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BLM-ALASKA TECHNICAL REPORT 7

AUGUST 1981

# EFFECTS OF PLACER MINING ON HYDROLOGIC SYSTEMS IN ALASKA

## status of knowledge

ROBERT J. MADISON

U.S.DEPARTMENT OF THE INTERIOR

Bureau of Land Management

Alaska

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# THE STUDY

THIS REPORT WAS PREPARED for the Bureau of Land Management by the Geological Survey under the terms of an Interagency Agreement. The general purpose of this contract study was to provide analytical assistance to BLM in evaluating the effects of placer mining on public lands in Alaska. The objectives included: (1) a review and interpretation of all available literature on the effects of placer mining on the environment in Alaska; (2) an interpretation of that literature as it relates to effects on hydrologic systems, water quality, water quantity, aquatic habitats, and aquatic organisms; and (3) an identification of gaps in knowledge on those subjects and suggestions for studies to fill in the missing information. The analysis and interpretations in this report are those of the Geological Survey.

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**16. Abstract (Limit: 200 words)**

Nearly all significant information about effects of placer mining on hydrologic systems in Alaska is referenced in available reports. Addition of sediment in quantities and sizes that cause significant changes in normal relationships among stream discharge and sediment size and concentration (and indirect changes generated) appears to be the primary impact of placer mining on Alaskan hydrologic systems. Other potential water-quality effects to be considered are: increases in organic loading and minor element content; potential for acid drainage; and impacts on aquatic biota. Existing information adequately defines parameters that may be affected by placer mining but cannot quantify hydrologic changes resulting from individual operations or predict magnitude or duration of impacts in unmined areas. Studies that would improve current knowledge include: Short term assessments, using aerial photography, satellite imagery, and existing hydrologic records, to document historical changes and active placer-mining features; short-term studies involving minimum data-collection efforts and using empirical sediment-transport formulas to estimate effects of mining activities; and river-quality assessments of selected basins affected by placer mining. These studies will not provide the quantitative information that could be gained from long-term detailed study of specific placer-mining activities, but will provide qualitative information for management decisions needed in the near future.

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ROBERT J. MADISON

FINAL REPORT FOR MEMORANDUM OF UNDERSTANDING AK-950-MU9-7
RELEASED AS U.S.GEOLOGICAL SURVEY OPEN-FILE REPORT 81-217

Prepared by the Geological Survey for the
**U.S.DEPARTMENT OF THE INTERIOR**
**BUREAU OF LAND MANAGEMENT**
**ALASKA STATE OFFICE**

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## INTRODUCTION

The Bureau of Land Management (BLM) is required by Public Law 94-579, Federal Land Policy and Management Act of 1976, to manage the Nation's land in a manner that will protect the quality of air and water resources, provide food and habitat for fish and wildlife, and provide for outdoor recreation and human occupancy and use [Section 102(a)(8)]. One land-use practice in Alaska that can have significant impact on the water resource is placer mining. Federal surface management regulations require the authorized officer, BLM, to evaluate and approve plans of operation for all placer mines in Alaska. In order to meet these requirements, BLM must have current information on the effects of placer mining on water and other resources associated with the hydrologic regime. BLM needs to identify areas where existing knowledge on the effects of placer mining is inadequate for good management decisions and to initiate additional studies to provide an adequate information base.

At the request of BLM, the U.S. Geological Survey agreed to make a literature search of the existing hydrologic information and data base, summarize knowledge of the effects of placer mining on the hydrologic system, identify data gaps and information needs, and evaluate the adequacy of existing technologies to fill those needs. In addition, recommendations would be made as to the types of hydrologic studies that could be accomplished in a timely manner and provide a useful information base for management-level decisions. The results of the literature review and evaluation would also be used to generate a computerized bibliographic data base on placer mining to be stored in BLM'S "FAMULUS" system in Anchorage.

This report includes the results of the literature review and provides general suggestions as to the types of studies that would be most useful in providing the kinds of hydrologic information necessary for management of placer mining activities. Specific study plans and cost estimates could be prepared at a later date, pending the review and acceptance by BLM of the suggestions contained herein.

## RESULTS OF INITIAL LITERATURE REVIEW

In addition to BLM, several agencies in the United States and Canada have been concerned with the environmental effects of placer mining and with the lack of adequate hydrologic information to support the establishment of regulatory stipulations or provide technical and management alternatives for the guidelines in placer mining operations. As a result of these concerns, several agencies have contracted for or initiated studies to:

- Define the effects of placer mining.
- Review the available literature.
- Provide alternative proposals for regulation of placer mining and suggest methodologies for meeting State and Federal pollution control guidelines.

The Alaska Department of Environmental Conservation (DEC), pursuant with Section 208 of the Federal Water Pollution Control Act, has contracted for a four-part analysis of placer gold mining in relation to water quality (Engineering Manpower Services 1977, 1978a and b). The purpose of this study was to develop an overall management plan for reducing non-point source water pollution associated with placer mining in Alaska. The first part of that analysis identifies sediment problems associated with overburden removal and describes mining practices, regulatory structures, and constraints on mining operations. It was based on a literature search and an evaluation of the available information on effects of placer mining. The second and third parts of that analysis evaluate the various sediment control practices in use, develop a set of best management practices (BMP's), recommend criteria or guidelines for their use, and develop a recommended implementation plan with alternative implementation strategies. The fourth part, now in draft status, will be a final summary report to be published at a later date.

A similar report was prepared by Hardy and Associates (1979) for the Yukon Territorial Water Board. It is titled, "Guidelines for Reclamation of Placer Mining Operations, Klondike Region." This report describes placer-mining methods and operations in Canada and recommends guidelines to be used to stabilize and rehabilitate mined areas when mining operations cease.

Woodward-Clyde Consultants (1976) prepared a preliminary report for the U.S. Fish and Wildlife Service on gravel removal in selected arctic and subarctic streams in Alaska. Their report contains an extensive review of published and unpublished information on the effects of instream and flood-plain disturbance on aquatic and terrestrial biota, water quality, stream hydrology, and esthetics. It also presents a preliminary set of guidelines for selection of sites, operation, and rehabilitation after cessation of gravel-removal operations. Although the report deals primarily with gravel removal, many of the hydrologic effects described are similar to those that may result from placer-mine operations.

The Institute of Water Resources, University of Alaska (Zemansky, Tilsworth, and Cook 1976), reviewed and evaluated information available on the impact of mining on water quality in Alaska. That report includes a review of existing regulations, base-line data, and state-of-the-art technology for the control of mining wastes.

More than 1,000 abstracts from about 10 bibliographic data bases and numerous annotated bibliographies, as well as many books, journals, and other processed documents, have been reviewed. The results of this study's review of literature and information gathered during numerous personal contacts indicate that nearly all of the available significant information on the effects of placer mining or related activities on the hydrologic system in Alaska and elsewhere is referenced in the above reports. Further literature search will probably be of little value in adding to what has been found or published in the previous reviews.

The following brief summary of the current state of knowledge regarding placer mining in Alaska is based on the information contained in these previous reviews, reports referenced by them, and some additional references or studies uncovered in our literature search.

The list of references at the end of this report covers only literature cited herein. Abstracts of all other literature containing significant information on the effects of placer mining have been included in the FAMULUS bibliographic data base.

