HANDBOOK
FOR THE
REMEDIATION OF ABANDONED MINE LANDS

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June 1, 1992
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ACKNOWLEDGEMENTS

Three members of the National Park Service, Mining and Minerals Branch are due a special note of appreciation for their participation in the preparation of this handbook: Phil Cloues for his support and his expertise in mining and environmental remediation, Jim Wood for drafting the figures, and Lael Cleys for preparation of the manuscript.
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INTRODUCTION

This booklet provides a summary of the abandoned mineral lands (AML) program in the National Park System (NPS). The summary is presented in a question and answer format along with a number of pictures to illustrate the concerns. The reader can simply scan the questions, and read only the answers that are of interest.

Photographs illustrate the extent of AML sites, dramatically show some safety hazards and resource damage, illustrate historical significance and interpretive possibilities, and show some innovative methods of preserving wildlife habitat. Several types of mine closures are shown along with some closures that have been vandalized.
QUESTIONS AND ANSWERS ABOUT THE ABANDONED MINERAL LANDS PROGRAM

1. Q. What are abandoned mineral lands?
   
   A. Abandoned mineral lands (AML) include all abandoned mines (hardrock, coal, industrial minerals, and sand and gravel), wells (oil, gas, and geothermal), access roads, and associated processing facilities. Mineral lands are considered abandoned when no responsible party can be identified, and responsibility falls on NPS for mitigating safety hazards and remediating environmental impacts.

   This handbook addresses abandoned mines and associated facilities while other documents cover abandoned wells.

2. Q. Why is the AML program important?
   
   A. There are many safety hazards in abandoned mines including vertical drop-offs, bad air, water, rotten timbers, loose and falling rock, undetonated explosives, and high levels of radioactivity. Decaying structures, attractive to climb, are often unstable. In addition, mine rescues at these sites endanger rescue teams.

   Environmental impacts from AML sites vary depending on the type and size of mine and local conditions. The greatest impacts involve surface water and groundwater, soil, vegetation, and aquatic life. In many cases, ecosystems are radically altered or destroyed. Acid mine drainage affects water quality, placer mines destroy riparian habitat, and vehicles crossing the tundra in Alaska damage permafrost. Chemicals leaching out of mine waste rock and chemicals used in ore processing soak into soils and groundwater, damaging soil productivity and water quality.

   Part of the NPS mission is preservation of the nation's historic and culturally significant sites. Estimates indicate that approximately two percent of the AML sites are culturally or historically significant. At several parks, the history of early mining is incorporated into interpretive programs. To ensure that historic structures are not lost forever, they must be stabilized before they deteriorate entirely.

   Liability of NPS and its employees is one of the major concerns that arises in connection with AML sites. Concern is warranted because many mines present an opportunity for serious injury or death. In addition, mines are man-made. The hazards associated with them are expected to be known, monitored, and actively managed to a much greater extent than natural features.
As land managers and custodians of the public resources, NPS has a responsibility to visitors to enable them to enjoy the parks with a reasonable degree of safety. Likewise, NPS employees should be able to work free of undue risks.

Courts have found that visitors can reasonably be expected to recognize and avoid most obvious hazards. But, when hazardous conditions are unusual or hidden, courts have found that there is a responsibility to provide warnings or take steps to mitigate the hazards.

3. **What is the scope and magnitude of the AML problem?**

Q. Current estimates indicate that 120 parks contain approximately 2,000 abandoned mines with nearly 10,000 associated hazards. Further, the inventory of AML sites is incomplete, and there may be many more sites. The following table summarizes the known abandoned mines by region.

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<td>86</td>
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<td>5. North Atlantic</td>
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<td>15</td>
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<tr>
<td>6. Pacific Northwest</td>
<td>7</td>
<td>39</td>
</tr>
<tr>
<td>7. Rocky Mountain</td>
<td>20</td>
<td>106</td>
</tr>
<tr>
<td>8. Southeast</td>
<td>13</td>
<td>164</td>
</tr>
<tr>
<td>9. Southwest</td>
<td>14</td>
<td>53</td>
</tr>
<tr>
<td>10. Western</td>
<td>23</td>
<td>923</td>
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<td><strong>TOTAL</strong></td>
<td>120</td>
<td>1,936</td>
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4. **What are the key features of an AML program?**

A. A comprehensive AML program should have the following four main objectives:

* Eliminate health and safety hazards,
* Eliminate or mitigate resource impacts,
* Preserve historically and culturally significant sites, and
* Manage sites for special wildlife habitat.

Achieving these objectives requires the following six basic program components, implemented at the park, region, and Washington office levels:
1. Inventory AML sites,
2. Use inventory data to rank sites,
3. Plan site remediation,
4. Obtain funding,
5. Implement site remediation, and
6. Monitor remediated and remaining sites.

5. Q. **What is the authority for the AML program?**

   A. The **Organic Act of 1916** - manage the national parks in such a manner and by such means as to leave them unimpaired for the enjoyment of future generations.

   **Wilderness Act of 1964** - protect and manage so as to preserve the natural conditions of wilderness lands.

   The **National Environmental Policy Act of 1969 (NEPA)** is the basic national charter for protection of the environment.

   **Endangered Species Act of 1973 (ESA)** authorizes the US Fish and Wildlife Service to list a species endangered or threatened which gives these species special protection.

   **National Historic Preservation Act of 1966 (NHPA)** sets forth the concern of the nation for preservation of its heritage.

6. Q. **What are the permitting and compliance requirements?**

   A. The remediation project may require permits under the following laws where applicable:

   * Clean Water Act, Section 404 permits projects in floodplains and wetlands.

   * Clean Air Act, air quality permits for fugitive dust generated by the remediation project.

   * State and local permits. Most States have regulatory programs specifically governing mining operations. Many States have air and water pollution control requirements and permits that implement the Federal Clean Air and Clean Water Acts.

   When planning a remediation project, consult NPS lead program offices such as the WASO Air Quality Division and Water Resources Division, and the Regional Solicitor's Office when appropriate.

7. Q. **What are the relevant NPS management guidelines?**

   A. **National Environmental Policy Act Guideline, NPS-12, Release No. 2, September 1982.**


Letter from Secretary Manuel Lujan, Jr. dated July 11, 1989 to all employees, "Each agency shall ensure that appropriate financial, personnel and other resources are allocated to effectively implement and administer the agency's safety and health program."

8. Q. What are the organizational roles and responsibilities?

A. Mining and Minerals Branch (MMB), Land Resources Division, Washington Office:

* Responsible for coordinating a servicewide AML program.
* Staff includes geologists, mine engineers, environmental specialists, and policy analysts.
* Provide AML technical expertise and policy guidance.
* Provide technical guidance on optimizing AML remediation at minimum cost.
* Assist in obtaining funding.
* Maintain a servicewide AML data base.
* Provide training.
* Design notices for the public.
* Prepare sample fact sheets on AML accidents for use by Public Affairs Officers.

Regional Offices:

* Direct and approve regional AML program.
* Cooperate with States on AML projects.
* Resolve conflicts regarding the type or method of mine closures and site remediation.

Parks:

* Conduct AML inventories.
* Implement AML remediation.
* Monitor both remediated and unremediated sites.
* Post warning signs at AML sites, along access routes, and in visitor centers.

For additional guidance on developing an AML program, refer to Tab II.
The objective of this handbook is to support park staff in the remediation of AML sites. Previously, information on abandoned mines was incomplete and scattered among numerous documents. The handbook attempts to consolidate existing information that is relevant to AML sites in the national parks.

When a specific need arises, the reader will want to go directly to useful information without having to wade through information not pertinent to the particular need. The triggers for action will come from the need to develop an AML program, perform site inventories, protect public safety, and remediate sites. The handbook is organized by these needs, and the reader can go directly to pertinent information.

The handbook must provide up-to-date information on the most effective and efficient methods for AML remediation. For this reason, the handbook is a set of booklets bound in a loose leaf binder. In this way, individual booklets can be revised without having to republish the entire handbook. For field trips, only Tab VII Field Guide is essential, and it can be removed from the binder. The Field Guide consolidates reference material and checklists for conducting site inventories and reconnaissance.

REFERENCE

WHAT IS AML?

ABANDONED MINERAL LANDS (AML) INCLUDE ALL ABANDONED MINERAL EXTRACTION SITES INCLUDING HARDROCK, COAL, AND SAND AND GRAVEL MINES, OIL AND GAS AND GEOTHERMAL WELLS, ACCESS ROADS, AND PROCESSING FACILITIES ASSOCIATED WITH THE OPERATIONS.

TALC MINE IN DEATH VALLEY NM

KENNICOTT MILL FACILITIES IN WRANGELL-ST. ELIAS NP&P

OIL AND GAS WELL AT CUYAHOGA VALLEY NRA
CINDER PIT IN LAVA BEDS NM

GEOTHERMAL WELL IN LASSEN VOLCANIC NP

MINE ACCESS ROAD IN WRANGLER-ST. ELIAS NP&P
IMPACTS TO RESOURCES

Resource impacts from abandoned sites vary depending on the type and size of operation and the local environment. The greatest impacts are to the water, soil, vegetation, and aquatic life. In many cases, the ecosystems have been radically altered or destroyed. Acid mine drainage has affected water quality, placer mines have destroyed riparian habitat, and vehicles crossing the tundra in Alaska have resulted in problems with the permafrost. Chemical substances used at mines and extracted from wells have soaked into the soils, ruining their productivity and creating kill zones.

Acid Mine Drainage in Big South Fork NR&RA

Placer Mine in Denali NP&P

Kill Zone Caused by Acid Mine Drainage in Big South Fork NR&RA

Topsoil Removal Site in Delaware Water Gap NRA
SAFETY HAZARDS

There are many safety hazards associated with abandoned sites. Mine openings are extremely hazardous and can contain vertical drop-offs, bad air, water, rotten timbers, loose rock, undetonated explosives, and high levels of radioactivity. Rescues at those sites can put park personnel into dangerous situations. Decaying structures, attractive to climb on, are often unstable. Abandoned oil and gas wells can leak methane and other poisonous gasses.

DANGEROUS HEADFRAME AT THE GOLDEN BEE MINE IN JOSHUA TREE NM

SKIDOO MINE IN DEATH VALLEY NM

ADIT IN WRANGELL-ST. ELIAS NP&P

METHANE LEAKING FROM A WELL IN BIG SOUTH FORK NR&RA

WARNING SIGN IN CANYONLANDS NP

CAUTION

RADIATION AREA

Radiation levels in this area are elevated due to uranium mining. A maximum of one day should be spent in the area. Water in the vicinity is highly contaminated and should not be ingested.

NO CAMPING

DO NOT DRINK THE WATER
HISTORICALLY SIGNIFICANT AML SITES

Part of the NPS mission is the preservation of the nation’s historic and culturally significant sites. About 2 percent of the abandoned sites in the NPS are culturally or historically significant. At several parks, the NPS is incorporating the theme of mining into Park interpretive programs. To ensure that historic structures are not lost forever, they must be stabilized before they deteriorate entirely.
WILDLIFE MANAGEMENT

Many AML sites provide habitat for wildlife. In some instances, the wildlife are rare, threatened and endangered species. In cases where AML sites are providing habitat to significant wildlife, innovative closures preserve the habitat and also ensure safety for visitors.

Townsend's Big Eared Bats in the Last Chance Mine in Grand Canyon NP

Bat Gate in New River Gorge NR Designed to Admit Rare Bats
MITIGATION MEASURES

There are many alternatives available to resolve the problems associated with abandoned mineral lands. Typical measures used to close underground mines include installation of flexible cable nets, grates, or bat gates; backfilling with waste material; and sealing mine openings by blasting or with polyurethane foam. Mine access roads, quarries, and other surface disturbance can be recontoured and reclaimed, and abandoned wells can be plugged. Costs can run from as little as $500 to several hundred thousand dollars, depending upon the site, the amount of reclamation, and the presence of hazardous materials.

Backfilling two openings at Terry Mine in Capitol Reef NP cost $7,000. Mine openings can be blasted shut. Costs vary from $500 to $2,000 per opening.

Bat gate at Kaymore Mine in New River Gorge NR cost $5,000.

Grates installed by helicopter at Victoria Mine in Organ Pipe Cactus NM. Grates cost from $700 to $8,300 depending on access and size.
INSTALLING A POLYURETHANE FOAM PLUG. COSTS VARY FROM $1,000 TO $31,000 DEPENDING ON SIZE, ACCESS AND SITE CONDITIONS.

RECLAIMED TIMBER HAULAGE AND QUARRY ACCESS ROAD IN REDWOOD NP. RECLAMATION OF THIS ROAD COST $189,000/MI. SMALLER ROADS COST AS LITTLE AS $11,000/MI.

CABLE NET AT STATE OF TEXAS MINE IN CORONADO NM. CONSTRUCTED AND INSTALLED BY DEATH VALLEY NM STAFF. COST AVERAGES $1,250 PER NET.

RECLAMATION OF JENSIK QUARRY IN CUYAHOGA VALLEY NRA COST $20,000. RECLAMATION OF LARGER QUARRIES WILL COST SEVERAL HUNDRED THOUSAND DOLLARS EACH.
FIELD INVENTORY AND MONITORING

Trained field personnel are critical to effectively implement an AML program. Park staff must be trained to collect site data. After mitigation, sites need to be monitored to ensure that changing conditions have not altered the closures.

Site Inventory in Great Basin NP

Earthquake-induced cable net failure at the Lost Horse Mine in Joshua Tree NM

Cut fence around the Orphan Mine in Grand Canyon NP

Hole dug to access shaft covered by a steel grate at the Desert Queen Mine in Joshua Tree NM. Of the 12 closures at this mine, all have been defeated.
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INTRODUCTION

A letter from Secretary Lujan to all employees dated July 11, 1989 states "Each agency shall ensure that appropriate financial, personnel and other resources are allocated to effectively implement and administer the agency's safety and health program."

The objective of the program presented in this handbook is to mitigate or eliminate safety hazards and environmental impacts associated with abandoned mineral lands (AML). For the purpose of this handbook, these are lands impacted by past mining or minerals exploration where a responsible party cannot be identified. In other context, AML also includes abandoned oil and gas wells and associated exploration.

Each National Park Service (NPS) park or unit with abandoned mineral lands should develop and maintain an inventory of AML sites, documenting safety hazards, impacts on natural and cultural resources, and visitor use. Such an inventory will provide the information to establish remediation priorities, and to monitor resource conditions and corrective actions.

Safety hazards and resource impacts associated with abandoned mines should be mitigated or eliminated as funding and personnel become available. Alternatives for treating mine openings include permanent closure, temporary closure, maintenance as wildlife habitat, no action, or, once safety problems are addressed, retention and interpretation as an historic feature.

Until AML sites can be remediated, visitors must be given a reasonable warning of hazardous conditions. This warning may include signs at mine sites, signs at visitor contact stations, notices in visitor guides, and verbal warnings during ranger contacts and interpretive presentations. Warnings must be sufficiently detailed so that a visitor can recognize hazards and make an informed decision to avoid them.

All remediation of abandoned mineral lands must be consistent with NPS policies on compliance with the National Environmental Policy Act (NEPA), protection of threatened and endangered species, and preservation of cultural resources. Where appropriate, AML issues should be addressed in park management documents including the statement for management, land protection plan, resource management plan, backcountry management plan, etc.
PROGRAM ELEMENTS

The source of guidance on AML issues is Loss Control Management, NPS-50, Chapter 30, Abandoned Mine Safety and Minerals Management Guideline NPS-66, Chapter X. The following text is paraphrased from NPS-50, Chapter 30.

LEGAL AUTHORITY


PROGRAM OBJECTIVES

The objectives for managing an AML program are broad-based and incorporate many facets of the National Park Service's (NPS) overall administrative responsibilities. There are four major objectives:

A. Elimination or mitigation of safety and health hazards associated with AML sites.

B. Mitigation of impacts to NPS resources.

C. Preservation of historically or culturally significant AML sites.

D. Management for specific wildlife habitats, especially threatened and endangered species.

PROGRAM REQUIREMENTS

A. Site Inventory - The first requisite of the program is to obtain a complete inventory of all the AML sites administered by NPS. The inventory should be an on-the-ground site inspection. This inventory may be complicated by the fact that many sites are in remote locations, access is difficult, and, in some parks, sites are so numerous that a complete AML inventory may take several years. Techniques for site investigation are found in Tabs IV and VII.

1. Team Selection - Inventories should be conducted by a team of at least two individuals. This approach allows multiple disciplines to be represented and provides for assistance in case of an accident. The team leader or coordinator should be a field person with an
understanding of collecting analytical data. This person should be well versed in identification and evaluation of AML sites and in recognition of hazards associated with each site. The team leader should ensure that members are briefed on potential hazards and trained on AML safety procedures.

2. **Presite Inspection Research** - The "on-the-ground" work will be most effective if some background research is done. This can include a brief literature search, obtaining existing maps and perhaps doing a fly-over of the area before going into the field. The following list provides possible sources of information and what to look for.

**Sources of Information:**

* USGS topographic maps.
* Maps and records of land status and mining claims.
* USGS publications and geologic maps.
* Industry maps and reports.
* Aerial photographs.
* Aerial reconnaissance.
* Interviews with old timers.
* Historic resource inventory.
* Historic publications and early accounts of area.
* Land protection plan.
* Foot search.

**What to Look For:**

* Topographic contours sometimes reveal mine features.
* Waste rock.
* Disturbed and subsided lands.
* Old roads and railbeds.
* Underground openings (adits, shafts, stopes).
* Structures, buildings, headframes.
* Symbols on maps.
* Developed springs, reservoirs, ditches.

3. **Preparation and Entry Procedures** - AML sites are inherently hazardous and must be treated as such by the park staff. Many hazards are not obvious and some cannot be detected without instruments. In most cases, there is no need to enter any of the abandoned mine workings; they are too dangerous. Coal mines in particular will not be entered unless substantial justification overrides safety concerns. Underground evaluations or reconnaissance should be conducted only by properly trained and equipped personnel and generally are necessary only where it is likely that visitors would enter the mines if they were in the
area. Underground mines that are not entered for evaluation should be considered very hazardous and a high priority for closure.

In the event entry is necessary, the team should be well prepared and trained. The team should have available to them the following items:

* Safety boots, gloves, hard hat, mine light, spare light, scaling bar, safety glasses.
* Multi-gas detector.
* At least two sources of light; all sources should be explosion-proof unless it has been previously determined that no explosive gases are present.
* Communication with someone outside the mine or site depending on the location of the site.
* Mine rescue contingency plan with trained rescue personnel and equipment available to respond in the event of an emergency.

Additional guidance on safety is given in Tabs VI and VII.

The following is a listing of potential hazards associated with AML sites:

Shafts may be hidden or have loose rock and rotten timbers.
Explosives may be deteriorated and unstable.
Water contaminated or may hide vertical shafts or conceal sharp rusty metal and creates a slipping hazard.
Dangerous Substances - left over from when the mine was active such as cyanide, ammonia and PCPs; asbestos insulation, etc.
Debris on the Floor - broken glass, nails, sharp and rusted objects.
Cave-ins or Cave-in Potential - Most mines were never meant to last more than a few years. Due to age, weathering and rotten shoring, walls and ceilings are susceptible to collapse.
Bad Air - insufficient oxygen, poisonous gases and explosive gases.
Animals - poisonous snakes, spiders, scorpions, rats, bears, mountain lions, wasps, bees, bats, etc.

DO NOT ENTER UNDERGROUND COAL MINES. DO NOT ENTER OTHER UNDERGROUND MINES IF CONDITIONS INDICATE THAT A CAVE-IN IS POSSIBLE, OR BAD AIR IS PRESENT.
4. **Documentation** - Forms have been developed for data collection. [See Tab VII.] They are in a checklist format and also provide for photographs. Each hazard at a specific site should be identified. Copies of the AML inventory, reconnaissance and monitoring forms should be filed with the Mining and Minerals Branch (MMB) of the Washington Office (WASO) to update their nationwide AML data base. "As built" plans of AML remediation projects should be sent to MMB.

B. **Hazard Mitigation** - A mitigation plan addressing all known AML sites in each park should be developed. The plan should include what is known about the sites, proposed actions, information and funding needs, and a list of action priorities. Alternative mitigation includes:

1. **Immediate, Short-Term Procedures**

   **Post signs** - Signs should be posted warning visitors of an abandoned mine, the hazards inherent with the site, and telling them to stay out. Signs should be designed to communicate the hazards to the broadest range of visitors including children and those who do not read English. Signs should be posted in the proximity of the AML site. If a number of sites exist in a particular area, signs warning of the presence of AML sites should be strategically placed at common access points where possible. Signs must be monitored periodically to see that they are not stolen or vandalized.

   **Discontinue leading interpretative walks or other entry into mine workings** if hazards have been noted with a potential for injury. The Regional Safety Officer should be notified of the situation as soon as possible. Only when corrective measures have been taken, will the public be allowed access. The Regional Safety Officer will approve in writing the resumption of visitor-related activities at the AML site.

   **Abandoned explosives** are a critical hazard that must be addressed immediately. All abandoned explosives must be disposed of by a specialist certified in explosives disposal. Certified blasters are not trained in the recognition, handling, and disposal of old and/or deteriorated explosive products.

   **Provide appropriate warning information** in park literature and delete references to AML sites unless the sites have been made safe or until appropriate warning signs have been posted.

   **During interpretive talks**, include appropriate warnings and information about AML sites.
2. **Intermediate, Reversible Solutions** - Installation of bulkheads, fencing, cinder block or stone walls, grating, netting, bat gates, etc. Intermediate closure methods vary widely in cost and effectiveness.

3. **Long-Term solutions** - Backfilling or blasting mine openings, recontouring and revegetating disturbed lands.

C. **Hazardous Waste** - The regional hazardous waste coordinator should be contacted if there appears to be soil, surface water, and/or groundwater contamination or other chemicals associated with the AML site. In many cases, it is difficult to tell through a visual inspection if there are hazardous wastes in the soil, air or water. Samples will be collected and analyzed.

D. **Mine Rescue Contingency Planning** - Mine rescue can be extremely dangerous. Life-threatening hazards can be present that are not apparent, even to those experienced in mine or other kinds of rescue operations. Rescuers have been killed because they followed a victim, and were unprepared for the hazard.

NPS parks with AML sites that have a potential for visitors or employees to become trapped, injured, or ill must develop a mine rescue contingency plan. This plan must be integrated into the park's emergency operations plan. The plan should be a concise reference that is available in the park dispatch, and search and rescue offices. Each plan should include the following elements:

1. **Known Hazards** - Those hazardous conditions that are known to exist and the specific mine openings where they occur.

2. **Other Suspected Hazards** - Hazards that are common to the area and the type of mines found in the park.

3. **Mine Rescue Contacts** - Specific names, phone numbers, and backup phone numbers of mine rescue organizations and individuals to be contacted for assistance. Sources of expertise will include the office of the State mine inspector, State and county search and rescue organizations, and professional mining organizations.

4. **Special Considerations** - Conditions under which body recoveries will not be attempted due to extremely hazardous conditions.

E. **Monitoring and Enforcement** - Regular patrols should be made to AML sites to ensure that safeguards remain in place. In
addition, patrols should monitor changing conditions that create the need for additional work to make AML sites safe.

F. **Interpretation of Abandoned Mines** - Visitors are often very interested in abandoned mine sites and will seek them out. In addition, there are cultural and historic opportunities for NPS to interpret many sites. However, AML visits and interpretation should not be done in a manner that will exposes visitors to undue hazards. AML sites should be fully evaluated for safety hazards prior to taking actions that encourage visitation and exploration.

G. **Mine Tours** - Taking visitors into mines or encouraging them to explore mines on their own requires a mine monitoring and maintenance program that is beyond the capabilities of all but a very few parks. Mines are temporary features that require frequent maintenance to remain open and safe. A mine that is sound today may not be in the future, and many sites can never be made safe. Parks which offer tours of mines need a mine safety specialist on staff and a regular monitoring schedule.
PROGRAM RESPONSIBILITIES

**Park AML Coordinator**

Coordinates all activities relating to abandoned mineral lands consistent with NPS guidelines and procedures.

Designated member of park and regional staff with expertise in the recognition and evaluation of AML sites.

Arranges and conducts field work and logistics.

Directs interdisciplinary team in conducting field work, including AML inventory, reconnaissance, monitoring, and other site visits.

Evaluates inventoried sites and applies priority ranking.

Develops safety and remediation plans for sites in accordance with priority ranking.

Prepares proper NEPA compliance documents.

Coordinates and incorporates AML needs and priorities with park's resource management plan.

Initiates and coordinates design and posting of adequate signs and warnings to notify public of nearby hazardous AML sites.

Requests specialists and other assistance from region or private consultants as required.

Trained in abandoned mine safety. Provides or coordinates mine and hazardous waste safety briefings to NPS staff and public who visit AML sites.

Prepares and maintains park AML data base.

Serves as project manager (or contracting officer in parks without this type of expertise) on AML construction projects.

Conducts or coordinates monitoring of completed AML remediation projects, and documents the condition of mine closure and remediation work. Ensures that emergency, seasonal, and routine maintenance are performed as needed.

Develops and recommends AML funding and personnel needs to park superintendent.

Manages park AML budget.
**Site Manager**

Ensures that an AML coordinator is appointed and trained.

Ensures that the site complies with NPS policy.

Ensures that NPS employees do not enter AML sites with the exception of personnel who have the expertise and have been authorized to do so or if the AML site is deemed safe for the general public.

**Interpretation**

Responsible for providing appropriate safety messages to visitors through verbal information at contact stations, park literature, interpretive displays and signs, and through interpretive programs.

Identifies sites with interpretive values to help formulate the type and extent of remediation or restoration of any given site.

**Rangers**

Ensure that signs are appropriately placed.

Enforce temporary AML site closures.

Monitor completed remediation projects, and report deterioration and maintenance needs to the park AML coordinator.

Develop a mine rescue contingency plan, acquire mine rescue equipment and train employees on mine rescue methods. This responsibility may be waived if the park has a cooperative agreement with another agency or organization to conduct mine rescues (e.g., State mining division, Mine Safety and Health Administration, etc.).

**Safety Officer**

Familiar with the NPS and regional AML health and safety programs

Participates in AML planning and activities in an oversight capacity.

Reviews AML sites and plans with regard to employee and visitor safety and health.

Understands the status of the safety conditions at all AML sites in the park.
Ensures that the safety conditions are adequate for AML sites being used for interpretation and sites being promoted on hikes, points of interest, and as destination points.

Prepares reports for park AML coordinator on hazardous conditions observed during patrols in the park. Reports include observations of visitor use of AML sites or signs that past use has occurred.

Monitors completed AML projects, and reports deterioration and maintenance needs to the park AML coordinator.

Maintains case incident reports on AML sites.

**Environmental Compliance Coordinator**

Reviews and approves any NEPA compliance documents.

Reviews and approves AML remediation proposals submitted by the park AML coordinator.

Provides guidance to inventory and reconnaissance teams in the recognition and treatment of environmental impacts.

Makes recommendations for appropriate remediation measures.

**Natural Resource Coordinator**

Investigates natural resource impacts of AML sites and recommends appropriate remediation.

Reviews and approves AML remediation proposals for possible impacts to natural resources.

Ensures compliance with ESA.

**Cultural Resource Coordinator**

Participates in AML inventories.

Makes determination of National Register eligibility for historic sites.

Reviews all proposed remediation projects for potential impacts to cultural or historical structures or objects.

Submits recommendations to the regional AML coordinator regarding important historic or cultural features of the mine site and actions that may be necessary to preserve or protect them.
Ensures compliance with Section 110 and 106 of NHPA and other laws concerning cultural and historic preservation.

Works with the State Historic Preservation Officer.

**Land Coordinator**

Determines ownership and land status of AML sites and their access prior to the initiation of any work.

**Maintenance Division**

Reviews and approves proposed blasting or explosives disposal.

Maintains mine closures and warning signs.

Constructs AML remediation projects as required.

**Regional AML Coordinator**

Provides overall regional coordination of the AML program.

Provides program direction, and information on technology changes or advancements to park and regional staffs.

Assists parks with field work and/or research concerning AML inventory, reconnaissance, or remediation projects.

Compiles and maintains regional AML data base as collected by park AML coordinators.

Reviews and approves AML remediation proposals for adequacy.

Acts as park AML coordinator in parks without available staff or mining expertise.

Responsible for AML contract preparation, and acts as project manager/contracting officer for AML projects in parks without available staff.

Ensures adequate coordination and review among all appropriate offices.

Coordinates AML management and policies with the WASO Mining and Minerals Branch to ensure consistency and effectiveness.
Serves as primary contact with State AML programs. Identifies AML sites suitable for inclusion on the State's AML inventory list. Coordinates remediation projects with the State office.

Actively seeks AML funding from all potential sources including, but not limited to, park and regional budgets, WASO Mining and Minerals Branch, State AML program, regional and WASO safety office, and EPA.

Manages regional AML budget.
**PARK MANAGEMENT AND PLANNING DOCUMENTS**

It is important that AML sites be addressed in park management and planning documents. This serves three important functions. First, the park must examine the extent of AML issues and develop a remediation strategy. Secondly, the stated policies and objectives presented become an action guide for park management and staff. Lastly, the documents serve as an educational tool for the interested public, and demonstrate an active concern on the part of the park.

Generally, management documents for parks with AML sites should include statements that:

1) Abandoned mines exist and are hazardous
2) The park has a program to identify and correct hazards and resource impacts.
3) Visitors will be advised of hazardous mines.
4) Remediation accomplished is dependent on available funding and other priorities.

The following paragraphs are a suggested AML section for the backcountry and wilderness management plan for Big Rock National Monument.

**Abandoned Mineral Lands**

**Safety:** There are at least 27 abandoned mines in eight mining districts within Big Rock National Monument. Topographic maps published by USGS show approximately 140 shafts and tunnels in backcountry and wilderness areas. Many more openings certainly exist, along with numerous shallow pits and prospects. Abandoned mines are popular destinations and offer visitors the opportunity to experience some of the history of the area, but they also present a significant risk of injury or death.

Potential hazards include falls into open mine shafts and pits, rockfalls and cave-ins in tunnels and adits, bad air, explosive gases, toxic substances, and dangerous wildlife. Underground cave-ins sometimes break through to the surface and can engulf unsuspecting people. Underground openings are often hidden by darkness and there is the danger of falling. Old explosives are extremely unstable and often encountered. Old buildings and equipment may collapse without warning. The remoteness of many mines makes emergency assistance very difficult. Additionally, rescues or body recoveries from abandoned mines are extremely hazardous and, in some cases, impossible.
Big Rock National Monument has developed a program to identify mine hazards, correct safety problems, and warn visitors of potential hazards. Mine openings are inventoried and evaluated for their hazards, amount of visitor use, the risks in performing a rescue, and environmental degradation. Priorities for remediating abandoned mines are established by ranking their hazards and environmental impacts. If a problem is identified, a more detailed investigation will be conducted and a plan developed to mitigate or remediate the problem. Potentially hazardous materials will be investigated and disposed of in accordance with appropriate State, NPS, and other Federal regulations.

The preceding text includes all the elements of a thorough AML program. This level of detail is important for two reasons. First, the public should know that there are hazardous abandoned mines in the park and that NPS has a remediation program. However, with limitations on funding and personnel, the work may be slow and many hazards will remain for some time. Secondly, this text offers the park an opportunity to present a management position with regard to abandoned mines, including a step-by-step approach to correct the problems. Such a clearly-stated approach will be useful in guiding park staff in the future and in supporting future funding requests.

Much less detailed text is appropriate for the Statement for Management:

Abandoned mines present a significant potential health and safety hazard for visitors and also impact natural resources. Big Rock National Monument has an active program to identify hazards and environmental impacts, and mitigate the most severe problems. Several shafts and adits have been capped with steel grates, backfilled, or closed with cable nets. Other mine openings will be filled or closed, in priority order, as funding and staff time are available. Visitors will be warned of the hazards that may be encountered at abandoned mines.
LIABILITY AND ABANDONED MINES

Liability of NPS and its employees is one of the major concerns that arises whenever abandoned mines are considered. Concern is warranted because many mines present an opportunity for serious injury or death. In addition, mines are man-made features. The hazards associated with them are expected to be known, monitored, and actively managed to a much greater extent than natural features. This section presents some background on liability, some of the specific cases involving abandoned mines, and appropriate actions to demonstrate the conscientious management of abandoned mines.

As land managers and custodians of the public resources, NPS has a responsibility to visitors to offer an opportunity to enjoy the parks with a reasonable degree of safety. Likewise, NPS employees should be able to work in an environment that is free of undue risks to life and health. Some natural and man-made hazards exist in parks. Courts have found that visitors can reasonably be expected to recognize and avoid most obvious hazards. But, when hazardous conditions are unusual or hidden, courts have found that there is a responsibility to provide warnings or take steps to mitigate the hazards.

Prior to 1945, the U.S. Government maintained sovereign immunity from damage claims. For an individual to collect retribution for damages caused by a government act, or an employees action, required a special act of Congress. After Congress found itself dealing with numerous such actions, the Federal Tort Claims Act of 1945 was passed. Under this act, the Federal government and its agents could be sued and were, in essence, to be treated like a private party. Negligence was the standard to be applied as defined by each State.

When the United States or an employee is accused of negligence, there are two principal defenses that are applicable to park management, the discretionary function defense and recreational use statutes.

THE DISCRETIONARY FUNCTION DEFENSE

The discretionary function defense is based on the Federal manager's ability to make decisions within their area of authority and responsibility. The Federal government cannot be found negligent for deciding on a course of action that is generally accepted and is within the scope of authority; even if that action results directly or indirectly in injury or death. However, and this is a critical point, a manager cannot use discretion to avoid responsibility.

NPS has stated a responsibility to provide for a safe visitor experience (NPS Management Policies, 1989). In addition, land managers have a responsibility to have a basic knowledge of
the resources they manage, including the hazards that are present. Therefore, the discretionary function defense would be a weak tool when used to defend a lack of knowledge of an abandoned mine or the hazards that exist there.

The U.S. Justice Department is sometimes reluctant to use the discretionary function defense in cases that involve a single injury or death. It is important that the concept of this defense not be weakened by an adverse decision in a relatively minor case, such as a single death in an abandoned mine. This would greatly reduce the effectiveness of this defense in cases involving major catastrophes or large-scale injury to the public (i.e., airline crashes or fallout from nuclear testing). The importance of this for parks is that in a case involving an injury in a park, even where managers used appropriate discretion, might well be settled out of court, with a settlement being paid by the park.

RECREATIONAL USE STATUES

The other major tools for defending the Federal land manager are Recreational Use Statues. Most states have adopted these statutes to protect landowners from suit when a member of the public enters their land for the purpose of recreation and is injured. Without this kind of protection, many private landowners would not allow any public recreation on their property. The public would lose recreation opportunities and the landowner would have to go to great effort and expense to exclude visitors. These laws apply to the NPS because the Federal Tort Claims Act of 1945 says that the U.S. Government is to be treated as an individual.

Most recreational use statutes contain some exceptions or have been held to have exceptions by the courts. One exception, called "consideration," says that recreational use statutes will not protect a person who collects money for the use of the land. This will probably apply to parks that collect entrance fees. However, collecting a fee specifically for camping does not necessarily exempt the remainder of the park from the protection of a recreational use statute. There is some state-to-state variability in the treatment of consideration.

Recreational use statutes are also limited when a park employee makes an "express invitation" to use the resource. This occurs when a park representative, or even park literature, assures a visitor that a mine, road, camp ground or other area is safe. Once that commitment is made, the NPS is no longer protected by recreational use statutes should an injury occur. This exception should not prevent us from being good hosts and providing useful information to visitors, but we should be perfectly honest when discussing hazards that might be present. NPS was unable to use the recreational use statute to support the defense in a recent case where a ranger at Yellowstone National
Park told visitors that it was safe to camp in an area, and the visitors were subsequently attacked by a bear.

If a judge feels that a landowner knowingly disregarded the presence of a hazardous situation, he can make a finding of "willfulness" and rule out the use of the recreational use statute. In making a determination of willfulness, the judge is evaluating whether the landowner willingly disregarded a hazardous situation, when a normal person would have corrected it to prevent injury to his or herself or visitors. This has implications for NPS when abandoned mines are inventoried while funds may not be available to correct the hazards that are found. As pointed out in the discussion of the Campbell case below, willfulness can be avoided by having a formal AML program, even if funds are not sufficient to address every hazard immediately.

CASE STUDIES

There are three cases involving injuries or fatalities in abandoned mines that are useful examples for discussing the liability associated with abandoned mines. Two occurred in NPS parks and one occurred on BLM lands.

Campbell v. United States

In 1981, a 14-year-old boy, Von Campbell, and his 16-year-old friend set off to explore a mine shaft near their home. They had thought about this expedition for some time and were prepared with rope, water, gloves and a homemade torch. After testing the shaft for depth, they tied the rope to a nearby tree and, with some reluctance, Von Campbell began a descent. He stopped shortly after entering the shaft because the crumbling wall was injuring his hands. He was unable to climb up or down, and his friend could not pull him up. Von lost his grip and fell to the bottom of the shaft suffering a broken femur and other injuries. As a result, his left leg is permanently shorter than the right.

The Folsom Resource Area Office of BLM was responsible for managing the area and had an AML program. It was a small program with only one employee, a heavy equipment operator, devoting half of his time to the inventory and remediation of abandoned mine hazards. BLM had inventory records of at least five shafts in the vicinity of the shaft where the accident occurred, but had not determined whether these shafts were truly abandoned or on active claims located nearby. No actions had been taken to mitigate the hazards at these shafts.

The judge found in favor of the United States and BLM. The finding stated that the hazard was open and obvious, the boys knew of its existence and the fact that it was hazardous, as evidenced by their preparations. Campbell had made a voluntary and reasonable decision to assume the risk of entering the shaft. He also found that BLM had used appropriate discretion in
allocating limited funds and staff to their AML program. They had staff working on the problem and were in the process of inventorying and correcting hazards even though they had not made much progress. BLM could not be expected to devote all of their resources to an abandoned mine program and neglect other management responsibilities.

This case points out the need for a formal AML program in each park that has abandoned mines, even if the resources are not available to address all of the problems immediately after they are identified. It is appropriate for an agency to work toward an ultimate solution within budgetary and staffing constraints.

**Eimer v. United States**

In June of 1984, Bill Eimer, his family and some friends were visiting Death Valley National Monument. They were at the abandoned Keene Wonder Gold Mine and Bill and a friend decided to make the arduous hike to the upper workings. There they discovered an interesting adit that did not look particularly hazardous. Bill entered the adit without a light. Darkness did not stop his progress as the adit was straight. Once his eyes adjusted, the light entering the mouth of the adit appeared sufficient to illuminate the entire adit to its terminus about 300 feet in. Unfortunately, this was an illusion. The illuminated end of the adit was actually light projected on the far wall of a large stope, a void left where a large amount of ore was removed. Bill could not see this because a few rocks on the floor appeared to shade the floor of the adit. In actuality, there was no floor. He fell about 20 feet into an area of large boulders sustaining severe head and back injuries. In spite of a heroic effort on the part of his friend and park staff to rescue him, Bill died before reaching a hospital.

The Keene Wonder Mine and several other mines are important historic resources in Death Valley and attract many visitors. They are located on park maps, mentioned in brochures and have road signs directing visitors to the sites. The park had known that some of the mines were hazardous and had posted signs stating "MINE HAZARD AREA" at many of the sites. The Keene Wonder Mine had been inventoried for hazards but that specific adit was "not explored for deep hazards." The adit was scheduled for closure, but funds that were planned for the closure were used for part of a large project to stabilize the spectacular historic tramway that carried ore from the mine to the mill on the valley floor.

This case was settled prior to going to trial. The Justice Department was willing to settle in part because NPS was vulnerable on several points. The warnings provided were inadequate. Bill Eimer may have heeded the warning that the area was hazardous. He entered the adit carefully, and only went as far as he could see. Since old mines are an attraction to the area and recognized as valuable resources by the park, the park
has a responsibility to provide adequate warnings. These warnings must be sufficiently detailed so that a reasonable person can make an informed decision to avoid the hazard.

The adit should have been explored to see if it contained hidden hazards. If it was considered too hazardous to explore, then it would have been rated a severe hazard and made a top priority for closure. Even if it had not been closed by 1984, the park would have been in a better position to defend its actions. Mine hazards should be evaluated with the curious and uninformed visitor in mind.

The decision to complete more stabilization rather than close those adits may have been an appropriate use of management discretion. The tram system was nearly intact, it represented a spectacular feat of engineering, and it was in eminent danger of collapse. Failure of any component of the system would have sent shock waves through the cables damaging other structures. In hindsight, mine closures should have been included as part of the project. The cost increase would have been less than 10%.

Jeffery v. United States

In May 1970, the Jeffery and La Blanc families were visiting Lake Mead National Recreation Area. They were riding dirt bikes in the vicinity of Katherine Landing and the Treasure Vault Mine. They had been advised by a ranger that they could not ride off-road in the recreation area and that there were mines in the vicinity. Though they were advised to go outside the park boundary for riding, they were apparently unaware of the location of the boundary and began riding in the vicinity of the mine. The father of the La Blanc family arrived at a mine waste pile. He rode slowly up the 3-foot-high bank then stopped because he was on the brink of a conical pit that surrounded an open mine shaft. Mr. Jeffery rode past Mr. La Blanc and, unable to stop, slid toward the shaft, grasping a piece of lumber that was over the shaft at the last moment. Douglas Jeffery was immediately behind his father. He was also unable to stop and could not grab the lumber or his father. Douglas fell 165 feet to his death.

NPS knew of the shafts. The subdistrict ranger had inventoried mines in the area and described their hazards in a memorandum in January 1969. There were no warnings or barriers at the mine. A notice posted at the camp ground listed the rules for off-road vehicle use, but did not mention the hazards. The court found NPS negligent for not maintaining the area in a reasonably safe condition or giving adequate notice of the hazardous conditions that were present. The court awarded the Jeffery's $135 000 plus court costs. This case points out the need to take at least minimal action when extreme hazards such as this particular shaft are known. It is at least as important to post warnings of hazards in the area as it is to post regulations. Park files should have included not only a record that the site was known, but a record of the actions to be taken.
Even if no action had been taken, the expressed intent to correct the hazard would have strengthened the park's position considerably.

RECOMMENDED ACTIONS

* Have a formal, proactive program to identify and mitigate abandoned mine hazards.

Having a recognized program will help change the balance of sympathy. It is far better to explain why the program had not corrected a specific hazard, than to explain why there is no program.

* Have an AML inventory.

This will provide the information needed to find out if the park has any severe hazards warranting immediate attention, and to seek funds to correct the problem. A good inventory will insure that limited funds are expended on the most important sites.

