche in the ecosystem (freshwater fish that can only live in a particular stream or lake). In contrast, in the marine environment the plants and animals tend to be relatively short-lived (algae, kelp, virtually no long-lived plant species), reproduce by production of thousands or even millions of eggs (most fish and shellfish), and tend to occupy broader niches within the ecosystem (smaller temperature extremes, easy dispersion of offspring by currents). However, there are some exceptions such as whales and dolphins with low reproduction rates, and rare ecosystems at seafloor hot vents.

When considering alternatives of on-land tailings disposal versus submarine disposal in an Environmental Impact Statement (EIS), the impacts to each ecosystem must be evaluated on an individual basis. Which ecosystem is the most common or most resilient? Are there unique species which will be irreparably and irreversibly impacted? How long will it take the ecosystem to attain stability after the disturbance ceases?

Long term hidden costs associated with on-land disposal of tailings need to be evaluated and compared with long term costs of STD. Especially in areas with high precipitation and high seismic activity, the potential for catastrophic failure of tailings dams exists, with the potential for human fatalities, and damage to human health and the environment. This risk is avoided with submarine disposal of tailings.

Because of possible oxidation and leaching of metals present in on-land tailing structures, the potential exists for groundwater and/or surface water contamination with their associated transport. Submarine burial of tailings in the marine environment eliminates the risk of surface water or groundwater contamination and associated transport of oxidized metals. Where dried tailings systems are used, they are subject to wind erosion and transport, while submarine disposal avoids this risk.

Deposition in the submarine environment represents a final solution, whereas land disposal does not. Erosion will eventually destroy tailings dams if they are not perpetually maintained. In cases involving mountainous terrain with high precipitation, tailings deposited on-land will ultimately be eroded into rivers and streams over the course of geologic time.

Finally, there is the fortuitous circumstance that almost all of the studied mineral occurrences are located along the southern Alaska coast where many glacially fed rivers carry enormous quantities of sand and silt (physically and chemically similar to tailings) to some of the same locations modelled as STD sites. Life forms in these locales are adapted to this environment, the seafloor is already sandy/silty, tailings would be commingled and buried very rapidly, and because the environment is one of constant burial there would be no significant loss or change of natural habitat.

SUMMARY AND CONCLUSIONS

On the basis of this evaluation, the only sites found within the U.S. and its territories that satisfied the initial screening criteria for STD use were thirty deposits located in Alaska and two in Puerto Rico. Ten Alaskan deposits and two Puerto Rican deposits were not evaluated in this report due to problems affecting their development potential such as size, land status, and unfavorable offshore conditions. Economic models for twenty known Alaskan deposits with STD potential were constructed to assess possible effects of a STD policy change on minerals availability to the United States.

The analysis estimated the price necessary for twenty known Alaskan deposits to become economically viable using both methods of tailings disposal. On average, STD use results in a 17.0% reduction in capital costs, and a 1.6% increase in operating costs. These cost differences result in average NPVs discounted at 15% that were 22.3% higher, and STD breakeven prices 7.1% lower than on-land prices.

Of the twenty models, three could benefit from STD in the near term, based on their economic NPVs; four may benefit in the intermediate to long term, based on their marginally economic NPVs; thirteen wouldn't benefit, based on their sub-economic NPVs.

Although STD has substantial economic promise for the state of Alaska, a change in STD policy would have little effect on short-term minerals availability to the United States as a whole. In the near term, a policy change would affect only three projects. An incremental increase in silver, gold, lead, and zinc availability is probable. Alaska would produce this incremental increase as a result of lower cut-off grades, which would allow the mining of lower grade resources that would otherwise not be recovered. The exact amount of additional metal that would be recovered is undetermined. However, assuming a 5% incremental increase in metal recovery, this would amount to about 1% of total U.S. mineral production for 1991 (67).

The on-land alternative for these three projects which have a Gross Metal Value of $9.75 billion would provide direct jobs for 1,055 persons and indirect jobs for another 780 persons. See Appendix C for further information. STD use would not create additional jobs, however STD would offer longer employment by possibly extending the mine lives by six months to a few years. As STD is a lower cost method, employment would be more stable during periods of lower metal prices, if STD was used.

On the basis of this evaluation, four projects with a Gross Metal Value of $19.5 billion are marginally economic and border on being economically producible. Total estimated employment for the four models was 680 persons in direct jobs and another 500 persons in indirect jobs. These models require further changes in economic or technological factors before additional minerals (gold, iron ore, chromite) would become available to the United States. STD use alone was not able to shift the four projects into the economic category. STD provided a significant improvement in project economics for the four models when compared to the on-land alternative. See Appendix C for further information.

Due to STD's lower cost, identified and undiscovered resources will cross the economic threshold sooner with STD than without it, especially in Alaska with its traditionally higher cost of doing business.

Based on the assumptions used in the models, there were no effects on go/no-go development decisions. Those projects currently in the development state will likely proceed regardless of a change in STD policy. Indications are that these projects would be more profitable, economically stable, and environmentally acceptable during their mine lives if STD use were allowed.

Changing the STD policy, prior to mine development, has a greater economic effect than after mining has started. The economic benefits of converting from existing on-land tailings systems at operating mines to STD are greatly diminished and may even be negligible in some cases.

Assuming that the tailings proposed to be discharged were non-reactive in seawater and did not contain toxic quantities of dissolved reagents or heavy metals, no significant adverse effect on sealife is anticipated. The major impact would be a change in the seafloor habitat to one that is perhaps shallower and sandy textured. These effects should be objectively compared to an on-land system which would also result in a permanent change to the environment, before a decision is made as to which system is best for a mine site.

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APPENDIX A. - COASTAL METAL DEPOSITS OF THE UNITED STATES

COASTAL METAL DEPOSITS OF THE UNITED STATES

A map of Alaska showing the locations of the twenty deposits is shown in Figure A-1. Tables A-1, A-2, and A-3 show United States deposits retrieved from the Minerals Availability System (MAS) database and the Gross Metal Value (GMV) of the deposits was calculated using the prices given in Appendix B, Table B-1 (8,13). In Alaska, the search was limited to mineral occurrences with resources located in coastal quadrangles. The database was also searched for possible STD candidates located on the U.S. west coast, Maine, Pacific and Caribbean islands. The west coast deposits were found to be too far from shore to be viable STD candidates. There were no deposits found in Maine. Geologic inference was used to eliminate most of the eastern seaboard and gulf coast. With the exception of Puerto Rico (Table A-3) there were no deposits found in any of the U.S. administered Caribbean or Pacific islands.

The deposits in Table A-2 and A-3 were eliminated for various reasons. The Klukwan Lode deposit was eliminated from consideration due to its immense size. With a GMV of $55 billion, its value exceeds that of the other twenty deposits combined, this would unduly influence the evaluation. The small deposits were eliminated because they are too small to be economically viable. The Lost River Tin deposit was eliminated due to unfavorable offshore conditions. The Hirst Chichagof deposit was eliminated because the resource estimate is questionable; recent drilling has shown poor results (73). Bokan Mountain's tailings were eliminated for disposal in the ocean because of potential high uranium content. Land status for Margerie Glacier and Nunatak eliminated them; both are located in Glacier Bay National Park and owned by the Park Service.