## HISTORY AND PRESENT SCOPE OF PLACER OPERATIONS

The history of placer mining in Alaska and the locations of placer deposits have been documented in numerous publications of the U.S. Geological Survey, U.S. Bureau of Mines, and the Alaska Division of Mines and Geology. Most of this information has been summarized by Cobb (1973). His report contains nearly 500 references and provides descriptions of the physiography, general geology, lode resources, and the history of placer mining for each mining region or district in Alaska. The most recent published compilation of active placer operations in the State is for the year 1975 (Carnes 1976). A brief summary of the history and location of placer mines is also given in the Alaska Department of Environmental Conservation's draft "208" reports on placer mining and water quality (Engineering Manpower Services 1977, 1978a and b). These reports also summarize information on the past and present methods of placer mining and provide data on costs, production, and manpower. Available figures (as of 1978) on the total number of operations and the exact methods used by individual operations are considered incomplete because of the short-term nature of the operations and lack of personnel to make adequate field observations. The Alaska Department of Environmental Conservation is currently updating its previously published inventory of water-pollution sources and management actions, Volume 2 of "Water Quality Management, 1978" (Imamura 1978). As a part of this effort the department is attempting to compile, from all available sources, the most up-to-date information on size, location, types of equipment used, water use, and other pertinent information for all active placer operations in the State. That office is probably now (1980) the best single source for this kind of information.

Although the exact methods used by individual operators are not well documented and will differ somewhat due to variations in mine-site topography, water availability, overburden, and placer types, the basic mining techniques are well known and adequately summarized in the existing literature (Wimmler 1927; Thomas 1959; Romanowitz, Bennet, and Dare 1970; California Division of Mines and Geology 1973).

## EFFECTS OF PLACER MINING ON THE HYDROLOGIC SYSTEM

The conventional operating procedures used in placer mining that can result in changes in the natural hydrologic regime of stream systems are:

1. Stripping of overburden material to expose the mineral-bearing materials;
2. Thawing of permafrost;
3. Ditching or stream diversion to obtain water;
4. Transportation of mineral-bearing material to the sluice box;
5. Sluicing or separating gold or other economically recoverable minerals from the mineral-bearing materials;
6. Construction of tailings ponds or other control structures; and
7. Disposal of tailings.

The physical changes that can occur at the mine sites are as follows:

1. Removal of the vegetative cover;
2. Changes in topography of the mined area;
3. Modifications of the stream channel through operations in the stream or diversion or re-routing of the stream channel; and
4. Introduction of materials (sediment) into the stream system.

The effects on the hydrologic system of these physical changes to the land surface will vary in magnitude and duration, depending on the amount and type of overburden removed, the size of the disturbed area, the methods of operation, the location of the site, the control practices, and many other factors related to the hydrologic characteristics of the stream systems involved.

## SEDIMENTATION

The addition of sediment to the stream system in quantities and sizes that can cause significant changes in the normal relationships among stream discharge, sediment size and concentration, and channel morphology, as well as all the indirect changes this generates, appears to be the primary impact of placer mining on the hydrologic system in Alaska.

In this respect, the effects of placer mining are similar to those of any other land disturbance activity that results in either more or less sediment being introduced into the stream system. Although little information is available that treats placer-mining effects specifically and directly, the literature contains many studies, literature reviews, and state-of-the-art discussions of the effects of increased sediment loads on stream systems and on their inhabitants and habitats. Extensive reviews of the literature and discussions of the effects of sediment on aquatic life have been made by Cordone and Kelley (1961), Hollis et al. (1964), and Sorensen et al. (1977). The published manual on sedimentation engineering (Vanoni 1975) contains hundreds of references to the literature and comprehensive reviews of sediment transport, erosion, engineering design, and sediment control. The hundreds of papers presented at the Federal Interagency Sedimentation Conferences (U.S. Department of Agriculture 1965, 1975; Water Resources Council 1976) review much of the work that has been done in the field of sedimentation and provide a good picture of the present knowledge of sediment-transport processes.

The major conclusions reached by workers in the field are that the effects or changes that can be expected are:

1. Physical effects

   * Increased turbidity and resultant reduction in light penetration;
   * Alteration of channels, including changes in slope, stream velocity, discharge, depth and width, scouring characteristics, stream length, pool-riffle ratio, ground-water/surface-water relationships, ground-water recharge characteristics, and water temperature; and
   * Changes in the stream bottom material, including changes in the particle-size composition which may change the rate of intergravel water flow, deposition of fine material and gravel on riffle areas, and changes in bedload movement.

2. Effects on aquatic plant life

   * Reduction in photosynthetic activity and consequent reduction in growth of algae and macrophytes;
   * Smothering of plant life inhabiting the stream bottom; and
   * Increase in the mobility of the substrate.

3. Effects on benthic invertebrates

   * Reduction in the abundance and diversity of benthos as a result of reduction in available food supply (plant life), increased drift and susceptibility to predation, clogging of the feeding apparatus by fine sediments, and loss of available or suitable substrate habitat; and
   * Changes in community composition from clean-water species to species more adaptable to higher sediment levels but possibly less suitable as fish-food organisms.

4. Effects on fish life

   * Loss of available food supply due to reductions in production at the lower trophic levels (plant life and benthic invertebrates);
   * Interference with the sight-dependent feeding habits of salmonids;
   * Obliteration of hiding or living areas in gravel by clogging of the interstices with fine sediment, or by reduction of pool areas;

- Temporary or permanent destruction or modification of spawning beds that can result in either failure to spawn or complete or partial mortality of eggs, alevins, or fry. The primary causes are: Reduction of dissolved oxygen, increase in the percentage of silt and sand in the spawning gravel, reduction in intergravel flow rates, scouring of the spawning gravels subsequent to spawning, or complete covering of the spawning beds with sediment;
- Short-term exposure to very large concentrations of suspended sediment that can cause fish mortality through damage to the gill structure; and
- Avoidance of normal spawning areas (even at relatively low turbidity) and preference for cleaner tributaries or other sections of a stream.

## WATER QUALITY

The consensus in the available literature is that the major effect of placer mining on water quality is an increase in sediment concentration and turbidity and that changes in dissolved constituents appear to be minimal. Zemansky, Tilsworth, and Cook (1976) reviewed the available literature on the effects of mining on water quality. Although their report contains more than 300 references, they found little information or data specific to Alaska. They do, however, list in considerable detail the water-quality effects reported by investigators outside Alaska and the potential water-quality problems associated with placer mines.

The major potential effects that should be considered are:

- An increase in organic loading in the stream system from the introduction of overburden sediments or innundation of organic-rich topsoils. This may produce anaerobic conditions in the sediment, decreases in dissolved-oxygen levels in the water, and increases in color, iron, tannin, lignin, organic carbon, nutrients, dissolved solids, and chemical or biological oxygen demand;
- An increase in the minor-element content of water or sediments as the result of exposure and oxidation of metal-bearing materials, the leaching of tailing deposits, or chemical treatment of the ores;
- Acid mine drainage. When sulfide minerals (most commonly iron sulfide, or pyrite) are exposed to weathering or oxidation, water passing over or through them may be acidic. Although the literature concern-

ing the effects of acid mine drainage in other states (Office of Water Resources Research 1975) is voluminous, there are no known studies or reports of acid drainage problems in connection with placer mining in Alaska. It has been generally assumed that because most Alaskan placer deposits contain low percentages of the easily oxidizable sulfide minerals, drainage of acid water from placer mines will not be a major problem; and

* Effects of the above water-quality changes in the form of toxicity to fish and other aquatic biota.