To not inventory mines and rely on a lack of knowledge as a defense is folly. As a land-management agency, we have the responsibility to know what resources exist. When visitors can easily find out about abandoned mines from topographic maps, brochures, trail guides, asking local residents, or even asking park staff, a manager would be negligent in not also knowing about these sites.

* Document decisions.

If discretionary function is to be a viable defense, it is important that there be a record of decisions. A record will also help avoid a finding of willfulness by demonstrating there were good reasons for the actions that were taken.

* Provide adequate warnings.

Warnings must explain the hazards in sufficient detail that the visitor can make a rational decision to avoid the danger. These warnings should be located as warranted by the number and type of mine hazards in the area. Locations may include at the mine site, at visitor contact stations, in pamphlets and guides, or given orally during visitor contacts. In spite of all warnings, some people will put themselves in danger. This is evidence of their negligence, not the Park Service's.

* Explore mines for deep hazards, if possible, or document decisions not to explore.

The persons evaluating mine hazards should approach mines as a curious visitor would. If a visitor would be enticed inside a mine, the inventory should include an evaluation of underground hazards. Particular attention should be given to surprises and problems that a visitor without a light or other proper equipment might encounter. The persons evaluating mine hazards must be properly equipped, trained, and should not subject themselves to undo hazards. If an opening cannot be entered safely, it definitely should not be entered, but must be assigned the highest hazard ranking.

* Do not imply complete safety where it does not exist.

Visitors should never be told that a mine is completely safe. Underground workings are never completely safe, and most above ground features have at least a moderate risk due to rotten wood, sharp metal, fractured rock and general deterioration. Visitors should always be told to use caution and specific hazards should be cited if they are known.
REMEDICATION PRIORITIES

In parks with a large number of AML sites, procedures must be developed to select the remediation sequence. Remediation funds will always be limited, and generally the worst sites should be fixed first to get the most benefit. High priority sites have the following characteristics:

* Extreme health and safety hazards.
* Ease of access.
* High visitation.
* Difficult rescues.
* Severe and progressive environmental degradation.

The field guide, Tab VII, includes an AML rating system with two scores, one score for health and safety hazards and a second score for resource impacts. This system gives equal ratings for hazards and resource impacts. The range in scores is one to three. Parks are free, of course, to develop their own rating system that more closely matches local conditions. Experts in developing rating methods have found that the ratings should not be too complicated, and there should not be more than three to six levels. Further, the score criteria should be written to limit the sites qualifying for the worst score with progressively more sites qualifying for a particular rating as the score criteria improve.

Some typical rating difficulties involve having:

1) Large numbers of similar sites where rating may be futile.
2) Many different people and interpretations of the ratings.
3) Skewed geographic distribution of visitors.
4) Tremendous ecological and physiographic variations.
5) Sites with historical significance.
6) Liability concerns.

Consistency is important in the site rating. If possible, one person should rate all the sites. Alternatively, the average score of a panel should determine the site rating. As AML sites are remediated, the remaining ratings may become inappropriate. In this event, the score criteria may require revision and the remaining sites rated again. The ratings may also require revision with time as more information becomes available.
Under some circumstances, it may be appropriate to select sites differently than given by the rating procedure. For example, there could be insufficient funds to permanently close and remediate the highest priority site. In this case, a park might decide to simply fence the worst site and permanently close a less costly site with a lower priority. Justification for circumventing the site ratings include cost-benefit analysis, limited funds, less costly temporary closures versus more costly permanent closures, and concerns over liabilities.

If funds are to be sought from the Office of Surface Mining Reclamation and Enforcement (OSM), a park will have to convert their ratings to the hazard ranking system mandated by the Surface Mining Control and Reclamation Act (SMCRA) of 1977. The OSM ranking system is heavily weighted toward health and safety hazards, as follows:

- Priority 1: Previous injury or death, or property damage.
- Priority 2: Significant health and safety threats.
- Priority 3: Resource impacts.

For NPS purposes, the OSMRE ranking system does not adequately differentiate between sites.
ORGANIC ACT OF 1916

Manage national parks in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.

WILDERNESS ACT OF 1964

Protect and manage so as to preserve the natural conditions of wilderness lands.

NATIONAL ENVIRONMENTAL POLICY ACT OF 1969 (NEPA)

NEPA is the basic national charter for protection of the environment. It requires that all Federal agencies develop procedures which will ensure environmental amenities and values be given appropriate consideration in decision-making. (42 USC 4321-4347 Sec. 102(2)).

AML mine closures are Federal actions that require NEPA compliance. In addition, the NEPA process is an ideal place to document decisions on an AML program.

For parks with numerous AML sites, NEPA documentation should be prepared for a park as a whole, not mine site by mine site. NEPA encourages agencies to tier their environmental impact statements to eliminate repetitive discussions of the same issues. "Tiering" refers to the coverage of general matters in broader environmental impact statements with subsequent narrower statements on site-specific issues.

The elements of an environmental assessment include the following:

a. Identify purpose and need for action.

b. Analyze environmental, safety, historic, and technical concerns.

c. Describe affected environment.

From past experience, special attention must be given to site access, new disturbances resulting from site remediation, impacts on threatened and endangered species and other wildlife, loss of historic and other features of interest to visitors and historians, impacts to prehistoric features, loss or improved visitor access and experience, and wilderness issues.

d. Analyze reasonable alternatives and consequences including direct and indirect effects, long- and
short-term results, any irreversible and irretrievable commitment or resources, and possible conflicts between restoration objectives.

e. Describe proposed action and rationale for choice.

f. Provide supporting evidence. (40 CFR Part 1502)

NEPA established the Council on Environmental Quality to advise and assist the President in carrying out the provisions of the act and in reviewing environmental impact statements.

As added in 1970, Section 309 of the Clean Air Act requires that the Environmental Protection Agency (EPA) review and comment on all environmental impact statements. If EPA determines that the proposed action is unsatisfactory from the standpoint of public health or welfare or environmental quality, the decision is published and referred to the Council of Environmental Quality. (42 USC Sec. 7609)

Refer to NEPA Guideline NPS-12 which describes the internal procedures for NPS implementation of NEPA.

ENDANGERED SPECIES ACT OF 1973 (ESA)

ESA authorizes the US Fish and Wildlife Service (USFWS) to list a species endangered or threatened because of any of the following factors:

1. The present or threatened destruction, modification or curtailment of habitat or range;

2. Over utilization for commercial, recreational, scientific, or educational purposes;

3. Disease or predation;

4. The inadequacy of existing regulatory mechanisms; or

5. Other natural or man-made factors affecting its continued existence. (16 USC Sec. 1533(1)(b)).

Some abandoned mines are habitats for threatened and endangered species including bats, ringtail cats, and spotted owls. If a threatened and endangered species is suspected, ESA clearance is required which means that wildlife studies must evaluate the impact of site remediation. ESA prohibits a Federal agency from taking, approving, or funding an action unless it finds that the action is not likely to jeopardize the continued existence of a threatened and endangered species or result in the destruction or adverse modification of critical habitat. (16 USC Sec. 1536(b)(3))
USFWS has published rules governing the ESA consultation process at 50 CFR Part 402. Formal consultation is requested by the authorizing agency and triggers the time limits for the consultation process. USFWS must respond in 90 days stating whether the proposed action is likely to jeopardize the species or adversely impact its critical habitat. If USFWS issues the jeopardy opinion, it must also propose reasonable and prudent alternatives that would not violate ESA. (16 USC Sec. 1536(d))

For NPS guidance, see Natural Resources Management, NPS-77 Chapter 2.

NATIONAL HISTORIC PRESERVATION ACT OF 1966 (NHPA)

NHPA sets forth the concern of the nation for preservation of its heritage. It provides for a National Register of historic places and objects significant in American history, architecture, archeology, and culture.

Under this law, if a property is on or eligible for the National Register, this fact must be considered when any Federally-funded or permitted project might adversely impact the property. For this consideration, note that the property need only be eligible for the National Register, and some AML sites may be eligible.

Section 106 of the act requires that the President's Advisory Council on Historic Preservation be afforded an opportunity to comment on any action which adversely affects properties listed on or eligible for the National Register.


Specific NPS management procedures are given in Cultural Resources Management Guideline NPS-28.

OTHER STATUTORY REQUIREMENTS

To ensure compliance with all relevant and applicable statutory requirements, the AML program coordinator must research park, regional, State, and Federal regulations and guidelines. MMB can assist this research with checklists for adequacy of mine plans and compliance with the NPS guidelines.
**FUNDING**

Some funding is available from Office of Surface Mining Reclamation and Enforcement (OSM), Environmental Protection Agency (EPA), some State AML programs, and NPS operating budget. At this time, these sources are limited, uncertain, and inadequate to address the AML problems. As recommended above, funding depends on adequate inventories and planning followed by appropriate coverage in park management and planning documents.

**NPS FUNDING SOURCES**

Base funding for the AML program as such is currently nonexistent through park and regional budgets. Funds are identified via other sources. Base funding and Fee and Natural Resource Protection funding have been used to address some of the most severe hazards; however, these funds are limited and generally allocated to the more visible problems. The development of a reliable and comprehensive AML inventory increases a park's chances of obtaining baseline funding to remediate the most serious problems. Additional funds may be available from the WASO-MMB, and the regional and WASO Safety offices.

**FUNDING UNDER THE SURFACE MINING ACT**

The Surface Mining Control and Reclamation Act of 1977 (SMCRA) established the Abandoned Mine Reclamation Fund for the purposes of reclaiming and restoring lands adversely affected by past mining. Monies for the fund come from a reclamation fee imposed on current coal production. The AML program under SMCRA is administered by OSM. Lands eligible for reclamation are those that were mined or affected by mining and abandoned or left inadequately reclaimed prior to August 3, 1977, and for which there is no continuing reclamation responsibility under State or Federal law.

Monies from the fund are available to States and Indian tribes with approved AML programs, and to the Secretary of the Interior. State funding is based on coal production of the State.

While primarily directed at coal mining, noncoal AML sites can be considered for reclamation with SMCRA funds under certain circumstances. Close coordination with the State and OSM are essential in obtaining funding under SMCRA.

SMCRA requires that each participating State or Indian tribe conduct an AML inventory as part of a national AML inventory. In order for a site to be considered for funding under SMCRA, it must be justified as part of this comprehensive inventory. The inventory concentrates on the most serious problems that are adversely affecting public health, safety, and general welfare and are identified according to priorities set by SMCRA.
Priority 1 is an extreme danger problem, Priority 2 has evidence of health, safety, and general welfare problem, and Priority 3 has environmental restoration problems.

Funding from OSM has been used to remediate abandoned coal mines in a few eastern parks. It is only available in States with active coal mining, and is only available for noncoal abandoned mines after all abandoned coal sites have been remediated. These funds are primarily obtained through the State AML programs. For example, the Colorado Mined Land Reclamation Division recently closed seven hazardous mine openings in Dinosaur National Monument. On occasion, NPS has negotiated interagency agreements with OSM for AML funds with conditions similar to those above for inventories and priorities.

**EPA FUNDING SOURCES**

EPA's Nonpoint Source Funding under Section 319 of the Clean Water Act possibly has funds for AML sites with acid mine drainage and contaminated groundwater. MMB is currently exploring the possibility of this funding source.

MMB also obtained EPA Superfund assistance in funding mine remediation. In April 1989, EPA agreed to undertake clean-up of the McLaren mine tailings adjacent to Yellowstone.
APPENDIX A

SELECTED REFERENCES


Farmer, Eugene, and Bruce P. Van Haveren, Soil Erosion by Overland Flow and Raindrop Splash on Mountain Soils, U.S. Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah, 1971.


Heede, Burchard H., Conversion of Gullies to Vegetation Lined Waterways, USDA Forest Service, Research Paper RM-40, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, 1968. (Dr. Heede is now located at the Forest Sciences Laboratory, Arizona State University, Tempe, Arizona.)


Stevens, R., "Techniques for Planting Shrubs on Wildland Disturbances," in *Shrub Establishment on Disturbed Arid and Semiarid Lands*, Wyoming Game and Fish Department, 1981.


ABANDONED - mineral lands are considered abandoned when no responsible party can be identified; therefore, the responsible party for correcting resource and safety problems falls to NPS.

ABANDONED MINERAL LANDS - includes the remains of any activity relating to the exploration or development for any mineral resource including hardrock minerals, mineral materials, industrial minerals, coal, oil shale, oil and gas, geothermal energy or topsoil. Abandoned mineral lands include mining or other extraction sites, mill and smelter sites, access roads, processing facilities, and associated disturbed land.

ALLUVIAL - pertaining to alluvium, may be loose gravel or soil.

ADIT - a horizontal or nearly horizontal passage driven from the surface for the working or dewatering of a mine. If driven through the hill or mountain to the surface on the opposite side, it would be a tunnel.

APEX - the top terminal edge of a vein on the surface or its nearest point to the surface (blind apex). The apex is the point from which inclination is measured to determine extralateral rights of the deposit.
ASSAY - 1) (verb) to determine the amount of metal contained in an ore; 2) (noun) the result of making such a determination.  
Note: difference between assay and analysis: in an analysis all of the chemical constituents are determined; in an assay only certain constituents are determined, usually those of commercial interest.

ASSESSMENT - annual work that must be done on an unpatented mining claim on US public domain lands.

BENEFICIATE - processing of ore to reduce size, remove unwanted constituents, and increase purity of commercial constituents.

BENCHES - ledges of all kinds of rock or gravel shaped like steps.

BLANKET DEPOSIT - flat ore deposit much larger and wider than thick.

BLOCK CAVING - see CAVING.

BORE HOLE - an exploratory or prospecting hole made by drilling.

CAPPING - a rock formation overlying a body of rock or ore such as the rhyolitic volcanos which form mesas and plateaus in the southwestern U.S.

CAVING - a mining method in which the ore is broken by induced caving.

Variations:  
top slicing. A horizontal slice of ore is removed allowing the ore above it to cave. Then, leaving the slice below temporarily intact, a still lower slice is removed, allowing the intervening slice to cave.

block caving. Similar to top slicing except that the slice which is allowed to cave is of much greater thickness, and may even constitute the full thickness of the ore body.

pillar caving. Ore is broken in a series of stopes or tall rooms, leaving pillars between. Eventually the pillars are forced or allowed to cave under the weight of the roof.

CHUTE - channel or shaft down which ore is shoveled or allowed to fall.

CLAIM - 600 x 1,500 feet for a lode claim; 600 x 1,320 feet for a placer claim.
COLLAR - the term applied to the timbering or concrete around the mouth or top of a shaft.

CONCENTRATE - (verb) to separate metal or ore from the associated gangue or barren rock.

CONCENTRATOR - mill or plant in which ore is concentrated by removing unwanted constituents.

CROSSCUT - a horizontal opening driven across the course of a vein or in general, across the direction of the main workings. A connection from a shaft to a vein.

COUNTRY ROCK - a general term applied to the rock surrounding and penetrated by mineral veins; in a wider sense applied to the rocks invaded by and surrounding an igneous intrusion.

DEVELOP - expose ore bodies for mining, as by sinking shafts and driving drifts.

DRIFT - horizontal opening in or near an ore body and parallel to the course of the vein or long dimension of the ore body. An underground passage following a vein.

DUMP - material deposited from a mine--usually waste material.

EPITHERMAL ORE DEPOSIT - deposit formed by hot ascending solutions at shallow depth and low temperature.

EXPOSURE - any part of a rock formation easily seen either in a mine or a surface outcrop.

FACE - in any adit, tunnel, or stope, the end at which work is in progress or was last done (i.e., "the working face").

FISSURE - an extensive crack, break, or fracture in rock. A mere joint or crack of a few inches or feet in length is not termed a fissure although in a strict sense it is one.

FLOAT - loose fragments of vein material found downhill from an outcrop.

FLOOR - that part of any underground opening upon which you walk or upon which a haulage way is laid.

FLOTATION - a method of concentrating ore by inducing particles of particular minerals to float to the surface of water or other solution (usually buoyed up by air bubbles) while the other particles sink to the bottom.

FLUX - a substance charged into a furnace for the purpose of combining with unwanted substances in the ore in order to form slag.
FOOTWALL - the wall or rock under a vein. It is called the floor in bedded deposits.

GANGUE - undesirable minerals occurring in ore.

GOPHERING - haphazard mining of the easiest and richest parts of an ore body.

GOSSAN - a weathered (oxidized) superficial cover of sulfide deposits often easily located due to the highly-colored iron oxides (and jasper), sometimes with manganese dioxide, and clay minerals.

HANGING WALL - the wall or rock on the upper side of an inclined vein. In bedded deposits (sedimentary) it is called the roof or top.

HEADFRAME - structure erected over shafts for hoisting purposes.

HYDROTHERMAL - pertaining to or resulting from the activity of hot aqueous solutions originating from a magma or other source deep in the earth.

LEVEL - underground mines are usually worked from a network of horizontal openings or drifts called levels. These are commonly spaced at regular intervals in depth and are either numbered from the surface in regular order or designated by their actual elevation below the top of a shaft.

LOCATION - staking out or making a mining claim.

LODE - 1) a fissure in the country rock filled with minerals; 2) tabular deposit of valuable minerals between definite boundaries.

MOTHERLODE - the principal lode or vein passing through a district or particular area.

MUCK - 1) (noun) rock broken in the process of mining; 2) (verb) to remove rock.

NATIVE - occurring in nature as a pure metal (e.g., native silver).

ORE - an aggregate of minerals which will yield a profit when mined and, if required, processed.

ORE PASS - an opening in a mine through which ore is delivered from a higher to a lower level.

ORESHOOT - concentration of primary ore along certain parts of an ore deposit.

OUTCROP - that part of a stratum or vein which appears on the earth's surface.
OVERBURDEN - material of any nature, consolidated or unconsolidated, that overlies a deposit of useful minerals, ores, or coal, especially those deposits that are mined from the surface by open cuts.

PARAGENESIS - the order of deposition or crystallization of the minerals present.

PILLAR - a piece of ground or mass of ore left to support the roof or hanging wall in a mine.

PITCH - inclination of an ore body or mine opening.

PLACER - deposit of alluvial gravel containing valuable minerals.

PORTAL - any nearly horizontal entrance to a mine.

PRIMARY ORE - ore not enriched or oxidized by supergene processes, i.e., the chemical effects produced by descending groundwater.

RAISE - a vertical or inclined opening driven upward from one mine level to connect with the level above, or to explore the ground above a level. See winze.

ROOM (mining) - a wide working place in a flat bed or vein.

ROOM AND PILLAR - a method of mining whereby the ore is mined in a series of rooms leaving ore pillars between the rooms to support the overlying rock.

ROUND - 1) rock broken or advance accomplished in a drift or other opening by simultaneously blasting a single set of drilled holes; 2) the set of holes drilled in preparation for a blast.

SCALING BAR - a bar used to knock down loose rock. Also called a pry bar.

SECONDARY ORE - ore enriched by supergene processes (descending groundwater).

SHAFT - a vertical or inclined opening, serving and providing access to various levels in a mine. Entry into and removal from a shaft of people, equipment, material and rock requires the use of mechanical hoisting equipment due to the steepness of the shaft.

SHOOT (oreshoot) - concentration of ore along certain parts of an ore deposit.

SINGLE JACK - a light single-handed hammer used in hand drilling.
SLIMES - ore reduced to a very fine powder and held in suspension in water so as to form a kind of thin mud.

SQUARE SET - a set of timbers consisting of vertical and horizontal posts all meeting at 90 degree angles.

SQUARE-SETTING (square-set stoping) - method of mining whereby the stope is supported with square-set timbering as the ore is removed.

STOPE - an underground opening from which ore has been or is being extracted. Does not include shafts, drifts, crosscuts, levels, etc. Usually applied to highly-inclined veins. An overhand stope is made by working upward from a mine level to the next level above. An underhand stope is made by working downward beneath a mine level.

STRINGER - a veinlet or small vein, usually one of a number which collectively make up a stringer lode or stockwork.

STULL - a timber prop set between walls of a stope.

SUMP - an excavation made to collect water which is then pumped to the surface.

SUPERGENE - generated from above. Refers to the effects (usually oxidation and secondary sulfide enrichment) produced by descending groundwater.

TAILINGS - refuse material resulting from the washing, concentration, beneficiation, or other treatment of crushed ore. TIMBER - any of the wooden props, posts, bars, collars, lagging, etc., used to support mine workings.

TUNNEL - a horizontal or nearly horizontal underground passage open at both ends.

VUG - cavity within a body of rock or ore, sometimes lined with crystals.

WINZE a vertical or inclined opening sunk downward from inside a mine for the purpose of connection with a lower level, or for exploring the ground below a level. In some mines, the opening when connected through, is called a raise no matter which direction it was driven originally.
APPENDIX C
DEFINITION OF ACRONYMS

AML - abandoned mineral lands.
BLM - Bureau of Land Management.
CFA - California Fertilizer Association.
CMLRD - Colorado Mined Land Reclamation Division
EA - environmental assessment (mandated by NEPA).
EIS - environmental impact statement (mandated by NEPA).
EPA - Environmental Protection Agency.
ESA - Endangered Species Act.
MMB - Mining and Minerals Branch of Land Resources Division, National Park Service.
NEPA - National Environmental Policy Act.
NHPA - National Historic Preservation Act.
NPS - National Park Service.
OTA - Office of Technology Assessment.
OSM - Office of Surface Mining Reclamation and Enforcement.
PDER - Pennsylvania Department of Environmental Resources.
SCS - Soil Conservation Service.
SMCRA - Surface Mining Control and Reclamation Act.
USFS - United States Forest Service.
USGS - United States Geological Survey.
WASO - Washington Office of the National Park Service.
WDEQ - Wyoming Department of Environmental Quality.
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INTRODUCTION

This booklet outlines how to manage an AML mine closure and remediation project. Topics include the elements of project management, project planning, levels of engineering detail, management of project construction, a checklist of quality assurance procedures, and finally a brief description of project management tools. Where appropriate, the discussion focuses on the unique aspects of AML projects. With this booklet, park staff have the guidance to manage small engineering and construction projects. For more detailed guidance, refer to the documents listed in the following box.

The planning phase for construction projects is most important in that early decisions affect the ultimate design and cost of a project. It is during this phase that the size, function, and technical performance requirements are determined and the budget is set. Once preliminary decisions are made, the nature and cost of a project are virtually predetermined.

The planning phase commences at initial identification of a project, and continues until receipt of detailed design and construction funds. Then the execution or construction phase begins and continues until completion and client (NPS) acceptance of the construction work.

LESSONS LEARNED

It is important to focus some attention on problems that repeatedly plague construction projects. These problem areas with recommended solutions include the following:

Failure to Design to Requirements. A tendency exists during design of a project to improve design by consideration of only the benefits of different design options. This tendency results in changes to project scope and cost that are substantially in excess of initial baseline estimates. Avoid this problem by insisting on a "design to cost" policy and tight fisted adherence to the project functional requirements.

Failure to Establish Realistic Baselines. There is a tendency to scope projects and establish schedules in such a manner that initial estimates are favorable. Establish baselines for cost, schedule, and technical requirements only when there is sufficient data to define realistic estimates. Further, require a careful review of project data by an independent organization prior to establishing baseline estimates.

Inadequate Change Control Procedures. Inadequate change control procedures lead to large scope and schedule changes that result in large cost increases. Change control procedures should be detailed, include cost considerations, and independent review.
Inadequate and Inaccurate Project Status Reports. To perform properly, project managers must continuously assess and analyze the project status. This analysis is impossible if reports are inaccurate or untimely. Minimize this problem by identifying early in the planning process what information is needed and when, and requiring the information in the contract. In addition, periodically verify submitted data against the data sources, and make corrections to the reporting procedure as necessary.

Lack of Experienced Project Management Staff. Personnel assigned or hired to manage a project must be experienced and knowledgeable in the specific type of construction. Assigned staff must be trained in the techniques for measuring performance against baselines, must have interdisciplinary experience related to the work, and must understand management techniques for successful project management.

Insufficient Use of Incentives. Even though incentives have been effective in the construction industry, the Federal government has not used incentives frequently. An incentive contracting policy could provide significant benefits.
PROJECT ELEMENTS

Effective management of construction projects requires the following elements:

* Clearly defined scope.
* Break down of work into appropriate contracts.
* Reliable cost estimates.
* Realistic schedules.
* Applicable functional requirements, performance criteria, constraints, and construction standards.
* Competent personnel.
* Efficient organization.
* Clearly designated authorities and responsibilities.
* Timely monitoring and reporting the status of work.
* Effective comparisons of progress and costs with schedules and estimates.
* Timely identification of potential or actual problems.
* Prompt action to eliminate or resolve problems.

The importance of planning in developing the preceding project elements cannot be overemphasized.

PROJECT ROLES

Responsibility for development of a project plan rests with the project manager. The role of project manager and other individuals and organizations that may participate in planning, design, and construction include the following:

The **contracting officer** is a representative of NPS who has the authority to enter into and/or administer contracts and make related decisions and findings.

The **project manager** has direct primary responsibility and accountability for management of the engineering and construction effort. He/she is designated the contracting officer's technical representative. Among the usual functions of the project manager are the following:
1) Assures costs, schedule, and scope requirements are met.

2) Acts as the principal contact between contractor and NPS.

3) Assures that instructions to the contractor are within terms of the contract.

4) Assures compliance by the contractor with technical, quality, safety, and administrative requirements of the contract.

5) Participates in formulation of plans and schedules, and recommends their approval/disapproval to the contracting officer.

6) Assures effective communication between project participants.

7) Submits requests for contract modifications to the contracting officer.

The **architect-engineer** furnishes preliminary and detailed plans and cost estimates, and sometimes validates construction engineering and contract bid cost estimates. The architect-engineer may also assist in preparation of design criteria, and perform special studies, trade-off studies, risk assessments, alternatives analysis, and estimates of contingency reserves.

The **construction contractor** usually furnishes all materials of construction, performs all construction work, and procures and installs equipment in accordance with construction drawings and specifications.

A **construction manager** provides professional management services, and functions in support of the project manager. The construction manager is generally not the same firm as the architect-engineer or construction contractor because there is a possibility of organizational conflict of interest. The decision to use a construction manager depends on size and complexity of the project, capabilities of the project management staff, and scope of the architect-engineer and construction contracts. Generally AML projects are small and straightforward, and do not require a construction manager.

**TYPES OF PROJECT PLANS AND COST ESTIMATES**

Six general types of plans and cost estimates are developed and used in the life of a construction project. Identification of a plan type denotes a certain level of accuracy and confidence.
in the plan. These six types are defined below and in Fig. 1. The figure defines plan types by the required content, and provides guidance on the probable level of accuracy and appropriate contingency allowance. Note that the figure provides contingency guidance for both first time (green-field) and routine projects.

**Order-of-Magnitude Plans and Estimates**
Crude plans and estimates are developed for each project at the time of project identification. Since these are developed prior to conceptual design, they are order-of-magnitude, ballpark type plans that have the least amount of accuracy. This type of plan would result from information gathered by the AML Inventory Form, Tab VII.

**Conceptual Plans and Estimates**
Budget plans and estimates are required to obtain project authorization and funding appropriations. These plans and estimates are generally based on a completed conceptual design. Often these plans are used as baselines for justification of cost overruns. Contingency allowances should be substantial from 10 to 18% due to the lack of definitive design information. This type of plan would result from the information gathered by the AML Reconnaissance Form, Tab VII, and the preliminary cost estimate, Tab V.

**Preliminary Plans and Estimates**
Preliminary plans and estimates are developed from detailed background, topographical, and subsurface data. These plans determine the requirements and criteria which govern subsequent definitive design. Tasks include preparation of preliminary engineering studies, preliminary drawings and outline specifications, life-cycle cost analysis, preliminary construction cost estimates, and scheduling for project completion. Preliminary design provides identification of long lead time procurement items and analysis of risks associated with project development. Contingency allowances generally range between 8 and 13%.

**Definitive Plans and Estimates**
Definitive design continues development of the project based on approved preliminary design. Definitive design includes any revisions required of the preliminary design; preparation of final working drawings, specifications, bidding documents, and cost estimates; coordination with all parties which might affect the project; development of firm construction and procurement schedules; and analysis of contract proposals and bids. Contingencies generally range from 5 to 10% of the construction cost dependent upon the extent of uncertainties remaining.
ESTIMATE TYPES

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PROBABLE CONTINGENCY AS A%

Lowell, E. D., 1975, p. 25-3
Engineer's Estimate

The engineer's estimate may be made when bid design (see below) is 30, 60, and 100% complete. These estimates are usually prepared by an architect-engineer (frequently the architect-engineer who prepared the definitive design) 1) to determine the reasonableness of competitive construction bids, 2) as a control in evaluating cost and pricing data in negotiated contracts, and 3) as a check on the construction contractor. They are based on quantity take-offs and pricing of partly or fully designed portions of the project. They are probably unnecessary for small, straightforward AML projects.

Construction Bid Design and Estimate

Bid design and estimates are based on completed construction drawings, technical specifications, and competitive quotations from specialty subcontractors. The quality and completeness of the plans and specifications have a significant impact on the final price of the project.

Each plan and cost estimate should always be fully documented, and contain the plan type, reference year for the dollar figures, and date of the plan. Most importantly, the project manager must follow the NPS procurement guidance as given by Acquisition Guidelines, NPS-62.

The following table indicates the highest level of engineering generally required based on expected construction cost.

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<th>Construction Cost</th>
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Exceptions to this guidance include unusual safety and health hazards, unproven or experimental technology, and any closures where the results would be uncertain without careful study and quality assurance.

The preceding six levels of planning are not all required for each project. For example, it is unnecessary to go through each of the six levels for a group of little prospect pits that have a high total closure cost but individually require nothing more than a few cubic yards of backfill and topsoil. Similarly, some parks have a large number of AML sites, and there is an opportunity to standardize designs and remediation methods. When a park provides standard designs and specifications, it is only necessary to perform conceptual design, and then final bid design and cost estimate.
SPECIAL FEATURES OF AML PROJECTS

Remediation of AML sites differ from typical construction projects in several ways.

First, there is the elimination or mitigation of public safety and health hazards associated with AML sites. Among others, the hazards include hidden shafts, abandoned explosives, bad air, and toxic substances. These hazards necessitate special training for investigators and construction workers, special construction methods, and coordination with mine rescue units. See Tabs VI and VII.

Second, there is the remediation of impacts to NPS resources. This necessitates closing the mines, constructing erosion and sedimentation control, and revegetation. Further, the remediation may constitute a major Federal action which triggers the NEPA process. See Tab II.

Third, there may be preservation of historically or culturally significant AML sites as mandated by the National Historic Preservation Act, and NPS standards and guidelines.

Fourth, management of the AML site for specific wildlife habitats may be necessary, specially for threatened and endangered species as required under the Endangered Species Act.

If you need help with the special aspects of AML sites or have any questions, phone Mining and Minerals Branch, (303) 969-2092.
PLANNING AND ENGINEERING

PURPOSE

The planning phase for AML projects is most important with respect to design and cost. It is during this phase that the closure method (temporary→permanent), environmental remediation, and historic preservation are determined, and the budget set. Once the preliminary decisions are made, the nature and cost of the project are virtually predetermined.

The planning phase starts with the initial decision to remediate an AML site, and continues until receipt of the detailed design for construction. In most cases, the work beyond conceptual design will be done by others, for example contractors or the federally funded State AML programs. Nevertheless, park AML project managers must decide the conceptual outlines of a particular project, oversee performance of the work, and approve final project acceptance on behalf of NPS.

This section very briefly summarizes the planning process to provide park AML project managers the background for their oversight role. In addition, this section will be useful in developing a plan to coordinate with other agencies and procuring the engineering and construction services. Of the various types of engineering studies shown in Fig. 1, only preliminary and definitive design are described in detail. Conceptual design is described in Tabs V and VII. The other levels simply represent variations of content and purpose from the levels described below.

DESIGN CRITERIA

Development of design criteria begins at the time a project is first identified. The foundation of the criteria is a statement of functional requirements that the project must meet. These functional requirements are further developed, validated, and expanded during conceptual and preliminary design.

The design criteria document should provide the architect-engineer with the following information:

1. Define purpose and functional requirements of project.
   a. Proposed mine closures, erosion and sedimentation control, revegetation, and historic preservation.
   b. Include a general arrangement drawing.

2. Provide a general description.
   a. Site location with map.
b. Construction conditions, temporary access, fencing, work areas, disposal areas, and borrow areas.

c. Site preparations.

d. Existing utilities.

e. Special security, environmental, safety (including mine safety), and health needs.

3. Provide all design requirements to be applied to meet the needs of the project such as performance criteria, limits, constraints, capacities, quantities, and area allocations.

4. Incorporate or reference construction specifications and guidelines.

a. NPS.

b. Applicable national and local building codes.

5. Incorporate or reference environmental regulations and permit requirements.

6. Define quality assurance measures.

7. Provide the designer with the following additional documents:

a. Studies, reports, and conceptual designs.

b. Copies of sketches and drawings including site and location plans, topographic maps, and plan of existing utilities.

c. List of government furnished equipment, supplies, and computer programs available for use by designer.

d. List of required drawings, and their size and scale.

e. Copy of project management plan.

f. Information on the procurement of construction such as required contract clauses, type of specifications, and contents of bid packages.

Completeness of the design criteria is important; however, avoid citing superfluous codes and standards. Superfluous criteria violate a primary goal which is to narrow the criteria to only those applicable to a specific design effort.
Give designer leeway to exercise expertise in the engineering disciplines and to use up-to-date design and construction methods.

REQUEST-FOR-PROPOSALS

When the need arises to procure engineering or construction services, follow NPS guidelines and the Federal Acquisition Regulations. The contracting officer has the prime responsibility for soliciting contract services; however, the project manager must provide technical material. The following outline summarizes the technical information typically provided in a request-for-proposals (RFP).

TABLE I
OUTLINE OF TECHNICAL PART OF REQUEST-FOR-PROPOSALS

I. Introduction
   A. Background and short history of project.
   B. Define project (what, where, when, why, who, how).
   C. Summarize need (level of engineering or construction).

II. Scope of Work
   A. Define the objective functional requirements.
   B. Define the limits and content of the work.
   C. Summarize the primary design criteria.
   D. List available data and reports.
   E. Provide a broad work breakdown structure.
   F. Provide project milestones and expected deadlines.
   G. Describe services, equipment, and facilities provided by client.

III. Client's Project Management
   A. Organization
   B. Responsibility and authority.

IV. Recommend Outline of Contractor's Technical Proposal
   A. Statement of work by work breakdown structure and task.
   B. Project schedule.
   C. Cost estimate (define outline in order to compare proposals and evaluate technical adequacy).
   D. Statement of contractor's qualifications.
   E. Project management and resumes of professional staff.

When deciding on who will perform design and construction work, consider the following factors:

1. Mine engineering and remediation expertise.
2. Availability, existing and projected work loads.

3. Size, complexity, and urgency of the project in regard to the candidate organizations qualifications and previous work experience.

4. Suitable professional and labor skills.

5. Adequate and appropriate construction equipment.

Some of the larger parks have substantial construction capabilities within their maintenance departments. The preceding factors also can be used to evaluate whether a particular maintenance department has the qualifications and availability to provide AML engineering and construction services.

CONCEPTUAL DESIGN

For an AML project, conceptual design is accomplished by completing the Site Reconnaissance Form in Tab VII and the cost estimate in Tab V.

PRELIMINARY DESIGN

The fundamental objectives of preliminary design are to satisfy the AML program objectives and the various statutory requirements while achieving minimum construction costs. The objectives that distinguish preliminary design from conceptual design include validation of technical adequacy and project feasibility; identification and quantification of any project risks; and estimation of reliable project costs and completion schedule. An outline of a typical preliminary design and cost report is given below.

These objectives are accomplished by developing the following (see also Fig. 1):

1. Requirements
   a. Project scope, performance requirements, general project criteria, and design parameters including applicable codes and standards.
   b. Statutory or other special requirements.
   c. Health, safety, and security requirements.
   d. Quality assurance requirements.

2. Design and Engineering
a. Potential environmental damage and methods of remediation.

b. Site development -- mine closures, erosion and sedimentation control, surface remediation, revegetation, historic preservation. Describe work breakdown structure and engineering methods. Include traceable backup details.

c. Trade-off studies and alternative design approaches to optimize design and minimize costs.

d. Types and materials of construction.

e. Specifications of major equipment and long lead-time items.

f. Drawings include layout and general arrangement. Generally, one line electrical, and piping and instrument drawings are also provided; however, these are not applicable to AML sites unless the project involves significant historic preservation.

3. Project Planning

a. Estimate resource needs -- labor, equipment, and capital.

b. Project schedule including engineering, procurement and construction. Special care must be placed on identifying long lead-time items and critical tasks.

c. Identification and elimination of uncertainties.

4. Feasibility

a. Estimate costs for the subsequent phases of design, engineering, and construction.

b. Estimate construction labor, equipment, and material quantities. Major items of construction and equipment should be estimated from quantity take-offs while remainder may be estimated by factors.

c. Provide contingency requirements and analysis.

d. Describe cost estimating methodology and provide backup details.
TABLE II
OUTLINE OF PRELIMINARY DESIGN REPORT

I. Introduction

II. Project Overview
   A. Project Background and Justification
   B. General Site Description
   C. Mine Closure and Remediation Options

III. Selected Mine Closure and Site Remediation
   A. Mine Closure
   B. Surface Remediation
   C. Revegetation
   D. Material Requirements
   E. Equipment Requirements
   F. Labor Requirements

IV. Engineering and Construction Schedules

V. Cost Estimate
   A. Mobilization
   B. Excavation and Backfill
   C. Mine Closure
   D. Site Grading
   E. Erosion and Sedimentation Control
   F. Site Cleanup
   G. Revegetation
   H. Wildlife Restoration
   I. Risk Assessment and Contingency Allowance
   J. Detailed Engineering
   K. Construction Cost and Maintenance

Appendix: Technical Specifications
1. General
2. Mobilization
3. Mine Closure
4. Excavation and Backfill
5. Site Grading
6. Site Cleanup
7. Revegetation
8. Wildlife

Engineering Drawings
D1 Site Location Map
D2 Pre-Remediation Site Plan
D3 Mine Closure Plan and Cross Sections
D4 Post-Remediation Site Plan
Preliminary designs may be performed by State AML programs, NPS park or central engineering services, and architect-engineering firms. A typical preliminary design report has the content and organization shown in the above box.

DEFINITIVE DESIGN

The architect-engineer firm utilizes the client (NPS) approved preliminary design and any revised project design criteria as the base for definitive design. Completion of definitive design ends the design phase of a project, and normally allows the beginning of the construction phase. Definitive design includes:

1. Restudy and redesign work resulting from necessary changes identified by preliminary design.

2. Development of final working drawings and specifications for procurement and construction.


4. Schedules for build-up and phase-out of construction labor, equipment, and materials. Schedules must provide for items that require a long lead-time for procurement, and adequate time for administrative actions and permitting.

5. Identification of work packages and subcontracts.

6. Identification of all required permits and plan for permit applications.

7. Preparation of procurement plan.


9. Design reviews by client. Client reviews typically occur after completing 30%, 60%, and 100% of design work.

10. Procedures for change control and client acceptance of work completed.

11. Quality assurance/quality control

As discussed above, many AML projects will not require detailed engineering design. If they do, generally it will be procured from engineering firms.
PROJECT RECORDS

A project record is maintained by the project manager, and typically contains the following documents:

1. All engineering plans.
2. Design criteria.
3. Management plan and changes thereto.
4. Selection plans for contractors.
5. Contracts.
6. Project authorization and all modifications.
7. All cost estimates.
8. Project reports.
9. Construction photographs (before, in-progress, and after).
10. Minutes of project meetings.
11. Construction completion, inspection, and acceptance reports.
12. As-built drawings.
13. Documentation required by NPS guidelines and Federal Acquisition Regulations.
CONSTRUCTION FOR SMALL PROJECTS

TYPES OF CONTRACTS

The two basic types of contracts are fixed-price (also called lump-sum) and cost-plus. Basis of payment for fixed-price is a stipulated amount. Fixed-price contracts should be used to the maximum extent feasible. Basis of payment for cost-plus is the actual cost of the construction plus a fee. Cost-plus contracts should be used only for specialty work and where it is unreasonable to expect the contractor to take the client's (NPS) risk on unknown elements. For example, when the volume of a shaft is unknown, the quantity of backfill should be contracted on a unit cost plus fixed or incentive fee.

If it is determined that a cost-plus contract is appropriate for a certain part of the project, separate this part from the main contract and handle the main contract on a fixed-price basis. As many elements of the project as practicable should be contracted on a fixed-price basis.

Other contract variations include fixed-price-incentive-fee, cost-plus-award-fee, and cost-plus-incentive-fee.

NPS PLANNING FOR CONSTRUCTION

NPS functions should be done on time with no unnecessary disruption to contractor plans. When equipment or materials are supplied by NPS or other participants, assure that deliveries comply with schedules to minimize requests for time extensions and cost increases. Allow time for bidding, bid evaluation, award, and subsequent mobilization by the contractor.

For cost-plus contracts, select contractor early so that contractor can contribute practical and economical suggestions, and help in project design and construction schedule.

In addition:

1. Set aside adequate work space for the contractor and free access to the work area. In situations where several independent contractors will be working in the same area at the same time, develop procedures to coordinate their work and handle the unavoidable conflicts.

2. Orient the contractor as to:

   a. Authority and responsibilities of the contract officer, project manager, architect-engineer, inspectors, and other project participants.
b. Administrative procedures for review and approval of shop drawings.

c. Procedures for changes to the contract.

d. Provisions for special safety (such as abandoned mines), environmental protection, security, quality assurance, and other requirements for performance.

e. Conditions under which the work shall be performed and accepted.

f. Reporting procedures, and coordination of contractor's cost and schedule control with NPS project management staff.

g. Furnish contractor with applicable NPS regulations and procedures.

3. Cost and schedule breakdowns must be reviewed by the project manager, architect-engineer, and approved by the contract officer. Upon approval, the breakdown and reimbursement factors become the basis for progress payments.

4. Approve contractor's management plan including organization, key personnel, reporting and records procedures, subcontract procurement, construction plan, manpower scheduling, and cost control.

As appropriate, the contract should incorporate the preceding items.

INSPECTION

The project manager may elect to have inspection services performed by the architect-engineer, a construction manager, or with in-house experts. NPS personnel should not conduct the inspections unless the construction is routine or qualified experts are performing the inspections. Inspection services are never performed by the construction contractor.

Generally, inspection services include the following:

1. Establish and maintain survey control and benchmarks for horizontal and vertical references.

2. Verify all shop drawings to assure conformity with approved design, working drawings, and specifications.
3. Inspect and approve workmanship, materials, and equipment.
   a. Functional inspections determine the overall compliance with contract drawings and specifications, determine the adequacy of the design work, and include testing of operating equipment.
   b. Detailed inspection includes verification of details, such as checking location and size of reinforcing bars, maintaining records of concrete testing, verifying the use of proper welding rods, checking riveting and welding, and other inspection for quality assurance purposes. It starts with initial construction operations and extends through all construction stages.
   c. Continuous inspection and testing must be done for all work where the quality cannot be determined after construction without detriment to the work. This would be the case for all permanent mine closures.

