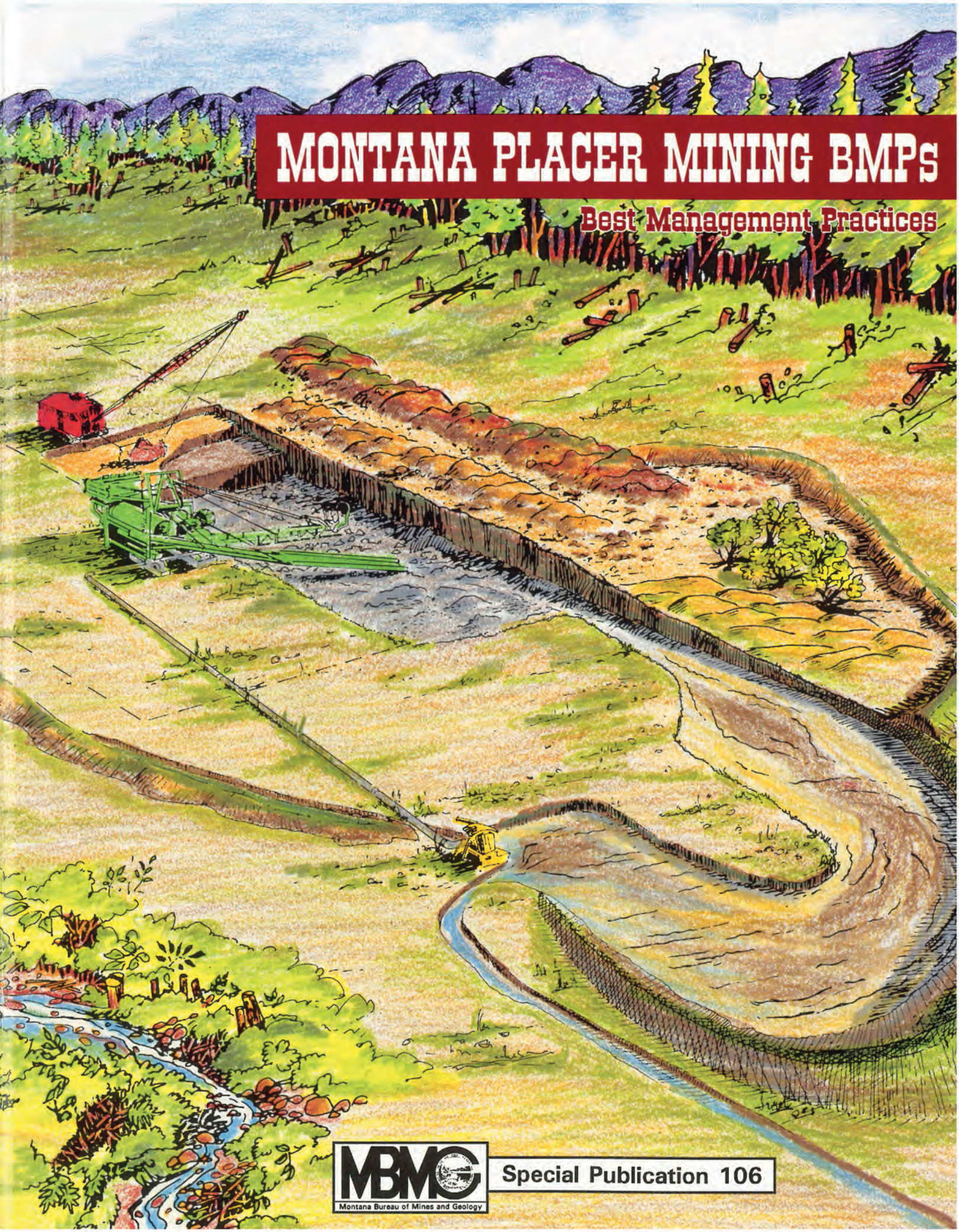


MONTANA PLACER MINING BMPs

Best Management Practices

MBMG
Montana Bureau of Mines and Geology

Special Publication 106

NOTE: The information presented herein was based on laws, regulations, best management practices, and contact information applicable in 1993. The reader is encouraged to contact the appropriate agencies for the most recent updates.

Special Publication 106

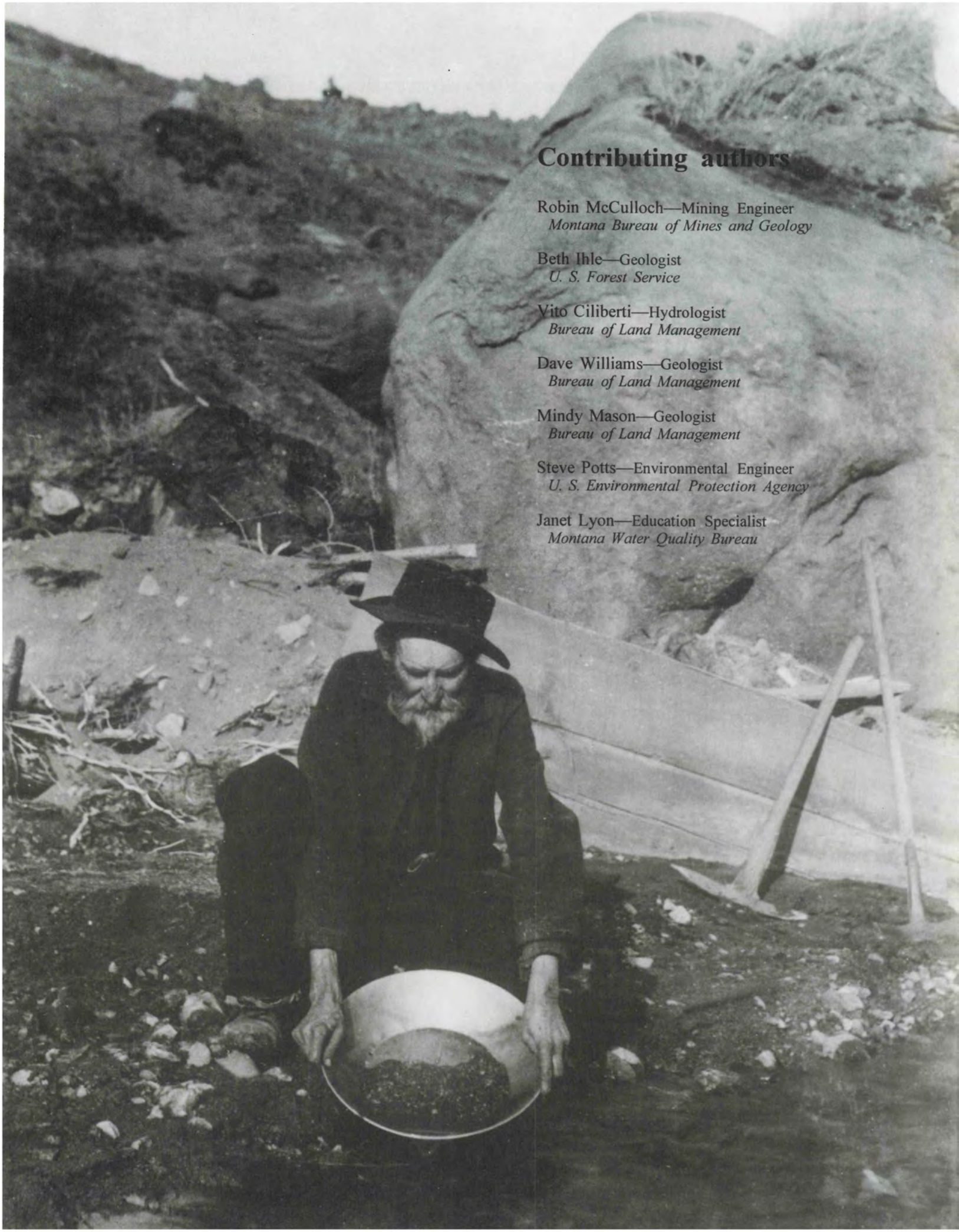
MONTANA PLACER MINING BMPS

(Best Management Practices)

Guidelines for Planning, Erosion Control, and Reclamation

Prepared in cooperation with the
U.S. Environmental Protection Agency
and
Montana Department of Health and Environmental Sciences—Water Quality Bureau

1993



Contributing authors

Robin McCulloch—Mining Engineer
Montana Bureau of Mines and Geology

Beth Ihle—Geologist
U. S. Forest Service

Vito Ciliberti—Hydrologist
Bureau of Land Management

Dave Williams—Geologist
Bureau of Land Management

Mindy Mason—Geologist
Bureau of Land Management

Steve Potts—Environmental Engineer
U. S. Environmental Protection Agency

Janet Lyon—Education Specialist
Montana Water Quality Bureau

This publication describes Best Management Practices (BMPs) that placer miners can use in arid to semi-arid, alpine and subalpine environments to prevent or decrease environmental damage and degradation of water quality. They are effective methods that must be planned in advance. Planning will help to limit damage to streamside areas, and reduce the amount of time and money spent. Planning is important even if an area was previously mined. Using **BMPs**, it is possible to make a profit, protect water quality and the environment, and operate within the confines of laws and regulations. Techniques discussed in this publication are not totally applicable to permafrost environments.

CONTENTS

Preface

This publication is designed to provide basic instruction, guidelines, and technology to placer miners and regulatory agencies. It will also inform the public about placer mining operations.

For those interested in placer mining, this publication will assist in the following:

- Identifying the economic potential of placer deposits.
- Planning mining operations.
- Utilizing operational techniques to protect water quality.
- Designing the reclamation of land and streams (if disturbed) to minimize costs while restoring the mined area to comparable uses of the adjacent lands and establishing proper ecosystem functions.
- Permitting.
- Securing professional assistance.

All sections of the publication were created with consideration given to engineering, economics, environment, laws, regulations, and the reality of accomplishment. If a task was determined to be unrealistic, alternative methods were considered.

Guidance and technology were provided by the Montana Placer Mining Advisory Committee. The members represent placer miners, environmental groups and consultants, as well as state and federal agencies that regulate the placer industry. It was their intention to make this document instructive and easily understood. Although each section could be a separate publication, the presentation was designed to be brief and informative, and to provide sources for professional assistance.

The inspiration for this project was provided by the *Montana Forestry BMPs*, issued by the Montana Department of State Lands, in cooperation with the Montana State University Extension Service. Assistance from Tom Brady and Lewis Martin of the U. S. Bureau of Mines, Spokane Research Center, was very helpful. Their research of placer problems in other states provided valuable insight into potential solutions. Funding for preparation of this publication was provided by the U. S. Environmental Protection Agency. Printing costs were provided by the Water Quality Bureau of the Montana Department of Health and Environmental Sciences.

Appreciation is also extended to the U.S. Forest Service and the Bureau of Land Management who reviewed drafts of the report and provided helpful suggestions. Special credit for the concept and format goes to Robert Logan, Montana State University Extension Service and Bud Clinch, Montana Department of State Lands. An additional note of appreciation is made to Sheri Medow Smith, formerly of the Montana Department of State Lands (Forestry Division), for her cooperation and assistance in the use of color separations from the *Montana Forestry BMPs*. The artwork is attributed to the talents of Elaine Locati of Butte.

Robin McCulloch
Mining Engineer

September 10, 1993
Butte

I WHY PROTECT WATER QUALITY ?

Placer mining has occurred in Montana since the 1850s. Historically, mining operations were conducted with little regard to the effects on ecosystems and especially streams and fisheries. Today's placer miners must consider water quality and stream environments since excessive runoff and sedimentation can lead to:

- **Increased filtering costs for drinking water.**
- **Clogged irrigation systems.**
- **Increased flood potential.**
- **Reduced fish populations.**
- **Downstream erosion, sedimentation, and channel instability.**

Ephemeral and **intermittent gullies**, which are most often dry, can be a significant sediment source to live streams during infrequent flow periods. Disturbed soils will be carried downhill during heavy rainfall or snowmelt.

Intermittent channels have alternating dry and flowing reaches. Whether wet or dry, intermittent channels have washed gravel bottoms and defined banks. Soil disturbance during the dry periods may result in soil transport to live streams during the wet season.

The **riparian** area (or "green zone") around streams, lakes, reservoirs, springs, and seeps is the area of active vegetative growth during summer months. Riparian areas contain wet soils, high water tables, and water-loving plants such as alder, willow, cottonwood, cedar, and spruce.

Perennial streams flow continuously. Sediment from ephemeral areas during periods of flow can be deposited in perennial streams causing downstream impacts. Erosion must be controlled in all mining operations to prevent impact to perennial streams.

Placer activities may also cause downstream impacts which affect wildlife that are dependent on stream environments to survive.

Watersheds collect water from rain and snow and funnel it through a network of smaller stream channels to downstream channels. Watersheds also contain wetlands which include seeps, springs, wallows, marshes and bogs. Some of these wetlands drain into streams. Since placer mining occurs in or around these areas, there is a potential for sediment from the mining operation to wash into streams.

