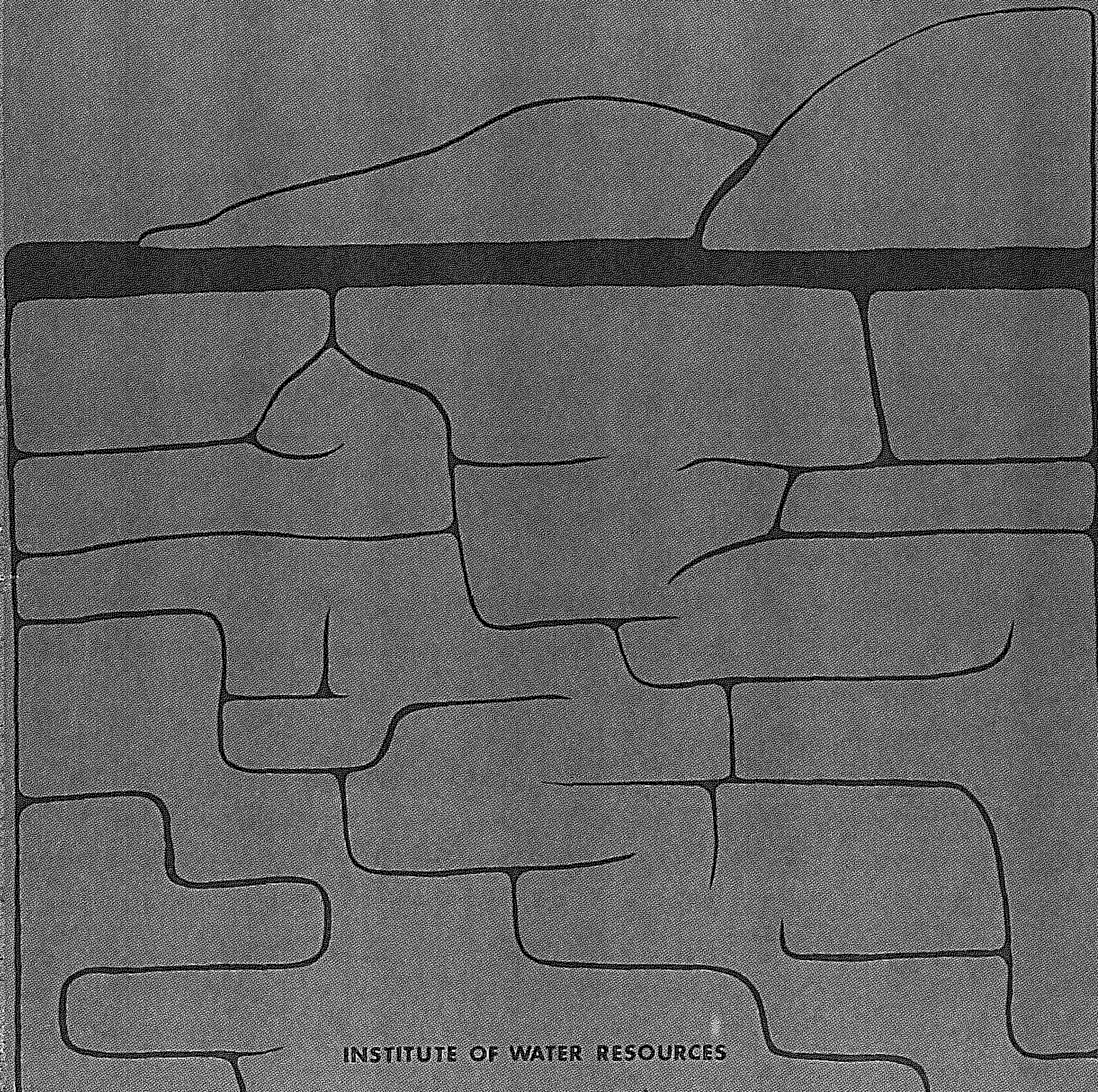
ALASKA MINING AND WATER QUALITY



INSTITUTE OF WATER RESOURCES

University of Alaska

Fairbanks, Alaska 99701

ALASKA MINING AND WATER QUALITY

Proceedings of the Symposium
University of Alaska
Fairbanks, Alaska
April 9, 1976

Alaska mining and water quality: Proceedings of the Symposium
Institute of Water Resources

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University of Alaska
Fairbanks, Alaska 99701

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Report IWR 93 April, 1979

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ABSTRACT

Very little information on Alaska mining activities and resulting environmental changes has been available. The objectives of this research were to: 1) review the literature pertinent to water quality deterioration resulting from mining activities, and 2) conduct a symposium, "Alaska Mining and Water Quality," in Fairbanks, Alaska. Alaska Mining and Water Quality (IWR Report 74) was published in June 1976. The report covers effluent limitations and water quality standards, physical parameters, chemical/biological parameters, and effects of Alaska mining on water quality. Over 300 references are cited, and a description of settling pond theory is appended. The literature review focused primarily on mining activities in Canada and the contiguous portion of the United States. The main emphasis of the literature review was directed at gold mining and coal mining operations; however, other mining activities relevant to Alaska were examined. The April 9, 1976, symposium was meant to achieve: 1) information dissemination, 2) increased and more effective communication, 3) environmental awareness, and 4) identification of environmental problems and potential solutions associated with mining activities in Alaska. Although there was good attendance and an exchange of information, the other objectives of the symposium were not attained. With few exceptions, both speakers and participants were aligned in extreme positions, and they presented little actual data to support their conclusions. The purpose of this publication is to present differing viewpoints on important and controversial issues in Alaskan water resources with the hope that effective solutions can be achieved through consideration of all facets of the problems.

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INTRODUCTION

The objectives were to: 1) review the literature pertinent to water quality deterioration resulting from mining activities, and 2) conduct a symposium, "Alaska Mining and Water Quality," in Fairbanks, Alaska.

Since very little information on Alaska mining activities and resulting environmental changes is available, the literature review focused primarily on mining activities in Canada and the contiguous portion of the United States. The main emphasis of the literature review was directed at gold mining and coal mining operations; however, other mining activities relevant to Alaska were examined.

Principal investigators Gil Zemansky and Timothy Tilsworth, Institute of Water Resources, and Donald J. Cook, Mineral Industry Research Laboratory, completed the report Alaska Mining and Water Quality, (IWR Report 74), in June 1976. The report covers effluent limitations and water quality standards, physical parameters, chemical/biological parameters, and effects of Alaska mining on water quality. Over 300 references are cited, and a description of settling pond theory is appended.

The symposium was meant to achieve: 1) information dissemination, 2) increased and more effective communication, 3) environmental awareness, and 4) identification of environmental problems and potential solutions associated with mining activities in Alaska. The symposium was held on April 9, 1976.

The symposium was expected to bring together miners, environmentalists, and regulators in a cooperative effort to identify problems and seek solutions. Although there was good attendance and an exchange of information, the other objectives of the symposium were not attained. With few exceptions, both speakers and participants were aligned in extreme positions, and they presented little actual data to support their conclusions.

The contributed papers have been edited for consistency in format. The purpose of this publication is to present differing viewpoints on important and controversial issues in Alaskan water resources with the hope that effective solutions can be achieved through consideration of all facets of the problems.

SOME WATER QUALITY PROBLEMS AND SOLUTIONS IN GOLD PLACER MINING

Jeff Mach

Water pollution has always been an integral part of placer mining in the past, with little or no regard for pollution prevention. The main planning element has been economic mineral recovery. Often the cheapest means of recovery resulted in the largest pollution problems. Recently though, pollution statutes have introduced the expense of water pollution control into the economics of mining.

Placer mining disturbs the natural surface systems of the earth. The resulting physical and chemical changes often contribute to pollution of the receiving water. Physical pollution stemming from mining activity includes, but is not limited to, increased erosion, increased landslide potential, and increased sediment loads. The sediment load in the water causes problems because it smothers aquatic insects, fish and insect eggs, and other associated benthic life. The water thus becomes aesthetically unpleasing. Chemical pollution results from the exposure of some minerals to oxidation and leaching. High concentrations of dissolved minerals and low dissolved oxygen levels are the primary problems with this type of pollution. Dissolved minerals may reach toxic concentrations for wildlife and man, while low dissolved oxygen levels will cause the death of aquatic animals.

In order to combat pollution problems, the active miner can take many steps to minimize pollution both during and after mining. Effective planning and site evaluation can minimize the amount of time and work that goes into pollution control.

Depending on the type of silt being discharged, settling ponds downstream of the mineral recovery area can effectively reduce sediment loads that enter the receiving water. Settling occurs because of a decrease in water velocity, which lowers the water's capacity to transport suspended material.

Proper design of the ponds is essential. The pond must be sufficiently large to accommodate the amount of anticipated flow and to retain that volume long enough for adequate settling. The "residence time" is controlled by the amount of flow into the pond and the capacity of the impoundment. The walls of the pond need to be constructed out of moderately sized tailing material in order to assure retention, but also allow some seepage through the tailings as a filter. Also the pond discharge structure is important. Design should employ effluent discharge weirs to control excessive discharge velocities. High effluent velocities will scour out settled solids. The diversion dam should be designed to allow only a constant flow of water into the ponds, especially at high river stage. This can be accomplished with a properly designed constant-flow float valve.

The placement of the ponds is quite important and can make the difference between very effective settling ponds and ponds that are almost useless. Figure 1 shows a settling pond configuration that is commonly seen. This design works well only if the stream is small and the flow is low, or if virtually all the water in the stream is used in sluicing. This configuration often causes problems because the additional volume of water added by the stream results in insufficient retention time in the ponds. In addition, periods of high water may destroy the ponds, releasing the trapped sediments into the watercourse. In larger streams this also represents a barrier to fish movement. The plan shown in Figure 1 does seem to work adequately in a very small stream and is especially effective where a recirculating water system is used.

Figure 2 represents no more than an attempt at a settling pond since the pond is not effectively isolated from the stream and much mixing occurs before the pond is reached. Dirty, untreated water is lost downstream, since water velocities remain high in the pond and the retention time is much too short.

Figure 3 represents a mining site where the sediment-laden water is effectively diverted and isolated from the receiving water until it passes through the settling basins. Unused and unwanted water bypasses the site completely. In this situation, no effort is expended and no space is wasted in treating water that remains clean. This type of arrangement can be accomplished by moving the mineral recovery area and the settling ponds off the stream, or by diverting the stream around the mining site.

Settling basins alone may not provide adequate treatment in all cases. Shown in Figure 4 is a settling pond where a flocculation system has been added. As the effluent leaves the sluicing area, a polymer "floc" is added at the weir, where flow can be measured, and the floc is mixed in through a series of baffles. The floc coagulates with the sediments and both settle out in the ponds.

Maintenance of settling ponds is minimal. They do have to be cleaned of sediments when they fill up or they will become ineffective. With isolated ponds, the water can be turned off and a dragline or a "cat" can be used to reexcavate the ponds. In the case of most placer mines these ponds are abandoned as the operation moves, before they become ineffective.

Diversion ditches may be utilized to control run-off around the mining site. If less water is required to pick up and transport sediments or dissolved minerals, then less water will need to be treated. Ditches or flumes may be used to divert run-off above the mining area, around the site, so that the run-off does not contribute to erosion or sediment problems. Diverting as much unwanted water as possible around the mining site will give the settling ponds their greatest operating efficiency. Rip-rapping may also be used in conjunction with diversionary channels to help decrease water velocities. Any diversion channels should be designed to accommodate the volumes and velocities of water expected.

The ground that is left behind (the tailings) is another environmental consideration. Mine drainage can be an almost indefinitely continuing source of pollution through leaching of dissolved minerals and erosion, unless control measures are taken. Regrading mined areas helps reduce erosion and landslide potential, decrease sediment-laden run-off, and eliminate such hazards as cliffs and deep pits. Regrading also provides a more suitable base for revegetation, encourages natural drainage, and helps present an aesthetic improvement to the area.

The miner can place his tailings so that much of the regrading is simplified. Necessary steps can be planned for and the work done while the site is active and the necessary equipment is on hand. The goal is to minimize erosion and leaching into the receiving water and achieve soil stabilization and revegetation as quickly as possible.

In this presentation, I have not attempted to look at all the pollution problems that come from mining, but only some of the more prevalent ones that I have seen. Nor have I looked at all the possible solutions for the problems that I have discussed. There still exists much room for experimentation in controlling water pollution and each operator must depend on trial and error to solve his unique problems. I hope that this symposium will encourage operators to evaluate and upgrade their own systems, so that water pollution from mining will be held to a minimum.

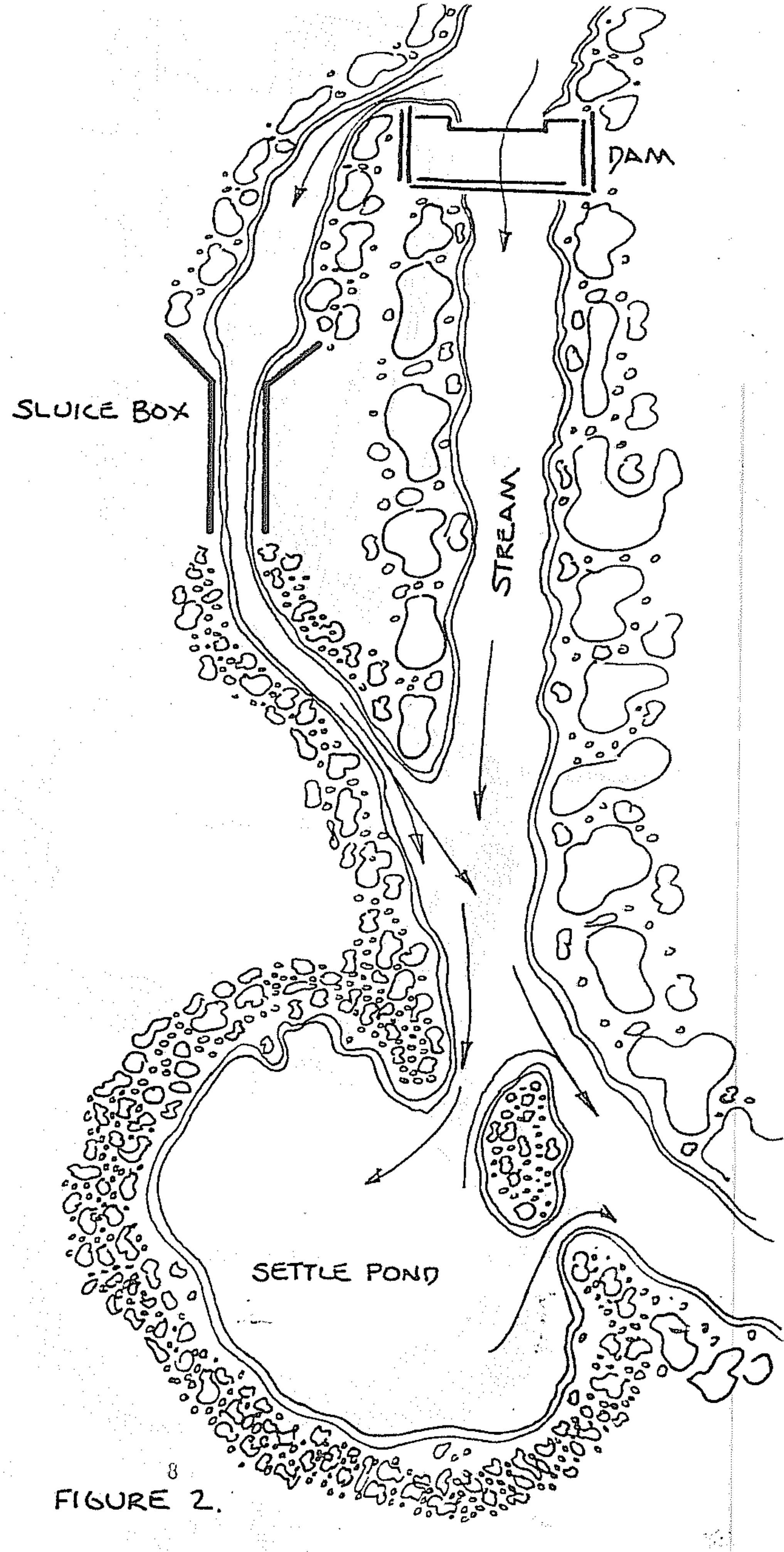

FIGURE 2.