## SEDIMENT CONTROL PRACTICES

The accepted method of controlling or eliminating sediment discharge to stream systems from mining operations is by the use of settling ponds. The benefits of such control techniques in reducing the effects of sediment are generally accepted. However, there are also potentially detrimental effects. These have been recently summarized by Guy (1979, pp. 432-434) as follows:

> Turbid outflows. The use of sedimentation ponds having the required design and performance characteristics will substantially increase the amount of time that downstream flow would be turbid, even though the pond may remove large qualities [quantities?] of fine sediment. This is caused by the fact that (1) very fine particles have long suspension periods, (2) the dewatering device will usually be placed at the bottom of the detention storage pool, and (3) the required detention time makes it necessary to limit the rate of outflow so that the outflow hydrograph will usually be about three times longer than the inflow hydrograph. Fortunately, the drainage areas of most sedimentation ponds used in surface mining are relatively small. Therefore, it can be expected that such highly turbid outflows would be greatly diluted before they reach fishing-size streams, especially in areas having substantial base flow. When base flow is very small or lacking, the turbid outflow would likely be noticable [sic] for long distances downstream.
>
> Downstream erosion. Where sedimentation ponds intercept the flow of sand-bed channels, the potential exists for adverse degradation of the stream bed, as well as bank erosion, for several thousand feet downstream. This is caused when sand and other coarser particles are trapped by the pond thereby causing a drastic change in the normal sediment regime of the stream. The problem could be alleviated by: (1) allowing a small part of the disturbed-area sediment movement to

by-pass the pond; that is, do not divert all of the disturbed-area flow into the pond (unfortunately, this is contrary to the regulations); or, (2) introducing some coarse material to armor the channel. The selection of appropriate particle sizes for this would be difficult because of the expected wide range of flow intensities. It is often environmentally inappropriate to introduce large particles into a sand-bed stream. Alternatively, it is possible that a beneficial effect may be attained by allowing moderate enlargement of a stream channel to improve conveyance of flood flows.

Space requirement. Sedimentation ponds having the required settling and detention capacity use considerable space--generally 1 to 5 percent of the disturbed area. Pond location would usually be in or adjacent to a small valley at the lowest part of the permit area. This space would usually occupy some of the best terrain, flora, and fauna in the permit area. In a humid climate, space requirements could be substantially reduced at many sites if the regulations would allow the ponds to be built over very small perennial streams. In such a climate, it is common for drainage areas of 40 acres or less to be drained by small perennial streams; especially in areas of rapid infiltration and ground-water recharge. The small valley of such streams provides the natural basin with a minimum of space needed for sedimentation ponds. At many steep-terrain sites, it will be impossible to provide the needed off-channel space for the required design. The small base flow of these perennial streams could easily be piped through the pond area, but the regulations may preclude such novel design.

In some mining situations it would be necessary to bring a number of small disturbed-area flows to a central pond area rather than build and maintain several small ponds. Though operational and sediment trapping efficiency would be improved by such a collection system, the 25- to 100-foot-wide strip needed to build the necessary diversions would be detrimental to the environment.

Surface stabilization. The construction of the pond and its required embankment will expose a minor area to potential erosion and intense sediment movement prior to vegetative stabilization. The potential for adverse effects from this is relatively small based on the expected short duration (a few weeks) of such exposure. The potential might be relatively high if the pond were built where and when it would be difficult to establish a protective vegetative cover, such as in the Appalachian region during winter.

> A similar, but somewhat more difficult, situation would exist upon removal of the pond after the reclaimed area has been stabilized and the inflow to the pond has reached ambient levels. The potential for adverse effects is greater for pond removal than it is for pond construction because (1) the deposited sediments must be regraded or moved to another area for disposal, and (2) the whole area is subject to erosion and sediment yield, whereas during construction the pond caught any sediment movement in its immediate area...
>
> Stagnant water. During extended dry periods in summer, water in the sediment storage basins may become stagnant. This stagnant water would be released in varying concentrations up to full strength when the pond receives the next substantial inflow. Aside from potential water quality problems with stagnant water, some people might complain that the ponds would be a source of additional mosquitoes--others might say that such mosquitoes would be a beneficial food source for other biota.
>
> Sediment removal. Deposited sediment must be removed from the pond on or before it accumulates to 60 percent of the design storage to help insure the maintenance of desired trap efficiency in the event of relatively large runoff. Much of this deposited sediment will be highly fluid fines. Therefore, special handling and disposal methods may be required to prevent adverse secondary erosion and sediment movement to streams. There are no specific criteria in the regulations as to how this can be accomplished. The operator must develop a plan, subject to regulatory authority approval. Sometimes the sediment may be suitable for top-soiling, but frequently it will be disposed [of] as spoil.

## MAGNITUDE AND DURATION OF EFFECTS

The occurrence, magnitude, or duration of the effects described above for a specific placer-mine operation will be dependent on many factors. These will include the size and type of operation, the amount and characteristics of the overburden material, the geologic, hydrologic, and geomorphic characteristics of the basin, the amounts and types of sediments added to the stream system, and the timing of these additions.

In the extreme situation that arose in the rivers of the Sierra Nevada, where hydraulic mining for gold was carried out extensively in the 1800's, mining sediment was still being transported out of the mined basins more than

50 years after mining ceased and was still impacting the fishery resource (Sumner and Smith 1940; Gilbert 1917). Other studies indicate that populations of fish and bottom organisms can recover relatively rapidly after sediment additions have ceased (Platts and Megahan 1975). However, where drastic alterations in stream channel hydraulics occur, the changes may be irreversible.

## ADEQUACY OF EXISTING INFORMATION BASE TO DEFINE AND/OR QUANTIFY THE EFFECTS OF PLACER MINING IN ALASKA

An evaluation of the few reports of studies of placer mining in Alaska and northern Canada confirms the conclusions reached in previous reviews (Zemansky, Tilsworth, and Cook 1976; Engineering Manpower Services 1977, 1978a and b) that information on the effects of placer mining in these areas is extremely limited. All studies reported have consisted of short-term investigations. Data-collection efforts ranged from a single field visit of a few days to monthly data collection over two or three summer field seasons.

The four studies of Alaskan placer operations (Federal Water Pollution Control Administration 1969; Calspan Corp. 1976; U.S. Environmental Protection Agency 1977; D. J. Cook, University of Alaska, 1979, unpublished manuscript) are based on grab samples collected above and below mining activities. The physical and chemical characteristics analyzed include pH, temperature, dissolved oxygen, conductivity, turbidity, suspended solids, settleable solids, arsenic, and iron. Some information on density of bottom organisms and visual observations of fish population are also recorded.

The 1979 study by D. J. Cook (cited previously) of the University of Alaska is in the report review stage and was conducted by the Mineral Industries Research Laboratory under contract to the U.S. Bureau of Mines. The report summarizes two studies (Chin-Chung Yang 1979; Shao-Sue Chang 1979) conducted as part of the requirements for master's degree theses. In addition to grab sampling above and below 16 small sluicing operations, laboratory flocculation tests were conducted on materials from the mining sites.

The Canadian studies (Knapp 1974, 1975; Williams 1973) contain the most comprehensive set of data presently available relating to the effects of placer mining in either

Alaska or Canada. Chemical, biological, sediment, turbidity, and fish-count data were collected during active mining operations. However, these studies, too, were of relatively short duration and consisted of grab samples collected over one or two mining seasons.

The general conclusion that can be reached from an analysis of these few available studies is that the effects observed elsewhere have been observed or can be inferred to have the potential for occurring as the result of placer-mining activities in Alaska. Increased sedimentation, reductions in fish and fish-food organisms, lowering of the dissolved-oxygen content, increases in dissolved solids, changes in streambed composition, and alterations of stream-channel hydraulics have all been observed to some degree in the areas studied.