Placer mining and its related activities can have minimal temporary impacts upon watersheds if planned and conducted with careful regard to water quality. In previously mined areas, the following techniques may be the only cost effective means to reclaim the environment.

What's wrong with sediment in streams?

(Reprinted from Montana Forestry BMPs.)

Trout and other fish reproduce by burying their eggs in streambed gravel. The eggs develop in the gravel and hatch into "sac fry". When the yolk or sac is absorbed, the young fish emerge from the gravel. "Sac fry" and young fish can be choked by sediment. When too much sediment falls to the stream bottom, it fills the gaps between the gravel and suffocates the fish. The streambed becomes cemented over. This tomb of sediment traps the young fish without clean water, oxygen, or food. For those fish that survive, the sediment has an abrasive effect on their sensitive gill tissue.

Ray Tillman

Sport fishing is enjoyed by thousands of Montanans, and generates substantial revenues.

Sediment also kills aquatic insects and algae (the major food for fish), fills in resting pools, and interferes with recreation. Excessive sediment in streams settles out and forms deposits which can destabilize channels and lead to additional bank erosion. This may result in reduced fish populations.

IT'S THE LAW!

Impacts to the environment by placer mining are regulated by the Montana Mine Reclamation Act, the Montana Environmental Protection Act, the Montana Natural Streambed and Land Preservation Act, and the Montana Water Quality Act. Further protection is provided on federal land by 43 (CFR) 3809 for the Bureau of Land Management, 36 (CFR) 228 for the U.S. Forest Service, and the Federal Clean Water Act.

It is possible to comply with these laws and regulations, but you must plan well and conduct operations with careful regard to water quality. Preplanning will allow you to:

- Avoid water-quality violations.
- Minimize environmental impacts.
- Maximize profits.
- Reclaim the land for uses comparable to those of adjacent undisturbed parcels.
- Establish proper ecosystem functions.

Accomplishment of these goals are possible when **BMPs** are incorporated into the operation. They are techniques that are currently available, simple to use, and highly effective in limiting the risk to you and the environment.

II IS IT A MINE, OR JUST A DEPOSIT ?

Placer deposits are the most complicated and unpredictable of all mineral deposits. Understanding and evaluating the deposit is **critical** to the success of your operation. Costs of reclamation must be planned and factored into the cost of the operation. Premature mining on an uneconomic deposit will be financially disastrous and may destroy the chances for a profitable venture. A partially or improperly mined deposit may be uneconomic to remine for decades.

Before mining, be sure you develop an appropriate exploration plan. Protect yourself, the deposit, and the environment by testing the deposit first! Read available materials and take courses on mining techniques to minimize mistakes and excessive startup costs (*see references*).

Sampling and testing

Sampling and testing is inexpensive to bond, is easy to reclaim, and consumes less time than bankruptcy court. **Apply for your exploration permits NOW!** *(See Part VII.)*

Panning is adequate for small-scale activities (less than one cubic yard per day). Panning is not going to provide adequate testing for a project where heavy equipment is going to be used. Any ground-disturbing exploration activities will require permits *(see Part VII).*

Although drilling will allow you to determine the gold content of deep gravel deposits, grades exceeding $35/yd^3$ (@ $380/Troy oz) for a 5-foot-thick pay zone may be necessary for over 50 feet of overburden. Thus, drilling beyond that depth should be justified. Pay gravel depths for economic deposits can be expected to be less than 30 feet and preferably less than 20 feet.

U. S. Bureau of Mines

Drilling is expensive. Deposits containing coarse gold may not be assessed accurately by this method as the recovered sample is usually quite small. Most near-source placer deposits have spotty values and must be analyzed using large samples on close intervals. Deposits that are distant from the source may be more evenly dispersed, have smaller sized gold particles, and be more easily evaluated using drilling techniques.

Trenching (or test pits) will give you an understanding of mining conditions and limitations while allowing you the flexibility to choose a sample size matching the deposit characteristics. Vertical sample intervals of 5 feet or less will allow you to determine whether the gravel is overburden (insufficiently mineralized to pay a profit after operating costs) or pay gravel (gold-bearing gravels containing economic values). Gravel thicknesses of more than 20 feet and ground water near the surface may make trenching difficult or impossible.

Follow drilling or trenching with a small (10 - 100 yd^3) bulk sampling program to verify the results of the testing program. This will allow for testing the deposit, mining methods, and recovery equipment. A typical sample usually does not exceed a few hundred cubic yards of gravel.

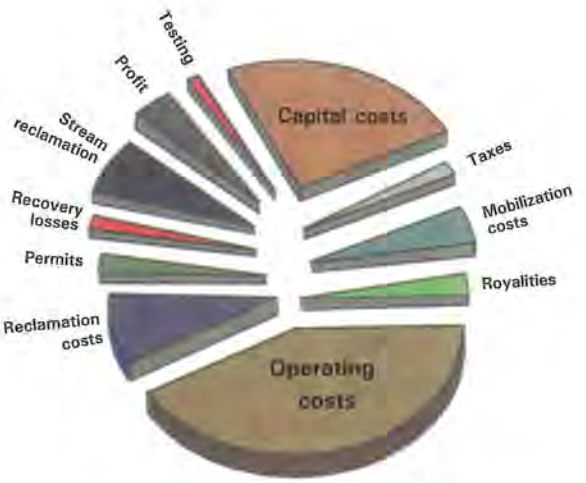
Project feasibility

After you sample the deposit, you should assess the following:

- The **amount of gold** in each gold-bearing gravel layer and thickness of each of the layers.
- The **volume of gold-bearing gravels.**
- **Mining difficulties** such as high ground water, high boulder content, overburden expansion, high bedrock strength and gravel compaction, and stormwater flow considerations.
- **Washing problems** such as high clay content, cementation, high boulder/cobble ratios, settling fines out, high black sand volumes, water availability, and surplus water disposal.
- **Reclamation factors** such as stream reclamation and riparian area restoration, soil depth, regrade costs, expected seed and fertilizer costs.
- **Permitting costs** and time delays while waiting for permits.

Carefully consider your options.

It is time to determine if this deposit can yield enough mineral value to cover costs and make a reasonable profit. **Extra costs of altering a stream unnecessarily may make the difference in whether or not a deposit is profitable.**



Obligations for gold values contained in the deposit.

Determining the economics of a deposit is difficult if you lack experience in placer mining. Assistance in determining your mining costs is available through:

Montana Bureau of Mines and Geology
1300 West Park Street
Butte, Montana 59701-8997
(406) 496-4171

U.S. Bureau of Mines, W.F.O.C.
E. 360 Third Ave.
Spokane, Washington 99202
(509) 353-2712

If the deposit is not economic at this time, then it is in your best interest, and the best interest of the environment and the deposit, to NOT MINE until economics or technology will allow a profit to be made.

APPLY FOR MINING PERMITS NOW!

Once the deposit has been proven to be economic and you decide to mine, you should contact the permitting agencies at the earliest possible time. It can take from several months to three years to obtain necessary permits (depending upon the nature and complexity of the mining operation). A list of permitting agencies and permitting requirements is included *(see Part VIII)*.

III PLAN BEFORE YOU MINE

Reclaimed placer bench in western Montana (Kennedy Creek). Wetland near road was the site of old settling pond.

Reclaimed stream in western Montana (Elk Creek).

On federal land, agency personnel will have to complete an environmental assessment. This will include an archeological study and the effect your project will have on wildlife, recreation, and other uses of the land. This will take **at least 30 days.**

Pre-mining site assessment

Reclamation of most lands and streams disturbed by mining is required. Think about reclamation when planning and assessing a site before mining! Reclamation of previously undisturbed mine sites must return the landscape, streams (if applicable) and riparian areas to proper functioning conditions. Mining of previously disturbed or historically mined sites should create stable, non-erosive landscapes and naturally functioning stream channels after mining. Obtain reclamation guidance from appropriate agencies when planning your mine.

Document the pre-mining condition of the site. Take photographs before mining. Mark the photo site locations so they can be compared when reclamation is completed. Collect a water sample downstream from your proposed mining area.

Determine the thickness of soil, overburden and pay gravel depths; also identify native grasses, shrubs and trees. Plan for use of shrubbery clumps in reclamation. Plan the best location for roads, soil stockpiles, settling ponds, and other mine facilities.

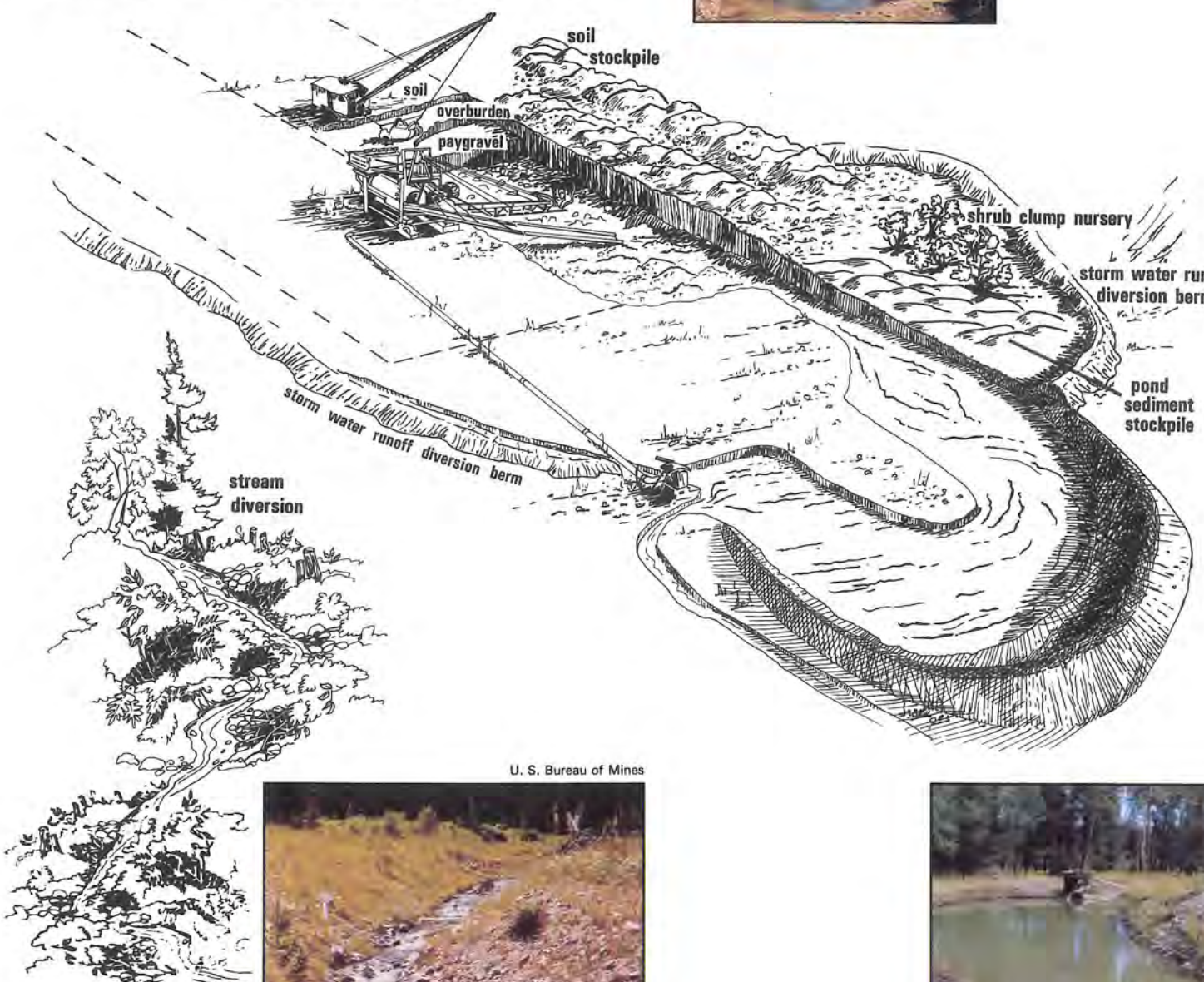
U.S. Bureau of Mines

Establish photo points.

Assess drainage, snowmelt and stormwater runoff. The watershed size, climate, topography, soil infiltration, and slope elevation all influence runoff and snowmelt. Collect climatology data (where possible) on local storm events (cloudbursts, chinook thaws, flash flood potential, avalanches) and the historic range of snow depths in the area. These data are usually available through local land management agencies (SCS, BLM, USFS). They will assist in water handling and treatment design and maintenance, in addition to stream design. Prevent site erosion through drainage and use of erosion control. **Divert surface waters and runoff from undisturbed land to flow around, not through, the site.** Plan and size berms, dikes and interceptor trenches to handle storms and snowmelt. Stabilize disturbed ground to minimize erosion using grass seed, erosion control blankets, hay bales, or other agency approved techniques. **Sediment from storm events is your responsibility. Divert clean water around your site, and keep silt-laden water on site until it can be treated for proper release. You should have your Stormwater Discharge Permit at this time** *(see Part VII)*.