4. Inspection instructions should provide the following:
   a. Statement of quality characteristics to be inspected.
   b. Organization or individuals responsible for inspection.
   c. Acceptance and rejection criteria.
   d. Methods of inspection.
   e. Evidence and records of inspection.

5. Conduct or procure field or laboratory tests of construction workmanship, materials, and equipment.

6. Evaluate scope changes and other proposals submitted by the construction contractor. Prepare estimates of changes in the contract price and schedules.

7. Prepare monthly progress reports including the status of material and equipment deliveries, and reports of work performed for payment.

8. Furnish reproducible "as built" drawings and marked up specifications showing construction as actually accomplished.

   Inspection schedules should be based on the construction schedules and the project quality assurance plan.

1. Inspection should be conducted prior to acceptance of the work.
2. Inspection should be done when and where necessary to provide the degree of assurance required to determine that the materials and construction comply with the contract, drawings, and specifications.

3. Inspection requirements and testing should be clearly defined in the contract documents along with the authority, duties, and responsibilities of the inspectors.

Final acceptance is a written statement by the project manager that the work performed by the construction contractor has been accepted as being in accordance with approved plans and specifications.
QUALITY ASSURANCE

The goals of quality assurance are to assure that the AML remediation projects are designed in a controlled manner; and designed and constructed according to sound engineering standards, quality practices, and technical specifications. Quality assurance begins with conceptual design and continues through preliminary design, definitive design, and construction. It comprises both quality engineering and quality control (inspection).

DESIGN

Quality assurance during design includes review of materials of construction and installed equipment for economics, compatibility with other components, and maintainability.

Continuous review of the design is required to ensure the project can be constructed as designed using the most efficient techniques. The cost of construction is greatly dependent on the design work. Constructability includes consideration of interference between project components and engineering disciplines, compatibility of specifications with changing seasons, and integration of different contractors on the job site.

The most important aspect of quality assurance during design is continuous surveillance of the design. Periodic design reviews are seldom, except in very small projects, adequate to assure a quality product. Continuous surveillance assists in reducing critical comments during design reviews, and reduces the total design effort by reducing time spent on change proposals and corrections.

To be acceptable, a quality assurance program for design should have a "yes' answer to the following questions:

<table>
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<th>YES</th>
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<tr>
<td>1. Is design surveillance continuous and are there reviews after each design phase (i.e., conceptual to definitive)?</td>
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<td>2. Are performance requirements specified?</td>
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<td>3. Are responsibilities and lines of communication defined?</td>
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<td>4. Are errors documented and corrective actions defined?</td>
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5. Does verification provide for qualified and independent review (immediate supervisors generally are not considered independent)?

6. Are design changes subject to the same review and verification as the original design?

7. Have procedures been established to determine that applicable regulations, codes, standards, design bases, acceptance/rejection criteria are included in procurement documents?

8. Do procurement documents require contractors to provide an acceptable quality assurance program?

9. Are procedures established that describe how obsolete or superseded documents are replaced by revisions?

CONSTRUCTION

The project manager must assure that the contractor establishes and follows a plan for certifying shop drawings, material testing, and work completion. The project manager must also assure that the architect-engineer, construction manager, and government staff act in a timely manner on approval of submittals. An effective program includes quality assurance reports from contractors and quality control inspectors together with procedures for reviewing the reports and taking prompt effective action.

The quality assurance program must be adequately staffed with qualified inspectors. In addition, continual checks must be made to assure that all of the quality assurance functions are being performed and prompt corrective actions are taken.

All quality assurance reports, test results, and inspections should be under the control of the NPS.

To be acceptable, a quality assurance program for construction should have a "yes" answer to the following questions:

YES  NO

1. Does the program describe what, when, where, and how inspections are performed?

2. Are the organizational responsibilities for inspection described?
3. Do inspection procedures provide acceptance and rejection criteria including receiving inspections for purchased materials, equipment, and services?

4. Do procedures identify hold points beyond which work may not proceed until inspected?

5. Are inspectors qualified?

6. Are inspection results documented and evaluated, and their acceptability determined by a responsible person?

7. Do test procedures provide instructions, methods of analysis, methods of documentation, acceptability of results, corrective action, and review by responsible individual?

8. Have procedures been established to calibrate test equipment according to recognized standards?

9. Have controls been established to identify and track samples?

10. Are procedures in place establishing an effective corrective action program?
MANAGEMENT TOOLS

GANTT CHARTS (BAR CHARTS)

Bar charts are the most common project control tool used in the construction industry. An example is shown in Fig. 2. In many cases, it is the only aid used. Perhaps the reason for this popularity is its simplicity, almost universal understanding, and ability to be used at all levels of supervision. Some of the shortcomings of bar charts include the following:

* Do not force detailed analysis and breakdown of activities.
* Do not model interdependencies of tasks.
* Greater likelihood that activities will be omitted.
* Fail to communicate as much detailed information (sequential activities, activities critical to project completion, slack time, earliest and latest start time).
* Fail to adequately show consequences of scheduling deviations.
* Unsuitable for updating purposes.

NETWORKING TECHNIQUES

Networks such as critical path scheduling (CPS, see Fig. 3) and project evaluation and review technique (PERT) were developed to overcome disadvantages of bar charts. Networking is extremely useful in scheduling of construction projects from most complex to a simple job. In complex projects, a hierarchy of networks are developed to meet the needs of different levels of management.

It is important to remember that networks are dynamic and require continuous update from the lowest detail in order to be useful for project management. When considering the use of networks, their dynamic nature must be considered along with the labor and computer resources required to maintain the system. Complicated and expensive procedures for updating the network may result in a useless system and a burden on the project.

PERCENTAGE COMPLETION CURVES (S CURVES)

Percentage completion curves plot forecasted and actual cumulative percent completion on a time scale. For example, during construction plot cumulative labor hours forecasted and actual hours expended to date. See Fig. 4. A number of
different plots can be made including material, equipment, and costs by various breakdowns. Plot variables that dominate progress of the project.
Fig. 2 Bar Chart Schedule
Example Mine Closure Project
Fig. 3 Network Schedule
Example Mine Closure Project
Fig. 4 Cumulative Cost Graph
Example Mine Closure Project

BIWEEKLY COST ACCOUNTING (MONTH/DAY)

COST (Thousands)

- BUDGET COSTS
- ACTUAL COSTS
REFERENCE


Professional Services Management Journal, 10 Midland Ave., Newton, MA 02158.
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*Dimensions given in this handbook are typical of the particular remediation method and are intended only for guidance. For a specific application, dimensions should be determined by detailed engineering design.
Remediation measures for AML sites are grouped into five main categories, as follows:

1) Site characterization and monitoring.
2) Underground mine closures.
3) Surface mitigation.
4) Erosion and sedimentation control.
5) Revegetation.

The guidelines emphasize mine closure measures because information on these measures are not readily available to park staff.

The site characterization and monitoring guidelines are organized by environmental media including land (mine openings and waste), groundwater and surface water (mine drainage), vegetation, and wildlife. A section on air quality has not been included. Except for mine fires and fugitive dust, AML sites generally have little impact on air quality. No known fires exist in National Parks, and fugitive dust is mitigated in the course of correcting the other AML disturbances.

After remediation, the sites must be monitored to evaluate success of the work and to identify maintenance necessary for continuing health and safety, and environmental protection. Monitoring methods are related to site characterization, and the these two topics are discussed together.

There are a number of alternatives available for mine closures including measures that are temporary, permanent, or preserve the historical values.

* Typical temporary closures are fencing, cable nets, grates or bat gates.

* Intermediate closures are concrete caps, plugs, and bulkheads.

* Permanent measures are backfilling with mine waste rock and sealing by blasting or with polyurethane foam.

* Mine access roads, quarries and pits, waste dumps, and other surface disturbances are mitigated with backfilling, reshaping, and landscaping.

* Historic preservation options range from documentation to interpretive signs to stabilization of the site.

Permanent mine closures reduce or eliminate health and safety hazards, reduce the need for future monitoring and maintenance, and reduce the threat of additional environmental
disturbance. Conversely, temporary closures allow continued access by wildlife, and access for geologic, archaeology, and park administrative purposes.

Mine closure methods also differ in scale. The small 1 to 2 acre 19th century site located in a remote area requires different remediation than a large quarry with highwalls and waste dumps. The small site may need nothing more than a little backfill and some hand built erosion control. The large site may require a modern earthmoving project utilizing special measures to isolate toxic waste, stabilize backfills, landscape highwalls, reshape drainage basins, revegetate grasses and trees, and may need years of maintenance and monitoring. Needless to say, the mine closure method must be suitable for the particular site, and in the following section, the handbook provides guidance on the selection of appropriate remediation measures.

The guidelines provide more detail on the small 19th century sites which make up the bulk of AML problems. Many parks have the resources to close these sites with their maintenance crews, and all they need is some guidance on what works. No one needs a $30,000 engineering study for a $2,000 mine closure project. (True story.) The larger sites invariably involve contract engineering and construction, and the guidelines for these closures are more general.

Surface mitigation is a combination of correcting the adverse impacts, and then controlling erosion and sedimentation until vegetation is re-established. This mitigation requires the reshaping of highwalls, roads, and dumps, correcting acid mine drainage, and removing or restoring abandoned structures and equipment.

Many AML sites are barren, and are the cause of significant erosion. Additionally, in the process of mitigating an AML site, the landscape often must be reshaped or regraded, and while the surface is vulnerable, special measures must be taken to prevent erosion and sedimentation.

* Hillslopes must be protected from rainsplash, sheet runoff, gullyng, wind, and ground instability (landslides, creep, earthflow, rockfalls).

* Drainage channels must be protected from bank erosion, scour, sedimentation, and changes in drainage patterns.

The guidelines first outline a landform design approach to the control of erosion and sedimentation. This guidance is primarily useful for large projects, on small projects control measures will be obvious. Landform design provides the basis for choosing appropriate control measures including salvage of topsoil, hillslope erosion control, various water energy dissipaters (drop structures and riprap), water diversion
(ditches and culverts), sedimentation basins, and handbuilt structures for small and remote projects.

The last step in a remediation project is revegetation. The guidelines provide a step-by-step outline for the revegetation of a site including topsoil replacement, fertilization and seedbed preparation, seeding and transplanting, and mulching. Most parks will have considerable local experience in revegetation, and this experience should prevail when developing a revegetation plan. Even where a park has considerable experience, the guidelines may be of help in special problems unique to AML sites such as treatment of acidic soils.

Mitigation plans must be consistent with park and regional requirements. Where there are conflicts between this handbook, and local park and regional requirements, final decisions regarding remediation lie with park management. The guidance given here is not mandatory, it is offered as a starting point and reference on methods that have been successful in mitigating AML sites. The following space is provided to write in references to local and regional guidance that must be consulted in completing a remediation plan.

PARK AND REGIONAL REQUIREMENTS DOCUMENTS

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All of the remediation measures described below have been used successfully in State AML programs, some NPS parks, and the reclamation of modern mines. Many states have very efficient and mature programs with sites that have now been restored for a number of years.

METHOD SELECTION

This section provides guidance on how to select appropriate measures for the remediation of a particular site. Charts, tables, and matrices provide selection criteria. In some categories, the remediation measures are self-evident or a step-by-step procedure, and not a question of choice. It is assumed that the decision has already been made whether a site will be temporarily or permanently closed, or preserved for its historic values.
### TABLE I
#### SITE CHARACTERIZATION DECISION MATRIX

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<tr>
<th>Impacts</th>
<th>Soil</th>
<th>Water</th>
<th>Vegetation</th>
<th>Wild Life</th>
<th>History</th>
</tr>
</thead>
<tbody>
<tr>
<td>More Than 2 Acres</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Acidic/Alkaline/Heavy Metals</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barren Vegetation</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extreme Erosion</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Requires Topsoil Borrow</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Threatened/Endangered Species</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Mine Fires (Requires special studies)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Structures/Artifacts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

**Site Characterization and Monitoring**

The initial site inventory and reconnaissance provides the information necessary to choose relevant baseline studies. The decision matrix of Table I can assist in selecting the appropriate baseline studies. Possible AML impacts are listed in the left hand column, and the top row lists the baseline studies. A tick appears at the intersection of row and column when a particular baseline study is recommended for the opposite impact.

The matrix recommends all baseline studies where the site disturbance exceeds a maximum acreage. This maximum may be adjusted to suit local park conditions. In addition, if a park has numerous similar AML sites, individual baseline studies may become redundant, and it will be more efficient to prepare a programmatic environmental impact study.

The matrix recommends mine drainage studies whenever there is a hint of toxic effluents. The chemistry of mine drainage is unique to each AML site, and the remediation generally must be site specific.
The mitigation of mine fires requires highly specialized technology. The baseline studies, engineering, and mitigation should be contracted to experts.

If there is a possibility that the site may be preserved in some form, a detailed historical survey should be conducted. If not, information collected in the site reconnaissance (Tab VII) is generally adequate for historical inventories.

Mine Closure

Mine closure methods are specific to the type of disturbance:

* Surface openings of underground mines.
* Area disturbances of surface mines, quarries, pits, and roads.
* Surface subsidence from collapse of underground mines.
* Mine drainage.
* Waste dumps including overburden, spoil, development muck (waste rock from underground mines), stockpiles, tailings ponds, impoundments, and processing wastes.
* Abandoned structures and equipment.

For all but underground openings, simply look up the disturbance in the Table of Contents for applicable remediation measures. To choose a closure method for underground openings, first answer the following questions:

* Will the site be preserved for its historical value?
* Is the opening vertical (shaft) or horizontal (adit)?
* Is the wall rock competent or incompetent?
* Will the closure be temporary or permanent?
* Is the site remote or accessible to construction equipment?
* Is the opening a habitat for threatened or endangered species?
* Is there a nearby source of building rock (12 in. to 18 in.) for bulkheads?
Once these questions are answered, enter the tree diagram Table II, and follow the indicated path to the bottom level. The bottom level recommends the appropriate closure method for the given circumstances.
TABLE II
DECISION TREE FOR UNDERGROUND CLOSURES

UNDERGROUND CLOSURES

ADITS
- COMPETENT ROCK
  Continues on Table IIA
- INCOMPETENT ROCK
  Continues on Table IIB

SHAFTS & STOPES
- PERMANENT CLOSURES
  Continues on Table IIC
- TEMPORARY CLOSURES
  Continues on Table IID
TABLE IIB
DECISION TREE - ADITS, INCOMPETENT ROCK

ADITS

INCOMPETENT ROCK

REMOTE SITE
  BLAST CLOSURE

ACCESSIBLE SITE
  PUF CLOSURE
  BACKFILL CLOSURE
TABLE II C
DECISION TREE - SHAFTS, RESTORE SITE

SHAFTS

RESTORE SITE

EASILY ACCESSIBLE SITE

REMOTE SITE

BLAST CLOSURE

PERMANENT CLOSURE

BACKFILL CLOSURE

MONOLITHIC PLUG

MEDIUM TERM CLOSURE

PRECAST CONCRETE PANEL

POURED CONCRETE CAPS

FOR INCOMPETENT ROCK
USE HOLLOW CORE FOOTING

SHORT TERM (< 3 YEARS)

SIGN & FENCE

PUF CLOSURE

PERMANENT CLOSURE

PRECAST CONCRETE PANEL

POURED CONCRETE CAPS

FOR INCOMPETENT ROCK
USE HOLLOW CORE FOOTING
TABLE IID
DECISION TREE - SHAFTS, MITIGATE IMPACTS

- SHAFTS & STOPES
  - MITIGATE IMPACTS
    - W/ RESOURCES
      - REMOTE SITE
        - CABLE NET CLOSURE
      - EASILY ACCESSIBLE SITE
        - STEEL GRATE CLOSURE
    - W/O RESOURCES
      - FEW SITES
        - POURD CONCRETE CAPS
      - REMOTE SITES
        - PUF CLOSURE
      - MANY SITES
        - PRECAST CONCRETE PANEL
          - FOR INCOMPETENT ROCK
            - USE HOLLOW CORE FOOTING
Erosion and Sedimentation Control

For small projects generally less than 2 acres, erosion and sedimentation control will primarily consist of diverting water around disturbed areas and dissipating water energy to prevent erosion. The decision matrix of Table III can assist in selecting the appropriate control measures. The left hand column lists erosion and sedimentation control measures, and the top row lists various applications. A tick appears at the intersection of row and column when a particular control measure is appropriate for the above application.

Larger projects require complete landform design including landscaping, estimates of runoff, and hydraulic analysis. The first subsection of Erosion and Sedimentation Control outlines the design process. After identifying the particular needs, Table III can help locate applicable erosion and sedimentation control measures.

<table>
<thead>
<tr>
<th>Control Measures</th>
<th>Erosion</th>
<th>Sediment</th>
<th>Channel</th>
<th>Land Form</th>
<th>Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil Removal &amp; Storage</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slope Erosion Control</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Drop Structures</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diversion Ditches</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Culverts</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Basins</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Handbuilt Slope Structures</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handbuilt Drop Structures</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Revegetation

The guidance on revegetation is a step-by-step procedure involving:

1) Topsoil replacement.
2) Fertilization and seedbed preparation.
3) Seeding and transplanting.
4) Mulching.

In general, each step is required for a successful project. However, on occasion, some steps may not be necessary. In particular, fertilization should be avoided where possible because it may not promote sustainable vegetation.

There are a number of seeding and mulching alternatives to choose from. Table IV summarizes the advantages and disadvantages of various seeding methods.

The mulching alternatives are listed in the left hand column of the decision matrix, Table V. The top row lists various mulch qualities. The matrix cells indicate whether a particular mulch possess the above qualities. For some qualities, a mulch either has the quality or not, and a positive response is indicated by a tick. For the other qualities, there are varying degrees which is indicated with a cell value of high (H), medium (M), or low (L). In addition, four of the mulches have special applications which are given in the table footnotes.

To choose a mulch, first characterize the desired mulch qualities, and then find in the matrix the mulch with the closest match.
TABLE IV
SEEDING METHODS - ADVANTAGES/DISADVANTAGES
(Thorne, 1987, p. 57)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Drilling</th>
<th>Broadcasting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topography</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steep slopes and access are problems; if slopes are greater than 3:1, broadcasting recommended</td>
<td>Less limited</td>
<td>Can handle steep terrain, depending on distance</td>
</tr>
<tr>
<td>Obstructions</td>
<td>Limits use</td>
<td>Unlimited</td>
</tr>
<tr>
<td>Compacted Soil</td>
<td>Possible</td>
<td>Possible</td>
</tr>
<tr>
<td>Seeding Depth</td>
<td>Variable and controlled</td>
<td>Variable; somewhat less controlled</td>
</tr>
<tr>
<td>Seed Size</td>
<td>Variable if drills can be adjusted</td>
<td>Variable if hand-held machines can be adjusted</td>
</tr>
<tr>
<td>Season</td>
<td>Limited by moisture</td>
<td>Limited by moisture</td>
</tr>
<tr>
<td>Precipitation</td>
<td>Slightly critical</td>
<td>Slightly critical</td>
</tr>
<tr>
<td>Soil Texture</td>
<td>Not critical</td>
<td>Not critical</td>
</tr>
<tr>
<td>Seed Distribution</td>
<td>Uniform</td>
<td>Uniform if person is well trained; seeds can be precisely placed</td>
</tr>
<tr>
<td>Mulching</td>
<td>Separate treatment</td>
<td>Separate</td>
</tr>
<tr>
<td>Cost</td>
<td>Medium</td>
<td>Depends on how many people needed</td>
</tr>
<tr>
<td>Equipment</td>
<td>Special in some cases</td>
<td>Some hand-held equipment available</td>
</tr>
</tbody>
</table>
TABLE IV
(continued)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Drilling</th>
<th>Hydroseeding</th>
<th>Broadcasting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Machine</td>
<td>Hand</td>
<td>Other Machines</td>
</tr>
<tr>
<td>Seed Rate</td>
<td>Less than broadcasting; drastically disturbed sites such as spoils require much heavier seeding rates than do sites where topsoil and some plant cover are intact. Examples: 10-15 lb/acre drilled on north-facing gentle slopes with small grass seed; 25-30 lb/acre if species seed is large; 40-45 lb/acre if conditions are severe, such as south-facing steep slopes</td>
<td>More; as much as double the drilling rate</td>
<td>More</td>
</tr>
<tr>
<td>Trash in Seeds</td>
<td>Must be cleaned from seeds</td>
<td>Must be cleaned from seeds</td>
<td>Cleaning not critical</td>
</tr>
<tr>
<td>Time required/acre to seed</td>
<td>Middle range</td>
<td>High range</td>
<td>Low range</td>
</tr>
</tbody>
</table>
### TABLE V
DECISION MATRIX FOR MULCH

<table>
<thead>
<tr>
<th>LEGEND:</th>
<th>X - Yes</th>
<th>H - High</th>
<th>M - Medium</th>
<th>L - Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>MULCH QUALITIES</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Requires Anchoring</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Provides Erosion Protection</td>
<td>M M M M M</td>
<td>L L L L L</td>
<td>H H H H</td>
<td></td>
</tr>
<tr>
<td>Provides Nutrients</td>
<td>H L M M M</td>
<td>M L H H H</td>
<td>L L L H</td>
<td></td>
</tr>
<tr>
<td>Effective Time of Erosion Protection</td>
<td>H M H H H</td>
<td>L L L L L</td>
<td>H H H H</td>
<td></td>
</tr>
<tr>
<td>Contains Beneficial Seed</td>
<td>X X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contains Unwanted Seed</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>May Require Fertilizer Additions</td>
<td>X X X X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Special Applications</td>
<td>X</td>
<td>X X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Slope Constraints</td>
<td></td>
<td>X X X X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td>M L H H H H</td>
<td>M M L H</td>
<td>H M H H H L L L L H</td>
<td></td>
</tr>
<tr>
<td>Moisture Retention</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SITE CHARACTERIZATION AND MONITORING

SOILS, MINE OPENINGS AND WASTES

DESCRIPTION

Mine openings represent the fundamental environmental impact of AML sites. They include shafts, adits, quarries, strip mines, and open pits. For the purpose of site characterization, these disturbances must be mapped.

Mine wastes (overburden, spoil, underground waste rock, stockpiles, tailings) often disturb a larger area and have a greater environmental impact than the mine openings. The chemical and physical character of these wastes are key factors in determining the success of remediation.

Soils serve as a chemical and physical buffer between the mine wastes and other environmental media -- water, land, air, wildlife.

Site characterization techniques are basically the same for soil and mine wastes.

Cost: $2,000 to $500,000 per project.

DATA REQUIREMENTS 1/

* Topographic site map of mine disturbances.

* Soil map of mine wastes and surrounding soils.

  ** Minimum scale: 1 in. to 100 - 700 ft depending on size of project.

  ** Level of detail: Soil units from 0.5 to 5 acres. Show sample location.

  ** Sample density and depth:

  For soils, 1 to 6 profiles per mapped soil unit depending on chemical and physical variability. Depth up to 7 ft or bedrock whichever comes first.

  For mine wastes, 1 auger hole per 40 acres, 3 minimum. Sample entire thickness on 2 - 10 ft intervals depending on chemical and physical variability.

  ** Local Soil Conservation Service office provides assistance with soil surveys and soil identification.
* Volume of mine wastes and available soil, normally estimated with isopach maps.

* Geologic map and cross sections.

* Chemical analysis of mine wastes and soils.

Table VI lists typical chemical analyses, and also provides criteria for unsuitable material. Unsuitable material must be treated, buried, and not used within reach of plant uptake. Test also for trace metals. Split samples and send 10% of duplicates to another lab for quality control. Check on State and local requirements. Heavy metal pollution found at some mine sites:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH acid</td>
<td>&lt; 6.0</td>
</tr>
<tr>
<td>pH alkaline</td>
<td>&gt; 8.5</td>
</tr>
<tr>
<td>Electrical Conductivity</td>
<td>&gt; 4.0 - 8.0</td>
</tr>
<tr>
<td>(millimhos/cm)</td>
<td></td>
</tr>
<tr>
<td>Texture</td>
<td>Excessively clayey, silty, or sandy</td>
</tr>
<tr>
<td>Moisture Saturation</td>
<td>&lt; 25% or &gt; 85%</td>
</tr>
<tr>
<td>Sodium Adsorption Ratio</td>
<td>&gt; 12 - 15 depending on texture</td>
</tr>
<tr>
<td>Exchangeable Sodium</td>
<td>&gt; 15% - 18% depending on texture</td>
</tr>
<tr>
<td>Boron</td>
<td>&gt; 5.0 ppm</td>
</tr>
<tr>
<td>Selenium</td>
<td>&gt; 0.1 ppm</td>
</tr>
<tr>
<td>Acid-Base Potential</td>
<td>&lt; -5 - 0 tons CaCO$_3$ per 1,000 tons</td>
</tr>
<tr>
<td>Mo</td>
<td>&gt; 0.5 - 1.0 ppm</td>
</tr>
<tr>
<td>Organic Carbon</td>
<td>&gt; 10%</td>
</tr>
</tbody>
</table>

REFERENCE: (USOTA, 1986, p. 190)

** Risks to public health include cations of arsenic, cadmium, mercury, lead, nickel, manganese, and molybdenum. Cyanide is a highly toxic chemical used for extracting precious metals. Fortunately it is usually short lived; however, it can remain in dry, alkaline processing wastes not exposed to air and sunlight.

** Risks to aquatic life include copper.

** Risks to plants include iron, aluminum, and zinc when they are in high concentrations.

** At mill sites, there will always be heavy metals present.
* Soil nutrients:

**Organic Matter**

**Macro Nutrients**
- Nitrogen (N)  Phosphorus (P)
- Potassium (K)  Calcium (Ca)
- Magnesium (Mg)  Sulfur (S)

**Micro Nutrients**
- Boron (B)  Copper (Cu)
- Manganese (Mn)  Zinc (Zn)
- Iron (Fe)  Molybdenum (Mo)
- Chlorine (Cl)

* Physical properties of mine wastes and soils including bulk density, texture, and size distribution.

* Evidence and possible extent of mine fires either underground or in smoldering waste dumps.

* Site climate including precipitation and temperature.

* Research State mine reclamation statutes for additional requirements.

**MONITORING**

Some mine closures have deteriorated to a condition that is more hazardous in regard to public safety than before the mine was closed. This deterioration results from the temporary nature of the closure, natural weathering, and vandalism. All abandoned mines including those restored and those not restored should be monitored regularly and their condition documented.

The monitoring schedule depends on:

* Environmental conditions.

* Type of closure.

* Type and number of visitors.

The following scenarios provide extremes in monitoring from which local guidance can be determined.

* Monitor weekly or daily heavily visited AML sites with numerous potential hazards.

* Monitor once every 3 to 5 yr remote, permanently backfilled sites.
* Monitor environmental conditions after winter and large storms.

* Use the Maintenance Management System to track monitoring and maintenance.

REFERENCE: This section paraphrased from USOTA, 1986, p.126.

**MINE DRAINAGE**

**DESCRIPTION**

Mine drainage problems include effluents of acid or alkaline waters and/or erosion and subsequent deposition of sediment in surface water. The adverse impacts of mine drainage relate to the degradation of water quality, which may affect wildlife habitat, park resources, water supply, and flooding.

Cost: $15,000 to $100,000 per project.

**PROBLEM IDENTIFICATION**

**Acidic Sites**

A fail-safe indicator of acidic conditions is the presence of ferric hydroxide precipitate on the bottom of a streambed. Typically, this precipitate has an orange color, but the color may vary from yellow-red through purple. The precipitate is known as "yellow-boy" in the mining industry. Other indicators include:

* Acid conditions in either mine wastes, surrounding soils, or surface water indicate acid mine drainage.

* Acidic stream water may be crystal clear, don't be fooled by water color.

* Acidic mine wastes and soils are bare of vegetation (except for an occasional hardy individual), and free of insects and small mammals.

* Sulphurous compounds in mine wastes often smell.

* Presence of pyrite (metallic, gold colored specs).

**Alkaline Sites**

A tell-tale sign of alkaline sites is noticeable accumulations of salts (white to dark color), and large surface cracks. Other indicators include:

* Alkaline soils usually support poor vegetation and the area may be entirely devoid of plants.
* Often alkaline sites are small, appearing nearly circular in shape, and easily distinguished from surrounding vegetated areas.

DATA REQUIREMENTS

**Surface Water Studies**

* Detailed location map of all surface water features.

* Streamflow quantity data including seasonal and annual variations, floods, and low flows.
  
  ** Perennial and intermittent streams should have continuous recording gages.
  
  ** Ephemeral streams should have crest gages read monthly and immediately on significant runoff events such as snow melt or storms.

* Streamflow quality data including both physical and chemical characteristics, and the relationship between mine discharge and quality. Quality parameters include:
  
  ** Field analysis: pH, EC, temperature, DO.
  
  ** Laboratory analysis: TDS, TSS, oil and grease, SAR, HCO₃, Ca, Cl, Mg, NH₃, NO₃, NO₂, PO₄, Na, SO₄, Al, As, B, Ba, Cd, Cr, Cu, F, Fe, K, Pb, Mn, Hg, Mo, Ni, Se, Zn.

  ** Sample perennial streams monthly or frequently enough to characterize quality.

** Sample intermittent and ephemeral streams twice a year and during significant runoff events such as snowmelt or storms.

* Description of climate including mean annual precipitation, precipitation frequency and duration relationships, and seasonal and annual variations in precipitation.

* Description of water use.

**Groundwater Studies**

* Map of all surface expressions of groundwater including mine drainage and influx, aquifer recharge and discharge, existing wells, and springs.
* Geologic data, maps, and cross-sections that show confining layers, hydrologic barriers and boundaries, faults, and folds.

* On affected aquifers:

  ** Static water level data including seasonal variations.

  ** Potentiometric surface maps.

  ** Water quality data including seasonal and annual variations. Refer to list of quality parameters under Surface Water Studies.

  ** Pump tests to determine permeability, transmissivity, and storage coefficients; effects of hydrologic barriers and boundaries; interaction between aquifers; and interactions between groundwater and surface water systems.

* Geochemical data on the mine wastes for use in predicting post remediation water quality.

MONITORING

Monitor stream gages and wells on the same schedule as above until revegetation has been successful. After successful revegetation, taper off monitoring over a two or three year period.

REFERENCES: This section paraphrased from USOTA, 1986, p. 139; (USFS, no date, p. 27 & 28.

VEGETATION

DESCRIPTION

Mining activity results in destruction of vegetation in the disturbed areas. While some AML sites have revegetated naturally, many remain barren from the unsuitable characteristics of the growing environment.

The purpose in characterizing site vegetation is to identify areas requiring remediation, and identify vegetation appropriate for use in remediation.

Cost: $2,000 to $30,000 per project.
DATA REQUIREMENTS

* Maps showing existing vegetation types on a scale of 1 in. to 400 - 700 ft.

* Cover data both relative and absolute. Sampled by quadrat, line intercept, or point intercept.

  **Absolute cover** is the actual percentage of ground shielded by each plant species, and may be greater than 100% where plant canopies overlap.

  **Relative cover** is the percentage of the total vegetative cover contributed by each species and must total 100%.

* Spatial and local density of woody plants by micro-environmental areas. Sampling by quadrats, belt transects, and plotless samples.

* Vegetation diversity by:
  
  **Species.**

  **Lifeform** (particular morphologic category of a species such as tree, shrub, grass, or subdivisions of these categories).

* Seasonality (time of year when a plant accomplishes most of its growth).

MONITORING

Monitoring determines the success of revegetation, and the need for remedial measures such as supplemental watering, additional seeding or transplanting, and weeding of unwanted species. Trends should be measured with statistically valid sampling techniques and photographic records.

Monitoring should occur seasonally until the vegetation is capable of self-regeneration and plant succession equal to the natural vegetation of the area. Continue monitoring for 10 yr in areas with rainfall less than 25 in. per yr and 5 yr in areas with rainfall greater than 25 in. per yr.

WILDLIFE

DESCRIPTION

Most AML sites are small and have little impact on wildlife. Even the larger sites have unpredictable impacts on wildlife because many species are mobile and have some capacity for adaptation. Indeed some endangered species adopt AML sites for their habitat including bats, ring tail cats, and spotted owls. Wildlife studies are required to ensure that remediation sustains wildlife and protects endangered species.

Cost: $3,000 to $25,000 per project.

DATA REQUIREMENTS

* Species and their seasonal occurrence.
* Relative population densities of ecologically important species.
* Maps showing habitat classification and delineation including special habitat features such as use of AML sites.
* Minimum one year of data collection.
* Studies cover site plus a 0.25 to 2 mi buffer zone.
* Refer to park guidance on acceptable data collection techniques.

MONITORING

Wildlife monitoring uses the same techniques as the other baseline studies, but generally tend to be much less intense. Refer to park guidance.

REFERENCE: This section paraphrased from USOTA, 1986, p. 159.

HISTORICAL SURVEYS

DESCRIPTION

Historical surveys identify cultural resources that contribute to the character of an area or illustrate the area's history.

Cost: $1,000 to $20,000 per project.
AUTHORITY

* Sections 106 and 110 of the National Historic Preservation Act.

* Secretary of the Interior's Standards and Guidelines for Historic Preservation.

* NPS-28.

DATA REQUIREMENTS

* Literature search.
  ** Site location and description information such as cultural and historic reports.
  ** Current and historic maps.
  ** Bureau of Land Management and county court house mining claim files, and State mining case files.
  ** Historical photographs, newspapers, Federal and State publications, location and legal notices.
  ** Interview long-time residents of the area.

* Inventory of cultural resources including:
  ** Significant structures (buildings, mine machinery, mill plants, housing, foundations).
  ** Building materials.
  ** Artifacts.
  ** Roads.

* Detailed condition of features.

* Describe impact of mine closure and remediation alternatives on historical and cultural resources.

* Identify any approved plans for historic preservation.

* Maps:
  ** Location.
  ** Site.
  ** Features.

* Photographic record.
MONITORING

If the site is preserved, use the Maintenance Management System to track monitoring and maintenance.

REFERENCES: This section paraphrased from Barker et al, 1990; NPS, 1990.
MINE CLOSURES

BACKFILL CLOSURES

DESCRIPTION

Backfill closures consist of filling mine openings with on-site or imported fill. See Fig. 1. Normally done with heavy equipment; however, can be done by hand for remote and shallow sites.

For adit backfills, an access-way can be provided where there is a need to re-enter the mine for archeology, geology, or NPS administrative purposes.

Advantages: Backfilled sites can be restored, and do not attract vandals or casual visitors. Less monitoring required.

Disadvantages: Wildlife habitat and historic resources in mine are permanently lost. Backfilled shafts may subside, and site should never be used for buildings. Any access through a backfill compromises the advantages.

Cost: $100 to $5,000 per project.

MATERIALS

Backfill: Well-graded rock to minimize voids, durable, impermeable, and insoluble in water. Free of debris or trash and not containing toxic or hazardous materials. May be any neutral rock material including mine waste. Final backfill must be comparable to surrounding surficial material.

Riprap: Minimum (2 ft*) diameter, hard, durable, and well-graded to minimize voids.

Drainpipe: Noncorrosive, sized for potential flow.

Corrugated steel culvert (optional): 30 to 36 in. diam, 14 to 16 gauge.*

Grated access door (optional): See separate guideline.

CONSTRUCTION

Clean-Up

Prior to backfilling, remove all wood, garbage, cribbing, or other debris from the mine opening as safe conditions permit.
Figure 2. Backfill Closures - Shafts
Figure 3. Backfill Closures - Adits
Shafts, Stopes, and Subsidence

Backfill the opening with graded riprap and rock in the following steps (refer to Fig. 2):

* Place a minimum (12 ft) height of riprap in the bottom of the opening or extending above any intersecting crosscuts.

** In deep or water filled openings, place riprap until visible from the edge of the opening.

* Fill remainder of opening with graded rock from on-site or comparable surrounding rock.

* Place rock fill in specified maximum (2 ft) lifts and minimum thickness (5 ft), and compact whenever possible with compactors or available heavy equipment.

* Mound final surface a minimum (3 ft) height and (2½%) grade above original ground level to allow for settlement.

Adits

If required, install access-way and drainpipe as follows.

* Clear floor of loose rock and debris to create a level bedding surface for culvert/drainpipe.

* Any fill placed to level the floor should not contain rock larger than a maximum (4 in.) diameter, and should be compacted.

* When water discharges from the adit, size a drainpipe for the flow, and perforate (1/2 in. diam holes, spaced 3 in. apart) on inside end of drainpipe on bottom side.

* Place culvert/drainpipe, and extend both inside and outside ends minimum (5 ft) distance beyond backfill.

* Prior to backfilling, cover culvert/drainpipe with a minimum (6 in.) thickness of compacted fill.

Backfill the opening 1) a minimum (15 ft) distance beyond the weathered zone, 2) a minimum 15 ft distance beyond any fractures induced by the mine opening, or 3) a minimum brow thickness of twice the mine opening height whichever is greater. See Fig. 3. Measure length of backfill along top of fill. Take care not to damage culvert and drainpipe. Additional requirements:
* No spaces between top of fill and roof of the adit that exceed a minimum (3 in.) height.

* No space between top of fill and roof at the entrance to the adit.

* Entire length of backfill must have rocks individually weighing more than a specified minimum (150 lb) to reduce erosion and discourage people from digging through backfill.

Install Monument  See separate guideline.

REFERENCE: This section paraphrased from CMLRD, 1989, p. 21.

BLAST CLOSURES

DESCRIPTION

Blast closures consist of filling or collapsing mine openings through the use of explosives. See Fig. 4. This closure method permanently prevents access to the mine.

Advantages: The site can be restored. Blasting can be used on openings that are too unstable and unsafe for other methods. For remote sites that do not require drilling, explosives can be backpacked.

Disadvantages: Requires experts and almost always involves some amount of trial and error. Wildlife habitat and historic resources in mine are permanently lost. Backfilled shafts may subside, and site should never be used for buildings.

Cost: $500 to $4,000 per project.

BLASTING PLAN

Blasting requires an expert to design and supervise the operation. The expert must have relevant experience, a Federal license, and usually a State license for both the storage and use of explosives. Blasting plans involve the following:

* Type of explosives and blasting agents.

* Blast hole pattern, powder factor, and charge design.

* Detonation method and timing.

* Direction of fly rock, maximum allowable wind velocity, date and time of blast.
Figure 4. Blast Closures
* Provisions for employee and public safety.
* Compliance with local regulations and notification of local law enforcement.

REFERENCE FOR STATE AND LOCAL REGULATIONS

* Applicable Federal regulations:
  ** 30 CFR Parts 1 to 199
  ** 30 CFR Parts 700 to End

MATERIALS

** Drainpipe: Noncorrosive, sized for potential flow.**

CONSTRUCTION

Collapse mine opening by controlled blasting for a minimum (15 ft*) depth beyond whichever is greater 1) the surface, 2) weathered zone, or 3) fractures induced by the mine opening. See Fig. 4. If conditions permit, drill blast holes and blast from inside the mine opening. Additional requirements include the following:

* Place a backstop at the specified minimum depth to force blasted rock to fill the mine opening.

* Entire length of blast fill must have rocks individually weighing more than a minimum (150 lb*) to reduce erosion and discourage people from digging through fill.

* No spaces that exceed a minimum (3 in.*) height.

* No spaces at the entrance.

* For adits that discharges water, place on the floor a drainpipe sized for the flow.
  ** Perforate inside end of drainpipe on under side (1/2 in. diam holes, spaced 3 in. apart*).
  ** Extend both ends of drainpipe a minimum (5 ft*) distance beyond blast area.
  ** Prior to blasting, cover drainpipe with a minimum (6 in.*) thickness of compacted fill.
CONCRETE CAP SHAFT CLOSURES

DESCRIPTION

Concrete caps or slabs placed over shaft openings are an intermediate closure method intended for use where the need may arise to re-enter the mine in future. See Fig. 5. The caps can be removed although not without considerable effort. In addition, culverts can be placed through the caps, if access is required for NPS administrative purposes.

Caps are constructed from a choice of slab either precast or cast-in-place, and a choice of slab support either steel beams or hollow core footings. If a park has numerous open shafts, precast concrete panels are an efficient and economical method of closure. Steel beams provide slab support where the shaft rock is competent, and hollow core footings where the rock is incompetent.

Construction involves clearing and grubbing, excavation of footings, installation of forms and reinforcing steel or steel beams, concrete work or placement of precast panels, installation of access-way (optional), and backfilling.

Advantages: Relatively inexpensive if there is road access to the site. Adaptable to a variety of site conditions. Moderately vandal proof.

Disadvantages: In time, cap may subside into mine opening if not constructed properly. Cap may deteriorate in 30 to 50 years. Only provides for public safety; does not restore natural environment or provide access for wildlife.

Cost: $3,000 to $5,000 per project.

MATERIALS

For Cast-In-Place Caps

Concrete and reinforcing steel: Refer to NPS specifications.

Forms: Wood or stay-in-place corrugated metal.

Drainpipe: Noncorrosive, 2 in. diam*. 

Install Monument  See separate guideline.

REFERENCE: This section paraphrased from CMLRD, 1989, p. 23; CMLRD, 1990, p. 4.
Figure 5. Concrete Cap Shaft Closures
(CMLRD, 1990)
For Precast Panels

Precast concrete panels: Supplied and delivered by a manufacturer to storage areas near the project site. Refer to NPS specifications. One panel may have an optional opening for installing an access way.

Steel beams, tie bars, and plates: Specified by a qualified structural engineer. Specify minimum (6 in.*) width of beams to provide an adequate bearing surface for panels.

Sacrete: Or equivalent.

For Both Cap Types

Corrugated steel culvert (optional): 30 to 36 in. diam, 14 to 16 gauge.

Grated access door (optional): See separate guideline.

Backfill: Unclassified rock and soil free of debris or trash, and not containing toxic or hazardous materials. May be any neutral rock material including mine waste. Final backfill must be comparable to surrounding surficial material.

CONSTRUCTION

Clearing and Grubbing

Clear and grub vegetation, debris, loose rocks, and other items that interfere with construction.

For Competent Rock – Excavation And Beam Installation

On occasion, excavation may reveal conditions that necessitate plan revisions. Contractors should be made responsible for site inspections to insure that their bids adequately reflect excavation conditions.

Competent rock is defined as rock which 1) cannot be readily removed by a medium sized excavator (weighing in the 45,000 to 55,000 lb range*), and 2) does not have adverse jointing which may slip and cause failure of the closure.

Excavation:

* Locate beam footings in competent rock.

