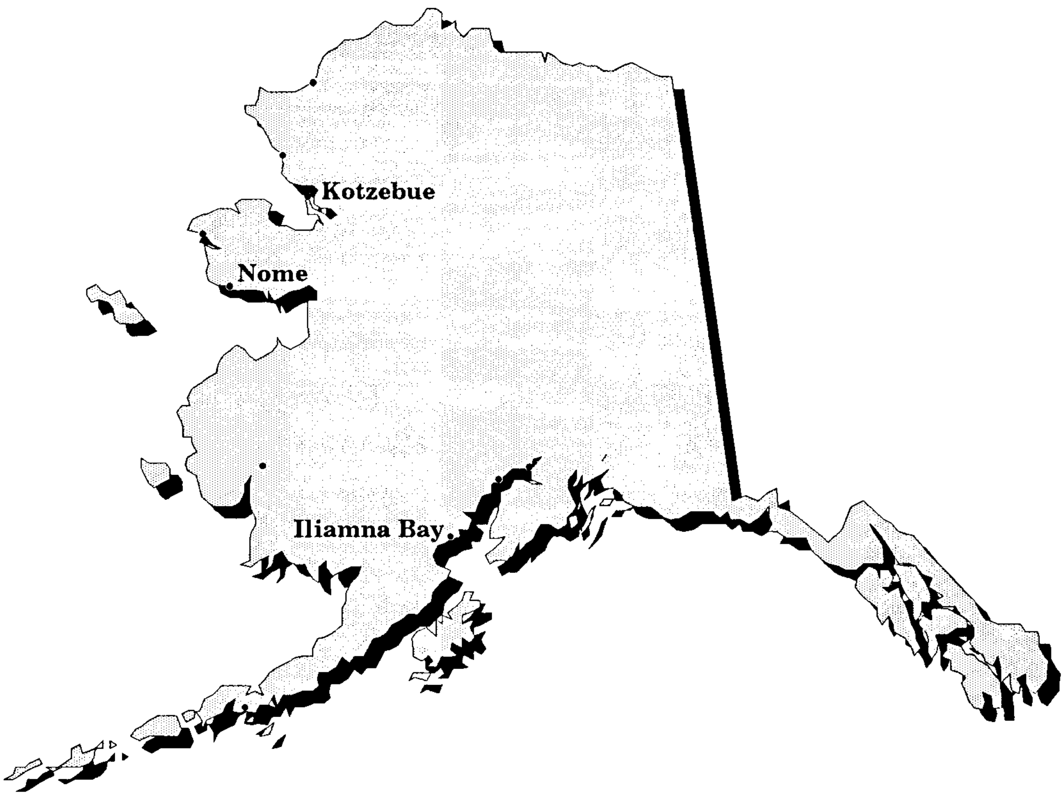
ANALYSIS OF ILIAMNA BAY, KOTZEBUE, AND NOME AS PORT SITES FOR USE BY THE MINERAL INDUSTRY

By Gary E. Sherman, Denise A. Herzog, James R. Coldwell, and Mark P. Meyer



UNITED STATES DEPARTMENT OF INTERIOR
Manuel Lujan, Jr., Secretary

BUREAU OF MINES
T S Ary, Director

OFR 21-90

CONTENTS

ILLUSTRATIONS

TABLES

CONTENTS -- Continued

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

bbl	barrels
BTU	British Thermal Units
DCFROR	discounted cash flow rate of return
ft	feet
gal	gallon
KW	kilowatt
lb	pound
mi/d	miles per day
NPV	net present value
st	short ton
st/d	short ton per day
st/hr	short ton per hour
st/yr	short ton per year
stu	short ton unit
tr oz	troy ounces
yd^3/d	cubic yards per day
yr	year

ANALYSIS OF ILIAMNA BAY, KOTZEBUE, AND NOME AS PORT SITES FOR USE BY THE MINERAL INDUSTRY

By Gary E. Sherman[1], Denise A. Herzog[2], James R. Coldwell[3], and Mark P. Meyer[4]

ABSTRACT

To aid the U.S. Army Corps of Engineers in their Resource Development Navigation Study of ten existing or proposed port sites in Alaska, the Bureau of Mines examined the potential for mineral development around three Alaska port sites: Iliamna Bay, Kotzebue, and Nome.

The mineral deposits near Iliamna Bay include gold, copper, and iron. Development of minerals in this area will require the discovery of new deposits or the definition of additional ore reserves at known deposits.

The mineral deposits near Kotzebue are primarily gold, copper, coal, lead, and uranium. Based on the character of these deposits, it appears that development of a small-scale mine supplying coal for regional use is the most likely scenario in the near-term.

The mineral deposits near Nome are primarily gold and copper. Development of small underground gold mines is possible, however it appears that expanded offshore gold dredging will have the greatest impact on the flow of freight and goods through the Nome port in the near-term.

[1]Mining Engineer
[2]Mining Engineer
[3]Mining Engineer
[4]Geologist
Alaska Field Operations Center, Bureau of Mines

INTRODUCTION

The objective of this report is to provide mining feasibility data to the U.S. Army Corps of Engineers for use in their on-going Resource Development Navigation Study. The study is examining the potential for developing or improving transportation infrastructure at ten proposed or existing port sites in Alaska. The port sites under consideration are Balboa/Herendeen Bay, Beluga, Bethel, Iliamna Bay, Kivalina (Red Dog), Kotzebue, Lost River, Nome, Omalik Lagoon, and Point MacKenzie. This report is the second in a series of three and examines the potential for mineral development within a 100 mile radius of the Iliamna Bay, Kotzebue, and Nome port sites. Figure 1 shows the location of the three port sites and the deposits[5] located within a 100 mile radius. Map numbers shown on figure 1 refer to deposit summaries in the Mineral Deposit Inventory volume[6] (24)[7]. There are a total of 234 deposits (excluding placer deposits) within the area of these three port sites. The breakdown by port site is: Iliamna Bay - 63, Kotzebue - 40, and Nome - 131. These represent deposits closest to each respective port. Other deposits may fall within the 100 mile radius but are closer to other ports such as Beluga, Kivalina, Lost River, Point MacKenzie, and Omalik Lagoon. The feasibility of mineral development around each port site was examined for typical (model) deposit types. These models were used to estimate the capital and operating costs, mine life, transportation costs, annual tonnage produced, and mine feasibility.

METHODOLOGY

Models were built and applied to each port site based on the types of mineral deposits that occur nearby. A model in this sense refers to a mining and milling scenario, based on factors such as deposit size, grade, orebody shape and attitude, type of wall rock, orebody depth, and depth of overburden. Once the physical aspects of a deposit type were determined, capital and operating cost estimates were prepared using a number of techniques. Cost information came from the Green Guide for Equipment (10), the Bureau's Cost Estimating System Handbook (CES) (22, 23), and in the case of the coal models, from published reports. The source of costs are described in the discussion of each model. Since major lode mining in Alaska is just now seeing a revival, actual cost data have generally been lacking. Development of the Red Dog Mine in Northwestern Alaska and the Greens Creek Mine in Southeast Alaska has provided some additional cost information which can be applied to mine models. When applicable, cost information from developing or producing mines in Alaska was used in assembling the mine models.

Typical cost items for mine models include exploration, permitting, acquisition, mine equipment, mine plant, mill plant and equipment, working capital, and infrastructure. In addition to determining costs for each model, a material balance calculation was completed which determined the quantity and grade of concentrate produced for each unique mill product.

---

[5]The term "deposit" is used loosely in this document in referring to a minerals location. Nothing is implied as to size or economic viability.

[6]For more information on deposits, refer to the "Mineral Deposit Inventory" prepared by the Bureau of Mines.

[7]Underlined numbers in parentheses refer to references listed at the end of the report.

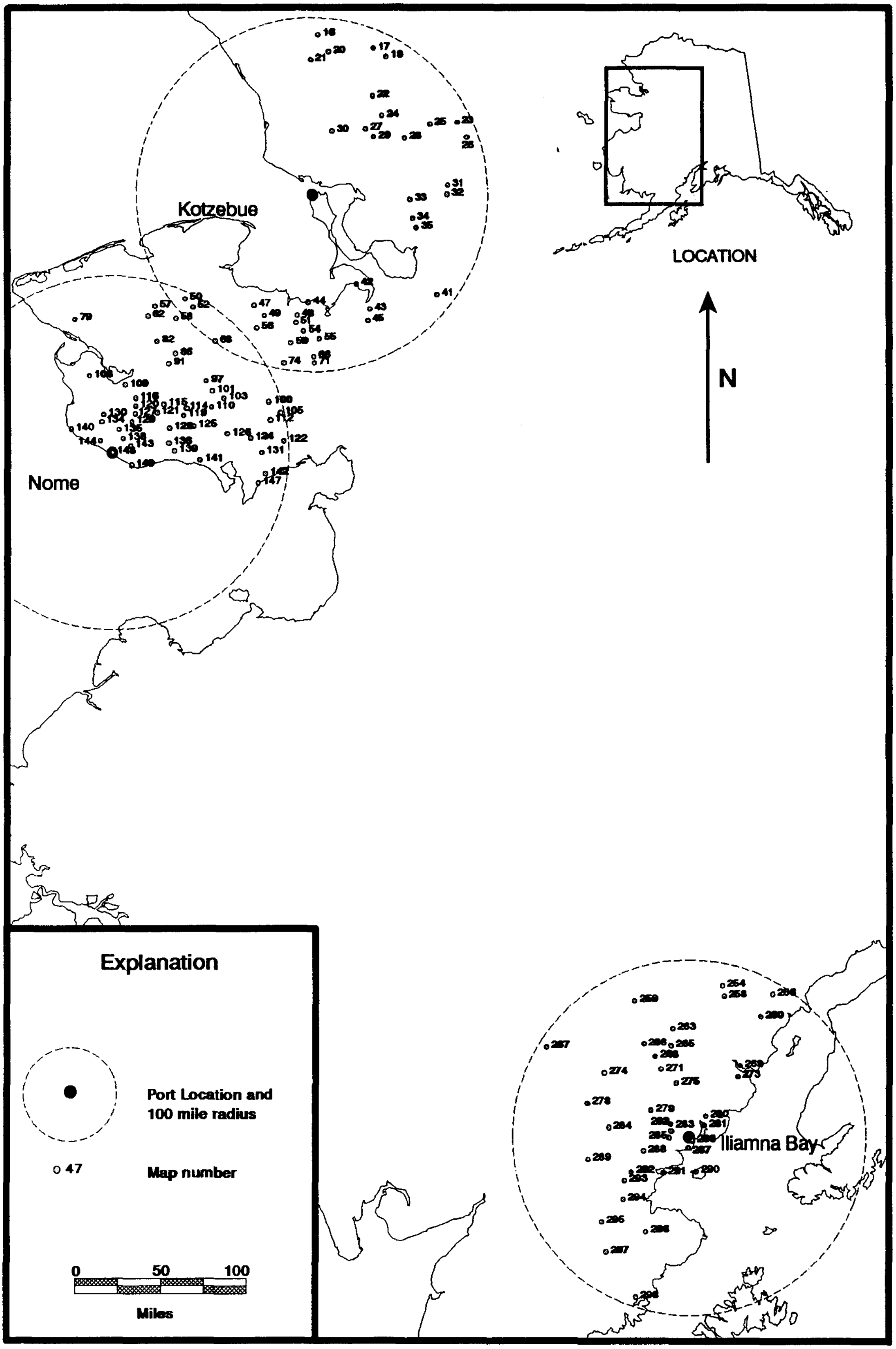


Figure 1. -- Location of the Iliamna Bay, Kotzebue, and Nome port sites and adjacent mineral deposits.