None of these studies, however, was of sufficient scope or duration to enable the authors to quantify the magnitude or areal extent of the effects, their seasonal or temporal variation in relation to streamflow characteristics, the total length of stream affected, or the long-term effects on water quality, aquatic life, or streamflow and channel hydraulics. None of the studies quantitatively relates changes to the actual amounts or types of material or overburden disturbed. Although the statement is made in several of the studies or literature reviews that mechanical removal of overburden has less impact than hydraulic stripping, the relative effects of each method were not evaluated.

The available data do, in several of the studies, document the degree of downstream change from natural conditions upstream of mining operations at the time of sample collection. However, no data have been collected at a frequency adequate to determine the net increase in dissolved or suspended-material loads contributed by placer-mining activities. Destruction or alteration of spawning habitat and changes in fish population have been documented or inferred, but the net long-term effect on the fishery resource of the specific mining activities has not been defined.

Many studies have been made outside Alaska, some of relatively long-term duration, that quantify the effects of specific land-use practices on specific stream systems. These studies reinforce the conclusion regarding the types of effects that will occur as the result of placer mining, but they have little transfer value for predicting the magnitude or duration of the effects in a specific Alaskan stream.

In summary, existing information is adequate to define those parameters that may be affected by placer mining. It is inadequate to quantify changes in the hydrologic system resulting from an individual mining operation or to allow the prediction of the magnitude or duration of the impact of mining in presently unmined areas.

## MANAGEMENT ALTERNATIVES FOR CONTROL OF PLACER MINING ACTIVITIES

Both Canadian and United States agencies have produced reports that suggest guidelines for the implementation of management plans to control the impact of placer mining.

A Canadian report, prepared for the Yukon Water Board by Hardy and Associates (1979), breaks placer operations into three types based on stream morphology. The three types considered are:

* Mining in narrow valleys (width less than 350 meters),
* Mining in wide valleys (width greater than 350 meters), and
* Bench operations that involve cutting back terraces or benches from the present streams.

Specific recommendations for methods of mining the ore, control of effluents, and for basin rehabilitation are made for each type of mining. One of the more important basic conclusions reached in their report is that

> ...in the short term the environmental impact on the narrow valleys is total, i.e. in order to mine these valleys economically, the stream must be totally disrupted for a period of years...It therefore follows that, at least in the short term, any question of fish passage is just not viable (addendum to guidelines, p. A1).

The report also states that the dividing line between broad and narrow valleys is largely dependent on the topography and location of the area in which mining will take place.

The reports prepared for the Alaska Department of Environmental Conservation by Engineering Manpower Services (1977, 1978a and b) recommend a set of best management practices (BMP's) to reduce non-point source water pollution associated with placer mining. Engineering Manpower Services concludes that a mixture of selected alternative implementation strategies is most promising. A mining practices committee concept is presented as the most reasonable mechanism of implementation of BMP's.

## ADEQUACY OF EXISTING METHODOLOGIES FOR QUANTIFYING AND/OR PREDICTING EFFECTS

The primary concern expressed by most agencies involved in the management or control of placer-mine activities is both the short- and long-term effects on the fish and fish-food organisms in the affected streams. As previously stated, the types of effect which can be expected are well documented. The degree or severity of the effects will be directly related to the degree or severity of the change in the chemical and sediment regime from natural conditions and the physical changes in the stream channel that result from this or from actual physical disruptions.

Two major problems are involved in obtaining reliable information to predict what the changes will be, how severe they will be, how long they will last, and how much of the stream will be affected:

* The changes will be site specific. That is, each stream system may react to sediment additions differently, depending on its specific hydraulic and hydrologic characteristics. Thus, detailed information on the effects along a single stream of a specific type of mining practice may not necessarily indicate what may happen in another stream system with the same mining practice.
* The present theories of sedimentation have not been sufficiently refined so as to predict natural sediment-transport and depositional processes with the accuracy often needed for determining environmental impact or for setting standards. Although many predictive models have been developed (Mason 1978), much is still unknown about how sediment will move through a given stream system and where and when it will be deposited. Wolman (1977) has summarized the many problems involved in the analysis and interpretation of sediment data.

The existing equipment and data-collection techniques are adequate for determining suspended-sediment concentrations, size distribution, and suspended-sediment loads. Well-planned data-collection programs including sufficient frequency and duration can provide accurate information on short-term changes in the suspended-sediment regime, both natural and man-made. In instances where good long-term flow information is available, properly collected periodic sediment data can sometimes be used to develop relationships that may give good estimates of naturally occurring suspended-sediment concentrations and loads for all expected discharges. On most streams, relations can also be developed between suspended-sediment yield and basin characteristics. These relationships can be used to estimate sediment yields from unmeasured areas having similar basin characteristics and can give an indication of probable base-line conditions.

Because of the complexity of sediment-transport processes, it is impossible to predict without sufficient historical information the exact changes in the natural suspended-sediment regime that will be caused by man's activities. An Agricultural Research Service report (U.S. Department of Agriculture 1975) contains a collection of papers covering the present and prospective technology for predicting sediment yields and sources. Although it contains no direct references to placer mining, the techniques and the relative accuracy of methods are well covered. The proceedings of the Federal Interagency Sedimentation conferences (U.S. Department of Agriculture, 1965; Water Resources Council 1976) are also a source of references and information on various aspects of sediment transport and sediment effects.

Measurement or estimation of the bedload component of sediment discharge is much less precise than the determination of suspended-sediment load. Techniques for the measurement and estimation of bed-material discharge exist, but results have shown that the differences between measured and computed values may be more than 100 percent. Even where bedload or total sediment yields can be measured or estimated with some accuracy, the present knowledge is not adequate to define accurately the precise source of sediments nor the path or timing involved in transport, deposition, and storage over the long term (Wolman 1977).

It is possible, using existing techniques, to measure relatively short-term gross changes in bed-material composition or bedload transport resulting from mining activities. The ultimate effect on the total sediment-transport regime of the streams or the total changes in bed-material composition (and consequently fish-food or spawning habitat) cannot now be accurately predicted on the basis of short-term data.

Current measurement and/or predictive capabilities in the area of the aquatic biological systems are much the same as for the sediment systems. Short-term gross changes can be measured with some accuracy. The long-term effects of a specific mining activity can be inferred but cannot be quantitatively predicted. Sorenson et al. (1977) reviewed more than 400 reports and articles on the effects of suspended and dissolved solids on freshwater biota. The following conclusions are cited from the abstract of that report:

> ...there is a dearth of quantitative information on the response of fresh-water biota, especially at the community level, to suspended and dissolved solids. Consequently, the major research need was defined as the development and/or application of concepts of community response to suspended and dissolved-solids concentrations and loads. These concepts need to be applied especially to the photosynthetic level and the microfauna and macrofauna levels. Fish studies are of lower priority since more and better research has been reported for these organisms.

## SUGGESTIONS FOR FURTHER STUDIES

The presently available guidelines for the management and control of Alaskan placer mining (Engineering Manpower Services 1978b) are based on the best available information. These guidelines point out that management plans must be, for the most part, site specific and that they must be based on adequate site-specific or regional hydrologic data. The following is extracted from the report's statement of requirements of a mining or operational plan:

> A suitable plan would be based on adequate site data setting forth all biological, physical and chemical data pertinent to prevention of pollution. Data on soil and water characteristics; aquatic biota; habitat and vegetative cover; details of operational needs; normal weather, water and biota cycles in nature; water classification and standards to be applied; species to be protected; and other related information must all be obtained, evaluated and utilized in plan preparation. Both qualitative and quantitative aspects of data are essential. Assessment of such data will provide the insight necessary to establish the framework within which a site-specific plan may be prepared [p. 5].
>
> Much of the above required information may not be site specific, but regional in nature. Such basic resource data also may or may not be available at the present time; regardless of current availability, industry is largely

> dependent upon government to provide such data. This information, plus particular details for each mine and mining operation, would constitute the site-specific mining plan [p. 6].