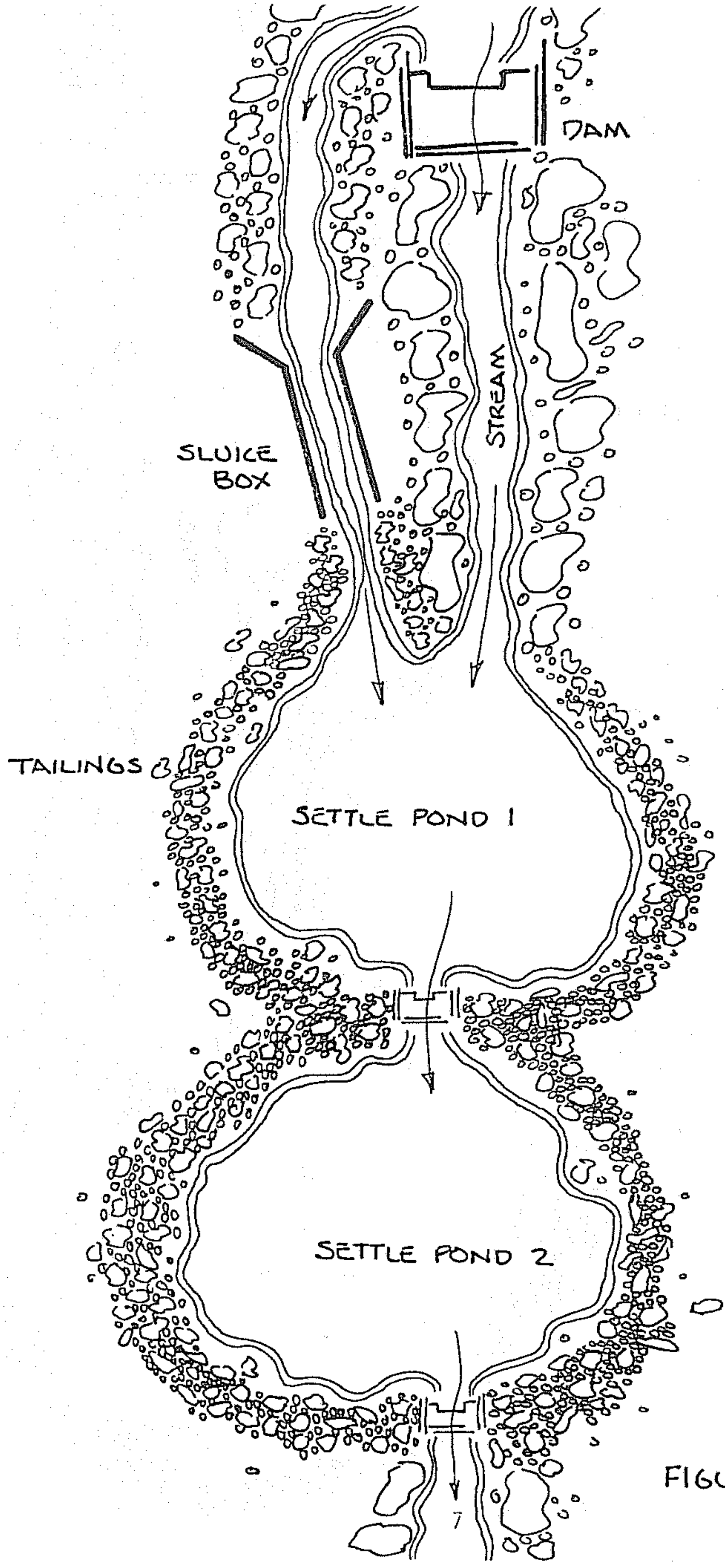

FIGURE 1

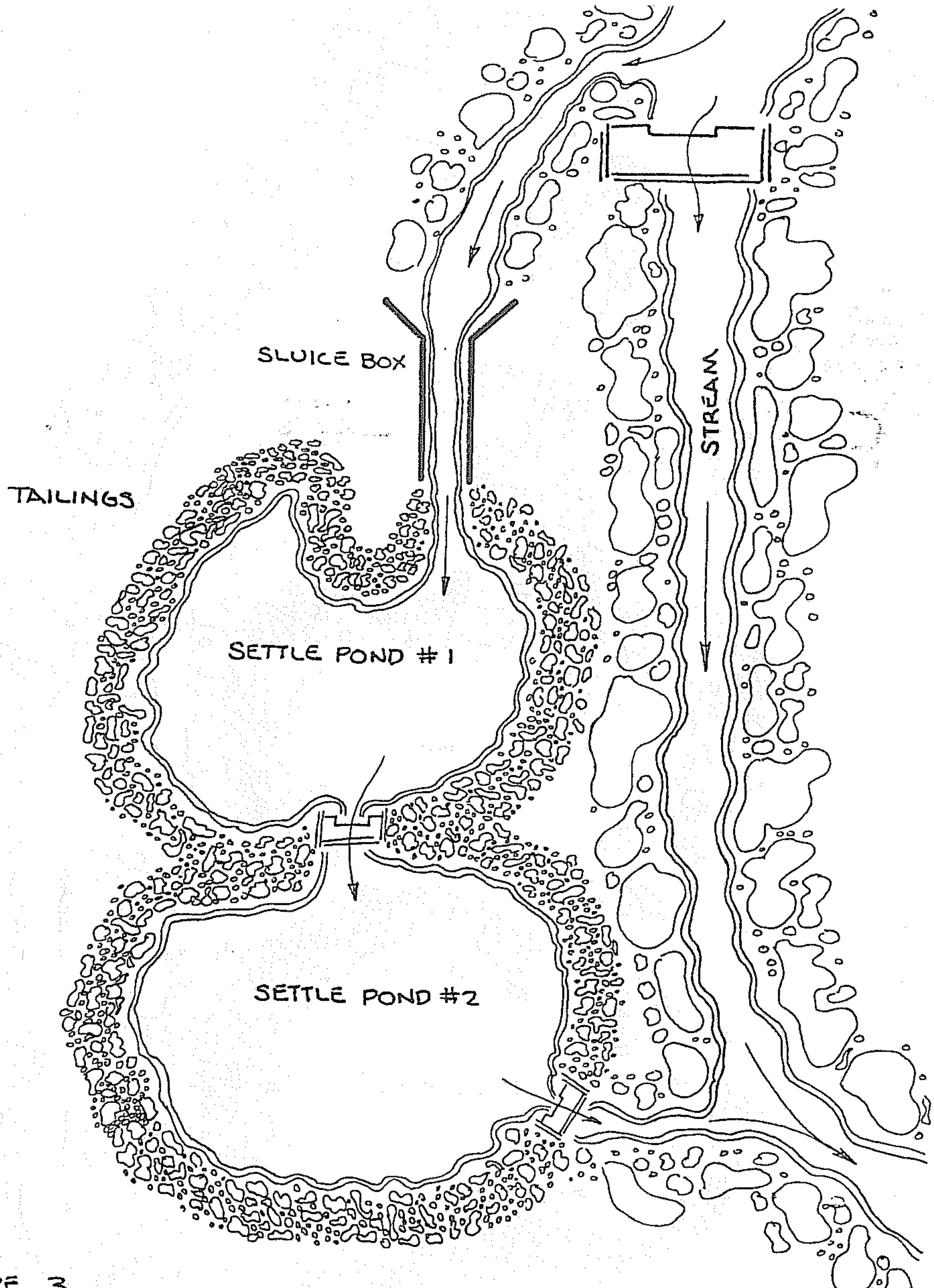

FIGURE 3

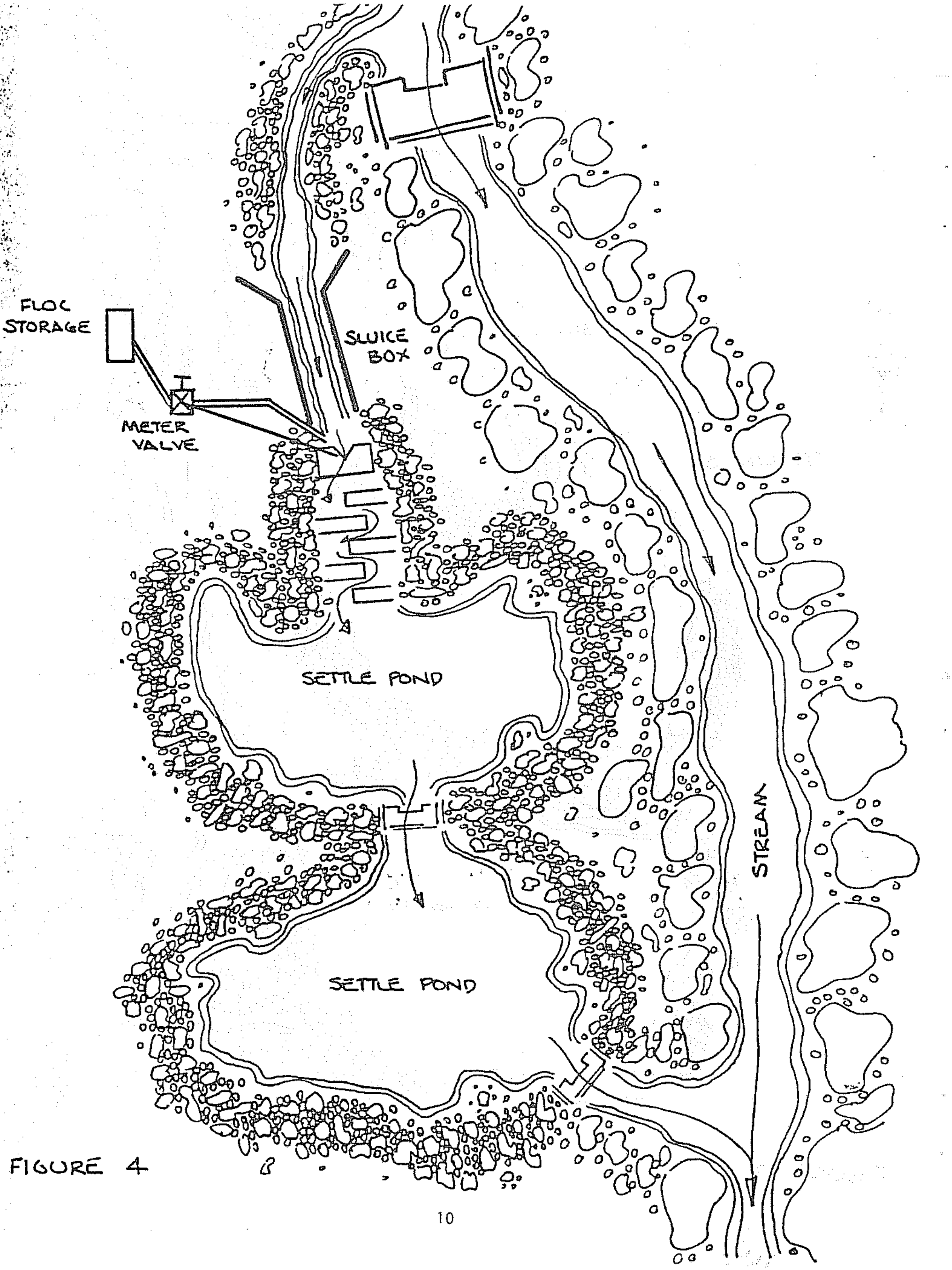
FLOC
STORAGE
SLUICE
BOX
METER
VALVE
SETTLE POND
SETTLE POND
STREAM

FIGURE 4

THE IMPACT OF THE NORTHERN INLAND WATERS ACT ON PLACER MINING IN THE YUKON TERRITORY

C. N. Williams

The Northern Inland Waters Act came into force in September 1972. Through it, all non-domestic users of water are required to apply for a water use license.

The Act specifically nullified the sections in the Yukon Placer Mining Act which dealt with the issuing of water grants. Basically, the Placer Act gave the miner the right to use all waters passing through his property. However, he had to apply for a water grant if he was diverting water out of its normal course. Now, under the Northern Inland Waters Act, the placer miner must receive authorization to use <u>any</u> waters.

It is important to understand the way the Act is administered, in order to appreciate the policy relating to the placer mining industry. The Yukon Territory Water Board was established to administer the Act. It has nine members, six representing various governmental departments and three private citizens. The objectives of the Board are: "to provide for the conservation, development and utilization of the Water Resources of the Yukon Territory . . . in a manner that will provide the optimum benefit . . . for all Canadians and (in particular) for residents of the Yukon."

This is important, for it identifies the Northern Inland Waters Act not specifically as an environmental control, but rather as a resource management tool. Therefore, the benefits of water use must be considered along with any environmental impact.

The Board has the power to accept or reject construction plans and specifications. It may also require an applicant to provide any information and studies concerning use of the waters (refer to Appendix "A" for requirements for an environmental impact study), provide proof of financial responsibility, and furnish a security deposit. It may hold public hearings and has all the powers of a Commissioner appointed under the Inquiries Act. It may attach to a water license any conditions it considers appropriate and recommend to the Minister approval, renewal, or cancellation of any license. Board decisions are by majority vote and are considered final. Appeals of these decisions must be taken to the Supreme Court of Canada, and are limited to questions of law or to decisions where the Board had no jurisdiction.

When the Act came into force in September 1972, there were 1,157 placer claims, 61 placer exploration leases and approximately 25 operating mines. The marginal industry was receiving subsidies under the Emergency Gold Miners Assistance Act.

With the removal of the pegged gold price, new interest immediately sparked within the industry. Today there are 2,461 claims, 401 exploration leases, 18 dredging leases, and in excess of 150 operations. In other words, what was thought to be a dying industry when the Act came into force has been given a new lease on life.

In 1973, the first steps undertaken by the Board were to study water use techniques in placer mining, and establish rapport with the miners. It soon became apparent that the flexibilities required in the industry were not too well suited to the formalities of water licensing. These formalities include advertising, holding a public hearing on each application, and issuing a license signed by the Minister. This all requires a minimum time period of six months. Any administering to the industry must react quickly to changing demands. If a miner runs into problems during the short operating season (3 to 4 months), he may want to move to another site quickly, increase his water demand, or work on several sites during the season.

A general public hearing on water use in placer mining was held in November 1973. The purpose of the hearing was to give the industry, environmental societies, and members of the general public the opportunity to participate in the policies of the Board. The scheduled hearing was given wide publicity in an attempt to contact all concerned individuals. Most briefs submitted to the Board were from members of the industry and virtually no input came from environmental societies.

Following the public hearing, the Board decided to administer placer mining as an "authorization to use water without a license," as permitted under the Northern Inland Waters Regulations. Interim guidelines were issued, based upon the information submitted to the Board.

In June 1974, authoriziations were issued to all applicants. The conditions to these authorizations, besides adhering to the guidelines, detailed the method in which the industry would be administered under the Northern Inland Waters Act. This represented an adoption of the applicable sections of the Placer Mining Act. The authorizations outlined the handling of disputes between miners. The operators were required to sign the authorizations to insure they understood and complied with the new procedures.

Three studies were undertaken during the 1974 season. The first was a Fisheries Service collection of data on aquatic life in the placer creeks. The second was a study sponsored by the Boreal Institute of North America to assess the impact of placer mining on the hydrology of the streams. Studies of this nature require several years of data for a complete assessment. The third study examined the effectiveness of various settling facilities. The use of dredge tailings provided between a 95 and 100 percent reduction of suspended sediment. Constructed dams reduced the suspended sediment by approximately 80 percent, and three-foot weirs installed in the drain reduced it by 65 percent. It also became very evident that maintenance of any settling facility is important to retain its effectiveness.

In late September of 1974, the Board held a second general public hearing on placer mining, to evaluate the 1974 operating season. The mining industry stated that it was satisfied with the Board's handling of the situation.