* Excavate soils, loose and weathered rock in general compliance with construction drawings.

* Beams and slab overlap competent rock by a minimum (1 ft*) length.
* Overlap must be equal on opposites sides of closure.

* Each slab side must have more than two thirds of its length resting on planar rock or concrete surface with no gaps greater than a specified minimum (1 ft long and/or 6 in. deep*).

* Fill low foundation areas (not more than a minimum 1.5 ft* depth) with compacted and confined waste rock or concrete.

**Beam Installation:**

* Prior to installation, coat steel beams with bituminous tar or epoxy resin for corrosion protection.

* For precast panels, set steel beams perpendicular to the long dimension of panels, and set top of beams in the plane of panel footings.

* Place steel beams on a concrete leveling course with minimum specified thickness (3 in.*).

* Encase steel beams totally in concrete for the entire length of footings, except for top. Specify a minimum (3 in.*) thickness of concrete as measured from outermost extremities of beam.

---

**For Incompetent Rock - Hollow Core Footing**

Hollow core footings are required where rock in shaft opening is inadequate to support beams and concrete slab. Definition of competent rock given under preceding subsection.

**Excavation:**

* Excavate soils, loose and weathered rock in a truncated cone shape leaving a minimum (1 ft*) ledge width in unweathered rock.

* For precast panels, outside ledge dimensions must match panel dimensions.

**Construct hollow core concrete form as follows:**

* Minimum (4 ft*) height.

* Specify height such that top of form is a minimum (2 ft*) distance from side walls of shaft.

* Install cross supports (4 ea 2X4's on 4 ft spacing*) in forms exceeding a maximum (8 ft*) height.
* Install hangars and reinforcing steel as specified by a qualified structural engineer.

* For precast panels, install steel tie plates with anchors.

* If form is to be removed, treat concrete contact surfaces with a bond-breaking coating. Coating must also prevent absorption of water where plywood forms are used.

* Construct form on surface and lower into shaft opening directly from overhead.

* Place rocks around toe of form to stabilize it from movement. Rocks should not fill more than a maximum (2 ft) height, and should not disturb reinforcing steel.

**Cast-In-Place Cap Forms**

Construct forms for the cast-in-place cap using corrugated metal stay-in-place forms, and steel or wood support beams.

* Forms should be mortar tight and sufficiently rigid to prevent distortion from pressure of the concrete, vibration, and other incidental construction loads.

* Lay reinforcing steel into form using plastic chairs or equivalent to support steel the proper distances.

* Reinforcing steel must be tied together and not welded.

* Install pipe (2 in. diam on 4 ft centers*) to drain water through the cap.

If an access-way is required, install culvert prior to pouring concrete, as follows:

* Form an opening the same size as culvert.

* Secure culvert to form opening and to the surface with guy wires.

* Install diagonal reinforcing steel around opening.

* Bottom culvert rim must rest on cap form or horizontal beams without obstructing culvert opening.

* Extend culvert a minimum (1 ft*) height above the backfill surface.
Concrete Placement

Concrete may be mixed at site or delivered by a commercial service.

* Inspect and approve forms prior to pouring concrete.

For the hollow core footing:

* Place concrete around outside and to top of the form.
* Pour in maximum (15 - 20 in.*) lifts.
* Systematically consolidated concrete using mechanical vibrators, and insure that the junction between layers is adequately vibrated.

For the cast-in-place cap:

* Control pouring rate to prevent deflection of the forms.
* Spade concrete by hand around reinforcing steel, and systematically consolidated using mechanical vibrators.
* Insert a pipe flange in concrete for monument pipe.

Concrete samples must be taken and tested in compliance with NPS specifications.

Precast Panel Installation

* Place precast concrete panels on panel end footings, and hollow core footing or steel beams.

  No more than a maximum (1 in.*) space between panels.

  Panel edges within a minimum (2 in.*) distance of beam center line.

  For adjacent panels not resting on a beam, minimum (6°*) deviation from a planar surface, and maximum (3 in.*) vertical gap.

* Panels must rest uniformly on footings and beams (no discernable rocking*). Under some circumstances, minor inadequate leveling can be corrected by shimming or additional footing concrete.

* If panels are placed more than a specified angle (15°*) from horizontal, key in and anchor panels to competent
rock. Specify anchors (#8 rebar or rock bolts, 18 in. deep, spaced on 24 in. centers).

* Remove lifting hooks from panels.

* Tack weld beam tie bars to panels.

If an access-way is required, secure culvert to opening in panel, and extend culvert a minimum (1 ft) distance above backfill surface.

Install Monument  See separate guideline.

Backfill and Drainage Berms

If cap is more than a maximum (8 ft) depth below ground surface, backfill cap completely. Cast-in-place caps must reach a minimum (3,000 psi) compressive strength prior to loading or backfilling.

Where a vertical culvert is not required:

* Backfill excavation with uncompacted rock to a maximum (1.5h:1v) gradient. Toe of backfill should overlap cap sides by a minimum (2.5 ft) distance, but should not cover optional grate, if installed.

* With uncompacted rock, construct drainage control berms to direct surface runoff away from opening. Specify appropriate berm design for local runoff conditions.

Where a vertical culvert is installed:

* Place backfill in maximum (2 ft) lifts, compact with mechanical compactors or available heavy equipment.

* Mound final surface a minimum (1 ft) height and grade (2%) above original ground level to provide drainage away from closure.

Weld a grated and locked access door to the top of the culvert or opening in cap, as appropriate. Weld must be continuous around the grate.

REFERENCES: This section paraphrased from CMLRD, 1989, p. 25; CMLRD, 1990, p.5.
MONOLITHIC PLUG SHAFT CLOSURES

DESCRIPTION

Monolithic plugs simply consist of pouring a specified (4 ft*) layer of concrete over mine shafts that have collapsed at the collar and have no apparent opening. May also be used for small subsidence features. The construction includes clearing and grubbing, excavation, placing riprap, and pouring concrete.

Advantages: Relatively inexpensive if there is road access to the site. Adaptable to site conditions. Moderately vandal proof.

Disadvantages: In time, cap may subside into mine opening if not constructed properly. Concrete may deteriorate in 30 to 50 years.

Cost: $1,000 to $3,000 per project.

MATERIALS

Concrete: Refer to NPS specifications.

Riprap: Hard and durable with a minimum (2 ft*) diameter.

Backfill: Unclassified rock and soil free of debris or trash and not containing toxic or hazardous materials. May be any neutral rock material including mine waste. Final backfill must be comparable to surrounding surficial material.

CONSTRUCTION

Clearing and Grubbing

Clear and grub vegetation, debris, loose rocks, and other items that interfere with construction.

Excavation

In most cases, no excavation is necessary because the shaft has collapsed to dimensions larger than the original cross section dimensions. If current dimensions are smaller than original dimensions, excavate opening to a cone shape so that plug dimensions exceed original dimensions by a minimum (2 ft.*) width on all sides.

Riprap Installation

Place a minimum (2 ft*) thickness of riprap in the bottom of the shaft depression. Finish riprap with a generally flat top such that no rock extends more that a minimum (2 ft*) height above the average level.
Concrete Pouring

Concrete may be mixed at site or delivered by a commercial service.

* Pour concrete over riprap for a minimum (4 ft*) thickness that includes the riprap thickness.

* Compact concrete thoroughly by a mechanical vibrator.

* Vibrating must be supplemented with hand spading to work concrete into riprap.

Concrete samples should be taken and tested in compliance with NPS specifications.

Install Monument  See separate guideline.

Backfill

After concrete attains minimum (3,000 psi*) compressive strength, backfill plug. Mound backfill a minimum (2 ft*) height and (2%*) grade above the surrounding area to insure drainage away from the closure.

REFERENCES:  This section paraphrased from CMLRD, 1989, p. 36; CMLRD, 1990, p. 5.

STEEL GRATE CLOSURES

DESCRIPTION

A steel mesh of expanded sheet metal, heavy steel rods, or angle iron is supported by a rigid steel frame, and cemented or bolted over an opening. See Fig. 6. This closure method is intended for use where there is a need to provide access for wildlife (bats, ring tail cats, spotted owls) or a need to frequently re-enter the mine (archeology, geology, NPS administrative purposes). Construction involves clearing and grubbing, excavation of loose material, trimming opening, fabricating, and installing grate.

Advantages:  Openings are closed for public safety, yet retain access. Effective at preventing accidental or intentional entry. Can be recessed to minimize visual intrusions. Should last indefinitely in arid climates. Allows natural ventilation. Smaller grates can be transported by helicopter or grates can be assembled on-site.
Figure 6. Steel Grate Closures
Disadvantages: Each grate must be custom designed. Installation is difficult away from road access. Rock foundation may weather and deteriorate with time. Grates are often defeated by persistent vandals. Require regular monitoring and maintenance. Can be visually intrusive, but massive appearance may deter unwanted entry.

Cost: $1,000 to $7,000 per project.

MATERIALS

Steel grating: Openings (1-1/4 in. by 1 in.*), bearing bars (15/16 in.* centers), and cross bars (2 in.* centers). Equivalent commercial grating is also available.

For adit bat gates, openings must be oriented horizontally with minimum (6 in. by 24 in.*) dimensions. Grate must be fabricated from heavy steel rods or angle iron. Modify grate design for the requirements of particular species.

Structural steel specified by structural engineer.

Footing Concrete: Refer to NPS specifications.

Anchors: Either 1) expansion rock bolts with minimum (2000 lb*) pullout for competent rock, or 2) reinforcing steel of minimum (No. 6 rebar*) size and (18 in.*) length as required by rock conditions.

Anchor Grout: Nonshrink mortar or epoxy resin capsules.

CONSTRUCTION

Clearing and Grubbing

Clear and grub vegetation, debris, loose rocks, and other items that interfere with construction.

Fabrication

On-site, cut commercial grating or weld together custom grating to fit irregularities of the opening.

* Weld grating to angle iron framework, every other bearing bar and all cross bars on both sides.

* Weld all edges of grate to each other.

* Chip, wire brush, and completely remove slag from welds.

* After cleaning, paint welds and steel with a zinc-rich protective coating.
* Welds must meet applicable standards of the American Welding Society.

**Adit Excavation and Grate Installation**

Specify a stable location not more than a given (10 ft\textsuperscript{*}) distance from opening. Trim opening to provide a uniform contact for the grate frame. If stable roof and sides are not found, select another closure method.

If the floor is unstable, excavate and construct a floor footing as follows:

* Minimum (8 in\textsuperscript{*}) width extending across entire adit.

* Depth to competent rock or a minimum (3 ft\textsuperscript{*}) distance below grade line.

* Drive (No. 6 rebar\textsuperscript{*}) anchors on specified (18 in\textsuperscript{*}) centers and minimum (36 in\textsuperscript{*}) depth. Extend anchors a minimum (8 in\textsuperscript{*}) distance above footing.

* Install reinforcing steel, pour and vibrate concrete.

If the floor is competent rock, set anchors as follows:

* Specify minimum anchor depth (8 in. for rock bolts, 18 in. for grouted reinforcing steel\textsuperscript{*}), and minimum (8 in\textsuperscript{*}) distance anchor extends into opening.

* Drill holes on specified (18 in\textsuperscript{*}) centers and slightly greater in depth than anchors.

* Insert non-shrink grout and anchors.

Weld grating frame to anchors. Weld a (2 in. by 3/8 in\textsuperscript{*}) strap between anchors and around the perimeter of the grate at a specified maximum (4 in\textsuperscript{*}) distance from the edges of the opening. Welds should meet specifications given in Fabrication subsection.

**Shaft Excavation and Grate Installation**

Grate dimensions must extend a specified (1 ft in competent rock, 3 ft in incompetent rock\textsuperscript{*}) distance beyond shaft opening.

Clear loose rocks and trim opening to provide a uniform contact with frame.

* Fill all voids between frame and opening larger than a maximum (1 in\textsuperscript{*}) width with mortar, rock wall, pieces of welded grating, or angle iron.
* Where gaps between the frame and bedrock exceed a maximum (6 in.*) height, fill gap with a mortared and durable rock wall of minimum (6 in.*) width.

In competent rock, set anchors as described above for adits.

If rock is incompetent, construct spread footings for frames as follows:

* Minimum (8 in.*) column diameter and base (24 by 24 in. for spans up to 30 ft, 30 by 30 in. for spans greater than 30 ft*).

* Depth to competent rock or minimum (3 ft*) below grade line.

* Maximum (10 ft*) spacing or less as required by irregular outline.

* Build concrete forms, install reinforcing steel as specified by structural engineer - minimum of four vertical rebar. Extend two of four vertical rebar above footing for welding to grate.

* Pour and vibrate concrete.

If shaft opening exceeds a maximum (3.5 ft*) span, install supporting steel beams as specified by a qualified structural engineer.

* Extend beams a minimum (1 ft*) distance beyond both sides of grating.

* Excavate footings for beams a minimum (3 in.*) beyond outer extremities of beams.

* Embed and cover beams in mortar for the entire length of footings except for beam top where grating is placed.

Weld grating frame to beams and anchors.

* First, remove any paint from weld areas prior to welding.

* Weld every other bearing bar of grating to support beams.

* After welding, paint steel with a zinc-rich protective coating.

* Welds should meet specifications given in Fabrication subsection.
Install Access

If ready access is required, cut and weld a doorway or hatch into grate (bottom center for adits and center for shafts.) See separate guideline.

Drainage Berms

With uncompacted rock, construct drainage control berms to direct surface water runoff away from shaft opening. Specify appropriate berm design for local runoff conditions.

Install Monument See separate guideline.


CABLE NET CLOSURES

DESCRIPTION

Cable nets are made of stainless steel cable with all intersections locked to form a 6 in. mesh or as required for wildlife access. See Fig. 7. The nets are anchored in or over a mine opening with rock bolts.

Advantages: Effective in preventing accidental and intentional entry. Allow small wildlife to pass including small bat species. Can be recessed to minimize visual intrusion. Flexible in being adapted to odd shaped openings including those with historic resources. Resistant to most vandals.

Disadvantages: Barrier to large bat species, although the net can fabricated with a larger mesh. Site is not restored. May create a challenge to visitor because one can see beyond barrier and it appears vulnerable. Nets can be cut with cable cutters but not the more commonly available bolt cutters.

Cost: $300 to $3,000 per project.

MATERIALS

Cable: Steel minimum 1/4 in.* diameter, crimp connectors.

Anchors: Either 1) expansion rock bolts with minimum (2000 lb") pullout for competent rock, or 2) reinforcing steel of minimum (No. 6 rebar*) size and (18 in.*) length as required by rock conditions.

Grout: Nonshrink mortar or epoxy resin capsules.
Figure 7. Cable Net Closures
TOOL LIST

Rock drill, drill rods, bits, and air compressor.
Cable sleeve crimper.
Cable cutter.
Sledge hammer.
Shovel.
Come-along.

CONSTRUCTION

Fabrication

Construct a jig to weave steel cables into a net configuration, typically 7.5 ft square. Stretch cable tightly and join intersections with hydraulically crimped two part steel sleeves. Crimped sleeves are preferable to wire rope clips because sleeves are more difficult to vandalize. If clips are used, the bolt heads must be stripped to prevent removal.

In the field, cut and join nets (crimped sleeves) to custom fit particular opening.

* For shafts, locate net over opening, and extend net a minimum distance (2 ft*) beyond opening.

* For adits, locate net over opening as for shafts, or locate net inside opening not more than a maximum (10 ft*) distance from surface. Inside closure is applicable only where rock is competent. Inside closure must have no gaps between adit walls and net greater than a maximum (4 in.*) width.

Holes may be cut in the net, and then closed with cable sections and crimped sleeves in order to fit net around projections or historic objects.

Anchors

For overlapped nets, place anchors a minimum of 4 to 5 ft back from net edges to provide room to tighten cables.

In competent rock, set anchors as follows:

* Specify minimum anchor depth (8 in. for rock bolts, 18 in. for grouted reinforcing steel*), and minimum (8 in.*) distance anchor extends into opening.

* Drill holes on specified (18 in.*) centers and slightly greater in depth than anchors.

* Insert non-shrink grout and anchors.
For openings with incompetent rock, set anchors as follows:

* Specify minimum anchor depth (3.5 ft*), and minimum (8 in.*) distance anchor extends above surface.

* Drive anchors into ground with sledge hammer. Mechanical methods are also available.

**Installation**

Weave boundary cables through net and perimeter rings on anchors, and connect ends. Tighten cables with come-along. If required, attach padlock shield.

Where possible, cover perimeter of nets with rock and dirt to obscure anchors and connectors.

**Install Monument** See separate guideline.

**REFERENCE**: This section paraphrased from Essington, 1988.

**POLYURETHANE FOAM CLOSURES**

**DESCRIPTION**

Polyurethane foam (PUF) closures consist of installing a bottom form, spraying PUF over the form to a minimum thickness, and then backfilling with common fill. See Fig. 8. Ventilation/drainage pipes, access-way, and locking grates may be installed, as required.

This closure method can be permanent or access-way can be installed where there is a need to re-enter.

Advantages: Materials are easily transported to remote sites. Forms require little structural strength. Site can be restored. Backfilled openings do not attract vandals or casual visitors. Less monitoring required.

Disadvantages: Wildlife habitat and historic resources in mine are permanently lost. Backfilled shafts may subside, and site should never be used for buildings.

Cost: $1 500 to $8,000 per project.

**MATERIALS**

**Form and cross supports**: Any commonly available building materials capable of sustaining the initial 2 to 4 ft of PUF. Form material must be physically and chemically inert to PUF. Examples of acceptable form materials include any combination of the following:
Figure 8. Polyurethane Foam Shaft Closures
Polyurethane foam (PUF): The Colorado Mined Land Reclamation Division recommends the following minimum standards:

<table>
<thead>
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<th>PUF CHARACTERISTIC</th>
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<td>Closed cell content</td>
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<td>ASTM D-1621</td>
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<td>Fire resistance</td>
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Estimate the required thickness of PUF from Table VII, as follows:

* Enter the table with the shortest dimension of the mine opening cross section, and the depth from the opening to the bottom form. At the intersection, read the required PUF thickness.

* To get total PUF volume in cubic yards, multiply PUF thickness by mine opening cross section width and length, and then divide by 27 cu ft per cu yd.

* Adjust total for significant irregularities in the sides of the mine opening and any access-way or pipes placed in the PUF.

Proportioning unit: Minimum (125° F*) temperature with heated hose. Hose must maintain or increase PUF temperature from the proportioner to the application gun.

Application gun: Mix PUF components in the proper ratio at a minimum (4 lb per min*) output.

Corrugated steel culvert (optional): 30 to 36 in. diam, 14 to 16 gauge.*

Grated access door (optional): See separate guideline.

Backfill: Unclassified rock and soil free of debris or trash and not containing toxic or hazardous materials. May be any neutral rock material including mine waste. Final backfill must be comparable to surrounding surficial material.
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REFERENCE: (CMLRD, 1989, p. 43)
SAFETY, HANDLING, AND TRANSPORT

Store PUF materials as specified by manufacturer. Observe all safety precautions outlined by the Polyurethane Division of the Society of Plastics Industries, NFPA, OSHA, EPA, and the manufacturer's Material Safety Data Sheets (MSDS). MSDS and technical data sheets must be on-site and available at all times.

No welding, smoking, or open flames within 25 ft of PUF applications. A minimum 15 lb, class ABC fire extinguisher must be on site during PUF application.

PUF workers must wear organic respirator masks, and safety glasses or goggles. Comply with any more stringent Federal, State, or local safety requirements.

Before and during installation of the bottom form, test air with flame safety lamp or oxygen meter. The oxygen meter shall be a National Mine Service (NMS) OX231 or equivalent, and must have an audible warning. Continuously monitor oxygen levels. Lower the flame safety lamp from the surface to the intended work level of the bottom form. If the flame safety lamp is extinguished upon withdrawal, then the mine may not be entered until the oxygen level increases to acceptable levels. Either lamp or meter shall accompany workers during their time in the mine. Withdraw from the mine if 1) the oxygen meter indicates oxygen content falls below 19 percent, or 2) the quality and/or intensity of the flame safety lamp decreases.

Comply with all applicable State and local regulations for transport of PUF components and spill response.

CONSTRUCTION

Clearing Debris

Clear debris, loose rocks, and other items that interfere with construction, as safety conditions permit.

Form Installation

Place form either 1) a minimum (2 to 4 ft*) distance below the level of competent rock, or 2) at the depth given by Table VII, whichever is greater. First, set cross supports which may be placed at an angle not greater than a maximum (20°*) from horizontal as long as both ends are seated in competent rock. Then set form over cross supports.

Drainpipe and Access-Way (Optional)

With no drainage, surface water may accumulate on top of the PUF plug. If this water is not desirable, install a drainpipe as follows:
* For that part of drainpipe exposed to backfill, cut slits or perforate with holes less than a minimum (0.25 in.*) width or diameter.

* Encase upper end in a steel sleeve (2 in., in diameter greater than pipe and 3 ft long*), and fill annulus with concrete.

* Extend one third of sleeve above final grade line.

* Weld steel strap or equivalent to top of pipe to reduce opening to less than a maximum (2 in.*) size. This prevents large rocks from being dropped and lodged in pipe.

* Cover pipe openings temporarily (visqueen or polyethylene tape*) during PUF application, and remove covering prior to backfilling.

Install access-way and drainpipe, as follows:

* Prior to placing culvert in shaft, weld grated door to top end of culvert. Weld must be continuous around culvert. Under no circumstances shall welding occur over exposed PUF.

* Cut openings in form for culvert and drainpipe.

* Support culvert and drainpipe on surface (tripod set up over shaft) so that form does not take the load. Secure fixtures to form openings.

* Bottom opening of fixtures must not be obstructed by cross supports.

* Extend fixtures a minimum (1 ft*) height above the final graded surface.

**PUF Application**

The following conditions must be met prior to applying PUF:

* Surfaces free of grease and water.

* No debris.

* Dry weather unless PUF is protected from water by a physical barrier.

* No foreign objects placed in PUF.
Apply PUF in lifts with a maximum (1.5 ft*) rise, as follows:

* Each lift must be tack free stage before applying the next lift.

* Apply PUF such that 1) the entire void is filled, and 2) there are no shadow zones or voids.

* At no time shall sprayed or poured PUF cut into rising foam.

* At no time shall foam temperatures rise to unsafe levels. Thermocouples can be used to monitor temperature of exothermic reactions.

* Stop application if off-ratio PUF or improper heating is observed.

* In backfill section, cover culvert on the outside with a minimum (0.5 in.*) thickness of PUF. PUF may be draped or splashed against culvert to achieve this cover.

* Wait a minimum (1 hr*) time before commencing backfill operations.

Correct off-ratio PUF as follows:

* Remove any off-ratio lift comprising over a specified (2%*) portion of total column.

* Off-ratio PUF less than the preceding maximum may remain if allowed to cool and if the outer perimeter is removed.

**PUF Field Quality Control**

PUF field quality control includes observation and density testing.

Acceptable PUF is tan-white to buff in color with no vesicles and a smooth to coarse orange peel surface. Stop PUF application if anyone of following conditions is observed:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Possible Cause</th>
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<tbody>
<tr>
<td>Dark color</td>
<td>Excess A component</td>
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<tr>
<td>Smooth and glassy</td>
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<tr>
<td>Friable or brittle</td>
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<tr>
<td>Improper density</td>
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<tr>
<td>Light color or white</td>
<td>Excess B component</td>
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<tr>
<td>Bad cell structure</td>
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</table>
Mottled appearance
Blowholes or pinholes

Slow rise
Poor cell structure
Frequent equipment clogging
Slow curing
Bad physical properties

Test and correct PUF ratio on a plastic sheet away from work area.

Collect density samples in center of shaft opening just above latest PUF lift. A sampling box can be constructed of aluminum and lined with polyethylene. Lower container into position and fill with applicator. Sample density should be within a maximum (8%) tolerance of required (2 lb per cu ft) density, and should exceed a minimum (1.85 lb per cu ft) density.

Adjust ratio for changes in barometric pressure.

Laboratory testing is available for PUF quality and tensile strength. These tests require 1 cu ft samples for quality, and 100 cu in. samples for tensile strength.

Backfilling

After a minimum (1 hr) curing time, backfilling may commence. Place the first 2 ft lift of backfill by hand, bucket, or chute to lower the velocity of impact against the PUF. In addition, protect drainpipe and culvert from damaged by backfilling.

Install Monument See separate guideline.


BULKHEAD ADIT CLOSURES

DESCRIPTION

There are two types of bulkheads one built of native rock, and the second built of concrete blocks where the native rock is incompetent or not readily available. See Fig. 9. A bulkhead of native rock and grout is built into the opening of an adit or inclined shaft. Alternatively, the bulkhead can be built with concrete blocks, reinforcing steel, and grout.

May be built with or without a grated access-way.
Figure 9. Bulkhead Adit Closures
(CMLRD, 1990)
Advantages: Native rock is indigenous, obtained locally, and visually less obtrusive. Applicable where the site is difficult to backfill or blast, very remote or access very difficult. Minimal construction impacts.

Disadvantages: Labor intensive. May not be as visually unobtrusive as backfilled or blasted closures.

Cost: $1 200 to $7,000 per project.

MATERIALS

Rock: Durable and produces a ringing sound when struck with a hammer (indicating lack of fractures).

Concrete Blocks: Refer to NPS standards.

Reinforcing steel: Specified by qualified structural engineer.

Grout: Refer to NPS standards.

Drainpipe: Noncorrosive, sized for potential flow.

Corrugated steel culvert (optional): 30 to 36 in. diam, 14 to 16 gauge.*

Grated access door (optional): See separate guideline.

CONSTRUCTION

For native rock, minimum wall thickness is 30 in. for 8 ft maximum adit dimension, 36 in. for 8 to 10 ft, and 42 in. for 10 to 12 ft*.

For concrete blocks, a single block wall is generally adequate for openings up to 8 by 8 ft. Use a double block wall for openings up to 15 by 15 ft.

Choose another closure method for larger openings.

Foundation

Place bulkhead in bedrock. Clear bulkhead site of all unconsolidated material prior to construction.

Install a footer, If bedrock is in excess of a maximum (36 in.*) depth below the original excavated floor, install a footer as follows:

* Place bottom of footing a minimum (3 ft*) depth below grade.

* Compact foundation to a minimum density.
* Drive No. 5 rebar on minimum (8 in\*) centers into foundation floor to minimum (36 in\*) depth or refusal.

* Pour concrete footing (12 in. deep, 30 in. wide\*).

**Installation**

Lay and mortar rock/blocks on foundation, and build bulkhead as close as possible to adit sides. In block walls, use partial blocks to minimize gaps.

* Grout all spaces between bulkhead and adit.

* Grout spaces between rocks/blocks and between courses.

* Cap top rocks/blocks.

* There must be no spaces between bulkhead and sides of adit.

For concrete blocks, incorporate the following reinforcement:

* On minimum (32 in.*) centers, grout inside space of concrete block and insert (No. 5*) reinforcing steel.

* On each side of access-way, grout inside space of concrete block and insert two (No. 5*) reinforcing steel.

* On each block course, insert two (15/16 in.*) wires on 16 in. spacing (or prefabricated equivalent such as Durawall). Only required on outer tier of double-block bulkheads.

* On double-block bulkheads, insert (No. 9*) wire, rectangular ties on 24 in. horizontal and vertical spacing.

For improved visual effect, mortar native rock of minimum (12 in.*) diameter to the exterior wall for the entire width and height of concrete block bulkhead.

**Drainpipe and Access-Way**

Where water discharges from the adit, install a drainpipe at bottom of bulkhead. Extend drainpipe a minimum (5 ft) distance beyond each side of bulkhead. Attach a minimum (12 in.*) perforated riser to the inside end. To reduce blockage, cover both ends with (2 in. mesh, 7 ga.*) rubber coated wire.
If access is required:

* For rock bulkhead, lay a horizontal culvert with grated door in the bulkhead as the wall is built up.

For concrete block bulkhead, frame a 4 by 4 ft opening in the center of the bulkhead with welded C 10 X 20's. Weld grate door to frame.

Install Monument See separate guideline.

REFERENCE: This section paraphrased from CMLRD, 1990, p. 12 & 14.

GRATE ACCESS DOORS AND COVERS

DESCRIPTION

Locking steel doors and grate covers for corrugated steel pipes (culverts), grate closures, and bulkheads. See Fig. 10.

MATERIALS

Grating, grate frame, door frame, and lock steel: Carbon steel, specified by qualified structural engineer.

Paint: Zinc-rich.

FABRICATION

Fabricate steel door or steel grate generally in conformance with the following instructions:

* Fabricate solid grate with 2 1/2 in. by 3/8 in. bearing bars on 1 3/16 in. centers, and cross bars on 4 in. centers. Equivalent commercial grating is available.

* Fabricate frame from L steel 3 by 3 by 3/8 in. Size frame to fit opening.

* Weld grate to frame at least very other bearing bar.

Fabricate a lock box from 1/4 in. thick steel plates. Weld all edges, and smooth burrs and rough edges. Size to accommodate a specified (No. 3 Master Lock with 1 1/2 in. shackle) lock. Free play between hasp and door must not exceed 1/4 in. when locked.

Fabricate extra heavy duty (4 in.) long door hinges with non-removable pins. Weld or bolt to hinge plate and grate frame. Weld or grind bolts to make them non-removable.
Figure 10. Grate Doors and Covers  
(CMLRD, 1990)
In the field, weld door cover to opening frame continuously around fixture. Paint entire fixture with a zinc-rich protective coating.

REFERENCE: This section paraphrased from CMLRD, 1989, p. 10.

MONUMENTS

DESCRIPTION

On each closure, install an identification monument that is visible to the eye or a metal detector in the case of backfills.

MATERIALS

Brass cap

Marker Pipe: 3 in. diam, noncorrosive (PVC, ABS, or HDPE).

CONSTRUCTION

Install brass cap on either grate, culvert, or exposed top end of buried marker pipe.

For grates or culverts, permanently braze brass cap to fixture. Care must be taken not to overheat the cap, which may result in breakage.

For other closures, bury pipe with the embedded end set in concrete closure cap or backfill. In backfills, encase buried end in a concrete footing (2 ft long, 1 ft dia.).

* Extend exposed top end (1 ft) beyond final graded surface.

* Fill pipe with high slump concrete.

* Grout brass cap into the pipe end using a nonshrink grout such as Pour-Rock, Kwik-Crete, or Epoxy Bond.

On occasion, it will not be feasible to set monument within closure, for example a blast closure. In this case, drill a short (2 in. diam. by 8 in. long) hole in competent rock as close to closure as possible. Install brass cap with anchor and nonshrink grout.

REFERENCE: This section paraphrased from CMLRD, 1989.
SURFACE MITIGATION

RESHAPING HIGHWALLS AND ROADS

DESCRIPTION

Highwalls of surface mines and roads are reshaped by backfilling or reduction. See Fig. 11.

Backfilling is generally applicable to surface coal mines, and involves the placement of fill material against the highwall until the wall is covered. Commonly, backfill consists of mine wastes, although at some sites conditions may require importation of fill material. Where necessary, surface and subsurface drainages are restored simultaneously with the backfill.

Highwall reduction is generally applicable to quarries, and involves the mitigation of visual scars and safety hazards. Where natural terrain is irregular, quarries leave long uniform benches. In addition, vegetation is sparse and contrasts with the surrounding area. The high walls can be reduced with blasting and earthmoving. Alternatively, the long continuous lines may be broken up with selective backfilling and blasting, construction of discontinuous benches, and rock sculpting.

Advantages: Backfilling enables complete environmental remediation. Highwall reduction can be effective under suitable conditions.

Disadvantages: Backfilling is costly. Highwall reduction does not restore original environment.

Cost: $0.40 to $1.50 per cu yd.

SITE CHARACTERIZATION

Locate and rank soil as suitable or unsuitable for salvage and use according to chemical or physical criteria that affect revegetation success.

Locate and rank backfill (overburden, mine waste rock, mine processing wastes) as suitable or unsuitable, the goal being a backfill that does not affect groundwater, the root zone, soil development, and plant growth. When mitigating a mine with toxic material, plan to monitor the site for 10 yr after successful establishment of vegetal cover.

Perform geomorphologic analysis of drainage including sediment transport and deposition, runoff volumes, and peak flows.

For additional information, refer to the section on Site Characterization and Monitoring.
Figure 11a. Typical Highwall Operation
(Thorne, 1987, p. 31)
Figure 11b. Recontouring Highwalls
(Thorne, 1987, p. 31)
SOIL HANDLING

Salvage soil and stockpile until needed for revegetation. Protect stockpile from erosion with flat slopes, surface drainage control, and vegetation cover. Keep in mind that soils stockpiled for more than 2 to 4 yr deteriorate biologically due to decreases in the viability of seeds, roots, and microbiota.

If possible, handle soil in two lifts. Segregate topsoil (A and B horizons) from subsoil (C horizon), and then redress disturbed areas with the topsoil over the subsoil.

Refer to discussion of topsoil under Erosion and Sedimentation Control. Comply with Federal and State regulations on handling topsoil.

EROSION AND SEDIMENTATION CONTROL

Water discharge from disturbed areas may increase total suspended and dissolved solids. Provide a stable landscape that is not subject to excessive erosion or deposition:

* During construction activities, divert upland runoff around operations.

* Below disturbed areas, leave natural barriers or undisturbed strips of vegetation to filter runoff. See Fig. 12. In addition, place interceptor ditches, contain and treat water as described under Erosion and Sedimentation Control.

* After remediation is complete and vegetation reestablished, ditches and other drainage control structures should be graded over and planted.

Refer to section on Erosion and Sedimentation Control for additional information, and get help from the local office of Soil Conservation Service.

BACKFILLING GUIDELINES

Backfill methods vary widely among modern surface mines depending on the physical and chemical characteristics of the soil, overburden, and configuration of the mine. Medium to large backfill projects will usually require detailed design studies involving earthmoving, drainage, landscaping, and revegetation. The following discussion provides a broad outline of the requirements for backfilling.

Available backfill on a particular site usually has both deleterious and benign zones.

* Where some or all of the backfill has deleterious qualities, ensure that the backfill plan stipulates a
minimum (4 to 8 ft*) top layer of suitable material. Otherwise isolate the unsuitable material with an impermeable barrier or treat, as described in the boxes. See Fig. 11b.

* Top 4 ft of backfill should be free of boulders larger than a specified minimum (1 cu yd*) size.
* Backfill should be free of vegetation which in time will decompose and cause slumping or minor subsidence.

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**Burial of Deleterious Materials**

* For extremely toxic material, prepare clay seals or barriers to prevent water seepage that could contaminate surface or groundwater.

* Acidic material should be buried below natural water level, if possible. This will inhibit acid production if the water table does not fluctuate over the burial.

* Material must be buried as soon as possible to minimize toxic effluents.

* Compact toxic backfill, to minimize movement of water through the material.

---

**Treatment for Acidic Materials**

* Consider any soil or water pH of 4.5 or less to be strongly acid.

* The most common treatment is application of lime to increase pH.

* Collect samples from the material, and determine acid production. Each sample should weigh approximately 1 lb, excluding rock and gravel.

* Table VIII specifies the amounts of liming required to achieve a soil pH of 5.5 from various initial pH levels.

* When the liming rate exceeds 5 tons per acre, scarify upper layer of overburden. Apply lime in 2 to 3 passes, and work lime into upper 8 to 10 in. between passes with ripping or scarifying.

* Apply gypsum to treat salt problems caused by migration of chemical salts to the surface.
Treatment for Alkaline Materials

* Alkaline soils have a pH of 7 to 10 or greater, depending on salinity.

* There are three methods of treating alkaline soils:

1. Leach out sodium and other salts by flooding with irrigation water. Flooding is primarily useful with high concentrations of calcium and magnesium. However, there is a risk flooding will increase sodium and OH ions.

2. Skim off surface incrustations of accumulated salts by physical removal. Rarely successful in long term because the basic evaporation process is not changed and salts continue to accumulate.

3. Chemically convert soils with gypsum, caustic alkali carbonates become sulfates. Scarify several tons per acre into soil and keep moist to hasten reaction.

### TABLE VIII
**LIMESTONE \((CaCO_3)\) SOIL TREATMENT**

<table>
<thead>
<tr>
<th>pH Change in Plow</th>
<th>Liming Rate, lb/acre</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sand</td>
</tr>
<tr>
<td>4.0 to 6.5</td>
<td>2,600</td>
</tr>
<tr>
<td>4.5 to 6.5</td>
<td>2,200</td>
</tr>
<tr>
<td>5.0 to 6.5</td>
<td>1,800</td>
</tr>
<tr>
<td>5.5 to 6.5</td>
<td>1,200</td>
</tr>
<tr>
<td>6.0 to 6.5</td>
<td>600</td>
</tr>
</tbody>
</table>

**Neutralizing Value of Pure Limes**

<table>
<thead>
<tr>
<th>Material</th>
<th>Chemical</th>
<th>Neutralizing Value, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium Oxide</td>
<td>CaO</td>
<td>179</td>
</tr>
<tr>
<td>Calcium hydroxide</td>
<td>Ca(OH)_2</td>
<td>136</td>
</tr>
<tr>
<td>Dolomite</td>
<td>CaMg(CO_3)_2</td>
<td>109</td>
</tr>
<tr>
<td>Calcium carbonate</td>
<td>CaCO_3</td>
<td>100</td>
</tr>
<tr>
<td>Calcium silicate</td>
<td>CaSiO_3</td>
<td>86</td>
</tr>
</tbody>
</table>

REFERENCE: (CFA, 1980)
Figure 12. Sedimentation Barriers
(PDER, 1978, p. 62)
Backfill openings to the approximate original contour unless there is limited fill:

* The four basic hillslope profiles are uniform, concave, convex, and complex. See Fig. 13. Complex and concave profiles are the more stable landforms, and reshaping should approach these stable profiles.

* Subsurface drainage is often required to prevent subsidence of backfill and extreme gullying on steep hillslopes. See Fig. 14. This subsurface drainage consists of French drains that collect water, and sometimes slope-pipes that carry water to the toe of the hillslope.

* Specify maximum (3h:1v to 2.5h:1v*) hillslopes.

* Place backfill in layers and compact all but the top zone (4 ft to 8 ft*). (Fig. 15) Improper fill covers floor with rubble that can cause voids, confine groundwater, and create unstable ground.

* In top 8 ft, keep dozing and grading to a minimum. Excessive grading leads to compaction which greatly reduces water-infiltration and the survival of vegetation.

Design restored surface channels as described under Erosion and Sedimentation Control.

HIGHWALL REDUCTION GUIDELINES

Mitigation of visual impact involves consideration of form, line, texture, and color. Selective blasting and/or backfilling, construction of discontinuous benches, and rock sculpting are illustrated in Fig. 16. Design landscaping, vegetation, and color that minimizes contrast between restored area and adjacent undisturbed area:

* Increase the number of benches by cutting down bench height and width. This reduction also enhances hillslope stability and revegetation.

* Create transition hillslopes between undisturbed areas and the quarry. Drill blast holes progressively more shallow away from crest of the highwall. Blast and grade rock into transition hillslopes. In some cases, surface rock may be weathered, and the transition hillslope can be ripped and dozed without blasting.

* Selectively blast and backfill quarry benches.

* Slope stability engineering is required to insure that unstable ground is not created.
Figure 13. Hillslope Profiles and Erosion
(Lidstone & Anderson, 1989, p. 480)
Figure 14. French Drains
(Thorne, 1987, p. 24)
Figure 15. Proper Backfill
(Thorne, 1987, p. 28)
Figure 16. Continuous vs. Discontinuous Benches
(Banta, 1989, p. 39)
* Mining exposes fresh unweathered rock which may contrast with the surrounding area. Color blend the exposed rock with vegetation, barriers or berms, or rock staining.

In active quarries, minimize visual impact by disturbing only portions of the mining area, and then mitigating mined-out areas as mining progresses into new areas.

ROAD GUIDELINES

Mine roads often have the greatest impact of the various mining activities. See Fig. 17. Mitigate road disturbances as follows:

* Remove road surface and subbase. Gravel can be salvaged for other uses.
* Remove culverts.
* Rip on contour to reduced compaction.
* On hillslopes up to 40%, large bulldozers can restore original contours.
* Roads on hillslopes greater than 40% can be restored to or near original profile with large backhoes or draglines.
* Pull berm and outside shoulder up the cut slope as far as possible. Use backhoe or dragline.

REFERENCES: This section paraphrased from Banta et al, 1990, p. 38; PDER, 1978; Thorne, 1987, p. 25 -41; USOTA, 1986, p. 63; USFS, no date, p. 44.

WASTE DUMP STABILIZATION

DESCRIPTION

Mine waste dumps include abandoned stockpiles, overburden and spoil banks from surface mines, development rock from underground mines, mill tailings, and other processing wastes. Often dumps are unconsolidated, unstable, and their side slopes are at risk from ground slides or flows. Fugitive dust is a major environmental hazard associated with dry and barren dumps. Many tailings dams contain polluted water that leaks either into surface or groundwater. In addition, dump material is often toxic. Surface runoff and subsurface water add to instability and toxicity of dumps.
Figure 17. Road Impacts
Ground slides develop as water infiltrates a dump and weakens the material shear resistance. In time, slumping or creeping becomes evident, the ground breaks, some material slides, or a bulge develops at the toe of the dump. Unstable dumps commonly slide to a configuration of relative stability, only to become unstable and slide again. Flows occur where the dump becomes wet enough to take on fluid properties. Flow failures may be sudden, rapid, and once in motion, generate considerable momentum.

Cost: $0.40 to $1.50 per cu yd.

STABILIZATION TECHNIQUES

If the particular waste dump contains toxic material, it must be removed, and isolated or treated, as described under Reshaping Highwalls and Roads. Otherwise, the dumps are stabilized and then revegetated. Where there are risks to public safety and the environment, stabilization projects require the expertise of a qualified geotechnical engineer.

Do not breach any tailings or slimes dams unless the material has been thoroughly characterized, the material behind the dam removed, and the breach carefully engineered.

Generally, the long term factor of safety for stable fills equals 1.25 or more.

Stabilization techniques include removal, restraint, and drainage control. These techniques are usually used in combination along with the techniques described under Erosion and Sedimentation Control.

Removal involves total or partial excavation of the dump and placing the material in an engineered fill. Removal requires heavy earthmoving equipment.

Restraint places walls at the toe of unstable ground, and there are two basic types -- gravity and cantilever.

Gravity walls include cribs, gabions, berms, and reinforced earth walls. Gravity walls are able to withstand settlement without major damage to their structural integrity.

Cantilever walls are built of reinforced concrete, and require removal of some dump material. They are less tolerant of settlement.

