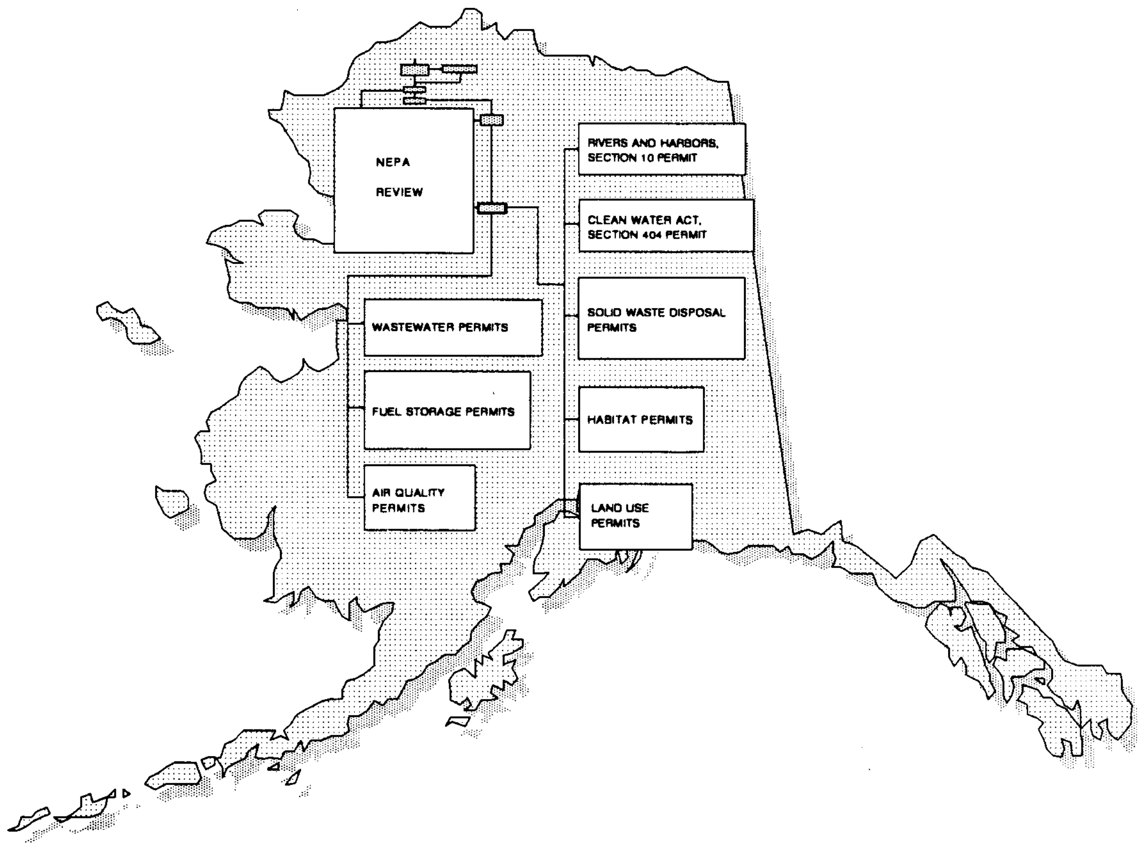
PERMITTING AND ENVIRONMENTAL CONSTRAINTS THEIR IMPACT ON MINING IN ALASKA

By Gary E. Sherman



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

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

bbl	barrel
d	day
gal	gallon
gpm	gallon per minute
h	hour
ml/l	milliliter per liter
NTU	Nephelometric turbidity units
%	percent
st	short ton
tr oz	troy ounce
yd^3	cubic yard
yr	year

AGENCY ABBREVIATIONS

ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
ADGC	Alaska Division of Governmental Coordination
ADLWM	Alaska Division of Land and Water Management
ADNR	Alaska Department of Natural Resources
ADR	Alaska Department of Revenue
BLM	Bureau of Land Management, U.S. Department of Interior
COE	Corps of Engineers, U.S. Army
EPA	Environmental Protection Agency, U.S.
MSHA	Mine Safety & Health Administration, U.S. Department of Labor
NPS	National Park Service, U.S. Department of Interior
USFS	U.S. Forest Service, U.S. Department of Agriculture
USFWS	U.S. Fish & Wildlife Service, U.S. Department of Interior

PERMITTING AND ENVIRONMENTAL CONSTRAINTS

Their Impact on Mining in Alaska

By Gary E. Sherman[1]

ABSTRACT

This report presents a Bureau of Mines study on the cost of mine permitting and compliance with environmental regulations in Alaska. It discusses permitting requirements and procedures for placer and lode mines.

Placer miners must comply with recently established (1988) water quality regulations and effluent treatment requirements. To estimate the impact differing treatment options (no recycle, 100% recycling, and flocculation) have on a placer mine's rate of return, three models (1,500, 1,000, and 500 yd^3/d) were simulated. Rates of return for these models show a marked decrease as effluent treatment is increased. The incremental increase in operating cost from one treatment option to the next is relatively small; however the opportunity cost of lost production is significant and accounts for the decreasing rate of return with increased effluent treatment.

Lode mines face greater costs for permitting and compliance than similarly sized placer mines as a result of the impact of the operation. Direct permitting costs for lode mines range from 2 to 6% of total project cost, with 4% the most common figure cited by industry. Total costs for permitting and compliance are approximately double those for permitting. Indirect costs associated with compliance include mitigation, monitoring, and reclamation.

[1]Mining Engineer, Alaska Field Operations Center, Juneau Branch, Juneau Alaska

INTRODUCTION

Mining in Alaska today requires strict attention to the regulatory requirements mandated by both State and Federal law. Since the mid-1960's, concern about the environment and its protection has increased as has the body of regulations with which all industry must comply. Environmental regulations have become an important factor in the planning and development of mining operations nationwide. A number of acts and regulations have been instituted to protect wildlife, air and water quality, and aesthetics of the land: the Clean Air Act (1963), the National Environmental Policy Act (1969), the Resource Conservation and Recovery Act (1976), the Clean Water Act (1977), and the Comprehensive Environmental Response, Compensation, And Liability Act (Superfund, 1980) (5)[2]. The 1980 Alaska National Interest Lands Conservation Act (ANILCA, Public law 96-487) also prescribes requirements for activities on ANILCA lands.

For small mines, the constraints of these regulations may severely affect the mine's ability to operate at a profit; for larger mines, they may increase the overall cost and lead time required. Placer mines in Alaska have the potential to be significantly impacted by these regulations, because topographic, climatic, and economic constraints--particularly regulations governing water quality--may limit their ability to comply.

This Bureau of Mines report examines the cost of permitting and compliance with pertinent environmental regulations for three sizes of placer mines, the incremental cost of compliance through use of two different water treatment technologies, and the impact on a project's rate of return. Permitting costs and mitigation/monitoring requirements for lode mines are also discussed.

PERMITTING

Regulations affecting the mining industry in Alaska include a variety of permits which must be obtained from various State and Federal agencies. The Alaska Department of Commerce and Economic Development has published a report describing permits and approvals that may apply to mining in Alaska (19). The permits and approvals discussed in the document include those covering environmental requirements, health and safety, access, land use, and acquisition of minerals.

Requirements for permitting vary depending on the nature of the activity, particularly whether the mine is a placer or lode mine.

PLACER MINES

A placer miner generally needs to file applications with the Alaska Division of Mining in Anchorage or Fairbanks, the EPA Region X office in Seattle, and the Army Corps of Engineers in Anchorage.

The State of Alaska has streamlined the permitting system for placer mining through its Annual Placer Mining Application (APMA). The applicant sends the APMA and a $100 fee to the Alaska Division of Mining, which then distributes the application to various land, wildlife, and water use agencies (eg. ADEC, ADF&G, ADGC, ADNR, ADR, BLM, and USFS) for action.[3] The APMA process generally satisfies the application requirements for many of the permits that

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

[3]Agency abbreviations are listed after the table of contents.

the miner would normally have to apply for individually. Table 1 lists the permits and requirements satisfied by the APMA.

TABLE 1. - Permits and requirements satisfied by the APMA.