During 1975, the Fisheries Service concentrated on two major streams, to identify total fish populations, fish food, and migration patterns. Bonanza Creek had no sediment control and Sulfur Creek had extensive settlement in dredge tailings. The hydrology study was also continued to include snow survey data. The interim guidelines were retained and a third public hearing was held in Dawson City, to critically review the Placer Mining - Water Board interaction that had taken place over the previous three seasons.

The Fisheries Service studies (the report is in draft form) suggest that fish and fish food organisms can exist within actively mined placer creeks. However, where tailings water is discharged directly into the stream, there is a complete absence of life. Further downstream, because of natural settling, the abundance of life does increase to some extent. Previously mined creeks were shown to reestablish their fish population over a period of time. Streams that have clear tributaries appear to support those fish populations moving out of turbid waters during the summer. The degradation of stream quality apparently alters the major fish species from grayling to longnose suckers. In summary, uncontrolled placer mining reduces the fish production of a stream.

The hydrologic study (the data is still being analyzed) appears to confirm the need for water conservation. Water shortage is forcing many operations into recirculation schemes to enable continued operation during dry periods. In addition, emergency spillways are essential to protect downstream users, especially on heavily populated creeks. The continued operation under the interim guidelines provided invaluable experience for the placer miners and the Board with respect to settling facilities. The inability to provide any settling facilities for some operations was noted. In addition, the economic importance of using water to thaw and strip the overburden was recognized.

The season was closed with the third public hearing, which yielded detailed assessment of the interim guidelines for the 1974-75 season. It was a dialogue between the Board, the inspectors, and the placer miners. At that hearing, the Board committed itself to produce permanent operating guidelines based upon what had been learned over the past three years. In developing permanent guidelines, the Board had to adhere to its objectives under the Act, to satisfy the fisheries concerns, and to satisfy the placer mining industry.

The permanent guidelines (see Appendix "B") recognize that placer mining should be permitted unrestrained on some streams, except for the provision of settling facilities where practicable. In other streams, fisheries are the most important resource, so control measures should be instituted. All parties involved agreed to this approach, so creeks not considered critical for sustaining fish stocks were identified (refer to Appendix "B").

The placer mining industry in the Yukon has been brought into the seventies with a realistic environmental control approach. It is recognized that fishes do exist in conjunction with placer operations, fishes reestablish their population in mined out streams, the pure economics of operating in a permafrost region dictates that water use must be unrestricted for successful placer mining, and that unsophisticated settling facilities can be provided. Therefore, a temporary reduction in the population of fishes within a stream is acceptable to permit the harvesting of gold, which is in demand throughout the world today.

APPENDIX "A"

GUIDELINES FOR THE ENVIRONMENTAL IMPACT STATEMENT FOR PLACER MINING

Primary Goals of Control Measures

a) Water Use:

(i) Control of the quantity of water used for placer mining.

(ii) Control of the quality of water discharged from the operation.

b) Land Use:

(i) Control of placer operations to minimize changes of hydrodynamics of the river and the degradation and/or destruction of the aquatic and terrestrial environments.

(ii) Establishment of requirements for any restoration procedures to be employed to assist in the recovery of both aquatic and terrestrial habitats in the area of operations and to restore stability to the physical environment.

c) Camp Operations:

(i) Control of camp and machine operations to prevent or minimize pollution factors.

(ii) Control of personnel to protect local wildlife and fisheries resources.

Study Objectives

a) Mining Procedures:

The description of the Mining operation should remain general in nature. The Operator should indicate the number of vehicles, equipment, men and camps proposed for operation(s) in the claim areas and the timing proposed for the general phases of the operations. The operator should also indicate the methods he intends to use to operate within general regions of the claim areas, especially those regions adjacent to creek systems.

The operator should also include an evaluation of alternative methods of water use and waste disposal in the mining operation.

The operator should indicate what action is planned to restore mined areas and to facilitate regeneration of river bottom and river bank vegetation. A list of controls for camp operations and human activities should be provided in the environmental statements.

b) Physical Environmental Studies:

The environmental studies should stress the collection of data on the hydrology of the entire river system and the physical characteristics of the surficial materials throughout the claim area. The hydrology of the river should be studied over one full year. Special attention should be given to characteristics of the river system in areas where channel manipulations have occurred or are proposed. The impacts to the system at these sites and downstream should be evaluated in relation to the characteristics of the aquatic environment. Data on water quality and seasonal flows should also be considered in relation to proposed channel manipulations to assist in the development of methods that may be used to undertake such changes with minimal affects to the environments.

c) Biological Studies:

The biological studies should stress investigations of the aquatic characteristics of the entire river system and should evaluate both the fish species present and the benthic fauna they utilize for food. Studies of the habitats of aquatic organisms and the locations and periodicity of their life cycle activities should be collated so that it may be readily correlated with information on the physical characteristics of the environment and the proposed mining operations.

Studies of the wildlife and botanical resources of the river basin should be general in nature. However, it should include an evaluation of alternative methods to facilitate revegetation and the restoration of natural drainage in the area.

Study Perspective

a) Mining Operations:

(i) Identify areas of interest.

(ii) Land clearing requirements, techniques and disposal methods.

(iii) General work layout and development procedures.

(iv) Equipment to be used.

(v) Fish control structures (screen, etc.).

(vi) Operation of settling pond and estimated discharge quality.

b) Stabilization Procedures:

(i) Erosion control of stripped material and areas.

(ii) Local tributaries.

(iii) River bank and streambed.

(iv) Settling ponds.

c) Fish Habitat and Composition:

(i) Cross-sectional dimension of stream.

(ii) Representative stream discharges.

(iii) Material composition of stream bed and banks.

(iv) Relative abundance.

(v) Which life history stages utilize the stream and where:

(a) distribution
(b) spawning
(c) rearing areas

(vi) Migration timing.

APPENDIX "B"

PLACER MINING OPERATING GUIDELINES IN REGARD TO WATER USE AUTHORIZATIONS

The Yukon Territory Water Board has directed that the Controller of Water Rights may issue Authorizations to Use Water Without a License for placer mining operations under Section 11(b) of the Northern Inland Waters Regulations (the proposed use will continue for a period of less than 270 days). The Board adopts the following criteria as guidelines for the issuing of authorizations:

1. All operations are to provide, where practicable, effective settling facilities to the satisfaction of the Controller.

2. In streams or parts thereof which are determined to be critical for sustaining fish stocks or for the protection of other water users, it may be mandatory to provide the following:

   a) fish passage facilities.
   b) uninterrupted minimum discharges.
   c) effective settling facilities.
   d) screens on water intakes to prevent the passage of fish.
   e) controls on the areas in which the stripping methods of ground sluicing, monitoring, and the use of automatic gates is practiced.

   The Controller will maintain a list of creeks that are not considered critical for sustaining fish stocks or critical for the protection of other water users. This list will be subject to review from time to time in consultation with the Fisheries Service.

3. Stabilization of the tailings and stripped areas to prevent a detrimental impact on the stream may be required.

4. Where the Water Board deems it necessary, an applicant will be required to provide an environmental impact statement or any other relevant information.

5. A Water Use License, rather than an authorization, will be required by a placer mining operation where the Board is satisfied that it will be in the public interest.

An appeal may be filed with the Board within ten days from any written notice, direction or order given by the Controller in applying these guidelines.

The Controller of Water Rights considers the following creeks or parts thereof are not critical for sustaining fish stock or critical for the protection of other water users (March 23, 1976):

Name of Creek	Description	Approx. Location Lat - Long
Allgold	entire length	63 57 138 37
Arch	entire length	61 30 139 43
Bear	entire length	64 02 139 45
Bedrock	entire length	63 58 140 51
Black Hills	above Minto Creek	63 25 138 50
Bonanza	entire length	64 03 139 25
Burwash	entire length	61 30 139 17
Clear	left fork	63 45 137 15
Dominion	excluding tributaries of Jensen, Rob Roy and Burnham	63 50 138 40
Dublin Gulch	entire length	64 03 135 48
Eureka	entire length	63 36 138 49
Glacier	entire length	64 01 140 43
Henderson	above North Henderson	63 21 139 28
Highet	above 2500 feet	63 43 136 22
Hunker	entire length	64 06 139 14
Livingstone	above 3000 feet	61 20 134 20
Miller	entire length	65 59 140 48
Nansen	left fork	62 00 137 17
Quartz	entire length	64 45 139 06
Revenue	entire length	62 18 137 10
Sulphur	above Beaver dam approximately one mile below Brimstone Gulch	63 38 138 40

Summit	entire length	62 06	137 13
Ten Mile	entire length	63 33	139 55
Thunder Gulch	entire length	63 55	135 15

MINING & WATER QUALITY - FEDERAL PERSPECTIVE

Bill H. Lamoreaux

I shall summarize activities of the U.S. Environmental Protection Agency (EPA) relating to mining in Alaska, touching upon existing laws and regulations, the implementation of these laws, and their possible impact on the environment and the mining industry. Some miners believe that the recent environmental laws were designed to shut down mining. At the other extreme, there are some "environmentalists" that see these regulations as a way to do just that. Miners view mining as not only critical to their own economic independence, but also as essential for a healthy economy. Others view it as a nonessential, destructive, and environmentally degrading activity.

To understand EPA's role in environmental controls affecting mining, you must realize that our primary objective is to implement the environmental laws enacted by Congress. This is where we get involved with the issues being discussed today.

Federal Water Pollution Control Act Amendments

The most important piece of federal environmental legislation that affects mining in Alaska today is P.L. 92-500, the Federal Water Pollution Control Act Amendments of 1972. This act created several new programs that are geared toward cleaning up the nation's waters. Highlights of the more important sections of this act follow.

Section 101 states that "the objective of this act is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." To accomplish this, "it is the national goal that the discharge of pollutants into navigable waters be eliminated by 1985." Also "it is the national goal that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the waters be achieved by July 1, 1983."

To carry out the objectives of the act, Section 301(1) requires that "not later than July 1, 1977, effluent limitations for point sources . . . shall require the application of the best practicable control technology currently available." In addition, "any more stringent limitations, including those necessary to meet water quality standards, treatment standards, or schedules of compliance, established pursuant to any state law or regulations or any other federal law or regulation, are required to implement any applicable water quality standard established pursuant to this act."

The act further states that "not later than July 1, 1983, effluent limitations 'for industries' shall require application of the best available technology economically achievable . . . which will result in reasonable further progress toward the national goal of eliminating the dishcarge of all pollutants." New sources, which are defined as those activities whose construction commenced after the publication of proposed regulations prescribing such standards of performance, are required to meet the new source performance standards for that industrial activity.

Section 304 provides for regulations that establish guidelines for effluent limitations for various industrial activities. The act requires that these regulations identify the degree of effluent reduction attainable, through the application of the best practical control technology currently available for the various classes and categories of point sources. It further states that factors relating to the assessment of this technology include consideration of the total cost of this technology in relation to benefits achieved. Other factors include the age of equipment and facilities involved, the process employed, the engineering aspects of the techniques, process changes, environmental impact (including energy requirements), and such other factors as the administrator deems appropriate. Also, Section 304 requires that these regulations identify the degree of effluent reduction attainable including treatment techniques, operating methods, and other alternatives for different point sources.

Section 401 of the act establishes the certification process whereby the state must certify or waive certification of all federally issued industrial and municipal permits. The applicable provisions of

Sections 301, 302, 306, and 307 of the act must be met. This includes the federally approved Alaska Water Quality Standards.

Section 402 establishes the National Pollutant Discharge Elimination System (NPDES), which requires that all discharges of pollutants from point sources to navigable waters be covered by a discharge permit. It is this permit program that has received increasing attention from many placer miners recently. Because of its importance, I am going to highlight the more significant items of this section:

1. Permits handled by the U.S. Army Corps of Engineers (USACE), pursuant to Section 13 of the Rivers and Harbors Act of 1899, are deemed valid. No permits were issued in Alaska under this program prior to October 1972; however, many applications had been filed.
2. The state may, upon meeting specific requirements of the act, assume the NPDES permit program. This event has not occurred in Alaska, so the federal government continues to handle the program.
3. Permits may not exceed an effective period of five years.
4. The public must be provided with public notice of each application and proposed permit. Public hearings will be held when necessary.
5. Violations of the permit program will be abated with civil and criminal penalties or other means of enforcement. Penalties for civil and criminal violations are established in Section 309. Civil penalties may reach $10,000 per day for first offenses and $20,000 per day for second offenses. Criminal penalties have a maximum of $25,000 per day and one year imprisonment for first offenses and $50,000 per day and imprisonment for not more than two years for second offenses.
6. Compliance with a permit issued pursuant to this section shall be deemed compliance for purposes of Section 301, 302, 306, 307, and 403 except for standards imposed under Section 307 for toxic pollutants injurious to human health.
7. Any discharges occurring 180 days after enactment of the 1972 Amendments for which an NPDES permit has not been filed shall be illegal. After April 16, 1973, all persons causing a

discharge to navigable waters must have filed a discharge permit application.

Section 404 of the act expands USACE authority to require permits for the discharge of dredged or fill material into navigable waters. Although the point source discharges covered under Section 402 are not included as dredge and fill, there are activities associated with mining such as channeling or stream diversion, which may fall into this category. USACE regulations have been published and are available upon request.

Section 502 includes general definitions. A few of the more important passages should help to understand the meaning of the act.

"The term 'pollutant' means dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water.

"The term 'navigable waters' means the waters of the United States, including the territorial seas. From the congressional record, it is clear that the broadest possible interpretation was to be used in deciding navigability.

"The term 'discharge of a pollutant' and the term 'discharge of pollutants' each means (A) any addition of any pollutant to navigable waters from any point source, (B) any addition of any pollutant to the waters of the contiguous zone or the ocean from any point source other than a vessel or other floating craft.

"The term 'point source' means any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft from which pollutants are or may be discharged.

"The term 'pollution' means the manmade or man-induced alteration of the chemical, physical, biological, and radiological integrity of water."

To summarize, every mining activity (primarily placer mining in Alaska), must obtain a permit from the U.S. Environmental Protection Agency if a discharge to navigable waters occurs. As I indicated earlier, applications for all existing mining operations should have been filed by April 16, 1973. EPA does not intend to penalize anyone for filing late for one of our permits, particularly if the individual involved is making attempts to reduce the discharge of pollutants to the receiving waters. We will, however, seek legal action against anyone who knowingly fails to apply for a permit, or for any individual who causes severe water quality problems without attempting to provide adequate treatment.

Permit Process

Once an application is filed, the normal procedure is to review the application, gather any additional information needed to help prepare a draft permit, and finally prepare the draft NPDES permit for public notice.

Once a public announcement is prepared from the Seattle office, the permit is officially advertised for a 30-day period for the purpose of receiving public input. A public hearing can be scheduled but unless there appears to be significant interest in such a hearing, the public notice will be our mechanism for getting comments from all interested parties.

Once all comments are reviewed, the permits are prepared with whatever changes are necessary. They are then sent to the Alaska Department of Environmental Conservation for state certification. The state has essentially four options at this point:

1. Certify the permit as prepared.
2. Deny certification. This would mean that no permit could be issued and thus no discharges would be allowed.
3. Conditionally certify. This involves certifying the permit provided certain modifications are made.
4. Waive the right to certify.

Once certification is received, the permit is issued to the applicant and becomes effective 30 days later. Normally the permitting process requires four or more months of effort from the time the permit was first drafted. If an adjudicatory hearing is requested by the applicant or another interested party, more time is required. When this occurs, as has been the case for many of the oil company permits in Cook Inlet, there will be a hearing and reevaluation by the Regional Administrator of EPA. The details of how this process proceeds are given in the following Federal Register publications: "National Pollutant Discharge Elimination System" (May 22, 1973), and "NPDES--Miscellaneous Amendments" (July 24, 1974).

I have tried to outline 1972 Amendments and NPDES permit program. Now I would like to explain where we are with permits for placer miners. To begin with, placer mining was not given the highest priority for receiving permits after the Amendments passed in 1972. Other significant industries such as petroleum, pulp mills, and seafood processing were given immediate attention. These industries consumed much of our time for several years after 1972.