U. S. Bureau of Mines

Better gold recovery will be achieved if you work in a dry condition. Determine the ground-water level and flow rates at the mine site. Plan trenches to drain off excess ground water.



U. S. Bureau of Mines

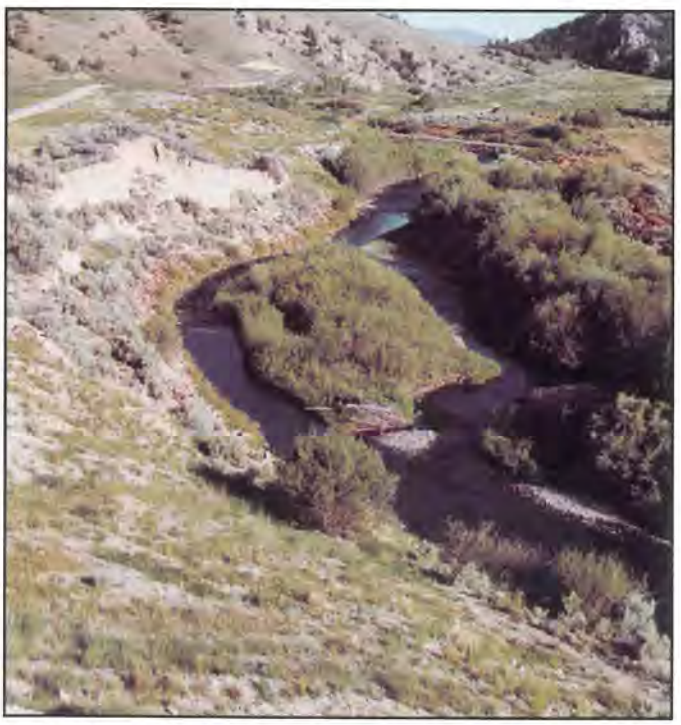
Divert surface waters and runoff from undisturbed land around the site.

Direct ground water from dewatering operations and runoff from disturbed lands to the settling pond.

Is stream disturbance necessary?

When natural streams are disturbed, reclamation becomes much more difficult and expensive. Be sure that extra gold recovery from mining the streambed will pay for the significant additional cost of stream reclamation. Reclamation of the smallest streams will require a bond ranging from $20 to $25 per linear foot of stream. Larger streams will require a larger bond. There are also additional permitting and regulatory requirements when streams are disturbed.

It makes sound business sense, and simplifies mine water handling and reclamation to leave natural streams and streamside vegetation undisturbed. It is often more profitable to mine dry benches and flood plain areas instead of stream channels.



Undisturbed stream with reclaimed placer operations on benches above.

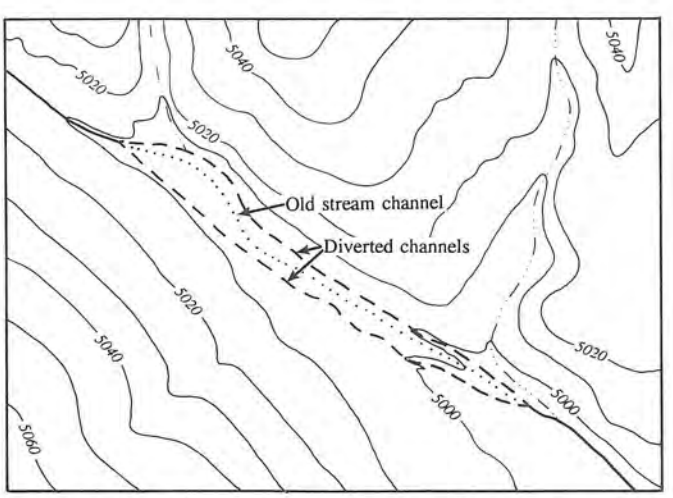
If sampling/testing shows that there is sufficient gold to pay for the extra costs of stream reclamation, then be prepared to construct a stable stream diversion that will not erode. The diversion should be capable of handling storm events and snowmelt. Be prepared to reconstruct a natural functioning stream channel and to revegetate riparian areas.

Stream reclamation planning and site assessment is a complex subject. A step-by-step approach to data collection, field measurements, planning and design is included in the *Handbook for Reclamation of Placer Mined Stream Environments in Western Montana*, Inter-Fluve, Inc. 1991. Available from:

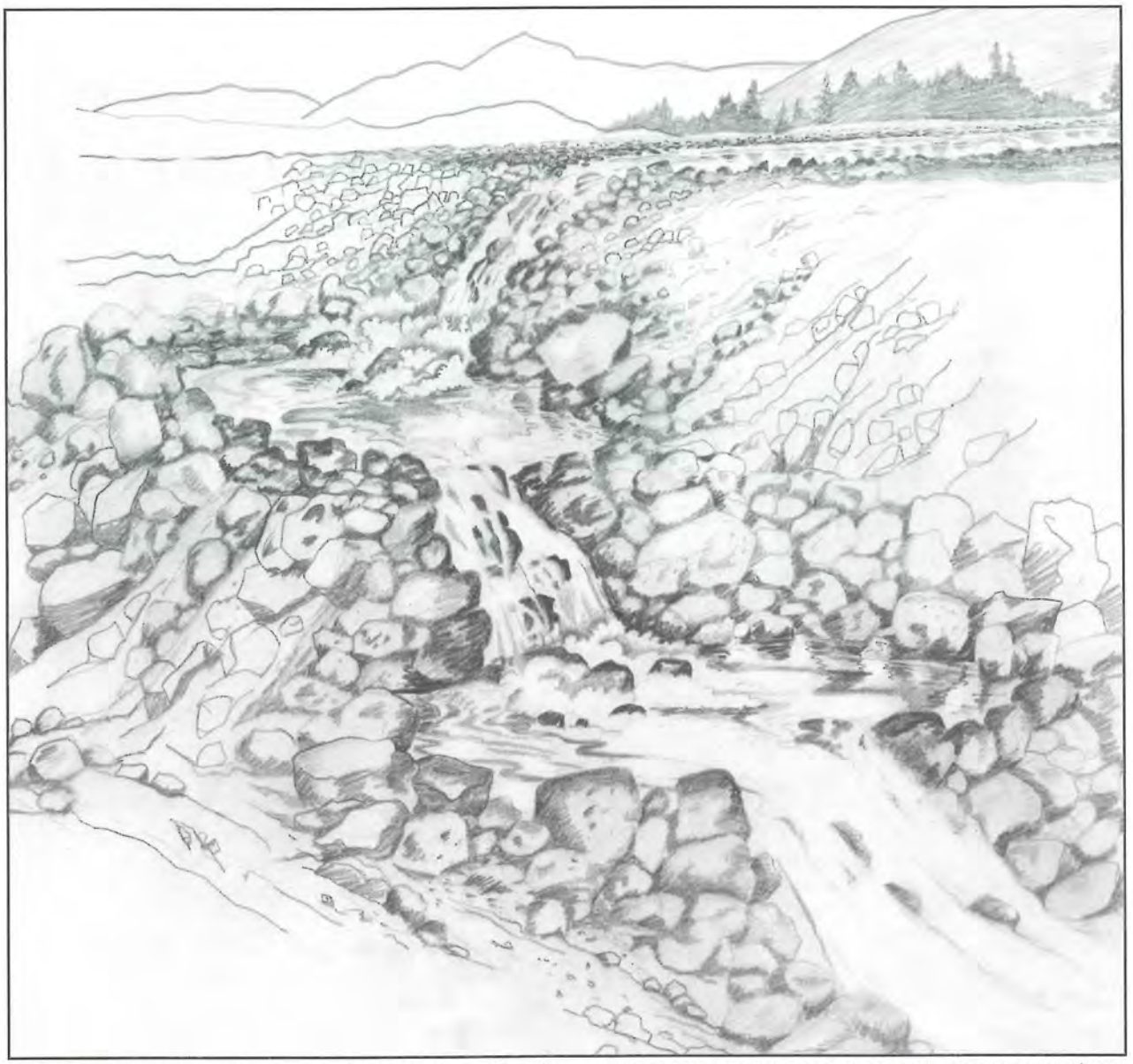
Department of State Lands
Hard Rock Bureau
1625 Eleventh Avenue
P.O. Box 201601
Helena, MT 59620-1601
(406) 449-2074

Stream diversion

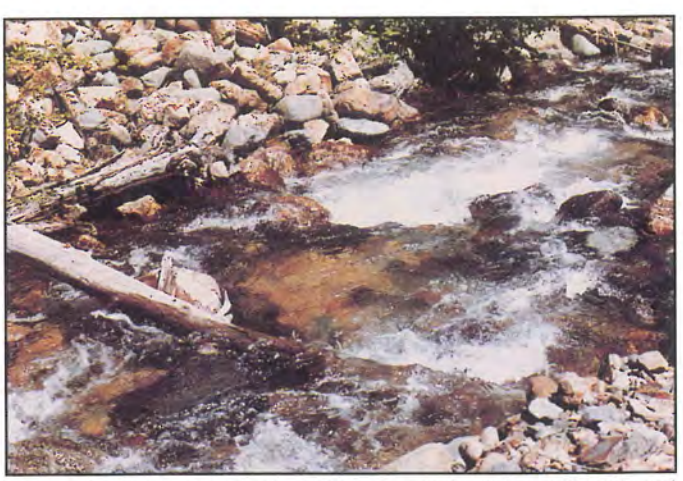
Diversion ditches are short-term solutions for excess water problems and should not be moved frequently. **Plan the mining sequence to limit the stream diversion to one move.** By reclaiming the stream in the first half of the mine plan, equipment can be on site to ensure successful reestablishment of the stream channel. Diversion ditches must be stable and capable of handling flood events without erosion. You may need to consider armoring the channel with cobbles.



Diversion ditches (for surface water) should collect water from feeder drainages both upstream from the work area and from side drainages, and should deliver water to the stream below the operation. If necessary, a small ditch along either side of a wider valley can be very effective in controlling excess surface water.



In steep mountainous environments, short stretches of heavily armored channel may be used to cascade the water to a lower elevation with minimal erosion and siltation. A small pool or silt trap at the bottom of each run will settle out fines and reduce the velocity in the channel.



Design diversions to be large enough to contain spring snowmelt and storm events (25 yr/6 hr) without ditch erosion in high velocity stretches. You should have enough coarse rock on the bottom and sides to armor the channel against erosion and to dissipate energy. Sides should not be vertical, but sloped at 3:1 if an adequate flood plain is not constructed.

Construct pools (energy dissipators) with rocks or boulders to reintroduce the channelized flow into the existing stream below the mine area.

Assistance in designing your stream diversion is available from:

Montana Department of State Lands
Hardrock Bureau
U.S. Forest Service
Bureau of Land Management
Montana Bureau of Mines and Geology
County Conservation Districts
Montana Department of Fish, Wildlife, and Parks

Road design

Planning, location, construction, and reclamation

Every placer operation needs access and work area roads. If a road is not already in place, plan for location and standards of construction and maintenance that avoid sedimentation or problems in landscape aesthetics. Consult *Montana Forestry BMPs* for a thorough guide on design, construction, and maintenance of roads. This publication is available from:

Montana Department of State Lands
2705 Spurgin Road
Missoula, MT 59801

Roads will collect and funnel water (causing problems) unless they are designed properly—**Plan to:**

- **Minimize the amount of road needed.** It will minimize your costs, too!
- **Properly locate road.** Avoid wet areas and streams; use appropriate grade.
- **Determine the standard of road needed** for the type of equipment that will be used.
- **Plan with reclamation in mind;** it will save work after operations are completed.
- **Plan for construction when the soil is dry.** This will prevent slumping of cut and fill materials and unnecessary disturbance from vehicle and equipment tracks on soft ground.
- **Cut trees first.**
- **Stockpile stumps** for reclamation or disposal.
- **Remove soil and stockpile** for reclamation.
- **Seed the road surface, cutbanks and fills** to prevent weed invasion and erosion.

Use existing roads where practical, unless use of such roads would cause or aggravate an erosion problem.

Wetlands are important habitat. Design roads around wetlands and avoid equipment operation in these areas.

Montana Department of State Lands

Slash filter windrows are very effective at keeping sediment from entering stream channels. They commonly measure 3 x 3 feet and consist of compacted slash installed along the base of the fill slope.

Roads will collect and funnel water unless you construct them with:

- An outslope/inslope (or crown) so that water will drain off.
- Ditches or slash filter windrows along base of fill slope to channel water from road (also serves to collect sediment).
- Culverts (if necessary); install to drain away from streams.
- Water bars (kelleys) to funnel rainfall or snowmelt from the road surface and into vegetated zones.

Drop inlets (left photo) installed at the head of a ditch relief culvert below the flow of water help settle out sediment and prevent the culvert from plugging. Rock armored inlets prevent water from eroding and undercutting the culvert and flowing beneath the road.