Permit	Agency
Coastal zone consistency determination	ADGC
Wastewater discharge permit	ADEC
Fish habitat permit	ADF&G
Miscellaneous land use permits	ADNR
Water use permit	ADNR
Alaska mining license	ADR
Annual notice or plan of operation	BLM, NPS
Notice of intent or plan of operation	USFS
Notice of startup	MSHA

Placer mines must also obtain a National Pollutant Discharge Elimination System (NPDES) permit from EPA, which is required for operations which discharge wastewater to surface waters of the United States. The EPA must receive the NPDES application at least 180 days before discharge begins. A wastewater discharge permit from the ADEC is not required when the mine has obtained an NPDES permit; however, the ADEC must certify that the terms of the NPDES permit will result in adequate protection of the environment and adherence to State water quality standards (Certificate of Reasonable Assurance, ADEC).

If dredge or fill tailings from the operation will be discharged into navigable waters or wetlands, a Section 404 (Clean Water Act) permit is required from the COE. If the applicant is unsure whether the project is located in wetlands, the COE can make a determination. The COE has recently devised a general permit that can be issued to placer mines that disturb 5 or fewer surface acres per year.

Federal agencies are bound by the National Environmental Policy Act (NEPA) to consider environmental concerns associated with their actions (5). While the majority of Alaska placer mines have not required an Environmental Impact Statement (EIS) in the past, BLM is performing Environmental Assessments (EAs) on all placer mines located on BLM lands that will disturb more than 5 acres or are located within certain conservation or critical land units. (NEPA is discussed in greater detail in the section on lode mine permitting.)

Generally, the placer miner need submit only an APMA, an NPDES application, and a COE Section 404 application (if required) to receive the permits required to operate. Figure 1 illustrates the general process through use of the APMA, as adapted from ADNR's Division of Mining (6). The application process has two or three parts: APMA, NPDES, and 404 (if required) applications. Assuming the APMA is completed in full and all the necessary information supplied, the State permits shown on figure 1 (and listed in table 1) can be acquired. Additional information may be required of the applicant in response to special situations or if the initial application is incomplete. The use of the APMA has greatly simplified the permitting process for placer miners, as permits and approvals from five State and three Federal agencies can be acquired with one application. Other permits may be required, particularly those concerned with health and safety of the workforce (eg. food service permit).

LODE MINES

At present the State does not have a master application form for lode mining permits. Partial permitting of a lode mine can be accomplished using the APMA if the project is not located in a coastal zone. The process is similar to that for placer mines, and the permits listed in table 1 can normally be obtained by this procedure, however additional permits may be required. If the project falls within a coastal zone, it is subject to review and

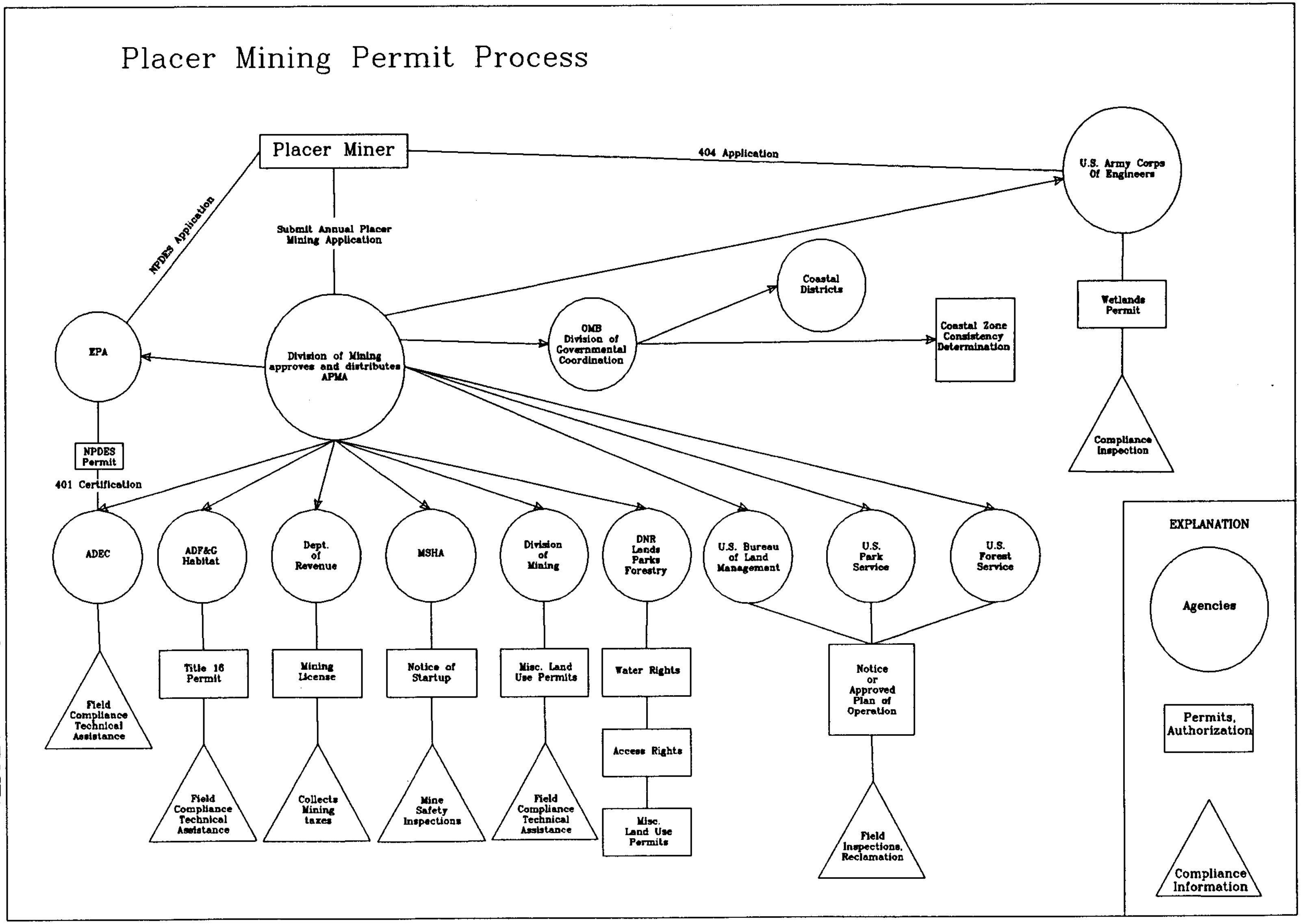

Figure 1. - Permit process for placer mines (Source: ADNR)

certification by the ADGC. In this case, the APMA is not adequate and the applicant must complete a Coastal Project Questionnaire from ADGC. The questionnaire allows the applicant to identify which permits will be needed from ADNR, ADF&G, and ADEC. The ADGC coordinates the contact between the applicant and the agencies involved. The ADGC also helps coordinate the State of Alaska's response to proposed Federal permits. ADGC has been involved in the review of a number of mining projects in Alaska that needed Federal permits, including the Red Dog Lead-Zinc Mine and the Quartz Hill Molybdenum project.

Lode mines tend to have greater infrastructure requirements than placers, and therefore generally require a greater number of permits. The same permit may be required for each aspect of a project (eg. road, drill pads, mine and mill site, and tailings ponds), depending on complexity.

Permitting of a major lode mine can be divided into three phases: preapplication, compliance with NEPA, and construction. Preapplication permits are for baseline environmental studies and include scientific collection permits needed to assess water and air quality, wildlife, fisheries, and the marine environment.

NEPA (Public Law 91-190) requires that Federal agencies consider the environmental consequences and address environmental concerns associated with their activities (5). Its goal is to "use all practicable means" to conduct Federal activities in a manner which is in "harmony" with the environment and will promote "the general welfare" (5). It does not require an agency to make a particular decision in any given case but rather requires only that the consequences of the action be considered (5). The Council on Environmental Quality (established by NEPA) has established regulations directing the NEPA process. Six general phases are associated with NEPA implementation: 1) categorical exclusions, 2) environmental assessments, 3) scoping process, 4) draft EIS, 5) final EIS, and 6) agency record of decision (5). Some routine activities that an agency has determined do not require an EA or EIS can be categorically excluded from further NEPA review. Projects which cannot be categorically excluded may require an EA to determine whether an EIS is required. If, after the EA is completed, the activity is found to have no significant impact on the environment, a Finding of No Significant Impact (FONSI) is issued and an EIS is not required. Activities which clearly represent a significant Federal action require an EIS. The scoping process is used to identify issues and concerns to be addressed in the draft EIS. After review and a comment period, the final EIS is issued, followed by the agency's record of decision.

An EA or EIS can be prepared by the mining company in consultation with appropriate State and Federal agencies, by the land manager such as the BLM or NPS, or by a third party consultant.

The construction permitting phase includes those permits required for actual development of the mine, including permits for road building, fish stream crossings, and port facilities.