When we finally prepared 81 draft permits for public notice last May, it was still without the benefit of Effluent Guidelines, as mentioned earlier and prescribed under Section 304 of P.L. 92-500. In the absence of "Guidelines," Region X of EPA attempted to define "best practicable treatment" and prepared permits accordingly. The development of the conditions contained in these draft permits included input from various state and federal agencies as well as input from miners themselves. The more important requirements contained in these permits were:

1. The operator will take whatever reasonable steps appropriate to reduce the amount of organic and inorganic solids reaching navigable waters including controls to limit erosion.
2. Fish passage will be provided in streams that support or have supported an indigenous fish population.
3. By July 1, 1976, the operator will provide either
   (a) Settling pond(s) which are designed to contain the maximum volume of process water used during any one day's operation, or
   (b) Treatment that achieves a daily maximum discharge of settlable solids from the mining operation to 1 ml/l or less.
4. Once a year, the operator will submit an operating plan summarizing the coming year's activities.

During the public notice stage, only a handful of comments were received. They did contribute, however, to several minor changes in the initial draft before it was submitted to the state for certification. By late 1975, the state conditionally certified the permits and required that, to help meet existing State Water Quality Standards, a turbidity limit of 25 JTUs above background conditions be met in the receiving water at a point 500 feet downstream of the discharge.

EPA was preparing to issue these 81 permits early in November 1975, when on November 6 our Washington D.C. office published in the Federal Register interim final effluent guidelines for the "Ore Mining and Dressing Point Source Category." These guidelines were so different from our permits (for reasons I will discuss shortly) that all activities toward issuance of permits ceased until we could clarify our position. That is where we are today. In addition, from the time we initially prepared public notices in May 1975, the total number of applications for placer mining in Alaska nearly doubled, leaving approximately 70 applications without even a public notice yet prepared.

The "Ore Mining" guidelines, which we are supposed to use in preparing permits, recognized that "best practicable treatment" consists of the use of settling or tailings impoundments for settling suspended solids. An alternative technology is the pumping of waste water from dredging operations back to a tailings disposal area for filtration through sands and gravels. Some operations may require the addition of flocculating agents to enhance the settling of suspended solids.

What makes these guidelines different is the effluent limits specified for this type of treatment. They are 30 mg/l monthly average and 50 mg/l daily maximum for suspended solids and a pH range of from 6.0 to 9.0 in the discharged water. Our initial permits had a settleable solids limit in the discharge and a turbidity limit for receiving water which were more easily measured.

We have made inquiries to the highest levels of EPA concerning possible changes in the guidelines. Until a reply is received, we will probably remain in a holding pattern with all of the placer mining permits. We are expecting a decision shortly and hope that permits can be issued before this summer for those persons who have applied for a permit.

We are often criticized that our requirements are overly restrictive in some areas and that natural conditions are as bad as any miner could make them. Others suggest that we are not doing enough to restrict the environmental impact of mining operations. I would like to point out, as P.L. 92-500 does, that we are interested in the manmade impacts to the nation's waters. Furthermore, the act is geared toward the uniform application of treatment technology for all similar activities. Water quality limitations are imposed only when it is seen that the treatment technology recognized as "best practicable" or "best available" is not enough to guarantee that water quality conditions will be maintained. Thus we are requiring that some uniform level of treatment be provided regardless of local conditions and that the water quality be maintained within acceptable limits.

To those who feel we have been too lax, I must say that until we have enforceable permits issued, we are somewhat limited in what we can do. I must also say that the treatment we require must be reasonable for the industry as specified in Section 304 of the act. Consideration must be given to the cost of application, effluent reduction benefits to be achieved, processes employed, the engineering aspects of the application of control techniques, and other factors. We cannot use our permit program as an excuse to shut down all mining in Alaska. To do so would be, in my opinion, a violation of the intent of the act.

When it comes down to treatment systems, we recognize that some combination of settling ponds and filtering through tailings is needed. This, of course, must be coupled with good planning. For instance, it is self-defeating to allow the unused portion of the stream flow to pass through the mining area and especially through the settling ponds. Routing the creek around the settling pond is therefore an important step in controlling discharges. Because settling ponds do fill in with time, mining in a manner that creates new settling areas is desirable. A series of ponds has some advantages since the pond nearest the sluice box will fill in more rapidly, but will help to extend the life of other basins. Planning by the miner is especially important in developing a treatment system that fits his particular operation.

Recycling offers a method of control, especially when turbidity of the effluent remains a problem even after settling. Flocculating agents can be used, although to date, they have not been used for treatment of mining waste in Alaska.

Generally speaking, the treatment system must be made a part of the mining operation and not just tacked on. It must receive the same kind of attention from the operator as the planning to open up new ground. By taking this approach, I think we can expect significant improvements from mining activities in regard to water quality.

MINING AND WATER QUALITY
ALASKA DEPARTMENT OF
ENVIRONMENTAL CONSERVATION PERSPECTIVE

Jonathan W. Scribner

I plan to discuss some of the policies of the Alaska Department of Environmental Conservation (DEC) related to placer mining including applicable water quality standards, status of the state permit program, and enforcement strategy. During the 1960s and early 70s there was a general decline in the activity of placer mining in Alaska. Alaska's environmental laws specifically exempted placer mining activities from the definition of pollution. The Alaska Department of Health and Welfare (which was responsible for enforcement of water pollution laws at that time) had little involvement in pollution caused by mining. However, there were occasional meetings with the miners to discuss pollution laws and ways to minimize mining impact on water quality. Also the U.S. Environmental Protection Agency's (EPA) predecessor, the Federal Water Pollution Control Administration, had produced a controversial report on the effects of placer mining on water quality. But the government generally left the dwindling mining operations alone.

In about 1970 the exemption for placer mines in state environmental laws was removed from the definition of pollution. Also, P.L. 92-500, the Federal Water Pollution Control Act Amendments of 1972, was passed. This legislation assured government involvement in placer mining operations. Controls on the value of gold were removed, resulting in greatly increased mining activity. Inevitably, this increased activity has lead to many conflicts between recreation, public water supply, and fish and wildlife protection.

Presently there are two types of standards relating to placer mining operations. EPA limits the amount of waste discharged without regard for receiving water quality. These limits are referred to as effluent limitations and supposedly are based upon the best technology currently available. EPA may require more stringent standards if the effluent limitations are inadequate to protect the receiving water quality. We have reviewed the Best Practicable Control Technology Standards and found them to be largely impractical when applied to Alaskan operations. They would cause the cessation of most placer mining in Alaska.

The State of Alaska Water Quality Standards provide more flexibility, since they consider existing water quality and quantity. But it is also true that this approach is more difficult to enforce. Generally, the State of Alaska has established a turbidity limit of 25 JTU above background, measured 500 feet downstream of mining operations.

Not only are there two types of standards but there are two permit systems. There is the NPDES permit issued by EPA after state certification. This has been discussed earlier by EPA. Then there is the State Waste Disposal Permit system administered by DEC. Unfortunately the state attorney general's office has determined that the state cannot accept the EPA permit in lieu of the state permit. Hence we often are required to issue duplicate permits. This system is inefficient and unfair to the permittee.

In an effort to rectify this conflict, the state administration has introduced legislation (SS for SB 267) which would allow the state discretion in accepting the federal NPDES permit. We are hopeful that this bill will receive passage this session, but is has moved slowly to date.

Until this conflict is resolved, the department will concentrate on issuing permits where the NPDES program does not apply, and where the state feels the NPDES permits do not adequately protect the receiving water. Further, our permitting efforts have been directed (in order of priority) to the petroleum industry, commercial operations, pulp mills, logging camps, seafood processors, and mining operations. Presently we are well along with permits for the petroleum industry and have only begun to consider permits for commercial operations such as trailer courts. Government involvement in mining operations will be proportional to the number of complaints and problems. It will reflect the degree of conflict that mining has with other public interests. For example, public water supplies, fish and wildlife protection, and recreation all are in potential conflict with placer mining. It would be to the advantage of the mining operators if they would begin to invest some time and money in self-control of water pollution so that these conflicts, and therefore government intervention, are minimized.

The State of Alaska recognizes many of the problems that strict compliance with the law would create. At this time, we are asking for steady improvement in the conduct of mining operations. We intend to continue to visit sites and learn about mining in Alaska. Gross violations of Water Quality Standards will be enforced, although an effort will be made to work with those making steady improvements.

Most operations should be able to comply fairly easily with the 25 JTU turbidity limitation. Some will be able to comply with some difficulty. Some, because of certain water quality, topographic, or soil constraints, will be unable to comply.

Summary

Increased activity in placer mining will increase water quality problems and conflicts with other legitimate uses of water. Increased problems will result in more government involvement. Motivation for the government will be a concern for fish and wildlife, and a desire to maintain high water quality in Alaska. A more significant motivating factor, however, will come from the other users of the water who have been affected adversely.

We would like to work with the miners to reduce adverse effects of mining on water quality. We will be happy if there are steady and positive efforts to improve. When conscientious efforts to improve water quality problems are not taken, the state will be obliged to pursue enforcement.

We will be making a concerted effort to understand the limitations of your operations and will assist you in achieving control of water pollution. In return we ask for your support and cooperation. Certainly, environmental constraints imposed during the next few years will result in significant changes in current operating practices, and will set the stage for deciding the economic viability of placer mining in Alaska.

MINING AND WATER QUALITY
ALASKA DEPARTMENT OF FISH AND GAME PERSPECTIVE

J. Scott Grundy

The Alaska Department of Fish and Game's statutory responsibility, as it pertains to this symposium, is to assure the perpetuation of the state's fish, game, and aquatic plant resources. Specifically, Alaska Statutes Title 16, Fish and Game, states that "if a person or governmental agency desires to construct a hydraulic project or use, divert, obstruct, pollute, or change the natural flow or bed of a specific river, lake, or stream, or to use wheeled, tracked, or excavating equipment or log-dragging equipment in the bed of a specified river, lake, or stream the person or governmental agency shall notify the commissioner of this intention before the beginning of construction or use" (AS 16.05.870(b)). The department has, in accordance with the Administrative Procedures Act (AS 44.62), identified waters that are important for the spawning or migration of anadromous fish.

Paragraph (C) of the above-mentioned section grants the commissioner or his representative the authority to request full plans and specifications of the proposed activity, to assure the proper protection of fish and game resources. Specifically, the miner should advise the Regional Habitat Protection Supervisor of his mining plans. We do not request these plans because we consider ourselves experts in mining, but because we have found it absolutely essential that we be totally aware of all proposed development. If there is a conflict with fish and game resources in the area, the time to rectify the situation is during the planning phase, not during the working season or after damage has occurred.

Once we have received the required information, we issue an authorization that is valid for the calendar year. Our authorization normally lists various stipulations or recommendations to reduce the impact on fish and game. It is important to recognize our response is tailored to fit the immediate mining situation. The restrictiveness of our authorization is directly proportional to the presence of fish and game in the area. In other words, mining in an area of high resource value is met with a more restrictive authorization than a mining operation creating little potential threat.

Concerns of the Alaska Department of Fish and Game include problems of fish passage, water quality, and hydrology:

1. Fish passage: If fish cannot bypass a mining operation, production of fish in the upstream segment of the tributary will suffer. We are also concerned with potential delay in the upstream migration of salmon to desired spawning locations.
2. Water quality:
   A. Spawning gravel: Clean gravel (containing little fine material) is essential to the reproductive success of fishes. When material from mining effluent settles in the stream bottom, the gravel interstices are filled. This smothers the fish eggs or alevins or ruins the area for future spawning. Generally, salmonid eggs will suffer a mortality of 85 percent when 15 to 20 percent of the spaces are filled with sediment.
   B. Benthos: Deposition of silt over the stream bottom also smothers or dislodges plants and invertebrates, which are extremely important for fish nourishment.
   C. Water column: It is obvious that turbidity affects the penetration of sunlight, greatly reducing the photosynthetic productivity of a tributary. Primary food production is reduced as the turbidity increases above 25 Jackson Turbidity Units (JTU).
   D. Fish: Siltation directly affects fish. Abrasive silt particles irritate gill surfaces and generate a thickening of the respitory epithelium, resulting in a condition known as "clubbed gills." Angling success is known to be reduced as the level of turbidity exceeds 30 JTU.
3. Hydrology: It is obvious that channelization, and dredge and fill actions greatly affect the hydrological "balance" of a watercourse. It is our objective to assure that the pool-riffle ratio of an important watercourse is not adversely

affected. Another hydrological concern is the actual dewatering of a tributary which would seriously impact aquatic resources.

Basic Techniques to Minimize Adverse Impact to Fish and Game

We usually recommend that large quantities of overburden be stripped by mechanical means, rather than by methods such as sluicing or stream diversion. We believe that unless the problems of siltation can be easily rectified, mechanical stripping will likely provide a savings in time, money, and environmental degradation.

We encourage the location of settling basins as far from a watercourse as possible. They should be sufficiently large to retain the entire discharge from the daily operation. Some colloidal material cannot be conveniently removed with settling basins. Other means such as chemical or electrical removal must be undertaken to meet both state and federal water quality criteria.

We also recommend that a miner reduce his demand for water to the greatest possible extent. The proper installation and use of water gates, to divert only the desired quantity of water through the operation, is essential. Recycling of water is extremely desirable, particularly in areas of insufficient runoff. Such operations often experience little difficulty in meeting water quality criteria, because there is often no discharge of water from their operation.

Sometimes the discharge of effluent to an adjacent muskeg area is an extremely efficient method of removing suspended solids from the discharged water. Few operations are in a location where they can utilize this technique. Yet this approach is preferable to use of settling basins located immediately adjacent to the stream channel because the watercourse will likely erode the abandoned settling basin. We also believe these natural filter areas will produce desirable browse stands. These woody plants will be utilized by game species normally found in association with early successional stage vegetation such as moose, hare, and beaver. Research is necessary to identify the merits and demerits of this approach.

Enforcement

This department has issued Title 16 authorizations to major mining operations for many years. However, in 1972 our jurisdiction was greatly expanded to include specified anadromous fish streams and their tributaries. Last summer (1975) our staff contacted as many of the active mining operations as possible. We alerted them to our requirements and concerns. It is the working policy of this department only to prosecute those mining operations that are found in violation and are subsequently uncooperative. We rarely prohibit projects.

It is the objective of this department to minimize the impacts of a proposed mining operation on the fish and game resources of an area. As I have stated, there are some positive effects of placer mining operations on game populations. If the miner complies with the water quality standards as administered by the Alaska Department of Environmental Conservation and the U.S. Environmental Protection Agency, does not directly affect a major stream channel, and provides for passage of fishes to upstream areas, he will experience little difficulty with the Alaska Department of Fish and Game.

MINING AND WATER QUALITY
ALASKA DEPARTMENT OF
NATURAL RESOURCES PERSPECTIVE

Ross G. Schaff

Let me begin with the most elementary questions of this symposium. Can placer mining for gold, platinum, and cassiterite proceed without serious damage to the environment? The second major question is what forms of control must man exert? How and where to implement these controls are important ancillary problems.

The answers hopefully lie somewhere between the two stated extremes: cessation of placer mining; or serious water quality degradation and environmental damage. If both are extremes and both are unreasonable, how do we get to a middle road? I have several suggestions for consideration:

1. The permitting process should be simplified. "Red tape" is costly to the mining industry. This expense is ultimately passed on the consumer, who paradoxically pays the taxes to maintain the regulatory agencies. A double expense is thus incurred. The Alaska Department of Natural Resources is planning to consolidate regulatory functions that are scattered among the various divisions. As an example, water rights are issued by the Division of Lands. Water inventory and mining inspections related to safety are the responsibility of the Division of Geological and Geophysical Surveys. Furthermore, a whole spectrum of regulations related to the petroleum industry is administered by the Division of Oil and Gas. The department is considering a minerals division which will handle the statutory functions of the department, in order to facilitate adherence to quality standards.
2. Regulations should be enforced by state agencies familiar with local environmental conditions. Thus "discharge elimination systems" would be compatible with premining conditions, rather than based on a hypothetical and unnatural ideal. It is

apparent that national and state needs commonly conflict. The dispute over the Gulf of Alaska is a case in point. And if the state does not initiate regulatory controls, the less perceptive federal government will.