To reduce and control hydrostatic pressures both types of walls must incorporate relief of subsurface drainage.
Drainage control diverts surface and subsurface water away from the dump. Flood water must not be allowed to traverse the top of fills. Any fills that cross drainages must provide for flow through the dump. This is normally accomplished through a rubble drain or french drain. As hydrologic conditions are a key factor in initiating instability, water control can reduce or eliminate problems associated with dump failures.

Surface water control involves reshaping dump surfaces and redirecting drainage channels away from the dump. Reshaping modifies the length, gradient, and shape of the dump slope. Long slopes must be broken up with terraces, benches, reverse benches, and drains or ditches that parallel the contours to divert surface runoff. (Also improves visual impact.) Maximum gradient should be 30° with a generally concave shape.

Subsurface drainage involves french drains made of nonerodable, nonslaking, permeable rock or perforated pipe that collects and removes groundwater. Drains must have sufficient capacity to transmit flood water safely though the base of the fill, typically the design criteria is a 100 yr flood event. They are placed in the bottom "V" of the fill surface. Where the fill is impermeable, the drains fan out onto the side slopes, and up into the fill.

COVER

If the material is toxic, it must be isolated as described under Reshaping Highwalls and Roads. If not, the dump must be revegetated which usually requires a source of soil and soil amendments as described under Revegetation.

Dumps also must be stabilized against blowing wind. Young vegetation will not survive wind blasting. For successful revegetation, dumps may require all or part of the following covering, from the bottom up:

* Where migration of salts or adverse chemicals is a problem, provide a capillary barrier (2 to 4 ft*) of coarse rock.

* A 12 in. layer of fine rock (10 to 12 in.*).

* Soil 24 to 48 in. thick.

REFERENCES: This section paraphrased from Thorne, 1987, p. 34; USFS, no date, p. 47 & 48; USOTA, 1986, p.63.
MINE DRAINAGE CONTROL

DESCRIPTION

While some drainage from mines is benign, frequently the drainage is highly acidic or alkaline and carries heavy metals. Polluted mine drainage forms by the percolation of water through material with soluble constituents. Polluted mine water often enters groundwater and nearby streams.

Acid mine drainage is most common and is characterized by low pH, and high concentrations of dissolved metals. The final products of the oxidation reaction are sulfuric acid and insoluble ferric hydroxide (yellowboy) precipitate. The acid may react with other minerals to yield compounds of aluminum, manganese, calcium, and others. Streams with high concentrations of these metals will not support desirable plant and animal life. Streams with a pH of 4 or below probably will be sterile except for acid tolerant bacteria and algae.

Mine water clean-up usually requires detailed investigation, analysis, process development, and engineering.

CONTROL TECHNIQUES

Mine drainage control techniques include mine sealing, land treatment, and water treatment.

Sealing involves placing (1) permanent bulkheads in mine openings, and (2) insitu grout curtains to cutoff flow of groundwater. Seals dam the flow of water from the mine so that the mine floods. This flooding creates an oxygen-deficient environment and prevents chemical reactions.

Advantages: Stops mine drainage and chemical reactions at source.

Disadvantages: Very difficult to implement. As bulkheads flood the mine, the water almost always finds another way out. Grout curtains are seldom completely effective in stopping flow of groundwater in or out of mine.

Cost: $10,000 to $500,000 per project.

Land treatment involves a number of techniques commonly used where surface water passes through mine waste dumps and becomes toxic. The techniques include surface water diversion, reprocessing dump material, and removal and burial. Refer to guidelines on backfilling (Reshaping Highwalls and Roads), and Waste Dump Mitigation.
Advantages: Very effective preventive measures.

Disadvantages: Generally applicable to only surface mines and surface facilities of underground mines.

Cost: $15,000 to $1,000,000 per project.

Neutralization is the most common treatment of acid mine drainage. Addition of lime or sodium hydroxide to the acidic water increases its pH. One problem is the instability of manganese. If there is substantial manganese in the water, the pH first must be raised to 10 or above. As the manganese precipitates out, the pH drops to acceptable levels. However, the manganese precipitate is easily resoluble at low pH, and must be removed.

Limestone barriers or limestone filled and perforated drums may be placed in low flow mine waters carrying mild acid drainage. This technique requires frequent maintenance.

Chemical oxidants, such as sodium hypochloride and potassium permanganate, are able to precipitate manganese while producing a relatively stable condition at near neutral pH. However, this method is more expensive than the excess alkalinity method.

Neutralization plants consist of multisequence processes in which tanks, bins, and other devices are used for chemical reactions.

Advantages: Currently the most effective means to treat mine drainage.

Disadvantages: High capital costs, continued operating and maintenance costs, and treatment must continue indefinitely.

Cost: $50,000 to $1,000,000 per project.

An environmental approach to treatment of acid mine drainage is wetlands. Wetlands have the capacity for removing metals. Practically, they are limited to small flows in that large areas are required.

The U.S. Bureau of Mines has a number of research projects underway on mine drainage problems. Contact the Assistant Director for Research for help.

REFERENCES: This section paraphrased from OSM, 1983, p. III-51 & III-58; Thorne, 1987, p. 32; USFS, no date, p. 27.
SUBSIDENCE MITIGATION

DESCRIPTION

Subsidence is the downward movement of the ground surface over an underground mine. See Fig. 18. For small areas of subsidence less than a few acres, use remediation measures described above for backfilling shafts.

For National Parks, most mining activities stopped long ago, subsidence has stabilized, and subsidence does not impact existing environmental resources or threaten public safety. Occasionally, subsidence results in steep drops, and to protect the public, the park should post warning signs and include warnings in park safety literature. In some cases, a park may want to control subsidence or backfill subsided areas to restore and protect natural resources.

There are significant risks from the unknowing construction of park facilities on subsided ground. Minor settling can continue indefinitely, and can damage foundations and break utility lines. In addition, because subsidence progresses in a cone shape up and outward from the underground openings, neighboring mines can cause subsidence into park land.

Cost: $50,000 to $1,000,000 per project.

CONTROL TECHNIQUES

Subsidence control is accomplished through surface treatment, local foundation support, and deep subsurface reinforcement.

Surface treatment consists of restoring drainage, either by breaching the higher ground between the lower subsided areas and the natural down-gradient drainage system, or by raising the subsided area with backfill, as described under Reshaping Highwalls and Roads.

Local foundation support is added to structures susceptible to subsidence. This involves jacking existing buildings, reinforcing and broadening foundations, realigning utilities, installation of flexible or hinged couplings in utility lines, and installation of gas and subsidence detectors.

Subsurface reinforcement includes backfilling of mine voids or providing support to unstable geologic zones. Techniques used are hydraulic and pneumatic backfilling, and insitu grouting.

REFERENCE: This section paraphrased from OSM, 1983, p. III-32.
Figure 18. Mine Subsidence
MINE FIRES

DESCRIPTION

Mine fires occur in coal seams and coal waste dumps. At this time, there are no known mine fires in National Parks. However, a number of parks encompass past coal mining activities, and mine fires may be discovered or initiate in the future. If so, action must be taken quickly because fires are easier to extinguish early. In addition, mine fires can burn indefinitely causing significant air pollution and hazardous conditions.

CONTROL TECHNIQUES

The three general methods of controlling mine fires are excavation, sealing, flushing, and grouting. It is often necessary to combine these methods.

Excavation requires complete removal and cooling of all burning or heated material. After cooling, excavated material is backfilled, mixed with noncombustible material, and compacted to reduce oxygen. Primarily used with dumps.

Sealing involves blanketing the burning area with fine-grained inert material to seal all sources of air from the burning coal seam or waste dump. Prior to sealing, it is necessary to remove all vegetation. Sealing of waste dumps generally requires extensive site preparation -- steep slopes must be reduced, surface water runoff must be controlled, and burning material at the surface removed.

Flushing is usually associated with underground fires. Noncombustible solid materials are injected into seams through boreholes drilled from surface. The solids fill voids and seal air from the fire.

Grouting is associated with dump fires. A slurry is pumped into voids in the dump to retard or eliminate the flow of air.

REFERENCE: This section paraphrased from OSM, 1983, p. III-44.

STRUCTURES AND EQUIPMENT

DESCRIPTION

Abandoned structures and equipment are often hazardous to public safety. The structures tend to be weathered and unstable. When the decision has been make not to preserve the site, the facilities should be demolished and removed to a landfill.
Alternatively, temporary barriers should be erected to prevent access until permanent remediation is undertaken.

Cost: $3,000 to $100,000 per project.

CONSTRUCTION

Demolition

There are 4 methods of demolition, as follows:

**Manual** demolition requires simple hand tools, such as crowbars, sledgehammers, cutting torches, and saws. Most often used at sites where high salvage value exists, liability and risk of property damage is high, or heavy equipment access is limited.

**Mechanical** demolition, through use of wrecking cranes, jackhammers, and bulldozers, is less costly than manual demolition. Used where sufficient access and working area is available, and as required by structural strength, mass, and extent of structures.

**Burning** can be used at some sites where structures are combustible and there is no risk of igniting adjacent facilities and areas. Because water is usually not available at AML sites, fire must be easily confined and controlled with water tank trucks.

**Blasting** is primarily used to reduce concrete or masonry structures. Requires specialized expertise.

Resultant rubble and scrap is usually buried onsite and sometimes transported to landfills. Factors determining which option is best include site accessibility, type of construction, existence of convenient disposal areas onsite and offsite, difficulty of excavation, and availability of cover material. Other considerations are economic — scrap value and transportation.

Barrier Construction

Barriers can be erected outside perimeter of the anticipated zone of collapse. Use NPS fencing specifications for barrier construction. In a few cases, where buildings are sound and will be used in future, barriers can be relatively simple seals blocking off entrances and windows.

REFERENCE: This section paraphrased from OSM, 1983, p. III-64.
EROSION AND SEDIMENTATION CONTROL

DESIGN PROCEDURES

The steps in executing a project of erosion and sedimentation control are:

1) Mapping significant erosion/sedimentation problems;

2) Designing land surfaces, drainage channels, erosion and sedimentation control structures;

3) Reshaping land surfaces and channels, and constructing control structures;

4) Revegetating;

5) Monitoring, evaluating, and maintaining remediation.

This section briefly outlines the first two steps -- mapping and design -- as an aide in choosing the appropriate remediation measures. The following sections provide construction guidelines on particular erosion and sedimentation control measures.

Mapping and evaluation must include the disturbed and undisturbed lands and channels both upstream and downstream of planned remediation activities. The geomorphic components are hillslopes, drainage network, stream channels, and geology. The investigation must assess these features with special attention given to gullies and hillslopes. The gullies must be mapped with their length, frequency, and extent on both natural and nearby reclaimed lands. Of primary importance, hillslopes are the sediment production zone. Under conditions of sufficient precipitation, and hillslope gradient and length, unconcentrated runoff becomes concentrated flow, and rills begin to form. As erosion intensifies in the rills, and as hillslope gradient and length increase, rills develop into gullies.

For large projects, design is an iterative process that starts with a design, followed by runoff estimates, hydraulic analysis, and returning to design if the hydraulic analysis shows inconsistencies. Generally, large projects are those where mining or the remediation intersects drainage channels. Typically, this includes most 20th century mines, and 19th century mining districts with concentrated activities.

For small projects, design simply requires some experienced judgement in reshaping impacted areas to stable shapes, and installing small, sometimes hand built, erosion control structures. Generally, small projects are those confined to hillslope areas of unconcentrated
runoff. Typically, this includes individual 19th century mining sites.

LANDFORMS

Stable landforms have appropriate shape, high infiltration rates, low sediment yields, low relief, and dense vegetation. The best guide is to replicate characteristics of native landforms by manipulating the length, gradient, and shape of hillslopes, as follows:

* The four basic shapes for hillslopes are uniform, concave, convex, and complex. See Fig. 13. Complex and concave hillslopes are the more stable landforms. Reshaping of landforms should approach these stable profiles.

* Erosion potential increases with increasing hillslope length. Keep hillslope length short by interrupting long hillslopes with terraces, benches, and reverse benches.

* Keep hillslope gradients gentle, never more than 2.5h:1v and preferably less than 3h:1v.

* Increase the density of primary drainage channels.

* In backfills, a subsurface drainage system is often required to prevent subsidence and extreme gullying on steep hillslopes. Subsurface drainage consists of French drains that collect water, and sometimes slope-pipes that carry water to the toe of the hillslope.

Generally, runoff and erosion are estimated with the Rational Method, Soil Conservation Service (SCS) triangular hydrograph technique, and the Universal Soil Loss Equation. First, consult State and local SCS offices for the preferred estimating methods. If no specific guidelines are given by those sources, use SCS engineering manuals.

CHANNELS

For restored channels, the native drainage network must be characterized and replicated for best results. The components include basin gradient, size, and shape; drainage density; channel geometry and lithology. In replicating these components, follow these guidelines:

* Over design assuming sediment loads and infiltration will be different than native conditions.

* Increase drainage density.
* Use native channels as a model for channel geometry (width, depth, shape). Adjust dimensions for estimated higher peak runoff and sediment loads.

* Match channel gradient with native channels, otherwise erosion may develop such as gullying, headcuts, and knickpoints at disturbed/undisturbed boundaries.

* Mimic native channel patterns.

* If necessary to achieve acceptable gradients, wind channels to spread the change in elevation over longer distances.

* Design channel bed characteristics including particle size gradation, wetlands, and revegetation.

Practical limitations on remediation may not lead to stable channel design. Headcuts may form, migrate upstream, induce erosion, and severely impact stability of the restored drainage and landforms. Typically the greatest challenge is to achieve a stable channel gradient, and when this is not feasible engineered structures must be planned to control erosion. Because these engineered structures require continuing maintenance, their use should be minimized. These structures include detention basins and impoundments to settle out sediments, and drop structures to reduce kinetic energy of fast flowing water.

After preliminary design of landform and drainage, the basin hydrology must be evaluated to determine whether design meets the remediation requirements. The cycle of design, runoff estimates, and hydraulic analysis repeats until the remediation requirements match the expected basin hydrology. For expertise on design, hydraulic analysis, and basic hydrology, consult with NPS experts, the local Soil Conservation Service office, or contract engineering services.

REFERENCE: This section paraphrased from Lidstone and Anderson, 1989, p. 478.

TOPSOIL REMOVAL AND STORAGE

DESCRIPTION

Topsoil is generally defined as the A and B horizons of the undisturbed soil profile. These two horizons should be removed and stored separately, and then returned in the same relative position. Topsoil quantity and quality available for reclamation must be determined by site specific evaluations. General guidelines for evaluating specific soil parameters are given under Site Characterization and Monitoring, and additional information may be obtained from local Soil Conservation Service offices and State regulatory agencies.
One of the first activities in mitigating a mine site is salvage of any topsoil that otherwise might be lost in the construction activities. Further, it may necessary to strip soil from other areas for use in reclaiming the mine site. This topsoil recovery exposes topsoil to splash and runoff erosion.

Cost: $0.40 to $1.50 per cu yd.

MATERIAL

Table IX indicates soil suitable for reclamation.

<table>
<thead>
<tr>
<th>Soil Property</th>
<th>Soil Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Good</td>
</tr>
<tr>
<td>Texture</td>
<td>Sandy loam</td>
</tr>
<tr>
<td></td>
<td>Loam</td>
</tr>
<tr>
<td></td>
<td>Silt Loam</td>
</tr>
<tr>
<td>Rock &amp; Gravel (% by volume)</td>
<td>0-10</td>
</tr>
<tr>
<td>pH</td>
<td>6-8</td>
</tr>
<tr>
<td></td>
<td>8-8.5</td>
</tr>
<tr>
<td>Sodium Absorption Ratio (SAR)</td>
<td>4</td>
</tr>
<tr>
<td>Electrical Conductivity (mmhos/cm)</td>
<td>3</td>
</tr>
</tbody>
</table>

*Check for excessive concentrations of heavy metals.
**Check for excessive boron or lime.

REFERENCE: (USFS, no date, p. 16)

Salvage both topsoil and subsoil if they fall within the good or fair categories. Soils in the poor quality class may also be saved to meet required soil cover depths.

Salvaged soils may show a variety of properties that fall into different suitability classes. For example, a soil may show texture, pH, sodium adsorption ratio, and electrical conductivity in the fair class but rock and gravel content in the poor class. In that case, the soil is classed as poor. Generally, a soil is judged by its lowest individual rating.

Recommended depths of cover soil:
* Where the underlying material is not highly acidic or saline, 12 in. of cover soil is adequate.

* Where the underlying material is highly acidic or saline, up to 48 in. of cover soil is required.

* Where the underlying material is coarse textured or rocky, up to 24 in. of cover soil is required.

After topsoil removal, it also may be necessary to protect the newly exposed surface as described in the sections Reshaping Highwalls and Roads, and Waste Dump Stabilization.

CONSTRUCTION

* Locate topsoil storage close to mine site.

* Choose a storage site that is as level as possible and away from intermittent water courses or gullies.

* Divert upland watershed drainage around topsoil recovery area and storage site with diversion dikes or ditches. Place interceptor diversions below cleared area. These diversions should not have gradients exceeding 2%. Seed or stabilize diversions immediately after construction.

* If diverted water accumulates sediments, first try to eliminate sedimentation by additional mulch, grass, or stabilization. If upland control is inadequate, provide means to settle solids in sediment traps, gravel filters, or filter strips. In some cases, sedimentation basins may be necessary.

* If diverted flow velocity is minimal (less than 1.5 fps), discharge directly into receiving streams; otherwise, install energy dissipators.

* From topsoil recovery area and storage site, clear and grub vegetation greater than 4 in. diameter. Alternatively, shred vegetation and remove with topsoil. Shredded vegetation acts as a mulch.

* Remove soil for storage as indicated by the above table and notes.

* Minimize cleared areas, and phase clearing to reduce unnecessary erosion.

* If the topsoil is stored for more than 2 months, revegetate stockpile with legumes or grasses.
* Reshape and revegetate topsoil recovery areas, storage areas, and erosion control measures after the topsoil operations are complete.

REFERENCES: This section paraphrased from PDER, 1978 p. 8; Thorne, 1987, p. 37; USFS, no date, p. 17.

HILLSLOPE EROSION CONTROL

DESCRIPTION

Hillslopes are the sediment production zone. Under conditions of sufficient precipitation, and hillslope gradient and length, unconcentrated runoff becomes concentrated flow, and rills begin to form. As erosion intensifies in the rills, and as hillslope gradient and length increase, rills develop into gullies.

Erosion from mine sites reaches large rates, up to 300 tons per acre per year. (19.8, p.17) In addition, storm water draining across backfills or mine dumps may saturate the ground, and increase the potential for slides.

Cost: $3,000 to $400,000 per project.

DESIGN GUIDELINES

The most effective erosion control method is the establishment of dense vegetation cover in as short a time as possible.

Reshaping

* Restore mine sites progressively, exposing as little of the surface as possible.

* For final grading, work from top of hillslope to bottom. Surface should be smooth and without depressions. Unintentional depressions accumulate runoff, and may cause ground instability.

* To minimize erosion, grade during periods of low precipitation, typically summer and fall. Grading may be appropriate in spring and fall when seeding is most successful. Grading should not be done in winter when the ground is frozen.

* Follow surface disturbances with erosion control and revegetation as soon as possible.
Watershed

First estimate the amount of runoff expected as described under Design Procedures, and then design the appropriate erosion and sedimentation structures, as outlined below. Note that additional guidance is given on some of the structures under separate headings.

* Divert upland watershed drainage around disturbed area with diversion dikes or ditches. Place interceptor diversions below the area. These diversions should not have gradients exceeding 2%. Seed or stabilize diversions immediately after construction.

* Leave natural barriers or undisturbed strips of vegetation below disturbed areas to act as filters for surface runoff, and cut flow velocity. See Fig. 12.

* If diverted water accumulates sediments, first try to eliminate sedimentation by additional mulch, grass, or stabilization. If upland control is inadequate, provide means to settle solids in sediment traps, gravel filters, or filter strips. In some cases, sedimentation basins may be necessary.

* If diverted flow velocity is minimal (less than 1.5 ft per sec), discharge directly into receiving streams; otherwise, install energy dissipators to cut velocity.

* Maintain diversion structures until remediation is complete and revegetation is established. Then, grade over structures and plant.

Hillslope Measures

* Disperse water with tracking, furrowing, benching, pitting, waterbars, wattling, and ravel catchers.

Tracking is used on steep hillslopes, and is the practice of running tracked equipment up and down hillslope. Track grooves reduce and disperse surface runoff. A disadvantage is increased soil compaction from additional passes of equipment.

Furrows are constructed on contour by ripping with a dozer or by angling dozer blade into hillslope. Safe up to a 2h:1v gradient.

Benching converts long, continuous hillslopes into a series of ridges and channels. In addition to reducing erosion caused by surface runoff, benches also conserve moisture, and can be designed to provide access to hillslopes for mulching, seeding, and maintenance.
**Pitting** (dozer basins) is the construction of small water catchment basins, see Fig. 19. Basins catch water and trap eroding sediments. Locate basins in a staggered pattern such that overflow from one basin exits the sides and drains into a lower basin. Basins provide deviations in microclimate that stimulate plant diversity.

**Waterbars, wattling, and ravel catchers**, see guidance under Handbuilt Hillslope Structures.

* Divert surface runoff with trenches and ditches that parallel hillslope contours.

* Cover bare ground and reduce the opportunity for rainsplash erosion with geotextiles, soil stabilizers, and mulching.

Soil stabilizers are chemicals that form a crust or protective sheath over soil. They often produce poor results where rainfall is abundant such as the eastern U.S.

**REFERENCES:** This section paraphrased from PDER, 1978, p. 13; Thorne, 1987, p. 34 & 35; USFS, no date, p. 17.

**RIPRAP DROP STRUCTURES**

**DESCRIPTION**

Where a stable drainage gradient is not feasible, riprap drop structures provide an efficient means to lower a channel, dissipate kinetic energy of water, and prevent erosion. As shown in Fig. 20, riprap drop structures consist of a transitional entrance, sloped drop section, and transitional exit or stilling basin. Construction involves clearing and grubbing, compaction, and placing filter fabric, gravel, and riprap.

Cost: $30 to $90 per cu yd.

**MATERIALS**

**Riprap:** Sized to remain immobile under a specified (100 yr, 24 hr) runoff event. Well-graded, hard, durable, and angular on all sides.

**Gravel:** See NPS specifications.

**Filter fabric.**
Figure 19. Pitting
(Lawson, 1990, p. 223)
Figure 20. Riprap Drop Structures
(Lidstone, 1989, p. 490)
DESIGN GUIDELINES

Design drop section to keep water velocity at critical or subcritical conditions, and minimize stresses on riprap. Typically, the gradient ranges from 3h:1v to 4h:1v. As length of drop increases, the likelihood increases of reaching supercritical flow conditions. When this occurs, plan multiple drop structures. Design exit section to accommodate hydraulic jump.

Gravel and geotextile filters significantly improve longevity of the structure.

Place riprap such that there is no segregation into size fractions.

REFERENCE: This section paraphrased from Lidstone and Anderson, 1989, p. 489.

GEOLOGIC DROP STRUCTURES

DESCRIPTION

Given the right conditions, geologic drop structures can replace or supplement engineered structures. Geologic drop structures use erosionally resistant rock formations where they outcrop in a drainage channel. A thorough review of site geology prior to channel design can save thousands of dollars in engineered drop structures and improve channel longevity. Construction involves drilling, blasting, and earthmoving.

Cost: $1.00 to $1.50 per cu yd of earthmoving.

MATERIALS

Resistant rock formation.

DESIGN GUIDELINES

Layout the geologic drop structure similar to the riprap drop structure with transitional entrance, slope section, and transitional exit or stilling basin. All three elements should be confined within the resistant rock formation to ensure against erosion. Typically the gradient of the slope section ranges from 3h:1v to 4h:1v.

REFERENCE: This section paraphrased from Lidstone and Anderson, 1989, p. 489.
DIVERSION DITCHES

DESCRIPTION

Uncontrolled or misdirected water causes unacceptable soil losses, extreme gullying, and often polluted drainage where water flows over mine wastes. Ditches intercept and divert water around disturbed areas, and control water during reshaping and remediation of mining disturbances.

Cost: $3,000 to $300,000 per project.

DESIGN GUIDELINES

Although many factors influence ditch design, the following general criteria are adequate for most applications:

* Design for 24 hr, 10 to 25 yr rainfall events.
* Use V-shaped ditches in temporary applications for their relative ease in design, construction, and maintenance.
* Use trapezoidal or parabolic ditches for permanent applications, and perform complete engineering design.
* Adjacent to roads, design ditch sides at 4h:1v or flatter except in extreme restrictive conditions. For vehicle safety, the road side should not exceed a 2h:1v gradient.
* Ditch sides not adjacent to a road may have a gradient that varies with the material encountered. In rock, the gradient may approach vertical; in erodable material, a 2h:1v gradient or flatter.
* Locate ditches in undisturbed earth or rock; avoid placing ditches through fill areas.
* Protect toe of fill slopes with interceptor ditches.
* Ditches should not discharge over fill slopes. In fill situations, convey discharge away with pipes or lined ditches.
* At discharge points, provide erosion protection as shown in Fig. 21, if flow velocity exceeds Soil Conservation Service recommended maximums.

First estimate the amount of runoff expected as described under Design Procedures, and then design channel gradient, ditch cross section, and ditch depth, as follows.
Figure 21. Erosion Control at Discharge Points
(IC 8758, 1977, p. 46)

Dumped-rock energy dissipator.
Channel Gradient

Generally ditches intended to intercept and divert sheet runoff are designed with a 0.5% gradient. Where ditches are required with steeper gradients in erodable soils, protect against excessive erosion (Fig. 22):

* Ditch gradient 0% to 3%, construct without liner except in extremely erodable material such as sand, or easily weathered shales and silts.

* Ditch gradient 3% to 5%, seed ditch and protect with jute matting until a substantial grass lining is established.

* Ditch gradients over 5%, line ditch with rock to a height no less than 0.5 ft above the expected high water level.

* Add drop structures to reduce channel gradients.

Ditch Cross Section

With the design criteria given above, choose appropriate gradients for the ditch sides given the type of ground encountered and position next to roads.

Ditch Depth

With runoff in cubic feet per second, determine the required water depth from Table X. Find the applicable ditch cross section, enter the table under ditch gradient, and follow the column down to the estimated runoff. Then, follow the row of that runoff to the extreme left column which contains the required ditch depth. Make the following applicable depth adjustments:

* Add 0.5 ft to the water depth for freeboard.

* Where the ditch is lined with grass, add 0.5 ft.

* Where the ditch is lined with rock, depth is measured to the top of the rock surface.

Perform ditch design in segments for each change in 1) ditch gradient, 2) additional runoff contributed by contiguous areas, and 3) type of ground.

Figure 22. Erosion Protection of Ditches
(IC 8758, 1977, p. 46)
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<th>Depth (ft)</th>
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Water discharge capacity for various well configurations, cubic feet per second (cfs).
CULVERTS

DESCRIPTION

Culverts are efficient and effective in conveying free-flowing drainage away from erosional areas. Full section culverts are used for conveying water through fill areas or under roads, and half sections are used to line surface channels either permanently or temporarily during construction.

Design considerations include location, sizing, installation, and inlet/outlet controls.

Cost: $30 to $60 per foot installed.

MATERIALS

Corrugated steel pipe: For the majority of culvert installations, this type of pipe is relatively light, high strength, readily available, and easily adapted to a variety of situations. Highly acidic conditions may preclude steel, in which case substitute PVC or concrete pipe.

CONSTRUCTION

Design

* Design for 24 hr, 10 to 25 yr rainfall events.

* Minimum 18 in. diameter, smaller culverts are difficult to clean and maintain.

* Design culverts for minimum impact on aquatic life:

  ** Perform construction during the time of year when impact is least.

  ** Use open bottom shapes if it is necessary to maintain character of streambed.

  ** For closed bottom culverts, install culvert with maximum 0.5% gradient, place invert 6 in. below natural gradient, and fill bottom with rock and gravel.

  ** Along roads, provide ditch relief as required by State standards. If there are no regulations regarding culvert spacing, use the following:

<table>
<thead>
<tr>
<th>Road Grade (%)</th>
<th>Culvert Spacing Not To Exceed (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 3</td>
<td>1,000</td>
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<tr>
<td>3 - 6</td>
<td>800</td>
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<td>6 - 9</td>
<td>500</td>
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<td>&gt; 10</td>
<td>300</td>
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</tbody>
</table>
Use Fig. 23 to determine pipe sizes for estimated flows in the following steps:

1. Enter graph from left side with required maximum flow in cubic feet per second (cfs).

2. Follow entry point horizontally to intersection with diagonal line.

3. From intersection, drop down vertically to pipe diameter axis, and read required dimension.

Example: 25 cfs requires a 32 in. pipe diameter.

This dimension represents a full flowing pipe without any water backup at the inlet. Generally, design pipe diameter to accept maximum flow without creating water backup. However, in some cases (temporary installations), it may be desirable to specify a smaller, less expensive pipe, and allow a small backup of water. Dashed lines on the chart provide backup head for restricted pipe diameters. Determine the backup head as follows:

1. Dashed lines are labeled with backup head.

2. Follow entrance capacity horizontally to intersection with a curved dashed line, and then down to required pipe diameter. There may be more than one intersection, choose the desired head.

Example: 25 cfs and backup head of 4 ft requires a pipe diameter of 21 in.

Installation

* Minimum recommended cover over a culvert is 12 in. or one half culvert diameter, whichever is greater.

* Where heavy earthmoving equipment passes over culvert, minimum cover should be 2 ft for vehicles under 100,000 lb in weight, and 3 ft for heavier vehicles.

* To provide a stable culvert base, tamp fill in 4 in. layers from bottom of trench to 2 to 3 ft over culvert.

* To minimize sedimentation and erosion, align culverts with natural channel and maintain natural gradient.

* For laterals or road crossings, skew culvert to form an entrance angle of 25° to 60° with approach ditch, and increase gradient slightly above that of ditch to minimize sedimentation in culvert.
Figure 23. Culvert Capacity
(Kaufman & Ault, 1977, p. 44)
* As necessary, protect culverts from debris with deflectors, racks, cribs, raisers, basins, or spillways.

**Inlet/Outlet**

At all culvert inlets, construct a protective headwall of stable nonerodible material. At all culvert outlets, install drop structures, energy dissipators, flared ends, headwalls, riprap, paving, or beveled ends, as described under Ditches and Hand Built Drop Structures. Additional guidelines:

* Flow from culverts must never be discharged over a fill slope. In fill situations, convey discharge away by extending culvert or provide ditches lined with nonerodible material.

* At the discharge, provide erosion protection where flow velocity exceeds Soil Conservation Service recommended maximums.

The Soil Conservation Service and many states have regulations specifying erosion and sediment control devices for storm drains. Contact these organizations for requirements that apply to the local situation.

**REFERENCES:** This section paraphrased from Kaufman & Ault, 1977, p. 39 & 42; USBLM, 1985, p. 28.

**SEDIMENTATION AND TREATMENT BASINS**

**DESCRIPTION**

Sedimentation and treatment basins are used to settle solids eroded from land disturbances, and to neutralize acid mine drainage. See Fig. 24.

**Cost:** $10,000 to $500,000 per project.

**CONSTRUCTION**

Design requires qualified geotechnical engineering. Integrity of the basin must be insured through adequate design and construction of the foundation, banks, liner, and the normal and emergency spillway or standpipe. Following guidelines list requirements for geotechnical engineering.

**Design**

* Generally a minimum of two basins, in series, are required to receive runoff and settle solids.
Figure 24. Treatment Basin
(PDER, 1978, p. 58)
* Specify minimum retention time (6 hr*), and design storm event (24 hr, 100 yr*). Check with Soil Conservation Service, State and local agencies for appropriate design criteria.

* Design capacity on the maximum watershed area.

\[ V = \text{Sum}(A_i \times C_i)(I)(1 + SF) \]

where:
- \( V \) is volume in cu ft.
- \( A \) is watershed area in sq ft.
- \( C \) is portion of rainfall not absorbed by soils (runoff):
  - \( C = 0.50 \) for open pit,
  - \( C = 0.30 \) for undisturbed area,
  - \( C = 0.25 \) for backfill area,
Note: Clayey soils may require higher runoff coefficient.
- \( i \) is index for subareas in watershed including open pit, undisturbed area, and backfill area.
- \( I \) is rainfall (ft per day) x detention time (0.25 day).
- \( SF \) is sediment factor
  - \( SF = 0.33 \) for primary basin,
  - \( SF = 0.20 \) for secondary basins.

* Specify minimum freeboard (2 ft*) to prevent overspilling.

* Specify maximum (1h:1v*) bank side slopes to control erosion and maintenance.

* For acid mine drainage, collect water in a sump as near source as possible, pump and pipe to treatment basin to minimize infiltration of pollution.

* For treatment basins, control leakage with 1) an impervious foundation blanket and leak collection system, and 2) an inside composite liner made up of clay, asphalt, plastic, or other suitable material.

* Provide sufficient capacity to settle solids by adding additional volume, \( SF \) in the above formula (1/3 for primary basin, 1/5 for secondary basins*).

* Design top of bank wide enough to allow repairs (typically width of backhoe or dragline used to clean out sediments).
* Discharges must meet applicable Federal and State effluent standards.

Location

* Locate basins to protect against erosion and breakthroughs from water courses.

* Locate basin to minimize channel gradient between basin discharge and native channel. See Ditches.

* Do not locate basins on steep slopes, poorly drained areas, or bedrock.

* Check for and do not locate basins near underground openings, mine subsidence, sink holes, oil, gas or water wells, and open fractures or joints.

Erosion Control

* Clear and grub all vegetation before construction.

* Use well-graded fill for banks, and compact to reduce void space and increase stability.

* Avoid acid-bearing material in constructing banks.

* Vegetate outslopes to reduce runoff velocity. Grasses are preferable to legumes because they allow inspection for cracks.

* Install drop structures, and riprap basin discharge and channel to minimize erosion.

Maintenance

* Clean sediment from basins when it reaches two thirds of design load.

* Check structure regularly for cracks, rills, piping, leakage, or other signs of instability.

* Maximum erosion generally occurs at outslope toes. Place riprap if toe erosion becomes a problem.

* Other evidence of instability usually requires the expertise of a geotechnical expert.

REFERENCE: This section paraphrased from PDER, 1978, p. 5 & 58.
HANDBUILT HILLSLOPE STRUCTURES

DESCRIPTION

Labor intensive erosion control techniques involve contour terracing structures that disperse concentrated runoff and cause deposition of eroded sediment. The techniques include contour trenches, ditches, water bars, whattling, and ravel catchers. See Fig. 25. They are intended for use in remote areas and small remediation projects.

If contour structures are not absolutely level, they may actually collect and concentrate runoff, and cause more erosion than they control. In this case, area treatments such as mulching should be substituted.

Cost: $0.50 (trenches) to $5.00 (whattling and ravel boards) per lineal ft.

Contour Trenches

Contour trenches are discontinuous ditches dug on contour. They act as small reservoirs to catch runoff before it concentrates and erodes the surface into rills and gullies. Trenches also stimulate infiltration. Typical trenches are 10 ft long, spaced 5 ft apart on contour.

Ditches

Hand dug ditches are used to drain wet hillslopes and divert runoff to stable areas. They are generally shallow compared to those excavated by earthmoving machinery. Ditches grade gently (0.5\%) in direction of discharge, and must not become steep enough to cause erosion. When gradients exceed 3\%, install drop structures or energy dissipators. In swampy areas, etch feeder channels into soil to drain standing water and saturated soils toward ditch.

Waterbars

Waterbars divert runoff from bare areas to vegetated areas or areas where flow is less apt to cause erosion. Waterbars should abut upslope bank, and grade gently (0.1\%) toward discharge. Final dimensions must not allow runoff to flow over top of waterbar. At discharge end, place a 3 ft long energy dissipator of rock or slash.
Figure 25. Hand-built Hillslope Structures
(Weaver, 1987, p. B10-18)
Whattling

Wattles are bundles of flexible twigs and branches tied together. Whattling is the practice of placing wattles in contour trenches or staking them on hillslopes to create terraces. After placement, wattles are partially covered with soil. Wattles retard erosion, and revegetate bare hillslopes when using sprouting species.

Bundles may vary in length, but must taper at the ends. To achieve the taper, cut half the stems 1.5 ft longer than average. Alternate stems in bundle so that half the butts are in each end. Compress and tie bundles on 15 in. centers with two wraps of binding twine and non-slipping knots. Finished bundles should be approximately 8 in. diameter.

For sprouting wattles, select live, sprouting species native to the site such as willows (Salix spp.) or coyote brush (Baccharis). Stem butts should not be more than 0.5 in. diameter. Prepare and place bundles preferably on the same day, and not more that one day after cutting stems. Keep bundles covered and wet until placed.

Ravel Catchers

Ravel catchers are boards, dug slightly into the hillside on contour. They catch and store ravel during dry seasons and runoff during wet periods. They also can be backfilled with fertile soil for protected planting sites.

Ravel boards are at least 1.25 in. thick, 16 to 18 in. wide, and 4 to 5 ft long. To install, dig trench a minimum 3 in. deep the length of the board. Place board in trench vertically on a long end, and anchor with wood stakes.

OTHER MATERIALS

Energy dissipators: Hard, durable, and angular rock, 5 to 6 in. diameter. Alternatively, slash with no pieces larger than 12 in. diameter and 24 in. long.

Stakes: Wood greater than 1.25 in. diameter and 24 in. long.

GENERAL CONSTRUCTION GUIDELINES

* Gradient for contour structures must be level. Stake out structure with Abney level, string level, or similar device.

* Design trench, ditch, and trough dimensions (width, depth, and length) for soil infiltration rates and expected short duration, peak rainfall events (24 hr, 20 yr).
* Excavate trenches, ditches, and troughs a minimum of 8 in. into substrate with a minimum top width of 12 in.

* Trenches, ditches, and troughs must be free and clear of vegetation, soil, and rocks that impede flow.

* Place any excavated earth in a berm on downslope side of structure to provide freeboard and increase capacity.

* Compact berms and backfill with hand tamp, shovel, or feet.

* On hillslopes, space contour structures on approximately 3 ft. centers. Arrange structures in a staggered pattern.

* Stake whattles or ravel boards in place on downslope side on minimum 36 in. centers. In addition, drive at least one stake at overlap of bundles or boards.

* Drive stakes at least 15 in. or until refusal. In tight soils, drive pilot holes with steel bars.

* Work should progress in a direction that minimizes soil compaction and damage to structures.

REFERENCE: This section paraphrased from Weaver et al, 1987, p. B-8.

HANDBUILT DROP STRUCTURES

DESCRIPTION

Handbuilt drop structures are used to protect small stream channels from erosion. Checkdams arrest downcutting, and rock armour arrests both downcutting and lateral channel erosion. In general, hand built structures are effective in drainage areas less than 25 acres or as long as flows do not exceed the capacity of dam spillways or the energy to move rocks.

ROCK ARMOUR

Rock armour is placed in small streams, gullies, ditches, or other expected water channels to increase turbulence and energy dissipation, slow water velocity, and eliminate scour of channel banks and beds. See Fig. 26.

Cost: $0.50 (w/o securing) to $2.50 (w/ securing) per sq ft.
Figure 26. Rock Armor
(Weaver, 1987, B25)
Construction Guidelines

* Design for 24 hr, 20 yr rainfall events.
* For new channels, excavate bottom slightly concave.
* Line channels well above expected high water level to protect against bank cutting.
* Size rocks and secure such that peak flows do not remove armour. For hand labor, maximum size rock is approximately 18 in. diameter.

CHECKDAMS AND OTHER DROP STRUCTURES

Checkdams are placed in streams or gullies to raise channels and drop flow onto energy dissipators. See Fig. 27. Sediment fills space behind checkdams, and stabilizes adjacent bank. Design checkdams such that entire runoff flows through spillway, and waterfall does not undermine checkdams on downstream side.

Cost: $20 to $400 each.

Submerged spillways are checkdams placed with spillway set at streambed level. Submerged spillways are applicable in broad channels with shallow, poorly defined banks and rock bottoms.

Alternatives to checkdams include 1) rock armour which can be built up to form checkdams, 2) tightly bound bundles of boughs for very small streams, and 3) water ladders. Generally water ladders have small capacity, and are expensive and difficult to build in remote areas.

Materials

Boards: Water resistant (redwood, cedar) 1 in. thick for lengths up to 6 ft, 1.25 in. thick for lengths 6 ft to 10 ft.

Anchors: Reinforcing steel (No. 5 or 6 rebar).

Construction Guidelines

* Locate checkdam perpendicular to channel to prevent concentrating flow at either bank.
* Key checkdam into banks a minimum 6 in. and channel bottom a minimum 3 in.
* In a series of checkdams, place lowest checkdam first in nonerodable bedrock or against immovable boulders. Locate next upstream checkdam so that sediment fill of lower checkdam abuts base of upper checkdam. Locate with a line level from spillway.
Figure 27. Check Dams
(Weaver et al., 1987, B28-30)
* Design freeboard height and width a minimum of 8 in. on both sides of spillway.

* Design effective height (bottom of channel to spillway) greater than 8 in. and maximize whenever possible.

* Total height equals effective height plus freeboard, and should not exceed 40 in.

* Use two boards to attain total height. Place widest board on top. Spillway notch must not cut through entire width of board.

* Design spillways for 24 hr, 20 yr rainfall events. Use trapezoidal shape, and adjust effective height and side angles to pass the design flow. Spillway must not be so wide that water impacts banks.

* Anchor checkdams with a minimum of 4 rebars driven 2 ft into channel or until refusal. Rebar must be long enough to extend out of channel and support checkdam a minimum 3/4's of its height.

* Place rock armour downstream of checkdam for a width greater than the spillway, and a minimum distance of 1.5 times effective height of checkdam. Slash may be substituted for rock, but must be anchored. There should be no gap between armour and dam.

REVEGETATION

TOPSOIL REPLACEMENT

DESCRIPTION

Loading, transport, and spreading of topsoil is the last major earthmoving operation in remediation of a mine site. If replaced topsoil is allowed to erode, not only is site damaged, but the lost soil must be replaced again at additional cost.

In general, topsoil is more easily eroded than rocky backfill, and topsoil is vulnerable to erosion until revegetation stabilizes surface soils. During this vulnerable period, erosion control devices and measures must be used to protect topsoil. This section discusses only control measures specific to topsoil. Refer to the section on Sedimentation and Erosion Control for additional information.

Cost: $0.40 to $1.50 per cu yd.

CONSTRUCTION

* Construct erosion and sedimentation measures prior to topsoil replacement.

* Replace and spread topsoil immediately prior to longest precipitation period or when moisture is most favorable for planting. Refer to the sections on Topsoil Removal Reshaping Highwalls and Roads, and Waste Dump Mitigation for guidelines on topsoil thickness.

* Apply acidic (lime) or alkaline treatments as recommended in Reshaping Highwalls and Roads. Soil pH should range from 5.0 to 7.5.