If grading produces excess material, feather it out or haul it away. **Never side-cast material into streams.** Avoid leaving a berm that channels water down the road unless it is routed into an effective vegetation filter which spreads it out and removes sediment.

Grass seeding on raw, exposed cut-and-fill surfaces is an important erosion control practice. Exact seed mixtures, proper timing, and fertilizers are important for success. Seed as soon as possible after dirt work is completed.

Seeding stabilizes soil, prevents erosion, and prevents weed invasion.

When mining is completed, reclaim/restore or leave the road in a condition that requires no maintenance or risk of stream sedimentation. Close these roads to traffic; recontour, scarify, and provide water bars or drain dips if necessary and reseed.

Road restoration means complete removal of all features of an existing road surface. It includes removal of roadside berms and fill to restore original contours, ripping compacted areas, restoring natural drainage, and reseeding with appropriate grasses.

One of the most common road drainage problems is allowing ditch drainage to flow directly into a stream. Always route ditch drainage through a filter (vegetated buffer zone, slash filter windrow) to remove sediment from the water before it reaches the stream.

If you decide to remove bridges and pull all culverts, you must restore all drainage features to their natural condition. This includes recontouring and reseeding all disturbed surfaces.

Stream crossing design

Do not let stream crossings delay your permit! Stream crossings can be bridges, culverts and temporary structures (or fords). All of these will require a **310 Permit** (Montana Natural Streambed and Land Preservation Act). Fords may limit your operating season, as they may be unusable during high water. It is important that crossings be considered, as they may require an additional permit. Also, **it's the law!** Under the **310 Permit**, any activity that will result in physical alteration of a perennial stream, its bed or immediate banks, must be approved by the supervisors of the local County Conservation District. If fill material is added to the stream or wetlands, a **404 Permit** may be required *(see Part VII)*.

- Consider the size of the stream and its capacity during runoff and snowmelt before determining which kind of crossing to construct.
- Consider cost and alternatives.
- Consult technical sources for information about construction and installation standards. The *Montana Forestry BMPs* publication provides a section on installation of stream crossings.
- Apply early for the necessary permits *(see Part VII)*.

Do not build crossings that result in unstable channel beds and banks.

Concrete planks, fastened together and stretched across the streambed, provide an improved ford crossing. Approximate cost: $100 per running foot, installed.

Limited traffic on this improved ford crossing has minimal impact on the streambed and produces little sediment.

Plan for flood (25 yr/6 hr storm event) conveyance. An improperly sized crossing will result in erosion and potential loss of the structure. When future floods are ignored, the potential for water-quality damage is enormous. Usually, costs of repair far exceed costs of proper installation.

Railroad flatcars can provide a low cost alternative to conventional bridge construction.

Use portable bridges when stream crossings are needed. These temporary bridges are convenient, economical, and can be installed with less impact than other alternatives.

IV DESIGNING YOUR MINE

U.S. Bureau of Mines

Mobile wash plant with draglines.

Success or failure of a placer mine is controlled by mine planning, mine design, and your ability to initiate the plan properly. "Mine" the property on paper before risking capital and the environment. The mine plan should be flexible enough to compensate for unknown conditions which may be encountered. Flexibility in a mine plan is very different from altering the plan in the middle of the operation.

THREE BASIC RULES TO BE FOLLOWED IN MOST PLACER MINE PLANNING:

1) **Always mine upgradient**—All placer mines should be designed so that surface, ground, and process water drains from the working area into the settling pond. The term "gradient" is in reference to the bedrock slope and not necessarily the surface. (The bedrock and ground surface sometimes do not slope in the same direction.) Only floating wash plants or dredges may mine downstream to maintain a pond.

2) **Never mine through a settling pond**—All settling pond areas should be placed in non-economic or non-mineralized ground. Mining into a settling pond will typically result in water-quality problems, increased reclamation costs, and material handling problems. The costs will nearly always be greater than the gold value you may recover.

3) **Utilize small panels in mine design**—This will result in lower bonding rates, lower seasonal closure costs, lower reclamation costs, less risk to the environment, and better control of water quality.

Pre-mining development

Before you begin full production (**after the appropriate permits are obtained**), it is necessary to:

- **Divert surface water flows**—Intercept surface water if existing channel must be disturbed.
- **Divert ground water**—Intercept ground water where possible and channel around mine area to reduce costs.
- **Construct settling pond or ponds**—Design for ease of reclamation and stability as well as flood potential from storm events.
- **Have a surplus water disposal system**—Construct a ditch or irrigation system for land application.
- **Divert ground water in the mining area into the settling pond**—Construct a drain if there is sufficient ground-water flow.

The mine design is dependent on the deposit. There are a variety of placer mining designs; two of the most common (mobile and stationary) will be discussed. Both methods have similar construction sequencing that revolves around land-based wash plants. A **mobile design** is a system where the wash plant is relocated (as many times as necessary) to remain in close proximity to the excavation area. A **stationary design** is one where the wash plant remains at a fixed location until the haul costs exceed the plant relocation cost. In this design, the wash plant typically is moved once or twice during an operating season and is rarely near the excavation area.

Each mine design has its own requirements for water treatment. A mobile design will typically need only a silt pond. The stationary design will require both a sand and gravel pond, and a silt pond.

Stationary wash plant.

Settling ponds

There are two distinct types of settling ponds—sand and gravel ponds and silt ponds. A **sand and gravel pond,** is designed to temporarily capture and store sand and gravel after processing. A **silt pond** is designed to settle out fine sediment from wash plant waste water and runoff from disturbed lands. For stationary operations, the sand and gravel pond is important. For mobile operations, it is unnecessary because that portion of waste material is recombined with the coarse rock immediately after washing.

The sand and gravel pond should be constructed large enough to contain 4-10 days of gravel and sand production. The pond must be narrow enough to be within the reach or capabilities of equipment necessary to clean the pond. The pond should never be more than 50 percent full before it is cleaned. Daily cleaning is preferred; however, cleaning intervals should not exceed a week.

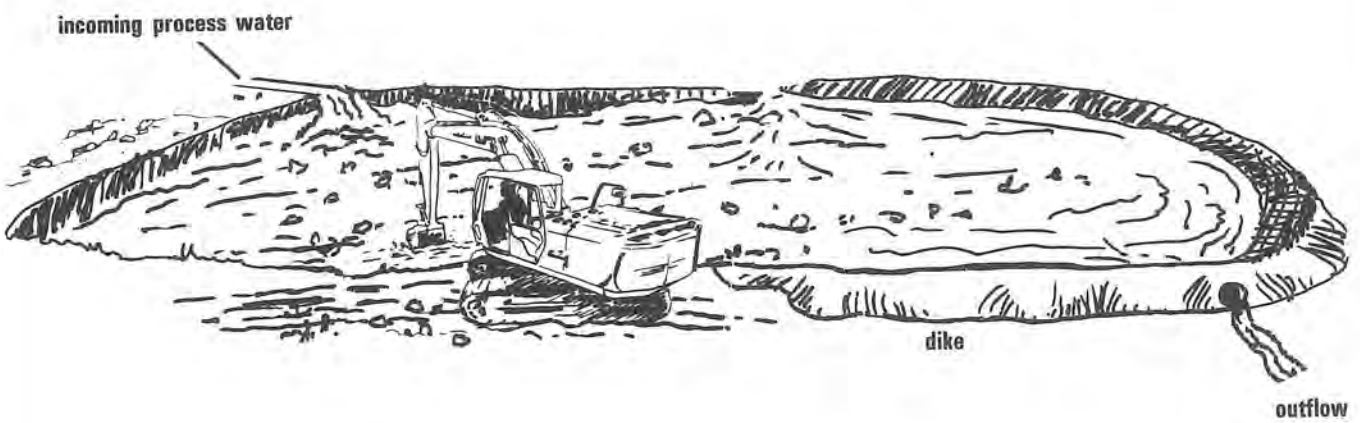
Sand and gravel removed from the pond should be stockpiled to dry before covering the coarse washed waste rock and overburden during the reclamation process.

Silt ponds are very different from sand and gravel ponds. These ponds are much smaller and need very little storage area. The pond should be designed to contain 1 to 2 days use of process water and **the expected storm runoff water (25 yr/6 hr event)**. The silt pond must slow the water flow to allow silt to settle out, whereby partially cleaned water will be discharged to the final treatment facility. By designing the pond in a "U" shape (or along topographic contours), maximum settling can be achieved in a minimum-sized area.

The ponds need to be excavated 8 to 10 feet into the ground to serve as storage for storm events or spring snowmelt. During normal operation at least 4 feet of freeboard should exist between the pond surface and the top of the dike. The dike should not retain water except during storm events. Any pond constructed with a dam that retains water on a consistent basis must meet engineering standards and agency approval.

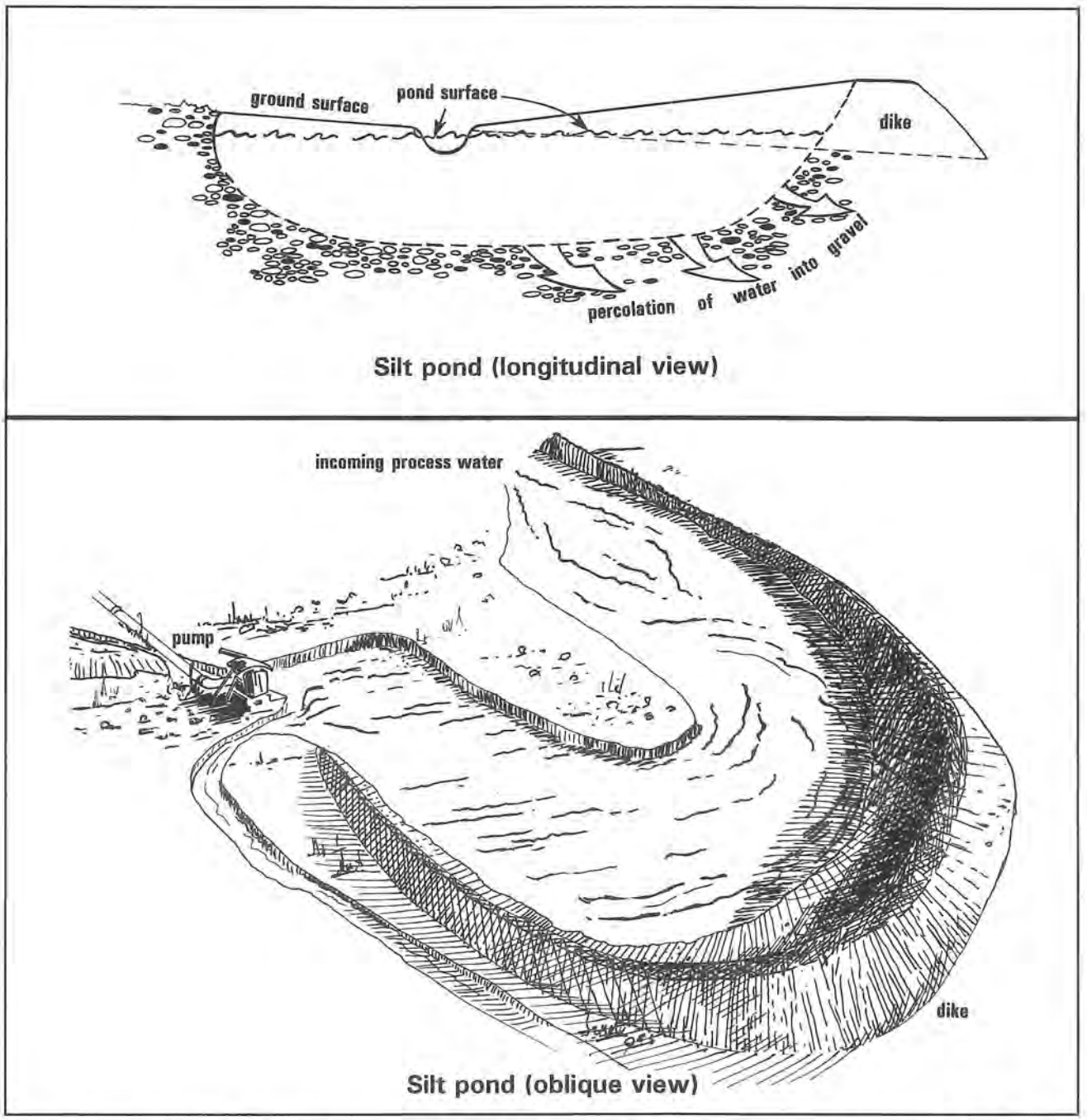
A ditch outlet from the settling pond will not plug like a culvert. If erosion is apparent, armoring those areas with cobbles is advisable.

Depending on the sediment load, clean your settling pond often enough to ensure that a storm event does not cause it to overtop and/or fail. Use the fine sediment removed from cleaning the silt pond to help establish vegetation during reclamation if adequate amounts of soil are not available.