3. Water quality studies should be expanded to improve the data base for Alaska.

4. Finally, we particularly need a balance between prohibition and reclamation. Alaska presently has four large dredges active in placer mining (three for gold and one for platinum). There are also two hard rock mines, one for barite and one for coal. An estimated 130 small placer mines operate seasonally in various parts of the state. Leasable minerals (such as coal, oil shale, sodium, phosphate, sulfur, and potassium) carry a reclamation statement on the lease (see 11 AAC 44.001-45.550 which can be obtained free of charge at our mining information offices). It is well known that the earth has its own reclamation systems, and that eventually the environmental change resulting from mining will shift back to an equilibrium state. Streams will rechannel and desilt themselves, for example. The process by man's clock is slow. As one who has derived something from the earth, it is appropriate that the miner accelerate the process through appropriate reclamation processes. The state should examine industry incentives for land restoration.

PLACER MINING OPERATIONS NEAR LIVENGOOD, ALASKA

Carl F. Heflinger

Klondike Placer Gold Corporation, a wholly owned subsidiary of Stanford Mines Ltd. of Toronto, is now in the process of developing a large placer deposit located at Livengood in central Alaska. Livengood Creek has been mined continuously since 1914. The present development has been going on for two mining seasons. The first season, 1974, was devoted entirely to repairs on the existing structures. The next season was spent on repair work, stripping, and a small amount of production.

To ensure a steady supply of water, the Hess Dam was rehabilitated in 1974. The dam is on the Yukon side over a low divide from Livengood. The divide is 100 feet high at the crest and 3200 feet long. In prior years, water was routed through a tunnel from the dam, and then via ditch to Livengood Creek. The tunnel was timbered but the floor and mud sills were all on frozen silty gravel. When warm water was run through the tunnel, it would thaw the frozen ground causing the tunnel to collapse. After continually timbering, the tunnel was ultimately considered irrepairable. The answer to the tunnel problem was to open cut all but the first 800 feet next to the dam. This section is all concrete and steel pipe, whereas the remainder of the tunnel was equipped with 48-inch wood stave pipe.

To cut the hill out down to the tunnel, the company first stripped the right of way with tractors. A large pump was installed on a floating barge. Water was pumped to the crest of the hill and allowed to run down over the old tunnel. An auxiliary pipeline was branched to a hydraulic giant that was used to keep the ground sluice straight. As the water dug the cut deeper, gravel was washed out. A 3/4-yard dragline was employed to bail out the gravel as the water washed it down. A 2½-yard dragline was also used intermittently.

All went well until the Alaska Departments of Environmental Conservation and Fish and Game began to harass the company. As far as we could tell, the dirty water was not interfering with anything or any-body. Dirty water has been running down Livengood Creek for the past 60 years without causing any apparent damage.

The company had several settling ponds immediately below the discharge point of the excavation. Since the ponds were constructed on frozen ground, they filled up and overflowed. The water cut them out and they were rendered virtually useless.

With some prodding by the Alaska Departments of Environmental Conservation and Fish and Game, the company agreed to construct two filter dams on No. 6 Above Discovery. These two impoundments were approximately three acres in size and 12 feet high. The overflow consisted of four 15-inch steel pipes buried on the crest of each dam. It looked like the dams were effectively filtering, but the water was still a milky color. This did not suit the Alaska Departments of Environmental Conservation or Fish and Game, so the company lined the dams with 6 ml visqueen.

Then the rain set in and a flood occurred. The dams overflowed because the 15-inch pipe would not carry all of the water. The pipe was washed downstream and buried in the gravel. After the flood waters subsided, the company repaired the two dams; this time they lasted about two weeks. In the meantime, the pump at the reservoir was reduced to one-third output. When the filter dams went out the second time, the company shut the pump down and discontinued the open cut operation on the divide between the Hess Dam and Livengood Creek.

By this time, sluicing had started on the Ready Bullion Claim, situated on the extreme lower end of the property. The company constructed four holding ponds downstream from the sluicing operation. They installed a 4 banger GMC diesel hog pump and pumped all of the sluice water into the holding ponds. This was a fairly successful process. They were able to achieve approximately 100 JTU at the creek below the outfall.

The extra effort to clean up the water cost the company about $20,000. The operating expenses during the height of the season amounted to $80,000 per month. The company has spent in excess of $1,500,000 on the Livengood Mine. The production last summer at $130 per ounce would amount to $220,000. This would not pay the operating expenses.

In the future, Klondike can utilize the huge pipe yard now used by Alyeska for a settling area. This will probably keep the water cleaner, but we do not think that 30 JTU can be achieved on Livengood Creek. Seventy to 80 feet of black frozen muck must be removed before the gravel section is reached. The economical way to dispose of this type of overburden is to wash it down the creek. Other ways of taking this frozen muck off are now being explored. In conclusion, we recommend that the state legislature pass a law requiring the Alaska Department of Natural Resources to name the creeks that are important for placer mining. This should give the mining industry the temporary preference over other activities and let the mining proceed under more relaxed rules than now proposed.

The mining people in Alaska feel that after a creek is mined for placer gold, its usefulness is greatly enhanced for recreation, wildlife habitat, homesites, and timber. This situation does not prevail in the lower 48 states. After mining, the frozen muskeg is washed off and gravel from the tailings is exposed. Vegetation quickly grows back on the mined-out ground. The exception is where dredging has occurred. Here, revegetation is slower. Large portions of the dredge tailings have been used for building sites. Livengood Creek is a good example of the value of dredge tailings since Alyeska Pipeline Service Company hauled all the existing dredge tailings to make a pad for their Livengood Camp located on the West Fork of the Tolovana River. Mined-out creeks will be used forever in Alaska simply because they have been vastly improved by mining.

A PLACER MINER LOOKS AT ENVIRONMENTAL CONTROLS

Lorne Ross

Like many others who are long time residents of the North, I have a concern for preservation of the land and for the well being of the people who have invested their dollars and their life's work to it. We are aware of proven environmental hazards, but are skeptical of the unproven theories of those who are on the environmental band wagon. The small operator is a much easier target for the many government agencies than cities or large corporations. These latter groups may pose far greater dangers to the environment than small placer operations.

In recent years we have seen an alarming growth of government regulations, which have little or no regard for people in the industry. In northern Canada the new regulations came as quite a shock to the placer industry.

In 1970 the Northern Inland Waters Act was passed by the federal government. Under these regulations, the Water Rights Section and the Yukon Territory Water Board were formed. This particular Board is comprised of nine members, one from each federal department most concerned with water use and three members from the private sector. The Board works well. Individuals do not have to deal with many government departments, but only with the operating conditions approved by the Board as a whole. The Board is administered by one official, the Controller of Water Rights, rather than by representatives from all the other federal agencies.

The Klondike Placer Gold Miners Association was formed in June 1974. They elected a board of seven directors to represent local miners in legislative affairs. The association is affiliated with the Yukon Chamber of Mines. After two and a half years, we have guidelines the industry feels it can live with, and at the same time there are controls to protect the environment.

General Features of the Klondike Area

The Klondike region forms part of the Yukon plateau. This area is deeply trenched by a number of small streams entering the Klondike and Indian Rivers. In comparatively recent times, a second elevation has taken place, resulting in a further deepening of the valleys some 700 feet. Portions of the old valley bottoms, still covered with heavy accumulations of gravel, occur at many points. These form areas of varying width bordering the newer valleys. Viewed from a distance, the Klondike district has a hilly, even mountainous aspect. In reality, it consists of a series of long branching ridges, the summits forming irregularly curved hills and hollows from unequal denudations.

Most of the ridges originate at or near King Solomon Dome, the topographic center of the district, and the highest eminence in it. The Dome is situated 19 miles southeast of Dawson, about midway between Indian River and the Klondike. It has a height of 4,250 feet above sea level, compared with 1,000 feet at Dawson.

Stream deposits consist of gravel beds varying from 2 to 20 feet in thickness, overlain by a mass of frozen organic soil (locally known as "muck") from four to more than 20 feet in thickness. This muck is very ice rich (30 to 50 percent ice). The muck is overlaid with a thin layer of peat. Since the peat provides excellent thermal insulation, the muck and gravel stay permanently frozen as long as they remain covered by even a thin coating of peat.

Using water to strip the muck is very important to placer mining. Its use speeds the thawing process greatly, and cuts the cost of stripping to 20 percent of mechanical methods. In times when fossil fuels are in short supply and costly, it would seem advantageous to use water.

Water Quality and Placer Mining

In the view of the placer gold industry, the material washed by stripping the ice-rich muck is not harmful to the environment. This process is little more than a natural phenomenon that can be witnessed in many parts of the Yukon and Alaska, and has been going on for thousands of years.

I feel that the suspended sediment in intermittent creeks (where most placer gold operations are found) should be allowed to settle out naturally, in the lower reaches of the alluvial fan. This avoids the problems created by using settling ponds. Ponds tend to cause greater damage, particularly on the intermittent streams, than their alternative. Settling pond minimum flow theory leaves a great many unanswered questions from both a practical and economic point of view. From the practical side, settling facilities prevent fish from migrating upstream, beyond the mining area, into the upper reaches of the stream and its tributaries. Settling facilities create unnecessary damage to the peripheral areas that are difficult to repair. It would be almost impossible to maintain settling dams in these intermittent streams, due to their steep gradient and extreme fluctuations in runoff.

The degradation of water from placer gold mining is certainly minimal and is confined to the operating period only, doing no permanent damage to the stream or the fish that inhabit it. This can be seen anywhere in the North by anyone who wishes to check for himself. The fish have again returned to these streams.

Environmental Impact

It must be kept in mind that I am speaking on environmental impact with respect to bulldozer sluicing or similar mining. Unlike dredging, there is not the separation of fines and coarse material. Dredging has a very different impact on secondary regrowth and other possible environmental damage.

With bulldozer sluicing, the operator is working in the smaller valleys. These areas have intermittent streams and ice-rich permafrost, where there is rarely anything but bunch grass and stunted black spruce.

If camps, roads, and mining are planned carefully, these areas can even show a considerable improvement to the environment. Soon one sees regrowth of grass, willows, berries, and deciduous trees. This provides food and cover for wildlife that these areas could not support prior to mining activities.

Summary

Placer gold mining has, over many years, been beneficial to all people of the North. Along with direct benefits to the economy, this industry has provided roads into many areas with little or no assistance from government. While tourists, hunters, and fishermen would not otherwise reach these areas without the roads, often these are the very people who are critical of the placer industry.

Many of the major transportation, merchandise, and machinery companies in the Yukon and Alaska were established and maintained through the placer gold mining in these areas. Though it is no longer the major industry, it certainly deserves the right of direct input to any legislation affecting it.

This industry recognizes the need for regulations concerning land use and welcomes these regulations where required. It is, however, extremely important that the people making the regulations have some basic knowledge of placer gold mining. It is equally important that the industry be consulted in all matters affecting it.

WATER USES - ALASKA GOLD COMPANY NOME OPERATIONS

Ed Hunter

Water is an integral part of the Alaska Gold Company operations in Nome. We use water to thaw frozen ground, float dredges, and wash gravel to concentrate the gold. We recycle our water through settling ponds and tailings to maintain water quality throughout our process. This is not just good conservation. It is good business. Pumping water with suspended solids quickly wears out pump impellers. Oily water interfers with the gold-saving processes. The Alaska Gold Company uses surrounding rivers and streams for fishing and other forms of recreation. Contrary to popular opinion, some people in Nome have been known to drink water. Before outlining our water quality control procedures, I would like to briefly discuss who we are and what our mining activities involve in the Nome area.

Company Background

The Alaska Gold Company was incorporated in 1974 by its parent company, UV Industries, Inc., to operate the properties of the corporation here in Alaska. UV Industries, Inc. was formerly the United States Smelting Refining and Mining Company, a name familiar to many Alaskans. U.S. Smelting first operated dredges in Fairbanks during 1928 and in Nome during 1924.

The Nome operations started when the company acquired the property and dredges of Hammon Consolidated Gold Fields. Except for the government-forced shutdown during World War II, dredging was carried on by the company until 1962. Gold operations were suspended after 38 years because it was no longer profitable to mine gold at $35 per ounce.

Feasibility studies indicated that the Nome operations could be resumed when gold prices started to rise. Rehabilitation began in 1973. Approximately $8,000,000 has been invested by the company in the Nome area. Dredging was resumed on July 11th of 1975 by Dredge No. 5. Operations continued until November 4th, when cold temperatures brought the season to an end. Alaska Gold plans to have both Dredges No. 5 and 6 working in the 1976 season.

Description of Operations

The placer deposits in Nome consist of gold particles accumulated in sand, gravel, or detrital material. These deposits are located on the coastal plain in five ancient beaches, which were formed at various elevations during successive stands of the Bering Sea. Liberated by erosion from the land mass, the gold was redistributed and concentrated by surf action in the ancient beaches. Continued erosion of the land mass covered these deposits with boulders, gravel, sand, and clay.

Prospecting: Suitable concentrations of gold for mining are found by prospect drilling with a churn-drill. After the limits of the favorable area are established, the gravels must be thawed prior to any dredging activity.

Thawing: Thawing is accomplished by introducing water at ambient temperatures into the ground through 1.5-inch diameter pipes extending to bedrock. These pipes or "points" are installed on 16-foot centers on the corners of equilateral triangles. It requires about 120 days to thaw the gravel for a year's dredging. Thawing must precede dredging by at least a year to assure an adequate supply of thawed gravel.

The pipe at each thaw point is connected by hose to a header pipe running through the thaw field. These pipes are connected in turn to larger supply pipes, which extend from a pump station at the water source. Water pumped down the pipe at the thaw point flows to the surface, thawing adjacent ground. When this water reaches the surface, it is collected in settling ponds and recycled for further use.

Dredging: Alaska Gold Company dredges are the bucket-line ladder type. The steel digging buckets are connected to form an endless chain, supported by a steel ladder at the bow end of the dredge. The ladder is lowered by winches below the water surface (on which the dredge floats) enabling the buckets to dig the gravel. The buckets discharge the gravel at the upper end of the ladder into a hopper. From here it passes through a trommel screen. High-pressure water is pumped through nozzles, which extend from a pipe running the full length of the screen.

This water is pumped from the dredge pond and returned to the pond after use.

The waste gravel, or tailings, which travel through the trommel are carried by conveyor belt up the stacker for discharge at the stern of the dredge. Fine sand and gold pass through the screen, and over riffled sluices on Dredge No. 5, or through gravity concentrating jigs on Dredge No. 6. The material from the riffles is periodically washed and concentrated. The concentrated material is taken in bags from the dredge to the processing unit in the main plant complex. Here the gold-bearing material is further processed and the resulting bullion poured into bricks.

Water Use

No. 5 Operations Area: The water used in thawing and dredging for No. 5 is taken from old tailings ponds. The overflow from the dredge pond flows to the settling basin, and is then pumped through the pipeline back to the dredge pond. In addition, water is pumped to the thaw field ahead of the dredge. Water from the thaw field also flows into the settling pond for reuse. Some water travels through dredged tailings and into Bourbon and Holyoke Creeks. Part of this water is picked up at the confluence of the two creeks, where it is pumped into the settling pond as make-up water. An auxiliary source of water this year, if needed, will come from tailings further west. This water, which migrates westerly through the tailings, will be pumped to the east for reuse.

No. 6 Operations Area: The No. 6 area lies adjacent to the Snake River. This river channel is a new one that was diverted closer to our dredging area, in order to build the Nome airport. Water is taken from the Snake River for the dredge pond and for make-up water in the thaw field. Dredge pond overflow is channeled through a series of settling ponds to be returned to the Snake River. Water from the thaw field returns to the series of settling ponds along the river and is recirculated by pumps to the thaw field.

Other: Water also cools the power plant's two 980 KW diesel generators, and provides our employee camp with potable water. The cooling water is drawn from Dry Creek, pumped through the engines, run through a cooling tower, and returned to a closed pond in Dry Creek for reuse. Water at the camp is pumped from a well in the tailings. Sewage at the camp is treated in a 7500 gal/day Purestream treatment plant. The clear effluent is pumped into a drain field in previously dredged ground.

