AN EVALUATION OF WATER QUALITY INFORMATION AND RECOMMENDATIONS FOR WATER QUALITY MONITORING ACTIVITIES IN AREAS OF LODE AND PLACER MINING OPERATIONS IN DENALI NATIONAL PARK, WRANGELL-ST. ELIAS NATIONAL PARK AND PRESERVE, AND YUKON-CHARLEY RIVERS NATIONAL PRESERVE, ALASKA

Prepared For
The National Park Service

By

WILLIAM J. SCHNEIDER
Consulting Hydrologist
McLean, Virginia

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I. INTRODUCTION

A. Background

Gold has been mined continuously in Alaska since its discovery in the 1860's from both lode and placer deposits. Mining claims abound in numerous mining districts throughout the state. In 1984, about 175,000 ounces of gold were produced from more than 250 mines, almost exclusively from placer operations.

In the late 1970's and early 1980's, large tracts of land were set aside and incorporated into the National Park Service. Three such areas are the Denali National Park and Preserve, the Wrangell-St. Elias National Park and Preserve, and the Yukon-Charley Rivers National Preserve. All three National Park units contain active gold-mining operations that are the center of environmental controversy over alleged noncompliance with federal and state water-quality regulations and standards. The National Park Service is currently under court order to prepare Environmental Impact Statements on the effect of the mining in these three areas.

B. Purpose and scope

This report has been prepared for the National Park Service under Purchase Order No. PX20006D043 dated April 10, 1986. It provides an evaluation of water quality information as well as recommendations for water quality monitoring activities in areas of lode and placer mining operations in Denali National Park and Preserve, Wrangell-St. Elias National Park and Preserve, and Yukon-Charley Rivers National Preserve. This information is necessary for preparation of Environmental Impact Statements (EIS) and Environmental Assessment (EA) documents being

prepared by the National Park Service in support of the Mineral Management Plans regarding mining activities in the three areas.

The evaluations are based on a determination of the minimum hydrologic data requirements necessary to meet the standards and guidelines as defined in the Alaska state water quality standards of the Alaska Department of Environmental Conservation; the EPA's proposed effluent limitation guidelines for placer mining and their effluent guidelines for lode mining; the National Park Service's 36 CFR 9A regulations governing mining and mining claims. An evaluation was made of the available database at each location to determine its adequacy for the development of necessary EIS or EA documents.

Based upon these evaluations, a water-quality monitoring program is proposed for the 1986 field season. Guidance and recommendations are provided for the development of a long-term compliance monitoring program, including both instream water quality data needs and effluent limitation monitoring needs.

II. APPLICABLE WATER QUALITY STANDARDS FOR LODE AND PLACER MINING IN ALASKA

The regulatory program for placer mining on National Park Service lands in Alaska requires action by the Environmental Protection Agency (EPA), the Alaska Department of Environmental Conservation, the Alaska Department of Natural Resources, the Alaska Department of Fish and Game, the U.S. Army Corps of Engineers (Corps), and the National Park Service (NPS). Each agency has singular responsibilities to manage separate aspects related to maintaining the quality of water affected by mining.

At the heart of the regulatory program are water quality standards, which are established by the State. Standards are made up of the use or uses that can be made of water bodies and the water quality criteria necessary to protect that use or uses. The purposes of water quality standards are to protect public health and welfare, enhance the quality of the water, and to serve the broader purposes of the Clean Water Act. The standards serve as the regulatory basis for the establishment of water quality-based treatment controls and strategies beyond the technology-based levels of treatment required by sections 301(b) and 306 of the Clean Water Act.

A. Alaska state water quality standards

Alaska's water quality criteria, when used in combination with the water use designation, constitute the water quality standard for a particular water body. The water quality standards regulate man-made alterations to the waters of the state. Water quality standards for Alaskan waters are set forth in Title 18, Chapter 70 of the Alaska Administrative Code, Register 84, January 1983. The waters in National Park Service units in Alaska are all classified for use as water supply,

the most stringent use category. As part of the Clean Water Act's antidegradation policy, the state regulations prohibit reclassification (i.e., downgrading) of uses for waters within units of the National Park Service.

Thirteen specific water quality criteria are designated under the Code to protect these waters. Three of these, turbidity, sediment and total arsenic, are of primary concern in placer mining operations.