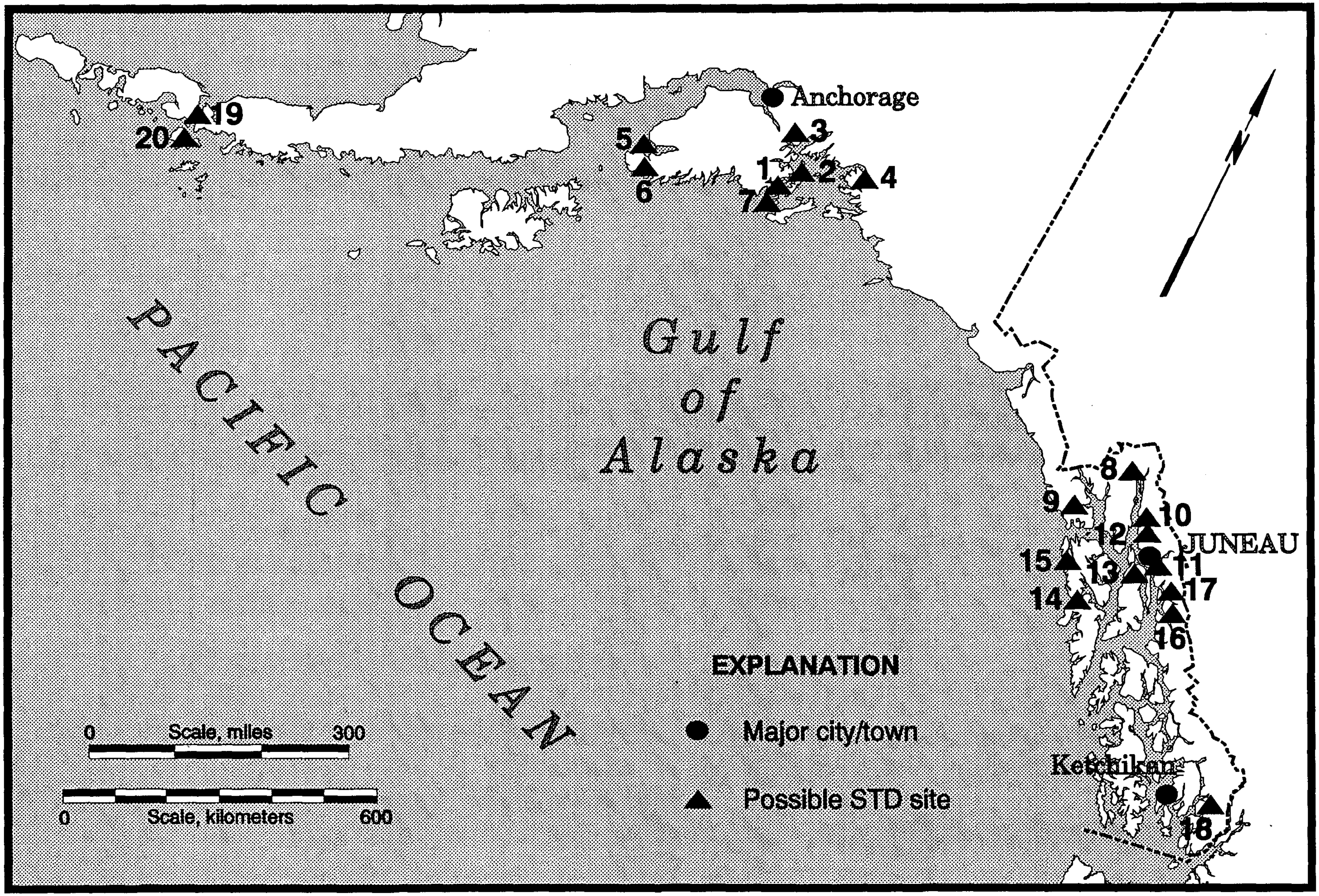

Figure A-1. - Location map depicting the 20 STD sites.

Table A-1. - Alaska Mineral Resources that may be Candidates for STD

Map No.	Name (Reference Number)	Metal	Estimated Resources (Mmt) **	GMV ($million)
1	Beatson (53)	Cu	4.5 of 1.0% Cu, 34.3 g/mt Ag, 0.75% Pb, 0.75% Zn	$280
2	Copper Bullion (41)	Cu	1.2 of 1.25% Cu, 0.17 g/mt Au, 3.43 g/mt Ag	51
3	Billings Glacier (41)	Mo	34 of 0.1% Mo	480
4	Keystone (41)	Cu	2.1 of 1.05% Cu, 0.19% Zn	73
5	Windy River (36)	Cr	38 of 1.33% Cr_2O_3	200
6	Red Mountain (19)	Cr	35 of 6.6% Cr_2O_3	790
7	Elrington Island (21)	Cu	1.0 of 1.25% Cu	39
8	Klukwan Fan (56)	Fe	900 of 10.8% Fe	9,900
9	Brady Glacier (35)	Ni	76 of 0.53% Ni, 0.33% Cu	4,400
10	Kensington (57)	Au	14 of 4.5 g/mt	950
11	Alaska Juneau (17)	Au	91 of 1.71 g/mt Au	2,400
12	Jualin (17)	Au	.91 of 10 g/mt Au	140
13	Greens Creek (57)	Ag	3.2 of 9.7% Zn, 3.9% Pb, 816 g/mt, 5.6 g/mt Au	1,800
13	Greens Creek West Orebody (7)	Ag	10 of 12.5% Zn, 4.0% Pb, 505 g/mt, 4.4 g/mt Au	4,600
14	Chichagoff (55)	Au	.56 of 10 g/mt Au, 3 g/mt Ag	150
15	Yakobi Island (58)	Ni	16 of 0.33% Cu, 0.21% Ni,	730
16	Sumdum (15)	Cu	25 of 0.57% Cu, 0.37% Zn, 10.29 g/mt Ag	640
17	Port Snettisham (24)	Fe	450 of 19 % Fe	8,700
18	Quartz Hill (70)	Mo	1,400 of 0.14% MoS_2	16,000
19	Balboa Bay (21)	Cu	91 of 0.5 % Cu, 0.03 % Mo	1,800
20	Apollo (1)	Au	.2 of 26 g/mt Au, 120 g/mt Ag	67
	TOTAL GROSS METAL VALUE			**$54,190**

** Estimated resources are taken from various publications. The reference number appears immediately after the deposit name. The reference list is found at the end of the report, preceding this appendix.

Table A-2. - Alaskan Deposits that were eliminated

Name	Metal	Resources (Mmt)	GMV ($million)
Bokan Mountain(72)	RE	34 of 0.02% U_3O_8, 0.03% ThO_2, 0.18% Y_2O_3, 0.83% ZrO_2, 0.13% Cb_2O_5, 0.30% REO	$1,800
Claim Point (9)	Cr	.91 of 8.4% Cr_2O_3	15
Funter Bay (9)	Ni	.5 of 0.34% Ni, 0.35% Cu, 0.15% Co	43
Groundhog Basin (9)	Zn	.5 of 8% Zn, 1.5% Pb	64
Hirst Chichagof (55)	Au	.2 of 27 g/mt Au, 9.6 g/mt Ag	100
Jumbo Basin (9)	Zn	.6 of 45.2% Fe, 0.75% Cu, 0.34 g/mt Au, 2.7 g/mt Ag	18
Klukwan Lode (9)	Fe	3,200 of 16.8% Fe	55,000
Lost River (9)	Sn	31 of 17.23% CaF_2, 0.03% WO_3, 0.15% Sn	2,100
Margerie Glacier (9)	Ni	150 of 0.2% Cu, 0.27 g/mt Au, 4.5 g/mt Ag, 0.015 WO_3	1,900
Nunatak (9)	Mo	130 of 0.03% MoS_2, 0.02% Cu	360
TOTAL			**$61,400**

Table A-3. - Puerto Rican Deposits that may be Candidates for STD

Name	Metal	Resources (Mmt)	GMV ($million)
Cala Abajos, Piedra Hueca, Tanama (43)	Cu	220 of 0.72 % Cu, 1.91 g/mt Ag, 0.31 g/mt Au	$6,100
Guanajibo, Punta Fuanajibo, Las Mesas, Rosario, Maricao (39)	Ni	82 of 0.88% Ni	13,000
TOTAL			**$19,100**

APPENDIX B. - ECONOMIC ASSUMPTIONS

ECONOMIC ASSUMPTIONS

This appendix includes information regarding the development of the twenty economic models. It notes most of the major assumptions regarding income tax rates, depletion, depreciation, commodity prices, exploration and permitting costs, working capital, salvage value, and reclamation expense. Additional cost information on submarine tailings disposal systems is located in Appendix F.

ECONOMIC FACTORS

It is important to emphasize that the mine models described in this report are based on hypothetical mining and milling scenarios. The models are not meant to represent a feasibility analysis of specific deposits. This would be inappropriate since such an analysis requires more precise data than that available for this report.

The models can be applied to get a preliminary estimate at a pre-feasibility level. The models are based on published resource and grade data and do not include proprietary company data which, if available, would probably change the outcome of the evaluation. When applicable, cost information from developing or producing mines in Alaska was used in constructing the models.

A number of factors control the feasibility of mineral development and STD utilization, including physical attributes of the deposit, oceanographic considerations, metal markets, infrastructure availability, political climate, environmental constraints, and corporate policy. Any forecast of the development potential should weigh all of the factors. Results and the conclusions presented here should be considered preliminary.

CASH FLOW ASSUMPTIONS

All commodity prices are free on board (f.o.b.) mine, therefore, all off-site transportation costs to market are not considered. Federal, Alaska corporate income, and mining license tax rates are simulated with a 40% tax rate during the first 3 years of production, 42% in the 4th year, and 44% thereafter. Property taxes were considered as necessary. All projects were assumed to be equity financed by a single corporate producer that could expense tax due against other income. Modified Accelerated Cost Recovery System (ACRS) depreciation and Percentage Depletion were utilized.

Exploration and permitting costs are considered to be sunk costs. It is assumed that salvage value will equal reclamation cost. Mine and mill reinvestment is not considered. Working capital equals ninety days operating costs and is recovered in the last year of the project. Project duration is limited to no more than 30 years.

COMMODITY PRICES

Most commodity prices used in the evaluation were determined by using an inflation adjusted thirty-year average for the years 1963-1992. The Gross Metal Value (GMV) for the 32 deposits was calculated using the commodity price list shown in Table B-1.