The cost information was entered into a discounted cash flow analysis software program to determine the rate of return for each model at discount rates of 0% and 15%. These results are reported in the discussion of each port site. Estimates of when an individual deposit will become economic are very tenuous since metal markets are unpredictable and vary with world supply and demand. A discussion of supply, demand, and production for the mineral commodities considered in this study will be included in a final summary report to be submitted at a later date.

Analysis of each of the models assumes that the port exists and is capable of servicing the mining operation. Costs are included for road construction from the mine site to the port and also construction of concentrate storage and loading facilities at the port site. Transportation costs from the mine site to the port and from the port to point of sale are also included as an operating cost.

ANALYSIS OF MINING FEASIBILITY

The following is an analysis of mining feasibility for the Iliamna Bay, Kotzebue, and Nome port sites. Each port and the mine models applied to it are discussed individually. Appendix A contains a summary of the mine models used in this report. The appendix includes the assumptions used in building each model, the source of costing information, and the output from each model in terms of annual concentrate or product produced.

It is important to stress that the mine models presented in this study are based on possible mining and milling scenarios for generalized deposits that may occur in a given area. The models are not meant to represent a feasibility analysis of specific deposits. To do so would be inappropriate since such an analysis requires an information base greater than that available for this study. The models can be qualitatively applied to similar deposits in the area to get a gross feel for the potential for mineral development. A number of variables govern the viability of a mineral deposit, including physical characteristics of the orebody, metal markets, availability of infrastructure, political climate, environmental constraints, and corporate policy. Any predictions of the future must consider all the variables; thus results presented here must be viewed as a "snapshot" at this point in time.

ILIAMNA BAY

Location and Access

Iliamna Bay is located on the west side of Cook Inlet 13 miles north of Augustine Island. The largest village within the 100 mile port site radius is Nondalton with a 1980 population of 173 (20). Populations of other villages are: Igiugig - 33, Iliamna - 94, Newhalen - 87, and Pedro Bay - 33 (20). Other villages in the area which have their populations counted as part of the regional total include Dutton, Fish Village, Iniskiu, Kaguyak, Kakhonak, Kakhonak Bay, Kijik, Kustatan, Old Iliamna, Port Alsworth, Pile Bay Village, Sevensens, Swikshak, and Williamsport.

Port facilities in the region consist of an existing dock located at Williamsport at the head of Iliamna Bay. Water depth in the bay ranges from 42 feet at its entrance to 6 feet at its head. The existing dock is dry during periods of low water (14). A 15 mile long road runs east-west between Williamsport and Lake Iliamna (14). This road is used to portage small vessels between Cook Inlet and Lake Iliamna and Bristol Bay via the Kvichak River. The largest airstrips in the area are at Iliamna and Newhalen. All other villages have airstrips capable of handling two seat-type aircraft.

Average annual precipitation in the Iliamna Bay area is roughly 23 inches (4). Temperatures range between an average low of 21.4 degrees to an average high of 52 degrees Fahrenheit (4). The proposed port site could be ice free all year round with a small amount of ice breaking in Kamishak Bay (14).

The 100 mile port site radius includes the Lake Clark National Park and Preserve, Katmai National Park and Preserve, lands controlled by the BLM, Native land (regional, village, and private) and the State of Alaska (McNeil River State Game Sanctuary and Kalgin Island State Critical Habitat Area) (15).

Presently the existing port facility at Williamsport is not used in supplying the villages of southwestern Alaska. Only personal supplies are hauled over the 15 mile road to Lake Iliamna.

Mineral Deposits

Gold, copper, and iron are the major mineral deposit types located within the 100 mile radius of Iliamna Bay. Zinc, silver, and mercury deposits are also present. Figure 2 shows the distribution of deposits by primary commodity for the Iliamna Bay area. The only past producing mine in the area is the Gorge Creek mine (map number 297) which reportedly produced some mercury although the extent of production is unknown. There has been substantial exploration of the area in the last decade. The Johnson River deposit was discovered in 1983 and contains an estimated 525,000 st of ore with grades of 9.4-24.8 % zinc, 2.8% lead, 1.7% copper, 0.6-1.2 tr oz/st gold (18). The Kasna Creek copper deposit (map number 271) has published reserves of 10 million st ore with a grade of 1 % copper (12). This deposit is in the Lake Clark National Park. Because of the land status, high iron content, and associated metallurgical problems, a mine model based on a "Kasna Creek type" deposit was not considered in this study. Reserve information on the remaining deposits in the area is limited.

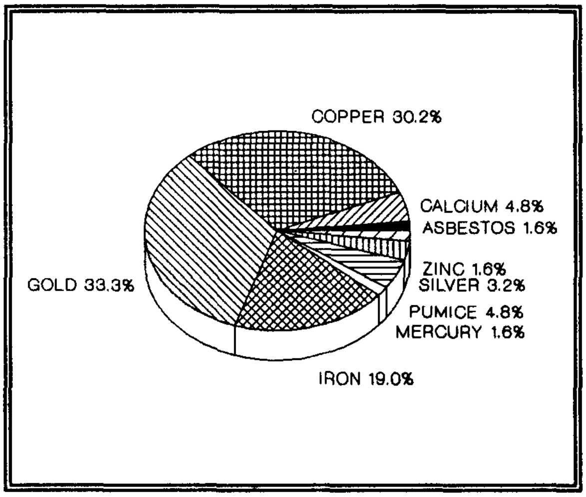


Figure 2. -- Distribution by primary commodity of deposits near the Iliamna Bay port site.

Open Pit Mine Model

Based on exploration work done in the region in recent years, there appears to be potential for the discovery of additional zinc-lead-copper-gold deposits in the region. To examine the feasibility of mining this type of deposit, a mine model based on ore similar to that found at Johnson River was constructed. The model assumes sufficient reserves to operate for roughly 8 years. Table 1 lists the assumptions made in designing the model and the commodity data for the model are listed in table 2.

TABLE 1. -- Assumptions used in designing the Iliamna Bay open pit mine model.

Mine life (years)	7.76
St ore/day	700
St waste/day	878
St ore mined/year	244,985
Stripping ratio	1.25:1
Personnel	100
Power generation (KW)	2400
Operating days/year	350
Mill feed, st/d	700
Mill method	Flotation
Tailings, st/d	466
Tons concentrate produced/year	81,550

TABLE 2. -- Commodity data for the Iliamna Bay open pit mine model.

Commodity	Grade	Recovery	Concentrate Grade	Tons/day Concentrate
Zinc (Zn)	15.0%	85%	51%	175.2
Lead (Pb)	2.8%	95%	70%	28.0
Copper (Cu)	1.7%	70%	28%	29.8
Gold (Au)	0.6 tr oz/st	30%	99%	126 tr oz/d
Silver (Ag)	0.13 tr oz/st	80%	2.6 tr oz/st	(contained in Pb)

Costs for the Iliamna Bay open pit mine model were estimated using CES (22, 23). All costs are in July 1989 dollars and have been escalated to account for the increased cost of mining in Alaska. Capital costs were escalated by a factor of 2.2, labor costs by 1.31, and supplies and equipment costs by 1.52 (7). Table 3 lists capital and operating costs for the mine and mill and transportation operating costs.

TABLE 3. -- Capital, operating, and transportation costs for the Iliamna Bay open pit mine model.

Cost Category	Capital Cost	Operating Cost $/st
Mine	$43,726,000	$31.43
Mill	$17,347,900	$25.40
Transportation	NAp	$35.00

NAp Not applicable

The total capital costs for a 700 st/d open pit mine are $61,073,900. This includes exploration, permitting, and infrastructure. Infrastructure development capital costs include construction of a 12 mile access road to the port site. The total mine and mill operating cost is $56.83/st ore mined and processed. The transportation operating cost includes concentrate haulage to the port site by truck and shipment to point of sale or smelting by barge. The CES provides estimates within ± 25% of actual costs. A summary of the costs and assumptions used in the model are presented in Appendix A.

Economic Analysis

To determine the economic viability of a deposit similar to that of the model, a discounted cash flow rate of return (DCFROR) analysis was done at discount rates of 0 and 15%. The model generated a DCFROR of 26.8% with NPVs of $149,126 (0% discount rate) and $28,331 (15% discount rate).

To examine the affect of costs and revenues on the model, a sensitivity analysis was done by varying capital costs, operating costs, and revenues. One variable was varied over a range of 75% to 125% of the base case (100%) while the other two were held constant. The results of the sensitivity analysis reveal which variables have the most impact on the models rate of return. Table 4 shows the results of the sensitivity analysis for each of the three cost/revenue variables. Examination of the results reveals that revenue has the widest range of DCFROR's and thus the greatest single impact on the rate of return of the model. This is illustrated in figure 3. Note the relative steepness of the revenue curve compared to those for capital and operating costs.

TABLE 4. -- DCFROR at levels of expenditure/revenue from 75 to 125% of base case (base is 100%), Iliamna Bay open pit mine model.

Percentage of base	DCFROR when Capital costs are varied	DCFROR when Operating costs are varied	DCFROR when Revenues are varied
75	34.00	28.66	16.06
80	32.35	28.31	18.57
85	30.82	27.94	20.88
90	29.40	27.58	23.02
95	28.07	27.21	24.99
100	26.84	26.84	26.84
105	25.68	26.46	28.58
110	24.58	26.08	30.24
115	23.55	25.69	31.82
120	22.58	25.30	33.33
125	21.65	24.91	34.74

In the base case the model has a DCFROR of 26.84%. If one assumes that a 15% DCFROR is the minimum acceptable return for a mining venture in this region of Alaska, the model deposit is economically viable. This statement needs to be qualified by saying that there are no deposits known in the region at this time with reserves equal to those of the model. To obtain a 15% DCFROR, a deposit with grades similar to the model would need to operate for 3 years. Assuming 95% recovery of the orebody, this requires a reserve of approximately 774,000 st of ore.