* After applying topsoil, rip surface to eliminate compaction, failure plane between layers, and preferential pathway for subsurface water. Ripping also promotes root depth and water infiltration.

  ** Ripping machinery includes dozer and grader rippers or rakes, loaders with bucket teeth, subsoilers, and klodbusters.

  ** When surface is dry, insure ripping shatters mantle. For thick topsoil layers, rip twice once before and again after applying topsoil.

  ** Deep ripping should be 2 to 3 ft deep on 2 to 3 ft centers. Distance between rippers should be equal to ripping depth.
** Rip on contour.

** Raise ripping depth if it brings excessive rock to surface.

* Fertilize site as described under separate guideline.

* Disk or harrow to smooth surface.

* Plant site with a drill or cultipacker type seeder to assure seeds are planted at proper depth, and have hydraulic contact with soil.

** For broadcast seeding, plant immediately after harrowing so that soil will settle around seed. Use a light chain, log drag or roller, where possible, to cover seed.

REFERENCES: This section paraphrased from PDER, 1978, p. 8 & 13; USFS, no date, p. 15.

FERTILIZATION AND SEEDBED PREPARATION

DESCRIPTION

Native soils of mine sites are often nutrient deficient, and topsoil salvage often dilutes existing nutrients. Soil should be analyzed prior to revegetation, see the section on Site Characterization and Monitoring.

Nitrogen and phosphorus are frequently deficient on mine sites, whereas potassium is usually adequate. Nitrogen deficiency is characterized by stunted growth, yellow leaves, and drying of the lower parts of plants. Phosphorus deficiency often causes a purplish color with very little stooling or spreading and poor seed production. These deficiencies generally have a more pronounced effect on grasses than on forbs, and where revegetation is predominantly grasses, fertilization may be necessary.

Nevertheless, on some modern mine revegetation projects fertilization has diminished because plant species dependent on high fertilizer rates have been removed from seed mixes. In addition, experience indicates that nitrogen fertilizers encourage vigorous growth of weeds and the more aggressive native grasses, to the detriment of less aggressive natives including woody plants.

Soil moisture influences the beneficial effect of fertilization. Nitrogen and phosphorus must be in soluble forms for plant consumption. On arid sites, fertilization may not be beneficial, because after precipitation, plants may utilize moisture before it dissolves the fertilizer.
Factors that affect revegetation include soil texture, depth, and alkalinity; site elevation, gradient, aspect, and wind exposure; and precipitation and temperature patterns. Because these factors are site specific, mine site revegetation must rely on local practices. What follows in this section are guidelines on how to start thinking about revegetation. In addition, sources are given for more detailed regional revegetation information.

Cost: $100 to $500 per acre.

GUIDELINES

* Where possible, replace topsoil directly without interim storage. Direct haul topsoil provides organically rich and biologically active medium which dramatically improves establishment of planted and volunteer species. Stockpiled soils deteriorate biologically after 2 to 4 years.

* Seedbed preparation may not be necessary if seeding is done immediately after grading. See Topsoil Replacement. Seedbed preparation scarifies the surface to reduce soil compaction and surface runoff which in turn enhances infiltration and root penetration. Common implements include discs, chisel plow, harrow, and ripper. On rough, rocky areas use heavy-duty equipment such as the offset disc or brush harrow. On severely compacted areas, use rippers.

* If necessary, apply mulch to conserve soil moisture and aide erosion control.

* Concern over early revegetation success and erosion control has led to irrigation. However, vegetation developed slowly under dryland techniques may reach the same level of cover in the long run as irrigated areas.

  ** Where erosion is a concern, two-stage planting or nurse crops may be applicable. Quick response grasses, legumes, and forbs are planted, followed in one to three seasons with trees and shrubs.

* Test soil and growing medium for nutrient deficiencies prior to undertaking any kind of revegetation. Refer to Site Characterization and Monitoring.

* Nutrient content of bagged and bulk fertilizers is expressed as a percent of content by weight.

  ** A 100 lb bag marked 5-10-5 contains 5% nitrogen (N), 10% phosphorous (P₂O₅), and 5% potash (K₂O₅).
To apply 20 lb per acre of phosphorous, it would require 20 / 0.1 = 200 lb of fertilizer mix.

* Consider fertilizing with materials other than commercial products such as cattle manure, poultry manure, treated sewage sludge, and fly ash. All municipal and industrial sludge must be tested for heavy metals content. Lifetime leaching rates of heavy metals cannot be exceeded. Get technical advice from the local office of the Soil Conservation Service when applying these materials.

* Apply fertilizer with spreaders, hydroteers, or aircraft. It also can be mixed with seed and mulch in a hydroteeder and applied in one pass. However, the mixture should be spread soon after mixing to avoid seed damage by fertilizer.

* Extremely acidic or alkaline soils limit plant growth. See Reshaping Highwalls and Roads for soil treatments.


SEEDING AND TRANSPLANTING

DESCRIPTION

The goal of revegetation at AML sites is to reestablish plant communities similar to premining vegetation, except where post mining land use is different from premining use, or where premining vegetation was poor quality. Species suitability is determined by site and environmental characteristics, and species adaptability and availability. Macro- and micro-environmental factors such as gradient, aspect, and elevation control local plant distribution within a landscape. Generally, native species must be used for reclamation in National Parks.

Cost: $100 to $300 per acre (does not include transplanting).

MATERIALS

Plant species suitable for adverse conditions:

Moderately Acid Soils

Agrostis Tenuis (Common bentgrass)
Deschampsia caespitosa (tufted hairgrass)
Poa alpina (Alpine bluegrass)
Phleum pratense (Common timothy)
Carex spp. (Sedges)
Achillea millefolium (Yarrow)
Sibbaldia procumbens (Creeping sibbaldia)

**Moderately Saline Soils**

Festuca arundinacea (Tall fescue)
Agropyron desertorum (Crested wheatgrass)
Agropyron elongatum (Tall wheatgrass)
Distichlis stricta (Desert saltgrass)
Lotus corniculatus (Birdsfoot trefoil)
Eriogonum umbellatum (Sulfur eriogonum)
Atriplex spp. (Saltbush)
Atremisia spp. (Sagebrush)

**GUIDELINES**

**Species Selection**

* Observe plant species found growing naturally nearby or on old disturbances near the site to be revegetated.

* Consider plant species that establish quickly to prevent erosion and build root biomass.

* Consult applicable research reports and papers regarding revegetation.

* Consult with NPS experts and Soil Conservation Service county agents.

**Seed Acquisition**

Seed either may be collected from plants in the vicinity of the AML site or purchased from a seed dealer. Seed collection may be expensive. General guides to seed collection include:

* Locate stands of desired species before seed matures.

* Collect seed only after it matures on the plant. Different species mature at different times; therefore, seed acquisition of various species may require several collection trips.

* Collect by hand-stripping or using a mechanized device designed for the purpose.

* Place seed in either cloth or paper bags, never seal in plastic. Plastic retains moisture and causes molding.

* Clean and separate seed from chaff and other debris as soon as dry.

* Store clean seed in a cool dry location in paper or cloth bags.
If seed is purchased, take the following precautions:

* Ensure that stock is made up of desired varieties, and verify date of collection.

* Specify germination percentage, collection location, species name, pure live seed, and maximum allowable weed or other contamination.

* Use Plant Material Centers of the Soil Conservation Service for information about seed and seed dealers.

**Seeding Method**

**Drill seeding** is primarily used for small seeded species such as grasses, legumes, and some shrubs.

Advantages: Less seed is required than other methods. When used on contour, surface runoff is slowed by furrows created by the drill.

Disadvantages: Limited to areas relatively free of stones, and hillslopes less than 3h:1v. Site must be level enough for use of farm equipment. Uniform seeding depth may preclude successful establishment of all seed species.

**Broadcast seeding** is beneficial in small or remote areas. When broadcast seeding, plant immediately after site disturbance so that soil will settle around seed. Use a light chain, log drag, or roller to cover seed.

Advantages: Fast, cheap, and results in a more natural looking stand. Requires only primary tillage, whereas drill seeding requires a smoother surface.

Disadvantages: Requires twice the seed rate as drilling because of uneven seed dispersal, poor coverage of seed, predation, and excessive drying if precipitation is inadequate.

**Hydroseeding** is a process where seed is mixed with water and sprayed onto a site. Fertilizer, mulch, and lime may be added to mixture.

Advantages: Provides moisture for immediate germination. Slurry agitation in hydroseeder may promote scarification of some hard-coated seeds thus enhancing germination. One step process of soil
treatment - seeding, fertilization, mulching, and initial watering.

Disadvantages: Some seeds are damaged by process. Time of planting is critical.

* Seeding rates:

<table>
<thead>
<tr>
<th>Seeding Method</th>
<th>Arid West (lb/acre)</th>
<th>Other Areas (lb/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drill</td>
<td>10 - 20</td>
<td>5 - 10</td>
</tr>
<tr>
<td>Broadcast</td>
<td>20 - 40</td>
<td>10 - 20</td>
</tr>
</tbody>
</table>

Where rainfall is less than 10 in. per yr, use transplanting.

* Schedule seeding just prior to longest period of precipitation or when moisture is most favorable for seed establishment.

* Protect seedlings from grazing until fully established.

**Transplanting**

Transplanting is labor intensive and expensive; however, it may have particular application to National Parks where introduction of specific plant communities is crucial to remediation objectives.

Survival and performance of seedlings is dependent on good quality stock, lifting date, methods of storage and handling, site conditions, weed competition, planting methods and spacing, fertilization, watering, and animal damage. Consult with NPS experts and Soil Conservation Service county agents.

* Protect transplants from competition by scalping the cover or applying herbicides before planting. Alternatively, inoculate seedlings with superior types of mychorrizal fungi.

* Protect transplants from browsing animals with high fences around entire site, poultry netting around individual trees, and polyethylene sleeves around trunks.

There are three methods of transplanting, as follows:

**Bare-root seedlings**

Advantages: Much cheaper than containerized stock. Bare root seedlings are usually dormant when shipped, and don't require hardening off.
Disadvantages: Transplanting success may be limited if stock is poor, soil moisture is inadequate at planting, or roots are not placed properly and are doubled under or crooked. Must be planted within 2 weeks of delivery. A dry, hot wind can dry out roots and kill seedlings in a very short time.

Containerized seedlings

Advantages: Longer planting season. Requires less experienced planters. Container stock may be the only viable alternative on harsh sites.

Disadvantages: Higher purchase cost, and more labor intensive planting. More susceptible to frost heaving. Require constant moisture prior to planting.

Live pads

Advantages: Transplanting pads or clumps of native vegetation provide an immediate source of mature growing plants. Pads are more immediately effective than other methods, and can be used in any location that is accessible to machinery.

Disadvantages: Distance between source and revegetation site is limited. Long haul distances damage pads and increase costs. Damages source areas.


MULCHING

DESCRIPTION

Mulches protect and stabilize soils until permanent plant cover becomes established. Mulch reduces rainsplash, surface wind, particle movement and other erosional effects. In addition to preventing erosion, a good mulch cover protects seeded areas from the severe effects of heat, cold, and drought. On the other hand, mulches sometimes immobilize nutrients, inhibit germination, contain weeds, and attract plant diseases.

Considerations in the selection of a mulch type include mulch effectiveness, cost, time of seeding, proposed land use, climate, topographic features, and application methods.

Cost: $300 to $500 per acre.
GUIDELINES

General

* Dark colored mulch raises spring soil temperature, and light mulch reduces summer soil temperature.

* Apply mulch to roughened surface and anchor. Anchor methods include:

  Manual anchoring ties down mulch with stakes, pegs, twine, or netting. Applicable to small, steep, or windy sites.

  Mechanical anchoring partially buries mulch in soil by crimping, discing, or rolling.

  Chemical anchoring sprays a tacifier onto mulch. Can be included in slurry for hydroseeding. There have been some difficulties in using chemical anchoring, get help from experts.

* Mulch can be applied by hand on sites up to 1 to 2 acres in size, and gradients less than 3h:1v. Larger and steeper sites require a power blower or mulcher.

* Mulch application rates are given in Table XI.

<table>
<thead>
<tr>
<th>Mulch</th>
<th>Seed Cover</th>
<th>Erosion Control</th>
<th>Plant Mulch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straw, ton</td>
<td>1.5-2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Hay, ton</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Manure, ton</td>
<td>10-15</td>
<td>30-40</td>
<td>40-60</td>
</tr>
<tr>
<td>Hardwood Bark, cu yd</td>
<td>45</td>
<td>240</td>
<td>480</td>
</tr>
<tr>
<td>Softwood Bark, cu yd</td>
<td>45</td>
<td>240</td>
<td>480</td>
</tr>
<tr>
<td>Hardwood Chips, cu yd</td>
<td>50</td>
<td>268</td>
<td>536</td>
</tr>
<tr>
<td>Softwood Chips, cu yd</td>
<td>50</td>
<td>268</td>
<td>536</td>
</tr>
<tr>
<td>Sawdust, cu yd</td>
<td>275</td>
<td>550</td>
<td>825</td>
</tr>
<tr>
<td>Leaves, ton</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Solid Waste, ton</td>
<td>20</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Sewage Sludge, ton</td>
<td>75</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Wood-Cellulose Fiber, lb</td>
<td>1 500</td>
<td>3,000</td>
<td>---</td>
</tr>
</tbody>
</table>

**Live Mulching**

Before topsoil removal, create mulch by shredding woody plants and removing with topsoil, rather than uprooting and discarding plants.

Advantages: Leaves a residue of chopped organic matter on soil surface that is removed along with topsoil. Some contained roots may sprout resulting in better densities than achieved by seeding and transplanting alone. Allows complete topsoil salvage in contrast to clearing and grubbing which wastes vegetation and soil clinging to roots.

Disadvantages: Only applicable to areas newly disturbed.

**Straw/Hay Mulch**

Advantages: Least expensive. Usually contains seed of grasses and legumes that may help revegetation.

Disadvantages: Contained seed may compete with preferred seed species, and weedy species may be introduced. Usually decomposes and becomes ineffective after one growing season. May be a fire hazard in dry weather. May immobilize soil nitrogen. Anchoring may affect soil microbial cycling and nitrogen availability which in turn may require additional fertilization.

**Bark Mulch**

Advantages: Hardwood bark is effective for 3 to 4 yr; softwood bark remains intact for 5 to 10 yr. No anchoring is necessary. Source for microorganisms and phosphorous. Trap for moisture and airborne seeds. Moisture retention can be adjusted by changing the particle size distribution. Bark may be composted which removes toxins and accelerates formation of humic acid.

Disadvantages: Soil nitrogen decreases as bark decomposes, and often nitrogen fertilizers must be applied. Too much fine bark may cause rapid decomposition, soil compaction, undesirable dust, and fire hazard. With the exception of cypress and cedar, softwood bark is more likely to move than hardwood bark in runoff or heavy wind.

**Wood Chip Mulch**

Advantages and disadvantages are generally the same as for bark mulch with the following additions:

Advantages: Does not favor insects or rodents.
Disadvantages: Decomposes slightly faster than bark due to cellulose content. Should not be stored outside for more than 3 to 4 mo because high temperatures will dry chips and kill beneficial microorganisms. Chips can inhibit seedling or grass emergence.

Sawdust Mulch

Advantages: Adds nutrients to soil, and absorbs water 2 to 6 times its own weight. Effective for 3 to 5 yr.

Disadvantages: Must be well-leached and stored for about one year. Tends to pack tightly and retard aeration and water infiltration. Slightly acidic which is not a disadvantage unless it necessitates liming. Must be anchored with tacifier. Not desirable on hillslopes because it tends to float and blow away.

Wood Cellulose Fiber Mulch (Hydromulch)

Hydromulch is short fiber made from either paper or wood, and applied with a hydroseeder.

Advantages: Used where rapid mulching is essential. Inexpensive, and may be stored for long periods. No chemical additives, and no germination or growth inhibitors. Weed free, non-polluting, and biodegradable.

Disadvantages: Effective for only 30 days. Not effective in moderating soil temperature, retaining moisture, or controlling erosion. Tends to suspend seed in mulch and limit direct soil contact, and on some sites may not promote better grass/legume cover.

Leaves

Advantages: Adds nutrients to soil. Inexpensive where there is a convenient supply.

Disadvantages: Only available in the fall unless stored. Must be anchored with discing which limits application to maximum safe gradients of farm equipment.

Livestock and Poultry Manure

Advantages: Valuable source of nutrients. Increases the number of earthworms and other beneficial organisms.

Disadvantages: Difficult to spread evenly on steep hillslopes. Limited erosion control. Odor may not be acceptable.
Municipal Sewage Sludge

Advantages: Inexpensive and readily available source of organic matter.

Disadvantages: Must be digested, stabilized, or composted prior to application. Potential plant toxicity from heavy metals and other substances. Must be tested prior to use.

Mats and Fabrics

Advantages: Effective on severe sites (terrain and/or weather) and critical areas (ditches). Organic mats (excelsior, jute, straw, coconut fiber) are biodegradable.

Disadvantages: Expensive. Must be anchored with staples or pegs. Inorganic mats (fiberglass, polypropylene, vinyl) are not biodegradable, and not appropriate for National Parks.

REFERENCES: This section paraphrased from Thorne, 1987, p. 38, USFS, no date, p. 24.
REFERENCES


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INTRODUCTION

Project cost estimates are prepared for different purposes and are of varying degrees of accuracy. A construction contractor prepares bid estimates from detailed design drawings and specifications. At the other end of the spectrum, a corporate planner may want a quick-and-dirty estimate of a new facility. Based on prior construction experience, an approximate total cost can be obtained from a unit cost and the proposed plant capacity. Between these two extremes lies a broad band of estimating methods and accuracy.

Cost estimates range in increasing quality as follows: order-of-magnitude, conceptual, preliminary, definitive, engineers, and bid. The level of accuracy given in the following cost estimating worksheets is conceptual, and the recommended contingency allowance is based on this accuracy level.

A conceptual plan requires a description of the project, a general layout - before and after, general arrangement drawings of major project elements (such as closures, backfill, landscaping, erosion control, and revegetation), and quantities (such as monitoring sites, rainfall, stream flow, disturbed areas, earthmoving, size of mine openings, and volume of topsoil). Please refer to Tab III and IV for more information on project planning.

Generally, conceptual cost estimates are adequate for studying or comparing the economic feasibility of alternative projects, funding or budgeting a project, and evaluating construction bids. Additionally, they can substitute for the final cost estimate on small projects (as defined by local management guidance), or where considerable experience has accrued on similar projects.

Cost estimate format and methods are generally unique to the individual estimator, project, and conditions. The estimator must spend a great deal of time in determining the scope and general parameters of a project, and then translate these into meaningful, measurable quantities with reasonable units of cost that are all-encompassing and reliable. The worksheets given below short cut this process of scoping and costing. These short cuts are made possible by the expanding base of experience on AML closures. To use the worksheets, all that is required is a conceptual remediation plan and quantity estimates. The worksheets provide the rest -- estimate format and unit costs.

Profit and fees for contractors are included in the cost estimates. Typically these fees are 10% to 15% of the cost estimate.
Some costs that are not provided for in the worksheets include:

* AML program management and administration,
* Initial site reconnaissance and inventory,
* Cost inflation during construction,
* Technical assistance and training, and
* External costs such as socio-economic and environmental impacts of a project.

Although the worksheets are conservative, the unit costs do not account for extreme conditions. Statistical distributions of costs are skewed with a long tail that indicates an ever present risk of unusually high costs far beyond the norm. Project managers must be on the alert for conditions that deviate from assumptions behind the remediation methods and unit costs given in this handbook. The cost estimates must be adjusted for site specific conditions, and where available, local cost data should be used in preference to this handbook.

Cost overruns are most likely to occur from inadequate site characterization and inadequate construction management.

Inadequate understanding of the site can result in significant changes in the quantities. In addition, surprises can lead to changes in project scope such as poor foundation conditions or the need to drill and blast when none was assumed.

Inadequate construction management results in poor quality control. Construction progress must be properly and accurately monitored in a timely manner. Construction must be measured against performance criteria and requirements.

COST REFERENCES

The best source of cost data is derived from previous experience on similar projects. This historical data must be analyzed and organized to be readily available for the estimator's use.

The sources of prices on mechanical equipment are the manufacturers who are generally willing to give prices that range from list prices to firm quotations. Many manufacturers also provide handbooks for estimating the productivity and operating costs of their equipment. The following is a sampling of cost guides available. Be sure to read and understand the introductions of these books, to determine the particular qualifications and applications.

COSTING PROCEDURE

The next section contains two summary worksheets -- the first for project construction costs and the second for annual project maintenance costs. Each cost heading has a page reference for a detail worksheet. Go to that page, fill-in the applicable worksheet blanks, and perform the indicated calculations. Sum the cost items and carry forward to the summary worksheet as instructed. Complete the cost estimate by performing the subtotals and totals indicated on the summary worksheets.

It may be helpful to preview the preceding steps early in project planning to learn what is required to complete a cost estimate. This preview can be a guide for obtaining the required information.
| 1.0 | SITE CHARACTERIZATION AND MONITORING (Page 6) | $ |  
| 2.0 | UNDERGROUND MINE CLOSURE (Page 9) |  
| 3.0 | SURFACE MITIGATION (Page 12) |  
| 4.0 | EROSION AND SEDIMENTATION CONTROL (Page 15) |  
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|     | Construction Subtotal --> |  
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| 7.0 | WITH COST INFLATION (Page 22) |  
|     | Construction w/ Adjustments --> |  
| 8.0 | ENGINEERING AND DESIGN (10% of Line 7.0) |  
| 9.0 | MOBILIZATION (Page 24) |  
| 10.0 | CONSTRUCTION MANAGEMENT (Page 25) |  
| 11.0 | NPS PROJECT MANAGEMENT (Page 26) |  
| 12.0 | CONTINGENCY (Page 27) |  
|     | Overhead Subtotal --> |  
|     | PROJECT TOTAL --> $ |
### SUMMARY

**ANNUAL PROJECT MAINTENANCE COST**

<table>
<thead>
<tr>
<th>Description</th>
<th>YEAR 1</th>
<th>YEAR 2</th>
<th>YEAR 3</th>
<th>YEAR 4</th>
<th>YEAR 5</th>
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<tbody>
<tr>
<td>13.0 MONITORING</td>
<td>______</td>
<td>______</td>
<td>______</td>
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<td>______</td>
</tr>
<tr>
<td>(Page 28)</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>14.0 REVEGETATION</td>
<td>______</td>
<td>______</td>
<td>______</td>
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<td>______</td>
</tr>
<tr>
<td>(Page 32)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15.0 MANAGEMENT</td>
<td>______</td>
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</tr>
<tr>
<td>(Page 30)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>______</td>
<td>______</td>
<td>______</td>
<td>______</td>
<td>______</td>
</tr>
</tbody>
</table>
1.0 SITE CHARACTERIZATION AND MONITORING

If the initial site inventory and reconnaissance reveals that additional site characterization is required, choose the applicable baseline studies given below, fill-in the blanks, and total the costs.

The given costs are typical for mine sites with insignificant to moderate environmental impacts. Keep in mind that costs could be 5 to 10 times the given costs where a site has significant impacts on the environment.

In this worksheet:

* A small site is an isolated mine with less than 2.5 acres of disturbed area (typically a 19th century underground mine).

* A medium site has up to 200 acres of disturbed area (historic mining districts, modern underground mines and small quarries).

* A large site is greater than 200 acres (modern open pit and strip mines).

1.1 Geology.

From above definition of site sizes, select one of the following cost estimates:

<table>
<thead>
<tr>
<th></th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>$2,000</td>
<td>$10,000</td>
<td>$50,000</td>
</tr>
</tbody>
</table>

1.2 Soil and mine wastes.

Estimate area of disturbed land:

(______ acres x $100/acre) =

If unstable ground (hillslopes, dumps, mine openings) is suspected, add $15,000.

1.3 Surface water.

Determine monitoring sites and number of samples per year (typically 3 - 7 times):

(______ sites x ___ samples/yr x $1,000/sample) = _______.

Cost
1.4 Groundwater.

Estimate depth of groundwater.

Space monitoring wells 500 ft apart down gradient from disturbed area and add one up gradient well.

\[(\text{_____ wells} \times \text{_____ ft/well} \times \$20/\text{ft}) = \text{______}.\]

\[(\text{_____ wells} \times \text{_____ samples/yr} \times \$1,000/\text{sample}) = \text{______}.\]

If a pump test is required, add $50,000.

1.5 Air quality.

A requirement for air sampling is most unlikely unless the site is a large strip mine, open pit, or tailings impoundment. If so, add the cost of a meteorological station and the cost of operation, analysis, and reporting at $150,000.

1.5 Vegetation.

Estimate size of study area:

\[(\text{_____ acres} \times \$25/\text{acre}) = \text{______}.\]

1.6 Wildlife.

From above definition of site sizes, select one of the following cost estimates:

<table>
<thead>
<tr>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
</tr>
</thead>
<tbody>
<tr>
<td>$3,000</td>
<td>$5,000</td>
<td>$15,000</td>
</tr>
</tbody>
</table>

If endangered species are suspected to be present, add $10,000.

1.7 Historical and cultural.

From above definition of site sizes, select one of the following cost estimates:

<table>
<thead>
<tr>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1,000</td>
<td>$5,000</td>
<td>$5,000</td>
</tr>
</tbody>
</table>

If items of historical/cultural relevance exist, add $15,000.

1.8 Permitting and NEPA compliance.

If site is not covered by a programmatic EIS and project must comply with local permitting
requirements, add the cost of compiling baseline information and preparing an environmental assessment:

<table>
<thead>
<tr>
<th></th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>$6,000</td>
<td>$12,000</td>
<td>$20,000</td>
</tr>
</tbody>
</table>

If the site requires an EA or EIS, add the cost as applicable:

<table>
<thead>
<tr>
<th></th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>$15,000</td>
<td>$30,000</td>
<td>$70,000</td>
</tr>
</tbody>
</table>

TOTAL ————>

Each of the above cost items stand alone, and when several items are selected there is double accounting and scale efficiencies. The total cost should not exceed the following estimates unless there are unusual and significant site characteristics. Significant impacts can drive costs up 5 to 10 times the following totals.

<table>
<thead>
<tr>
<th></th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>$50,000</td>
<td>$150,000</td>
<td>$500,000</td>
</tr>
</tbody>
</table>

Enter total or revised total on 1.0, Summary Cost Estimate

REFERENCE: (USBM, 1986)
2.0 UNDERGROUND MINE CLOSURE

Choose only applicable closures, fill-in blanks as indicated, and total cost estimates.

2.1 Backfill adits.

Fill-in number of adit openings:

(______ openings x $3,500/opening) = ________

2.2 Backfill shafts and stopes.

Estimate total volume of openings, and fill-in applicable blank.

Less than 100 cu yd:

(______ cu yd x $26/cu yd) = ________

More than 100 cu yd:

(______ cu yd x $10/cu yd) = ________

2.3 Blast adit and shaft.

Fill-in number of adit and shaft openings:

(______ openings x $3,200/opening) = ________

2.4 Cast-in-place concrete cap shaft.

Fill-in number of shaft openings:

(______ openings x $8,000/opening) = ________

2.5 Precast concrete cap shaft.

Estimate number of 5 x 10 ft panels, and fill-in cost formula:

Panel Rows = \( \sum_i \text{INT}(\text{length}_i/10 + 1) \)

Panel Columns = \( \sum_i \text{INT}(\text{width}_i/5 + 1) \)

Total Panels = Panel Rows x Panel Columns

where: \( \text{INT} \) - round to next whole panel.

i - index for the number of openings.

(______ panels x $900/panel) = ________
For openings with the largest dimension greater than 8 ft, estimate length of steel support beams, and fill-in cost formula:

Total Beams = Panel Rows x (Panel Columns x 5 + 2) 

(______ ft x $50/ft) = ________.

2.6 Monolithic plug shaft and stopes.

Estimate volume of riprap:

(______ cu yd x $46/cu yd) = ________.

Estimate volume of concrete cap:

(______ cu yd x $150/cu yd) = ________.

Estimate volume of backfill:

(______ cu yd x $26/cu yd) = ________.

2.7 Steel grated shafts and adits.

Estimate total area of grating, and fill-in applicable blank.

For standard grates:

(______ sq ft x $60/sq ft) = ________.

For bat grates:

(______ sq ft x $80/sq ft) = ________.

2.8 Cable net shafts and adits.

Estimate total area of netting:

(______ sq ft x $11/sq ft) = ________.

2.9 Polyurethane foam (PUF) shaft.

Estimate total PUF volume:

(______ cu yd x $300/cu yd) = ________.
2.10 Bulkhead adits.

Fill-in number of openings, as applicable.

For openings up to 8 x 8 ft:

\[
\text{(_____ openings x $2,200/opening) = ________ .}
\]

For larger openings up to 15 x 15 ft:

\[
\text{(_____ openings x $4,000/opening) = ________ .}
\]

\[
\text{TOTAL \rightarrow ________ .}
\]

Enter total on 2.0, Summary Cost Estimate

REFERENCES: (CMLRD, 1989) (Essington, 1988)
3.0 SURFACE MITIGATION

3.1 Reshaping highwalls and roads.

Estimate area of clearing and grubbing, and fill-in applicable blank.

For dense vegetation cover (woodlands):

(____ acres x $1,500/acre) =

For moderate vegetation cover (small trees, shrubs):

(____ acres x $1,000/acre) =

Estimate volume of earthmoving including topsoil removal, and fill-in applicable blank.

For small jobs less than 10,000 cu yd, machine productivity is not relevant. Estimate number of days on site and multiply by daily rental rate:

\[ \text{Sum}_i[(____ days x daily rate_i)] = \]

where: \( i \) is index for cost item.

daily rate = $250/day, backhoe or truck.
    $350/day, dozer or loader.
    $165/day, operator.

For medium sized jobs from 10,000 to 100,000 cu yd., estimate total volume of earthmoving:

(____ cu yd x $2.40/cu yd) =

For large jobs greater than 100,000 cu yd., estimate total volume of earthmoving:

(____ cu yd x $2.00/cu yd) =

If drilling and blasting is required, estimate the volume:

(____ cu yd x $1.15/cu yd) =

If lime treatment is required, estimate liming rate (see Table VIII, Tab IV) and acres:

(____ lb/acre x ____ acres x $0.12/lb) =
3.2 Waste dump stabilization.

If dump is relocated in a natural drainage channel, cost a French drain. Estimate volume of channel:

\[
(\text{____ cu yd} \times \$46/\text{cu yd}) = \text{______}.
\]

If dump is relocated or volume of earthmoving is under 10,000 cu yd, use 3.1 for cost estimate.

For reshaping dump, estimate volume of earthmoving and fill-in applicable blank:

For medium jobs from 10,000 to 100,000 cu yd:

\[
(\text{____ cu yd} \times \$1.00/\text{cu yd}) = \text{______}.
\]

For large jobs greater than 100,000 cu yd:

\[
(\text{____ cu yd} \times \$0.70/\text{cu yd}) = \text{______}.
\]

If lime treatment is required, estimate liming rate (see Table VIII, Tab IV) and acres:

\[
(\text{____ lb/acre} \times \text{____ acres} \times \$0.12/\text{lb}) = \text{______}.
\]

3.3 Mine drainage control.

Estimate volume of flow.

For flow less than 20 gpd, treat with limestone barriers or other simple neutralizing structures which can cost up to $20,000.

For greater flows, a treatment plant can cost from $500,000 and up to build, and also incurs annual operating and maintenance costs. Get help.

[Should we substitute the USBM cost formula?]

3.4 Subsidence mitigation.

For reshaping and backfilling subsidence, estimate 1) volume of earthmoving 2) length of French drains, and 3) lime treatment, and calculate cost under 3.1.

Foundation support and subsurface reinforcement range in cost from $1,000 to $80 million. These items are beyond the scope of this handbook. Get help.
3.5 Mine fires.

A typical cost for extinguishing seam and dump fires is $500,000. This item is beyond the scope of this handbook. Get help.

3.6 Structures and equipment.

Assuming mechanical demolition, estimate volume of structures and equipment:

\[ (\text{_____ cu ft} \times $0.20/\text{cu ft}) = \text{_______}. \]

Locate a landfill, get a quote for transportation and disposal:

\[ (\text{_____ cu ft} \times $\text{_____}/\text{cu ft}) = \text{_______}. \]

\[
\text{TOTAL} \rightarrow \text{_______}.
\]

Enter total on 3.0, Summary Cost Estimate

4.0 EROSION AND SEDIMENTATION CONTROL

4.1 Hillslope erosion control.
For reshaping, water diversion, and water
dispersion on large projects using earthmoving
equipment, estimate volume of earthmoving:

\[ \text{Cost} = \text{cu yd} \times \$1/\text{cu yd} \]

Caution: Do not double account costs. This cost
is not applicable in areas where costs already
have been estimated for 3.1 Reshaping Highwalls
and Roads, and 3.2 Waste Dump Stabilization.

4.2 Riprap drop structures.
Estimate volume of earthmoving:

\[ \text{Cost} = \text{cu yd} \times \$2.40/\text{cu yd} \]

Estimate length and cross sectional area of
riprap:

\[ \text{Cost} = \text{yd long} \times \text{yd}^2 \text{ area} \times 2.3 \text{ tons/cu yd} \times \$20/\text{ton} \]

4.3 Geologic drop structures.
Estimate volume of earthmoving:

\[ \text{Cost} = \text{cu yd} \times \$2.40/\text{cu yd} \]

If drilling and blasting is required, estimate
volume:

\[ \text{Cost} = \text{cu yd} \times \$1.15/\text{cu yd} \]

4.4 Diversion ditches.
Estimate total length of diversion ditches:

\[ \text{Cost} = \text{ft} \times \$1.25/\text{ft} \]

Estimate area of jute matting and grass lining:

\[ \text{Cost} = \text{acres} \times \$1 \ 100/\text{acre} \]

Estimate volume of riprap:

\[ \text{Cost} = \text{cu yd} \times \$46/\text{cu yd} \]
4.6 Culverts

Estimate number, size and cumulative length of culverts and fill in the following blanks. Cost assumes corrugated metal culvert, and includes culvert, headwall, end section, and installation.

30 in. diameter
_____ ea x $1,100 + _____ ft x $32/ft = ________.

36 in. diameter
_____ ea x $2,300 + _____ ft x $38/ft = ________.

42 in. diameter
_____ ea x $2,800 + _____ ft x $44/ft = ________.

48 in. diameter
_____ ea x $3,100 + _____ ft x $51/ft = ________.

54 in. diameter
_____ ea x $3,700 + _____ ft x $58/ft = ________.

4.7 Sedimentation and treatment basins.

Estimate volume of embankment:
(_____ cu yd x $1.50/cu yd) = ________.

If the basin requires a liner, estimate area of basin up to freeboard level. For basins up to 2.5 acres:
(_____ acres x $40,000/acre) = ________.

For larger basins up to 25 acres:
(_____ acres x $30,000/acre) = ________.

Estimate volume of riprap at spillway:
(_____ cu yd x 2.3 tons/cu yd x $20/ton) = ________.

4.8 Handbuilt hillslope structures.

Estimate length of structures.

Trenches and ditches:
(_____ ft x $0.50/ft) = ________.

Waterbars:
(_____ ft x $3.00/ft) = ________.

Whattling and ravel catchers:
(_____ ft x $5.00/ft) = ________.
4.9 Handbuilt drop structures.

For rock armour, estimate cover area.

If rock armour is placed without securing:

\[ \text{\( \text{\( (\text{ft}^2 \times \$0.50/\text{ft}^2) = \)}) \] = \]

If rock armour is placed with securing:

\[ \text{\( \text{\( (\text{ft}^2 \times \$2.50/\text{ft}^2) = \)}) \] = \]

For checkdams, estimate number:

\[ \text{\( \text{\( (\text{checkdams} \times \$25 \text{ each}) = \)}) \] = \]

\[ \text{TOTAL -------> \( \)} \]

Enter total on 4.0, Summary Cost Estimate.

REFERENCES: (USBM, 1986) (Weaver et al, 1987)
5.0 REVEGETATION

5.1 Topsoil replacement.

If topsoil is replaced from one area directly to another area without temporary stockpiling, only topsoil removal costs are incurred and there is no additional expense for topsoil replacement.

If topsoil is replaced from a stockpile, estimate volume:

\[ \text{Volume} = \text{cu yd} \times \$1.50/\text{cu yd} \]

5.2 Fertilization and seedbed preparation.

If fertilization is required, estimate area:

\[ \text{Area} = \text{acres} \times \$200/\text{acre} \]

If irrigation is required, estimate sprinkler system:

\[ \text{Sprinkler System} = \text{acres} \times \$15,000/\text{acre} \]

If lime requirements have not been estimated under 3.1 or 3.2, estimate liming rate (see Table VIII, Tab IV) and acres:

\[ \text{Lime} = \text{lb/acre} \times \text{acres} \times \$0.12/\text{lb} \]

5.3 Seeding and transplanting.

Estimate area of seeding and choose one of the following methods:

- Broadcast -- $500/acre
- Drill -- $1,200/acre
- Hydroseeding -- $1,900/acre (includes mulch)

\[ \text{Seeding} = \text{acres} \times \$\text{rate/acre} \]

For transplanting, decide on number of trees and shrubs per acre:

\[ \text{Transplanting} = \text{acres} \times \text{plants/acre} \times \$2/\text{plant} \]
5.4 Mulching.

Hydromulch is included in hydroseeding, 5.3.

For all other mulches, estimate area of application:

(______ acres x $200/acre) = __________.

TOTAL --------> __________.

Enter total on 5.0, Summary Cost Estimate.
6.0 REGIONAL ADJUSTMENT

Two adjustments must be made to construction costs for the project location. First, the costs are adjusted for regional location based on the city cost indexes given by R.S. Means Company (1990, p. 316). This adjustment must be revised annually with publication of the latest city cost indexes. Second, the costs must be revised for remoteness of the project. Above costs assume that construction services and materials are within 50 miles of the project site. From the description given below, choose the appropriate remoteness factor.

6.1 Regional Adjustment.

Choose the applicable regional adjustment factor from the following list and fill in the first blank in the formula of 6.3.

<table>
<thead>
<tr>
<th>Region Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mid Atlantic States 0.97</td>
</tr>
<tr>
<td>Mid West States 1.00</td>
</tr>
<tr>
<td>North Central States 0.92</td>
</tr>
<tr>
<td>Southern States 0.95</td>
</tr>
<tr>
<td>Rocky Mountain States 1.02</td>
</tr>
<tr>
<td>Intermountain States 0.95</td>
</tr>
<tr>
<td>West Coast States 1.05</td>
</tr>
<tr>
<td>Alaska 1.45</td>
</tr>
</tbody>
</table>

6.2 Remoteness Adjustment

Choose the site description that most nearly matches the project site and fill in the given remoteness factor in the second blank in the formula of 6.3.

From a labor pool and source of construction materials, the site is:

<table>
<thead>
<tr>
<th>Remote Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less that 50 miles away. 1.00</td>
</tr>
<tr>
<td>Readily accessible by road, and is from 50 to 200 miles away. (Includes Fairbanks area.) 1.30</td>
</tr>
<tr>
<td>More that 200 miles away or the last 25 to 50 miles is overland from the nearest road. (Includes South Alaska.) 1.45</td>
</tr>
<tr>
<td>Accessible only on foot or by 1.65</td>
</tr>
</tbody>
</table>
helicopter. Only valid for handbuilt construction (Includes Central Alaska below the Artic Circle.)

6.3 Total Regional Adjustment.

(_____ Subtotal #1 x _____ Region Factor x _____ Remote Factor) =

6.4 Helicopter Support.

If required, check local rates for helicopter services and capacity to the project site. Estimate the number of trips.

(_____ trips x $_____/trip) =

TOTAL -------> ________.

Enter amount on 6.0, Summary Cost Estimate.
7.0 COST INFLATION

The unit costs given in this handbook are current as of spring 1991. These unit costs can be updated for the effect of cost inflation with indices provided by the U.S. Bureau of Labor Statistics. To adjust costs for a future year, multiply the handbook cost times the index, \( I \), for the future year divided by the index for 1991.

For the labor index, \( I_L \), use Employment and Earnings C-1 Construction.

For the equipment index, \( I_E \), use 112 Construction Machinery and Equipment.

Apply the adjustment only to items 2.0 through 6.0, and assume that costs components are 60% equipment and 40% labor:

\[
\left[(0.6 \times \frac{I_E}{1991 I_E}) + (0.4 \times \frac{I_L}{1991 I_L})\right] \\
\times \text{Regional Adjusted Subtotal} = \text{Cost}
\]

Enter amount on 7.0, Summary Cost Estimate.

8.0 ENGINEERING AND DESIGN

Engineering and design fees typically range from 10 to 20 percent of total project construction costs exclusive of mobilization, contingency, and project overheads (construction and project management). Contingency allowance must cover any additional engineering.

Because the engineering and design for AML projects is straightforward and can be standardized, use the low end of this cost factor, 10 percent.
9.0 MOBILIZATION

Estimate mobilization at $1,500 per major item of earthmoving equipment. Include items such as blast hole drills, dozers, loaders, and trucks larger than 30 ton capacity. Do not include items such as service trucks, vans, and compressors. Total mobilization allowance should not exceed 15% of construction cost (Line 7.0).

\[
\text{Cost} = (\text{_____ units} \times $1,500/\text{unit}) = $
\]

or

\[
\text{Cost} = (\$\text{_____ Subtotal #3} \times 0.15) = $
\]

Choose lower amount =

Enter total on 9.0, Summary Cost Estimate.

10.0 CONSTRUCTION MANAGEMENT

Construction management fees are not applicable for projects valued under $500,000. Construction management for larger projects is typically 1.5% of construction costs, Line 7.0.

\[
\text{Cost} = 0.015 \times (\$\text{_____ Subtotal #3}) = $
\]

Enter amount on 10.0, Summary Cost Estimate.
11.0 NPS PROJECT MANAGEMENT

11.1 Salaries.

\[(\text{staff } \times \text{ average salary/yr } \times \text{ duration in yr})\]

\[= \text{staff } \times \$\text{average salary}/\text{yr } \times \text{ yr} \]

11.2 Payroll burden and fringe benefits.

\[(\text{item 11.1 } \times \text{ benefit allowance})\]

\[= \$\text{benefit allowance} \times 0.\text{benefit rate} \]

11.3 Administrative supplies and equipment.

Estimate requirements for communications, small tools, postage, computer services, office supplies, etc.