Controls: Sampling of various discharges was carried out in 1975 in accordance with the requirements of our several permits. This, of course, will be continued in 1976 to conform to regulations of the various agencies and our own in-house restrictions.

Regulation

Alaska Gold Company has made every effort to comply with federal and state regulations affecting its operations. I think most of you can appreciate that the proliferation of agencies and regulations often makes it difficult for the operator to determine what is required.

It would appear that a coordination of state and federal agencies surely would avoid costly duplication of effort by the regulatory agencies, as well as simplify the procedure for the miner. The single coordinator concept would save countless tax dollars and free both agency employees and placer miners for more productive work.

PLACER MINING - A LOOK AT COST/BENEFIT CONSIDERATIONS

Charles F. Herbert

Introduction

For more than thirty years, the price of gold remained fixed at the level it had during the Great Depression while costs of labor, equipment, and supplies climbed ever higher. A few placer miners continued to struggle against the harsh odds, but many were forced to quit. The list of abandoned mines grew. Finally, the price of gold was freed from governmental control, so it now approaches parity with inflated costs.

The economic yoke has been lifted from placer mining. However, seemingly inflexible environmental controls form the most dangerous threat to existence ever encountered by placer miners. Faced with extinction, placer miners are going to fight for their property, for their "way of life," with every possible weapon, including that ancient and honored protector of human rights - trial by a jury of peers.

We recognize that a complicated society cannot tolerate the use of property in a manner that endangers the health and safety of others, or creates a public nuisance. We can point to a long history of placer mining in this state and challenge any competent observer to name more than a very few instances of damage from placer mining.

Mining outranks in national importance the large and glamorous activities like television, travel and so on. Yet it remains essentially unknown to the public. Somehow, at this time in their fight for survival, placer miners must make known the facts of their operations with respect to environmental objectives. A review of damage claims follows.

Placer Mining Renders the Land Unfit for Agriculture, Wildlife, or Recreation

This may be the most frequently heard accusation but it is the most readily refuted, even by casual inspection of old placer mines. With only minor exceptions, placer mines in Alaska exploit ancient stream deposits formed during or before the Pleistocene. These deposits were buried under wind-borne silt and mud slides during and after the great glacial periods. Most frequently they are frozen. A swampy surface is covered with bunch grass and stunted, black spruce. Such areas are totally unusable for agriculture and incapable of sustaining wildlife.

Only 10,000 acres of Alaskan land (less than half of a single township) have been disturbed by placer mining in the period from 1888 to the present. That disturbed land, where a free market place exists (especially near Fairbanks and Nome), has a value three to five times the value of undisturbed bottom land. Obviously it has been made fit for human use. Since placer mining turns the creek bottom upside down, the soggy surface with its stunted vegetation is removed or buried, and the land is freely drained through clean gravel. The upper surface of weathered bedrock is rich in plant nutrients. When it is brought to the surface, browse and cover for birds and small animals flourish. As every Alaskan hunter or photographer knows, this greatly improves game habitat.

Placer Mining Ruins Fishing Streams

This is widely believed, even though there is overwhelming proof that fish are not killed by discharge water from placer mines. Worked out placer streams are actually better stocked than nearby virgin streams. Biologists attribute these benefits to the release of nutrients into the streams, the development of wider spawning areas within mine tailings, and removal of stream obstructions.

However, biologists also show proof that siltation of spawning beds can suffocate fish eggs. Placer mine discharges must be studied to see if they adversely affect important spawning areas, and if those discharges are any more damaging than the recurrent flash floods that deposit vast quantities of silt in the downstream portions of a stream and block fish passage with debris. The superior fish count in placer streams is proof that the benefits of placer mining, in most cases, outweigh the detrimental effects.

I know that a placer miner's insistence that placer mining improves fish habitat is not going to meet with complete acceptance. Yet there are many obvious examples such as Resurrection Creek, now one of the most important salmon streams in the Cook Inlet Basin. Resurrection Creek is also one of the oldest placer mining streams in the state, with the highest gold production of any stream on the Kenai Peninsula. Consequently, before arguing the placer miner's case to Interior Secretary Stewart Udall in 1968, I contacted Urban Nelson, then Commissioner of the Alaska Department of Fish and Game and, formerly, Alaska Director of the U.S. Fish and Wildlife Service.

Commissioner Nelson agreed that placer mining did improve fish habitat. I called him a few weeks ago to see if his opinion had changed within the last eight years. He assured me that his opinion remained firm and that he would so advise any interested party.

Placer Mining Impairs Water Quality

This is true during the time that a placer mine is operating, but only while the mine is operating. Certainly placer mining cannot be permitted to discharge silt-laden waters into a stream used as a public water supply. I can think of only one would-be placer miner in Alaska who ever attempted to do so. His "operation" lasted less than a day.

Conclusions

Normally, placer mining leads to a permanent improvement in water quality. Streams that drain the muskeg areas covering most of the valuable placer deposits in interior Alaska are polluted by decaying vegetation, have unpleasant odor and taste, and are subject to flash floods because of the extremely high rate of run-off from frozen ground. Groundwater, when it can be found in thawed portions of a valley, is often high in dissolved salts. After stream gravels have been mined, the clean surface facilitates recharge and circulation of groundwater. This reduces run-off and the severity of flash floods.

We maintain that placer mining provides permanent benefits to the environment and creates no more than temporary inconvenience. It is true that water quality laws and regulations seek to prevent even that temporary inconvenience. Consequently, placer miners and conscientious administrators of these laws find themselves in direct confrontation. If there is a solution, it must come from continued efforts by placer miners to reduce even temporary damage. Administrators must distinguish between temporary and permanent damage to the environment, and recognize that in placer mining (as in most human activities) cost/benefit relationships must be considered.

MINING IN ALASKA - ENVIRONMENTAL IMPACT AND POLLUTION CONTROL

Nils I. Johansen

Abstract

Environmental factors affecting mining are difficult to establish due to the absence of large-scale hardrock mining in Alaska. Current information is based on construction of above-ground facilities such as roads, pipelines, and buildings.

Past mining activities appear to have had little lasting effect on the natural environment, excluding changes in the environment introduced by mine tailings and surface structures.

This paper, summarizing a project sponsored by the U.S. Bureau of Mines (Contract No. S0133059), presents general engineering activities, considers the interaction of permafrost and underground mining, summarizes available literature, and indicates possible environmental problems that might be encountered in Alaska, based upon Scandinavian experiences in large-scale northern mining operations. Some of the Scandinavian solutions are discussed in some detail. The opinions expressed are those of the author and not necessarily those of the U.S. Bureau of Mines or the University of Alaska.

Introduction

The Mineral Industry Research Laboratory (MIRL) was awarded the U.S. Bureau of Mines Contract S0133059, "Mining in Alaska - Environmental Impact and Pollution Control," in June 1973. The Laboratory was charged with analyzing selected mineral deposits in Alaska that may be brought into production in the near future. Environmental problems associated with developing these deposits under Alaskan climatic conditions were to be investigated and solutions suggested. Lost River and Bornite were specifically mentioned as two such possible areas. However, it appears that neither area is likely to be brought into production in the immediate or near future.

The Alaska hardrock mining industry is quiescent because of the current land situation. Until the status of the land under the Alaska Native Claims Settlement Act has been clearly established, there is little evidence that any new large-scale mining operation will take place. Many of these factors are currently being studied by others (9). Questions of access across federal and Native land selections are also under debate at the present time. Taxation of mineral and petroleum resources in the ground must be addressed.

For these reasons, it is difficult to specify the impact of mining operations on the environment under Alaskan conditions. This study, therefore, has concentrated on a literature search and on the more general relationships between climate and permafrost on the one hand, and mining practices under northern conditions on the the other. The study also addresses revegetation of mine tailings, construction practices, environmental considerations, and mining and exploration parameters.

The issue of environmental protection versus mining is an old one revolving around conflicting human values. Since there is little evidence of environmental damage caused by mining operations (even the dredge tailings from the gold mining in the Interior of Alaska are becoming revegetated), the impact of current placer operations on stream water quality may be debatable. Scandinavian experiences suggest that large-scale mining operations can be compatible with protection of such environmental factors as vegetation, animal life, and water quality.

The issue quite often breaks down into value judgment. An abandoned mining operation can be looked upon as a historical monument or an eye sore depending on the observer.

As a final note, it is likely that mining activity in Alaska will increase over the next decade, when the land status has been decided and the mineral deposits are better known. It is possible that the energy and mineral shortage facing the United States will be an added incentive for developing oil, coal, and mineral deposits. In the Yukon Territory of Canada, mining is taking place on a fairly large scale. The oil and gas development in Alaska may facilitate further mining activities. The haul roads related to the pipeline construction may, in time, provide better access to known mineralized areas and may also open other areas to more thorough exploration efforts.

Mining, Exploration, and Construction Activities

The one problem people associate with arctic mining is permafrost. Permafrost is defined in the United States as ground that has been frozen for at least two years. The Soviet definition is at least three years. Amount of ice in the ground, and hence thaw stability, is not part of the definition.

The areas of Bornite and Lost River both lie within the continuous permafrost zone in Alaska. Sainsbury (12) reports the permafrost at Lost River to be at least 200 feet below the surface. Any underground mining operations will be affected by permafrost to some degree. The Society of Mining Engineers' Mining Engineering Handbook gives some general information (14)(15). Specific information is currently gathered by MIRL. A MIRL team (consisting of Drs. Lambert and Lynch) visited the coal mines in Svalbard in the summer of 1974 (13). However, some of Lynch's observations of mining practices are of interest here (Lynch, personal communication).

Some of the more typical problems with underground mining related to permafrost are:

1. Loss of strength of the rock upon thawing.
2. Discontinuities in the permafrost, especially those containing water or pockets of thawed ground within the permafrost.
3. Change in ground strength parameters upon penetration of the permafrost layer and entering the thawed ground below.
4. Dust suppression.
5. Ventilation.
6. Handling of frozen ore.
7. Filling of old works with ice.

The coal mines operated by Store Norske Spitzbergen Kulkompani A/S at Svalbard may serve to illustrate some of the problems in Arctic underground mining, although coal mining will also have other problems (such as gas) that metals may not have.

With one exception, the Norwegian coal mines are within the permafrost zone. The roof-support problems are thus minimized as long as the roof stays frozen. The major roof-support problems are related to the thermal regime. The mine opening penetrates the shallow, active layer where annual freeze-thaw conditions and associated roof-support problems exist. Further in the mine, possible thaw conditions exist until the surrounding rock (at about -4°C) cools the air to below freezing temperatures.

Thawing conditions from another heat source were observed in another mine, now closed. A portion of the mine underneath a glacier was outside the permafrost zone. A water problem in this area was handled by normal pumping. In permafrost, dust suppression may be a problem. Water has limited value, since the ice might do more harm than good. The Russians have used water for dust suppression. They argued that freezing problems in the mined coal would not be significant, as long as the moisture content remained below about 7 percent. The mining operation is not a high speed cutting operation. If the mining methods were changed, some new problems involving frozen moisture might occur.

When the permafrost coal is mined out, the Norwegians have traditionally abandoned the mine. The Soviet mining operations by Arktik Ugol' at Svalbard are below the permafrost. One mine is below sea level and another is in the sub-permafrost layers. Again, according to Lynch, the mines seemed to have no typical problems due to ground temperature.

The philosophy of mine ventilation has two schools at Svalbard. The Soviets blow heated (i.e. above -20°C) air into the mines in winter; the Norwegians exhaust air. Again, national mining practices as well as peculiarities with the deposits probably account for these diametrically opposite ways of ventilating the mines. The Norwegians (using their method for mining permafrost coal) are thus minimizing the thaw by removing "warm" air from the mines, the Russians (being out of the permafrost) may be less affected by the "warmer" air entering the mine.

Another problem in permafrost, as well as in areas of seasonal frost, is refreezing of broken ore. Controlled use of water and circulation of hot air may solve this problem for each individual mine in operation. In north central Norway at Rana Mines, this problem has largely been solved in the design of the ore bins. In Svalbard, the problem is handled in the stockpiling process. The frozen pile is exposed to the summer thaw, and successive layers of thawed coal are "shaved" off and shipped.

A final problem with permafrost mines is ice development in the mine. Abandoned works get filled with ice, making reopening of the mine a long and difficult process.

This same phenomenon may be used to an advantage in Arctic mining operations. Fangel (4) outlines a method whereby ice would support the walls and make the roof, thus turning an open pit operation into an underground operation. The downward mining progresses ahead of the ice creep. By adjusting the underground openings to adjust the ice flow, Fangel can control for different rates of progress. The method may be superior to refrigeration in areas close to permafrost, where natural cooling would form and maintain the ice.

With the need for new materials and fuels putting pressure on limited nonrenewable resources, the world is headed toward a major conflict. If the developing nations had a similar material standard as the western world enjoys today, the pressure on development of natural resources would be incredible. According to statistics by the U.S Bureau of Mines, the United States now imports some 90 mineral commodities, including such critically needed items as manganese, tin, and chromium. In addition to this growing dependence upon foreign sources, the domestic industry is hampered by increasingly stringent regulations. Certainly, the mining industry has made thoughtless mistakes in the past, and efforts to rectify these mistakes have been urgently needed.

This pressure has created new interest in the Arctic and Northern Regions as one of the two remaining terrestrial frontiers (the other being the Tropics) for minerals and fuels. New technology is needed to relieve the enormous pressure on natural resources utilized in the conventional manner.

In order to investigate practices in areas similar to Alaska, a three-man team from the Mineral Industry Research Laboratory visited mines in Norway, Sweden, and Svalbard to observe mining practices. This work was part of two contracts with the U.S. Bureau of Mines (16)(17). In addition to the primary objectives of the two projects, the trip also gave insight into the Scandinavian practices of environmental conservation during mining operations.

There are two departments of the Norwegian government generally involved in the aspects of mining and environmental considerations. These departments are the Royal Ministry of Industry and Handicraft and the Royal Ministry of Environment. The bulk of Norwegian law pertaining to the mineral industries is contained in the Norwegian Mining Law (22) and the law regarding protection of nature (20). Portions of other laws also influence the relationship between mining and environmental concerns. The National Building Law (19) and the law concerning outdoor life and recreation (18) are two very important ones.

Several laws dealing with air and water pollution and relationships between neighbors bear on the environmental aspects of mining (21), both from domestic and industrial sources. Some regulations regarding mining and environmental issues are based upon Royal Decrees (Executive Orders). These regulations are established by the King (Executive Branch).

The appropriate Ministry issues regulations (forskrifter) on how the law is to be implemented. Appropriate safeguards and fines for not following the regulations are specified. In addition to the general regulations, the Ministry of Industry, through the Office of Mines and Petroleum, issues the permits (konessjon) to operate a mine and the rules governing that particular mine (bergverkskonsesjon). These two different types of regulations will be discussed in some detail below.

North Sea oil has placed considerable pressure on the Norwegian government to open vast areas of the Norwegian continental shelf and the Svalbard area for exploration. This has resulted in Norwegian regulations (23)(24) that try to provide realistic stipulations for environmental conservation techniques.

The booklet containing the environmental regulations for Svalbard points out special features of the Arctic environment, features that are not commonly known (or anticipated) by people in milder climates. The regulations surrounding the trans-Alaska pipeline may serve as a United States counterpart.

The Norwegian booklet states, in the general introduction, "experience shows that violation of regulations and damage to the environment on Svalbard occur most frequently due to inadequate knowledge of the regulations and the special conditions in the Arctic." The book also contains several "do and don'ts":

1. Winter in the arctic requires special attention. Food is limited and energy costs are high for mammals and birds. Do not chase them with snowmachines, aircraft, or helicopters because this may upset the energy balance of the animals and increase mortality.
2. It is normally no use burying garbage because the frost soon brings it to the surface again. Burn what is possible and bring the rest back or bury it in screes. Broken glass, cans, wires and cables, etc. must not be left behind. Such waste is a continual threat to birds and mammals. Do not consider the sea as a garbage can. It will soon return the waste to the beaches.
3. If you come across a deserted camp which has not been cleaned up, please devote some time to cleaning it up.
4. Pay attention to the arctic environment. It is extremely vulnerable. Respect for the environment costs little and means much.