Prices for the years 1963-1992 from various Bureau publications were escalated to 1992 dollars using Department of Commerce, Bureau of Economic Analysis Gross National Product implicit price deflators and then averaged (59-66). Prices for U_3O_8 are from Engineering and Mining Journal's annual reviews and the Department of Energy Information Administration (25-34).

Thirty year average prices were selected for all commodities except gold and silver. Twenty year average prices for gold and silver were selected due to the effects of government policies on these metals prior to 1973. Longer term prices were considered more realistic for policy purposes than the ten year average price (1983-1992) which is usually lower. All prices shown in Table B-1 are given in 1992 dollars.

Table B-1. - Ten, Twenty, and Thirty year Average Constant Dollar Commodity Prices (1963-1992)

	English Units				Metric Units			
Commodity	30 YR AVG	20 YR AVG	10 YR AVG		30 YR AVG	20 YR AVG	10 YR AVG	
Chromite	$175.76	$167.00	$153.65	st	$193.74	$184.09	$169.37	mt
Cobalt	12.77	15.67	12.14	lb	28.16	34.55	26.77	kg
Columbium Oxide	5.29	5.13	3.62	lb	11.66	11.31	7.98	kg
Copper	1.40	1.31	1.10	lb	3.08	2.89	2.42	kg
Fluorspar	201.66	209.89	232.26	st	222.29	231.36	256.02	mt
Gold	362.72	470.52	453.95	tr oz	11.66	15.13	14.59	g
Iron	1.01	1.01	0.87	ltu	1.02	1.03	0.89	mtu
Lead	0.50	0.48	0.37	lb	1.10	1.06	0.81	kg
Molybdenum	6.37	6.50	3.85	lb	14.04	14.33	8.49	kg
Monazite	0.52	0.50	0.50	lb	1.15	1.10	1.09	kg
Nickel	4.08	4.23	3.91	lb	8.99	9.32	8.61	kg
Silver	9.25	10.94	7.68	tr oz	0.30	0.35	0.25	g
Thorium Oxide	27.86	24.86	24.84	lb	61.42	54.80	54.77	kg
Tin	7.02	7.51	4.70	lb	15.48	16.56	10.37	kg
Tungsten Oxide	144.70	150.38	72.85	ltu	147.02	152.79	82.13	mtu
Uranium Oxide	26.05	25.22	16.33	lb	57.42	55.60	35.99	kg
Zinc	0.63	0.67	0.63	lb	1.39	1.48	1.38	kg
Zirconium Oxide	$283.81	$329.03	$321.59	st	$312.85	$362.70	$354.50	mt

APPENDIX C. - ECONOMIC MODELS

ECONOMIC MODELS

This appendix gives brief descriptions of the twenty models (A - T) in tabular form. Each table is divided into sections which provide the following specifications for each model.

Model - Bureau policy prohibits issuing any report as to the value of any mine or other private mineral property. The models were arbitrarily assigned the letters A through T to disguise their actual identity.

Mining Rate - The projected production rate in metric tons per day, followed by the number of days per year production was scheduled.

Mine Life - The projected mine life given in years at the specified production rate.

Mining Method - The mining method that will be used during the scheduled mine life.

Concentration Method - A brief description of the assumed milling process that was used for commodity recovery.

Mill Recovery - Assumed commodity recovery expressed as a percentage of the available commodity found in the mill feed.

Concentrating Rate - Projected annual commodity production calculated from the mill feed rate, mill feed grade, recovery, and concentrate grade.

Estimated Expenditure - Capital and operating costs that were estimated for both methods of tailings disposal.

Employment - Estimated number of full time mining, milling, and administrative jobs at the projected production rate. It was assumed either choice of tailings disposal method would not change the total amount of jobs.

Economic Analysis - The discounted cash flow rate of return (DCFROR) is given for both methods of tailings disposal. The long term average commodity prices used in calculating the DCFROR are given in Appendix B, Table B-1. Actual DCFRORs for models with -50.0% indicated are undetermined due to limitations of the cash flow simulation program.

Prices at 15% DCFROR - The commodity prices required for the model to achieve a 15% return was calculated for both methods of tailings disposal.

MODEL	A				
Mining Rate	20,412 mtpd, 365 dpy				
Mine Life	12.2 yrs				
Mining Method	Block Caving				
Concentration Method	Gravity, Flotation				
Mill Recovery	90% Au, 90% Ag				
Concentrating Rate	16,545 kg Au/yr, 16,545 kg Ag/yr				
	ON - LAND DISPOSAL		SUBMARINE TAILINGS DISPOSAL		EMPLOYMENT
ESTIMATED EXPENDITURE	CAPITAL COST	OP COST $/MT	CAPITAL COST	OP COST $/MT	450
TOTAL	$310,010,000	$11.05	$275,010,000	$10.92	
ECONOMIC ANALYSIS	PRICE ON-LAND	DCFROR 18.46%	PRICE STD	DCFROR 20.90%	
15% DCFROR	$13.73/g Au, $0.23/g Ag		$12.87/g Au, $0.22/g Ag		

MODEL	B				
Mining Rate	200 mtpd, 350 dpy				
Mine Life	3.6 yrs				
Mining Method	Shrinkage stoping				
Concentration Method	One product flotation				
Mill Recovery	90% Au, 50% Ag				
Concentrating Rate	1,008 kg Au/yr, 2,695 kg Ag/yr				
	ON - LAND DISPOSAL		SUBMARINE TAILINGS DISPOSAL		EMPLOYMENT
ESTIMATED EXPENDITURES	CAPITAL COST	OP COST $/MT	CAPITAL COST	OP COST $/MT	86
TOTAL	$26,759,000	$134.58	$24,273,000	$136.16	
ECONOMIC ANALYSIS	PRICE ON-LAND	DCFROR 2.41%	PRICE STD	DCFROR 5.06%	
15% DCFROR	$18.53/g Au, $0.31/g Ag		$17.64/g Au, $0.30/g Ag		

MODEL	C				
Mining Rate	12,000 mtpd, 350 dpy				
Mine Life	18.9 yrs				
Mining Method	Surface				
Concentration Method	Two product flotation				
Mill Recovery	91% Cu, 63% Cu				
Concentrating Rate	66,150 mtpy 28% Cu concentrate, 844 mtpy 91% MoS_2 concentrate				
	ON - LAND DISPOSAL		**SUBMARINE TAILINGS DISPOSAL**		**EMPLOYMENT**
ESTIMATED EXPENDITURES	**CAPITAL COST**	**OP COST $/MT**	**CAPITAL COST**	**OP COST $/MT**	225
TOTAL	$220,169,000	$14.42	$173,265,000	$14.82	
ECONOMIC ANALYSIS	**PRICE ON-LAND**	**DCFROR** -5.27%	**PRICE STD**	**DCFROR** -6.98%	
15% DCFROR	$4.45/kg Cu, $17.19/kg Mo		$4.15/kg Cu, $16.02/kg Mo		

MODEL	D				
Mining Rate	1,411 mtpd, 350 dpy				
Mine Life	9.1 yrs				
Mining Method	Shrinkage Stoping				
Concentration Method	Three product flotation				
Mill Recovery	80% Ag, 90% Pb, 90% Zn, 91% Cu				
Concentrating Rate	4,154 mtpy 73% Pb conc, 5,228 mtpy 58% Zn conc, 14,596 mtpy 28% Cu conc				
	ON - LAND DISPOSAL		**SUBMARINE TAILINGS DISPOSAL**		
ESTIMATED EXPENDITURES	**CAPITAL COST**	**OP COST $/MT**	**CAPITAL COST**	**OP COST $/MT**	**EMPLOYMENT**
TOTAL	$104,316,000	$75.42	$96,709,000	$75.36	205
ECONOMIC ANALYSIS	**PRICE ON-LAND**	**DCFROR** -27.65%	**PRICE STD**	**DCFROR** -27.56%	
15% DCFROR	$7.32/kg Cu, $0.75/g Ag $2.43/kg Pb, $4.17/kg Zn		$7.08/kg Cu, $0.73/g Ag $2.35/kg Pb, $4.04/kg Zn		

MODEL	E				
Mining Rate	5,600 mtpd, 350 dpy				
Mine Life	21.6 yrs				
Mining Method	Surface Mining				
Concentration Method	One product flotation				
Mill Recovery	90%				
Concentrating Rate	1,396 mpty of 91% MoS_2 concentrate				
	ON - LAND DISPOSAL		**SUBMARINE TAILINGS DISPOSAL**		**EMPLOYMENT**
ESTIMATED EXPENDITURES	**CAPITAL COST**	**OP COST $/MT**	**CAPITAL COST**	**OP COST $/MT**	270
TOTAL	$113,307,000	$16.47	$86,503,000	$15.56	
ECONOMIC ANALYSIS	**PRICE ON-LAND**	**DCFROR** -50.0%	**PRICE STD**	**DCFROR** -50.0%	
15% DCFROR	$56.36/kg Mo		$51.95/kg Mo		