In May, 1984, the Alaska Departments of Environmental Conservation, Natural Resources, and Fish and Game met to consider interagency guidelines for placer mining. Although no specific criteria were developed, the resulting document enunciates overall policy regarding placer mining operations and recommends a general program for State action. Several of the recommendations are currently proposed by the Alaska Department of Environmental Conservation (ADEC) as amendments to 18AAC70. Three of the proposed eleven amendments could affect the application of 18AAC70 to placer and lode mining. These are proposals to (1) extensively modify the provision for short-term variances from water quality standards, (2) clarify the wording of the mixing-zone section to emphasize that mixing zones will be as small as practical, and (3) add criteria that would be considered in deciding whether to allow a zone of deposit and require that an applicant provide information necessary to assess the criteria.

In addition to the water quality criteria under 18AAC70 cited above, an additional state regulation may apply. Under 16AAC05, the Alaska Department of Fish and Game has discretionary authority with regard to operations that might impact anadromous fish species through placement of spoil material (tailings) in streams or water bodies or in

an unstable configuration likely to erode into the water. Mining operations must take place in a manner that will not harm the anadromous fishery.

B. Federal water quality requirements

Under the National Pollution Discharge Elimination System (NPDES), permits are issued to dischargers to ensure that pollutant discharges do not violate water quality standards following the general requirements of section 402 of the Clean Water Act. In the case of Alaska, the state does not have primacy for issuing NPDES permits; such permits are issued by the EPA for all dischargers in Alaska. EPA issues the NPDES permits that contain water quality-based permit limitations which EPA believes meet the requirements of the state's water quality standards.

The Environmental Protection Agency proposed effluent limitation guidelines and standards for placer mining in November, 1985. The draft guidelines define the technology-based discharge standards that must be met by placer mining operations. The guidelines, which define best practicable technology (BPT), best conventional technology (BCT), best available technology (BAT), and new source performance standards (NSPS), establish different requirements depending on the size of the proposed placer mining operation, but all the guidelines are designed to ensure that the State's water quality criteria are met.

The four classes of operations, based on the amount of materials processed daily, are: (1) mines processing fewer than 20 yd^3; (2) all mines processing between 20 yd^3 and 500 yd^3; (3) all mines, (except group 4 below), with production of greater than 500 yd^3; and (4) large dredges operating in self contained ponds and producing more than 4000

yd^3. EPA concluded that effluent limitations for mines producing fewer than 20 yd^3 per day are not warranted at this time. As a consequence, EPA proposes that permit limitations will be developed based on the best professional judgment of the permit writer for this smallest class of operation. For the second class of operations, EPA proposes that the control technology for BPT, BCT, and BAT be simple settling ponds with a minimum six hour detention time, a discharge effluent quality of 0.2 ml/l settleable solids and a total suspended solids loading of 2000 mg/l. For the remaining two classes, EPA proposes that BCT, BPT, and BAT effluent limitation guidelines be based on total recycle of process wastewater pollutants.

At this time, it is not clear when the final effluent limitation guidelines and standards will be promulgated. Until they are published as final, the NPDES permits issued will be developed on a case-by-case basis. Permits issued in 1986 contain effluent limitations for turbidity, settleable solids and total arsenic. Generally, a turbidity increase in the receiving water of only 5 NTU (nephelometric turbidity units) above the background is allowed. However, if the operation can provide the EPA with discharge information for the receiving water, higher turbidities in the effluent may be allowed, if dilution is adequate so that the turbidity of the receiving water (below the mixing zone) is not increased above the 5 NTU limit (personal communication, USEPA, 28 Aug 86). The criteria for settleable solids in the effluent is an instantaneous maximum increase of not more than 0.2 ml/l. Additionally, the total arsenic concentration of the effluent is not to exceed 0.05 mg/l.

In addition to NPDES permits, placer mining operations are sometimes required to obtain permits from the Army Corps of Engineers under section 404 of the Clean Water Act. That section deals with the discharge of dredge or fill material into the waters of the United States. The Corps issues the section 404 permit, subject to certification by the State that State water quality standards will be met.

C. National Park Service regulations

All mining operations in units of the National Park Service are required to comply with the requirements of 36 CFR 9A which implements the Mining in the Parks Act. The regulations require, among other things, that operators prepare and submit plans of operation for NPS approval. Before the Regional Director of NPS may approve a plan of operation, he must assure that the applicant has taken all steps necessary to comply with applicable Federal, State or local laws or regulations. For placer mining, this often includes both an NPDES and a section 404 permit. The applicant must also clearly set forth his proposed operating methods and outline his plans for protecting the resources of the park during mining. In addition, the plan requires the operator to describe his plans for reclaiming any lands disturbed in the course of his operations.