Permitting of a lode mine is more complex than simply filling out the requisite forms. Typically the process requires meeting with representatives of the agencies involved to describe the project and explain various aspects and options. An example of the general procession of activities in lode mine permitting is illustrated in figure 2, which is adapted from a report on the Red Dog Mine, a world class lead-zinc mine in northwestern Alaska (13). Coordination and communication with the permitting agencies is important at all levels of the process to identify and address all potential environmental impacts and regulatory requirements.

Substantial lead time can be necessary in permitting a lode mine. For the Red Dog, environmental baseline studies extended from winter of 1981 through summer of 1983 (13). EIS preparation began in January of 1983; the final EIS was published in September, 1984.

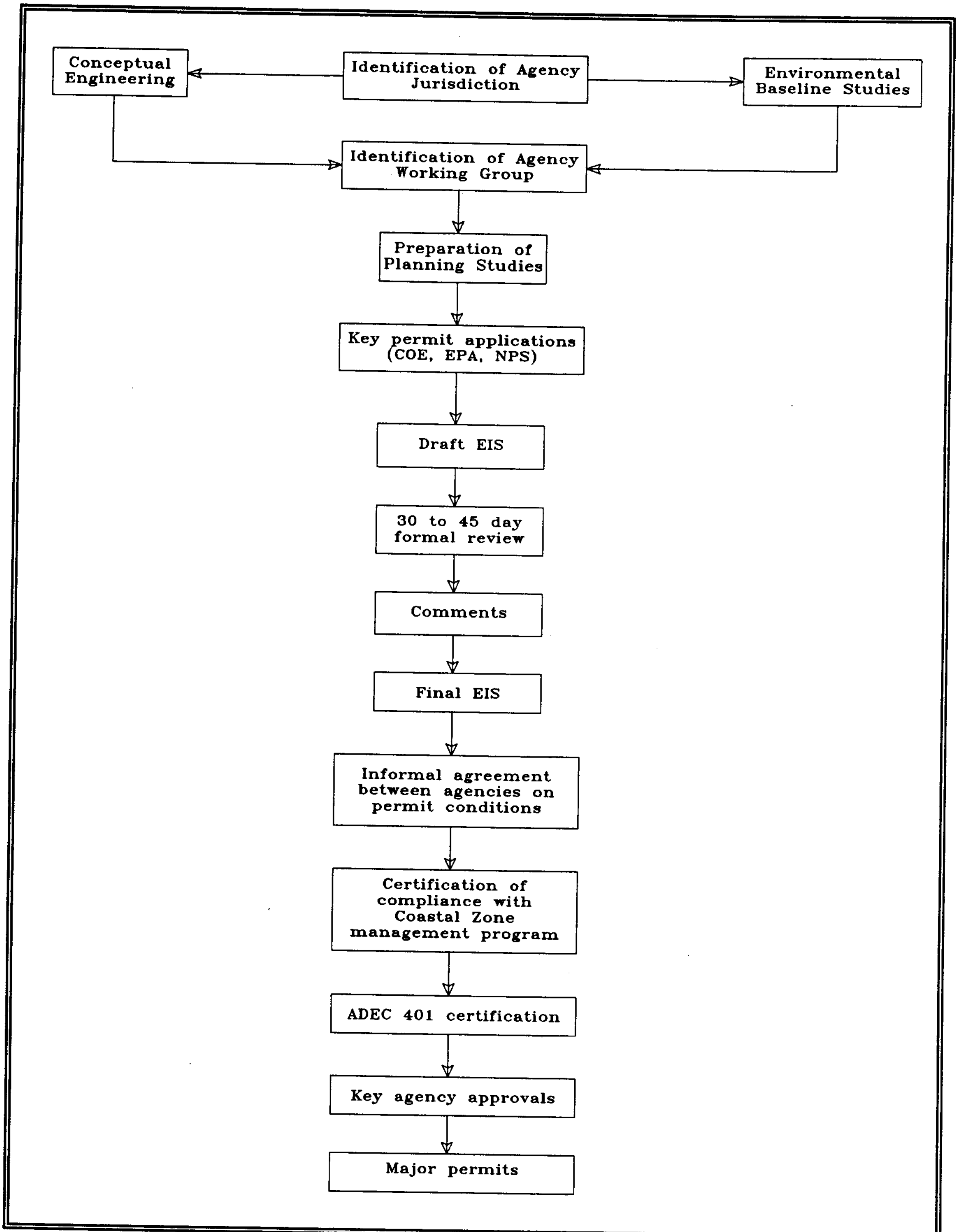

Figure 2. - Permitting process, Red Dog Mine (15).

Additional time was required to obtain access across the Cape Krusenstern National Monument. While access across ANILCA lands is governed by Title XI of the Act, in the case of the Red Dog Mine, access through the monument was obtained through a legislative land exchange controlled by the NANA Native Regional Corporation (3). To date, the Title XI provisions of ANILCA have been untested; no right-of-way has been granted and no applications appear to be pending.

Obtaining major permits for a project can take 2 or 3 yr, possibly longer depending on site-specific conditions. After the major permits are obtained for construction, development, and production, the permitting process generally continues on a reduced scale until project start-up. The last-minute permits should be minor, the major issues being addressed and resolved early in the development stages of the project.

An important consideration in lode mine design and permitting is the disposal of wastewater and tailings from the mill. Current law allows no discharge of mill process water, except for an amount of water equal to the difference between precipitation and evaporation (40 CFR 440). Mine tailings are not classified as hazardous waste under the Resource Conservation and Recovery Act but are treated as solid waste by the permitting agencies. In Alaska, ADEC is responsible for issuing solid waste disposal permits for mine tailings. Water discharged from the pond through seepage must meet current standards for metal content and ground water monitoring wells may be required.

Figure 3 shows the general process for major environmentally-related permits for a lode mine, beginning with identification of agency responsibility and proceeding through the application phase. Lode mine permitting is not a sequential process; permit applications may be submitted concurrently. Figure 3 is not a flowsheet, but rather identifies the major categories of permits and conditions associated with each. Because the same permit may be required for different phases of a project, some of the branches in figure 3 will be traversed more than once in the course of developing a project. The decision about whether a permit is required is up to the responsible agency. The applicant cannot determine need for a permit when the impact of the proposed action must be determined.

DISCUSSION

Directory of Permits, published by ADEC, is an additional source of information on permits for mining and other projects in Alaska (1). It describes State, Federal, and local requirements and lists not only permits but also various licenses and approvals that may be required in Alaska.

The Directory indicates that a small placer mine may require up to 36 permits, approvals, or licenses, while a major mining project may require as many as 75 (the Red Dog lead-zinc mine required over 90 permits (2)). Separate permits may be required for each phase of a project (eg. in wetlands, a COE 404 permit for mill site construction, tailings pond, road building), thus increasing the total number of permits needed. Not all mines will require all permits and many of the permits pertain to site-specific conditions. Many small placer mines can be permitted through the use of only the APMA, NPDES, and COE 404 applications. Many of the permits that pertain to larger operations concern air quality, fuel operations and storage, and oil spill contingency plans that may not be applicable to small placer mines.

Table 2 lists the major permits concerned with environmental protection which may be required of a mine in Alaska. For more detailed information on permits pertaining to health and safety (occupational and industrial structure, camps, building construction and occupancy, drinking water treatment and supply, and food service) that may be required of a mining operation, the reader is referred to the Permit Guidelines Handbook (19) or the Directory of Permits (1) for a complete description.

TABLE 2 - Major permits which may be required of placer and lode mines in Alaska.