The economic analysis presented for the Iliamna Bay open pit model can be considered to be an estimate of feasibility at current metal prices. Metals prices used in the base case are $0.41/lb lead, $0.77/lb zinc, $1.10/lb copper, $400/tr oz gold, and $5.00/tr oz silver.

Development of deposits similar to the model first requires extension of reserves at existing deposits or the discovery of new deposits in the region. Owing to the lag between discovery and production, it is unlikely that a deposit similar to the model would be developed in the next ten years. Based on the geology of the area, additional discoveries are possible. Because of the difficulty in forecasting metals prices, it is not possible to state absolutely that mineral resources around the Iliamna Bay site will be developed in the near term. Given the results of the mine model analysis, it appears that potential exists for development in the next 20 to 50 years. This of course depends on a multitude of factors that cannot be predicted (e.g. political and economic climate, present and future environmental restrictions, commodity prices/world supply and demand, and technologic changes).

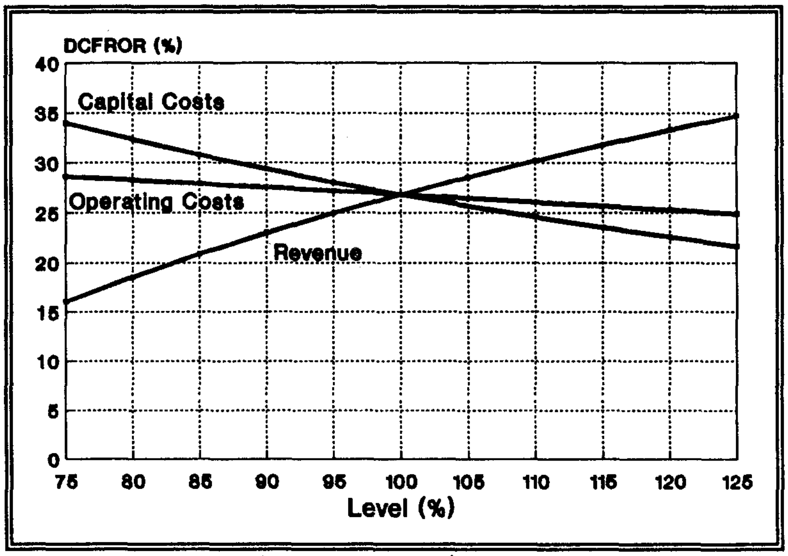


Figure 3. -- Affect of varying costs/revenues on DCFROR for the Iliamna Bay open pit mine model.

Assuming the development of two deposits similar to the mine model, a total of 163,100 st/yr of concentrate would pass through the port. While potential for deposits similar to the model exist, additional exploration on an intensive scale will be required to determine if economically viable reserves are present.

KOTZEBUE

Location and Access

Kotzebue is located on the northwestern end of Baldwin Peninsula, northern Kotzebue Sound and is the largest community in the region with a 1980 population of 2,054 (20). Population of other villages within the 100 mile port site radius include Deering - 150, Kiana - 345, Kivalina - 241, Noorvik - 492, and Selawik - 535 (20). At least 17 smaller villages are found within the port site area.

An existing port site is located at the northern end of the village. The port facilities consist of a 220 foot long two-berth wharf with a minimum depth of 6 feet, fuel storage tanks (6 million gallon capacity), two buildings for covered storage (7,400 square feet), and plenty of open storage space (14). All cargo from seagoing ships and barges must be lightered from an anchorage 12 miles west of Kotzebue and ferried to the port in 4 foot draft barges (14). All dry cargo arrives in 20 foot size containers or unit loads (14).

A major airport is located at Kotzebue which services the Seward Peninsula area. Airstrips with the capacity of handling two seat-type aircraft are located at the other villages in the port site radius. The shipping lane used to supply northern and western Alaska is located west of Kotzebue in the Bering Sea.

The average annual precipitation in the Kotzebue area is approximately 16.5 inches (14). Temperatures range from an average low of 4 degrees to an average high of 53 degrees Fahrenheit (4). The port site can receive supplies during the ice free season lasting from June to October (14).

The port site area includes the Bering Land Bridge National Preserve, Cape Krusenstern National Monument, Kobuk Valley National Park, Noatak National Preserve, Selawik National Wildlife Refuge, BLM administered land, Native land (regional, village, and private), and lands controlled by the State of Alaska (15).

Kotzebue receives incoming cargo consisting of construction materials, food, and fuel. These commodities are then transshipped to villages along the Kobuk and Noatak Rivers or transferred to the airport for air shipments to those villages not serviced by the rivers.

Mineral Deposits

Gold, copper, coal, and lead deposits make up the majority of the mineral deposit types found within 100 miles of the Kotzebue port site. Uranium, silver, and chromium deposits are also present within the area. Figure 4 shows the distribution of deposits by primary commodity for the Kotzebue area.

Coal has been mined from several deposits in the Kotzebue area, including: Chicago Creek (map number 48), Kobuk River (map number 32), and the Wallin Coal Mine (map number 51). An unknown amount of silver has been produced from one deposit, the Golden Circle Mine (map number 59). The nearest identified deposit is a chromium prospect called the Sours Prospect (map number 30),and is located 38 miles from Kotzebue. The majority of the deposits are greater than 60 miles from Kotzebue. Most of the deposits in the Kotzebue area are prospects with limited exploration or development work. Data on reserves and grades are generally lacking for the deposits in this region.

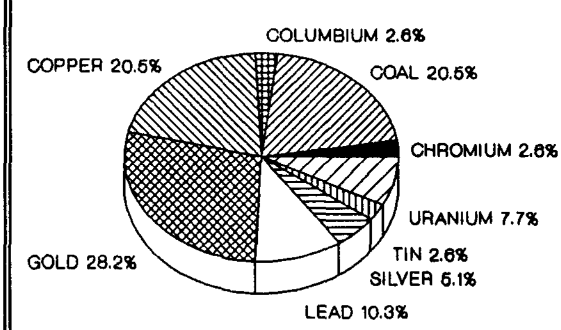


Figure 4. -- Distribution by primary commodity of deposits near the Kotzebue port site.

Coal Mining Constraints

Coal mining in the Arctic and Subarctic presents a challenge owing to the cold climate, high winds, permafrost, and remoteness from major centers of population and supply. These factors can have a major influence on productivity, transportation, personnel, dust generation and suppression, coal washing, and surface plant (14). The following is a synopsis of the economic and technologic constraints associated with mining coal in the Arctic.

The Chukchi Sea is ice free for about 100 days a year, presenting a serious limitation to the import of materials and supplies and export of coal from a mine. Because of the short shipping season, a larger than normal inventory of supplies and equipment parts would be required. Stockpiling of the coal at the port would be necessary until shipment during the ice-free season. Additional equipment and larger scale loadout facilities may be necessary to load out the stockpile in the time available.

Cold permafrost is considerably stronger than that with a temperature just below freezing (14). Ice-rich permafrost is more likely to cause difficulties than ice-free permafrost. Appropriate measures for preventing permafrost degradation under surface structures need to be taken, as well as measures for insuring vehicle operation.

Hiring and retaining a labor force would be difficult due to the remote location and harsh weather. To maintain a consistent labor supply, higher wages and comfortable camp accommodations would be required. High turnover rates and the resulting high training costs can be anticipated regardless of benefits provided to employees. Productivity drops due to the weather; employees aren't able to operate as efficiently in the cold weather. Frostbite can be a problem if measures aren't taken to protect the work force by providing heated equipment cabs and other necessities.

Equipment wear is accelerated in cold climates; special lubricants and maintenance procedures are required to keep equipment operating throughout the winter season. Equipment should be housed indoors when not in use so it will be functional when called into service. Cold temperatures can make steel brittle causing increased breakdowns; rippers on bulldozers are easily broken (14). Lighting expenses for portable light systems and generators increase during the long winter nights for a year round operation (26). Heating expenses also increase dramatically during the winter months.

The use of water in coal washing operations would require a heated plant and the coal would have to be dried after washing to prevent freezing in the storage piles (14). Other problems are associated with the use of water. Haulage of wet coal can result in considerable handling problems when the coal freezes in large lumps. Usibelli Coal Mine (UCM), the only producing coal mine in Alaska, has modified its coal trucks in response to this problem; the coal boxes have double floors through which vehicle exhaust is piped to keep the truck bed warm to prevent the coal from freezing to the bed (26). In addition to these problems, maintaining water supplies and availability may be a problem (5).

There is no over-riding reason, why coal in the Kotzebue region could not be mined at the present time with current technology and mining practices. However, the environmental constraints discussed above pose significant economic factors (i.e. high costs) which may inhibit development and operation of a coal mine in this region of Alaska. While mining is currently taking place in comparable parts of Alaska (e.g. Red Dog), the fact that coal has a low unit value per ton mined compared to metals tends to limit the ability of a coal mine to absorb the increased operating costs of mining under Arctic conditions.

Small-Scale Coal Mine Model

Based on the nature of the deposits in the region and the lack of reserve data, metal mine models were not considered for the Kotzebue port site. The most likely scenario for developing mining near Kotzebue in the short term is small-scale coal production for regional use. This assumes the development of a coal market in the nearby villages through conversion of existing equipment from fuel oil to coal fired. Because of the low probability of large-scale production in the near term, only a small-scale mine producing coal for village use was modelled.

The mine model is based on mining a deposit similar in characteristic to the Chicago Creek coal deposit and is based on a previous study of the Chicago Creek mine (19).

Table 5 lists the assumptions made in designing the small-scale coal mine model. For details of the coal mine model as well as a history of past activity in the region, see Appendix A.

TABLE 5. -- Assumptions used in designing the small-scale open pit coal mine model.

Mine life (years)	30
St coal/day	500
Bank Yards overburden/day	850
St coal mined/year	50,000
Stripping ratio	1.70:1
Personnel	18
Power generation (KW)	300
Operating days/year	100

The coal produced from the mine would be subbituminous with a rating of 7,700 btu/lb, 29% moisture, and 0.8% sulfur.

Costs for the Chicago Creek coal mine model were estimated by the Alaska Division of Geological and Geophysical Surveys (ADGGS) (19). The costs from the ADGGS study were escalated to July 1989 dollars to estimate the current mining costs. Table 6 lists the capital and operating costs for the mine and transportation system.

TABLE 6. -- Capital, operating, and transportation costs for the small-scale coal mine model.

Cost Category	Capital Cost	Operating Cost $/st
Mine	$19,520,000	$34.12
Transportation	NAp	$ 9.91

NAp Not applicable

The mining operating cost includes mine costs only; there is no post-mine processing of the coal (e.g. washing) to prepare it for market. The transportation operating cost includes trucking to a loading site at Willow Bay and barging to market in Kotzebue.