MODEL	F				
Mining Rate	14,000 mtpd, 363 dpy				
Mine Life	9.4 yrs				
Mining Method	Blasthole open stoping				
Concentration Method	One product flotation				
Mill Recovery	75% Ni, 87% Cu				
Concentrating Rate	193,600 mtpy of 10% Ni, 7% Cu concentrate				
	ON - LAND DISPOSAL		**SUBMARINE TAILINGS DISPOSAL**		**EMPLOYMENT**
ESTIMATED EXPENDITURES	**CAPITAL COST**	**OP COST $/MT**	**CAPITAL COST**	**OP COST $/MT**	430
TOTAL	$599,563,000	$34.27	$552,781,000	$35.53	
ECONOMIC ANALYSIS	**PRICE ON-LAND**	**DCFROR** -9.78%	**PRICE STD**	**DCFROR** -11.53%	
15% DCFROR	$14.13/kg Ni, $3.98/kg Cu		$13.94/kg Ni, $3.92/kg Cu		

MODEL	G				
Mining Rate	450 mtpd, 350 dpy				
Mine Life	3.2 yrs				
Mining Method	Shrinkage stoping				
Concentration Method	One product flotation				
Mill Recovery	90% Au, 90% Ag				
Concentrating Rate	1,418 kg Au/yr, 472 kg Ag/yr				
	ON - LAND DISPOSAL		SUBMARINE TAILINGS DISPOSAL		EMPLOYMENT
ESTIMATED EXPENDITURES	CAPITAL COST	OP COST $/MT	CAPITAL COST	OP COST $/MT	120
TOTAL	$48,275,000	$98.69	$45,712,000	$99.84	
ECONOMIC ANALYSIS	PRICE ON-LAND	DCFROR -17.34%	PRICE STD	DCFROR -17.03%	
15% DCFROR	$29.23/g Au, $0.68/g Ag		$28.31/g Au, $0.65/g Ag		

MODEL	H				
Mining Rate	760 mtpd, 260 dpy				
Mine Life	5.9 yrs				
Mining Method	Shrinkage stoping				
Concentration Method	One product flotation				
Mill Recovery	90% Cu, 76% Au, 80% Ag				
Concentrating Rate	6,263 mtpy 28% Cu concentrate				
	ON - LAND DISPOSAL		SUBMARINE TAILINGS DISPOSAL		EMPLOYMENT
ESTIMATED EXPENDITURES	CAPITAL COST	OP COST $/MT	CAPITAL COST	OP COST $/MT	85
TOTAL	$34,718,000	$61.83	$30,846,000	$62.40	
ECONOMIC ANALYSIS	PRICE ON-LAND	DCFROR -50.00%	PRICE STD	DCFROR -50.00%	
15% DCFROR	$11.27/kg Cu, $55.11/g Au, $1.27/g Ag		$10.60/kg Cu, $52.07/g Au, $1.20/g Ag		

MODEL	I				
Mining Rate	450 mtpd, 260 dpy				
Mine Life	9.3 yrs				
Mining Method	Shrinkage stoping				
Concentration Method	One product flotation				
Mill Recovery	90%				
Concentrating Rate	4,272 mtpy 28% Cu concentrate				
	ON - LAND DISPOSAL		SUBMARINE TAILINGS DISPOSAL		EMPLOYMENT
ESTIMATED EXPENDITURES	CAPITAL COST	OP COST $/MT	CAPITAL COST	OP COST $/MT	85
TOTAL	$41,651,000	$105.27	$37,618,000	$105.61	
ECONOMIC ANALYSIS	PRICE ON-LAND	DCFROR -50.0%	PRICE STD	DCFROR -50.0%	
15% DCFROR	$18.88/kg Cu		$18.06/kg Cu		

MODEL	J				
Mining Rate	907 mtpd, 350 dpy				
Mine Life	10 yrs				
Mining Method	Cut and fill				
Concentration Method	Three product flotation				
Mill Recovery	76% Ag, 55% Au, 72% Zn, 65% Pb				
Concentrating Rate	25,550 mtpy 53% Zn conc, 5,402 mtpy 55% Pb conc, 41,062 mpty 27% Zn, 15% Pb concentrate				
	ON - LAND DISPOSAL		SUBMARINE TAILINGS DISPOSAL		EMPLOYMENT
ESTIMATED EXPENDITURES	CAPITAL COST	OP COST $/MT	CAPITAL COST	OP COST $/MT	265
TOTAL	$131,552,000	$99.16	$134,571,000	$96.23	
ECONOMIC ANALYSIS	PRICE ON-LAND	DCFROR 23.76%	PRICE STD	DCFROR 23.99%	
15% DCFROR	$11.68/g Au, $0.27/g Ag $1.07/kg Zn, $0.85/kg Pb		$11.57/g Au, $0.27/g Ag $1.06/kg Zn, $0.84/kg Pb		

MODEL	K				
Mining Rate	650 mtpd, 350 dpy				
Mine Life	8 yrs				
Mining Method	Vertical Crater Retreating				
Concentration Method	Gravity separation, flotation, cyanide leaching, Merrill-Crowe				
Mill Recovery	95%				
Concentrating Rate	934 kg Au/yr				
	ON - LAND DISPOSAL		**SUBMARINE TAILINGS DISPOSAL**		**EMPLOYMENT**
ESTIMATED EXPENDITURES	**CAPITAL COST**	**OP COST $/MT**	**CAPITAL COST**	**OP COST $/MT**	115
TOTAL	$58,759,000	$65.43	$52,740,800	$66.13	
ECONOMIC ANALYSIS	**PRICE ON-LAND**	**DCFROR** -25.52%	**PRICE STD**	**DCFROR** -25.96%	
15% DCFROR	$31.57/g Au		$30.06/g Au		

MODEL	L				
Mining Rate	3,629 mtpd, 365 dpy				
Mine Life	7.7 yrs				
Mining Method	Longhole Stoping				
Concentration Method	Gravity separation, flotation, cyanide leaching, Merrill-Crowe				
Mill Recovery	92%				
Concentrating Rate	6,655 kg Au/yr				
	ON - LAND DISPOSAL		**SUBMARINE TAILINGS DISPOSAL**		**EMPLOYMENT**
ESTIMATED EXPENDITURES	**CAPITAL COST**	**OP COST $/MT**	**CAPITAL COST**	**OP COST $/MT**	340
TOTAL	$194,185,000	$33.98	$183,430,000	$34.35	
ECONOMIC ANALYSIS	**PRICE ON-LAND**	**DCFROR** 19.53%	**PRICE STD**	**DCFROR** 20.89%	
15% DCFROR	$16.58/g Au		$16.15/g Au		

MODEL	M				
Mining Rate	737 mtpd, 350 dpy				
Mine Life	8.8 yrs				
Mining Method	Shrinkage Stoping				
Concentration Method	Two product flotation				
Mill Recovery	90% Zn, 91% Cu				
Concentrating Rate	627 mtpy 58% Zn concentrate, 7,259 mtpy 28% Cu concentrate				
	ON - LAND DISPOSAL		**SUBMARINE TAILINGS DISPOSAL**		**EMPLOYMENT**
ESTIMATED EXPENDITURES	**CAPITAL COST**	**OP COST $/MT**	**CAPITAL COST**	**OP COST $/MT**	280
TOTAL	$68,326,000	$93.23	$64,945,000	$94.64	
ECONOMIC ANALYSIS	**PRICE ON-LAND**	**DCFROR** -50.0%	**PRICE STD**	**DCFROR** -50.0%	
15% DCFROR	$16.64/kg Cu, $9.48/kg Zn		$16.39/kg Cu, $9.34/kg Zn		

MODEL	N				
Mining Rate	100,000 mtpd, 357 dpy				
Mine Life	25.1 yrs				
Mining Method	Alluvial Mining				
Concentration Method	Screening, magnetic cobbing and separation				
Mill Recovery	72%				
Concentrating Rate	4,246,000 mtpy 65.5% Fe concentrate				
	ON - LAND DISPOSAL		**SUBMARINE TAILINGS DISPOSAL**		**EMPLOYMENT**
ESTIMATED EXPENDITURES	**CAPITAL COST**	**OP COST $/MT**	**CAPITAL COST**	**OP COST $/MT**	305
TOTAL	$699,771,000	$5.02	$454,423,000	$5.47	
ECONOMIC ANALYSIS	**PRICE ON-LAND**	**DCFROR** 9.57%	**PRICE STD**	**DCFROR** 12.12%	
15% DCFROR	$120.98/mt Fe		$108.57/mt Fe		