Each of these regulatory requirements is designed to ensure that placer mining operations do not adversely affect natural resources that are of national significance. Both the Mining in the Parks Act and the Clean Water Act were passed to ensure that activities permitted or

licensed by the Federal government would not result in degradation to the environment.

III. EVALUATION OF EXISTING WATER QUALITY DATA

Presently available water quality data from mining areas in the three units of the National Park Service have generally been obtained for three specific purposes: (1) background data and subsequent monitoring at active mining sites, (2) hydrologic data for National Park Service planning efforts, and (3) background data for preparation of the proposed EPA regulations for placer mining under Federal Statutes 40CFR440 (now pending). By far, the largest water-quality data base exists for Denali National Park and Preserve; almost no data exist for either Yukon-Charley Rivers National Preserve or for Wrangell-St.Elias National Park and Preserve.

A. Denali National Park and Preserve

Because of the prominence of Mt. McKinley, the relative accessibility of the area, and the extent of mining in the Kantishna and Dunkle areas, a significant amount of water quality data are available. Almost all available data relating to mining activities are from the Dunkle and Kantishna areas.

Reports by Deschu (1984, 1985a), Deschu and Kavanagh (1983), May (1979), Sexton (1982, 1984), West (1982), and West and Deschu (1984) describe water quality data activities in the Kantishna area. In addition, a report by Solin and Harrold (1984) describes the physical characteristics of both mined and unmined streams in the Kantishna area. Available data are summarized in a report by Deschu (1985b) and in the Final Environmental Impact Statement for the Kantishna Hills/Dunkle Mine Study Report (National Park Service, 1984).

Limited data are available for lode mining areas. In 1983 and 1984 water quality information was collected in lode mining areas along Slate Creek and Stampede Creek (Nancy Deschu, National Park Service, personal communication). Additionally, during 1985, data on heavy metals were obtained on six separate occasions at six sites in the vicinity of the antimony mining operations in the Slate Creek and Eldorado Creek basins of the Kantishna area (Dr. Mark Oswood, University of Alaska - Fairbanks, personal communication). This heavy metal sampling was part of a study of the effects of antimony mining operations on the aquatic biology. Although the field samples were not collected by standard field methods, the laboratory analyses followed standard procedures which should render the results usable as background data.

The data base available at the time, provided for an adequate assessment of water quality in the 1984 Final Environmental Impact Statement for the Kantishna Hills and Dunkle Mine areas of Denali National Park and Preserve. Additional field studies in 1985 further strengthen this data base. While water quality information in other areas of Denali National Park and Preserve is sparse, the water quality data base for the Kantishna Hills and Dunkle Mine areas is generally adequate for the overall assessment of water quality in areas of lode and placer mining. However, the collection of site specific data in 1986 will greatly enhance the accuracy of Environmental Assessments/Environmental Impact Statements focused upon specific operations or stream segments. Also, discharge information for the major water courses of this area is sparse. An effort should be made to collect as much discharge information as possible in conjunction with

any additional field monitoring, and consideration should be given to establishing continuous recording discharge stations at key locations.

B. Wrangell-St. Elias National Park and Preserve

Except for turbidity measurements made at 28 sites in 1984 and 34 sites in 1982, no other measured data on water quality are available for areas of mining claims. There is no adequate data base for a water quality assessment at this time.

C. Yukon-Charley Rivers National Preserve

Some measurements of water quality were made in 1974-1975 as part of limnological studies in the area. Thirteen parameters, mostly of limnological interest, were measured on eleven streams in the Charley River Basin. No measures of turbidity or sediment were obtained (Young, 1976), nor do the data document effects of mining on water quality. The current data base is inadequate to document these effects.