Permit	Agency	Comment
Air quality control permit to operate	ADEC	Major sources of air contaminants may need a permit, to be determined based on location, total emission, and change in emissions.
Certificate of Reasonable Assurance: Water Quality Certification	ADEC	Required to protect the waters of the State from pollution. Assures that the issuance of a Federal permit (eg., NPDES or 404 permit) does not result in the violation of State water quality standards.
Collection permits (various)	ADF&G, USFWS	Required for collection of species during EIS baseline studies.
Coastal Zone Management Consistency Certification	ADGC	Assures that activities in the Coastal Zone are consistent with the Coastal Zone Management Program.
Fish habitat permit and special area permit	ADF&G	Required for activities that may affect fish and wildlife habitat, including stream crossings, diversions, and other activities within or across fish streams. Special area permit covers activities in refuges, critical habitats, and sanctuaries.
Miscellaneous land use	ADNR	Required for mining, development, or exploration on State land which involving equipment that may damage the surface.
National Pollutant Discharge Elimination System	EPA	Required for discharge of wastewater from one or more point sources into waters of the United States.
Oil discharge contingency	ADEC	Covers oil operations such as tankers, oil barges, and terminals with a capacity of 10,000 bbl or greater.
Open burning permit	ADEC	Required for burning of materials that emit black smoke (rubber, oil waste, etc.) and for burning of vegetation.
Park use permit	ADNR	Needed for recurring or permanent access across State park lands to inholdings or property partially within a park.
Plan of operations	BLM, USFS, EPA	USFS may require information in addition to that contained on the APMA.
Prevention of significant deterioration	ADEC	Required for sources that emit > 100 st/yr of any pollutant (eg., incinerators, smelters, gas turbines, mill plants).
Section 10 (River and Harbors Act of 1899)	COE	Permit for structures or work in or affecting navigable waters of the United States, including docks, boat ramps, mooring buoys, and similar structures. May require a Coastal Zone Management Consistency Certification.
Section 404 (Clean Water Act)	COE	Required for discharge of fill or dredge material to the waters of the United States, including wetlands (requires 401 water quality certification from the State).
Solid waste disposal	ADEC	Required for disposal of mine wastes (eg., cyanide leach wastes).
Spill prevention control & countermeasure	EPA	Required for 660 gal single or 1,320 gal aggregate above-ground fuel storage sites or 42,000 gal below-ground sites. Not required if a spill could not possibly reach navigable waters or their tributaries.
Tideland lease	ADNR	Required for activities involving a permanent improvement of or on State tidelands or submerged lands (eg., dock construction).
Wastewater disposal	ADEC	Required for an operation that disposes of wastewaters into waters or upon the surface of the land in the State. State certification of a NPDES permit may satisfy this requirement.
Water use	ADLWM	Water rights and temporary water use permits.

COST ANALYSIS

To examine the economic impact of effluent treatment options on project viability, mine models were used to simulate the capital and operating costs for three sizes of placer mines. The models were analyzed from a project perspective, meaning the impact of treatment options was examined over the life of the mine. The capital outlay and cash flow over the life of each model was simulated in order to determine the rate of return for each alternative.

PLACER MINING

Placer mines in Alaska, including dredges, produced an estimated 223,200 tr oz of gold in 1987; amounting to 97% of total gold production in the State. (6). While total gold production increased 44% over 1986, regulatory and legal problems continue to impact the small-scale placer mine (6).

Compliance with water quality regulations and reclamation requirements are the major cost-related issues facing placer mines in Alaska. Effluent guidelines issued by EPA May 24, 1988 require 100% recycling of plant process water for all mines processing greater than 1,500 yd^3/yr (11). The new guidelines do not apply to dredges which process under 50,000 yd^3/yr. In August of 1988, the Department of Interior (DOI) asked EPA to set aside the new regulations, citing serious deficiencies in the economic impact analysis. DOI's analysis indicated that more than 75% of the small placer mines would be forced to close even with stable gold prices (4, 10). EPA responded, saying DOI had presented no convincing evidence and that the regulations would stand as promulgated. Litigation is currently pending on the new regulations, but as of September 1989, the guidelines were in effect. Mine operators can apply for a variance, but such application must be based on site-specific factors not covered by the effluent guidelines. Such a request is based on "fundamentally different factors" (FDF), the procedure for which is documented in 40 CFR 122.21m. Economic factors (eg., hardship, excessive cost) are not a basis for a FDF determination. FDF variances are not granted as a matter of course by EPA.

Reclamation has become an increasingly important cost consideration for placer miners. Minimum reclamation, in the form of reshaping and recontouring the mine area, is generally required. In some cases, revegetation through reseeding may be required, depending on site-specific conditions. Reclamation bond requirements vary by agency, with many State and Federal agencies requiring no bond except for operators with a record of non-compliance. Other agencies determine the need for a bond based on the nature of the operation. Reclamation costs per acre are site-specific and depend the extent of reclamation required. BLM estimated the cost per acre to perform various levels of reclamation in the cumulative EISs for the Beaver Creek, Minto Flats, Fortymile River, and Birch Creek watersheds (20, 21, 22, 23). Costs ranged from a high of $1,700 per acre (1987 dollars) for recontouring, reshaping, spreading soil over reshaped tails, reseeding, and reestablishing the stream channel to a low of $500 per acre for recontouring and stabilizing soils and streams. Because of the site-specific nature of reclamation costs and the fact that little hard data on reclamation costs for placer mines exist, the effect of reclamation on placer mine feasibility was not examined in this study.

The intent of this section is to examine the impact of total recycle and flocculation as effluent treatment options on a placer mine's feasibility. The costs derived for this analysis are not intended to represent actual mining costs for operations in Alaska, and are based on assumptions which cannot be universally applied to the industry. The intent rather is to show the decrease in the expected rate of return for a project when compliance costs are considered. A previous analysis by Shannon and Wilson (16) laid the groundwork for the estimates of lost production time used in this report. While alternative effluent treatment options may present a relatively nominal increase in yearly overall operating costs, the impact from a project point of view can be significant when amortization of capital equipment, payback of initial investment, and the value of lost production are considered.

Industry Profile

Data from the 1988 APMAs were used to develop a picture of current industry practice. It should be stressed that the following data are based on *intended* mining plans for 1988 rather than actual operations. Submission of an APMA does not necessarily mean that a mine actually operated during the season. Data were aggregated for non-dredge mines planning to process at least 250 yd^3/d. Keeping the foregoing caveat in mind, the data can be used to get a feeling for current industry practice.

Figure 4 illustrates the intended methods of processing gold from placer mines in Alaska for 1988. Because of the manner in which the use of processing plants is reported on the form, there is some overlap between methods. The categories in figure 4 are not mutually exclusive, but are intended to show the highest level of feed classification that takes place. The majority of non-dredge placer mines (38%) use only a sluice box to process gold-bearing pay. Many operators use some type of classification system ahead of the sluice, eg., grizzly with spray bars, vibrating screens, or trommels. Other recovery systems in use may include jigs and spiral concentrating devices. "Unspecified plant" in figure 4 indicates mines using something other than a simple sluice for processing pay gravel. Sluice boxes have the advantage of being relatively inexpensive and simple to maintain, contributing to their widespread use in the industry. Other gravity devices, such as jigs and spiral concentrators, are more expensive and require higher maintenance than sluice boxes but, if properly used under the right circumstances, result in better fine gold recovery. Use of jigs and spiral concentrating devices requires feed classification for proper operation. Classifying feed reduces the amount of wash water required and contributes to fine gold recovery.

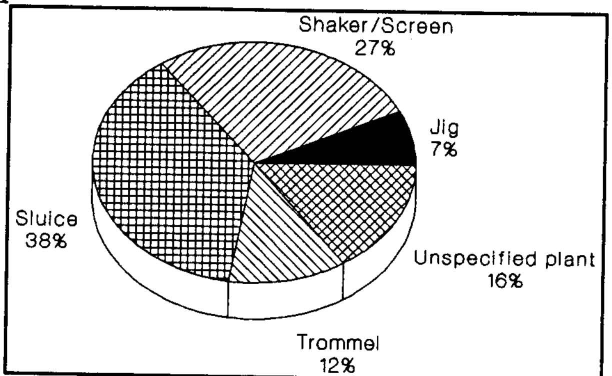

Figure 4. - Placer processing plants, Alaska placer mines, 1988. Based on mines producing greater than 250 yd^3 per day.

Maintaining water quality standards presents one of the highest environmental costs associated with placer mining. Methods for treating placer plant effluent include settling ponds, tailings filtration, 100% recycling of process water, and flocculants. The last two methods present significant cost and time factors which can impact placer mine productivity and project feasibility. Other methods of improving effluent water quality exist but are generally site-specific in their application.

Based on the 1988 APMA data, over 50% of the placer mines in Alaska practiced or intended to practice 100% recycling. Roughly 25% planned to do no recycling; the remaining operations planned to recycle varying amounts of their process water (figure 5).