Sand and gravel pond (oblique view)

Sand and gravel ponds provide temporary storage of processed sand and gravel before use for reclamation at stationary placer operations.



Construct settling ponds in undisturbed gravel rather than the fill material of the dike. The excavated material will form the dike, providing inexpensive material handling costs for pond reclamation and construction. Percolation from the pond into gravels removes surplus water and eliminates sedimentation to surface water.

Surplus settling pond water can be disposed of using several methods:

1) A system of flood irrigation ditches will provide long-term solutions with minimum cost and maintenance.

2) The water may be pumped into an irrigation system and sprinkled onto the landscape. This method is expensive to build, operate, and maintain.

3) With limited space available in narrow, steep drainages, shallow percolation trenches or drain fields may be the only available method.

4) If water-quality standards are met, water may be discharged into the stream with appropriate permits. **It is unlikely that standards can be met during the operating season.**

Mobile placer mine design
(with concurrent reclamation)

This design provides better environmental safeguards and the lowest operating costs. While basically a low to medium rate production design (<500 yd^3/day), profitability has been demonstrated under ideal conditions, with 4 feet or more of pay gravel grading $3 to $6/$yd^3$ (@ $380/Troy oz.) and less than 14 feet of overburden, with a minimum investment.* It can provide minimum ground disturbance and rapid revegetation of the land.

Benching down to pay gravel.

Mine sequence

1) Strip soil and stockpile for respreading and seeding during reclamation; seed soil to grass while stockpiled if it will be exposed to weed seeds longer than one month. (Place no closer than 15 feet from a stream with adequate sediment control procedures such as berms, bales, and filter fences.

2) Strip overburden and place in a separate location. (The definition of overburden is a gravel-cobble-silt mixture that lacks sufficient gold values to pay for washing, additional capital costs, and additional reclamation costs to warrant processing.) Use berms, bales, silt fences or diversion ditches near a stream or drainage.

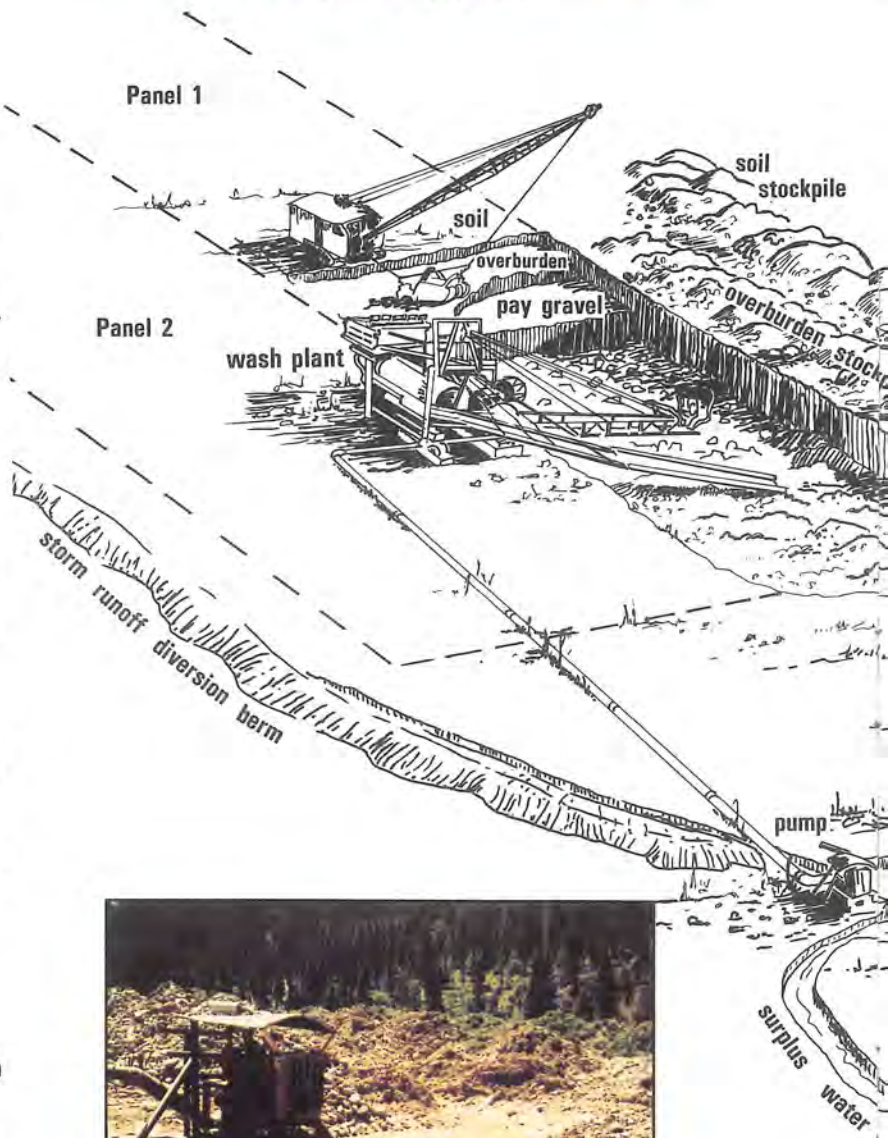
3) Excavate pay gravel and process it in a wash plant, thus removing the gold and returning the remaining gravel components to the excavated trench.

4) Move machine and repeat sequence to the end of the panel.

5) Upon completion of the panel, recontour overburden over the washed gravel.

6) Clean silt pond and place sediment (silt/clay) on top of regraded overburden. The silt may be used as a soil substitute if cover soil is scarce. If used as soil, seed at this time if advised by your regulatory agency.

7) Move soil stockpile over the silt pond sediment where overburden from the next panel **will not** be placed; seed if advised by your regulatory agency.



Pump for recycling wash water.

* Because placers have such variable conditions, this range may not be applicable to your deposit. Consult Project Feasibility (page 4), and obtain assistance in determining your potential costs.

8) Move equipment to beginning of next panel and repeat the sequence.

9) Near the end of the operating season, prepare and seed any unseeded areas, including staging areas, roads, piles and settling pond dikes.

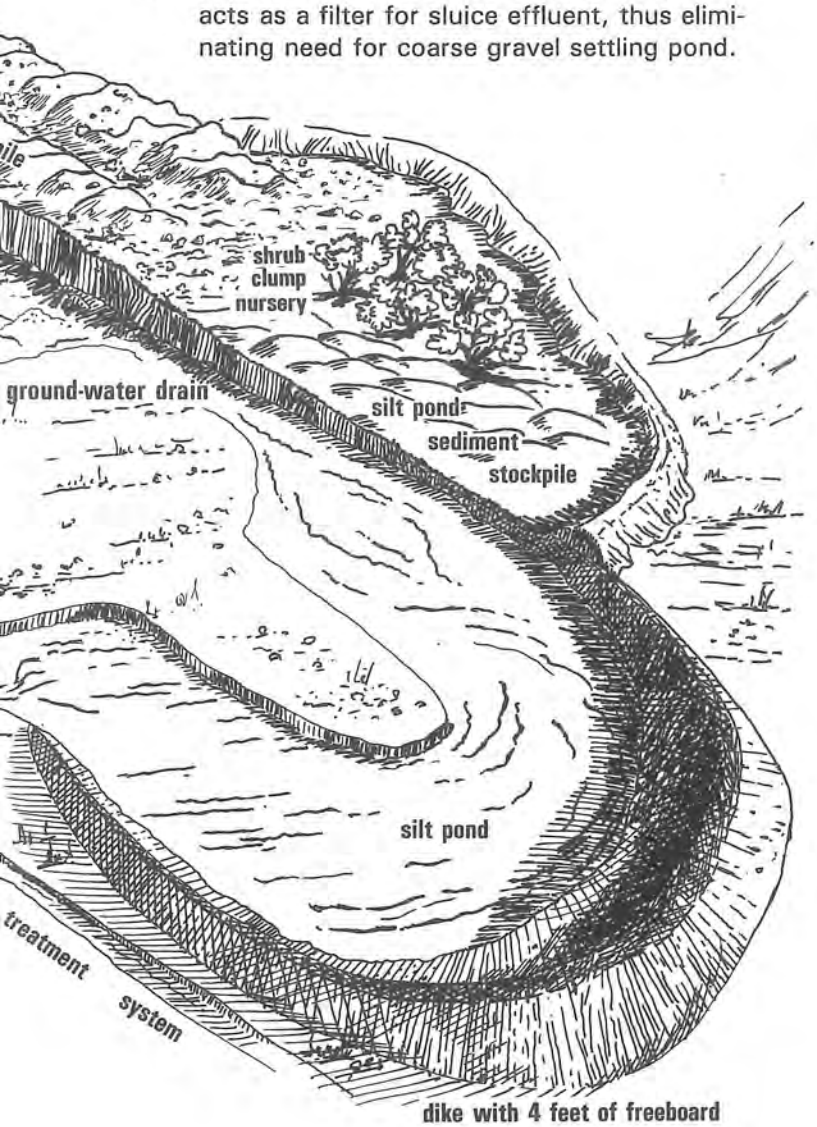
ADVANTAGES of a mobile wash plant

A. Minimum ground disturbance
- Minimizes exposure to weed infestation.
- Reduces sedimentation potential of surface water.
- Reduces bond costs.
- Lowers seasonal reclamation costs.
- Reduces final reclamation costs.

B. Minimum pond area
- Washed material from oversize conveyor acts as a filter for sluice effluent, thus eliminating need for coarse gravel settling pond.
- Replaces fines between washed material in trench which assists in reclamation of French (coarse rock) drains.
- Reduces need for settling pond area, sediment stockpile, and subsequent risk of sedimentation of streams.
- Reduces chance of sedimentation in streams.

C. Minimizes need for roads
- Lowers capital investment.
- Minimizes fugitive dust and the sedimentation of streams.

D. Low operating costs
- Requires fewer pieces of equipment.
- Decreases need for hazardous materials.
- Eliminates hauling costs.



DISADVANTAGES of a mobile wash plant

A. Confines operation to low/medium production rates by limiting equipment size.

B. Limited to 18-25 feet of gravel depth. Thicker gravels may require a change in mine sequence or equipment size.

C. The length of the mine panel is limited by pump capacity, and by the size of washed oversize and clay content of the pay gravel.

D. May not be a viable alternative in narrow steep stream valleys.

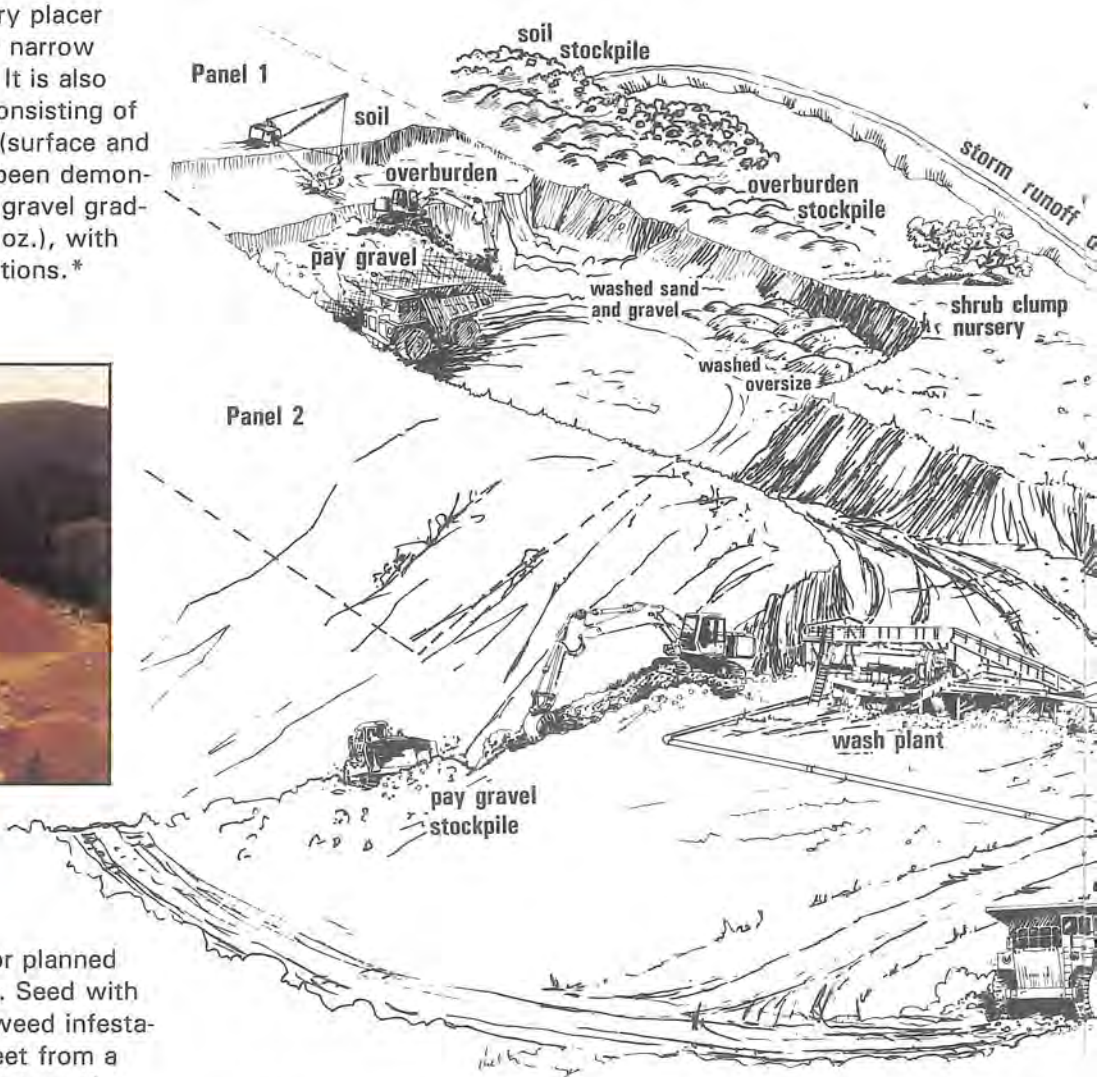
U. S. Bureau of Mines

Silt pond dike showing adequate freeboard.