The foregoing discussion indicates that the present data base is inadequate to quantify the effects of placer mining, to define the base-line hydrologic environment of the streams involved, or to provide the information on natural hydrologic processes for Alaskan streams that is necessary to model or predict effects.

Long-term and detailed studies of specific basins should generate data that lend themselves to rigorous statistical analysis. However, such studies are costly and time-consuming and provide information from which it will be difficult to generalize. Rigorous statements can be made about the impact of one type of mining on one particular basin, but it would be difficult to extrapolate the study results to other types of mining in other types of basins. In addition, such detailed studies often do not provide data for management decisions for 10 or more years. However, several other shorter term approaches can be taken to improve the existing knowledge of the effects of placer mining on the hydrologic system and to provide useful information for management purposes.

Some of the more important hydrologic impacts of placer mining are directly related to changes in sediment storage, channel conditions, and routing of sediment. Some of these changes can be estimated reasonably or adequately from sequences of aerial photographs. In addition, some of the more important components of the sediment-transport regime can be estimated by using existing formulas in conjunction with a minimum of easily collectible field data. The following suggested studies are based on the use of these estimating techniques. They are not mutually exclusive but rather are listed in the order that they might reasonably be accomplished. The objective of the initial efforts would be to provide immediate information for planning purposes while providing building blocks for subsequent or concurrent studies that would provide more detail but could still be accomplished in a relatively short time frame.

## I. SHORT-TERM ASSESSMENTS, UTILIZING AVAILABLE INFORMATION, TO DOCUMENT HISTORICAL AND EXISTING EFFECTS OF PLACER-MINING ACTIVITIES

This type of study is probably the most reasonable first approach and the one that would provide immediate (within about 1 year) information. It would require no additional field data-collection activity but would use existing or planned aerial photography, topographic maps, and the hydrologic data base presently available.

The first effort in this kind of assessment would be detailed evaluation of aerial photographs or satellite imagery to determine what placer-mining features or placer-mining effects can be identified. Those features that can be separated from natural or other man-made modifications would be compiled on 1:63,360-scale topographic maps. The following types of information would be evaluated and mapped:

Historical features

* Areal extent of land disturbed;
* Residual placer-mining features, such as tailings, debris deposits, evidence of erosion, and the like;
* Extent of revegetation of old workings or tailings;
* Displacement of stream channels; and
* Classification of stream-channel types.

Active mining features

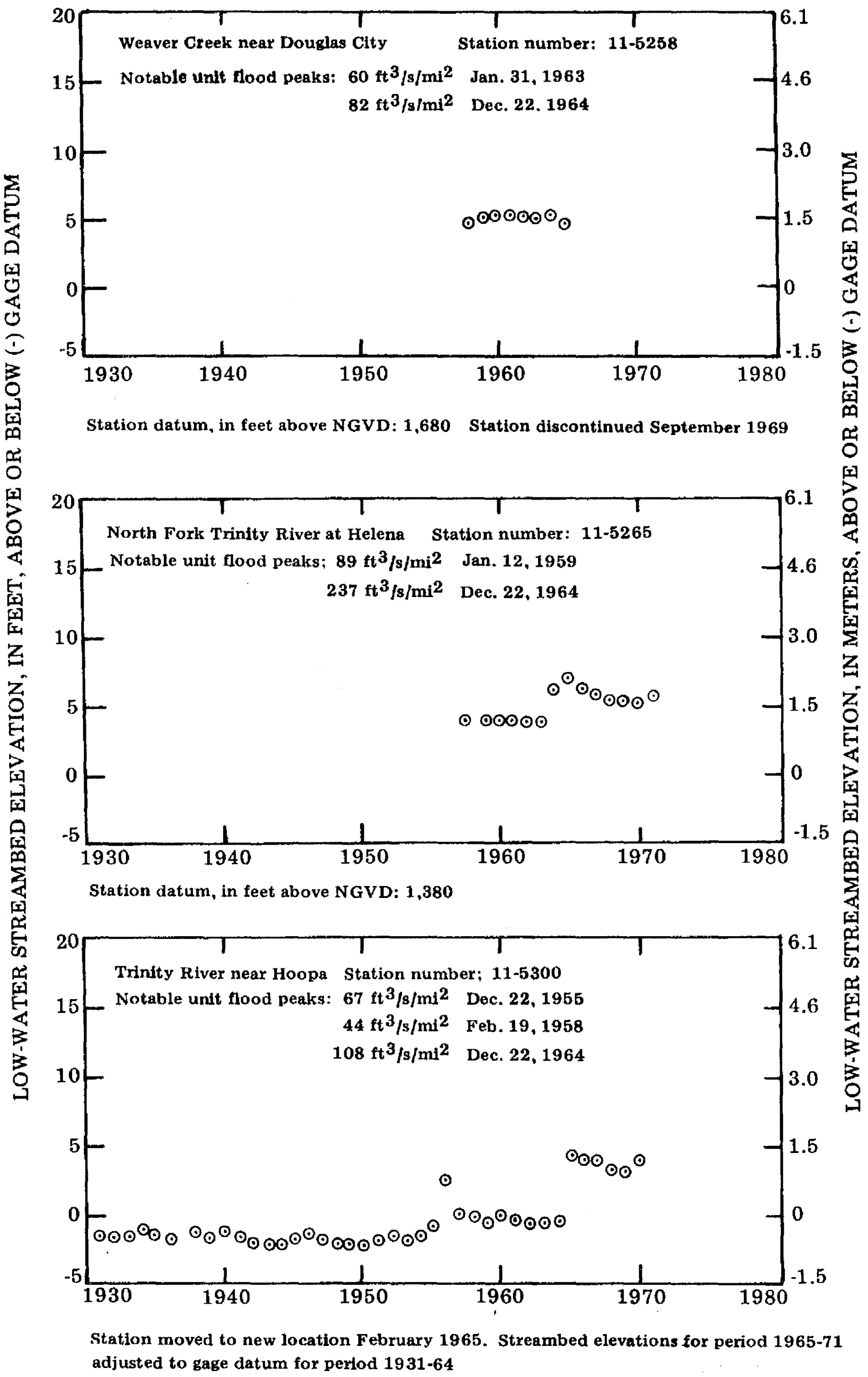
* Areal extent of mined area;
* Occurrence and extent of turbid waters; and
* Physical characteristics of receiving waters and streambed (turbidity, erosional or depositional areas, and the like.)

Additional physical and/or geologic features, such as type and structure of bedrock, natural vegetation cover, topography, and types of overburden, may be discerned from the air photos. These features will be of considerable value in developing more detailed studies or management plans.

A related effort would be to attempt to evaluate the long-term effects of past placer mining through the analysis of existing hydrologic records. One of the primary management concerns in placer mining is the downstream effects of increases of sediment on the channel and bed characteristics of streams. Considerable information on the occurrence or magnitude of historical changes can be gained through an evaluation of existing gaging-station records and streamflow measurements (Leopold and Maddock 1953; Knott 1974). By looking at historical changes in low-water streambed elevations and changes in hydraulic geometry (depth, velocity, width, discharge), it may be possible to see order-of-magnitude changes that have resulted from past placer-mining activities. Knott (1974) used this technique to show the effects, including increased sedimentation, of a historic storm and flood event in the Trinity River basin, California. Through an analysis of historical gaging-station records and low-water flow measurements, he was able to show immediate and long-term changes in streambed elevations and hydraulic geometry resulting from the storm event. Examples of Knott's results for some of the affected streams are shown on the next two pages.