Economic Analysis

The cash flow analysis of the model was run at discount rates of 0 and 15%. Since coal prices vary considerably and the actual retail price of coal from this model at the point of sale is unknown, the price of coal required to achieve a 0 and 15% DCFROR was determined for coal delivered to Kotzebue. The results of the analysis are listed in table 7.

TABLE 7. -- Economic analysis results for the small-scale coal mine model.

DCFROR	Point of sale	Price Required
0%	FOB Kotzebue	$58.70
15%	FOB Kotzebue	128.05

To put the results in table 7 in perspective, prices for coal (FOB mine) from UCM are in the mid-$30/ton range and range from $30-$50/ton delivered in Seward. Idemitsu Alaska Inc., which is working on developing the Wishbone Hill coal deposit in the Matanuska Valley, is estimating a $40/ton cost for coal delivered in Seward (1). Based on the recoverable heat for fuel oil (at 75% efficiency) and Chicago Creek coal (at 66% efficiency), it would take 19.9 lb of coal to equal one gallon of fuel oil. The 15% DCFROR FOB Kotzebue scenario presented in the economic analysis required a coal price of $128.05/ton which is equivalent to a fuel oil price of $1.28/gal.

At present a local market for coal large enough to support the proposed model does not exist. Development of coal in the Chicago Creek area would require a commitment on the part of villages in the area to convert to coal-fired heat and/or power plants. ASCE estimated conversion costs for residential heating to be $1,500 per unit and for large units (schools etc.) to be $100,000 (5). ADGGS estimated the capital cost for a 10 MW coal fired power plant to be $28.3 million (Avg 1985 dollars) (19).

NOME

Location and Access

Nome is located on the south side of Seward Peninsula at the mouth of the Snake River, northern Norton Sound. Nome is the largest community within the 100 mile port radius with a 1980 population of 2,544 (20). Populations of other communities include Brevig Mission - 138, Elim - 211, Golovin - 87, Portage - 48, Port Clarence - 29, Teller - 212, and White Mountain - 125 (20). There are 40 other smaller villages within the port site area.

Existing port facilities include a small boat harbor on the Snake River and a causeway into Norton Sound. The small boat harbor can accommodate vessels with drafts of approximately 6 ft. The causeway has a 1,250 ft berthing space with shallow water mooring. Vessels with greater than 6 ft draft must moor to transfer barges which then tie up to dolphins at the end of the causeway to unload (25).

Dry cargo is unloaded onto the causeway and then transported onshore to the open storage area (capacity 500, 20 foot containers) or the covered storage area (6,500 square feet). Petroleum is pumped through the causeway via five buried pipelines into the onshore storage tanks which have a capacity of 168,000 bbl. Presently one half of the fuel shipments use the causeway and the other half is lightered ashore (14).

Nome is the economic and transportation hub of the Seward Peninsula. The overland transportation system from Nome includes the 72 mile Nome-Teller Highway to the west, the 73 mile Nome-Council Highway to the east, and the 87 mile Nome-Kougarok River Highway to the north. The shipping lane used to supply northern Alaska is an extension of the lane used in supplying Nome. The largest airport in the region is located at Nome with smaller airstrips capable of handling two-seat type aircraft located in the other villages.

The average annual precipitation in the Nome area is approximately 16.5 inches and the temperature varies from an average low of 5 degrees to an average high of 50 degrees Fahrenheit (4). The Nome port facility is ice-free from June through September (14).

The area within the 100 mile port site radius includes the Alaska Maritime National Wildlife Refuge, The Bering Land Bridge National Preserve, BLM administered land, Native land (regional, village, and private), and land controlled by the State of Alaska (15).

The Nome port facilities currently handle the movement of construction materials, fish, food, fuel, and water (14). These commodities are transported both into and out of the Nome to the surrounding villages being serviced by the existing port. Future offshore oil, gas and mineral exploration/development could be serviced using the port facilities at Nome.

Mineral Deposits

Gold, copper, and lead are the major mineral deposit types located within 100 miles of Nome. Figure 5 shows the distribution of deposits in the area by primary commodity. Gold deposits are by far the most prevalent in the area. There are a number of past producing mines within the 100 mile port site radius. Table 8 lists the past producing lode mines in the Nome area by commodity.

Gold production from the Nome Mining District is in excess of 3.6 million tr oz, the majority of which has come from placer deposits (6).

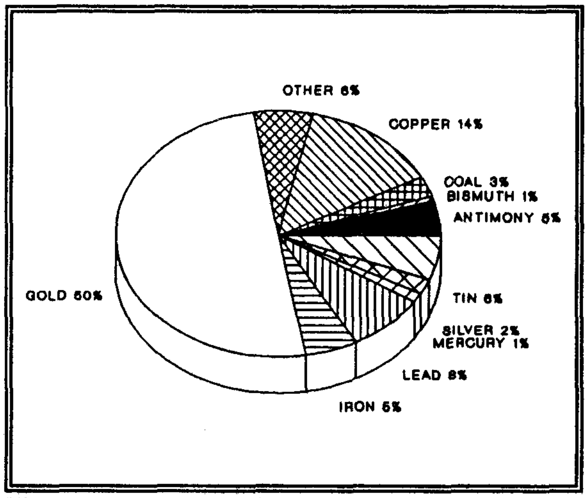


Figure 5. -- . Distribution by primary commodity of deposits near the Nome port site.

Placer Deposits

There are approximately 440 placer gold deposits within the 100 mile radius. Of these 440, 312 have or are now producing gold. Although placer gold mines typically ship low volumes of product, potential exists for significant use of Nome as a port to service new or expanded placer gold mining operations. This is particularly true when the possibility of additional offshore gold dredging is considered. The Bima dredge (operating offshore of Nome) produced 35,500 tr oz refined gold in 1988 (12) and contributed approximately $8 million to the local economy (2).

Potential exists for increased offshore dredging activity in the area. The State issued 97,000 acres in leases during 1988 and an additional 62,000 acres are unleased, pending settlement of a dispute involving the local coastal zone management district (2). The Minerals Management Service is currently planning for a Federal lease sale of 147,050 acres offshore of the Nome area. The sale, termed the OCS Mining Program, Norton Sound Lease Sale, is scheduled for February of 1991. Development of additional offshore reserves will require extensive exploration prior to production. The development of additional offshore dredging operations would increase the flow of fuel, repair parts, and supplies through Nome. Although export from these operations would not be large, the potential of the placer mining industry to increase the usage of the Nome port site should not be ignored.

TABLE 8. - Past producing lode mines in the Nome area. (Includes only those deposits for which Nome is the closest port).

Mine name	Map#	Commodity
Hed & Strand	127	antimony
Sliscovich	129	antimony
Steep Creek	129	antimony
Waterfall Creek	129	antimony
Big Hurrah	136	gold
Bluff	141	gold
Boulder Creek	135	gold
Copper Gulch	143	gold
Dahl	86	gold
Homestake	141	gold
Lamareaux	138	gold
Spruce	119	gold
Wheller Sherrette	119	gold
Imuruk Basin Graphite	109	graphite
Fish	126	lead
Omilak	105	lead
Wheeler	115	lead
Pargon Mountain	103	mica

Gold Mine Model

Based on the known deposits and reserve information, a small underground gold mine is considered the most likely type of lode mine development to occur in the near term. The model presented for the Nome area is patterned after a deposit with ore types similar to that of the Big Hurrah (map number 136). Table 9 lists the assumptions made in designing the model and the commodity data for the model are listed in table 10. For specific information regarding the model, see Appendix A.

Costs for the underground gold mine model were estimated using CES (22, 23). All costs are in July 1989 dollars and have been escalated to account for the increased cost of mining in Alaska. Capital costs were escalated by a factor of 2.6, labor costs by 1.62, and supplies and equipment costs by 1.65 (7). Table 11 lists capital and operating costs for the mine and mill and transportation operating costs.

TABLE 9. -- Assumptions used in designing the Nome underground gold mine model.

Mine life (years)	11.6
St ore/day	220
St waste/day	0
St ore mined/year	55,000
Personnel	56
Power generation (KW)	1250
Operating days/year	250
Mill feed, st/d	220
Mill method	Flotation
Tailings, st/d	219.78
Tons concentrate produced/year	55

TABLE 10. -- Commodity data for the Nome underground gold mine model.

Commodity	Grade	Recovery	Concentrate Grade	Concentrate
Gold (Au)	0.35 tr oz/st	90%	99%	70.0 tr oz/d
Silver (Ag)	0.38 tr oz/st	90%	99%	76.0 tr oz/d
Tungsten (WO_3)	0.1%	50%	50%	0.22 st/d

TABLE 11. -- Capital, operating, and transportation costs for the Nome underground gold mine model.

Cost Category	Capital Cost	Operating Cost $/st
Mine	$32,123,800	$92.72
Mill	$11,732,900	$36.00
Transportation	NAp	$35.00

NAp Not applicable

The total capital costs for the 220 st/d underground gold mine are $43,856,700. This includes exploration, permitting, and infrastructure. Infrastructure development capital costs include construction of a 12 mile access road to the port site. The total mine and mill operating cost is $128.72/st ore mined and processed. The transportation operating cost includes concentrate haulage to the port site by truck and shipment to point of sale or smelting by barge. The CES provides estimates within ± 25% of actual costs. A summary of the costs and assumptions used in the model are presented in Appendix A.

Economic Analysis

To determine the economic viability of a deposit similar to that of the model, a discounted cash flow rate of return (DCFROR) analysis was done at discount rates of 0 and 15%. The model generated a DCFROR of -6.4%.

To examine the affect of costs and revenues on the model, a sensitivity analysis was done by varying capital costs, operating costs, and revenues. One variable was varied over a range of 75% to 125% of the base case (100%) while the other two were held constant. The results of the sensitivity analysis reveal which variables have the most impact on the models rate of return. Table 12 shows the results of the sensitivity analysis for each of the three cost/revenue variables. Examination of the results reveals that both revenue and operating cost have a greater impact on the rate of return of the model as illustrated in figure 6. This is a moot point however, since the model does not attain a positive rate of return for any scenario in the sensitivity analysis. An increase in revenues of 152% would be required for the model to attain a 0% DCFROR.

TABLE 12. -- DCFROR at levels of expenditure/revenue from 75 to 125% of base case (base is 100%), Nome underground gold mine model.