Recycling 100% of process water may not be technically feasible at all mine sites because of site conditions such as steep-walled, narrow canyons which limit the size of settling and recycle ponds. It should be noted that 100% recycle is not equivalent to zero discharge. Zero discharge means that no water is released from the mine area, whereas 100% recycle means that no process water is discharged. Under normal circumstances, 100% of the

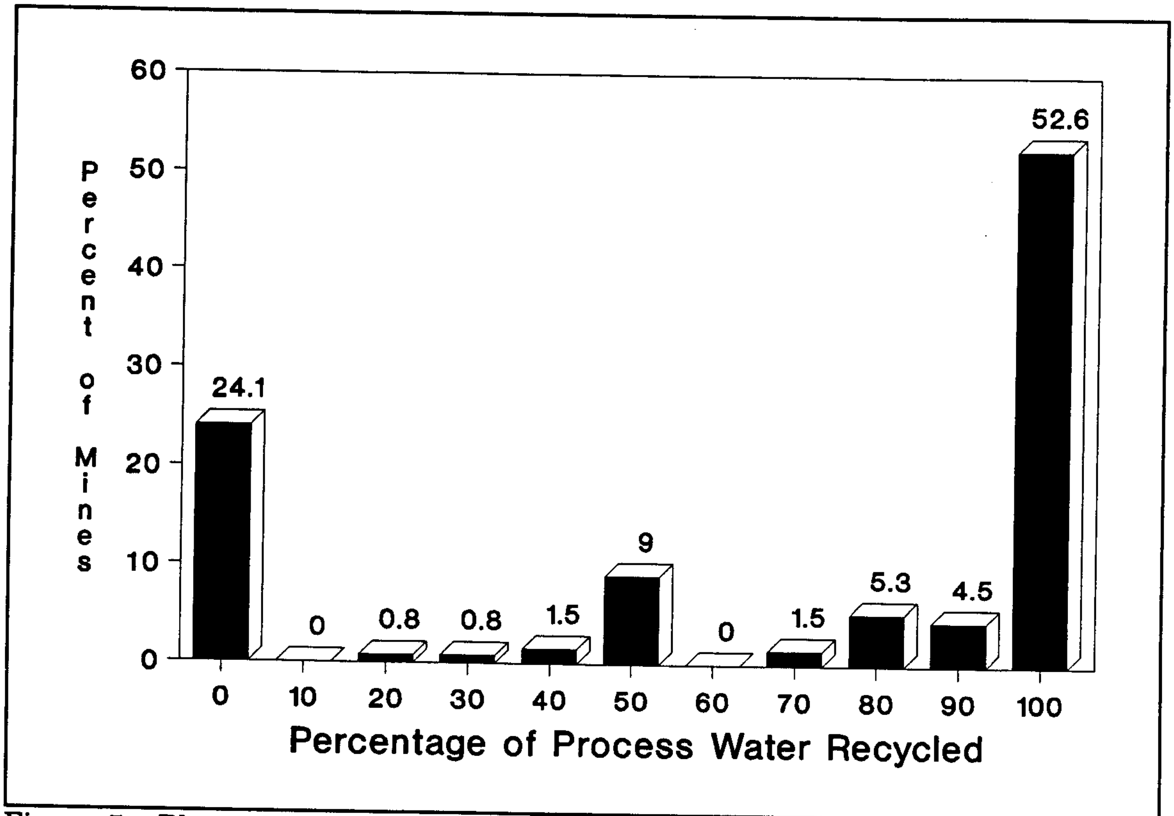

Figure 5 - Planned recycling practice, Alaska placer mines, 1988. Based on mines processing greater than 250 cubic yards per day.

process water may be recycled, but as a result of factors such as infiltration and non-channeled flow, some discharge of water is inevitable.

Flocculants provide a means of reducing settleable solids but may present an added capital and operating cost that most operators are unwilling or unable to accept. Tests of the flocculant polyethylene oxide (PEO) by the Bureau at several mining sites in Alaska demonstrated that the settleable solids limit could be met. While turbidity standards of 5 NTU were not achieved in any of the tests, turbidity was significantly reduced in many instances (17).

Financial Analysis

The costs associated with recycling for several placer mines were estimated by Shannon & Wilson (16) as part of a study for ADEC. Cost of a total recycle system varied from 8.5 to 20% of the total yearly operating cost. Lost production as a result of recycling ranged from negligible in one case to 27.3% of yearly operating time. Lost production represents a major cost to the placer miner when recycling or using flocculation. Additional maintenance, downtime, and cleanups associated with the recycle system result in less mining time and therefore lost revenue. In most cases, additional labor required by a recycling system does not warrant the addition of another employee; rather existing employees are taken away from sluicing to maintain the system. This lost production is an opportunity cost and, in a financial analysis, can affect the project's payback and rate of return. For a small placer mine already operating on a narrow margin, it could mean the difference between continued production or closing down. The increased frequency of sluice cleanup is attributed to the increased solids content in the recycled process water.

Three placer mine models were designed for this study based on what were considered average operating capacities in Alaska. These models assume that the mines are not currently recycling and that they will recycle solely to comply with water quality regulations. Many placer mines recycle to maintain adequate water for operation during periods of low water. The incremental cost of going from a partial recycling system to 100% recycling was not examined.

The costs of the model operations are based on average assumptions and therefore do not represent any specific mining operation. Mining costs depend on a number of variables, including site-specific conditions, pay gravel characteristics, and experience of the individual miner (14, 8). Models were designed for three mine sizes: 500, 1,000, and 1,500 yd^3/d. Sources of mine and plant costs for the three models include the Green Guide for Equipment (7), the Bureau's Cost Estimation Handbook for Small Placer Mines (18), and the Bureau's Cost Estimating System Handbook (24, 25).

Each model was examined for a baseline case (no recycling), 100% recycling, and 100% recycling with treatment of 1,000 gal of effluent/d by flocculation using PEO. Water use rates are based on data from Shannon & Wilson (15, pp. 3-5), with each model assuming a baseline operation consisting of bulldozer(s) and a front-end loader, trommel, sluice box with undercurrents, and concentrate cleanup by table. Each mining season has 100 operating days and each mine works one 8-h shift/d. All mines have sufficient to operate 10 yr in the baseline case. Each model was evaluated over a range of feed grades at $400 and $450/tr oz gold to examine the impact of fluctuations in grade and price on the rate of return. Total gold recovery was assumed to be 80% for all the models.

Estimates of lost production time resulting from recycling and flocculation were based on information from Shannon and Wilson (16). The lost time estimate for 100% recycling assumes the loss of 0.5 h/shift plus the burden of additional cleanups, resulting in the loss of 6 shifts/season or total lost time of 98 h/season. Lost time for the flocculation treatment option is considered cumulative and includes the estimate for recycling plus an additional 1.5 h/d for mixing and for maintaining the system. The result is an estimated of 248 h/yr total lost time for a mine using both recycling and flocculation.

1,500 Yd^3/d Model

Operating costs and data for the 1,500 yd^3/d placer mine are shown in table 3 for the baseline case (no recycling), 100% recycling, and 100% recycling with flocculation treatment by PEO. Costs for the PEO treatment are based on field studies in Alaska by the Bureau (12, 17). Recycling process water results in the need for more water to wash an equivalent amount of pay (15). The baseline operation requires 2,400 gpm, while 100% recycling requires 3,125 gpm of water. Table 3 also shows the rate of return for each option at $400 and $450/tr oz gold and a grade of 0.015 tr oz/yd^3.

The value of the lost production is assumed to be an opportunity cost and is estimated by taking the difference of the value of the lost production and the cost of production under baseline conditions. The value, cost per cubic yard, and percent of operating cost of lost production for flocculation shown in table 3 are incremental values in relation to the 100% recycling operation, not the baseline case. Compared to the baseline model, the flocculation would result in a total value of lost production equal to $139,035 at

0.015 tr oz/yd^3 and $450/tr oz gold.[4] The cost of lost production, representing 36.7% of the total operating cost, would be $1.40/$yd^3$.

Note that the mine life is extended 1 yr in the recycling model and 4 yr in the flocculation model. The lost time inherent in each option has the effect of lengthening the mine life, as less ore is processed each year.

TABLE 3. - Cost and operating data for the 1,500 yd^3/d placer model

	No recycling	Recycling	Flocculation
Mine capital cost ($)	1,163,100	1,163,100	1,163,100
Plant capital cost ($)	331,300	393,500	439,400
Working capital ($)	108,450	116,093	118,300
Mine operating cost ($/$yd^3$)	1.55	1.55	1.55
Plant operating cost ($/$yd^3$)	0.86	1.39	2.26
Mine life (yr)	10	11	14
Lost time (hrs)	NAp	98	150
Lost production value ($)[1]	NAp	54,941	69,188
Cost of lost time ($/$yd^3$)[1]	NAp	0.53	0.87
Lost production% of operating cost[1]	NAp	18	23
Rate of return (%) at grade of 0.015 oz/yd, $400 gold	7.17	0.05	-8.62
Rate of return (%) at grade of 0.015 oz/yd, $450 gold	14.51	6.91	-3.47

NAp Not applicable

[1]Incremental change over previous operation (ie. baseline vs recycle, recycle vs flocculation).