IV. RECOMMENDED PROGRAM FOR 1986 FIELD SEASON

A. Rationale

There is currently a reasonable data base on the effects of mining on water quality in Denali National Park and Preserve. No such data base exists for either Wrangell-St. Elias National park and Preserve or Yukon-Charley Rivers National Preserve. Of immediate concern is the need for such data in the preparation of Environmental Impact Statements currently underway for all three areas. Efforts for the 1986 field season should be directed, insofar as possible, to extending the site specific data base in Denali National Park and Preserve and acquiring baseline data in both Wrangell-St. Elias National Park and Preserve and Yukon-Charley Rivers National Preserve. Detailed field inspection of streams in both Denali and Wrangell-st. Elias indicate clearly that direct extrapolation of available water quality data from Denali to Wrangell-St. Elias is not feasible, primarily because of the background sediment load of streams in Wrangell-St. Elias from glacial runoff. However, because streams in Yukon-Charley tend to be clear and free of glacial sediments, extrapolation from the data base at Denali to Yukon-Charley is possible. This possibility is enhanced by the generally similar physiographic characteristics of the latter two areas.

Efforts in Denali National Park and Preserve should be directed towards two objectives. First, additional site specific data is needed to expand and reinforce the available data base in the preparation of EA/EIS documents. Secondly, an attempt should be made to monitor the impact of major storm events on sediment loading from placer mining spoil banks. Because of the scarcity of information, this season's

efforts at Wrangell-St. Elias National Park and Preserve and Yukon-Charley Rivers National Preserve should be directed towards collecting background data in the general vicinity of mining claims.

Active mining during the 1986 field season should also be monitored, both for compliance with regulations and for additional data on active mining operations.

B. Water quality parameters

Those water quality parameters directly associated with mining activities should be emphasized in the overall data collection program. Of prime importance in placer mining are turbidity, total suspended solids, and settleable solids. Because of its toxicity and presence in the placer deposits, arsenic should also be measured. Occasional determinations of other heavy metals should be obtained for general background information. Water temperature, pH, specific conductance, and dissolved oxygen should also be determined.

In areas of lode mining, emphasis should be placed on the mineral being extracted and those closely associated with the deposit. Discharge should be determined for each set of water quality parameters by standard methods with a velocity meter, or when this is not possible, an accurate as possible estimate of discharge should be made.

C. Field and laboratory procedures

Several of the recommended water quality parameters can be directly determined on-site; others require laboratory procedures, some of which can be performed at a field camp while others will require sophisticated laboratory procedures. Full descriptions of field methods for the

measurement of sediment and for the collection and analyses of water samples are given in Techniques of Water Resource Investigations of the United States Geological Survey (Book 3, Chapter C2 (1976) and Book 5, Chapter A1 (1974)). Additional field and laboratory methodology are presented in Standard Methods for the Examination of Water and Wastewater (APHA, 1985), National Handbook of Recommended Methods for Water Data Acquisition (USGS, 1977) and draft sampling procedures utilized by Nancy Deschu in earlier water quality sampling for the Alaska Regional Office (NPS). These sources provide the necessary guidance to ensure both accuracy and acceptability of results.

In this summer's program, it is suggested that water temperature, specific conductance, pH and dissolved oxygen be determined directly on site. Turbidity and settleable solids may be determined directly on-site or within 24 hours at the base camp. Total suspended solids, arsenic and heavy metals analyses require special laboratory procedures and will have to be sent to Anchorage or Fairbanks for analysis. Care should be taken to assure that containers, preservatives and holding times conform to EPA procedures documented in the Federal Register (49:209, 1-29, 26 October 1984).

For affected waters with turbidities in excess of 100 NTU, careful dilution will be necessary. Serial dilution is recommended, using Gilson microliter precision pipettes and volumetric flasks.

Water samples for laboratory analysis are collected directly in the stream. In shallow streams, two acid washed, one liter cubitainers may be used for a single grab sample. In water deeper than 0.75 m it is recommended that a depth integrated sample be taken. Depth integrated samples are collected in standard one pint bottles mounted in a sediment

sampler. Properly taken, they will represent a composite for a vertical profile of the stream.

Usually a water quality sample taken at midstream is sufficient if both the cross-section and flow are relatively uniform. The sampling site, however, should be selected where velocity is strong and pools are to be avoided. Care should be exercised when sampling below an actively-mined site to ensure that adequate mixing has occurred. These samples should be taken approximately 500 feet downstream from the point source of discharge from the mining operation. If mixing has not occurred, as evidenced by a visible plume of discharge, multiple samples should be taken - some in the plume itself and others in the clear section of the stream. Field notes and photos should also be used to document the extent of the plume.