Percentage of base	DCFROR when Capital costs are varied	DCFROR when Operating costs are varied	DCFROR when Revenues are varied
75	-5.24	-4.085	-7.926
80	-5.504	-4.626	-7.648
85	-5.75	-5.144	-7.357
90	-5.978	-5.599	-7.051
95	-6.191	-6.006	-6.729
100	-6.391	-6.391	-6.391
105	-6.579	-6.756	-6.036
110	-6.755	-7.102	-5.663
115	-6.921	-7.43	-5.261
120	-7.078	-7.741	-4.788
125	-7.227	-8.035	-4.296

Metals prices used in the base case were: gold, $400/tr oz, silver, $5.00/tr oz, and tungsten, $41/stu ($2.05/lb). Based on this analysis, a small, seasonally operated underground gold mine with reserves equivalent to the model is uneconomic. Such mines would ship a relatively small amount (55 st/yr) of product through the Nome port site. An increase in grade of the commodities, gold in particular, or metals prices (152%) would be required for the mine model to become economic. Additional costs of startup and shutdown were not estimated for the model nor was the $35/st transportation cost used in the analysis. If these are considered, the model is even further from being economic. Development of small underground gold mines in this region depends primarily on the definition of higher grade reserves.

The most likely increase in usage of Nome as a port site for the minerals industry will come from the eventual development of offshore placer resources. This assumes the discovery of additional economically minable reserves which will require exploration drilling by current leaseholders and the successful bidders in the upcoming MMS lease sale. Again, the increased flow of materials through the Nome port will be incoming, rather than an outgoing bulk product from mining operations. Port improvements have already been made as a result of Westgold's offshore dredging. Westgold financed the construction of a new modern dock consisting of an open-cell steel-sheet-pile structure (3). The dock will partially fulfill the need for a staging and moorage facility for the Bima gold dredging operation.

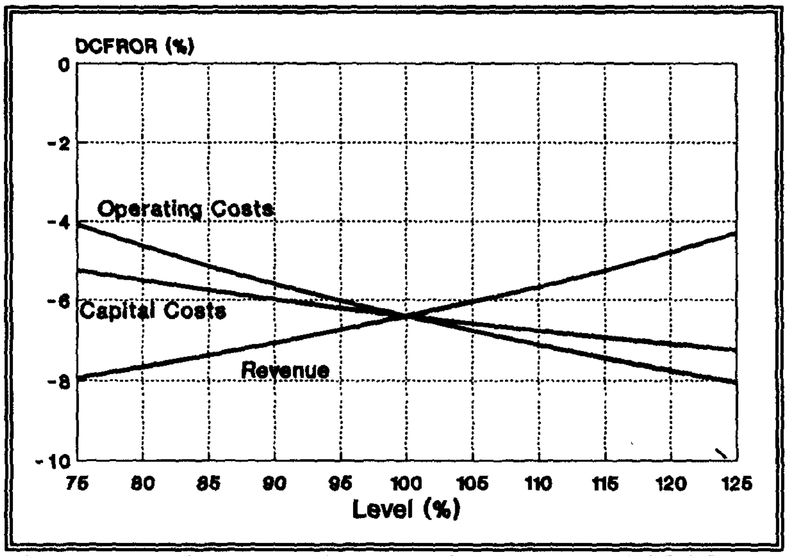


Figure 6. -- Affect of varying costs/revenues on DCFROR for the Nome underground gold mine model.

CONCLUSIONS

Based on the analysis of the deposits surrounding the proposed Iliamna Bay, Kotzebue, and Nome port sites, it appears the Nome site has the highest potential for use by the mineral industry in the near future.

While there are known mineral deposits with reserves in the Iliamna Bay area, the reserves are not sufficiently defined at this point to determine their feasibility. An Iliamna Bay deposit model (zinc-lead-copper-gold) proved to be economic under the assumptions made. There are no known deposits with reserves equal to that of the deposit model. For this reason, and the amount of lead time required to bring a mine into production, development of such a mine in the area is considered unlikely in the next 10 years. Potential for mineral development does exist in the area and active exploration is being carried out in attempts to define minable ore bodies.

The Kotzebue port site is surrounded with deposits (excluding coal) for which there is little reserve information making modeling inappropriate. Kotzebue is similar to the Omalik Lagoon site in that the most likely scenario for mineral development in the short term is a small-scale coal mine producing coal for regional use. Analysis of the coal mine model yielded prices which equate to approximately $1.28/gal fuel oil for coal delivered to Kotzebue (15% DCFROR case). Development of coal resources in the Kotzebue area will require a market; namely conversion of existing oil-fired equipment in the villages to coal-fired.

The same problems that hamper the Omalik Lagoon area in terms of large-scale production hold true for the Kotzebue area, even though there is an existing port site. Competition in the world coal market is viewed as being difficult at this time for a mine operating in the Arctic region of Alaska, primarily due to increased cost of mining.

The Nome port site is surrounded by a large number of deposits; primarily placer gold deposits which have not been included in the economic analysis. Analysis of a small, seasonally operated lode gold mine indicates that such an operation is not economic at this time. Nome is viewed as having potential for supporting offshore gold dredging in the future. A total of over 306,000 acres in offshore leases could ultimately be in the hands of mining companies. Definition of reserves will require extensive drilling programs but could result in additional offshore dredging operations. These operations would likely use Nome as a port for importing fuel, supplies, and equipment.

REFERENCES

1. Alaska Economic Report. Wishbone Hill Coal Project in Trouble. Number 15-89, Anchorage, Alaska, 1989.

2. Alaska Economic Report. Offshore Mining: Slow Buildup. Number 22-89, Anchorage, Alaska, 1989.

3. Alaska Journal of Commerce and Pacific Rim Reporter. Dredge Gets a Modern Open-cell Dock. December 18,1989, p. 12, Anchorage Alaska, 1989.

4. Alaska Western Sun. Alaska Solar and Weather Information. (DOE contract no. DE-AC02-79CS30159), 1980, 71 pp.

5. Arctic Slope Consulting Engineers. Western Arctic Coal Development Project Phase III Final Report. April 1988, 391 pp.

6. Baggs, D. W., M. J. Northam, M. P. Meyer, and K. M. Mass. Selected Significant Mineral Deposits in Alaska: A Minerals Availability System Overview. BuMines IC 9177, 1988, 124 pp.

7. Bottge, R.G. Company Towns Versus Company Camps in Developing Alaska's Mineral Resources. BuMines IC 9107, 1986, 19 pp.

8. Bundtzen, T.K., G.R. Eakins, C.B. Green, and L.L. Lueck. Alaska's Mineral Industry, 1985. Div. of Geol. and Geophys. Surveys, Spec. Rep 39, 1986, 68 pp.

9. Dames and Moore. Assessment of Coal Resources of Northwest Alaska. Volume II, Coal Resources of Northwest Alaska. prepared for Alaska Power Authority. December 1980. 217 pp.

10. DataQuest. Green Guide for Construction Equipment. Dun and Bradstreet Corp., San Jose, CA, 1987.

11. Eakins, G.R., T.K. Bundtzen, L.L. Lueck, C.B. Green, J.L. Gallagher and M.S. Robinson. Alaska's Mineral Industry 1984. Div. of Geol. and Geophys. Surveys, Spec. Rep 38, 1985, 57 pp.

12. Green, C.B., T.K. Bundtzen, R.J. Peterson, A.F. Seward, J.R. Deagen, and J.E. Burton. Alaska's Mineral Industry 1988. Div. of Geol. and Geophys. Surveys, Spec. Rep 43, 1989, 79 pp.

13. Henshaw, F.F. Mining in the Fairhaven Precinct. Ch. in Report on Progress of Investigations of Mineral Resources of Alaska in 1908. U.S. Geol. Surv. Bull. 379, 1909, pp. 355-369.

14. Louis Berger & Associates, Inc. Western and Arctic Alaska Transportation Study, Phase III: Project Evaluation, Final Report, Volume III: Marine Infrastructure. Prepared for the State of Alaska Department of Transportation and Public Facilities, May 1981, 213 pp.

15. Maas, K. M. Maps Summarizing Land Availability for Mineral Exploration and Development in Northern Alaska. BuMines OFR 18-87, 1986.

REFERENCES - CONTINUED

16. Moffit, F.H. Gold Mining on the Seward Peninsula. Ch. in Report on Progress of Investigations of Mineral Resources of Alaska in 1905. U.S. Geol. Surv. Bull. 284, 1906, pp. 132-144.

17. Nokleberg, W. J., T. K. Bundtzen, H. C. Berg, D. A. Brew, D. Grybeck, M. S. Robinson, T. E. Smith, and W. Yeend. Significant Metalliferous Lode Deposits and Placer Districts of Alaska. U.S. Geol. Surv. B1786, 1987, 104 pp.

18. R&M Consultants, Inc. Alaska Mineral Development Navigation Improvements Study. May 1987, 84 pp.

19. Retherford, R.M., T.K. Hinderman and C.C. Hawley, Preliminary feasibility study of a coal mine at Chicago Creek. Div. Geol. and Geophys. Surv. Public-data File 86-25, May 1986, 183 pp.

20. State of Alaska. Alaska Population Overview: 1986 and Provisional 1987 Estimates. August 1989, 131 pp.

21. Toenges, A.L. and T.R. Jolley. Investigation of Coal Deposits for Local Use in the Arctic Regions of Alaska and Proposed Mine Development. BuMines RI 4150, 1947, 19 pp.

22. U.S. Bureau of Mines. Cost Estimating System Handbook, 1. Surface and Underground Mining. BuMines IC 9142, 1987, 631 pp.

23. U.S. Bureau of Mines. Cost Estimating System Handbook, 2. Mineral Processing. BuMines IC 9143, 1987, 566 pp.

24. U.S. Bureau of Mines. Mineral Deposit Inventory For Ten Alaska Port Sites; U.S. Army Corps of Engineers, Resource Development Navigation Study. Unpublished BuMines report, 1990, 286 pp.

25. U.S. Corps of Engineers. Resource Development Navigation Study: Kivalina, Nome, Unalaska, Point MacKenzie. Portland District COE, Planning Division, Evaluation Branch, Economics Section, October 1989, 70 pp.

26. Usibelli, J. Mining Constraints and Operations at Usibelli Coal Mine. Paper in Proceedings of Focus on Alaska's Coal '75, Univ. of Alaska. Fairbanks, AK, 1975, pp. 93-99.

27. Western Mining News. Anaconda Minerals Discovery. March 2, 1984, p. 5.

APPENDIX A. -- MINE MODEL SUMMARY

ILIAMNA BAY OPEN PIT MINE MODEL

The Iliamna Bay open pit mine model is based on a deposit with ore mineralogy similar to that of the Johnson River deposit which is located at the headwaters of Johnson River, approximately 12 miles west (inland) of Cook Inlet and 90 miles from the proposed Iliamna Bay port site.

The Johnson River deposit discovery was the result of a 1981 joint venture agreement between ARCO (Anaconda Minerals Co.) and Cook Inlet Region, Inc. (CIRI) (27). In succeeding years, the prospect was drilled, and geochemically and geophysically sampled, resulting in the Discovery Creek find. Drill hole intercepts looked promising with nearly 1.2 oz/ton gold found in one intercept. In 1984, Anaconda continued sampling, drilling over 20,000 ft of core (11). In 1985, however, ARCO dissolved Anaconda Minerals and work on the project was suspended (8). Exploration work by another group apparently resumed in 1987 and has been ongoing. CIRI estimates the reserves of the deposit at 525,000 tons (18).