11.4 Site visits.

\[(\text{number of visits } \times \text{ miles } \times \text{ mileage rate})\]

\[= \text{visits } \times \text{mi} \times \$\text{mileage rate} \]

\[(\text{visits } \times \text{ days/visit } \times \text{ per diem})\]

\[= \text{visits } \times \text{days/visit } \times \$\text{per diem} \]

11.5 Other expenses.

\[\text{[annual maintenance costs]}\]

TOTAL \[\rightarrow \]

Enter total on 11.0, Summary Cost Estimate.
## 12.0 CONTINGENCY

<table>
<thead>
<tr>
<th></th>
<th>No Experience</th>
<th>Previous Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preliminary Design</td>
<td>25%</td>
<td>15%</td>
</tr>
<tr>
<td>Definitive Engineering</td>
<td>15%</td>
<td>10%</td>
</tr>
<tr>
<td>Contract Bid</td>
<td>10%</td>
<td>5%</td>
</tr>
</tbody>
</table>

\[
(\text{Line 7.0} \times \text{Contingency Rate}) = \text{Contingency}
\]

\[
(\text{______} \times \text{______}) = \text{______}.
\]

Enter amount on 12.0, Summary Cost Estimate

## 13.0 MONITORING MAINTENANCE

### 13.1 Water sampling.

Decide on the number of site visits per year. Each site visit includes surface water and groundwater sampling, and chemical analysis. The groundwater sample requires pumping out standing water.

\[
(\text{______ sample sites} \times \text{______ samples/yr} \times \$500/\text{sample}) = \text{______}.
\]

Recalculate for each year as required for changes in number of sample sites or samples per year and enter amount on line 13.0, Annual Maintenance Cost.
14.0 REVEGETATION MAINTENANCE

14.1 Fertilization.

Generally, areas with more than 12 in. of topsoil only require one follow-up application of fertilizer. Less topsoil may require up to 4 applications over a 6 to 8 year period.

Estimate area requiring fertilization:

\[ (\text{_____ acres} \times \$100/\text{acre}) = \text{______} \]

14.2 Irrigation.

Estimate area requiring irrigation:

\[ (\text{_____ acres} \times \$3,000/\text{acre}) = \text{______} \]

\[ \text{TOTAL --------> ____} \]

Recalculate for each year as required for changes in fertilization and irrigation, and enter total on line 14.0, Annual Maintenance Cost.

REFERENCE: (USBM, 1986)
15.0 NPS MAINTENANCE MANAGEMENT

Monitor sites based on environmental conditions, type of closure, and number and type of visitors.

Weekly or daily for heavily visited sites with numerous potential hazards.

Weekly, monthly, or quarterly for sites that have been closed temporarily and receive numerous visitors.

Every 3 to 5 years for remote, permanently closed sites.

After winter, heavy precipitation, or winds and before numerous visitors until closed sites have stabilized.

15.1 Salaries.

\[(\text{staff} \times \text{average salary/yr} \times \text{duration})\]
\[= \text{Cost}\]

15.2 Payroll burden and fringe benefits.

\[(\text{item 15.1} \times \text{benefit allowance})\]
\[= \text{Cost}\]

15.3 Administrative supplies and equipment.

Estimate requirements for communications, small tools, postage, computer services, office supplies, etc.

15.4 Site visits.

\[(\text{number of visits} \times \text{miles} \times \text{mileage rate})\]
\[= \text{Cost}\]

\[(\text{visits} \times \text{days/visit} \times \text{per diem})\]
\[= \text{Cost}\]
15.5. Other expenses.

TOTAL -------> ________.

Recalculate for each year as required for changes in monitoring schedule, and enter total on line 15.0, Annual Maintenance Cost.
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INTRODUCTION

Mining is the most dangerous work in the United States. Hundreds of miners are killed every year, and tens of thousands more are seriously injured. In addition, occupational diseases like black lung, silicosis, and lung cancer attack more slowly and silently, but they kill just the same.

In recent years, notably 1969 and 1977, public support for better health and safety protection resulted in the passage of strong Federal laws. The Federal Coal Mine Safety and Health Act of 1969 was the first strong Federal mine safety and health law. Then the Federal Mine Safety and Health Act of 1977 extended coverage to all miners and encouraged the Mine Safety and Health Administration (MSHA) to enforce extensive regulations. The Act mandates the basic requirements for mine safety and health, and provides the authority for detailed regulations. The regulations are published in the Code of Federal Regulations (CFR) under Titles 30 and 42. MSHA is part of the Department of Labor.

This section provides an elementary discussion of mine safety and health to acquaint the reader with the unique aspects of mining concerns. Along with the references, this section is intended to be a springboard to an effective safety and health program for closing abandoned mine land (AML) sites. In addition, Tab VII Field Guide contains safety tips and a checklist of safety equipment for conducting site inventories and reconnaissance.

TO ENTER OR NOT?

The first answer to the question of whether or not to enter an abandoned underground mine is "don't, unless you have proper training and equipment." Federal regulations require training for all persons entering mines. The minimum required training differs based on the type of mine, and the individual's task and prior mining experience.

Once you have the required training and experience, the second answer on whether to enter or not is "don't, unless you have an appropriate need." Appropriate needs include the following:

* To determine which AML sites are the most hazardous and should be closed first.

* To assess impacts on park resources when assessment is not possible from the surface.

* To have a mine map available for rescues.

* Mine rescues.
* Mine closure.

National Park Service (NPS) guidance on abandoned mine safety is given in Loss Control Management, NPS-50, Chapter 30, "Abandoned Mine Safety." This guidance states that "Coal mines in particular will not be entered unless substantial justification overrides safety concerns. Underground evaluations should be conducted only by properly trained and equipped personnel and generally are necessary only where it is likely that visitors would enter the mines if they were in the area." Refer to Tab II for additional information on Chapter 30.

The Office of Surface Mining Reclamation and Enforcement (OSM) forbids entry of underground workings in excess of 25 feet or any deeper than is required to construct a suitable closure for each opening. OSM administers a program for reclamation primarily of abandoned coal mines. NPS sites reclaimed under this program are subject to the Surface Mining Control and Reclamation Act of 1977 and its regulations.
SAFETY TRAINING

(To be completed when Joe Nuggent, Chief Mines Inspector for Colorado, has the time to consult on the training content.)
ABANDONED MINE HAZARDS

A. Oxygen (O\textsubscript{2}) Deficiency (Anoxia) - Oxygen deficiency may result from combustion (including blasting), oxidization of organic material (e.g., mine timbers, coal), respiration in confined spaces, or replacement by other gases.

<table>
<thead>
<tr>
<th>Oxygen Content (% by Volume)</th>
<th>Effects and Symptoms (At Atmospheric Pressure)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical ambient air conditions.</td>
<td>20.95</td>
</tr>
<tr>
<td>Minimum permissible oxygen level.</td>
<td>19.5 *</td>
</tr>
<tr>
<td>Decreased ability to work strenuously.</td>
<td>15 - 19</td>
</tr>
<tr>
<td>May impair coordination and can induce early symptoms in persons with coronary, pulmonary, or circulatory problems.</td>
<td></td>
</tr>
<tr>
<td>Respiration increases in rate; pulse up; impaired coordination, perception, and judgement.</td>
<td>12 - 14</td>
</tr>
<tr>
<td>Respiration further increases in rate and depth; poor judgement; lips blue.</td>
<td>10 - 12</td>
</tr>
<tr>
<td>Mental failure; ashen face; blue lips; nausea; vomiting; fainting; unconsciousness.</td>
<td>8 - 10</td>
</tr>
<tr>
<td>8 minutes: 100% fatal</td>
<td>6 - 8</td>
</tr>
<tr>
<td>6 minutes: 50% fatal</td>
<td></td>
</tr>
<tr>
<td>4-5 minutes: recovery with treatment</td>
<td></td>
</tr>
<tr>
<td>Convulsions; coma in 40 seconds; respiration ceases; death.</td>
<td>4 - 6</td>
</tr>
</tbody>
</table>

The area should be evacuated at oxygen concentrations of less than 19.5%.
B. Common Life-Threatening Gases

1. **Carbon Monoxide (CO)** - Carbon monoxide is an odorless, tasteless, colorless gas that may build up in a confined space, usually as a result of combustion or blasting. It can also be produced by certain coals at room temperature. CO is slightly lighter than air, so may tend to stratify toward the roof of a drift. CO inhibits the oxygen-carrying capacity of the blood by combining more readily with hemoglobin than oxygen. In high concentrations of carbon monoxide, a person may collapse with little or no warning and thus be unable to aid himself.

<table>
<thead>
<tr>
<th>ppm</th>
<th>Effects and Symptoms</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 *</td>
<td>Permissible exposure level</td>
<td>8 hours</td>
</tr>
<tr>
<td>200</td>
<td>Slight headache; discomfort</td>
<td>3 hours</td>
</tr>
<tr>
<td>400</td>
<td>Headache; discomfort</td>
<td>2 hours</td>
</tr>
<tr>
<td>600</td>
<td>Headache; discomfort</td>
<td>1 hour</td>
</tr>
<tr>
<td>1000-2000</td>
<td>Slight heart palpitations</td>
<td>30 minutes</td>
</tr>
<tr>
<td>1000-2000</td>
<td>Tendency to stagger</td>
<td>1.5 hours</td>
</tr>
<tr>
<td>1000-2000</td>
<td>Confusion; headache; nausea</td>
<td>2 hours</td>
</tr>
<tr>
<td>2000-2500</td>
<td>Unconsciousness</td>
<td>30 minutes</td>
</tr>
<tr>
<td>4000</td>
<td>Fatal</td>
<td>Less than 1 hour</td>
</tr>
</tbody>
</table>

The area should be evacuated at carbon monoxide concentrations in excess of 50 ppm.

2. **Methane (CH₄)** - Methane is the most common flammable gas in mines, but other hydrocarbons such as ethane and propane may also be present in trace amounts. While hydrocarbon gases are most often associated with coal mines, they may also be found
in mines adjacent to oil and gas fields, or in strata which contain combustible materials. Methane is odorless, tasteless, and colorless, and stratifies along the ceiling of a drift since it is much lighter than air. Although it is not toxic, it acts as an asphyxiant by diluting oxygen concentration in the air. At a 5% concentration (by volume), methane in air will ignite. This is termed the "lower explosive limit," or "100% LEL." Methane also has an upper explosive limit at 300% LEL (15% by volume in air). Above this level, methane has displaced so much oxygen that there is no longer adequate oxygen to support combustion. These properties of methane are diagramed below:

![Methane Explosive Limits Diagram](image)

Figure 1. Methane Explosive Limits

The area should be evacuated at methane concentrations in excess of 20% LEL (1% by volume in air).
3. **Oxygen (O₂)** - Oxygen is potentially explosive in high concentrations. This would usually only be a problem where leaky oxygen tanks are stored.

The area should be evacuated at oxygen concentrations in excess of 23%.

4. **Carbon Dioxide (CO₂)** - Carbon dioxide is produced through respiration, combustion (including blasting), or it can exude naturally from coal seams, carbonate strata, and other rock types. It is colorless, much heavier than air, and has a slight acid taste when present in high concentrations.

While carbon dioxide is commonly present in the air (0.03%), it is hazardous in higher concentrations. The following chart demonstrates some of the effects of carbon monoxide.

<table>
<thead>
<tr>
<th>Concentration</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>5000 ppm (0.5%)</td>
<td>Breathing (ventilation) is deeper and faster than normal</td>
</tr>
<tr>
<td>3%</td>
<td>Ventilation doubles</td>
</tr>
<tr>
<td>10%</td>
<td>Tolerable only for several minutes at low activity (note: due to air displacement, 10% CO₂ concentration reduces oxygen content to 18.9%)</td>
</tr>
</tbody>
</table>

In typical respiration, we breath air at 20.95% O₂ and 0.03% CO₂, and exhale 16% O₂ and 4% CO₂. In confined spaces, therefore, oxygen can quickly be replaced by carbon dioxide.

Additionally, mining may intercept pressurized CO₂-bearing strata. Being much heavier than air, CO₂ stratifies along the floor of a drift and low-lying areas, displacing the air. This is why extreme caution, proper instrumentation, and approved procedures should be used when descending into a mine.

When entering a mine on a steady downgrade, a person may not be aware of elevated CO₂ until his mouth reaches the CO₂ level. By walking into the area,
however, the person has mixed the stratified gas with the good air above. The resulting mixture may be incapable of supporting respiration, and the person may not be able to evacuate the mine.

The area should be evacuated at carbon dioxide concentrations in excess of 5000 ppm (0.5%).

5. Hydrogen Sulfide ($\text{H}_2\text{S}$) - Hydrogen Sulfide is a colorless, toxic, and flammable gas which can be formed when blasting in sulfide ores, or may occur in some natural gas, oil, and coal fields. Although its foul odor (like rotten eggs) is easily detected at low concentrations, exposure and higher concentrations quickly desensitize the olfactory nerves, leaving a person unaware of its presence. In high concentrations, a person may collapse with little or no warning.

<table>
<thead>
<tr>
<th>ppm</th>
<th>Effects and Symptoms</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Permissible exposure level</td>
<td>8 hours</td>
</tr>
</tbody>
</table>
| 50 - 100 | Mild eye irritation  
             |          | 1 hour  |
|       | Mild respiratory irritation                              |         |
| 200 - 300 | Marked eye irritation  
             |          | 1 hour  |
|       | Marked respiratory irritation                            |         |
| 500 - 700 | Unconscious; death  
             |          | 0.5 - 1 hour |
| > 1000 | Unconscious; death                                       | minutes |

The area should be evacuated at hydrogen sulfide concentrations in excess of 10 ppm.

6. Radon gas (Rn-222) - Radioactive elements are unstable because, on the atomic level, their nuclei have more
protons and neutrons than they can hold. For instance, uranium-238 (U238) will decay through time to lead-206 (Pb206) in a defined sequence of steps. (See the Uranium Series chart below.) When an atom of a certain element "throws off" an alpha particle (composed of two neutrons and two protons, with an atomic mass of four) from its nucleus, it becomes a new element ("daughter," or "progeny" in the plural form) with an atomic mass of four less than the original element ("parent"). Discharge of an alpha particle in this manner is called "alpha radiation." Due to their size and mass, alpha particles are very damaging to sensitive living tissues.

When the atomic nucleus discharges a beta particle (a massless particle similar to an electron, but found only in the nucleus), the atom becomes a new element of the same atomic mass, but different atomic number. Discharge of beta particles is called "beta radiation."

Gamma rays (non-particulate energy rays) may accompany either of these processes. The half-life of an element is the time it takes for half of all the atoms present to undergo radioactive decay.
Most health-threatening radiation problems in natural settings are caused by alpha radiation emitted in the decay of the immediate progeny of radon gas. In brief, three radon daughters [notably Radon-A (RaA), Radon-C (RaC), and Radon-C' (RaC')] are the most active and dangerous alpha-emitters in nature. This is due partially to their short half-lives. For instance, U238 has a half-life of 4.5 x 10^9 years, so at any given time, any U238 present is emitting little alpha radiation. RaC', however, has a half-life of 16.4 microseconds, so it decays as soon as it is formed, thereby emitting large quantities of alpha.

When an atom of radon gas undergoes radioactive decay, an alpha particle and a RaA atom are produced. RaA then decomposes to Radon-B (RaB) by emitting an alpha particle. Through beta particle emission, RaB decays to RaC and RaC', which in turn decay by giving off more alphas.

The other reason why radon daughters are dangerous has to do with their high affinity for particulates in the air. Radon daughters are solid at standard temperature and pressure, and immediately attach, or "plate out" on dust particles, which can get lodged in lung tissue when inhaled. When the attached daughter undergoes radioactive decay in the lungs, it emits a high-energy alpha particle which in turn collides with and damages cells of the lung tissue. Since there is no "trapping mechanism" for radon gas (i.e., radon gas which has not decayed is simply exhaled, and the half-life of radon gas is 3.8 days, so it is not directly emitting much alpha radiation), it has relatively little effect on lung tissue.

With extreme or continued low-level exposure to radon progeny, lung tissue is scarred in such a manner that it cannot take oxygen into the bloodstream, thereby reducing breathing efficiency. Damage from this process is irreversible and cumulative through one's lifetime.

While radon progeny are certain to be present to some degree in abandoned uranium mines, they are not limited to this occurrence. Radioactive elements may be associated with other mineralization episodes, and occur in varying proportions throughout nature. Any confined airspace may host radiological activity.

Since radon progeny are airborne, they are controlled by ventilation and dust suppression. Personal protection is achieved through the use of a dust-filtering respirator in low concentrations, and an oxygen-supplied breathing apparatus in high
concentrations. In AML situations, the primary radiological concern is damage to lung tissue. Human skin effectively stops alpha radiation. While skin cells may get damaged from alpha exposure, the effect is much less hazardous than typical sunburn damage, and the damaged cells are replaced with new, healthy cells.

Radon daughter concentrations are measured in **working levels (WL)**. Occupational (mining) standards require that respirators be worn in radon daughter concentrations in excess of one WL. Concentrations in excess of ten WL require a supplied-oxygen breathing device. Miners, furthermore, are only allowed to accumulate an exposure of 692 **working level hours** per year. (1 WLH is the equivalent of 1 WL exposure for 1 hour, 2 WL for 1/2-hour, etc.) It is important to note that EPA guidelines for the general public are 10% of occupational standards. Therefore, the **general public is allowed 69.2 WLH exposure per year.**

MMB has the instrumentation and expertise to monitor for radon contamination of mine air. Additionally, samples can be taken of soil and water around mines to check for radium-226 (Ra226) levels. (Ra226, a solid, is the direct "parent" of Ra222, and is therefore the best parameter on which to test soil and water contamination. Soil and water radiological pollution standards are therefore primarily based upon Ra226 concentration.) NPS samples are currently being analyzed by EPA through an informal interagency agreement.

For those interested in a detailed paper entitled *Radioactivity and Abandoned Mineral Lands* is available from MMB.

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**The area should be evacuated at radon daughter concentrations in excess of 10 WL.**

**Respirators should be worn in radon daughter concentrations in excess of 1 WL.**

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**C. Falling Hazards**

1. **Shafts (Winzes, Raises)** - Shafts are vertical or declined openings exposed on the ground's surface, whereas winzes and raises are declined or inclined openings (respectively) underground inside of a mine. The area around the top of these openings is called the "collar." One of the primary dangers of vertical
openings is when the collar has deteriorated through weathering and wear. Loose rock around a collar, which slopes gradually into a shaft, creates a slipping hazard that can draw its victim into the shaft. Inside a mine, raises and winzes often connect between different levels. An explorer with inadequate lighting could easily walk into a winze left open in the floor. Rotten boards or plywood may also conceal a winze or shaft, and should never be trusted. Always check under any covering in a mined area which looks like it could conceal a vertical opening. Falls could result in a serious injury or death by the following means:

a. Impact on the walls or at the bottom of the shaft during a fall could cause an injury or fatality.
b. The shaft may be a trap for contaminated or oxygen-deficient air, so that the victim who survives the fall may be asphyxiated.
c. The shaft may be flooded at depth, presenting the possibility of drowning.
d. The victim may be unable to climb out, especially if injured. If he were unaccompanied in a remote situation, the victim could starve to death.

2. Glory Holes - Many underground mines will follow a mineralized area upward near or to the ground's surface. When underground workings reach or collapse to the surface in this manner, a glory hole is the result. Quite often, the caved area underground is much larger than the hole at the surface, thereby causing the glory hole to collapse and enlarge through time.

3. Stopes - Underground stopes are large, often irregular mine openings where an entire zone of mineralization has been excavated. Generally, the larger the stope, the less stable it is. Stopes may reach the ground's surface in the form of a glory hole, or may connect between levels in a mine. With inadequate lighting inside the mine, a person may fall into a stope breaking into the floor from a lower level.

4. Collapse Zones - Underground mine workings of any type which are near to the ground's surface may be subject to subsidence or collapse at any time. Be particularly aware of surface depressions around mine sites. Avoid walking in these areas, and see if they may correlate to mapped underground workings in the area.
5. **Highwalls and Steep Pit Walls** - Although this presentation primarily addresses underground mine hazards, it is appropriate to mention these surface mining features briefly. A highwall is the vertical (or near-vertical) exposure of an open cut on its uphill side. Open pits may also have extremely steep walls on all sides, or at least on faces which are not "benched" with roadways. Any steep rock wall exposed by blasting will tend toward instability through time, especially in a surface location where the rock is fully exposed to the forces of weathering. As with shaft collars, erosion near the edges may lead to a decayed, loose surface which increases the possibility of slipping and falling over the edge. For this reason, do not approach the perimeter of a pit or highwall to look over the edge.

D. **Cave-ins** - Unlike caves, mines are artificial, temporary openings which are designed to last as long as it takes to extract the ore. Left untended, rock and ground-support measures deteriorate and become incompetent. Soft, stratified rock types such as shale tend to collapse more easily, but often in smaller pieces. Harder, more massive rock types such as granite or sandstone collapse less frequently, but often more catastrophically in large blocks. Cave-ins may be the result of:

1. **Weak Rock** - The first way to assess rock stability is to look at the floor of the mine. If the floor is covered with loose rock, the mine is most likely unstable. If the floor is clean, rock conditions are most likely fairly stable. Stratified or severely jointed rock types are most prone to collapse under the forces of gravity, or from the force of "overburden" (pressure exerted by overlying rock). An area which is "taking on weight" may make creaking and popping noises, and sometimes rock under stress can be seen to shoot off in splinters. Timbers under stress are also prone to splintering and emitting creaking noises. Other signs of weight stress are crushed timbers or bent support steel beams.

2. **Decayed Timbers** - Through time, timbers which once supported the rock above will oxidize and rot. Although they may remain in-place and appear to provide support, they could be totally ineffective.

3. **Ineffective Rock Bolts** - Rock bolts are used to stabilize weak areas in a mine. Sometimes an abandoned mine may have entire areas where numerous bolts are found dangling several feet below the roof. In these areas, the rock which these bolts once supported has since collapsed.
E. **Explosives** - It is not uncommon to find explosives in abandoned mines. **Under no circumstances should explosives be handled or touched by anyone other than a certified blaster.** When explosives are found, any distinguishing characteristics should be noted, such as the form of the explosive and any printing on cases or on the explosives themselves. If there is any doubt whether the material in question is an explosive, assume that it is. The chief safety officer and superintendent should be notified and a certified blaster should be contacted to arrange for disposal.

Explosives may be found in several different forms:

1. **Powder** - "Powder" is the miner's term for explosives. Miners will often store their supply of explosives at the end of a drift, or in a small side room off of a main drift in the mine. Explosives are also often stored in a separate cache, away and separate from the rest of the mine. Explosives come in many forms, some of which are listed below:

   **Stick Dynamite** - Dynamite is produced in various sizes, but basically looks like a paper-wrapped mixture of packed moist sawdust or powder. It may vary typically from 6 inches to 2 feet in length, from 1/2 to 1-1/2 inches in diameter, and is usually packed in 50-pound cases. If the sticks appear wet or have clear beads of moisture on the surface, this is most likely nitroglycerine which has "bled" out of the dynamite. Nitroglycerine is the explosive component of dynamite, and is highly unstable when separated from the matrix of the dynamite stick. Bleeding can occur with age or when dynamite is heated.

   **Water Gels** - Water gels are similar in shape and packaging to stick dynamite, but have a plastic wrapper enclosing a jelly-like or creamy mixture in any variety of colors.

   **ANFO-Prill** - Prill, small porous pellets, typically comes in 50-pound bags. Rather than being placed in blast holes by hand, it is typically blown into the holes using compressed air.

   **Boosters** - Supplement caps and detonating cord when using less sensitive explosives. Vary in size and diameter weighing from 1/3-1 pound. Packaging varies from cans to plastic tubes.

   **Detonator Cord** - "Det cord" is round, flexible, brightly-colored, hard nylon cord with a center core of
high explosive. It is used to connect explosive charges together.

**Detonators** - Detonators, or blasting caps, are metallic cylinders about the size of a small cigarette with attached wires, plastic tubing, or cord. They may be found in storage caches, or, since they are easy to drop or misplace through carelessness, can be found laying about a mine site. They are very sensitive and are powerful enough to blow off a hand. Should be treated with the same respect as other explosives.

2. **Misfires** - Misfires are explosive charges which for some reason did not detonate with the rest of a blast. Miners check for misfires after each blast, but may sometimes overlook them. In entering a mine, an inspector watches the ribs (sides) back (roof, or ceiling), and faces (ends) of all drifts for misfires. If wires or dynamite can be seen protruding from a drill hole, it should be treated as a misfire. Misfires must be blasted in-place by a certified blaster. No attempt should be made to remove a misfire from the hole.

F. **Unsafe Structures and Ladders** - Due to rotting and desiccation, wooden headframes, platforms, ladders, etc. become weak and unstable. They should not be trusted to support your weight.

G. **Pools of Water** - Standing water may conceal flooded lower levels of a mine. Upon entering an abandoned mine, inspectors should probe any standing water in front of them with a bar or stick before proceeding.

H. **Disorientation** - In larger mines, it is easy to become disoriented. This can be quite unsettling, and may lead to panic. In a panic situation, all of the other underground hazards become that much more dangerous.

I. **Dangerous Animals** - An abandoned mine may serve as a refuge for poisonous snakes, disease-infested rats or bats, or to larger predatory mammals.

J. **Hazardous Materials** - Drums or other containers of unknown materials are often abandoned on a mine site or inside the mine itself. These containers should not be opened, and should only be handled by a hazard materials specialist.
K. **Danger to Rescue Teams** - Many people have lost their lives in attempting to rescue someone else. Parks with AML sites should contact State mine inspectors and safety officers at any nearby active mines. These people may have certified mine rescue teams at their disposal which could be used if a visitor or staff person required rescue from an abandoned mine. The park dispatcher should have emergency phone numbers for any available certified mine rescue teams.
REFERENCES


Mine Safety and Health Administration, Safety Manuals:
- Accident Investigation
- Accident Prevention
- Coal Mine Maps
- Coal Mine Roof and Rib Control
- Coal Mining
- Electrical Hazards
- Fault Tree Analysis
- Fire Safety
- First Aid
- Heat Stress in Mining
- Industrial Hygiene for Healthier Miners
- Job Safety Analysis
- Laboratory Safety
- Mine Escapeways
- Mine Gases
- Mine Ventilation
- Permissibility-Electric Face Equipment
- Personal Protective Equipment
- The Radiation Hazard in Mining
- Safety Tips for Underground Coal Mining
- System Safety Engineering
- Winter Alert

National Mine Health and Safety Academy, Beckley, West Virginia.

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CAUTION

ABANDONED MINES ARE HAZARDOUS

There are risks of falling, roof collapse, bad air, radon (even if uranium was not mined), toxic materials, abandoned explosives, rotten ladders and supports, and animals that consider the mine their territory.

Mines are temporary features that were never intended to last for centuries. Roof spans and support were intended to last only long enough to get the ore out, and must be continuously maintained. Operating mines are ventilated; and once abandoned, the fans are shutdown and passages critical to air circulation often collapse.

FOR INVENTORY AND RECONNAISSANCE, DO NOT ENTER COAL MINES, VERTICAL OR NEAR VERTICAL OPENINGS, AND DO NOT ENTER OTHER MINES UNLESS SUBSTANTIAL JUSTIFICATION OVERRIDES SAFETY CONCERNS AND UNLESS PROPERLY EQUIPPED AND TRAINED.
The field guide is a ready reference and checklist of procedures recommended for the inventory, reconnaissance, and monitoring of AML sites. A set of forms provide a logical sequence for collecting information required to inventory AML sites; plan site characterization, remediation or restoration; and prepare conceptual plans and preliminary cost estimates for budgeting. In addition, the guide contains back up information including engineering tables, formulas, and definitions useful in field work.

First, identify and locate AML sites:

* Search through archive records
* Talk to local people and park staff
* Search air photographs
* Follow old dirt roads
* Look on maps for mining symbols

The records search is most important; it provides investigators an idea of what to look for beyond the obvious. Many of the hazards and environmental impacts are hidden, buried, or lie below the surface. Graphic materials, such as old photographs, maps, and engineering drawings are particularly useful in identifying where to look to insure that the AML inventory is all inclusive.

Prior to field work, the investigators should become familiar with this guide, its forms, recommended field equipment, and safety procedures. To keep the guide as concise as possible, it assumes the investigators are generally familiar with AML inventory and remediation methods, and it assumes they have the required safety training.

Blank AML forms are found at the back of the guide. These forms can be separated and used as originals to make additional copies. Use these forms to guide the field work. Simply collect the data requested and fill in the blanks. When questions arise concerning what is required, refer to the form instructions which follow in the next section. For additional guidance, refer to the completed example forms following the instructions.

Complete only the AML Inventory Form if the purpose is simply to inventory the site.

Complete the AML Reconnaissance Form when the time comes to develop conceptual plans and estimate costs. The inventory and reconnaissance forms can be filled out on the same site visit which will save time and the expense of multiple visits.
After remediation or restoration, use the **AML Monitoring Form** to periodically update the condition of the site, report the environmental trends, and recommend additional remediation if required.

The third section of this guide, *Underground Reconnaissance Safety*, provides safety procedures for entering underground openings. This section is no substitute for underground safety training; it is simply a list of safety reminders. Underground reconnaissance teams must have the requisite training and experience.

Finally, the appendices contain additional useful information for field work. This information includes a checklist of recommended field equipment, methods for locating land features on topographic maps, procedures for compass and pace surveys, rating system for hazards and environmental impacts, formulas for calculating areas and volumes, a table of material weights, unit conversion factors, and definitions of selected mining terms.
INSTRUCTIONS ON AML FORMS

Go to each site and collect the information requested by the forms. At a minimum, fill out the AML Inventory Form. Fill out the AML Reconnaissance Form, if you want to develop a conceptual remediation plan and preliminary cost estimate. As described in Tab III, this plan can be used to execute small projects or used to contact the engineering and construction of larger projects. After project construction, follow up on how well the site has responded to the remediation, and document the resource trends with the AML Monitoring Form. Appendix A, Field Equipment, provides a check list of useful equipment for field work.

Do the best you can in filling out the forms. If you do not know some information, leave the question blank. If you can quantify, please do so. Where the forms have inadequate space, copy additional sheets of the form or continue on blank sheets that clearly refer back to the applicable question. Completed example forms are included after the instructions. Refer to these examples for additional guidance on how to fill out the forms.

If you are confused or have any questions, feel free to call MMB and ask:

MMB - (303)969-2092 or FTS 327-2092

AML INVENTORY FORM

TITLE BLOCK

Fill in the requested information as indicated in the Title Block.

Note that there is space for name and date of both the person conducting the original inventory and the person making any subsequent revisions. If additional revisions become necessary, continue to leave a trace of all revisions by repeating the previous inventories and adding the name and date of the latest revision in the form margins or attached sheets. The revised inventories should only show changes from the previous inventory so that it is clear what has been changed.

The Title Block asks for either the mine or district name. One inventory may be adequate for small mining districts. In addition, this block asks for the claim names. While historical records generally refer to the mine or district names, government land records use claim names. To avoid confusion, both names are required to clearly identify the site. The sources for this information include park historical records, county records [Phil
can you help on this], and MILS: Mineral Industry Location System of the Federal Bureau of Mines, Information Circular 8815.

LOCATION BLOCK

Location information is critical to the AML program. This information allows others to find the site, insures against duplication of sites in the AML inventory, and preserves a record of the site after remediation.

You will need the 7.5' quadrangle topographic map that covers the site. Obtain this map from the U.S. Geological Survey. First locate the site on the map. Then select a central or nearby reference point that is easily identified on both the map and ground. The reference point should be within the site, large and permanent, and accessible to field verification. Remember that both natural and man-made features can change with time. For quality assurance, provide both the Universal Transverse Mercator (UTM) coordinates and the land subdivision of the reference point. If you are unsure, Appendix B explains how to obtain this information.

Describe how to get to the site, particularly the part that leads up to the Location Map given in the next block.

LOCATION MAP

On the 7.5' topographic map, mark the 1) access route, 2) reference point with cross hairs and UTM coordinates, and 3) boundaries of the site including the area encompassing the AML features and their environmental impacts. Cut this part out of the map or copy, and attach to the space provided. Alternatively, attach the map frame prepared as described in Appendix B and add items 2) and 3).

Locate the AML features on the map. Number each feature for reference and describe the feature as instructed below in the Hazards and Environmental Impacts block.

If the surrounding terrain has significant relief, the location can be determined simply by matching the map contours and features with the actual ground surface. Alternatively, if the land surface is not distinctive or verification is required for hidden AML locations, the compass and pace survey explained in Appendix C is adequate for the AML inventory and preliminary planning.

GENERAL DESCRIPTION

In the first two lines, simply check the type of mining facilities present at the site, and list the commodities or minerals that were of interest. If commodities are unknown, research park records and MILS: Mineral Industry Location System of the Federal Bureau of Mines, Information Circular 8815.
Describe the salient features of the site in a concise statement that provides other readers an overall picture and general impression. Some features that might be described include the major mining impacts, environmental impacts, terrain, site aspect and slope, dominant vegetation, historic/cultural resources, scenic/visual resources, wildlife, and so on.

Describe evidence of visits to the site and inside underground openings and structures.

Fill in the overall site hazard and environmental ratings from the individual ratings given below for each hazard and environmental impact. The overall ratings should equal the highest individual ratings. These ratings will be used in deciding which sites to remediate first. Take care not to dilute their usefulness by inflating the ratings.

Indicate the presence of historic/cultural resources and the possibility of threatened and endangered species by circling the applicable answer. Before undertaking an AML inventory, the investigators must become familiar with 1) NPS and park policy on what constitutes an historic/cultural resource, and 2) local threatened and endangered species and their habitat.

HAZARDS AND ENVIRONMENTAL IMPACTS

Locate each feature on the Location Map with a unique reference number. List these features and their reference numbers in the space provided. Name the feature, describe the overall dimensions, hazards, and environmental impact. Recommend remedial action. Some features to look for include:

Hazards

* Are there hazardous underground openings such as shafts, adits, and subsidence; and surface excavations such as pits and quarries?
* Are there any highwalls or unnatural benches?
* Are there any pools of water evident in the mine workings or water draining from the mine workings?
* Are there any abandoned explosives in the workings?
* Are there tailings, spoil, refuse piles, or waste rock piles around? Comment on the size.
* Is there evidence of erosion, surface slumping, cave-ins, or landslides in and around the site (e.g. on the hillside in which the mine is located)?
* Is there evidence of active or past burning in underground workings or surface spoil piles?
* Are there structures, machinery, or debris around the site? If so, describe their number, type, and condition.
* Is the rock in which the mines are excavated stable (competent)? Does it appear that rock slabs and chunks
could easily be dislodged? A good indicator is how much loose rock is lying on the floor of underground openings (visible from entrance), pits, or quarries.

**Resources and Environmental Impacts**

* Water: Flowing out of mine or standing in mine workings; flowing onto, over, or through any dumps; stunted vegetation around and downstream from the site; discolored stream bottoms or ground; and no life in drainages.

Take samples and pH readings upstream and downstream from site. Locate sampling sites on map.

* Air: Airborne dust from barren mine workings or dumps.

* Soil: Topsoil removed or damaged; erosion; sedimentation; acidic or alkaline materials; heavy metals are almost always present at mill sites.

Take grab samples and locate on map.

* Vegetation: Healthy, stunted, or dead.

Describe plants that are damaged and why, if you know. Quantify damage.

* Wildlife: What kinds inhabit or visit the site.

Look for droppings, nests, and tracks particularly at the openings of underground workings. Evidence of animal habitation in underground workings is not a good clue to the air quality. Dead animals are fairly common in abandoned mine openings for a variety of reasons. Pay special attention to possible presence of threatened and endangered species.

* Visual: Landscape scars or easily spotted.

Rate each hazard and environmental impact with the evaluation criteria given in Appendix D.
NPS Unit: Rocky Mtn. N.P.  Inspector: Bob Higgins  Date: 8-7-90.
Mine/District: Miner Bills  Revised By:  Date:
Access: From Estes Park, take highway 34 to Fall River Rd. to Stop #10 (BM 9691).

STATE: CO  COUNTY: USGS 7.5' Quad: Trail Ridge
UTM Coordinates: 4474730 N  440800 E
T: 5N  R: 74W  Sec: 1/4 1/4

LOCATION MAP
**GENERAL DESCRIPTION**

<table>
<thead>
<tr>
<th>Type: Pit/Quarry</th>
<th>Underground</th>
<th>X</th>
<th>Placer</th>
<th>Mill</th>
<th>Buildings</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Historic Resources:</td>
<td>y/n</td>
<td>Threatened or Endangered Species:</td>
<td>y/n</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hazard Rating</td>
<td>18</td>
<td>Environmental Rating</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Description**: Cabin foundations at head of trail; vague 1/4 mi. trail to mine site; two small adits and associated waste rock; one adit collapsed.

**Visitation**: Infrequent; only mountain climbers may stumble onto site. No evidence of visits.

**HAZARDS AND ENVIRONMENTAL IMPACTS**

<table>
<thead>
<tr>
<th>Ref/HR/ER*</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/3A/3</td>
<td>Foundations of several cabins and head of trail.</td>
</tr>
<tr>
<td>2/1B/3</td>
<td>Lower adit - Portal partially timbered which is rotten. Opening is 5' wide by 7' high and is open more than 15'. Waste rock does not appear to have any sulfide minerals. Waste rock is too coarse for revegetation.</td>
</tr>
<tr>
<td>3/3B/3</td>
<td>Upper adit - Either collapsed or only a test pit. Very little waste rock and no visible timbering. Some revegetation has occurred. Between the limited amount of waste rock.</td>
</tr>
<tr>
<td>4/NA/2</td>
<td>Miners cut river bank to access water. Cut continues to erode.</td>
</tr>
</tbody>
</table>

*Sketch Reference Number/Hazard Ranking/Environmental Ranking
AML RECONNAISSANCE FORM

TITLE BLOCK

The Title Block must be exactly the same -- letter for letter -- as the Title Block in the AML Inventory Form; otherwise, computers are not likely to treat the information as coming from the same site.

SITE SKETCH

The Site Sketch must be drawn on a much smaller scale than the Location Map of the AML Inventory Form. Access shown in the Location Map need not be included in the Site Sketch. However, the reference point should be shown as it is the base for surveys.

For small sites, use a scale of 1:500 (1:480 is equivalent to 1 in. = 40 ft). The most common scale for the layout of mining facilities is 1:1200. A scale of 1:6000 is the maximum in common use. It is used to show an overview of large mining operations such as coal strip mines.

When plotting the site features, use the standard symbols shown in Fig. 1.

![Fig. 1 Standard Map Symbols for Mine Features](image)

Plot the inventory reference points at the selected scale. At each reference point, sketch in the AML feature with approximate dimensions. Pace off the dimensions, and if the feature is large or irregular in shape, conduct a compass and pace survey as described in Appendix C.

If you are unsure about what to measure, check the following instructions for the dimensions required for each type of feature. In some cases such as underground openings, a vertical cross section of the feature will significantly help in developing a remediation plan. The sample AML Reconnaissance Form illustrates the use of cross sections.
HAZARDS AND ENVIRONMENTAL IMPACTS

This section guides the investigators in obtaining the additional information required for conceptual project planning and preliminary cost estimating. In the following blocks of the form, the hazards and environmental impacts inventoried previously are classified into types to simplify the work. The impacts are grouped by underground closures, surface remediation, erosion and sedimentation control, revegetation, site characterization, and historical/cultural resources.

Keep a record of all calculations in the field notebook so that later on they can be checked.

Underground Closures

List all the underground openings in this block along with their reference number from the AML Inventory Form. Decide on a closure method, and measure the applicable dimensions.

Listed below are the dimensions required for each closure method. In some cases, all that is required for cost estimating is a count of the closure type. In other cases, the investigators must measure various dimensions to obtain lengths, areas, and volumes. Appendix E provides formulas for common geometric shapes.

For all closures, the investigators should draw a detail sketch with dimensions on the last page of the form.

<table>
<thead>
<tr>
<th>Closure Method</th>
<th>Required Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backfill Adits</td>
<td>Number of adits</td>
</tr>
<tr>
<td>Backfill Shafts</td>
<td>Volume- cu yd.</td>
</tr>
<tr>
<td>Blasting</td>
<td>Number of openings.</td>
</tr>
<tr>
<td>Cast-In-Place Cap</td>
<td>Number of shafts.</td>
</tr>
<tr>
<td>Precast Cap</td>
<td>Length and width- ft; overlap competent rock by minimum of 1 ft.</td>
</tr>
<tr>
<td>Monolithic Plug</td>
<td>Riprap- cu yd; concrete- cu yd; backfill- cu yd.</td>
</tr>
<tr>
<td>Standard Grates</td>
<td>Area- sq ft; for shafts, overlap competent rock by 1 ft and incompetent rock by 3 ft.</td>
</tr>
<tr>
<td>Bat Grates</td>
<td>Area- sq ft; for shafts, overlap competent rock by 1 ft and incompetent rock by 3 ft.</td>
</tr>
<tr>
<td>Cable Nets</td>
<td>Area- sq ft; for surface installation, extend dimensions minimum 2 ft beyond opening.</td>
</tr>
<tr>
<td>PUF</td>
<td>PUF volume, cu yd.</td>
</tr>
<tr>
<td>Adit Bulkhead</td>
<td>Number of openings up to 8 x 8 ft; number of larger openings up to maximum 15 x 15 ft.</td>
</tr>
</tbody>
</table>

Surface Remediation

On the Site Sketch, outline the various surface impacts and drainages that require remediation.
Distinguish the different types of areas with the recommended line types. Measure dimensions of the impacts and calculate volumes or areas with the formulas given in Appendix E. Total various areas and volumes of the same type and enter totals in the blanks.

Reference location of mine drainage on the Site Sketch, estimate flow rates, and fill in amount.

Collect grab samples of mine soils and drainage according to laboratory sampling protocols.

**Erosion and Sedimentation Control**

There is a large variety of erosion and sedimentation control methods each with their own estimating requirements. This block provides blanks for filling in selected control methods and applicable quantities.

Listed below are the quantities required for each method. Locate selected methods on the Site Sketch along with a unique reference number. For each selected method, find required quantities in the following list, measure dimensions, calculate quantities, and fill in the blanks.

<table>
<thead>
<tr>
<th>Control</th>
<th>Quantities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reshaping and Dozing</td>
<td>Earthmoving volume- cu yd.</td>
</tr>
<tr>
<td>Riprap Drop Struct.</td>
<td>Excavation volume- cu yd; structure length, width, height- yd.</td>
</tr>
<tr>
<td>Diversion Ditches</td>
<td>Total ditch length- ft; matting &amp; grass lining- acres; outfall riprap- cu yd.</td>
</tr>
<tr>
<td>Culverts</td>
<td>Length- ft; diameter- in.</td>
</tr>
<tr>
<td>Basins</td>
<td>Embankment volume- cu yd; liner- acres; spillway riprap- cu yd.</td>
</tr>
<tr>
<td>Handbuilt Ditches</td>
<td>Length- ft.</td>
</tr>
<tr>
<td>Handbuilt Waterbars</td>
<td>Length- ft.</td>
</tr>
<tr>
<td>Handbuilt Whattling</td>
<td>Length- ft.</td>
</tr>
<tr>
<td>Handbuilt Ravel Catch.</td>
<td>Length- ft.</td>
</tr>
<tr>
<td>Handbuilt Rock Armour</td>
<td>Cover area- sq ft.</td>
</tr>
<tr>
<td>Handbuilt Checkdams</td>
<td>Number of checkdams.</td>
</tr>
</tbody>
</table>

**Revegetation**

On the Site Sketch, outline various surface areas that require topsoil replacement, fertilization and seedbed preparation, seeding, transplanting, mulching, and irrigation.