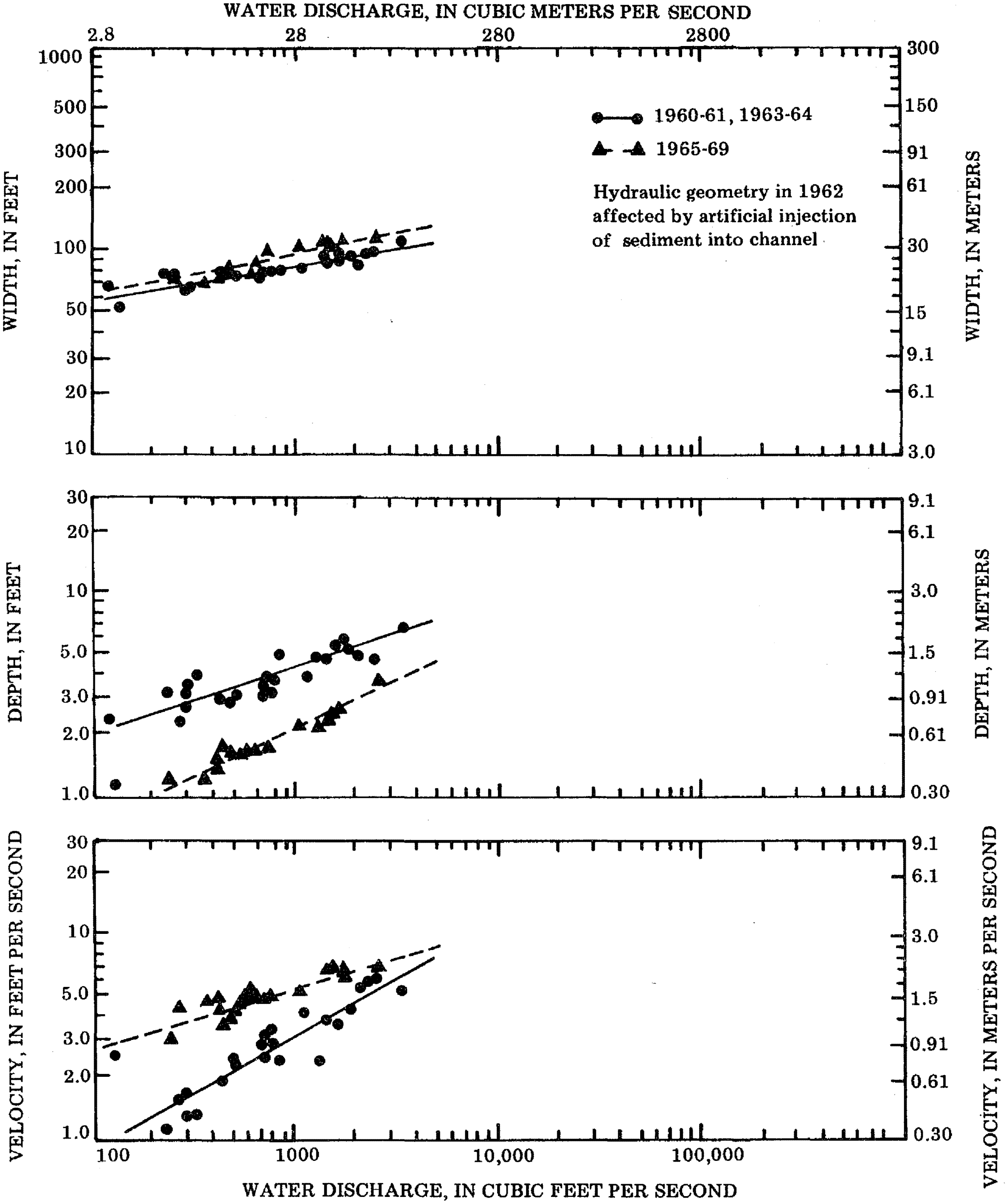
The amount of information to be gained from this type of analysis will be limited by the availability and quality of existing aerial photography and the location of long-term surface-water data sites in relation to past placer-mining activities. However, this approach has the potential for improving the present information base in a relatively short time, using presently available data, and without expensive field data-collection programs.

If the analysis of photographic imagery is successful in identifying past or present placer-mining features and separating them from other natural or man-induced modifications, there is the additional potential for longer term monitoring of existing placer-mining activities. High-altitude aerial photography, using U-2 and WB57-F aircraft, is presently being obtained for the entire State under a joint Federal-State program. [See State of Alaska (Division of Geological and Geophysical Surveys), Mines and Geology Bull., vol. 29 (2), 1980 (cited as Anonymous)]. These photos, along with images produced during additional future flights over specified areas, could provide a relatively economical method for monitoring large areas of the State. The location of mining activities and the extent of turbidity of receiving streams could be monitored. Obtaining this type of information through on-the-ground investigations is presently difficult at best and sometimes impossible because of manpower limitations and the remoteness of areas in which mining operations occur.



Graphs showing variations in low-water streambed elevations at selected gaging stations in the Trinity River basin, 1931 - 71 (from Hickey 1969, and subsequent streamflow data available in U.S. Geological Survey files). National Geodetic Vertical Datum of 1929 (NGVD)

[This page is a modification of figure 15 in Knott 1974]



New River at Denny, water years 1960 - 61, 1963 - 69.

[This page is a modification of figure 16 in Knott 1974]

The current historical water-quality data file of the U.S. Geological Survey contains many hundreds of water-quality analyses of samples collected in Alaska for various purposes over the past several decades. A compilation and evaluation of these data should be made in order to determine their adequacy to define base-line conditions or changes in water quality that may have resulted from past placer-mine operations. The results of this evaluation would be the basis for determining the types of additional water-quality data that should be collected as a part of the short-term and assessment studies outlined below.

## II. SHORT-TERM STUDIES INVOLVING A MINIMUM DATA-COLLECTION EFFORT AND USING EMPIRICAL SEDIMENT-TRANSPORT FORMULAS TO ESTIMATE THE EFFECTS OF PLACER-MINING ACTIVITIES

Methodologies for estimating sediment-discharge characteristics of stream systems and their capacity to transport sediment are presently available. Empirical sediment-transport formulas or models can be used to predict these characteristics; they require a minimum of field data that can be collected in a relatively short time (one or two mining seasons). Although the predictions obtained from this kind of assessment would not be strictly quantitative, they can provide a reasonable indication of sediment-transport characteristics of stream systems under varying natural or modified flow or sediment-discharge regimes.

These methodologies are extensively documented in a study of the Trinity River basin in California by Frederiksen, Kamine and Associates, Inc. (1979). The sediment load in the Trinity River basin has been affected by past and present road construction, logging, and placer-mining activities. The hydrologic characteristics of the rivers have also been changed by the Trinity River Project which was completed in 1960. Some of the techniques used to evaluate the effects of altered conditions on the flows and sediment regimes of these rivers could be applied to streams affected by placer mining in Alaska.