Since sediment loading from spoil piles, natural sources and inactive mining sites is probably greatest during periods of peak runoff, sampling during storm events is important. For sampling during unattended storm events, a bank of single-stage samplers similar to the US-U-59 is necessary (Federal Interagency Sedimentation Project, 1986). The number of samplers necessary at a site will be determined by the anticipated rise in stage during the storm event. They should be mounted in a sturdy manner in the stream channel.

Field techniques for water quality sampling were recently demonstrated to appropriate National Park Service personnel at a Water Quality and Placer Mining Training Course held in Anchorage, Alaska on May 13-16, 1986.

D. Data collection program

The following program is designed to provide a maximum of data obtainable in a short field season limited by weather conditions, access, and logistics, and is considered a realistic effort.

In the following discussion, the term "sediment" refers to both settleable solids and total suspended solids, and the term "in-situ parameters" refers to water temperature, pH, turbidity, and dissolved oxygen. Determination of total recoverable metals is recommended for conformance with presently proposed regulations for placer mining.

The following program is proposed for Denali National Park and Preserve.

1. Sediment and turbidity should be measured both above and below the general mined areas on the following streams:

   Caribou Creek

   Glacier Creek

   Moose Creek

   Slate Creek

   Glenn Creek

   Eldorado Creek

   Stream conditions should be described qualitatively. This should include water color; a description of pool and riffle characteristics in the vicinity; a general description of the floodplain / valley conditions, including physical characteristics and streambank vegetation; and a description of bottom materials (boulders, gravel, silt, etc.).

The site locations for measurements should be those previously used by Deschu (1984, 1985a). Assistance in locating the specific sites may be obtained from Nancy Deschu, presently working out of the NPS Alaska Regional Office in Anchorage.

If additional time and resources should become available, this recommended sampling program could beneficially be extended to other sites previously measured by Deschu. Of particular importance in this series of site measurements is the determination of total suspended solids, which has not been previously measured.

2. At two locations, water samples should be obtained, using remote samplers, during one or two storm events for measurement of both sediment and turbidity. Recommended sites include an undisturbed stream (to be selected) and Caribou Creek at the Koppenberg placer mine (a site of stable spoil banks). Remote samplers should be mounted to sample at two depths, approximately 0.5 and 1.0 feet above the normal water level at the time of installation. Care must be exercised in the collection and transport of the samples to ensure laboratory analysis within seven days of collection. Samples should be obtained both above and below appropriate reaches of streams.

The following program is proposed for Wrangell-St. Elias National Park and Preserve.

1. Baseline data should be collected to the extent possible in the areas of placer and lode claims, including Dan Creek, Chititu Creek, Rex Creek, and Calamity Gulch. Specific site locations will be governed by access in some of the narrow valleys. Sampling should follow a program similar to that accomplished by Deschu (1984, 1985a) in Denali National Park and Preserve. Measurements should include in-situ parameters, discharge, sediment, and turbidity. Qualitative descriptions of stream and flood plain conditions such as those proposed for Denali National Park and Preserve, should also be recorded. Selected samples should be forwarded to a certified laboratory for a full-scan ICP analysis for total recoverable metals, with additional analyses for low concentrations of arsenic and mercury. Because of the current limited data base, emphasis during this field season should be placed on geographic coverage rather than repetitive sampling.

2. At the time of this report, a cyanide leaching demonstration project is in the planning stages for the Nabesna District of Wrangell-St. Elias National Park and Preserve. The initial permit application submitted to the National Park Service did not propose water quality monitoring, but subsequent discussions were held between the NPS and applicant during which a water quality monitoring regime was agreed to. Monitoring will occur from a valve that will access a network of drainage channels underneath the leach pad. Under ideal

operation, no water from the leaching operation should reach these drains. However, if water is collected at the monitoring valve, a sub-sample of the collected water will be sent to a laboratory where the concentration of cyanide will be determined.

In addition, three shallow monitoring wells will be constructed down-gradient from the leach pad and a fourth well will be located downgradient from the tailings pile. This network should be adequate to assess potential infiltration of cyanide solution to the groundwater in the vicinity of the leaching operation.

The following program is proposed for Yukon-Charley Rivers National Preserve.

1. A program similar to that for Wrangell-St. Elias should be followed to obtain baseline data, particularly in the vicinity of existing patented claims on Woodchopper Creek.
2. Similar baseline data should also be obtained in the vicinity of mining claims identified in the July 1982 as "Coal Creek above Discovery" and "Coal Creek 21." If additional time and resources should become available, baseline measurements should be made to the extent possible in the vicinity of mining claims on other streams. Consideration should be given to Thanksgiving Creek, Sam Creek, Ben Creek, and Fourth of July Creek.