1,000 yd^3/d Model

The 1,000 yd^3/d placer mine operates under conditions similar to those of the 1,500 yd^3/d mine; however the grade was varied from 0.0125 to 0.0225 in the financial analysis. The baseline mine requires 1,600 gpm, while recycling and flocculation require 2,100 gpm of water. Table 4 lists the operating data and results of the analysis for the three options.

500 yd^3/d Model

The 500 yd^3/d placer mine operates under conditions similar to those of the other mine modes; however, because smaller operations characteristically mine higher-grade deposits, the grade was varied between 0.015 and 0.025 tr oz/yd^3 gold. The baseline mine requires 800 gpm while recycling and flocculation require 1,050 gpm of water. Table 5 lists the operating data and results of the analysis for the three options.

[4] (248 hrs X 187.5 yd^3/hr X 0.015 oz/yd^3 X 0.8 recovery X $450/oz) -(248 hrs total lost time X 187.5 yd^3/hr X $2.41/$yd^3$ baseline cost)

TABLE 4 - Cost and operating data for the 1,000 yd^3/d placer model

	No recycling	Recycling	Flocculation
Mine capital cost ($)	704,612	704,612	704,612
Plant capital cost ($) ...	275,500	316,800	362,600
Working capital ($)	86,600	92,700	93,500
Mine operating cost ($/$yd^3$)	1.80	1.80	1.80
Plant operating cost ($/$yd^3$)	1.09	1.72	2.72
Mine life (yr)	10	11	14
Lost time (hr)	0	98	150
Lost production value ($)[1]	0	41,773	52,125
Cost of lost time ($/$yd^3$)[1] .	0	0.63	1.00
Lost production % of operating cost[1]	NAp	18	22
Rate of return (%) at grade of 0.0175 tr oz/yd^3, $400 gold	10.63	1.25	-9.30
Rate of return (%) at grade of 0.0175 tr oz/yd^3, $450 gold	19.25	9.23	-3.24

NAp Not applicable

[1]Incremental change over previous operation (ie. baseline vs recycle, recycle vs flocculation).

TABLE 5 - Cost and operating data, 500 yd^3/d placer model

	No recycling	Recycling	Flocculation
Mine capital cost ($)	393,800	393,800	393,800
Plant capital cost ($) ...	189,300	227,800	273,600
Working capital ($)	52,900	56,730	56,400
Mine operating cost ($/$yd^3$)	2.33	2.33	2.33
Plant operating cost ($/$yd^3$)	1.20	1.98	3.12
Mine life (yr)	10	11	14
Lost time (hr)	0	98	150
Lost production value ($)[1]	0	22,479	27,094
Cost of lost time ($/$yd^3$)[1] .	0	0.51	1.14
Lost production % of operating cost[1]	NAp	18	21
Rate of return (%) at grade of 0.02 tr oz/yd^3, $400 gold	8.07	-1.27	-10.97
Rate of return (%) at grade of 0.02 oz/yd^3, $450 gold	16.63	6.37	-5.63

NAp Not applicable

[1]Incremental change over previous operation (ie. baseline vs recycle, recycle vs flocculation).

Results

The discounted cash flow analysis of the three mine models indicates that recycling and flocculation significantly impact the profitability of a mining project. The estimated rates of return in tables 3, 4, and 5 illustrate the progressive decrease in a project's viability as effluent treatment is increased.

To determine the effect varying grades and gold prices have on the rate of return, sensitivity analysis was performed for each model. Curves in figures 6 through 11 present the results of this analysis for each model at gold prices of $400 and $450/tr oz (see Appendix). The curves illustrate the magnitude of the impact effluent treatment has on a placer project.

For example, the 1,500 yd^3/d baseline mine (0.015 tr oz/yd^3, $450/tr oz gold, figure 9) generates a 14.5% rate of return over the project's life. Recycling drops the return to 6.9%, a substantial decrease. Adding flocculation treatment lowers the rate of return to -3.5%.

Some mines will operate down to a 0% rate of return, as long as they can pay wages. By examining the rate of return for the effluent treatment options, one can examine the attractiveness of placer mining as a business proposition. More attractive business opportunities are available than investing $1.5 million (1,500 yd^3/d, recycling model) for a 7% rate of return. This rate of return may make it difficult for mining operations to obtain capital for a new operation.

The effect of recycling on an existing operation's costs was examined by Shannon & Wilson and the overall effect on project return in those cases is unknown. Use of flocculants to improve the quality of recycled water and prevent the buildup of suspended solids proved to be uneconomical for all mine models in this study except in the case of high grades and gold prices. In no case did the rate of return reach 15% when flocculation was used (see Appendix), primarily because of the lost time involved with mixing and maintaining the system. Use of flocculants may be economical at some placer mines, depending on site specific conditions such as grade. Flocculants in the form of gel logs have been used to a minor extent in Alaska for decreasing the solids content of process water. The log-shaped mass is placed in the effluent stream and adds flocculant to the water by slowly dissolving.

If one were to ignore the aspect of lost production in the recycling and flocculation options, the impact would appear to be much less. For example, table 6 lists the rate of return for each model at the median grade and $450/tr oz gold for each treatment option without including the cost of lost production. The rate of return improves dramatically for the recycling and flocculation when only the direct operating cost is considered. These results indicate that the lost production aspect of placer mining is a significant cost and should be included in any analysis of effluent treatment options. When lost production was not included as an operating cost, all of the mines showed significantly improved rates of return for all options, including flocculation. This outcome indicates that while the direct incremental cost of effluent treatment options is not fatal to a mine's feasibility, it is the loss of revenue resulting from lost production which forces a mine into a negative rate of return.

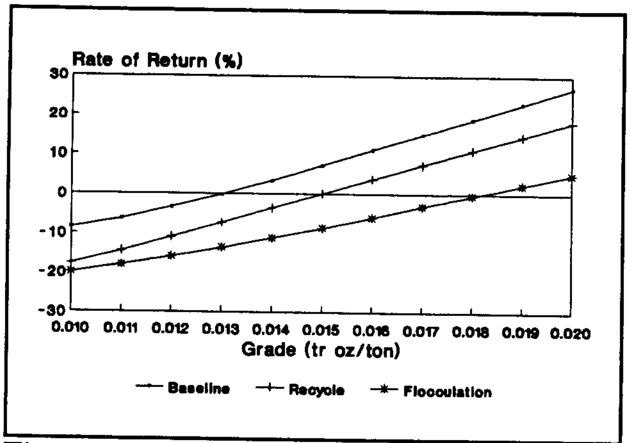

Figure 6. - Grade versus rate of return, 1,500 yd³/d model, $400/tr oz gold.

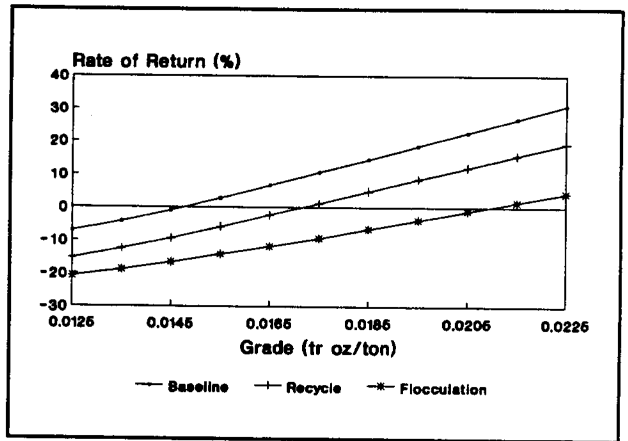

Figure 7. - Grade versus rate of return, 1,000 yd³/d model, $400/tr oz gold.

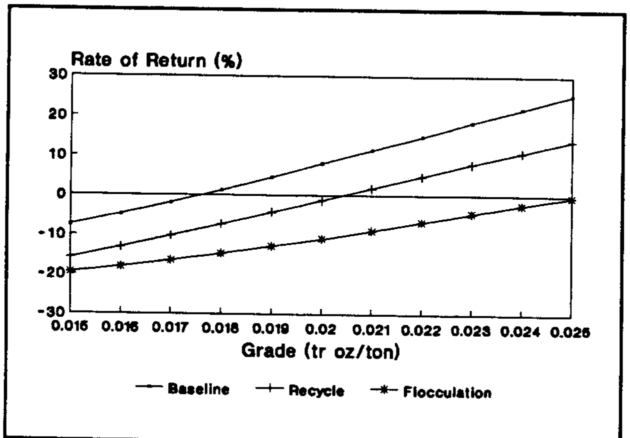

Figure 8. - Grade versus rate of return, 500 yd³/d model, $400/tr oz gold.