Stationary placer mine design
(with limited concurrent reclamation)

This design is not preferred under ideal conditions, but allows variability for development on a case-by-case basis. The stationary placer mine design is especially suited for narrow gulches with limited water supply. It is also ideal on elevated gravel benches consisting of large surface areas and low water (surface and ground) volumes. Profitability has been demonstrated with 4 feet or more of pay gravel grading of $6 to $9/yd^3 (@ $380/Troy oz.), with low stripping ratios and ideal conditions.*

Overburden removal



Mine sequence

1) Stockpile soil and vegetation for planned disturbance on edge of deposit. Seed with a grass mixture to discourage weed infestation. Place no closer than 15 feet from a stream with adequate sediment control measures, such as berms, bales, or filter fences.

2) Strip overburden and stockpile. Use berms, bales, silt fences or diversion ditches to prevent sediment from entering stream or drainage.

3) Mine pay gravel and transport to wash plant.

4) Clean ponds and dewater sand and gravel and silt.

5) Transport oversize rock and washed sand and gravel to backfill pit.

6) Repeat steps 2-7 until panel is complete.

7) Begin next panel and place overburden on top of backfill of last panel.

8) Complete panels planned for operating season.

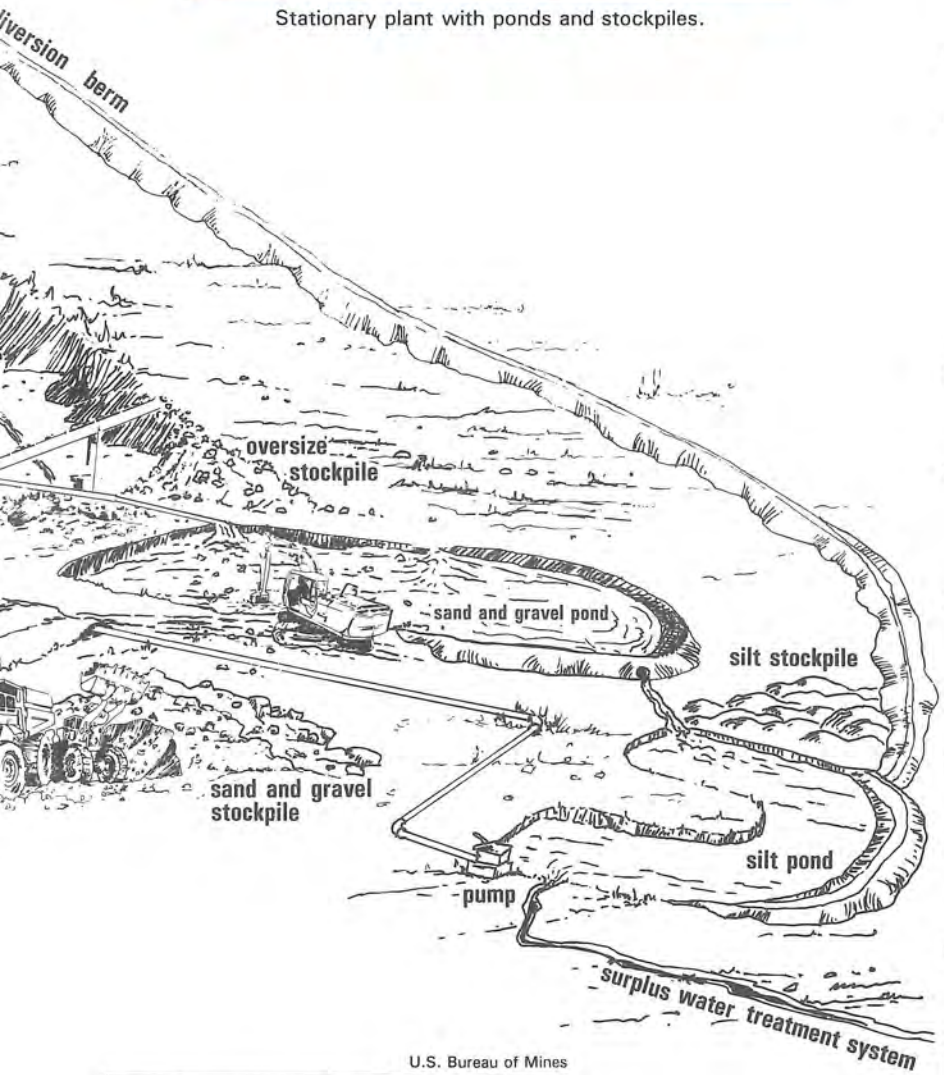
9) Regrade.

10) Transport silt stockpile and place on overburden. (Keep for use as soil substitute if adequate cover soil is not available.)

11) Spread soil stockpile over regraded silt and then seed the final surface.

* Because placers have such variable conditions, this range may not be applicable to your deposit. Consult Project Feasibility (page 4), and obtain assistance in determining your potential costs.

Stationary plant with ponds and stockpiles.



ADVANTAGES of a stationary wash plant

A. High production capability.

B. Stockpiles are sorted; washed gravel available for reclamation.

C. Higher recovery rates from wash plants, which may be critical in deposits containing small gold particles.

D. Stockpiled pay gravel available for gold production during down time.

DISADVANTAGES of a stationary wash plant

A. Large ground-disturbance area
- Increased need for pond areas.
- Additional need for roads.
- Increased excavation area needed to accommodate equipment.
- Additional area needed for stockpiles.
- Higher fuel storage volumes needed.

B. High bond cost due to area of disturbance and equipment removal costs.

C. High operating costs
- Requires additional equipment.
- Requires additional labor.

D. Additional high costs (from amount of disturbed ground)
- Seasonal closure.
- Weed control.

E. Difficulty of working in areas of high ground-water levels.

F. Delays most of the final reclamation to end of operating season.

G. Increased final reclamation costs.

U.S. Bureau of Mines

Coarse rock stockpile.

U. S. Bureau of Mines

Surplus water drain.

V NOW THAT YOU ARE OPERATING

During the mining phase of your operation, extended periods of time will exist when the surface is disturbed. Overburden, topsoil piles and stockpiled pay gravel have the potential to periodically contribute silt to surface water. Roads may gather water and transport silt to streams. Hazardous materials may contaminate both surface and ground water if you do not handle, store and use them correctly. All of these potential sources of pollution can be prevented by various techniques that are inexpensive and easy to implement. If preventative measures are not taken and water-quality rules are violated, then considerable costs to you will result. Down time, fines, and court costs, along with considerable scrutiny from regulatory agencies are the source of some of these costs.

Floating wash plant used in a mobile operation.

Controlling sediment and erosion

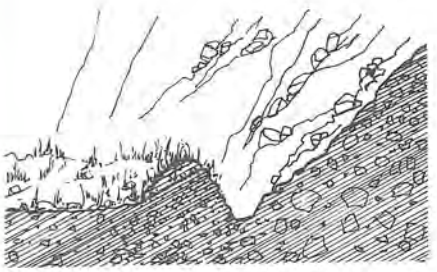
Silt/filter fences are often used to control sediment from disturbed ground until the area is revegetated. They are, however, more expensive, require higher maintenance, and may not be effective in clay soils. The stream is located below the riprap (bottom of photo).

Maintain buffer strip of undisturbed and ungrazed ground next to live streams to capture and trap sediment. The zone between the piles and the stream must be heavily vegetated to be effective.

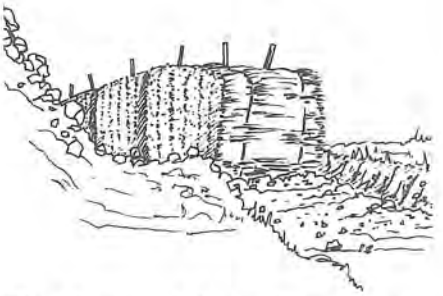
Spread brush and slash from clearing operations on reclaimed ground to trap sediment being transported to live streams and protect new vegetation. To effectively control erosion, the slash must touch the soil surface.

Overburden/spoils, silt, topsoil, sand and gravel piles should never be placed closer than 15 feet from the drainage. **Use berms, silt fences, and/or straw bales to eliminate sedimentation** from storm runoff.

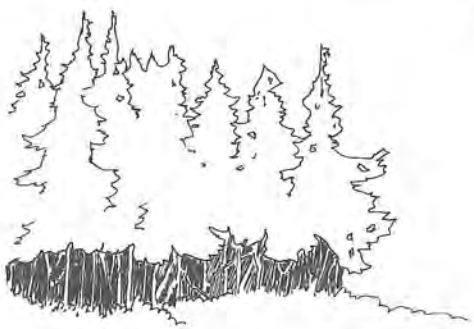
Place riprap in diversion ditches to prevent ditch erosion and subsequent failure.

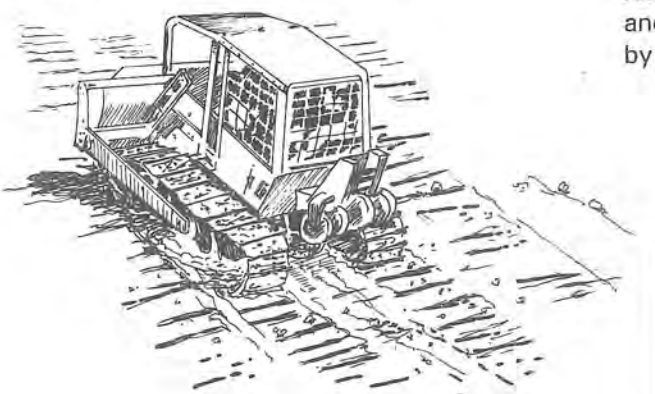


On dirt piles and in the operating area near surface water, **construct berms or diversion ditches** to channel storm runoff and process water into the water treatment ponds.

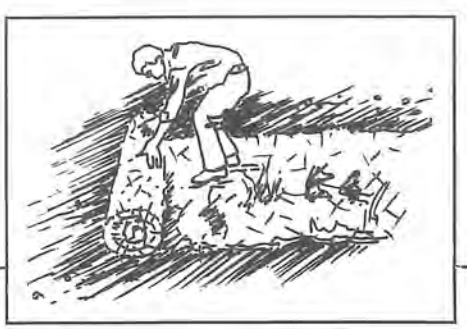


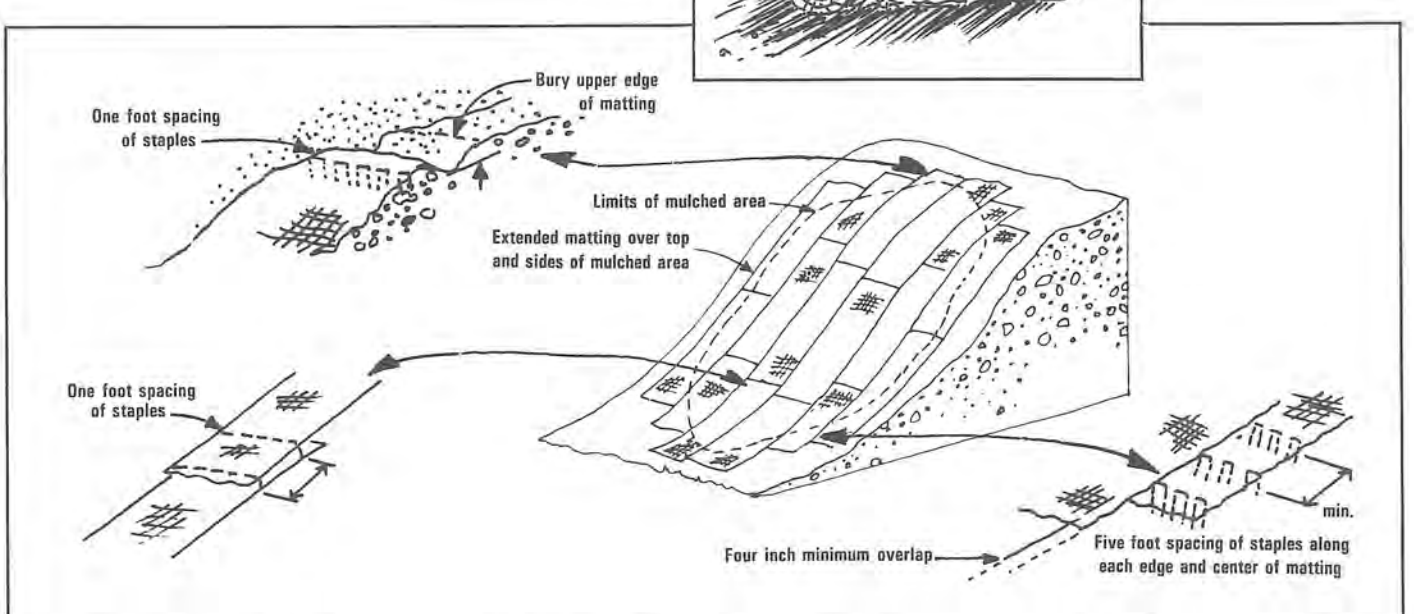
Weed-free straw bales may be used temporarily in place of berms for sediment control in the active mine area.