The USGS described the deposit as "Quartz-sulfide stockwork with chalcopyrite, pyrite, sphalerite, galena, and gold. Stockwork occurs in a discordant, pipelike body of silicified volcanic rocks..." (17).

Since the known reserves appear to be insufficient for development at this time, the model was developed using the same grades, geology and location, but with sufficient reserves to mine for approximately 8 yrs. The model was assumed to have 2 million tons of ore in a pipelike body of 175 ft depth and diameter of 413.47 ft. With a maximum slope of 50 degrees and 10 ft benches, overall dimensions would be 185 ft depth, and 723.94 ft diameter. The waste to ore stripping ratio was estimated to be 1.25:1. Processing 700 tons ore per day, 350 days per year, 2 shifts/day, with an average mine recovery of 95%, total mine life for the Johnson River Mine would be 7.76 years.

A 12 mile gravel road would be required to connect the mine and mill with the inlet at Fossil Point. This route has been selected because of its proximity to a similar prospect located at Discovery Creek 6 miles to the northeast of the proposed Johnson River Mine.

The assumptions used in designing the mine model were:

Mine life (years)	7.76
St ore/day	700
St waste/day	878
St ore mined/year	244,985
Personnel	100
Power generation (KW)	2,400
Operating days/year	350
Mill feed, st/d	700
Mill method	Flotation
Tailings, st/d	466
Tons concentrate produced/year	81,550

Mine haulage would be by front-end loaders and 20 ton trucks. The waste would be hauled 2,400 ft to the rim of the pit for later re-emplacement. Ore would be hauled 3,711 ft to the mill. Power for both the mine and mill would be provided by diesel generators. A total of 100 personnel would work and live at the mine and housing would be provided in trailers.

The Johnson River mill would process ore at a rate of 700 st/d, 2 shifts per day, 350 days per year. Ore would first be crushed by a jaw crusher to 0.75 inch and then ground in a ball mill to -200 mesh. The ground pulp would then be sent through a jig where the free gold is separated and passed on to an amalgamation circuit. The gold which is locked in the sulfides would not be leached since, the sulfides in the ore act as cyanicides (cyanide killers). Because of the large amounts of cyanide which would be consumed, vat leaching is considered to be too costly.

The jig overflow returns through the ball mill and moves on to a conditioner tank and then to a flotation circuit for bulk zinc, copper, lead, and silver recovery. Approximately one-third the feed (233 st/d) would end up in this concentrate. The tailings from the flotation circuit (466 st/d), are partially dewatered and sent to a double-lined tailings pond.

The bulk concentrate is then reground to -325 mesh and conditioned with zinc sulfate and cyanide to repress the sphalerite, producing 29.8 st/d copper concentrate. The remaining concentrate returns to the flotation circuit to produce a zinc concentrate and a lead/silver concentrate. The commodity data for this mine model are:

Commodity	Grade	Recovery	Concentrate Grade	Tons/day Concentrate
Zinc (Zn)	15.0%	85%	51%	175.2
Lead (Pb)	2.8%	95%	70%	28.0
Copper (Cu)	1.7%	70%	28%	29.8
Gold (Au)	0.6 tr oz/st	30%	99%	126 tr oz/d
Silver (Ag)	0.13 tr oz/st	80%	2.6 tr oz/st	(contained in Pb)

The copper, lead/silver, and zinc concentrates would then be dewatered, dried, and trucked to Fossil Point for shipment by barge to Seattle and by rail to refineries in Arizona, California, and Ohio. Shallow-draft barges would be used to ship the concentrates out of Fossil Point to the Iliamna Port. Concentrates would then be shipped from Iliamna Bay to Seattle using deep-draft vessels and towed barges. From Seattle, the containers would be transported by rail to smelters in either California, Arizona, or Ohio. The gold bullion would be shipped by air to Anchorage or Fairbanks for refining. The shipping season at Iliamna Bay and Fossil Point would be year-round.

Calculations of mine and mill costs were made using the Bureau's Cost Estimation System. The base costs were escalated according to July 1989 costs and location. The location indices used in the analysis were: labor - 1.31; supplies - 1.52; equipment - 1.52, and capital costs - 2.2 (7). The costs were estimated to be:

Cost Category	Capital Cost	Operating Cost $/st
Mine	$43,726,000	$31.43
Mill	$17,347,900	$25.40
Transportation	-	$35.00

The CES provides costs estimates within ±25% of actual costs.

KOTZEBUE SMALL-SCALE COAL MINE MODEL

The small-scale coal mine model was based on mining a deposit similar to Chicago Creek (map number 48), located 70 miles south of Kotzebue.

History

The following history summarizes past activity in the Chicago creek area and is adapted primarily from Retherford, et. al. (19).

Coal was first discovered on Chicago Creek by gold prospectors in 1902 (16). Some development work was done that year, but there was little demand for the coal until the winter of 1904-1905 when gold was discovered on the terraces above Candle Creek and the need arose for a source of fuel for steam-thawing of placer ground. The coal deposit was staked in 1905 and the mine began production in 1908.

The mine operated during the winter months only and was sealed in the summer, probably to prevent thawing and subsequent instability of the workings. In 1908 the coal was being mined through a 330 foot shaft which was inclined at an angle of 18 to 36 degrees to a depth of about 200 feet (13). Coal was being mined at four levels at depths of 33, 80, 100 and 144 feet. The mine had an estimated total production of about 100,000 tons to 1911 when it was abandoned (21).

Other coal mines which operated in the Chicago Creek area include the Wallin Mine (Kugruk) and the Superior Mine, 4 and 5 miles upstream from the Chicago Creek Mine respectively. There is some disagreement in the literature about the size of the main coal seams at these mines, and their overall production is questionable (9). However, it seems clear that the seam at Chicago Creek was much larger and its production was at least an order of magnitude larger than the other mines combined (19).

From 1981-1986, Hawley Resource Group, Inc. under contract by the Alaska Division of Geological and Geophysical Surveys (ADGGS) analyzed the feasibility of providing electrical power for Kotzebue and nearby villages using coal mined at Chicago Creek (19).

Model Parameters

The coal mine model assumes open pit mining using trucks, shovel, and loaders with haul-back of waste occurring as the mine proceeds. Initially, excavated waste rock would be used as road base material, but excess or unsuitable material could be stockpiled just downstream of the operation. Ultimate pit depths of 300 feet below the surface would be reached during the 30 year life of the mine. Coal and wall rock alike are permanently frozen, suggesting slopes should remain reasonably stable and little, if any, ground water will be encountered. Mining and transportation will be sequenced according to climate and ground conditions. Stripping and mining will be restricted to the spring and summer months in order to take advantage of the long hours of daylight and warm weather and to minimize equipment maintenance.

In a typical year, operations would begin in early April when the exposed coal bed would be mined and hauled to Willow Bay and stockpiled. This mining and hauling would take one month. All heavy haulage over the road to Willow Bay will be complete by early May before spring thaws. The crews will then strip the overburden for the next season's mining which will continue for 2 to 3 months, depending on the depth of pit. Stripping and reclamation operations would be completed by September 1 (19).

Initial development of the mine would require the construction of a 10 mile haul road from the mine to Willow Bay, a coal stockpile pad, a 70 ft X 5,280 ft airstrip and 20 man camp facility, 6,000 ft^2 shop, 4,000 ft^2 warehouse/office, 1,500 ft^2 cafeteria 1,000 ft^2 recreation center. Electricity for the camp would be provided by two 150 KW generators. Chicago Creek would be diverted around the mine by constructing a small earthfill dam and 5,000 ft diversion ditch. The mine would be a seasonal operation, a total crew size of 12 for mining operation during a 3 month season with year-round staff of three stationed in Kotzebue.

Coal handling facilities at Willow Bay would include a 90,000 ft^2 gravel pad for stockpiling the entire season's production of 50,000 tons, a 250 ft long and 30 inch wide wire rope conveyor system with a hopper feeder and a telescoping barge loader, and a barge dock. All barging would take place during the ice free season, which typically extends from mid-July to mid-October. It is assumed that a commercial marine transportation company would be used. A 988-size loader would load the barges at the rate of 300 st/hr. Assuming the use of a tug and two tandem 2,000 ton shallow draft barges traveling at a speed of 100 mi/day, it would be possible to move 50,000 tons of coal in about 22 days of continuous operation.

Based on drilling completed in 1982, 1983 and 1985, the potentially minable identified coal resource at Chicago Creek was estimated to be about 4.7 million st, of which 1.5 million could be mined at a stripping ratio of 1.7:1 (85,000 yd^3 overburden stripped: 50,000 tons coal annual average). The remaining 3.2 million st of coal would have a stripping ratio in the range of 4:1 to 5:1. The open pit mine would have a highwall slope of 1/2 (horizontal) to 1 (vertical), with intermediate benches 15 to 30 ft wide. The footwall slope will be 45 degrees (the dip of the coal seam) unless slope failures cause it to become flatter. The mining cost estimates assumed purchase of new equipment. Parameters for the mine model are:

Mine life (years)	30
St coal/day	500
Bank Yards overburden/day	850
St coal mined/year	50,000
Stripping ratio	1.70:1
Personnel	18
Power generation (KW)	300
Operating days/year	100

The coal produced from the mine would be subbituminous with a rating of 7,700 btu/lb, 29% moisture, and 0.8% sulfur.

Costs for the Chicago Creek coal mine model were estimated by the Alaska Division of Geological and Geophysical Surveys (ADGGS) (19). The costs from the ADGGS study were escalated to July 1989 dollars to estimate the current mining costs. The capital and operating costs for the mine and transportation system were estimated to be:

Cost Category	Capital Cost	Operating Cost $/st
Mine	$19,520,000	$34.12
Transportation	NAp	$ 9.91

NAp Not applicable

NOME UNDERGROUND GOLD MINE MODEL

The Nome underground gold mine model is based on a deposit with ore mineralogy similar to that of the Big Hurrah with is located approximately 12 mi north of Solomon and 30 miles east of Nome. There is an unimproved gravel road connecting the Big Hurrah Mine with Solomon. An unimproved road also connects Nome with Solomon, however during the summer this road is dependent upon tides and needs ferry service in at least one section. Road travel is much more reliable during the winter months due to ice. Heavy equipment and fuel to support the model mine would be shipped into Nome while mine concentrates would be shipped out for sale. This would be accomplished by deep-draft vessels and towed barges. Because of the shallow depths of Norton Sound, only shallow-draft vessels can be supported near shore. For this reason, supplies, equipment, and mine concentrates must be lightered between the vessels and shore. The shipping season at the Nome port site lasts approximately 100 days, from July to October

The Big Hurrah Mine was first discovered in 1901. In 1903, a 10-stamp mine was built and the mine was operated continuously until 1907. During this time approximately 50,000 tons were processed. The mine then remained idle until 1944, when C. O. Roberts leased the property. For the next two years, the mine was operated, producing an unknown amount. During 1952, the mine was again active, producing $21,000 worth of commodities. Since 1952, activity at the mine has consisted of exploration by a number of companies.