For a study of Alaskan streams, the method of approach might be first to select several areas in which various representative mining practices and stream types occur. Field data collection could be accomplished in one or two mining seasons and would consist of measurements of flow, channel cross-section characteristics, channel geometry, bed-material size, bank-material size, and suspended-sediment concentration and size distribution in the streams being mined and upstream and downstream of receiving tributaries. These data would provide the basis for applying empirical sediment-transport formulas to estimate the average sediment-discharge characteristics during the mining season. Concurrently, for each area data could be obtained on the mining practices used, estimated amount and particle-size characteristics of overburden, estimated amount of water used, sediment-control practices, and other pertinent information for the mining activity. From this information a relatively accurate estimate could be made of the total amount of sediment available for transport, the amounts being added to the stream system, and the capability of the stream systems involved to transport the additional sediment load. The fact that large quantities of specific constituents occur in the overburden and stream sediments being mined will not necessarily imply a large impact on the stream system. However, a knowledge of their availability will give an indication of the relative potential for changes in water quality.

## III. RIVER-QUALITY ASSESSMENT OF SELECTED BASINS AFFECTED BY PLACER MINING

A major objective of river-quality assessment is to design and develop approaches and methodologies for collecting and presenting in a timely manner water-quality information that will provide a sound technical basis for evaluating management alternatives.

The goal of this third phase of suggested studies would be to develop a mining-impact matrix as a guide for making land-management or best management practices decisions. The approach would be similar to the procedures initially developed by the U.S. Geological Survey (Rickert, Hines, and McKenzie, 1976; Brown et al. 1979). The following example of an impact matrix and its application to planning is taken from Brown et al. (1979, pp. L37, L40-L41).

Table 6.--Matrix for estimating interactive erosional impact of land-use activities with terrain properties of geology and slope, Molalla River basin, Oregon

☐ Ratings of $10^{-2}$ or less reflect low erosional impact.
▨ Ratings from $10^{-1}$ to $10^{1}$ reflect moderate erosional impact.
■ Ratings of $10^{2}$ or greater reflect major erosional impact.

| Slope (percent) |  | 0-3 | 3-7 | 7-12 |  | 12-20 |  | 20-60 |  | >60 |  |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Slope-erosional factor |  | $10^{-2}$ | $10^{-1}$ | $10^{0}$ |  | $10^{1}$ |  | $10^{2}$ |  | $10^{3}$ |  |
| Geologic group[1] |  | $V_1/V_2$ | $V_2/I_1$ | $C_1$ | $V_2/I_1$ | $C_2$ | $I_2$ | $C_2$ | $I_2$ | $C_2$ | $I_2$ |
| Geologic-erosional factor |  | $10^{0}$ | $10^{0}$ | $10^{-1}$ | $10^{0}$ | $10^{-1}$ | $10^{0}$ | $10^{-1}$ | $10^{0}$ | $10^{-1}$ | $10^{0}$ |
| Product[2] |  | $10^{-2}$ | $10^{-1}$ | $10^{-1}$ | $10^{0}$ | $10^{0}$ | $10^{1}$ | $10^{1}$ | $10^{2}$ | $10^{2}$ | $10^{3}$ |
| Land-use activity | Land-use erosional factor[3] | Erosional-impact rating[4] |  |  |  |  |  |  |  |  |  |
| Mature forest | $10^{-3}$ | $<10^{-3}$ | $<10^{-3}$ | $<10^{-3}$ | $10^{-3}$ | $10^{-3}$ | $10^{-2}$ | $10^{-2}$ | $10^{-1}$ | $10^{-1}$ | $10^{0}$ |
| Managed siliviculture or nursery | $10^{-3}$ | $<10^{-3}$ | $<10^{-3}$ | $<10^{-3}$ | $10^{-3}$ | $10^{-3}$ | $10^{-2}$ | $10^{-2}$ | $10^{-1}$ | $10^{-1}$ | $10^{0}$ |
| Forest regrowth or mixed woods and shrubs | $10^{-2}$ | $<10^{-3}$ | $10^{-3}$ | $10^{-3}$ | $10^{-2}$ | $10^{-2}$ | $10^{-1}$ | $10^{-1}$ | $10^{0}$ | $10^{0}$ | $10^{1}$ |
| Helicopter or balloon logging | $10^{-2}$ | $<10^{-3}$ | $10^{-3}$ | $10^{-3}$ | $10^{-2}$ | $10^{-2}$ | $10^{-1}$ | $10^{-1}$ | $10^{0}$ | $10^{0}$ | $10^{1}$ |
| Metropolitan (developed) | $10^{-2}$ | $<10^{-3}$ | $10^{-3}$ | $10^{-3}$ | $10^{-2}$ | $10^{-2}$ | $10^{-1}$ | $10^{-1}$ | $10^{0}$ | $10^{0}$ | $10^{1}$ |
| Orchard with ground cover | $10^{-1}$ | $10^{-3}$ | $10^{-2}$ | $10^{-2}$ | $10^{-1}$ | $10^{-1}$ | $10^{0}$ | $10^{0}$ | $10^{1}$ | $10^{1}$ | [illegible] |
| Pasture or grassland (light grazing) | $10^{-1}$ | $10^{-3}$ | $10^{-2}$ | $10^{-2}$ | $10^{-1}$ | $10^{-1}$ | $10^{0}$ | $10^{0}$ | $10^{1}$ | $10^{1}$ | [illegible] |
| Semirural (developed with light farming) | $10^{-1}$ | $10^{-3}$ | $10^{-2}$ | $10^{-2}$ | $10^{-1}$ | $10^{-1}$ | $10^{0}$ | $10^{0}$ | $10^{1}$ | $10^{1}$ | [illegible] |
| Paved roads (well maintained) | $10^{-1}$ | $10^{-3}$ | $10^{-2}$ | $10^{-2}$ | $10^{-1}$ | $10^{-1}$ | $10^{0}$ | $10^{0}$ | $10^{1}$ | $10^{1}$ | [illegible] |
| Cable logging | $10^{-1}$ | $10^{-3}$ | $10^{-2}$ | $10^{-2}$ | $10^{-1}$ | $10^{-1}$ | $10^{0}$ | $10^{0}$ | $10^{1}$ | $10^{1}$ | [illegible] |
| Powerlines (dirt maintenance road) | $10^{-1}$ | $10^{-3}$ | $10^{-2}$ | $10^{-2}$ | $10^{-1}$ | $10^{-1}$ | $10^{0}$ | $10^{0}$ | $10^{1}$ | $10^{1}$ | [illegible] |
| Cropland | $10^{0}$ | $10^{-2}$ | $10^{-1}$ | $10^{-1}$ | $10^{0}$ | $10^{0}$ | $10^{1}$ | $10^{1}$ | [illegible] | [illegible] | [illegible] |
| Orchard without ground cover | $10^{0}$ | $10^{-2}$ | $10^{-1}$ | $10^{-1}$ | $10^{0}$ | $10^{0}$ | $10^{1}$ | $10^{1}$ | [illegible] | [illegible] | [illegible] |
| Pasture or grassland (heavy grazing) | $10^{0}$ | $10^{-2}$ | $10^{-1}$ | $10^{-1}$ | $10^{0}$ | $10^{0}$ | $10^{1}$ | $10^{1}$ | [illegible] | [illegible] | [illegible] |
| Gravel roads | $10^{0}$ | $10^{-2}$ | $10^{-1}$ | $10^{-1}$ | $10^{0}$ | $10^{0}$ | $10^{1}$ | $10^{1}$ | [illegible] | [illegible] | [illegible] |
| Tractor logging | $10^{0}$ | $10^{-2}$ | $10^{-1}$ | $10^{-1}$ | $10^{0}$ | $10^{0}$ | $10^{1}$ | $10^{1}$ | [illegible] | [illegible] | [illegible] |
| Fallow agricultural land | $10^{1}$ | $10^{-1}$ | $10^{0}$ | $10^{0}$ | $10^{1}$ | $10^{1}$ | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Light construction and excavation | $10^{1}$ | $10^{-1}$ | $10^{0}$ | $10^{0}$ | $10^{1}$ | $10^{1}$ | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Temporary dirt roads (poorly maintained) | $10^{2}$ | $10^{0}$ | $10^{1}$ | $10^{1}$ | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Heavy construction and excavation | $10^{2}$ | $10^{0}$ | $10^{1}$ | $10^{1}$ | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