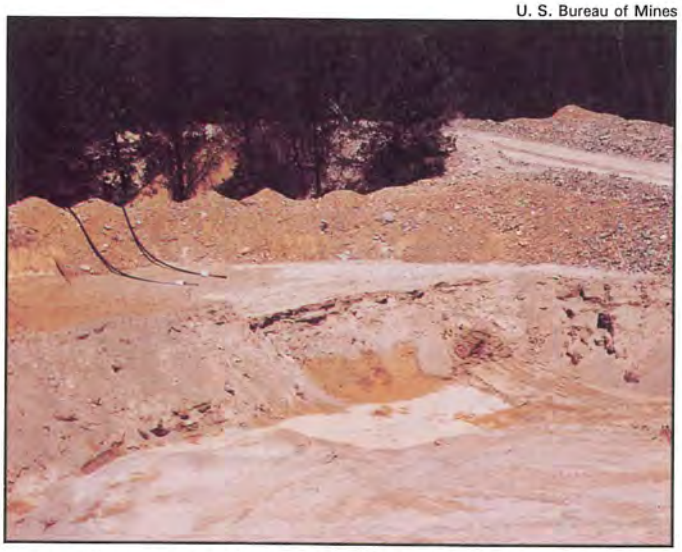
Soil near surface water may be **textured** with tracked equipment to control sediment movement. Make certain that grouzers (track cleats) are at 90° angles to the slope to reduce sediment transport to streams. Dirt stockpiles that will not be removed within the operating season should also be stabilized and seeded. **Contour furrowing** and other measures approved by your regulatory specialists may be useful.





Erosion control blankets made of jute, straw, or plastic netting placed over seed and mulch will protect recently reclaimed highly erosive soils on steep slopes until vegetation is established.

U. S. Bureau of Mines



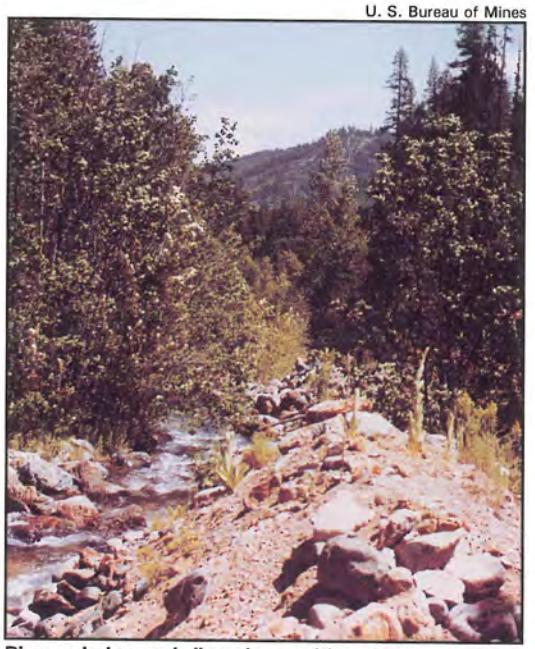
Clean settling ponds daily to weekly depending on design. The ponds should never be more than 50 percent full of sand, gravel, or silt.

U. S. Bureau of Mines

Inspect erosion control practices during and after storms to insure effectiveness of your sediment control program.

Construct interceptor trenches or diversion berms to gather storm water from the disturbed areas and channel it into the settling pond or heavily vegetated areas.

U. S. Bureau of Mines



Riprap drains and diversions with cobbles and boulders. Place riprap in areas which may erode during high flows.

Weed control

Keep your operating area in a weed-free state. Controlling weeds after they become established is more costly than early prevention. Here are some tips to keep weeds out of your operating area:

- **Seed topsoil** stockpile, roadcuts or other work areas that will not be further disturbed in the operating season.
- **Buy seed mixes** that are certified weed free and approved. Request assistance from your county extension agent, or specialists within land management agencies.
- **Minimize** total disturbance; even a onetime equipment track can provide a surface for weeds to germinate.
- **Wash** your equipment (off site) before you take it on site. Whenever you move it to a new area - **wash it again!**

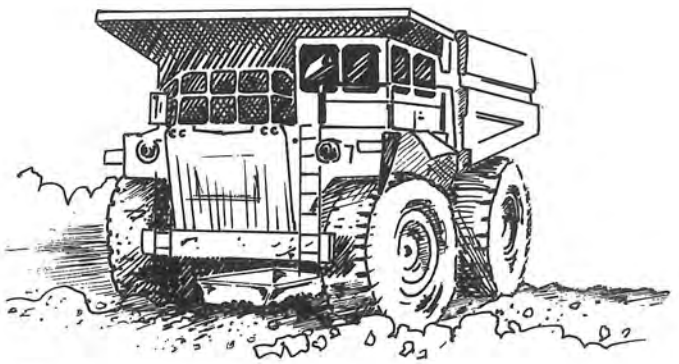
If weeds have already become established on your site, contact your county extension agent, U.S. Forest Service or Bureau of Land Management for authorized methods of control.

Use and storage of hazardous materials

Machinery lubricants, fuel, flocculants and other chemicals that you use in your placer operation will contaminate underground and surface water supplies if they are used or stored improperly. Since most placer deposits are porous, take extra precautions with the use of these materials in your operating area.

Here are some suggestions:

- Keep your chemicals, lubricants, and fuels away from streams, wet areas, and drainages.
- Make sure that storage containers do not leak and are secure under freezing and thawing conditions.
- Promptly repair oil and hydraulic leaks on equipment. Oil in water will decrease gold recovery, as well as pose environmental risks.
- Mercury should not be used at the mine site unless a special containment facility is permitted and constructed.
- Use "bed pans" or other adequate spill collectors under all fuel and chemical tanks.



- Dispose of old filters, used oil, parts and containers at approved sites. **Do not bury or drain oil on the ground!**

Failure to follow these suggestions will lead to pollution of the ground water. This is not only a violation of numerous laws, but cleanup is extremely expensive.

Safety

Limit public access to your mining area by using cables (where permitted), or gates, and limiting the number of roads entering the site. Access restrictions must be approved by land management agencies on public land. Place warning signs to advise the public of mine area dangers.

Portable electric fences using solar or battery power can limit access of livestock to active pits and revegetated areas. Most reclaimed blocks will require several years (without livestock grazing) to fully re-establish vegetation.

Large visible signs are important to advise the public of dangerous features and equipment at the mine site.

Place fire extinguishers on every piece of equipment. Fires are not common on placer projects because of available water, however, a wildfire starting at a mine site may eliminate all projected profits from operation. Fire-fighting agencies will recapture their costs from whoever is responsible.

All operations must comply with Federal Mine Safety and Health Administration (MSHA) standards. Before mining, notify the office in Helena of your interest and ask for the guidelines and regulations that pertain to your planned operation (406) 449-5357.

Seasonal and temporary closures

Your operating season is going to depend on weather. By late September or October, nighttime freezes can create havoc with your equipment. Your days may be better spent during this time completing seasonal reclamation requirements and preparing your area for shutdown. Use the following examples to prepare for seasonal and temporary closures.

Move equipment to higher and drier ground.

In forested areas, fall is a good time to clear trees for subsequent mining panels. Spread slash over newly reclaimed excavations. Make certain that slash is in contact with the ground for maximum effectiveness. Clearing activities require approval from state and federal agencies.

Seed everything, including berms, ponds, piles, excavations, roads, and landing areas, especially if you have not been seeding as your disturbance progressed. Tree planting should be done after reclaimed areas have had a chance to "settle". Use approved seed mixtures.

Reclaim excavations by spreading topsoil. Seed immediately, or as advised by your regulatory specialist.

Stabilize your stockpiles by constructing berms or slash filter windrows. Straw bales will also work. Make sure spring runoff doesn't destroy your stockpile.

Clean settling ponds. Containment berms should be stabilized with enough freeboard to allow for spring runoff and snowmelt.

Construct and stabilize diversion berms to divert spring runoff and snowmelt.

VI RECLAIMING THE MINED LAND

Reclamation is an essential part of the entire mining process. With proper use of current technology, you can avoid the severe impacts of early-day placer mining without excessive costs. The goal of reclamation is to return the landscape and streams to a proper riparian functioning condition. Stream and riparian area rehabilitation, revegetation and erosion prevention are major features of reclamation.

Include reclamation in the mining process from the beginning and continue as you mine. The reclamation will be of higher quality, easier to complete, and less expensive than if it is done at the end of the mining operation.

Placer mine during operations.

Stream reclamation

Stream channel and riparian area reclamation and restoration must occur at the same time to reestablish proper channel and riparian area functions. Channel reconstruction can be expensive unless it is part of your overall mining plan designed to reduce materials handling to an absolute minimum. Appropriate reconstruction will avoid additional reclamation and possible loss of your bonding funds.

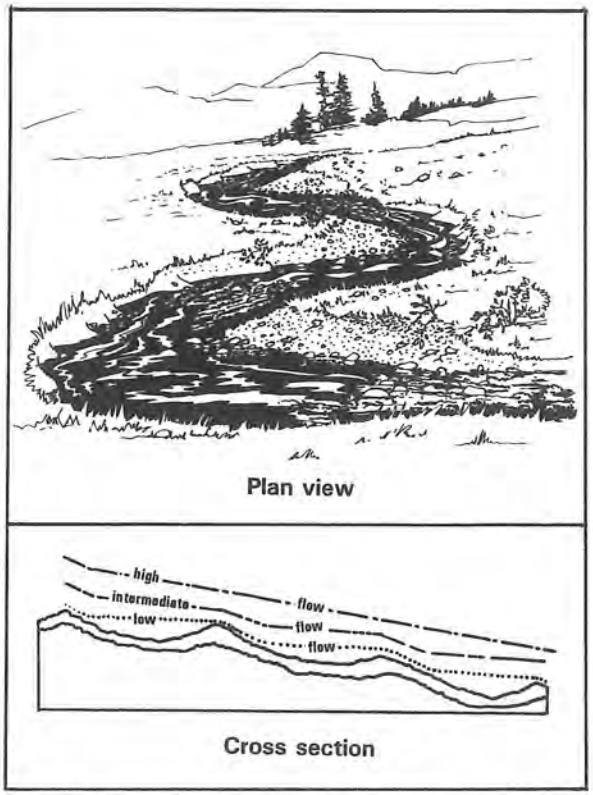
Two general situations occur in stream restoration/ reclamation:

1) Reclamation **in a previously undisturbed site** requires that you inventory your site before you begin *(see Part III)*.

Your objective will be to restore the general topography in the channel area. This must include channel cross section, sinuosity (length and width of bends), gradient (channel slope, bank slope, channel materials), and channel character (resistance to flow). The adjoining flood plain areas should resemble the condition that existed before you mined.

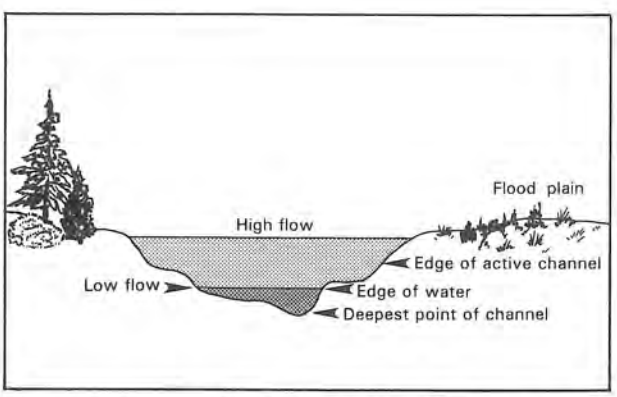
Reconstruct streams when they are dry to minimize sediment production. Isolate the reconstruction area so water can bypass the site *(See Part III)*. Proceed upstream, with channel reconstruction, beginning at the downstream barrier. This will insure that channel work will occur in a mostly dry condition. Use stockpiled material (gravel, cobbles, boulders) after compacting fine sediment in the streambed base to form the stream channel. This will aid channel water surface flow and will increase resistance to erosion. After reconstructing the channel and riparian area, recontour all non-essential soil and rock material and remove the downstream barrier. The upstream barrier can be removed and the stream can be reestablished in its new channel. The diversion ditch should be reclaimed to near original contours and reseeded.