MODEL	0				
Mining Rate	40,000 mtpd, 365 dpy				
Mine Life	30.8 yrs				
Mining Method	Surface Mining				
Concentration Method	Magnetic Separation				
Mill Recovery	65%				
Concentrating Rate	2,717,425 mtpy 66% Fe concentrate				
	ON - LAND DISPOSAL		**SUBMARINE TAILINGS DISPOSAL**		**EMPLOYMENT**
ESTIMATED EXPENDITURES	**CAPITAL COST**	**OP COST $/MT**	**CAPITAL COST**	**OP COST $/MT**	130
TOTAL	$589,145,000	$6.84	$432,006,000	$7.28	
ECONOMIC ANALYSIS	**PRICE ON-LAND**	**DCFROR** 11.14%	**PRICE STD**	**DCFROR** 14.02%	
15% DCFROR	$121.57/mt Fe		$105.74/mt Fe		

MODEL	P				
Mining Rate	72,575 mtpd, 350 dpy				
Mine Life	53.6 yrs				
Mining Method	Surface Mining				
Concentration Method	One product flotation				
Mill Recovery	85%				
Concentrating Rate	47,049 mtpy 67% MoS_2 concentrate				
	ON - LAND DISPOSAL		**SUBMARINE TAILINGS DISPOSAL**		**EMPLOYMENT**
ESTIMATED EXPENDITURES	**CAPITAL COST**	**OP COST $/MT**	**CAPITAL COST**	**OP COST $/MT**	1,020
TOTAL	$3,770,055,000	$10.80	$909,690,000	$10.24	
ECONOMIC ANALYSIS	**PRICE ON-LAND**	**DCFROR** -50.0%	**PRICE STD**	**DCFROR** -7.59%	
15% DCFROR	$41.96/kg Mo		$24.01/kg Mo		

MODEL	Q				
Mining Rate	4,200 mtpd, 350 dpy				
Mine Life	12.8 yrs				
Mining Method	Surface Mining				
Concentration Method	Gravity Separation				
Mill Recovery	80%				
Concentrating Rate	133,206 mtpy 48% Cr_2O_3 concentrate				
	ON - LAND DISPOSAL		**SUBMARINE TAILINGS DISPOSAL**		**EMPLOYMENT**
ESTIMATED EXPENDITURES	**CAPITAL COST**	**OP COST $/MT**	**CAPITAL COST**	**OP COST $/MT**	160
TOTAL	$81,617,000	$10.47	$66,733,000	$11.46	
ECONOMIC ANALYSIS	**PRICE ON-LAND**	**DCFROR** 8.89%	**PRICE STD**	**DCFROR** 9.66%	
15% DCFROR	$481.18/mt Cr_2O_3		$456.49/mt Cr_2O_3		

MODEL	R				
Mining Rate	6,057 mtpd, 180 dpy				
Mine Life	20 yrs				
Mining Method	Shrinkage stoping				
Concentration Method	Two product flotation				
Mill Recovery	74% Cu, 80% Zn, 75% Ag				
Concentrating Rate	19,161 mtpy 24% Cu conc, 6,454 mtpy 50% Zn conc				
	ON - LAND DISPOSAL		**SUBMARINE TAILINGS DISPOSAL**		**EMPLOYMENT**
ESTIMATED EXPENDITURES	**CAPITAL COST**	**OP COST $/MT**	**CAPITAL COST**	**OP COST $/MT**	275
TOTAL	$95,261,000	$46.47	$74,481,000	$47.11	
ECONOMIC ANALYSIS	**PRICE ON-LAND**	**DCFROR** -39.13%	**PRICE STD**	**DCFROR** -39.37%	
15% DCFROR	$9.57/kg Cu, $5.45/kg Zn $0.98/g Ag		$9.20/kg Cu, $5.24/kg Zn $0.94/g Ag		

MODEL	S				
Mining Rate	15,000 mtpd, 180 dpy				
Mine Life	14 yrs				
Mining Method	Placer mining				
Concentration Method	Size, wash & screen, tabling, grinding, electrodynamic separation				
Mill Recovery	38%				
Concentrating Rate	26,702 mtpy 46.9% Cr_2O_3				
	ON - LAND DISPOSAL		**SUBMARINE TAILINGS DISPOSAL**		**EMPLOYMENT**
ESTIMATED EXPENDITURES	**CAPITAL COST**	**OP COST $/MT**	**CAPITAL COST**	**OP COST $/MT**	260
TOTAL	$106,061,000	$7.34	$80,735,000	$7.71	
ECONOMIC ANALYSIS	**PRICE ON-LAND**	**DCFROR** -50.0%	**PRICE STD**	**DCFROR** -50.0%	
15% DCFROR	$2,851.73/mt Cr_2O_3		$2,569.26/mt Cr_2O_3		

MODEL	T				
Mining Rate	5,000 mtpy, 330 dpy				
Mine Life	9.8 yrs				
Mining Method	Surface Mining				
Concentration Method	One product flotation				
Mill Recovery	92% Cu, 86% Ni				
Concentrating Rate	80,520 mtpy 3.4% Cu, 5.4% Ni concentrate				
	ON - LAND DISPOSAL		**SUBMARINE TAILINGS DISPOSAL**		**EMPLOYMENT**
ESTIMATED EXPENDITURES	**CAPITAL COST**	**OP COST $/MT**	**CAPITAL COST**	**OP COST $/MT**	380
TOTAL	$103,978,000	$27.48	$90,272,000	$27.75	
ECONOMIC ANALYSIS	**PRICE ON-LAND**	**DCFROR** -8.52%	**PRICE STD**	**DCFROR** -8.31%	
15% DCFROR	$13.38/kg Ni, $3.76/kg Cu		$12.84/kg Ni, $3.61/kg Cu		

APPENDIX D. - OFFSHORE EVALUATION OF PHYSICAL FACTORS

OFFSHORE EVALUATION OF PHYSICAL FACTORS

Copies of U.S. Charts covering Alaska's South, Southeast, and Peninsula were used to evaluate STD potential offshore of the twenty sites. Two constraints were considered, suitable bathymetry (depth > 100 meters) and nearshore steepness (shore to outfall - slope > 5%).

Slope from the outfall to depth and the distance from shore to the outfall are also given in the table. These criteria and others were recommended by Poling et. al. 1992 (47,71). The results of the evaluation are summarized in Table D-1.

All of the deposits appear to meet the criteria. The Hirst Chichagof and Chichagoff are marginal on meeting the arbitrary depth limitation of 100 meters. Once tailings deposition began, the tailings would encroach on the 100 meter mark.

Table D-1. - Offshore Evaluation Results

Deposit Name	Maximum depth (m)	Slope to 90 m (m)	Slope from 90 m to depth (m)	Distance from shore to 90 m depth (m)	NOAA Chart
Alaska Juneau	210	100.0	45.0	90	17315
Apollo	120	7.5	5.0	1,220	16553
Balboa Bay	140	5.6	5.6	1,620	16553
Beatson	230	8.2		1,120	16702
Billings Glacier	240	45.0	25.0	200	16706
Brady Glacier	170	12.0	2.2	760	17301
Chichagoff	100	15.0		610	17322
Copper Bullion	190	14.7	9.5	620	16701
Elrington Island	140	15.0	6.6	610	16702
Greens Creek	710	24.0	17.0	430	17300
Jualin	270	11.0	10.0	820	17316
Kensington	710	18.0	6.1	510	17317
Keystone	190	9.0	3.2	1,010	16708
Klukwan	400	30.0	38.0	300	17317
Port Snettisham	230	43.0	22.0	210	17313
Quartz Hill	250	43.0	9.8	210	17424
Red Mountain	150	11.0		840	16645
Sumdum	290	20.0	17.8	460	17360
Windy River	150	11.0		840	16645
Yakobi Island	300	45.0	16.0	200	17303

APPENDIX E - ENVIRONMENTAL INFORMATION

ENVIRONMENTAL INFORMATION

This section provides a description of shoreline types, sensitive biological resources, and human usage in the area near where a STD outfall would probably be located for each modelled deposit. Only if there were a failure of the mixing chamber causing suspension of fine material would there be a potential adverse affect on some of the shoreline types. With adequate baseline oceanographic studies and a properly engineered mixing chamber and outfall such a possibility could only be described as remote. The shoreline types which would most likely be affected should such an unlikely failure occur would be the low energy environments such as marshes or tidal flats. At these locations deposition of fines could cause burial and smothering of sessile life forms. However, recolonization would probably take place relatively quickly. Until recolonization occurred animals or humans utilizing these ecosystems as a primary food source would experience a reduction in available food.

Normal (as designed) operation of the STD system should only affect human usage where tailings deposition occurs on traditional bottom fishing (halibut, flounder, shrimp, crab, etc.) locations. There should be no effect on commercial or sport fishing of salmon or other anadromous fishes.