[1] V-Surficial, weakly coherent, alluvial deposits readily eroded by water. ($V_1$-≤3 percent slope; $V_2$-≤12 percent slope). I-Incompetent, or weakly coherent, bedrock such as shales and tuffs readily eroded by water and (or) prone to mass movement on steep slopes ($I_1$-≤12 percent slope; ($I_2$->12 percent slope). C-Competent, or strongly coherent, bedrock such as layered lava flow rocks and igneous intrusives not readily eroded by water, nor generally prone to mass movement except for rockslides and rockfalls from very steep slopes and cliffs ($C_1$-≤12 percent slope; $C_2$->12 percent slope).

[2] Product of slope- and geologic-erosional factors.

[3] See table 7 for details.

[4] Ratings are the product of land use-, slope, and geologic-erosional factors. The ratings roughly approximate the average annual order-of magnitude sediment production in tons/acre/year.

## Application to Planning

In conjunction with the erosional-depositional province map, the completed matrix provides a means for making tentative estimates of the erosional impact of human activities on various lands in the basin. The following sequence of steps provides a guide for using the map and matrix:

1. Locate the parcel of land for which a particular land-use activity, or set of activities, has been proposed.
2. Identify the province in which the proposed activity would occur and examine the prevailing patterns and land-use activities and erosional features. The existence, or absence of erosional features and their type will indicate to some degree the possible magnitude of erosional impact in terms of land deformation that would be generated by the proposed change in land-use activity.

3. Note the prevailing geologic and slope conditions for the area in question by cross referencing (a) the province (for example, $I_2$) within which the parcel of land is enclosed with (b) the geologic and slope criteria shown in table 6.
4. Enter the matrix body under the specified combination of slope, geology, and land-use activity. Note the appropriate erosional-impact number or range of numbers. An impact rated below $10^{-1}$ indicates minimal potential for erosion. Impacts in the $10^{-1}$ to $10^{1}$ range indicate that moderate to high erosion could be generated and hence that management (conservation) practices may be required. Impact ratings of $>10^{2}$ indicate that high to extraordinary erosional impacts are likely to be generated and that the proposed land-use activity should be questioned.

The erosional-impact ratings in table 6 were developed as guidelines for regional planning purposes. High impact ratings do not necessarily mean that a proposed land-use cannot be reasonably undertaken provided stringent conservation and engineering practices are applied. Final judgments as to land-use suitability, particularly for lands receiving ratings of above $10^{1}$, should be based on detailed site investigations.

This matrix was developed to look primarily at relative erosional impacts of a wide suite of land-use practices on a variety of terrain features. The impacts are defined by the order-of-magnitude sediment yield that would result from a given practice in a particular terrain unit. The development of a matrix specific to placer mining would require some modification of the original in that the components of the new matrix would be constructed to look at order-of-magnitude changes in the hydraulic and sediment-transport regimes of various stream types affected by placer mining, rather than just at sediment yields.

Initial design of the matrix would be based on the information gathered from the two suggested short-term studies outlined above. Those studies will provide the opportunity to evaluate the effectiveness of simplified assessment approaches to the Alaskan environment. They will also provide many of the data necessary to develop relationships among the effects of mining and the various mining practices, basin characteristics of mined areas, or sediment- and erosion-control practices.

The exact content and format of the matrix will depend on the results of these initial investigations. However, the design should be directed at providing the following types of information:

- Definition of a set of field data that could be easily collected in one or two days and that would become a part of the matrix for evaluating specific mining sites or mining plans.
- The sediment yield (order of magnitude) that might be expected from specific mining practices or types of material disturbed.
- The relative capacity of different stream types to transport these additional sediment loads and, indirectly, the potential for effects on fish habitat.

The success of this approach will depend to a great extent on how well the relationships necessary to define the components of the matrix can be determined and on whether the numerical values assigned to the matrix components are reliable enough to distinguish natural effects from those of different mining practices and stream types. For example, at least order-of-magnitude differences would have to be shown for sediment production in relation to different mining practices, overburden or vegetational characteristics, and basin or stream type for the matrix to be a useful tool.

The applicability and usefulness of the matrix concept for planning or management purposes could be tested by conducting an intensive evaluation in several stream systems typical of those affected by various placer-mine activities. Because this approach has not previously been attempted in Alaska, the exact scope of the study and the length of time required to produce meaningful results cannot be stated with certainty. However, similar studies by the U.S. Geological Survey in other States have been accomplished in a 3- to 4-year period. These studies have involved extensive pre-planning and coordinated input by many management and scientific agencies prior to the final impact matrix design. Although they are manpower intensive and may not be significantly less expensive than long-term data-collection efforts, they can provide useable information in a much shorter time frame.

## SUMMARY

In this evaluation of the existing information on the hydrologic impacts of placer mining, this report points out the limitations of the existing knowledge and has proposed in general terms the types of studies that could provide a better hydrologic information base. Because so little background hydrologic information is presently available for Alaska and specifically for areas now or previously mined, it is difficult to predict precisely the level of information that could be gained or the total length of time required for the proposed studies before useful results can be produced.

The proposed documentation of effects and locations of historical placer mining through the evaluation of existing data would provide considerably more information than is presently available. Results could be obtained within 1 to 2 years. This detailed evaluation of the existing historical data base would also provide the information needed to define more clearly the direction of future data-collection programs and to fill existing information gaps.

The proposed short-term studies, involving the use of empirical sediment-transport formulas to estimate the effects of placer-mining activities, may provide good site-specific information. If the areas to be studied are carefully selected to be representative of the different mining practices and stream types, the results might have transfer value to other unstudied areas. Initial results from these studies could probably be available in 1 or 2 years. The total duration of study required to provide optimum amounts of useful information will depend partly on what is learned during the initial data evaluation and on the total number of sites selected for study. The techniques and methodologies developed in a project of this type could also be applied to longer term monitoring of specific mining activities.

The basic techniques for river-quality assessment and the development of impact matrices are available and have been used successfully in other parts of the country to provide regionalized information for planning and management purposes. The application of the assessment approach to a specific land-use practice such as placer mining would be an extension of those techniques. There is, therefore, some uncertainty as to the ultimate precision to be obtained. The magnitude of effort involved in the implementation of the river quality assessment phase of the proposed studies is difficult to predict at this time. Because no previous work of the type needed for the assessment has been done in Alaska, considerable effort would have to be expended in study design prior to initiation of a project. A minimum of 6 months probably would be necessary for planning and defining objectives, 1 or 2 years for collecting and analyzing data and preparing initial reports, and 6 months for completing the analysis of data and the final reports.

We consider the three short-term studies outlined in this report to be the most reasonable approaches, collectively or individually, to providing timely hydrologic information for the evaluation of the effects of placer mining. They will not provide the quantitative information that could be gained from a long-term, detailed study of specific placer-mining activities. They will, however, provide qualitative information for management decisions needed in the near future. A total approach to the placer-mining problem should probably include a combination of both long- and short-term studies.

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