The booklet also contains general (and practical) information concerning Svalbard, including population, administration, accommodations (there are none), and supplies. Other regulations govern the exploration and drilling for petroleum and other resources on Svalbard (23). These regulations outline restraints to assure a safe exploration program. If, for example, petroleum is found, Sections 50 and 51 state:

"The finding of petroleum shall promptly be reported to the Ministry together with the licensee's evaluation of it.

"Complete information relating to the nature of the finding and what further steps the licensee has taken to determine the extent of the deposits and the results thereof shall be submitted in writing to the Ministry as soon as possible. Furthermore, information shall be given as to whether the deposits are considered commercially exploitable. As soon as a plan for the exploitation has been completed, it shall be submitted to the Ministry for approval.

"Wells where petroleum finds have been made shall be secured in a proper manner according to good oil field practice, so as to facilitate production, to protect the well against penetration of water or other alien matter into the well, to prevent the escape of petroleum from the well, and to protect the surroundings and air against pollution."

The mining laws for Svalbard and Norway are quite different. The discussion below applies to Norway only. The Ministry of Industry and Handicraft issues a concession which permits a company to operate a mine for a certain period of time, usually 50 years. After that, the concession goes back to the government free of charge. The basis for the concession is the Mining Law (22) and the detailed interpretations and rules based on the Mining Law.

The Mining Concession defines the company structure to some degree: the head office shall be in Norway, the board shall consist of Norwegian citizens, and 80 percent of the company stock shall be in Norwegian hands. The document also specifies some of the key personnel needed to operate the mine (i.e. registered mining engineer, a mine foreman, etc.).

One section is devoted to the interaction between mining operations and environmental conservation. A typical concession may state that the company will, as far as possible and at company expense, protect plant and animal life, geologic formations, and other environmental assets. If the work unduly damages sites of historical interest, the cost of exploring such sites is carried by the company. The company is also charged with insuring that the least possible eyesore is created. This goes for the physical plant as well as the tailings disposal areas. At the close of the mining operation, the company is responsible for cleaning the area and making openings safe for people and animals. These regulations result in a cooperative effort to preserve the environment, carried out by the mining company and the appropriate government agencies. This in turn has resulted in modern, efficient mines where the preservation of a quality environment has a high priority.

Examples

The copper mine at Repparfjord may serve as an example. Copper mineralization around the Repparfjord in North Norway has been known for centuries. In 1758, 60 pounds of "pure copper" passed through the

Hammerfest customs office. The source of this copper must have been one of the many small high-grade deposits in the area. The ore body of the Repparfjord mine was discovered about 1900 and mined intermittently until 1913. Further exploration was carried out, but results were inconclusive. Operations were suspended. By the 1960s, reserves of 10 million metric tons containing 0.72 percent copper were delineated. This lead to Folldal Verk A/S developing the mine. The first construction work started in 1970, and by June of 1972 the mine was in full production. Design production is 600,000 metric tons of ore per year. This represents about 8 to 13,000 metric tons of copper concentrate with a copper content of 45 to 50 percent.

The mine lies at tidewater. About a mile from the head of the fjord a salmon river, Repparfjordelva, empties into the fjord. During our visit to the mine, we saw several 10- to 15-pound salmon that had been taken out of the river. Commercial fishing takes place in the fjord in addition to sport fishing. The mill tailings are deposited in the fjord about one mile further out from the mine, or two miles from the mouth of Repparfjordelva. The tailings are deposited about 60 m deep. An underwater pipeline carries the effluent from the mill to the disposal site. The pipeline is about 20 m above the bottom and is arranged so that the disposal takes place over a 600 m length. To assure a fast settlement, a flocculating agent is added to the tailings. Reports from a diving bell at the disposal site verify the effectiveness of the method; there is essentially no turbidity at the site. Observations from the diving bell also indicate that fish may even be attracted to the disposal area.

One of the iron mines visited, Sydvaranger, also disposes of tailings in the fjord. No flocculating agents are needed since the tailing material is essentially all quartz, and the magnetite ore is separated from the quartzite magnetically.

In other mines in the interior of the Scandinavian Peninsula, tailings were disposed of in ponds. The ponds were quite long downstream, thus making the effluent clear. The water could either be reused in the mill, discharged into existing streams to maintain low flow, or both. From an environmental and engineering standpoint, these solutions were adequate. Any inadequacy would hinge on the "visual pollution" aspects. The aesthetics of a partially dry-and-dusty, partially wet-and-muddy tailings area are somewhat questionable. (Some people would probably be equally or more distressed by an open pit mine). The local population accepts the mine and the associated tailings disposal area. The objections to it were raised by environmental groups from other parts of the country. The parallel to Alaska is striking.

The big difference is the local attitude. The northern parts of the Scandinavian Peninsula have been a source of raw materials and natural resources for over a millenium. The Lapps with their reindeer herding have the old hunting and fishing rights in the interior, trading in fur and meat. The coast people trade in fish. Since the Thirty Year War (1618-1648), there has been an increasing interest in the mineral resources of the region. The mineral industry has a natural place in the economy. What may be considered environmental damage by certain groups is a way of life and an economic base for large segments of the local population.

There is a minor conflict between reindeer herding and mining. The mining operations sometimes occupy land used for grazing. Mine and associated road systems may present an obstacle to the annual movement of reindeer between the interior and coast, or between winter and summer grazing areas. These conflicts are settled in or out of court. A small but never-ending problem remains in trying to keep the reindeer out of a mine. Fences are set up with some success, but fences do not work if people forget to shut the gates.

Environmental Considerations

The conservation and preservation of the Alaskan environment, especially the tundra, has received considerable publicity since the Prudhoe Bay oil discovery. This publicity has served to focus public attention on some of the problems of the North, especially biological aspects such as revegetation, disruption of migratory routes for caribou, and the slow rate of waste decay. This public attention has often lead to pressure against development, especially by the mining and petroleum industries.

Research on the mining and exploration activities in Alaska is more or less continuous. Grybeck, Peek and Robinson (7) suggest that more consideration needs to be given to preserving the environment during exploration such as:

1. Hauling out old gas cans and not leaving them sprinkled over the countryside.
2. Leaving clean camp sites and removing leftover gear and debris.
3. Not leaving debris at remote sites where helicopters land.

Crews need to respect the property of local miners, prospectors, and residents. They should not disturb cabins and equipment around them, even if they appear abandoned.

There is no question that the Arctic environment is sensitive to pollution. The problem is compounded by the 1) often one-way type of operation and 2) slow degradation of materials in the North. An extreme example of the latter may be the preservation of Pleistocene mammal remains in the permanently frozen silt (locally termed muck) in interior Alaska.

Another Arctic problem is the availability of water. The Arctic regions have low precipitation, and reliable sources of year-round water may be difficult to obtain. Clark (3) makes a brief outline of the problem:

"Rivers east of the Colville River in the Arctic Coastal Plain have numerous braided channels, whereas rivers west of the Colville meander sluggishly in valleys 50-400 feet deep (Wahraftig, 1965). Most streams in the Arctic Foothills have swift braided courses across broad gravel flats. The major rivers of the Brooks Range flow north to the Arctic Ocean, and south to the Kobuk, Koyukuk and Yukon Rivers.

"The many small lakes on the Arctic Coastal Plain are limited to low volume utilization because low annual precipitation results in slow replenishment rates. In most areas, permafrost to depths of over 1000 feet prevents the formation of any subsurface water (Parker, 1972).

"In winter, ice cover of approximately 6 feet builds up on all the surface water bodies. Many streams are locally covered in winter with extensive sheets of anchor ice. Even in the largest rivers, flow in winter is approximately 5 percent of the summer flow . . . .

"Water is available from lakes which do not freeze to the bottom and from unfrozen aquifers beneath the rivers. Williams (1970) reported that aquifers in the Colville River yield from several hundred gallons per minute from alluvium to less than ten gallons per minute from bedrock."

Mining operations in the Arctic will be of several kinds: open pit, underground or placer operations. Each of these operations will potentially impact the Arctic. Placer mining operations have been a source of discontent for decades. Much of Alaska's early mining industry was placer mining, and several papers discuss its impact.

The Alaska Water Laboratory (2) discusses the effects of placer mining on water quality in the interior of Alaska. The report presented four general conclusions:

1. Placer mining operations degrade downstream water quality by an increase in turbidity, a reduction in dissolved oxygen (DO), and a resulting significant reduction of fish and fish-food organisms.
2. The major impact on water quality from placer mining comes from the hydraulic stripping operation.
3. The termination of mining operations does not necessarily eliminate water quality degradation.
4. Techniques for the control of sediments from mining operations are available but are generally not being employed at the present time.

Silting is a source of pollution in Alaska. Many streams are glacier-fed and hence naturally carry a heavy load of silt. A study by Guymon (8) focuses on the natural sediment yield of Alaskan streams. Such data helps evaluate the environmental impact of engineering works on rivers, lakes, and coastal areas. The study also looked at the water supply of sediment-laden streams, and the sedimentation in natural or man-made lakes. Forrest (5) examined a variety of parameters, in interior Alaska:

1. Topsoil disturbance or removal.
2. Subsoil disturbance or removal.
3. Relocation of soils.
4. Silting in streams.

5. Effects of removal of vegetation (especially surface vegetation).
6. Changes in pH and/or hardness of water.
7. Effect upon ground water level.
8. Effect upon stream water level.
9. Changes in stream and lake geography.
10. Possible pollutants introduced due to mining activity.

Forrest points out that the major source of stream pollution is caused by the removal of muck, the organic silt that typically overlies the gold-bearing gravels in interior Alaska. By hydraulic removal of the muck, both turbidity (silt) and BOD are introduced into the stream. The result is a reduction in the DO of the stream. Values of zero have been reported (5). In addition, the high turbidity reduces the amount of light that would benefit aquatic plants in their photosynthesis.

The silt itself also has a detrimental effect on the fish life, reducing the fish population by blanketing spawning grounds and interfering with the operation of the gills. Personal communication (in 1974) with local placer miners, however, brought out disagreement with the statement that the high turbidity downstream from placer operations is detrimental to fish life. Quite often miners would point out the benefits from a placer operation in providing dredge tailings as a source of construction material.

The increased price of land and the increased building activity in the Fairbanks area in connection with construction of the trans-Alaska pipeline shows the new use of the tailings. The ice-rich permafrost valleys are still undeveloped while substantial use is being made of the tailings area, both as sources of construction materials and as homesites.

Greenwalt (6) wrote a short paper regarding the environmental changes caused by the dredging operations in the Fairbanks area. He used the tailings at Fox as an example. Before onset of the dredging operations, the terrain was like that along the unmined areas of Goldstream, just north of Fairbanks. The area is characterized by permafrost, muck, and black spruce vegetation. Animal life included moose, squirrels, fox, lynx, wolf, and black bear. Lynx and wolf have essentially vanished, since these animals are the most sensitive to human occupation. An occasional black bear can still be found. The area supports a fox population similar to what existed before the onset of mining and the subsequent human influx.

The moose population was favored by the change in vegetation to deciduous trees from evergreens, and the occurrence of the many ponds with associated aquatic plants. Squirrels, on the other hand, experienced some decline by the change in vegetation and topography. Similar observations can probably be made for other mined-out areas in the Interior.

Open-pit operations may impose other problems. The only major open-pit operation in Alaska at present (1975) is the Usibelli Coal Mine at Healy. This operation probably does not have typical problems of mining in the far North. The coal-mining operations at Svalbard cannot be termed typical either. They are underground and, as far as the Norwegian mines are concerned, mostly within the permafrost layer.

Jirik (10) points out some considerations for coal mining in a permafrost region. While he admits that the available information is meager, his observations are interesting. Jirik is concerned with the coals in the Cape Beaufort area, where continuous permafrost is present. It is likely that North Slope coal will be mined at some future date. There is some exploration at the present time and also some interest in domestic use by local villages. Jirik's list of potential problems include:

1. Change in the thermal regime due to altered topography from piling of cast overburden.
2. Change in the surface by stripping vegetation and subjecting areas to possible thawing, subsidence, or erosion.
3. Generation of acid mine waters. This may or may not be a problem because the coals have a low sulphur content and the amount of precipitation is low. But ironstones have been reported, and the possibility of some acid mine drainage does exist.
4. Slope stability. Permafrost may be a help or a hindrance here. This very subject is under investigation by the Mineral Industry Research Laboratory, University of Alaska (11).

Jirik did not consider management decisions regarding mining operations. Proper understanding of the interactions between the mining operations and the environment may significantly reduce the environmental impact of many of the factors he mentions. An example is the mining method proposed by Fantel (4) using ice for wall support and the mine roof.

Both underground and open-pit operations may have a tailings disposal problem. The interactions between tailings and permafrost are not fully understood, but research (11) is underway. Some of the construction problems on the trans-Alaska pipeline can be related to the interaction between a fill (tailings) and the permafrost ground (ice rich or dry). The final solution to the mining vs. environment question is in part legal.

Another point that will have to be considered is the value of the land for other purposes, such as preservation of wilderness for future generations to enjoy. Perhaps areas could be set aside after a mineral inventory has been made and then periodically reviewed in the light of the national needs for minerals.

The conflict between mining and environmental conservation is an old one. The following quotes are from Georgius Agricola's book, De Re Metallica, published in 1556 and translated by Hoover in 1912 (1): "Since there has always been the greatest disagreement amongst men concerning metal and mining, some praising, others utterly condemning them, I have therefore decided that before imparting my instruction, I should carefully weight the facts with the view to discovering the truth in this matter.

"Again, those who condemn the mining industry say that it is not in the least stable and they glorify agriculture beyond measure. But I do not see how they can say this with truth, for the silver-mines at Freiburg in Meissen remain still unexhausted after 400 years and the lead mines of Goslar after 600 years. The proof of this can be found in the monuments of history. The gold and silver mines belonging to the communities of Schemnitz and Cremnitz have been worked for 800 years, and these latter are said to be the most ancient privileges of the inhabitants.

"But besides this, the strongest argument of the detractors is that the fields are devastated by mining operations, for which reason formerly Italians were warned by law that no one should dig the earth for metals and so injure their very fertile fields, their vineyards, and their olive groves. Also they argue that the woods and groves are cut down, for there is a need of an endless amount of wood for timbers, machines, and the smelting of metals. And when the woods and groves are felled, then are exterminated the beasts and birds very much of which furnish a pleasant and agreeable food for man. Further, when the ores are washed, the water which has been used poisons the brooks and streams, and either destroys the fish or drives them away. Therefore, the inhabitants of these regions, on account of the devastation of their fields, woods, groves, brooks and rivers, find great difficulty in procuring the necessaries of life, and by reason of the destruction of the timber they are forced to greater expense in erecting buildings. Thus it is said, it is clear to all that there is greater detriment from mining than the value of the metals which the mining produces.

"But what need of more words? If we remove metals from the service of man, all methods of protecting and sustaining health and more carefully preserving the course of life are done away with. If there were no metals, men would pass a horrible and wretched existence in the midst of wild beasts; they would return to the acorns and fruits and berries of the forest. These would feed upon the herbs and roots which they plucked up with their nails. They would dig out caves in which to lie down at night, and by day they would rove in the woods and plains at random like beasts, and inasmuch as this condition is utterly unworthy of humanity, with its splendid and glorious natural endowment, will anyone be so foolish or obstinate as not to allow that metals are necessary for food and clothing and that they tend to preserve life?

"Moreover, as the miners dig almost exclusively in mountains otherwise unproductive, and in valleys invested in gloom they do either slight damage to the fields or none at all. Lastly, where woods and glades are cut down, they may be sown with grain after they have been cleared from the roots of shrubs and trees. These new fields soon produce rich crops, so that they repair the losses which the inhabitants suffer from increased cost of timber. Moreover, with the metals which are melted from the ore, birds without number, edible beast and fish can be purchased elsewhere and brought to these mountainous regions."