Alaska Juneau

Shoreline: Between Bishop Point and Cooper Point; about 25% exposed rocky shores, about 40% wave-cut platforms, and about 35% mixed sand and gravel beaches and gravel beaches. Further north is almost completely sheltered, impermeable rocky shoreline. Greely point area; 75% wave-cut platform and 25% gravel beaches. Further north is almost completely sheltered, impermeable rocky shoreline. These energetic environments are not as sensitive to oil spills or suspended solids as marshes or tidal flats would be.

Sensitive Biological Resources: Numerous eagle nests are found on both sides of Taku Inlet. Bear concentrations are noted on the west shore and inland of Taku Inlet. Sea mammals utilize the Inlet on an intermittent basis.

Human Usage: Taku Inlet is heavily used by cruise ships during the summer months. Both shorelines of Taku inlet are used for commercial fishing, sport fishing, and tanner-crab fishing. Taku Inlet and Taku River provides a water route into British Columbia.

Apollo

Shoreline Type: Exposed rocky shores and coarse-grained sand beaches. These energetic environments are not as sensitive to oil spills or suspended solids as marshes or tidal flats would be.

Sensitive Biological Resources: Northern (stellar) sea lion haulout and rookery on Unga Cove (1.6 to 3.2 km east of STD pipeline location). Bald eagle nesting area 8 km west of STD pipeline. Humpback, Gray, Minke, Killer, Fin whales, Dall porpoise, Bairds Beaked whale found March - November in Pacific Ocean migration area. Generally associated with offshore, pelagic or deep, nearshore, waters.

Human Usage: Commercial harvesting of groundfish south of Unga Island, nearshore Unga Cape fished for chum, coho, pink, and sockeye salmon, and fishing for red king and tanner crab occurs nearby. Sport fishing for sockeye and pink salmon and dolly varden trout occurs in the waters nearby.

Balboa Bay

Shoreline Type: Balboa Bay is mostly mixed sand and gravel, coarse gravel or sand beaches. Albatross Anchorage on the north end of Balboa Bay has mixed sand and gravel beaches, marshes, sheltered rocky shores and exposed tidal flats.

Sensitive Biological Resources: Pink and Chum salmon spawn in Bishop, Johnson, Coleman, and unnamed creeks north and south of Monolith Point. Bald eagles nest south of Monolith Point April through August.

Human Usage: Commercial fishing of herring sac roe, sockeye, pink, coho, and chum salmon, and red king, tanner, and dungeness crab occurs in the area.

Beatson

Shoreline Types: Fine-grained sand, coarse-grained sand, and mixed sand and gravel beaches.

Sensitive Biological Resources: Pink salmon are in Wilson Bay and Horseshoe Bay spring, summer and fall. Chum and Pink salmon are in LaTouche Passage, Crab Bay and unnamed bay spring, summer and fall.

Human Usage: Commercial salmon fishing takes place in the area and limited sportfishing for rockfish takes place.

Billings Glacier

Shoreline Types: Most of the shoreline tends to be gravel beaches except for marshes and sheltered tidal flats 1.5 km south of proposed outfall and in area of proposed pipeline.

Sensitive Biological Resources: Seals and sea otters are throughout the nearshore zone year round. Dungeness crabs are in Passage Canal. Chum salmon are in Shotgun Cove (about 5 km east of proposed outfall area) in spring and fall. Black-legged Kittiwakes are about 10 km southwest of the proposed outfall site. Glaucous-winged Gull and Pigeon Guillemot are found in the area during the summer.

Human Usage: This is a commercial salmon fishing area. Sportfishing for king, coho, sockeye, pink, and chum salmon, halibut, dolly varden trout, and rockfish takes place.

Brady Glacier

Shoreline Types: Mostly exposed beaches and rocky shorelines.

Sensitive Biological Resources: Large multi-species seabird nesting colony 0.8 km southeast of proposed tailings line. Harbor seal haulouts are located 1.6 km to north and 1.6 km to south of proposed tailings line.

Human usage: Dungeness crab fishery nearshore. Commercial fishery nearshore and offshore. Cruise ships visit the area (Glacier Bay) during summer months.

Chichagoff

Shoreline Types: Mostly rocky shorelines and exposed sand and gravel beaches. Some protected sand beaches.

Sensitive Biological Resources: Sea otters use entire area year-round. Seabird nesting colonies are 8 to 13 km away. Pacific herring spawning area 5 km away.

Human Usage: Sport and commercial fishing occurs in the entire area.

Copper Bullion

Shoreline Types: Exposed rocky shorelines and coarse grained sand beaches.

Sensitive Biological Resources: Nearshore zone utilized by sea otters, seals, various diving birds.

Human Usage: Recreational fishing.

Elrington Island

Shoreline Types: Gravel beaches and sheltered rocky shores.

Sensitive Biological Resources: None noted.

Human Usage: Field survey site, a biological and geological field station is nearly what would be the proposed STD tailings line location.

Greens Creek

Shoreline Types: Almost half of the shoreline in the area is exposed wave-cut platforms. There is also significant areas of sand beaches, mixed sand and gravel beaches, exposed tidal flats, sheltered tidal flats, and intertidal marshes.

Sensitive Biological Resources: Numerous bald eagle nests on north end of Admiralty Island and Mansfield Peninsula. Numerous species of shorebirds use north end of Island near Hawk Inlet.

Human Usage: Adjoining area receives substantial use from nearby Juneau residents doing sport and commercial fishing for King, Coho, Pink, Sockeye, and Chum salmon, Steelhead trout, Herring, Tanner crab, and King crab. The waters around Admiralty Island are frequented by cruise ships during the summer months.

Jualin

Shoreline Type: Within 3 km of the proposed STD outfall the shoreline is gravel beaches , over half with wave-cut platforms. At a distance of 3 to 7 km, there are sheltered impermeable and permeable rocky shores, intertidal marshes, and sheltered tidal flats.

Sensitive Biological Resources: Eagle nesting areas nearby. Bear concentrations 5 km to the north. Pacific herring spawning area 5 km to the south.

Human Usage: King crab and Tanner crab fisheries are in the immediate area. Dungeness crab fishing areas are 3 km away. Commercial fisheries are in the area. Cruise ships use Lynn Canal.

Kensington

Shoreline Type: Mixed sand and gravel beaches and gravel beaches with wave-cut platforms.

Sensitive Biological Resources: Eagle nesting areas exist along the shoreline in the area.

Human Usage: Tanner crab and King crab fisheries are common throughout the area. To the south about 1 km away are commercial fishing areas. Cruise ships using Lynn Canal would be able to see the downstream slope of the proposed on-land tailings impoundment embankment.

Keystone

Shoreline Types: Sheltered rocky shores, mixed sand and gravel beaches, some with wave-cut platforms.
Sensitive Biological Resources: Pink and Chum salmon use Landlocked Bay in the spring, summer and fall.
Human Usage: Commercial harvesting of salmon takes place nearshore. Sportfishing for coho, pink, and chum salmon, halibut, dolly varden trout, halibut and rockfish occurs.

Klukwan Fan

Shoreline Types: Mostly sheltered impermeable rocky shores and some significant gravel beaches. About 2 km to the south is Kochu Islands with exposed rocky shores and wave-cut platforms. About 5 km to the northwest is McClellan Flats, an extensive exposed tidal flat of the Chilkat River discharge area.
Sensitive Biological Resources: Alaska Chilkat Bald Eagle Preserve is 4 km southwest of deposit.
Human Usage: Numerous tourist cruise-ships visit the area during the summer months.

Port Snettisham

Shoreline Types: Within 3 km the shoreline is exposed rock or exposed wave-cut platforms of gravel beaches.
Sensitive Biological Resources: Eagles nest in the area and pink and chum salmon spawn in some of the streams nearby.
Human Usage: Areas nearby are commercially fished for brown king crab, tanner crab and shrimp. Sportfishing is done for king and coho salmon, halibut and dolly varden trout. Some logging takes place in the area.

Quartz Hill

Shoreline Types: Wilson Arm and Boca de Quadra are typical glacial fjords characterized by steep side walls and a rocky shoreline. Large estuaries and tidal flats exist at the upper ends of each fjord where freshwater rivers enter.
Sensitive Biological Resources: Eagle nests are present in the area along with shorebirds. Harbor seals are periodically present in Wilson Arm and Boca de Quadra. There are also bear concentrations in the area.
Human use: Boca de Quadra is used sporadically for sport and commercial fishing for salmon, shrimp, and dungeness crab.