Water quality determinations should include the in-situ parameters, discharge, sediment, turbidity and total recoverable metals. In

addition, qualitative descriptions of stream conditions, flood plain characteristics and riparian zone vegetation should be made, as well as any appropriate fisheries surveys.

V. LONG-TERM DATA COLLECTION AND MONITORING

A. Objectives

The goal of the National Park Service in water resources should be to preserve and protect the high-quality waters of the national parks as much as possible. In Alaska, where placer mining may occur under approved plans of operation, adequate water-quality monitoring will be necessary. Basically, two components of such monitoring will be required.

The first component is to ensure compliance with federal and state regulatory requirements for water quality. However, enforcement of these water quality standards is primarily the responsibility of the U.S. Environmental Protection Agency and various state agencies, including the Alaska Department of Conservation, the Alaska Department of Natural Resources, and the Alaska Department of Fish and Game. Because of its continuing role in overseeing permitted mining operations, the National Park Service is able to detect early warning signs of potential water quality problems and work cooperatively toward rapid elimination of such potential problems or refer more serious problems to appropriate enforcement agencies for correction.

The second component is to provide the necessary data for assessing, to the extent possible, the long-term cumulative impacts of mining on water quality.

Cumulative impact assessment is, at best, an inexact science. Any major man-made disturbance can result in significant changes to both terrestrial and aquatic systems. When the impacts of one source of disturbance overlap with those of another, sometimes the overall impact may be greater than that of the individual disturbances alone. One

component of cumulative impact assessment relating to placer mining perations is water quality. Not all constituents in a typical water quality survey will be affected by mining. However, sediment loading, transport, and deposition are influenced by mining, and it is probable that they may be one of the important components of an overall cumulative impact assessment.

B. Recommended long-term data collection and monitoring strategy

The following suggestions and recommendations are provided to assist the National Park Service in developing an overall program for achieving the goal of protecting the high-quality waters of the National Parks.

In order to reinforce the data base currently being acquired during this field season, additional water quality data for both Wrangell-St. Elias National Park and Preserve and Yukon-Charley Rivers National Preserve should be acquired during the 1987 field season. This data collection program should be similar to the 1986 program, with emphasis on mining areas. Priority should be given to active mining areas, if any, with additional concentration on both previously-mined areas and undisturbed areas with mining claims. Exact locations and parameters can best be determined after analysis of data obtained this year.

In addition, periodic measurements of sediment and turbidity will be required at all placer mining locations above and below the mining activity in all three national parks. The necessity for heavy-metals monitoring largely will be a function of the control of particulates at the site of the mining operation. If sediments can be controlled within regulatory standards, and the pH values of the streams are not lowered

by mining or other activity, monitoring for heavy metals will not be necessary. However, if cumulative mining activities along a given stream appreciably increases the cumulative sediment load above natural background levels or significantly lowers the pH of the stream, monitoring for heavy metals will be required.

The determination of long-term cumulative mining impacts on water quality presents a much more difficult and complex problem. A review of methodologies for sediment transport indicates that none are directly applicable to areas of placer mining. Neither U.S. Forest Service studies on sediment yields from logged watersheds nor U.S. Geological Survey laboratory studies on sediment transport can be directly extrapolated to the disturbed streams in the three national parks. However, potential relationships of sediment transport with stream hydraulics and channel geometry offer promising avenues of investigation. Stream hydraulics and channel geometry have been shown to exhibit unique relationships with flow characteristics in certain areas. Facets of sediment transport, such as concentration and particle size of suspended sediment and weight and size distribution of bedload material, can be related to streamflow and aspects of channel geometry, such as channel slope, channel width, water surface gradients, and flow velocities.

The development of such a relationship could provide the basis for a mechanism that predicts the cumulative impacts of placer mining on water quality under various sets of mining scenarios. The development of such a mechanism appears to be the most reasonable approach to the difficult and complex problem of determining the long-term cumulative effects of placer mining on the water quality streams in the three

national parks. The design and implementations of such studies will require the expertise of a specialist in both sediment transport and channel geometry. In the development of a predictive methodology, consideration should be given to the logistics and cost of detailed field measurements of remote sites, which essentially precludes extensive data surveys over lengthy reaches of streams.

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