Conclusion

To be able to pinpoint potential pollution problems related to mining activities, the specific mining and ore-processing methods at the mine site will have to be known. Another factor which complicates the issue of the environmental impact of mining, especially in Alaska, is the intimate relationship between the mine operation and the access to the mine. The environmental impact from the access may be more objectionable than that caused by the mine itself, although the impact is often blamed on the mine. The environmental impact of the mining operation per se is usually slight, since the amount of land involved is usually quite small. Environmental impact often relates to the disposal methods of waste from the mining and milling operations.

Some environmental damage or degradation from mining operations is probably unavoidable. The conflict has been with us for hundreds of years, and it is not likely that the arguments will quiet down over the next decades. With the competing pressures for development of natural resources and the preservation of a quality environment, we will see more arguments from both camps. Maybe Agricola said it best when he wrote: "it is not metals that are to be condemned, but our vices."

Recommendations

This paper has pointed out several general features of Alaskan mining. Some specific points to keep in mind are the following:

1. Revegetation following the mining operation takes place, even if the reclamation efforts done by the mining company has been minimal. This is clearly seen in the Fairbanks area where the old dredge tailings support heavy growth of willow and birch in many places. If conscientious reclamation efforts are carried out, the regrowth is quite good. The present coal operations near Healy have carried out a highly successful revegetation project on their tailings.

2. The total land area disturbed by mining operations is quite small in acres. However the mining area may be an eyesore, especially if the access road has been cleared without regard to the ground conditions (such as permafrost), and littering has been taking place. The trans-Alaska pipeline road demonstrated that controlled access and a dedicated effort to minimize environmental impact can create a road that does not unduly disrupt the natural environment.
3. A negative impact created by roads is one of providing easier access to the land. Increased hunting and fishing pressures may follow. The results are seen around Fairbanks where increased population and hunting pressure have combined with natural causes to create a significant decrease in certain species such as moose and caribou.
4. Water quality is being affected by placer mining operations; however, the impact on clear-water streams can be minimized by reducing the amount of silt released into the waterway. Sometimes the natural runoff is silty and mining operations do not really affect the stream. The latter is evident in glacier-fed streams which naturally carry a heavy silt load.

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STREAM WATER QUALITY AND BENTHOS CHARACTERISTICS SUBSEQUENT TO PLACER MINING

Laurence A. Peterson and Dennis L. Ward

Thirty years of large-scale placer mining near Fox, Alaska, (Figure 1) had a detrimental effect on the water quality and benthos of the small creeks in the area while mining was in progress. Eleven years after the cessation of mining operations, however, studies indicated the effects were not permanent (Ward, 1972; Peterson, 1973). Data from these studies, in addition to unpublished data collected by Peterson, resulted in the following conclusions:

1. Goldstream Creek exhibited high water quality characteristics in the tailings area near Fox. Surface water runoff through the tailings had no measurable effect on the quality characteristics.
2. Goldstream Creek within the tailings area supports a diverse aquatic fauna characteristic of a clean, clear stream.
3. A localized deposit of pyrite was the probable source of "unnatural" water quality found in lower Engineer Creek.
4. Suspended material was trapped in tailings and tailing ponds, thereby reducing turbidity levels in Engineer Creek.

Placer mining has created the greatest manmade disturbance to the natural water quality and benthos of interior Alaskan streams. These operations require the removal of the muck and soil overburden, followed by washing the gold-bearing gravel found sandwiched between the overburden and bedrock. The stripping and gravel washing operations undoubtedly added a large quantity of suspended solids to streams, thereby increasing the turbidity and organic load. Although large-scale dredging operations ceased 15 years ago, many streams are still recovering from the effects of placer mining.

In 1902, gold was discovered sixteen miles northeast of Fairbanks on Pedro Creek, which established Fairbanks as a major mining center. During the boom years of 1903 to 1905, creek towns were established on Pedro, Gilmore, and Fox Creeks, which are tributaries of Goldstream

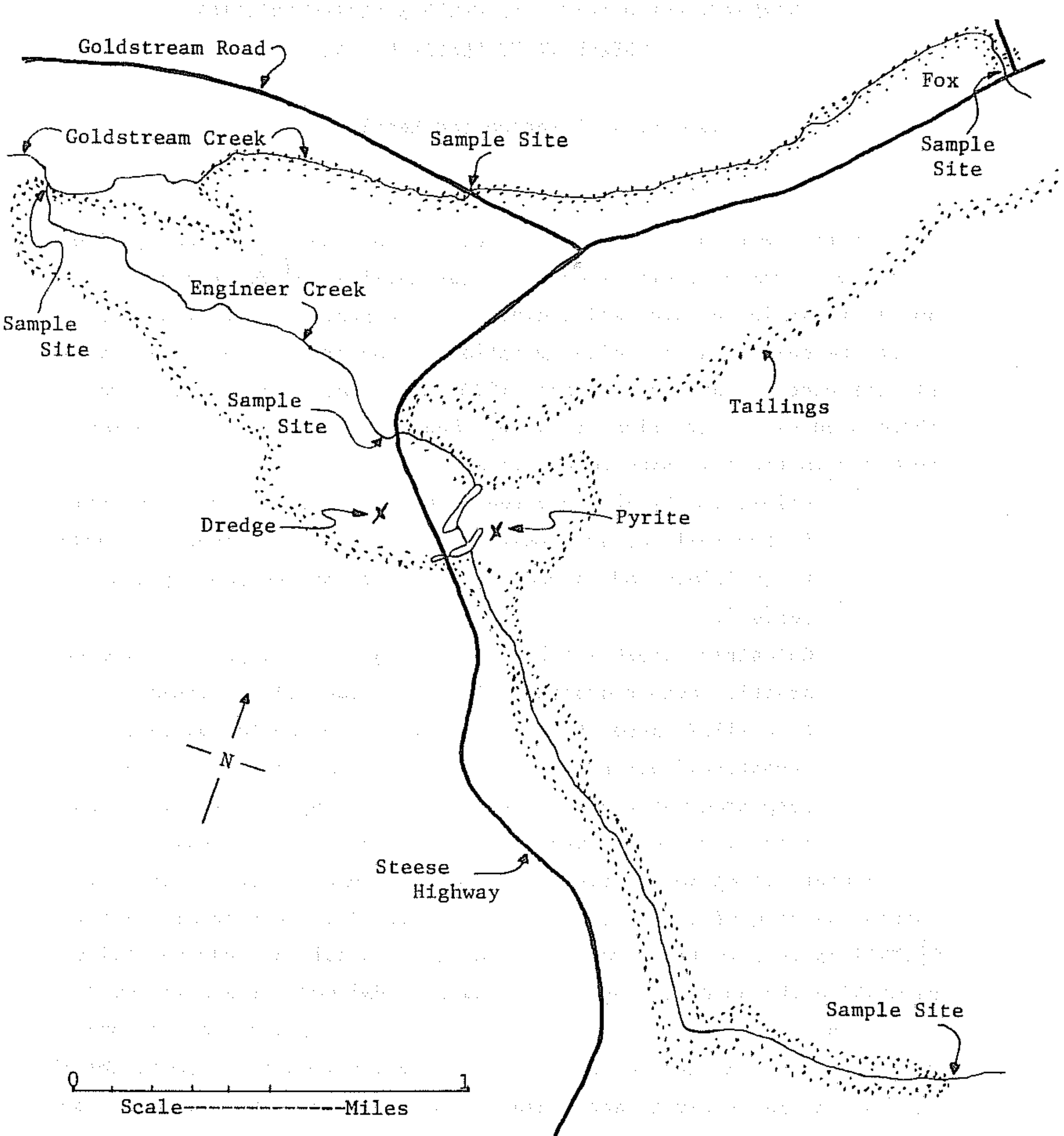

Figure 1. Tailings area and sample sites near Fox, Alaska.

Creek. Goldstream Creek was first worked for gold in the summer of 1903. Engineer Creek, also a tributary of Goldstream, was first worked in 1908 (Anon., 1916). A decline in mining activity began in 1910 and continued until the early 1950s, even though hydraulic dredges were used during the latter half of this period. The U.S. Smelting, Refining, and Mining Company had 12 dredges in operation in the Fairbanks Mining District in 1930, but only 6 in 1953 (Cooley, 1954). Four dredges of different sizes (not all working at the same time) mined in Goldstream, Pedro, and Engineer Creeks from about 1930 until 1959. The dredge presently located near Engineer Creek worked up and then down this drainage, and was the last to operate in the Goldstream area.

This paper presents a discussion of the water quality and benthic invertebrate populations characteristic of Goldstream Creek within the tailings area near Fox. Also presented is a discussion of the water quality of Engineer Creek.

Goldstream Creek

Peterson's (1973) two-year study of Goldstream Creek assessed a complete range of water quality parameters. During this study (which began in July 1970) dissolved oxygen (DO), pH, turbidity, and suspended solids (SS) were measured at two sample sites within the tailings area near Fox (Figure 1). These parameters exhibited the following ranges.

Parameter	Range
DO, mg/l	5.4 to 12.6
pH	6.9 to 7.9
Turbidity, JTU	0.0 to 35.0
SS, mg/l	3.9 to 65.0

These ranges are comparable to values common in natural interior Alaskan streams.

The relatively low DO value of 5.4 mg/l was measured under ice during winter, when values of this magnitude are common. The next lowest DO value of 7.6 mg/l was also measured during winter. The lowest DO concentration measured during the open-water season was 8.6 mg/l.

The DO levels measured in Goldstream Creek are common in interior Alaska and are adequate to support a diverse biota.

Both Goldstream Creek sites exhibited pH values that fall within limits of natural streams. During the open water season, pH ranged from 7.0 to 7.9, and from 6.9 to 7.2 under ice. The slightly lower pH values during winter resulted from goundwater flow into the stream. Winter pH values less than 7.0 are common to interior Alaskan streams.

Although turbidity and SS do not necessarily correlate well with each other, they both measure properties of suspended material in water. It is interesting to note that 50 percent of the turbidity values measured by Peterson (1973) were 5 JTU or less, which was the U.S. Public Health Service (1962) drinking water standard. This value has been superseded by the U.S. Environmental Protection Agency standard of 1 JTU.

Turbidity and SS are normally high during spring breakup and periods of heavy rainfall. The highest values of these parameters, measured during spring breakup, were 35 JTU for turbidity and 65 mg/l for SS. High values also occurred after periods of heavy rainfall. For example, in July 1971, suspended solids were 44 and 59 mg/l and turbidity values were 23 and 29 JTU at the two sites after a heavy rain. The observed values of these parameters in Goldstream Creek are typical of clear, natural streams, but significantly lower than values found in glacial streams during the summer.

One of the most immediate effects of placer mining on a stream is siltation that smothers most bottom-dwelling organisms and fish eggs. The quantitive effects of this type of disturbance are dependent upon natural stream conditions, including stream gradient and substrate composition, water quality, and species composition of the aquatic organisms. The natural recovery time of a stream, subsequent to mining activities, depends upon similar variables, plus natural stream channel restabilization and flushing time.

During 1970 through 1971, biological samples were collected from Goldstream Creek at two locations within the previously mined area near Fox (Figure 1). They exhibited a diverse population of macrofauna (Ward, 1972).

Goldstream Creek had reestablished a stable channel through several miles of tailings by 1970. This was demonstrated by relatively low levels of turbidity and suspended solids, and clean gravel substrate in this region. If it had not stabilized and erosion was occurring, the channel would have been visibly silted. The substrate also provided suitable habitat for benthic populations.

Approximately 48 species of organisms were found to inhabit Goldstream Creek including nematodes, annelids, and arthropods. The arthropods were represented, in part, by plecopterans, trichopterans, dipterans, coleopterans, and ephemeropterans. In July of 1971, approximately 33 to 58 ephemeropterans/ft^2 were found in the dredged regions of Goldstream Creek, as compared to 3 to 172/ft^2 in natural regions of other nearby streams. The density of caddis flies within the dredged area is also comparable to those in nearby unaffected streams.

Engineer Creek

Engineer Creek flows into Goldstream Creek at the downstream limit of the tailings area near Fox (Figure 1). Certain water quality characteristics of Engineer Creek were reported by Peterson (1973) in conjunction with his Goldstream Creek study. This discussion is based upon those data and unpublished data collected by Peterson during the same period. Although water quality measurements were taken throughout the tailings area, they were concentrated in the stretch immediately upstream from the confluence with Goldstream Creek. This area was shown to have decidedly different quality characteristics than Goldstream Creek and the middle to upper reaches of Engineer Creek.

The "unnatural" quality characteristics in the lower stretch of Engineer Creek are exemplified by extremely low DO levels, low pH, low temperature, and high iron concentrations. The following ranges were measured immediately above the confluence of the respective creeks on the same sample days during the summer and early winter.

	Engineer Creek	Goldstream Creek
DO, mg/l	0.0 to 1.2	10.2 to 12.7
pH	6.2 to 7.4	6.6 to 7.8
Temperature, °C (Open water season)	1.5 to 3.0	7.5 to 10.5
Iron, mg/l	7.1 to 11.7	0.4 to 3.2

In addition, the middle to upper stretches of Engineer Creek exhibited characteristics similar to those of Goldstream Creek. For example, in June 1972, DO ranged between 9.1 and 9.9 mg/l, pH from 7.5 to 7.6, temperature from 9.5 to 11.0°C, and iron was between 0.5 and 0.8 mg/l.

Although there was a significant difference in the quality of these streams, Engineer Creek had little effect on the quality of Goldstream Creek. The flow of Engineer Creek on June 30, 1971, was only 2 percent of the flow of Goldstream Creek (0.5 cfs compared to 27.8 cfs). The measurable effects were limited to a slight decrease in DO and a slight increase in iron concentration 30 feet below the confluence. It should be noted that flow within Engineer Creek disappears into the tailings and reappears at various locations along the channel. In addition, flow was shown to increase along the lower stretch of the creek.

The above flow and quality characteristics of Engineer Creek indicate that groundwater flow into the creek is responsible for the unnatural characteristics. A localized bedrock outcropping of pyrite, located near the Steese Highway (Figure 1) (Hawkins, personal communication), is available to leaching by groundwater. The normal results of leached pyrite are that the groundwater will have zero DO, low pH, and high iron concentrations--precisely the characteristics of lower Engineer Creek. Low temperatures are also characteristic of groundwater.

It is likely that the groundwater flowing over the pyrite deposit follows the channel of Engineer Creek, and surfaces near the confluence of Engineer and Goldstream Creeks. The question arises whether this situation was enhanced by placer mining. The answer was not determined, but it is likely that placer mining exposed the pyrite to flowing ground water, which promoted leaching. In other words, placer mining simply accelerated a natural process.

Measurement of turbidity and suspended solids demonstrated that the middle to lower end of Engineer Creek usually carried few solids and had low turbidity values. Upper Engineer Creek, however, was characterized by high values for both of these parameters. For example, in late May 1972, samples taken above the tailings (upper), just west of the Steese Highway (mid), and near its confluence with Goldstream Creek (lower), exhibited the following values:

	Turbidity, JTU	Suspended Solids, mg/l
Upper	40.0	80.0
Mid	4.5	1.1
Lower	1.1	0.5

The reduction in turbidity and suspended solids results from flow through the tailings and tailings ponds immediately east of the Steese Highway. These relatively large ponds, coupled with low flow in Engineer Creek, provide sufficient detention time to allow solids to settle out.

Muck removal and dredging operations associated with placer mining in the Fox area undoubtedly had a detrimental effect on the water quality and benthos. Yet eleven years after mining operations ceased, the channel through the tailings area had stabilized. As a result, a diversified benthic population had reestablished itself. In addition, the water quality of Goldstream Creek was high, and surface-water runoff through the tailings into the creek had no measurable effect on the water quality.

The probable effects of mining on Engineer Creek were twofold. First, tailings and tailings ponds acted as suspended sediment traps which reduced turbidity and suspended solids. Second, it is likely that dredging enhanced leaching of a bedrock outcropping of pyrite, thereby degrading the quality of lower Engineer Creek.

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