Red Mountain

Shoreline Types: Jakolof Bay consists of mostly sheltered rocky shores with some marshes and mixed sand and gravel beaches. Kasitsna Bay consists of sheltered rocky shores, exposed rocky shores, and mixed sand and gravel beaches.
Sensitive Biological Resources: Kachemak Bay Critical Habitat Area is nearby. Bald eagles are found year-round at Nubble Point, Herring Islands, and Kasitsna Bay shoreline. Pacific herring, Pink, and Chum salmon are in Jakolof Bay during spring and summer. The nearshore area of Kachemak Bay is used by 5 species of marine mammals and 48 species of marine birds.
Human Usage: Sport and commercial harvesting of king, coho, and pink salmon, halibut, dolly

varden trout, rockfish, and lingcod takes place. Some logging takes place west of the site.

Sumdum

Shoreline Types: Most of the shoreline to the north, east and southeast consists of sheltered rocky shores but there are a few stretches of sheltered permeable rocky shores and intertidal marshes. About 4 km to the southeast and 2 km to the northwest are extensive areas of exposed tidal flats, sheltered tidal flats, intertidal marshes, and sheltered permeable rocky shores.

Sensitive Biological Resources: Eagles nest along the shorelines of Tracy Arm and Endicott Arm. Bear concentrations are present nearshore at the north end of Endicott Arm. Harbor seals frequent Tracy Arm and Endicott Arm. Waterfowl concentrations occur west and northwest of Sumdum.

Human Usage: Tracy Arm and Endicott Arm are fished for Tanner and King crab. Tracy Arm is frequently visited by cruise ships during the summer months.

Windy River

Shoreline Types: Jakolof Bay consists of mostly sheltered rocky shores with some marshes and mixed sand and gravel beaches. Kasitsna Bay consists of sheltered rocky shores, exposed rocky shores, and mixed sand and gravel beaches.

Sensitive Biological Resources: Kachemak Bay Critical Habitat Area is nearby. Bald eagles are found year-round at Nubble Point, Herring Islands, and Kasitsna Bay shoreline. Pacific herring, Pink, and Chum salmon are in Jakolof Bay during spring and summer. The nearshore area of Kachemak Bay is used by 5 species of marine mammals and 48 species of marine birds.

Human Usage: Sport and commercial harvesting of king, coho, and pink salmon, halibut, dolly varden trout, rockfish, and lingcod takes place. Some logging takes place just west of the site.

Yakobi Island

Shoreline Types: Lisianski Strait is a typical glacial fjord characterized by steep side walls and a rocky shoreline. Some tidal flats exist where freshwater rivers enter.

Sensitive Biological Resources: Sea otters and Stellar sea lions utilize nearshore areas.

Human Usage: Area is used for sport and commercial fishing. Lisianski Strait is used for subsistence and Tanner crab fishing.

APPENDIX F - COST ESTIMATES FOR SUBMARINE TAILINGS DISPOSAL

COST ESTIMATES FOR SUBMARINE TAILINGS DISPOSAL[3]

PRELIMINARY FEASIBILITY, ENVIRONMENTAL STUDIES AND CONCEPTUAL DESIGN

A preliminary feasibility includes a one to two week field study to investigate the physical constraints of the site in regards to submarine tailings disposal. The study would follow basic design criteria to investigate the feasibility of discharging tailings at depth and the transport of the tailings away from the outfall terminus.

A reconnaissance level environmental study conducted at the same time as the field feasibility investigation provides an initial appreciation of the sensitive issues to be addressed. The study would include water column stratification, water quality, bottom profiling, sediment coring, and sediment geochemistry which would provide both a present and historical insight into the system being investigated. A conceptual submarine tailings disposal system with a ±25% cost estimate would be developed.

This preliminary feasibility, reconnaissance level environmental studies and conceptual design form an important component of the initial decision whether to proceed with further investigations. Also, the reconnaissance level environmental studies provide a basis for designing the detailed environmental studies required to prepare the EIS. The estimated cost for this component range from $30,000 to $100,000 depending somewhat on project size. The smaller projects, i.e., 1,000 mtpd, cost less simply for the reason that the project cannot afford more in cost/mt of material discharge. See Table F-1 for an outline of costs versus capacity.

DETAILED ENVIRONMENTAL STUDIES

The detailed environmental studies for submarine tailings disposal are usually very extensive and costly. The major effort involves predicting the deposition and dispersal of the tailings in the receiving environment. Certain effort is required to establish the background environmental conditions in order to assess the impacts of the discharge on the environment. The cost varies from $250,000 to $2,000,000.

Perhaps, more important is the time required to obtain the necessary approval in order to proceed. Delays in development schedules are very costly.

LICENSING AND PERMITTING

The licensing and permitting process for submarine tailings disposal can be lengthy and controversial. A relatively small amount of money has been allocated for a small project because if lengthy hearings are involved the project will not be able to afford the cost. For larger projects, $500,000 has been estimated for the licensing and permitting process provided the EIS has been approved. These costs can escalate dramatically if stiff public opposition to a proposal develops (i.e., Quartz Hill).

CAPITAL COST OF SYSTEM

The capital cost of the system will vary depending on the capacity of the system and the geographic setting. For small projects (500 mtpd), a submarine tailings disposal system

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[3] This appendix is an excerpt from Poling et. al. 1992 (47).

discharging at a depth of 50 m below the surface would cost approximately $600,000. For a larger system such as 75,000 mtpd operation, the capital cost is estimated at $2,500,000. The costs are in 1991 U.S. dollars and are based on 20-year operating life.

As presented in the estimated cost summary Table F-1, the capital costs have been divided into five categories:

i) Collection line and civil works--shoreline to mixtank.
ii) Causeway and bridge to mixtank.
iii) Seawater mixtank including foundation and anchors.
iv) Seawater intakes and fish protection screens.
v) Outfall pipeline and anchors.

The system consists of high density polyethylene (HDPE) Series 60 pipe, mixtank with appropriate corrosion protection, and anchoring system for 25° bottom slope.

ANNUAL OPERATING COST

The systems generally operate with minimum supervision. The labor costs for operating the system have been included in the maintenance and replacement cost. The replacement category includes general items such as HDPE pipe, corrosion protection, etc. The reagents include coagulant (lime) and flocculent for the operation of tailings thickeners. The costs are based on over 20 years of historical operating data from the Island Copper Mine and two years of data from the Kitsault Mine. The total reagent cost is estimated at $0.055/mt of tailings discharged. The reagent cost includes all handling and storage.

COMPLIANCE MONITORING

Permit compliance monitoring cost with a submarine tailings disposal system is usually high due to the extensive receiving environment surveillance required. A significant amount of effluent toxicity monitoring is usually required to demonstrate compliance. Long-term monitoring to assess chronic and subchronic impacts require a high level of technical sophistication in the program. The estimated cost for this component of the study was based on 20 years of operating experience in Canada. A significant amount of the compliance monitoring being performed by the Island Copper Mine is by inhouse staff. External monitoring by consultants would be more expensive.

DECOMMISSIONING AND CLOSURE

The decommissioning and closure cost estimate category includes removing all structures and disposing of the material off site. The cost includes labor for dismantling and transporting scrap material by a salvage operator, reclaiming the shoreline to original conditions and the administrative cost of closure.

CLOSURE MONITORING

Closure monitoring is usually required to demonstrate natural underwater reclamation and rehabilitation and ensure conditions are acceptable for the release of the environmental bond. The amount allocated for this category ranges from $10,000 to $40,000 per year. The time frame considered for the closure monitoring is five years.

COSTS VERSUS CAPACITY

The soft capital, operating and closure costs for submarine tailings disposal are somewhat dependant on the size of the operation. However, the soft cost which includes all environmental issues may not be significantly different for a small project. The unit cost for small operations may make submarine tailings disposal uneconomical.

A summary of the unit costs is provided in Table F-1. The estimates are also depicted in graphical form in Figures F-1, and F-2. Figure F-1 illustrates the relationship between operating cost of a STD system and mill capacity. Figure F-2 illustrates the relationship between capital cost of a STD system and mill capacity.