While proven, inferred, and indicated reserves at the Big Hurrah Mine are 104,000 st of ore (12), the mine model was assumed to have defined reserves of 670,000 st. The dimensions of the model deposit average 1200 feet (366 m) length, 164 feet (50 m) width, and 1092 feet (333 m) thick. Processing 220 tons per day, 250 days per year, 2 shifts/day, with an average mine recovery of 95%, total mine life for the mine model will be 11.55 years.

The mill would produce approximately 55 st/yr of tungsten concentrates, 17,500 tr oz gold, and 19,000 tr oz of silver. Shipment of the tungsten concentrate would be made using closed shipping containers aboard shallow-draft vessels to Nome, where the containers would be loaded on barges for shipment to Seattle. From Seattle, the containers would be transported via rail to smelters in either Michigan or Ohio. Assumptions made in designing the Nome underground mine model are:

Mine life (years)	11.6
St ore/day	220
St waste/day	0
St ore mined/year	55,000
Personnel	56
Power generation (KW)	1250
Operating days/year	250
Mill feed, st/d	220
Mill method	Flotation
Tailings, st/d	219.78
Tons concentrate produced/year	55

Ore would be extracted using shrinkage stoping. One 1000 ft shaft would be sunk in the footwall of the deposit. This shaft would provide for ore haulage, ventilation, and equipment and personnel access. A 110 st/hr friction hoist would be installed. Power would be provided by diesel generating equipment with a total capacity of 1,250 KW.

Total drift length would be 4,802 ft and total length of raises would be 4,795 ft. Ore haulage in the mine would be accomplished by load-haul-dump (LHD) vehicles. Ore haulage from the mine to the mill would be by 20 st rock trucks over a distance of 0.6 miles. Rock bolts would be used for supporting the underground openings. Water would not be needed for mining and drainage water would be pumped out of the mine at a rate of 2,614 yd^3/d.

A total of 56 personnel would work and live at the mine with housing consisting of modular trailers. Since an unimproved road connects the mine site with Solomon, general refurbishing would be needed as well as widening to 19.6 ft. Gravel surfacing over 12 miles would also be needed.

The ore would be processed at a rate of 220 tons, 2 shifts per day. Ore would first be crushed by a jaw crusher to -4 inches and then ground in a ball mill to 60 mesh. The ground pulp would then be sent through a jig where the course gold is separated and passed on to an amalgamation circuit, producing gold dore'. The overflow from the jig returns through the ball mill, moves on to a conditioner tank, then to a flotation circuit for scheelite recovery. The tailings from the flotation circuit are sent to tables and then back through the amalgamation unit. The mill therefore produces two products, a gold/silver bullion (dore') and a scheelite concentrate. The bullion would be shipped by air to Anchorage or Fairbanks for refinery. The scheelite concentrate would be hauled at the rate of 55 st per year by truck to Solomon, lightered to Nome, via barge to Seattle, and then by rail to either Michigan or Ohio for refining.

Tailings would be dewatered and contained in a double-lined pond. Water from the mill tailings as well as the mine would be reused in the mill once it is clarified with flocculants.

The commodity data for the gold mine model are:

Commodity	Grade	Recovery	Concentrate Grade	Concentrate
Gold (Au)	0.35 tr oz/st	90%	99%	70.0 tr oz/d
Silver (Ag)	0.38 tr oz/st	90%	99%	76.0 tr oz/d
Tungsten (WO_3)	0.1%	50%	50%	0.22 st/d

Calculations of mine and mill costs were made using the Bureau's Cost Estimation System. From various input parameters describing the specifics of the proposed mine and mill operations, costs were developed as follows:

Cost Category	Capital Cost	Operating Cost $/st
Mine	$32,123,800	$92.72
Mill	$11,732,900	$36.00
Transportation	NAp	$35.00

NAp Not applicable

The base costs were escalated according to 1989 costs and location. The location indices used in this analysis were: labor - 1.62; supplies - 1.65; equipment - 1.65, and capital costs - 2.6 (7).

APPENDIX B. -- SAMPLE CASH FLOWS

ILIAMNA BAY ZINC-LEAD-COPPER-GOLD-SILVER MINE MODEL

(All Values in Thousands) Page 1
Run Date : 2/28/1990
Evaluation Date : 01/90
Project Start : 01/90
Evaluator : dah

Reversion at 10/94 Reversion Amount: 56960.06

Period Ending	12/90	12/91	12/92	12/93	12/94	12/95	12/96	12/97	12/98	12/99	12/00
Revenue	0.	0.	0.	0.	71272.	71272.	71272.	71272.	71272.	71272.	71272.
-Smelting Cost	0.	0.	0.	0.	-12503.	-12503.	-12503.	-12503.	-12503.	-12503.	-12503.
Net Smelt Retn	0.	0.	0.	0.	58768.	58768.	58768.	58768.	58768.	58768.	58768.
-Royalties	0.	0.	0.	0.	-11754.	-11754.	-11754.	-11754.	-11754.	-11754.	-11754.
Net Revenue	0.	0.	0.	0.	47015.	47015.	47015.	47015.	47015.	47015.	47015.
-Oper Costs	0.	0.	0.	0.	-12630.	-12630.	-12630.	-12630.	-12630.	-12630.	-12630.
-Sever, Ad-Val	0.	0.	0.	0.	-3114.	-3114.	-3114.	-3114.	-3114.	-3114.	-3114.
-Development	-1029.	-1029.	-6441.	-6441.	0.	0.	0.	0.	0.	0.	0.
-Depreciation	0.	0.	-1800.	-5012.	-5729.	-4496.	-3571.	-2917.	-2649.	-2397.	-2146.
-Amortization	-88.	-176.	-729.	-1281.	-1281.	-1192.	-1104.	-552.	0.	0.	0.
-Writeoffs	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Before Depltn	-1117.	-1205.	-8970.	-12733.	24260.	25581.	26595.	27801.	28621.	28873.	29124.
-50% Limit	0.	0.	0.	0.	12130.	12791.	13298.	13900.	14311.	14436.	14562.
-Percent Depl	0.	0.	0.	0.	-9196.	-9196.	-9196.	-9196.	-9196.	-9196.	-9196.
-Cost Depltn	0.	0.	0.	0.	6151.	0.	0.	0.	0.	0.	0.
-Loss Forward	0.	-1117.	-2323.	-11293.	-24026.	-8962.	0.	0.	0.	0.	0.
Taxable	-1117.	-2323.	-11293.	-24026.	-8962.	7423.	17399.	18605.	19425.	19676.	19928.
-Tax @ 40%	0.	0.	0.	0.	0.	-2969.	-6959.	-8186.	-8547.	-8658.	-8768.
Net Income	-1117.	-2323.	-11293.	-24026.	-8962.	4454.	10439.	10419.	10878.	11019.	11160.
+Depreciation	0.	0.	1800.	5012.	5729.	4496.	3571.	2917.	2649.	2397.	2146.
+Depletion	0.	0.	0.	0.	9196.	9196.	9196.	9196.	9196.	9196.	9196.
+Amortization	88.	176.	729.	1281.	1281.	1192.	1104.	552.	0.	0.	0.
+Loss Forward	0.	1117.	2323.	11293.	24026.	8962.	0.	0.	0.	0.	0.
+Writeoffs	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
-Capitl Costs	-2300.	-2300.	-19729.	-19729.	-4148.	0.	0.	0.	0.	0.	0.
Cash Flow	-3329.	-3329.	-26170.	-26170.	27123.	28301.	24311.	23084.	22723.	22613.	22502.

ILIAMNA BAY ZINC-LEAD-COPPER-GOLD-SILVER MINE MODEL - CONTINUED

(All Values in Thousands)
Run Date : 2/28/1990
Evaluation Date : 01/90
Project Start : 01/90
Evaluator : dah

Period Ending	12/01	12/02	Salv.
Revenue	54173.	54173.	4148.
-Smelting Cost	-9504.	-9504.	0.
Net Smelt Retn	44669.	44669.	0.
-Royalties	-8934.	-8934.	0.
Net Revenue	35735.	35735.	0.
-Oper Costs	-9600.	-9600.	0.
-Sever, Ad-Val	-2367.	-2367.	0.
-Development	0.	0.	0.
-Depreciation	-2146.	-1073.	0.
-Amortization	0.	0.	0.
-Writeoffs	0.	0.	-4148.
Before Depltn	21622.	22695.	0.
-50% Limit	10811.	11348.	0.
-Percent Depl	-6990.	-6990.	0.
-Cost Depltn	0.	0.	0.
-Loss Forward	0.	0.	0.
Taxable	14632.	15705.	0.
-Tax @ 40%	-6438.	-6910.	0.
Net Income	8194.	8795.	0.
+Depreciation	2146.	1073.	0.
+Depletion	6990.	6990.	0.
+Amortization	0.	0.	0.
+Loss Forward	0.	0.	0.
+Writeoffs	0.	0.	4148.
-Capitl Costs	0.	-868.	0.
Cash Flow	17330.	15990.	4148.