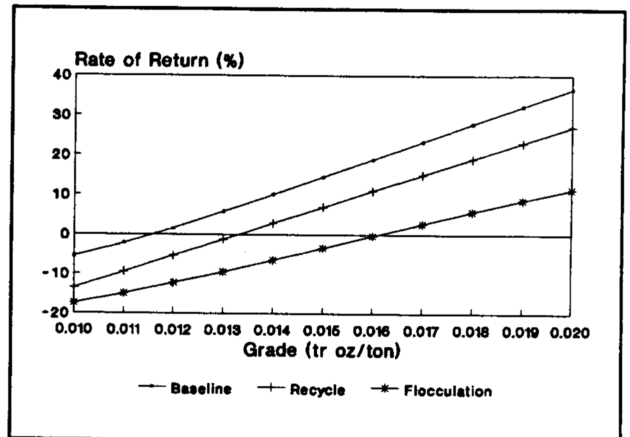

Figure 9. - Grade versus rate of return, 1,500 yd³/d model, $450/tr oz gold.

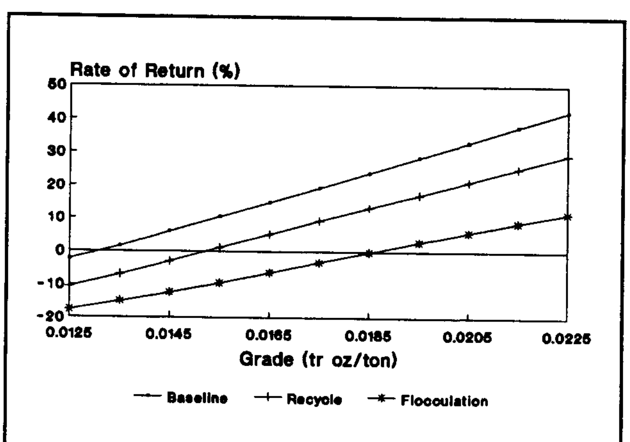

Figure 10. - Grade versus rate of return, 1,000 yd³/d model, $450/tr oz gold.

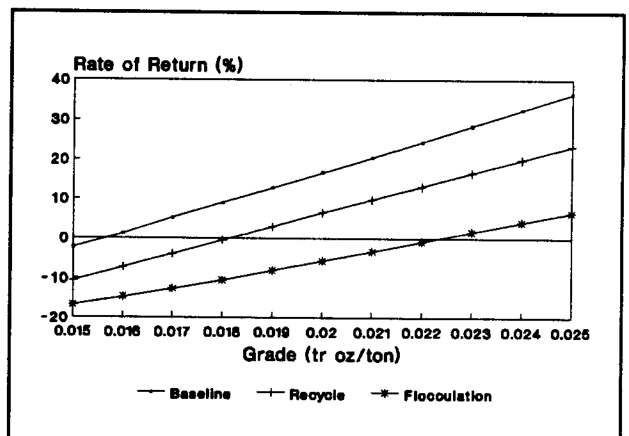

Figure 11. - Grade versus rate of return, 500 yd³/d model, $450/tr oz gold.

TABLE 6. -Rate of return for placer models when lost production is not considered ($450/tr oz gold).

Model	Baseline	Recycling	Flocculation
1,500 yd^3/d, 0.015 tr oz/yd^3	14.51	12.67	7.44
1,000 yd^3/d, 0.0175 tr oz/yd^3	19.25	15.73	9.05
500 yd^3/d, 0.02 tr oz/yd^3	16.63	12.19	4.72

This point can be argued from two perspectives. One might say that lost production is not significant, because the operation will eventually recover the gold in later years. When the mine is viewed on a yearly basis rather than a project basis, this statement appears to be true. The additional operating costs of recycling or flocculation may not force a mine into the red. Much of the analysis of placer mining and the impact of proposed effluent guidelines has examined mines on a yearly basis. Modeling a mine over its life provides an estimate of the impact additional water treatment requirements can have on the project's overall rate of return.

The other perspective is that lost production is a real cost, as revenues cannot be applied to the payback of the operation. Future cash flows have a diminishing impact the later they occur after initial investment. Because the effective life of the mine is being stretched and the annual cash flows are smaller as a result of lost production, the initial investment may not be recouped. Just as excessive lead time can affect an operation's rate of return (initial capital outlay with no offsetting cash flow during lead time), the stretching of the mine's operation and decrease in annual cash flow can reduce the rate of return considerably. From an investment standpoint, neither option for treating effluent is particularly attractive.

The ability of a placer operator to remain in business depends on a number of factors. From the results presented in this section, it is clear that both grade and the price of gold impact the viability of a placer mine. Analyzing placer mines on a project rather than yearly basis illustrates the impact effluent treatment options can have on rate of return. Probably the biggest single factor that has often been overlooked is lost production. The cost associated with lost production affects not only yearly income but also payback of initial investment and rate of return.

While direct permitting costs for placer miner are low compared to lode mines, the unique seasonal nature of placer mining coupled with the opportunity cost of lost production can make compliance with environmental regulations a costly proposition.

LODE MINES

Lode mining in Alaska has been relatively small scale since gold mines were closed during WW II. As a result of increasing inflation and labor costs, most of the mines that were operating at a profit were unable to resume production after the war. Lode mining has not been entirely absent in the State, but only now are major projects underway. Because no large mines have opened in Alaska in the last 20 yr, permitting a major mine under the requirements of the laws passed in the 1960s and 1970s has been a ground-breaking experience.

Direct costs associated with permitting a lode mine are generally easily determined: EA/EIS baseline studies, EA/EIS preparation costs, construction permits, application fees, and consultant and management fees. The indirect costs of compliance are much more difficult to assess, however, because they become an integral part of the engineering and construction phases. Examples are routing of roads and pipelines and locating surface facilities. Assuming development under conditions of minimal environmental impact, sites for facilities and roads would be chosen solely on an economic basis, given comparable functionality. Development on environmentally sensitive Federal land proceeds after the EIS process is completed and permits and approvals are issued. The operator may submit alternatives for road routes and plant sites, which might include an economic comparison. Once the final site is approved, however, the operator does not track the incremental cost incurred due to the more environmentally desirable alternative. Therefore, indirect costs and costs related to mitigation are generally not readily available from mine operators because they are imbedded in the overall cost of each project phase. Such indirect costs are very difficult to simulate in a mine model, because they are highly site and mine specific. Thus, lode models were not used to estimate the impact of compliance or the cost of mitigation and monitoring.

Instead, companies involved in major exploration or development projects were contacted to determine the impact of permit requirements. Direct permitting costs for those companies contacted ranged from 2 to 6% of the project's total cost; the most common estimate of direct costs was 4%. Companies contacted ranged from those currently in development to those carrying on exploration that requires permitting for roads, drilling sites, and so on. The number of permits required varied from fewer than 10 to more than 90.

In the case of indirect costs, operators estimated that the total cost of compliance with environmental regulations (permitting plus mitigation and monitoring) probably was double that for the permitting process alone, which would indicate that 4 to 12% of the project's total cost is devoted to permitting and compliance. Not enough information was available to examine the relationship of a project's size with its cost; therefore, the form (linear, exponential, etc.) of the size-environmental cost curve is unknown.

The following information on mitigation and monitoring requirements is derived from the EISs for the Red Dog (9) and Greens Creek (26) projects. Mitigation procedures include those measures that must be taken to prevent or minimize environmental impact, subject to the conditions of the permit(s) governing the activity in question. Mitigation can be required during all phases of a project, from exploration through development and production. Examples of such procedures include controlling surface drainage during construction, reclaiming quarry sites, dust suppression on roads, open cuts, and overburden piles, noise abatement, ponds to capture runoff from quarry sites, locating roads and facilities out of view to lessen visual impact, routing of air traffic to avoid nesting sites and wildlife concentrations, design of bridges and culverts so that they can pass storm flows, incinerating garbage to prevent scavenging by bears, constructing minimum-width roads to lessen impact, and treatment of runoff, domestic, and mill wastewater.