Table F-1. Submarine Tailings Disposal Cost Estimates (1991 dollars)

COST COMPONENTS	OPERATING CAPACITY (mtpd)				
	500	1,000	25,000	50,000	100,000
PRELIMINARY FEASIBILITY, ENVIRONMENTAL STUDIES & CONCEPTUAL DESIGN	$30,000	$50,000	$80,000	$100,000	$100,000
DETAILED ENVIRONMENTAL STUDIES & EIS	250,000	250,000	1,500,000	2,000,000	2,000,000
CAPITAL COST OF SYSTEM	20,000	30,000	250,000	500,000	500,000
Collection Line & Civil Works	100,000	150,000	350,000	400,000	500,000
Causeway and Bridge to Mixtank	100,000	150,000	225,000	250,000	250,000
Seawater Mixtank including Foundation and Anchors	200,000	250,000	500,000	650,000	750,000
Seawater Intake and Screens	50,000	75,000	275,000	325,000	350,000
Outfall Pipeline/Anchors, etc.	150,000	200,000	550,000	600,000	650,000
ANNUAL OPERATING COST					
Reagents (Coagulant and/or Flocculent)	10,000	25,000	500,000	1,000,000	1,500,000
Maintenance & Replacement	50,000	60,000	250,000	500,000	700,000
COMPLIANCE MONITORING Cost/Annum	75,000	100,000	350,000	500,000	500,000
DECOMMISSIONING & CLOSURE	30,000	50,000	100,000	250,000	250,000
CLOSURE MONITORING Cost/annum - 5 yrs	50,000	60,000	100,000	200,000	200,000
TOTAL COST SUMMARY					
Licensing & Capital	900,000	1,155,000	3,730,000	4,875,000	5,100,000
Annual Operating	135,000	185,000	1,100,000	2,000,000	2,700,000
Decommissioning & Closure	$280,000	$350,000	$600,000	$1,250,000	$1,250,000

Source: Poling et. al. 1992 (47)

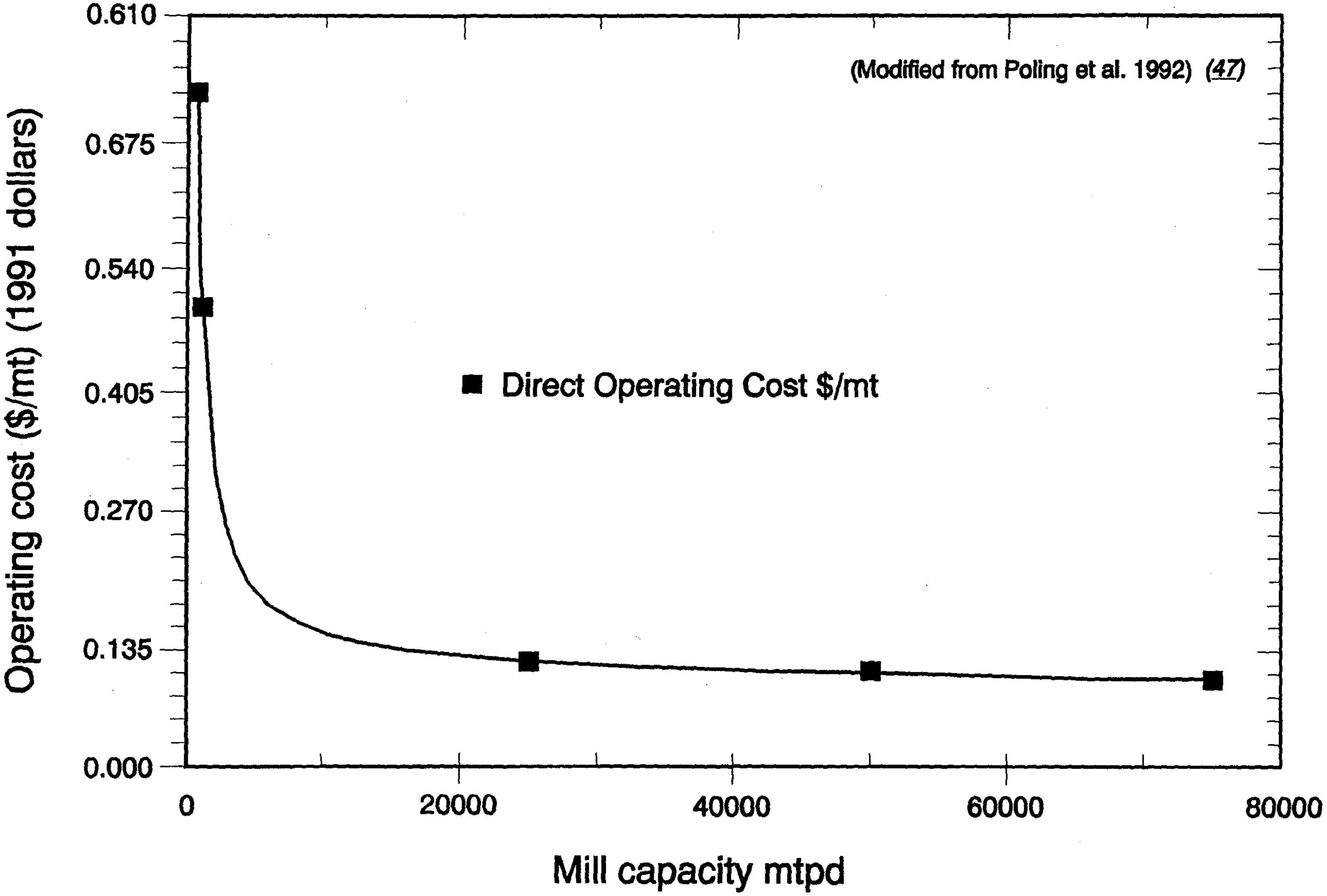

Figure F-1 - Operating cost ($/mt) submarine tailings disposal versus daily mill capacity.

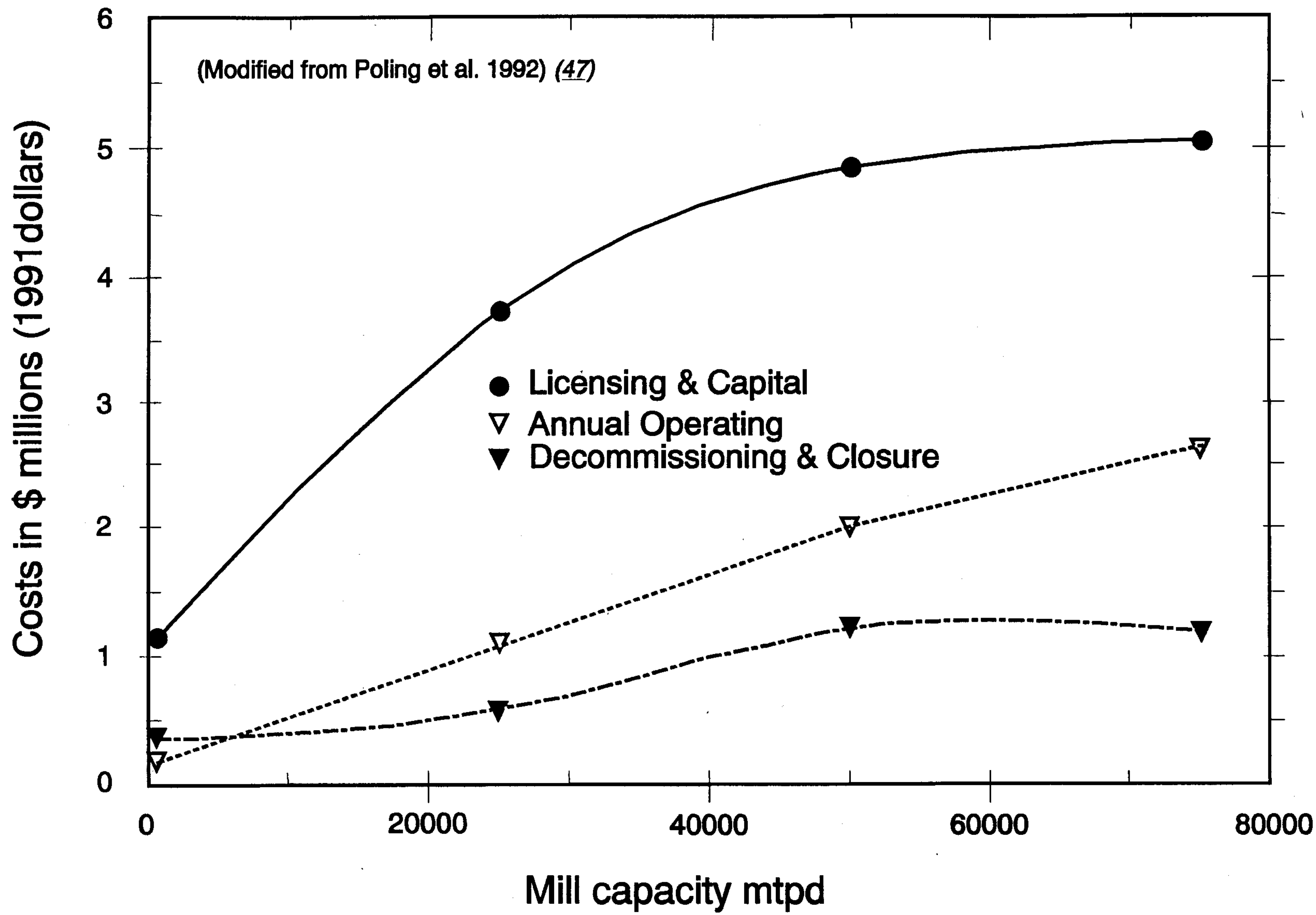

Figure F-2 - Submarine tailings disposal costs versus daily mill capacity.