SMALL-SCALE COAL MINE MODEL

(All values in Thousands)

Run Date : 2/2/1990
Evaluation Date : 01/90
Project Start : 01/90
Evaluator : JRC

Period Ending	12/90	12/91	12/92	12/93	12/94	12/95	12/96	12/97	12/98	12/99	12/00
Revenue	0	0	6,402	6,402	6,402	6,402	6,402	6,402	6,402	6,402	6,402
-Oper Costs	0	0	-2,202	-2,202	-2,202	-2,202	-2,202	-2,202	-2,202	-2,202	-2,202
-Sever, Ad-Val	0	0	-498	-498	-498	-498	-498	-498	-498	-498	-498
-Development	-466	0	0	0	0	0	0	0	0	0	0
-Depreciation	0	-2,387	-4,002	-2,715	-1,966	-1,733	-1,166	-1,166	0	0	0
-Amortization	-40	-40	-40	-40	-40	0	0	0	0	0	0
-Writeoffs	0	0	0	0	0	0	0	0	0	0	0
Before Depltn	-506	-2,427	-339	948	1,697	1,970	2,537	2,537	3,703	3,703	3,703
-50% Limit	0	0	0	-474	848	985	1,268	1,268	1,851	1,851	1,851
-Percent Depl	0	0	640	640	-640	-583	-512	-512	-512	-512	-512
-Cost Depltn	0	0	-52	52	37	14	0	0	0	0	0
-Loss Forward	0	-506	-2,933	-3,325	-2,850	-1,794	-406	0	0	0	0
Taxable	-506	-2,933	-3,325	-2,850	-1,794	-406	1,619	2,025	3,191	3,191	3,191
-Tax @ 40%	0	0	0	0	0	0	-728	-911	-1,436	-1,436	-1,436
Net Income	-506	-2,933	-3,325	-2,850	-1,794	-406	890	1,114	1,755	1,755	1,755
+Depreciation	0	2,387	4,002	2,715	1,966	1,733	1,166	1,166	0	0	0
+Depletion	0	0	52	474	640	583	512	512	512	512	512
+Amortization	40	40	40	40	40	0	0	0	0	0	0
+Loss Forward	0	506	2,933	3,325	2,850	1,794	406	0	0	0	0
+Writeoffs	0	0	0	0	0	0	0	0	0	0	0
-Capitl Costs	-1,719	-15,134	-2,202	0	0	0	0	0	0	0	0
Cash Flow	-2,185	-15,134	1,501	3,703	3,703	3,703	2,974	2,792	2,267	2,267	2,267

Period Ending	12/01	12/02	12/03	12/04	12/05	12/06	12/07	12/08	12/09	12/10	12/11
Revenue	6,402	6,402	6,402	6,402	6,402	6,402	6,402	6,402	6,402	6,402	6,402
-Oper Costs	-2,202	-2,202	-2,202	-2,202	-2,202	-2,202	-2,202	-2,202	-2,202	-2,202	-2,202
-Sever, Ad-Val	-498	-498	-498	-498	-498	-498	-498	-498	-498	-498	-498
-Development	0	0	0	0	0	0	0	0	0	0	0
-Depreciation	0	0	0	0	0	0	0	0	0	0	0
-Amortization	0	0	0	0	0	0	0	0	0	0	0
-Writeoffs	0	0	0	0	0	0	0	0	0	0	0
Before Depltn	3,703	3,703	3,703	3,703	3,703	3,703	3,703	3,703	3,703	3,703	3,703
-50% Limit	1,851	1,851	1,851	1,851	1,851	1,851	1,851	1,851	1,851	1,851	1,851
-Percent Depl	-512	-512	-512	-512	-512	-512	-512	-512	-512	-512	-512
-Cost Depltn	0	0	0	0	0	0	0	0	0	0	0
-Loss Forward	0	0	0	0	0	0	0	0	0	0	0
Taxable	3,191	3,191	3,191	3,191	3,191	3,191	3,191	3,191	3,191	3,191	3,191
-Tax @ 40%	-1,436	-1,436	-1,436	-1,436	-1,436	-1,436	-1,436	-1,436	-1,436	-1,436	-1,436
Net Income	1,755	1,755	1,755	1,755	1,755	1,755	1,755	1,755	1,755	1,755	1,755
+Depreciation	0	0	0	0	0	0	0	0	0	0	0
+Depletion	512	512	512	512	512	512	512	512	512	512	512
+Amortization	0	0	0	0	0	0	0	0	0	0	0
+Loss Forward	0	0	0	0	0	0	0	0	0	0	0
+Writeoffs	0	0	0	0	0	0	0	0	0	0	0
-Capitl Costs	0	0	0	0	0	0	0	0	0	0	0
Cash Flow	2,267	2,267	2,267	2,267	2,267	2,267	2,267	2,267	2,267	2,267	2,267

SMALL-SCALE COAL MINE MODEL - CONTINUED

(All Values in Thousands)
Run Date : 2/2/1990
Evaluation Date : 01/90
Project Start : 01/90
Evaluator : JRC

Period Ending	12/12	12/13	12/14	12/15	12/16	12/17	12/18	12/19	12/20	Salv.
Revenue	6,402	6,402	6,402	6,402	6,402	6,402	6,402	6,402	6,402	2,202
-Oper Costs	-2,202	-2,202	-2,202	-2,202	-2,202	-2,202	-2,202	-2,202	-2,202	0
-Sever, Ad-Val	-498	-498	-498	-498	-498	-498	-498	-498	-498	0
-Development	0	0	0	0	0	0	0	0	0	0
-Depreciation	0	0	0	0	0	0	0	0	0	0
-Amortization	0	0	0	0	0	0	0	0	0	0
-Writeoffs	0	0	0	0	0	0	0	0	0	-2,202
Before Depltn	3,703	3,703	3,703	3,703	3,703	3,703	3,703	3,703	3,703	0
-50% Limit	1,851	1,851	1,851	1,851	1,851	1,851	1,851	1,851	1,851	0
-Percent Depl	-512	-512	-512	-512	-512	-512	-512	-512	-512	0
-Cost Depltn	0	0	0	0	0	0	0	0	0	0
-Loss Forward	0	0	0	0	0	0	0	0	0	0
Taxable	3,191	3,191	3,191	3,191	3,191	3,191	3,191	3,191	3,191	0
-Tax @ 40%	-1,436	-1,436	-1,436	-1,436	-1,436	-1,436	-1,436	-1,436	-1,436	0
Net Income	1,755	1,755	1,755	1,755	1,755	1,755	1,755	1,755	1,755	0
+Depreciation	0	0	0	0	0	0	0	0	0	0
+Depletion	512	512	512	512	512	512	512	512	512	0
+Amortization	0	0	0	0	0	0	0	0	0	0
+Loss Forward	0	0	0	0	0	0	0	0	0	0
+Writeoffs	0	0	0	0	0	0	0	0	0	2,202
-Capitl Costs	0	0	0	0	0	0	0	0	0	0
Cash Flow	2,267	2,267	2,267	2,267	2,267	2,267	2,267	2,267	2,267	2,202

NOME UNDERGROUND GOLD MINE MODEL

(All Values in Thousands)
Run Date : 2/28/1990
Evaluation Date : 01/89
Project Start : 01/90
Evaluator : dah

Period Ending	12/90	12/91	12/92	12/93	12/94	12/95	12/96	12/97	12/98	12/99	12/00
Revenue	0.	0.	0.	0.	6976.	6976.	6976.	6976.	6976.	6976.	7069.
-Smelting Cost	0.	0.	0.	0.	-439.	-439.	-439.	-439.	-439.	-439.	-439.
Net Smelt Retn	0.	0.	0.	0.	6537.	6537.	6537.	6537.	6537.	6537.	6630.
-Oper Costs	0.	0.	0.	0.	-7094.	-7094.	-7094.	-7094.	-7094.	-7094.	-7094.
-Sever, Ad-Val	0.	0.	0.	0.	-458.	-458.	-458.	-458.	-458.	-458.	-464.
-Development	-924.	-924.	-2382.	-2382.	0.	0.	0.	0.	0.	0.	0.
-Depreciation	0.	0.	-1404.	-3916.	-4497.	-3553.	-2830.	-2294.	-2067.	-1941.	-1814.
-Amortization	-79.	-158.	-363.	-567.	-567.	-488.	-408.	-204.	0.	0.	0.
-Writeoffs	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Before Depltn	-1003.	-1082.	-4149.	-6865.	-6078.	-5055.	-4252.	-3513.	-3082.	-2955.	-2742.
-50% Limit	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
-Percent Depl	0.	0.	0.	0.	988.	988.	988.	988.	988.	988.	1002.
-Cost Depltn	0.	0.	0.	0.	-2845.	-2845.	0.	0.	0.	0.	0.
-Loss Forward	0.	-1003.	-2086.	-6234.	-13099.	-22022.	-29922.	-34175.	-37688.	-40769.	-43725.
Taxable	-1003.	-2086.	-6234.	-13099.	-22022.	-29922.	-34175.	-37688.	-40769.	-43725.	-46467.
-Tax @ 40%	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Net Income	-1003.	-2086.	-6234.	-13099.	-22022.	-29922.	-34175.	-37688.	-40769.	-43725.	-46467.
+Depreciation	0.	0.	1404.	3916.	4497.	3553.	2830.	2294.	2067.	1941.	1814.
+Depletion	0.	0.	0.	0.	2845.	2845.	0.	0.	0.	0.	0.
+Amortization	79.	158.	363.	567.	567.	488.	408.	204.	0.	0.	0.
+Loss Forward	0.	1003.	2086.	6234.	13099.	22022.	29922.	34175.	37688.	40769.	43725.
+Writeoffs	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
-Capitl Costs	-2493.	-2493.	-14540.	-14540.	-4666.	0.	0.	0.	0.	0.	0.
Cash Flow	-3417.	-3417.	-16922.	-16922.	-5681.	-1014.	-1014.	-1014.	-1014.	-1014.	-928.

NOME UNDERGROUND GOLD MINE MODEL - CONTINUED

(All Values in Thousands)
Run Date : 2/28/1990
Evaluation Date : 01/89
Project Start : 01/90
Evaluator : dah

Period Ending	12/01	12/02	12/03	12/04	12/05	Salv.
Revenue	7069.	7069.	7069.	7069.	3959.	4666.
-Smelting Cost	-439.	-439.	-439.	-439.	-246.	0.
Net Smelt Retn	6630.	6630.	6630.	6630.	3713.	0.
-Oper Costs	-7094.	-7094.	-7094.	-7094.	-3973.	0.
-Sever, Ad-Val	-464.	-464.	-464.	-464.	-260.	0.
-Development	0.	0.	0.	0.	0.	0.
-Depreciation	-1814.	-907.	0.	0.	0.	0.
-Amortization	0.	0.	0.	0.	0.	0.
-Writeoffs	0.	0.	0.	0.	0.	-4666.
Before Depltn	-2742.	-1835.	-928.	-928.	-520.	0.
-50% Limit	0.	0.	0.	0.	0.	0.
-Percent Depl	1002.	1002.	1002.	1002.	561.	0.
-Cost Depltn	0.	0.	0.	0.	0.	0.
-Loss Forward	-46467.	-49209.	-51044.	-51973.	-52901.	0.
Taxable	-49209.	-51044.	-51973.	-52901.	-53420.	0.
-Tax @ 40%	0.	0.	0.	0.	23505.	0.
Net Income	-49209.	-51044.	-51973.	-52901.	-29915.	0.
+Depreciation	1814.	907.	0.	0.	0.	0.
+Depletion	0.	0.	0.	0.	0.	0.
+Amortization	0.	0.	0.	0.	0.	0.
+Loss Forward	46467.	49209.	51044.	51973.	52901.	0.
+Writeoffs	0.	0.	0.	0.	0.	4666.
-Capitl Costs	0.	0.	0.	0.	0.	-1154.
Cash Flow	-928.	-928.	-928.	-928.	22985.	4666.