In many instances, engineering and construction plans must be developed with mitigation of a particular impact in mind, for example, routing of a road to avoid a sensitive anadromous stream or a raptor nesting site. Doing so may result in additional cost, because the required route may be longer or require more expensive construction techniques. The location of tailings ponds is another example, where, to avoid impact on a sensitive area or species, tailings must be transported farther from the mill than originally planned. These two examples illustrate the manner in which mitigation costs become integrated into the total cost of a project. Mill location, wastewater disposal, overburden storage, tailings disposal, camp location, and road location can all be influenced by the need to mitigate the impact on some portion of the environment.

Monitoring requirements during development and production are designed to assess the impact of the current activity on a variety of environmental concerns. Such programs are generally formulated based on permit conditions and requirements. Examples of programs that have been required for projects in Alaska include monitoring: anadromous fish spawning gravels, wildlife species, road corridor vegetation (to assess damage caused by dust), marine water quality, fresh water quality, ground water quality up and downslope of tailings pond, air quality, heavy metals in fish, and problems associated with increased recreation caused by improved access. Some continual monitoring may be required while other programs might require only periodic monitoring.

Additional costs related to protecting the environment come in the form of reclamation requirements during development, production, and after completion of the project. Reclamation bonds are normally required for projects that cause a major surface disturbance. Bond amounts are set by the land manager and are usually based on an estimate of the reclamation costs should the operator abandon the property or go out of business. Bonds are therefore site-specific in nature and vary depending on location and the agency in charge. Some recent exploration projects have spent more money on permitting than they have had to post in reclamation bonds. In such cases, it costs more to obtain permits than the estimated reclamation costs (i.e., "damage").

CONCLUSIONS

Permitting in Alaska can be expensive and time consuming, especially for large projects. Project planners should recognize this factor at the outset, taking into account the lead times required to complete the process. While permitting in Alaska is not a simple task, the process has been simplified for placer miners through the APMA. Assuming no overriding environmental issues are involved, a "typical" placer mine could be permitted by submitting only 3 applications: APMA, NPDES, and COE Section 404. These three applications can provide all the environmentally related permits needed for a placer mine.

While the process has been simplified, operators must do their homework before submitting permit applications. Details of the mining operation, including location of the camp, settling ponds, fuel storage, and stream bypass must be laid out in the permit applications in adequate detail. The more completely thought through an application is before it is submitted, the easier the approval process becomes. Submitting incomplete plans and applications will result in requests for additional information and likely delays in obtaining the required permits.

The cost of complying with environmental regulations significantly affects the rate of return for placer mines. Compliance with water quality regulations represents a significant environmental cost for placer mines. The analysis performed for each of the placer mine models indicates a marked decrease in rate of return as additional effluent treatment options are added. While the incremental operating cost per cubic yard may appear small, it is the opportunity cost of lost production that affects a project's viability. Analysis on the basis of increased operating cost (ignoring lost production) makes the impact of added treatment options appear to be relatively minor; however, examination of the decrease in rate of return through added treatment options reveals the actual impact on the project as a whole. The use of 100% recycling and flocculation have a real impact on placer mines, both in terms of increased direct costs and the opportunity cost of lost production, which can decrease both the project's rate of return and its ability to pay back the initial capital investment. Reclamation costs, while not examined in this study, are also a significant factor which must be considered.

Lode mine permitting is significantly more complex than that for placer mines, primarily because of the increased scale and impact of the project. Because no simplified permit process exists for lode mines, applicants must be aware of current requirements and be able to coordinate project work with permitting progress. Major lode mines generally have at least one full-time person dedicated to permitting during development. Coordination with responsible agencies is essential throughout the permitting process.

Costs for permitting lode mines are significantly higher than those for placer mines because of the differences in project scale, environmental baseline studies, and engineering required to mitigate impact. Estimates of the direct cost of permitting for lode mines average 4% of the total project cost. Compliance costs for lode mining take the form of mitigation and monitoring programs as required by terms of the permits. Indirect costs of compliance, such as increased road costs to bypass sensitive habitat, are generally not available from mine operators, but estimates of this indirect cost average roughly twice that of direct permitting costs.

ADDENDUM

A number of regulatory changes have been implemented or proposed since the research for this report was originally completed. These regulations will impact mining operations in Alaska. Items that the reader should be aware of are listed below:

1) 6i legislation requiring rents and royalties on State mining claims.

2) Reclamation requirements on all mining lands in Alaska (State of AK SB 544).

3) RCRA subtitle D proposed modifications requiring specific means of disposal for solid waste from mining (Strawman II process).

4) Stormwater discharge regulations that may require NPDES permits for storm runoff from all industries, including mining (previously limited to municipal systems).

5) No-net loss of wetlands Memorandum of Agreement between EPA and Corps of Engineers.

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APPENDIX A. - GRADE VERSUS RATE OF RETURN FOR VARIOUS EFFLUENT TREATMENT OPTIONS

TABLE A-1. - Grade versus rate of return, 1,500 yd^3/d placer model, $400/tr oz gold

Grade	Baseline	Recycling	Flocculation
0.010	-8.47	-17.64	-19.96
.011	-6.21	-14.41	-18.02
.012	-3.39	-10.87	-15.89
.013	-0.22	-7.24	-13.6
.014	3.32	-3.59	-11.16
.015	7.17	0.05	-8.62
.016	11.10	3.71	-5.89
.017	15.00	7.37	-3.13
.018	18.88	10.98	-0.40
.019	22.90	14.55	2.29
.020	26.90	18.12	4.99

TABLE A-2. - Grade versus rate of return, 1,000 yd^3/d placer model, $400/tr oz gold

Grade	Baseline	Recycling	Flocculation
0.0125	-7.08	-15.40	-20.79
.0135	-4.16	-12.46	-18.80
.0145	-0.92	-9.33	-16.63
.0155	2.72	-5.86	-14.30
.0165	6.67	-2.33	-11.85
.0175	10.63	1.25	-9.30
.0185	14.58	4.93	-6.51
.0195	18.50	8.56	-3.75
.0205	22.55	12.09	-1.04
.0215	26.68	15.62	1.63
.0225	30.82	19.13	4.27

TABLE A-3. - Grade versus rate of return, 500 yd^3/d placer model, \$400/tr oz gold

Grade	Baseline	Recycling	Flocculation
0.015	-7.59	-15.91	-19.64
.016	-4.85	-13.21	-18.12
.017	-1.92	-10.26	-16.48
.018	1.20	-7.28	-14.74
.019	4.64	-4.28	-12.89
.020	8.07	-1.27	-10.97
.021	11.50	1.75	-8.93
.022	14.92	4.82	-6.73
.023	18.33	7.89	-4.54
.024	21.80	10.90	-2.37
.025	25.34	13.90	-0.22

TABLE A-4. - Grade versus rate of return, 1,500 yd^3/d placer model, \$450/tr oz gold

Grade	Baseline	Recycling	Flocculation
0.010	-5.54	-13.55	-17.51
.011	-2.25	-9.51	-15.05
.012	1.49	-5.42	-12.39
.013	5.71	-1.32	-9.58
.014	10.12	2.79	-6.59
.015	14.51	6.91	-3.47
.016	18.88	10.98	-0.04
.017	23.41	14.99	2.63
.018	27.89	19.01	5.66
.019	32.25	23.04	8.56
.020	36.67	27.14	11.39

TABLE A-5. - Grade versus rate of return, 1,000 yd^3/d placer model, $450/tr oz gold

Grade	Baseline	Recycling	Flocculation
0.0125	-2.38	-10.72	-17.60
.0135	1.51	-6.95	-15.04
.0145	5.93	-3.00	-12.31
.0155	10.39	1.02	-9.46
.0165	14.82	5.16	-6.33
.0175	19.25	9.23	-3.24
.0185	23.83	13.20	-0.20
.0195	28.49	17.15	2.79
.0205	33.1	21.11	5.74
.0215	37.73	25.14	8.64
.0225	42.44	29.26	11.44

TABLE A-6. - Grade versus rate of return, 500 yd^3/d placer model, $450/tr oz gold

Grade	Baseline	Recycling	Flocculation
0.015	-2.30	-10.63	-16.69
.016	1.20	-7.28	-14.74
.017	5.07	-3.91	-12.66
.018	8.93	-0.52	-10.47
.019	12.79	2.89	-8.10
.020	16.63	6.37	-5.63
.021	20.48	9.77	-3.18
.022	24.45	13.15	-0.75
.023	28.49	16.52	1.65
.024	32.54	19.90	4.03
.025	36.59	23.31	6.39