Reclaimed stream through old placer mine.



Views of channelbed elevation showing repeating pool riffle sequences (Inter-Fluve, Inc., 1991).

2) Reclamation in previously mined areas offers an opportunity to improve previously mined landscapes and streams. **In these instances, assistance from the U. S. Forest Service, Bureau of Land Management, Montana Department of State Lands, or the Soil Conservation Service is advisable** to establish how the site and stream channel should appear after reclamation. Channel capacity and riparian area flood-flow storage is particularly important. Proceed with reconstruction as described previously for undisturbed sites.



Diagrammatic view identifying top of banks, edge of active channel, and riparian area (*modified from* Inter-Fluve, Inc., 1991).

Stream reclamation is a complicated subject. Please consult the *Handbook for Reclamation of Placer Mined Stream Environments in Western Montana* for detailed guidance. This is available through the:

Hardrock Bureau
Montana Department State Lands
1625 11th Ave.
Helena, MT 59620-1601
(406) 444-2074

Land reclamation

Reclamation of mined lands includes recontouring the spoils piles and other disturbed areas to a stable form compatible with the surrounding landscape. This is achieved through replacement of topsoil and revegetating the area with native grasses, shrubs, and tree species to provide a diverse vegetative cover. Reclaim disturbed areas at the earliest possible time. You may complete some tasks during the mining process to promote rehabilitation and reduce costs.

Placer mine site one year after recontouring and revegetation. Full vegetative recovery typically takes three to five years.

- Backfill pits with overburden and washed gravel.
- Recontour excess overburden.
- Spread soil and silt from settling pond and grade the entire disturbed area. Soil depth should be 18 inches (if possible) for rooting depth and water retention.
- Grade slopes to agency-approved contours.

- Stabilize disturbed areas by contour furrowing and revegetate with appropriate perennial non-weedy species including grasses, shrubs, and trees.
- Seed grass while the surface is porous to provide an acceptable seed bed.
- Reclaim roads to the approximate original contour (unless otherwise approved), and stabilize the surface as described above.
- Control sediment from storm runoff.
- Implement a weed control program.
- Design permanent culverts to withstand at least a 25-yr/6-hr event. Minimum culvert size must be 18 inches.
- Fence the project area to restrict humans and animals from hazardous sites. This will also restrict livestock from damaging reclaimed ground until vegetation is effectively reestablished.

Disturbed stream drainage during mining operations.

Steps in final reclamation

- Site preparation (grading/contouring).
- Seed-bed preparation.
- Fertilization and conditioning of seed-bed material.
- Mulching.
- Spring or fall seeding and planting.
- Weed control.

Assistance is available from the U.S. Forest Service, Bureau of Land Management, Soil Conservation Service, and Montana Department of State Lands.

Regrading of mine site and reestablishment of stream channel and flood plain.

Partial revegetation of stream drainage within three years.

VII PERMITS

Permits are required by state and federal agencies to assure consideration of other resource values, provide for reclamation, and protect water quality for downstream users. There are two basic types of permits: 1) permits to operate, and 2) permits that protect water quality.

Operating permits

Exploration License

Required for all exploration and placer testing, all lands.
Minimal processing time (approx. 2 weeks).
Bonding: $50-$250/test hole, $1.50-$2.50/linear foot of road, $5.00 filing fee.
Bulk sample bonding: Based on proposed area of disturbance.

Small Miners Exclusion Statement (SMES)

For operations disturbing less than 5 acres and mining less than 36,500 tons per year.
Placer operators must supply $5,000 bond or if a Plan of Operations is submitted, the Hard-rock Bureau may request a lessor amount based upon the proposed disturbance.

Operating Permit

Required for all mining operations not covered by the SMES.
Requires full review and permit approval.
Bonding: Rate based on proposed disturbance.
$25 filing fee.
One year processing period.

The permits above are administered by the Montana Department of State Lands, Hard Rock Bureau, (406) 444-2074 in Helena.

U.S.Forest Service (for operations located on USFS land)

Notice of Intent: Required for operations that do not use mechanized equipment.
Plan of Operations: Required for any operations using mechanized equipment.
Review and coordination with DSL required.
Bonding: Rate determined by proposed surface disturbance and government reclamation costs.
Environmental analysis (30 days).

Contact your local USFS District Office.

Bureau of Land Management (for operations located on BLM land)

Casual use: Causes negligible disturbance, no notification required.
Notice: Required for all operations disturbing less than 5 acres per year.
Submit to BLM 15 days before operating.
No approval required.
Plan of Operations: Similar to Forest Service or DSL (for disturbances larger than 5 acres).

Contact your local BLM office.

Water-quality permits

Montana Pollutant Discharge Elimination System (MPDES)

Applies to all water discharges to surface and ground water.
Wise to have in place for emergencies.
Mining activity and road construction that disturbs significant acreage (usually more than 5 acres) requires a MPDES permit.
Process period (approximately 180 days).

Storm Water Runoff Permit

Required if any surface disturbance has the potential to contribute sediment or pollutants (fuel, etc.) to State waters during a storm event. There is no minimum acreage—it applies to all surface disturbance.

3A Authorization

Necessary for short-term violation of water-quality standards (turbidity).
May be useful for emergencies or during construction phase.

Suction Dredge Permit

Necessary for small scale (<4" intake) suction dredging operations.
Permit is site specific and may have restrictions.

The permits above are administered by the Montana Department of Health and Environmental Sciences, Water Quality Bureau, (406) 444-2406, in Helena.

404 Permit

Required before placement of dredge or fill material in waters of the United States including wetlands.
Process period (90 days).

Available through the U.S. Army Corps of Engineers, Helena. (406) 444-6670

310 Permit

Necessary if activity alters, modifies, or affects the bed and banks of a perennial stream.
A bond may be required.
Process period (60 days).

Contact your local Conservation District.

If you use water in your operation, you must comply with Montana Water Rights law and obtain a water right.
Application for water rights is made through the Water Rights Bureau, Montana Department of Natural Resources and Conservation, 1520 East Sixth Avenue, P.O. Box 202301, Helena, MT 59620-2301, (406) 444-6610.

Conclusion

Placer mining technology has changed little in the last several years. Universities rarely mention the subject and federal research agencies decline to fund programs on placers. Large companies have no interest in exploring known placers or bringing properties into production. This is due to uncertainty and the small size of the deposits.

Placer deposits remain, however, as one of the few mining opportunities remaining for individuals or small companies.

With little opportunity for formal training, placer miners are inclined to follow practices outlined in publications of the 1930s. These techniques severely damage the environment, and many have been prohibited. The cost of mining with those techniques, and repairing the damage they cause, usually exceeds any potential profit.

The techniques illustrated in this document allow mining, while minimizing environmental impacts and costs. At many placer mines, the necessary environmental protection can be achieved simply and economically by using extra care in handling materials, or by modifying the sequence of operations. Damage to drainages by historical operations can be eliminated at no additional cost by remining those areas (where sufficient values exist) using these new techniques. Since most placer deposits have been mined many times, an opportunity exists to improve existing environmental conditions, and in many cases, provide jobs and support for the economy.

Placer mining BMPs provide low cost, common sense quidelines and solutions to environmental problems, and will help prevent similar damage from occurring again.

Bibliography

Cost Estimation Handbook for Small Placer Mines, 1987, Scott A. Stebbins, Western Field Operations Center, Spokane, WA: U.S. Bureau of Mines Information Circular 9170, 94 p.

Guidelines for the Design and Construction of Stream Channels for Yukon Placer Mined Streams, 1991, Hardy BBT Limited; prepared for Habitat Management Division, Pacific Region, Fisheries and Oceans Canada, 95 p.

Handbook for the Alaskan Prospector, 1964, Ernest Wolff: The Burnt River Exploration and Development Company, Ft. Collins, Colorado, and College of Earth Science and Mineral Industry, University of Alaska: Part I, Geology and Part II, Prospecting Techniques, 428 p.

Handbook for Prospectors, Richard M. Peall, 1973: McGraw-Hill, Inc., 470 p.

Handbook for Reclamation of Placer Mined Stream Environments in Western Montana, 1991, Inter-Fluve, Inc., U. S. Environmental Protection Agency, 340 p.

Mining Cost Service, 1990, Section CM, Cost Models, Appendix B: Placer Gold; Western Mine Engineering, Spokane, WA.

Montana Forestry Best Management Practices (BMPs), 1991, Bob Logan and Bud Clinch: Montana State University, 33 p.

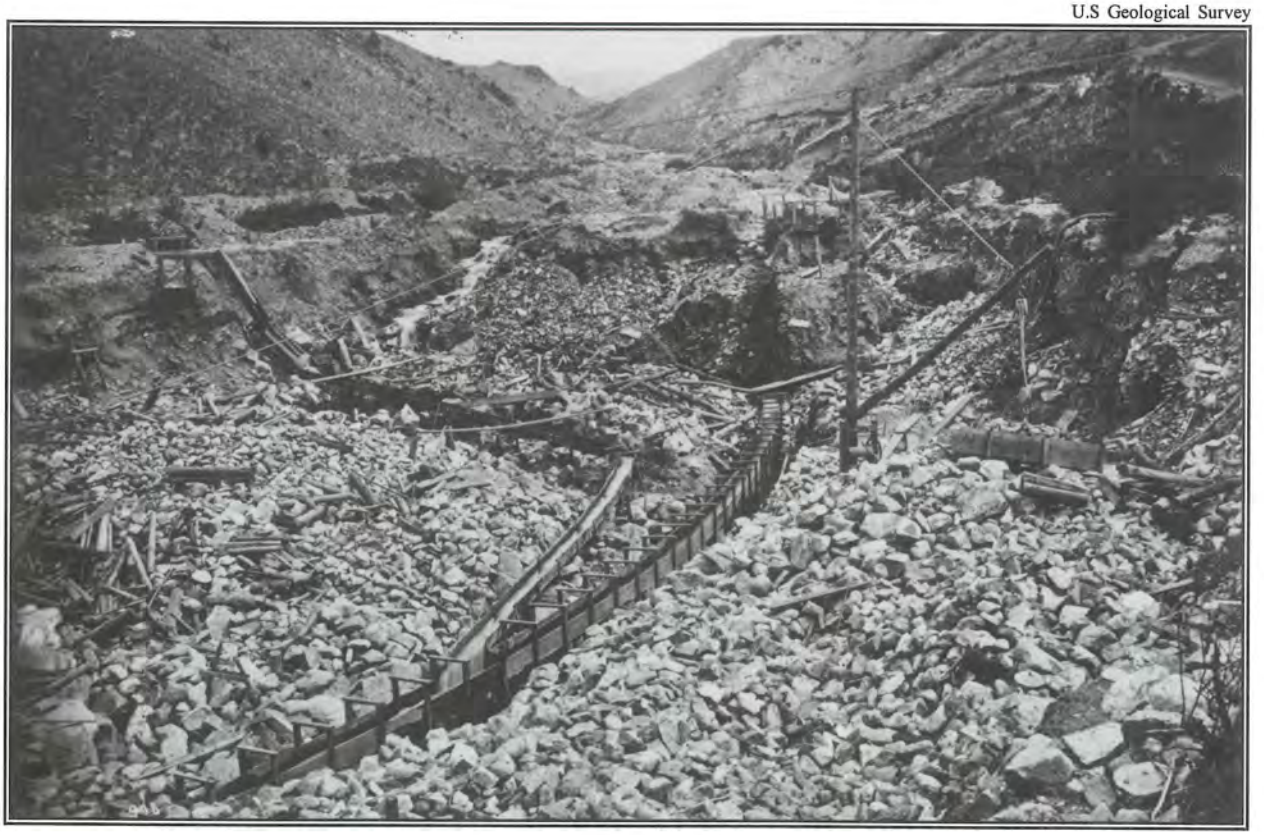
Permitting and Environmental Constraints; Their Impact on Mining in Alaska: Gary E. Sherman, OFR 35-90, 28 p.

Placer Examination, Principles and Practice, 1969, Technical Bulletin 4: U.S. Department of Interior, Bureau of Land Management, 155 p.

Prospecting and Operating Small Gold Placers, 1936, William F. Boericke: John Wiley and Sons, Inc., 144 p.

NOTES

U.S Geological Survey



Alder Gulch, 1872.

NOTES

Montana Historical Society

Confederate Gulch, 1868.