Distinguish the different types of areas with the recommended line types. Measure dimensions of the areas and calculate the required volumes or areas with the formulas given in Appendix E. Total areas and volumes of the same type, and enter totals in the blanks.
Site Characterization

Site characterization requirements were deliberately left towards the end of the site reconnaissance tasks. This way the investigators will have a more in-depth understanding of the site, and hence any needs for further site characterization.

Locate study areas and monitoring sites on the Site Sketch. Outline study boundaries with the recommended line types, and reference monitoring sites with unique reference numbers. Estimate areas, count monitoring sites, and enter results in applicable blanks.

From park wildlife surveys, summarize the potential for threatened or endangered species. For these species, describe the presence of habitat and report sightings or spoor.

Describe the natural and environmental resource trends -- improving, deteriorating, or no apparent trend.

Access to the site influences the selection of remediation methods. Access may not be feasible for heavy construction equipment, and may be limited to backpacking, helicopter, small overland vehicles, etc. Describe the site access in sufficient detail for making decisions on construction methods.

HISTORICAL/CULTURAL RESOURCES

Check-off the presence of various types of historical and cultural resources. In addition, indicate the possible presence of buried or subsurface features by circling the applicable answer.

In the space provided, record historical/cultural features, and locate them on the Site Sketch with unique reference numbers. There is no need to repeat listing of features already referenced in other blocks.

Describe significant structures, roads, objects, the relationship of these features to each other, building materials, and artifacts. Report characteristics that seem special or unique. In addition, describe general condition of the features and trends -- improving, deteriorating, or no apparent trend.

PHOTOGRAPHS BLOCK

Photographs have great value as a memory aid, and a check on data collected for the inventory and reconnaissance. Most importantly, photographs help in understanding and visualizing the site, specially for those who do not have an opportunity to participate in the field work. The space provided in this block will help in recording photographs and eliminating confusion over their identity.
First, the roll of film should be identified with some unique marking. Locate the photographic site on the Site Sketch and give this point a unique reference number. Fill in this reference number in the first column of the Photographs Block. In the next two columns list the film marking and frame number of the photograph. From the point where the photograph is taken, measure the azimuth or bearing to the photographed feature, and record this direction in the fourth column. Alternatively, fill in the reference number of the photographed feature. Finally, give the photograph a title and add any explanatory comments.

DETAIL SKETCHES

Use this space for detail sketches and cross sections of referenced features. Be sure to label the detail sketch with reference number and scale. For guidance on drafting the sketches, use the instructions given under Site Sketch.
### HAZARDS AND ENVIRONMENTAL IMPACTS

Use the same reference numbers as on the AML Inventory Form.

#### UNDERGROUND CLOSURES

<table>
<thead>
<tr>
<th>Ref</th>
<th>Closure Type</th>
<th>Dimensions/Quantities &amp; Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Adit Bulkhead</td>
<td>5' x 7' use mine waste and nearby rock</td>
</tr>
<tr>
<td>3</td>
<td>Backfill</td>
<td>3yd x 4yd, average 1yd deep</td>
</tr>
</tbody>
</table>

Measure to applicable construction limits of closure type.

For depth use:
- Actual depth, if measured or known from records.
- ">"15 ft", if unknown and it appears open.
- "C", if opening is collapsed.

#### SURFACE REMEDIATION

<table>
<thead>
<tr>
<th>Map Symbol</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clearing and grubbing 0 acres</td>
</tr>
<tr>
<td></td>
<td>Earthmoving and backfilling 140 cu yd</td>
</tr>
<tr>
<td></td>
<td>Rock blasting 0 cu yd</td>
</tr>
<tr>
<td></td>
<td>Lime treatment 0 acres</td>
</tr>
<tr>
<td></td>
<td>Reshaping and dozing 0 cu yd</td>
</tr>
<tr>
<td></td>
<td>Structure demolition 6 cu yd - foundations</td>
</tr>
<tr>
<td></td>
<td>Mine drainage (Ref/gpd) none</td>
</tr>
</tbody>
</table>

#### EROSION AND SEDIMENTATION CONTROL

<table>
<thead>
<tr>
<th>Ref</th>
<th>Impact</th>
<th>Item/Quantity</th>
<th>Item/Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Bank Erosion</td>
<td>Rock armour 8yd³</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
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</tr>
</tbody>
</table>
AML RECONNAISSANCE FORM

REVEGETATION

Map Symbol/Ref Mitigation

- Topsoil replacement __ cu yd
- Fertilization __ acres Neutralization? yes/no
- Seeding __ acres Mulching? yes/no
- Transplanting __ acres
- Irrigation __ acres

SITE CHARACTERIZATION

Map Symbol/Ref Investigation

- Air monitoring station: yes/no (circle answer)
- Soils study area N/A acres
- Surface water monitoring sites N/A ea
- Groundwater monitoring wells N/A ea
- Vegetation study area N/A acres

Potential for threatened or endangered species None.

Describe environment and impact trends: Slightly above tree line; primarily alpine grasses; no erosion at edges; slow, long term revegetation trend. Erosion on river.

Describe access for construction: 1/4 mi mule trail, overgrown, elevation difference of 1300 ft.

HISTORIC/CULTURAL ALTERNATIVES TO REMEDIATION

Alternatives A. If there are other more complete sites, remediate this site and record history. B. Stabilize lower, edit and foundations, install gate in portal, improve trail, add interpretative signs.

Describe general condition: Mine, cabin foundations and stream bank continue to erode.

Evidence of subsurface features? yes/no (circle answer)
<table>
<thead>
<tr>
<th>Ref</th>
<th>Roll</th>
<th>Frame</th>
<th>Azimuth</th>
<th>Title/Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>N17°W</td>
<td>Lower Adit w/ view of pinnacles</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>2</td>
<td>N17°W</td>
<td>Close up of lower Adit</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>3</td>
<td>N45°E</td>
<td>Close up of upper Adit</td>
</tr>
</tbody>
</table>

**DETAIL SKETCHES**

- **Plan View**
  - Lower Adit
  - Waste Dump

- **Cross Section A-A**
AML SITE MONITORING FORM

This form documents the condition of AML sites during periodic monitoring. It is intended as a follow-up to inventory, reconnaissance, or remediation of a site. A monitoring form should be completed during each site visit, even if no changes are observed. Retain the completed forms as a record of site inspections.

TITLE BLOCK

The Title Block must be exactly the same -- letter for letter -- as the Title Block in the AML Inventory Form; otherwise, computers are not likely to treat the information as coming from the same site.

CURRENT HAZARD AND ENVIRONMENTAL CONDITIONS

Note changes in condition of a site or changes in visitor use patterns so that management of the area can be adjusted accordingly. All mine closures must be monitored because they can become ineffective through weathering or vandalism.

RECOMMENDATIONS

Recommendations should address whether the mine closure, remediation, or restoration that are currently in place are appropriate. The best management of the area will be effected by changes in the type and amount of visitor use; condition of mine closures; remediation or restoration; available funding; and management philosophy.

PHOTOGRAPHS BLOCK

Photographs from the original reference points provide further documentation, and help identify long term trends. See AML Reconnaissance Form for instructions on completing this block.
AML MONITORING FORM

TITLE BLOCK

Park Unit____________ Inspected By____________ Date____________.
Mine/District__________
Claim Name(s)______________ ______________ ______________.

HAZARD CONDITIONS

Describe original mitigation of hazards__________________________

Condition
Is mitigation functioning?__________________________ Yes__ No__ N/A__
Is there evidence of visitation?__________________________ Yes__ No__ N/A__
Is there evidence of vandalism?__________________________ Yes__ No__ N/A__
Are warning signs in place and functioning?__________________________ Yes__ No__ N/A__
Describe current conditions__________________________

ENVIRONMENTAL CONDITIONS

Describe original reclamation__________________________

Trends
Resource       Improving       Deteriorating       No Trend
Vegetation     ___             ___             ___             ___
Soils          ___             ___             ___             ___
Water          ___             ___             ___             ___
Visual         ___             ___             ___             ___
Structures     ___             ___             ___             ___
Other__________ ___             ___             ___             ___
Describe current conditions__________________________

RECOMMENDATIONS


Page VII - 19
## PHOTOGAPHS

<table>
<thead>
<tr>
<th>Ref</th>
<th>Roll</th>
<th>Frame</th>
<th>Azimuth</th>
<th>Title/Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>
Abandoned mines are inherently hazardous and must be treated as such by NPS staff. Many hazards are not obvious, and some cannot be detected without instruments. In most cases, there is no need to enter any of the abandoned mine workings; they are too dangerous.

COAL MINES, VERTICAL OR NEAR VERTICAL OPENINGS WILL NOT BE ENTERED UNLESS SUBSTANTIAL JUSTIFICATION OVERRIDES SAFETY CONCERNS AND UNLESS PROPERLY TRAINED AND EQUIPPED.

Underground reconnaissance should be conducted only by properly trained and equipped personnel, and generally are necessary only where visitors are likely to enter the mine. Underground mines that are not entered for reconnaissance should be considered very hazardous and a high priority for closure.

In the event entry is necessary, the team should have available the safety equipment listed in Appendix A, Field Equipment.

REFERENCE

Loss Control Management Guideline, NPS-50, Chapter 30, Abandoned Mine Safety.

UNDERGROUND PROCEDURES FOR ADITS

1. The team will be trained and experienced in underground mine safety and health, including potential hazards, underground mine safety procedures, and the use of safety equipment. Health and safety equipment must be approved by the Mine Safety and Health Administration (MSHA).

2. Underground teams will consist of at least two people. If three or more people are present, one person will remain at the mine entrance. The underground crew will check in with this person at predetermined time intervals.

3. Underground teams must have a communication link with park officials and mine rescue teams. This link can be done effectively by radio to the park dispatcher.

4. Underground teams will enter with one person in front followed by the second person at a minimum distance of 50 ft.
5. Rock conditions will be checked with a scaling bar by a properly trained person. Entry will not continue if extensive barring of loose rock is required.

6. If multi-gas detector signals an alarm, or at the first sign of symptoms from bad air (i.e., headache, dizziness, slurred speech, nausea, etc.) in any team member, the symptoms will be announced to the team, and the mine will be evacuated by all personnel immediately.

7. Only when necessary, the team may work for reasonable periods of time in concentrations of airborne contaminants exceeding permissible levels if they are protected by appropriate respiratory equipment. At least one other person with backup equipment and rescue capability is required in the event of failure of the respiratory equipment.

8. Underground team members will maintain voice contact with each other at all times.

9. Underground teams will not:
   a. proceed through caved areas.
   b. proceed over rotten ladders or structures.
   c. enter shafts or other near vertical openings.
   d. disturb explosive materials.

   Record presence and description of explosive material on AML Inventory Data Sheet, and notify park superintendent, chief safety officer, and regional blasting officer to arrange for disposal.

10. Water courses and pools will be probed for depth with a bar or pole to determine whether it is safe to proceed through water.

11. Underground team will remain underground only long enough to complete the necessary work.

HAZARD MITIGATION

1. For immediate, short term mitigation, post warning signs of the abandoned mine. Refer to Tab VI for additional information on warning signs.

2. If hazards have been noted with a potential for injury, notify regional safety officer and recommend that any interpretative walks or other entry into mine workings be discontinued.
DANGER!
ABANDONED MINE HAZARDS

ROTTEN STRUCTURES

DEADLY MINE OPENINGS

LETHAL GAS & LACK OF OXYGEN
DANGEROUS ANIMALS

UNSAFE LADDERS

CAVE-INS & DECAYED TIMBERS

UNSTABLE EXPLOSIVES

DEEP POOLS OF WATER

STAY OUT
STAY ALIVE
DANGER! ¡PELIGRO!
ABANDONED MINE HAZARDS
PELIGROS DE MINAS ABANDONADAS

UNSAFE MINE SHAFTS & HIGHWALLS
POZOS DE MINAS PELIGROSOS

DEADLY GAS & LACK OF OXYGEN
GASES MORTALES Y FALTA DE OXIGENO

CAVE-INS & DECAYED TIMBERS
HUNDIMIENTOS Y MADERAS PODRIDAS

UNSAFE LADDERS
ESCALERAS PELIGROSAS

UNSTABLE EXPLOSIVES
EXPLOSIVOS INESTABLES

DEEP POOLS OF WATER
CHARCOS DE AGUA PROFUNDOS

ROTTEN STRUCTURES & EQUIPMENT
ESTRUCTURAS PODRIDAS Y EQUIPOS DAÑADOS

STAY OUT NO ENTRE
STAY ALIVE PROTEJA SU VIDA
3. If explosive material is present, notify park superintendent, chief safety officer, and regional blasting officer to arrange for disposal.

SUMMARY OF HAZARDS

Shafts may be hidden or have loose rock and rotten timbers.

Explosives may be deteriorated and unstable.

Water may be contaminated, hide vertical shafts, conceal sharp rusty metal, or create a slipping hazard.

Dangerous substances may be left over from when the mine was active such as cyanide, ammonia, PCB's, asbestos insulation, etc.

Debris may be present such as broken glass, nails, sharp and rusted objects.

Cave-ins or cave-in potential may exist in that most mines were never meant to last more than a few years. Due to age, weathering, and rotten shoring, walls and roof are susceptible to collapse.

Bad air may exist including insufficient oxygen, poisonous, radioactive, and explosive gasses.

Animals may inhabit the mine workings including poisonous snakes, spiders, scorpions, rats, bears, mountain lions, wasps, bees, bats, skunks, javelina, ring tailed cats, coyotes, etc.
COSTING DATA

1.0 SITE CHARACTERIZATION AND MONITORING

<table>
<thead>
<tr>
<th>Description</th>
<th>AMOUNT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Soils study area, acres</td>
<td></td>
</tr>
<tr>
<td>1.2 Surface water monitoring sites, ea</td>
<td></td>
</tr>
<tr>
<td>1.3 Groundwater drilling depth, ft</td>
<td></td>
</tr>
<tr>
<td>1.4 Monitoring wells, each</td>
<td></td>
</tr>
<tr>
<td>1.5 Air monitoring, yes/no</td>
<td></td>
</tr>
<tr>
<td>1.6 Vegetation study area, acres</td>
<td></td>
</tr>
<tr>
<td>1.7 Presence of historical/cultural items, yes/no</td>
<td></td>
</tr>
</tbody>
</table>

2.0 UNDERGROUND MINE CLOSURE

2.1 Openings:

<table>
<thead>
<tr>
<th>ID</th>
<th>CLOSURE TYPE</th>
<th>DIMENSIONS (ft x ft x ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td># 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td># 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td># 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td># 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td># 5</td>
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</tr>
<tr>
<td># 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td># 7</td>
<td></td>
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</tr>
<tr>
<td># 8</td>
<td></td>
<td></td>
</tr>
<tr>
<td># 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td># 10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For cross section dimensions, measure to applicable construction limits of closure type.

For Depth Use: - Actual depth, if measured or known from records.
- ">15 ft", if actual depth is unknown and opening is clear to a depth greater than 15 ft.
- "C", if opening is collapsed.

### 3.0 SURFACE MITIGATION

<table>
<thead>
<tr>
<th>Activity</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clearing and grubbing, acres</td>
<td>.</td>
</tr>
<tr>
<td>Earthmoving and backfilling, cu yd</td>
<td>.</td>
</tr>
<tr>
<td>Rock blasting, cu yd</td>
<td>.</td>
</tr>
<tr>
<td>Lime treatment, acres</td>
<td>.</td>
</tr>
<tr>
<td>Reshaping and dozing, cu yd</td>
<td>.</td>
</tr>
<tr>
<td>Acid mine drainage, gpd</td>
<td>.</td>
</tr>
<tr>
<td>Demolition, cu ft</td>
<td>.</td>
</tr>
</tbody>
</table>

### 4.0 EROSION AND SEDIMENTATION CONTROL

<table>
<thead>
<tr>
<th>Activity</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reshaping and dozing, cu yd</td>
<td>.</td>
</tr>
<tr>
<td>Riprap drop structures:</td>
<td></td>
</tr>
<tr>
<td>Earthmoving, cu yd</td>
<td>.</td>
</tr>
<tr>
<td>Drop length, yd</td>
<td>.</td>
</tr>
<tr>
<td>Structure cross section, yd x yd</td>
<td>.</td>
</tr>
<tr>
<td>Geologic drop structures:</td>
<td></td>
</tr>
<tr>
<td>Earthmoving, cu yd</td>
<td>.</td>
</tr>
<tr>
<td>Drill and blast, cu yd</td>
<td>.</td>
</tr>
<tr>
<td>Diversion ditches:</td>
<td></td>
</tr>
<tr>
<td>Length, ft</td>
<td>.</td>
</tr>
<tr>
<td>Jute matting and grass lining, acres</td>
<td>.</td>
</tr>
<tr>
<td>Riprap, cu yd</td>
<td>.</td>
</tr>
<tr>
<td>Culverts:</td>
<td></td>
</tr>
<tr>
<td>Sedimentation and treatment basins:</td>
<td></td>
</tr>
<tr>
<td>Embankment, cu yd</td>
<td>.</td>
</tr>
</tbody>
</table>
4.6.2 Liner, acres
4.6.3 Spillway riprap, cu yd

4.7 Handbuilt hillslope structures:
4.7.1 Trenches and ditches, ft
4.7.2 Waterbars, ft
4.7.2 Whattling and ravel catchers, ft

4.8 Handbuilt drop structures:
4.8.1 Rock armour, ft²
4.8.2 Checkdams, each

5.0 REVEGETATION

5.1 Topsoil replacement, cu yd
5.2 Fertilization and seedbed preparation, acres
5.3 Seeding and transplanting:
5.3.1 Seeding, acres
5.3.2 Transplanting, acres
5.4 Mulching, acres
APPENDIX A

FIELD EQUIPMENT

FOR SITE INVENTORY

USGS 7.5' Topographic Map of Site

Camera and Film

Mine Hazard Warning Signs

AML Field Guide

FOR COMPASS AND PACE SURVEY

Professional Magnetic Compass

Clinometer

Protractor

Engineer's Scale

Engineer's Field Notebook and 4-H Pencil

Hand Calculator w/ trigonometric functions

FOR SITE RECONNAISSANCE

In addition to preceding items:

pH Meter

Sample Containers
Obtain from analytical laboratory the appropriate soil and water containers, and correct sampling and quality assurance/quality control procedures.

FOR UNDERGROUND RECONNAISSANCE

Health and safety equipment must be approved by the Mine Safety and Health Administration (MSHA). All personnel entering underground workings must receive MSHA approved health and safety training.

Individual Equipment:

Hardhat

Gloves
Safety Boots

Mine Light
Spare Light
The underground team should have at least two sources of light. All sources should be explosion-proof unless it has been previously determined that no explosive gases are present.

Eye Protection
Safety glasses are required. The use of contact lenses is discouraged.

Self Rescuer
Use self-rescue units approved by MSHA for use in coal mines. Each person must be trained in use of self-rescue units.

Radon Respirator
Worn at all times in radon daughter concentrations in excess of 1 WL.

Oxygen Supply
Activated when bad air is present.

Additional Equipment for Lead Person:

Scaling Bar

Multi-Gas Detectors
Monitors for acceptable levels of oxygen and hazardous levels of carbon monoxide, explosive gases, and radon.

Communication
Before entering mine, establish communication with someone outside the mine.

Mine Rescue Contingency Plan
Plan should include 1) known hazards; 2) other suspected hazards; 3) mine rescue contacts: names, phone numbers, backup phone numbers, radio contact; and 4) special conditions under which reconnaissance will not be attempted. Refer to Loss Control Management Guideline, NPS 50, Chapter 30, Abandoned Mine Safety.
APPENDIX B

LOCATING LAND FEATURES ON TOPOGRAPHIC MAPS

UTM COORDINATES

To determine the Universal Transverse Mercator (UTM) coordinates, you will need 1) the 7.5' quadrangle topographic map that covers the site area, 2) a metric scale, and 3) a sharp pencil. The maps are published by the U.S. Geological Survey.

Note that UTM coordinates are metric, whereas all other measures used in this handbook are the English system. Appendix F lists some common conversion factors.

With the help of the map legend, find the tick marks for the UTM grid. Determine which of the grid cells contain the AML site and reference point. With a straight edge, frame the site by drawing lines between opposing tick marks of the grid cells.

When drawing the lines, align the straight edge so the pencil point will intersect the tick marks. Be sure that the edge is not directly over the tick marks or the width of the pencil will offset the framing line. Strive to keep the pencil point against the straight edge at all times.

For the north UTM coordinate, lay the 0 division of the scale on the bottom framing line, and lay the appropriate upper scale division on the upper framing line. The UTM grid is 1000 meters on each side, so the upper framing line should fall on a multiple of 1000 meters that equals the number of included cells.

Slide the scale laterally until it intersects the reference point. Be careful to keep the 0 division and top division on the framing lines.

Read up the scale from the 0 division to the reference point. Add this value to the north coordinate value of the lower framing line. The result is the north coordinate of the reference point.

For the east UTM coordinate, repeat the last three steps except use the left and right framing lines, and place the 0 division of the scale on the left framing line.

To improve map readability, note that the first two digits of the number are printed small, the three trailing zeros are printed intermittently, and some tick marks are not numbered when there is overlapping information.

The framed area of the map makes an excellent base for a Location Map. Label the framing lines with their UTM coordinates, cut the area out or copy including the last leg of
easily recognizable access, and attach to the AML Inventory Form in the space provided for the location sketch.

PUBLIC LAND RECTANGULAR SURVEY SYSTEM (LAND SUBDIVISION) - SECTION, TOWNSHIP, AND RANGE

For land subdivision, the area between a pair of standard parallels and a pair of guide meridians is subdivided into approximate 36 square mile areas (approximately 6 miles on a side). These areas are defined as Townships, and a system was devised to designate the location of a particular Township and its subdivisions. This system provides a backup check for the location of an AML site. See Fig. B1 for an illustration of the system.

The east-west rows of Townships are counted north or south from a baseline, for example Township 3 South (T3S). A Range is a north-south column of Townships which are counted east or west from a principal meridian, for example Range 93 West (R93W).

The Townships are divided into approximate squares of land of sides approximately one mile long, and these subdivisions are called Sections. The sections are numbered as shown in Fig. B1.

Sections are subdivided into quarters and into quarters or halves of quarters. These quarters are not shown on the 7.5' quadrangle maps and must be determined with the template provided in the pocket of the back cover. A particular subdivision is designated starting with the smallest subdivision first and expanding to the next largest subdivision followed by the Township and finally the Range. For example, in Fig. B1 a point is given in the illustration of a section subdivision along with its designation.

Some townships are smaller than the standard size. In this case, the subdivision is done by running section lines parallel to the east and north boundaries so as to place all error and convergence into the west and south tiers of sections. In these small townships, align the section template in the northeast corner.

Figure B1. Township/Section Location System
(Kelly, 1964, p.86)
APPENDIX C

COMPASS AND PACE SURVEY

The survey will require 1) professional magnetic compass, 2) clinometer, 3) protractor, 4) engineer's scale, 5) calculator with trigonometric functions, and 6) engineer's field notebook with stiff binding and sharp 4-H pencil.

DIRECTION

The compass is used to determine horizontal angles. There are two basic compass types -- one indicates azimuths and the other bearings.

For azimuths, the compass circle is graduated in degrees from 0° to 360° counter clockwise.

For bearings, each quadrant of the compass circle is numbered from 0° to 90° degrees, and a typical bearing is N 30° W.

With both types, the compass circle is lettered and degrees numbered in reverse: east and west are interchanged and the degrees are numbered counter clockwise. This way, north of the graduated compass circle is pointed at a feature, and the compass needle points to the azimuth or bearing which can be read directly from the compass circle.

The compass is held waist high and flat in the left hand with left forearm pressed against the waist. The compass is further steadied with the right hand. The compass needle must be free floating and not bind on the compass case. The compass is correctly sighted when north of the compass circle points to the feature. The north seeking end of the compass needle (usually painted white) then points to the feature's azimuth or bearing on the compass circle. Record this bearing in the field book (sample field notes are shown in Fig. C1) and correct for magnetic north, as follows:

The magnetized compass needle seeks and points toward magnetic north which differs from the geographic north pole by an angle equal to the magnetic declination. Magnetic declination is found in the margin notes of 7.5' topographic maps. Fig. C2 illustrates a typical magnetic declination. Some compasses have the means to adjust the compass circle for local magnetic declination, and geographic north can be read directly. In this case, adjust the compass circle as directed by the compass instruction manual.

If the compass circle cannot be adjusted, geographic north must be calculated from magnetic north and declination.
Figure C1. Survey Notes
(Kelly, 1964, p. 181, 184)
Figure C2. Magnetic Declination
(Kelly, 1964, p. 72)

Figure C3. Horizontal Distance
(Kelly, 1964, p. 74)
For azimuths, this calculation is simply an addition or subtraction of the declination angle from the magnetic north reading. Add the declination if magnetic north is east of geographic north, and subtract if magnetic north is west of geographic north.

For bearings, the calculation depends on both the relative position of magnetic and geographic north, and the quadrant. If magnetic north is east of geographic north, add the declination angle to magnetic north in the NE and SW quadrants, and subtract in the NW and SE quadrants.

**DISTANCE**

Determine the distance between site features by pacing. Count paces between features and convert to ground distance by multiplying paces by your pace length. Beware that pace length is not a consistent quantity. Many things affect pace length such as fatigue, speed at which one walks, slope of the ground, and weather conditions.

Before leaving for the field, pace a known or tape measured distance. Count your steps and time the course. The distance should exceed 100 ft for a reliable average pace length. Divide the distance by the number of paces, and the result is average pace length. Use the course times to control your walking rate. Repeat this procedure several times to obtain an average pace length. In addition repeat the procedure for various types of terrain -- level and steep, up and down hill, etc. Record the results below and use to measure length in the field.

(1) Level Ground: Measured Distance=______ft
Trial: 1 2 3 4
Time: _____ _____ _____ _____ Average=_____.
Paces: _____ _____ _____ _____ Average=_____.
Unit Pace Length = ____ ft / ____ paces = ____ ft/pace

(2) Up Slope: Measured Distance=______ft
Trial: 1 2 3 4
Time: _____ _____ _____ _____ Average=_____.
Paces: _____ _____ _____ _____ Average=_____.
Unit Pace Length = ____ ft / ____ paces = ____ ft/pace

(3) Down Slope: Measured Distance=______ft
Trial: 1 2 3 4
Time: _____ _____ _____ _____ Average=_____.
Paces: _____ _____ _____ _____ Average=_____.
Unit Pace Length = ____ ft / ____ paces = ____ ft/pace
In the preceding trials, do not include suspect values that deviate significantly from the trials.

Slopes must be converted to horizontal distance. First pace the slope, and convert paces to distance with the appropriate unit pace length. Measure the vertical angle (angle of slope) between points. See Fig. C3. Convert slope distance to horizontal distance with the following formula:

\[ \text{Horizontal Distance} = \text{Slope Distance} \times \cos(\text{Vertical Angle}) \]

The measured distance must be a relatively constant slope. If there are any significant breaks in the slope, it must be broken into segments that are individually surveyed.

Vertical angles are measured with a clinometer. Alternatively, some professional compasses have built-in clinometers. For measuring vertical angles, follow instructions with clinometer or compass. Because there is such a variety of these tools, here it is not possible to provide any general instructions on their use.

FIELD NOTES

The following instructions should be observed in recording a survey (refer to Fig. C1 for example field notes):

1. Use standard engineers' field notebook with stiff binding.
2. Use 4-H or harder pencil sharpened so as to indent paper.
3. Print all notes and never erase. Make notes permanent, legible, and complete.
4. Record all observed and calculated data immediately. All field calculations should be recorded in the notes.
5. Anticipate questions that may arise concerning interpretation of the notes and arrange notes to be self-explanatory.
6. Good notes have many explanatory remarks and sketches.
7. Set up a Table of Contents before starting the first survey. Column headings should include name of AML site, survey title, date, and page number. Leave enough blank pages for a complete Table of Contents.
8. Number the right hand pages only, in upper right-hand corner.
9. Write AML site and survey title at the top of each left-hand page.

10. Always start a new survey on a new pair of pages.

11. The left-hand page should contain the field data in table form.

12. The right-hand page should include:
   a. Date of survey.
   b. Place of survey.
   c. Name of field notes recorder.
   d. Names of other members of party and their roles.
   e. Weather conditions.
   f. Sketches.
   g. Descriptions.

13. Whole pages in error should be marked "abandoned," and one diagonal line drawn across the page.

TRAVEL WISE PROCEDURE

Set-up field notes as shown in Fig. C1. Sketch the survey on the left-hand page.

Plan the route of the traverse so that it becomes a polygon, a closed plane figure bounded by three or more line segments. If it is impractical to incorporate all the AML features as vertices in a polygon, add intermediate turning points or break-up the survey into several polygons. Polygons provide a convenient method of quality control.

Start the compass traverse from the reference point selected and mapped in the above Location Block. With the compass, find the direction of the first AML feature or turning point. Record the point and its direction in the field notebook.

Pace the distance to the point, record paces, and convert to distance. Sketch significant objects along or crossing this traverse segment such as buildings, fences, roadways, power lines, waterways, etc.

At each turning point or AML feature in the traverse, measure the forward magnetic bearing to the next point, and, for quality control, the back magnetic bearing to the preceding point. Calculate average bearings of the foresight and backsight except in cases that indicate a magnetic disturbance causing a wide difference between back and forward bearings. In these cases, use as true bearing the value obtained from the sighting not affected by the magnetic disturbance.
From the average bearings of adjacent lines calculate the interior angles between lines. Fig. C4 illustrates the conversion of bearings or azimuths to interior angles.

Repeat the distance and bearing measurements to each of the AML features and intermediate turning points. Finally, close the survey by returning to the reference point or beginning point.

QUALITY CONTROL

For a quick check, total the interior angles which should approximate 360°. In the field notes, indicate the total error and the average error per angle. If the average error is more than 3°, look for calculation errors and/or repeat the traverse. If the average error is acceptable, adjust each angle by the average error.

For a more thorough check, use the method of balancing latitudes and departures. The method is illustrated in Fig. C5. The upper half of the figure illustrates the definitions of latitudes and departures.

**Latitude** is the projection of a given course on a north-south line. It is taken as positive towards the north.

\[
\text{Latitude} = \text{Length} \times \cos(\text{Bearing Angle})
\]

**Departure** is the projection of a given course on an east-west line. It is taken as positive towards the east.

\[
\text{Departure} = \text{Length} \times \sin(\text{Bearing Angle})
\]

The algebraic total of latitudes, and the algebraic total of departures in a closed traverse should equal zero. However, it is impossible to run a survey with sufficient accuracy to accomplish this condition. If the error of closure, that is the difference between the algebraic total and zero in latitudes or departures, is relatively small or less than 3%, the traverse is balanced so that the totals do come out to zero. First, the angles must be balance as described above. Then adjust the latitudes and departures with the following formula:

\[
\text{Segment Error (Lat or Dep)} = \frac{\text{Total Error} \times \text{Total Traverse Length}}{\text{Total Traverse Length}}
\]

After this adjustment, calculate the adjusted segment length by solving either of the above latitude or departure formulas, as follows:

\[
\text{Length} = \frac{\text{Adjusted Latitude}}{\cos(\text{Bearing Angle})} \quad \text{or}
\]

\[
\text{Length} = \frac{\text{Adjusted Departure}}{\sin(\text{Bearing Angle})}
\]
If the total error is unacceptable, check for computation errors and/or repeat the traverse.

Figure C4.
(Kelly, 1964, p. 81)

Figure C5.
(Kelly, 1964, p. 93)
APPENDIX D

WEIGHTS AND MEASURES

For site inventory or reconnaissance, this section describes quick-and-dirty methods for estimating the physical size of AML sites when in the field with nothing more than the equipment listed in Appendix A. Estimate length with paces and convert to feet or yards as described under Distance in Appendix C. The following methods provide crude estimates of area, volume, and tonnages. These methods are adequate only for preliminary planning, cost estimates, and budgeting. Afterwards, if the site warrants detailed characterization and engineering, revise estimates with professional land surveys.

AREA

Match the given area with one of the shapes below. Pace the indicated sides and convert into length with preceding unit pace length. Substitute lengths into given formula and calculate area. For a complex area, subdivide into simple shapes given below, calculate area for each shape, and add areas for a total area.

Square:

Area = $a^2$ or Area = $0.5 \, d^2$

Rectangle:

Area = $ab$

Parallelogram (opposite sides parallel):

Area = $ah$
Trapezoid (four sides, two parallel):

Area = 0.5h(a+b) or Area = hm

Triangle:

Area = 0.5bh

Circle:

Area = 3.14r² or Area = 0.785d²

Circumference = 6.28r or = 3.14d

Alternative Method For Irregular Shapes

Area = h[.05(y₀+y₁)+y₁+y₂+y₃+…+yₙ₋₁]

VOLUME

Match the given volume with one of the shapes below. Pace the indicated sides and convert into length with above unit pace length. Where a formula requires a base area, calculate area with formulas in preceding section. Substitute lengths and base areas into given formula and calculate volume. For a complex volume, subdivide into simple shapes given below, calculate volume for each shape, and add volumes for a total volume.

In the following formulas B is area of base, and h is altitude of the volume. Altitude can be obtained from topographic maps by subtracting contour elevation of the base from contour elevation of the top. Alternatively, pace the side slope, measure its vertical angle with clinometer, and use trigonometry to determine the altitude.
Prism or Cylinder:

Volume = Bh where B is area of base.

Pyramid or Cone:

Volume = 0.33Bh where B is area of base.

Frustum of Pyramid or Cone:

Volume = 0.33[A_1 + A_2 + (A_1A_2)^{0.5}]h
where A_1 and A_2 are areas of bases.

Wedge:

Volume = 0.5Bh((L_1 + L_2 + L_3)/3)
where B is area of base.

TONNAGE

Select appropriate unit weight from Table D-I. Substitute unit weight and volume in the following formula and calculate tonnage.

Tonnage = ____ yd^3 x ____ tons/yd^3
<table>
<thead>
<tr>
<th>Material</th>
<th>Loose</th>
<th>Bank**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basalt</td>
<td>1.65</td>
<td>2.50</td>
</tr>
<tr>
<td>Bauxite, Kaolin</td>
<td>1.20</td>
<td>1.60</td>
</tr>
<tr>
<td>Caliche</td>
<td>1.05</td>
<td>1.90</td>
</tr>
<tr>
<td>Carnotite, Uranium Ore</td>
<td>1.38</td>
<td>1.85</td>
</tr>
<tr>
<td>Cinders</td>
<td>0.48</td>
<td>0.73</td>
</tr>
<tr>
<td>Clay-Natural Bed</td>
<td>1.40</td>
<td>1.70</td>
</tr>
<tr>
<td>*Dry</td>
<td>1.25</td>
<td>1.55</td>
</tr>
<tr>
<td>*Wet</td>
<td>1.40</td>
<td>1.75</td>
</tr>
<tr>
<td>Clay &amp; Gravel-Dry</td>
<td>1.20</td>
<td>1.40</td>
</tr>
<tr>
<td>*Wet</td>
<td>1.30</td>
<td>1.55</td>
</tr>
<tr>
<td>Coal-Anthracite, Raw</td>
<td>1.00</td>
<td>1.35</td>
</tr>
<tr>
<td>*Washed</td>
<td>0.93</td>
<td></td>
</tr>
<tr>
<td>Ash, Bituminous Coal</td>
<td>0.45-0.55</td>
<td>0.50-0.75</td>
</tr>
<tr>
<td>Bituminous, Raw</td>
<td>0.80</td>
<td>1.08</td>
</tr>
<tr>
<td>*Washed</td>
<td>0.70</td>
<td></td>
</tr>
<tr>
<td>Decomposed Rock-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>75% Rock, 25% Earth</td>
<td>1.65</td>
<td>2.35</td>
</tr>
<tr>
<td>50% Rock, 50% Earth</td>
<td>1.45</td>
<td>1.93</td>
</tr>
<tr>
<td>25% Rock, 75% Earth</td>
<td>1.33</td>
<td>1.65</td>
</tr>
<tr>
<td>Earth-Dry Packed</td>
<td>1.28</td>
<td>1.60</td>
</tr>
<tr>
<td>*Wet Excavated</td>
<td>1.35</td>
<td>1.70</td>
</tr>
<tr>
<td>Loam</td>
<td>1.05</td>
<td>1.30</td>
</tr>
<tr>
<td>Granite-Broken</td>
<td>1.40</td>
<td>2.30</td>
</tr>
<tr>
<td>Gravel-Pitrun</td>
<td>1.63</td>
<td>1.83</td>
</tr>
<tr>
<td>*Dry</td>
<td>1.28</td>
<td>1.43</td>
</tr>
<tr>
<td>*Dry, 1/4-2 in.</td>
<td>1.43</td>
<td>1.60</td>
</tr>
<tr>
<td>*Wet, 1/4-2 in.</td>
<td>1.70</td>
<td>1.90</td>
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<tr>
<td>Gypsum-Broken</td>
<td>1.53</td>
<td>2.68</td>
</tr>
<tr>
<td>*Crushed</td>
<td>1.35</td>
<td>2.35</td>
</tr>
<tr>
<td>Hematite, Iron Ore</td>
<td>2.00-2.70</td>
<td>2.35-3.20</td>
</tr>
<tr>
<td>Limestone-Broken</td>
<td>1.30</td>
<td>2.20</td>
</tr>
<tr>
<td>*Crushed</td>
<td>1.30</td>
<td>-</td>
</tr>
<tr>
<td>Magnetite, Iron Ore</td>
<td>2.35</td>
<td>2.75</td>
</tr>
<tr>
<td>Pyrite, Iron Ore</td>
<td>2.18</td>
<td>2.55</td>
</tr>
<tr>
<td>Sand-Dry, Loose</td>
<td>1.20</td>
<td>1.35</td>
</tr>
<tr>
<td>*Damp</td>
<td>1.43</td>
<td>1.60</td>
</tr>
<tr>
<td>*Wet</td>
<td>1.55</td>
<td>1.75</td>
</tr>
<tr>
<td>Sand &amp; Clay-Loose</td>
<td>1.35</td>
<td>1.70</td>
</tr>
<tr>
<td>*Compacted</td>
<td>2.03</td>
<td>-</td>
</tr>
<tr>
<td>Sand &amp; Gravel-Dry</td>
<td>1.45</td>
<td>1.63</td>
</tr>
<tr>
<td>*Wet</td>
<td>1.70</td>
<td>1.88</td>
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<tr>
<td>Sandstone</td>
<td>1.28</td>
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<tr>
<td>Shale</td>
<td>1.05</td>
<td>1.40</td>
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<td>Slag-Broken</td>
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<td>Snow-Dry</td>
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<tr>
<td>*Wet</td>
<td>0.43</td>
<td>-</td>
</tr>
<tr>
<td>Stone-Crushed</td>
<td>1.35</td>
<td>2.25</td>
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<tr>
<td>Taconite, Iron Ore</td>
<td>1.80-2.10</td>
<td>2.60-3.05</td>
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<tr>
<td>Top Soil</td>
<td>0.80</td>
<td>1.15</td>
</tr>
<tr>
<td>*Tap Rock</td>
<td>1.48</td>
<td>2.20</td>
</tr>
</tbody>
</table>

*Varies with moisture, grain size, compaction, etc. Perform tests to determine exact material weights.

**Bank: quantity of an excavation measured in place before being disturbed.

# APPENDIX E

## NPS ABANDONED MINE PROBLEM RATINGS

### HEALTH AND SAFETY PROBLEM RATINGS

<table>
<thead>
<tr>
<th>RATING</th>
<th>EVALUATION CRITERIA</th>
</tr>
</thead>
</table>
| **1A** |  ■ Extreme hazard to public health and safety.  
            ■ Site is easily accessible and receives regular or frequent visitation.  
            ■ Hazards may be hidden and/or not recognized by most visitors.  
            ■ Strong risk of accident that will likely result in serious injury or death.  
            ■ Little or no opportunity for self rescue or obtaining emergency assistance.  
            ■ Rescue or body recovery will be very hazardous to emergency personnel. |
| **1B** |  ■ Same characteristics as 1A, but with infrequent visitation. |
| **2A** |  ■ Moderate hazard to public health and safety.  
            ■ Site is easily accessible and receives regular or frequent visitation.  
            ■ Serious hazards are not hidden, but may not be recognized by most visitors.  
            ■ Moderate risk of accident that may result in serious injury or death.  
            ■ Some opportunity for self rescue or obtaining emergency assistance.  
            ■ Rescue or body recovery can probably be conducted safely, but may be technical. |
| **2B** |  ■ Same characteristics as 2A, but with infrequent visitation. |
| **3A** |  ■ Minor or no hazard to public health and safety.  
            ■ Site may be easily accessible and receives regular or frequent visitation.  
            ■ Hazards that are present are obvious and will be recognized by nearly all visitors.  
            ■ Slight or no risk of accident that may result in minor injury.  
            ■ Self rescue or obtaining emergency assistance is likely.  
            ■ Rescue is not technical and presents only minor hazards to emergency personnel. |
| **3B** |  ■ Same characteristics as 3A, but with infrequent visitation. |

### ENVIRONMENTAL PROBLEM RATINGS

<table>
<thead>
<tr>
<th>RATING</th>
<th>EVALUATION CRITERIA</th>
</tr>
</thead>
</table>
| **1**  |  ■ Condition deteriorating.  
            ■ Large area affected and impacts extending off-site.  
            ■ Sensitive resources are being adversely impacted.  
            ■ Impacts will result in long term changes in productivity or species composition.  
            ■ Significant cultural resources are being lost or severely impacted. |
| **2**  |  ■ Condition stable.  
            ■ Area affected is small and impacts are generally confined to the site.  
            ■ Sensitive resources are not being impacted.  
            ■ Impacts to productivity and species composition are short-term, limited in scope and correctable.  
            ■ Impacts to significant cultural resources are limited. |
| **3**  |  ■ Condition improving.  
            ■ Area affected is small and impacts are confined to the site.  
            ■ Sensitive resources are not being impacted.  
            ■ Little or no impact to productivity and species composition, or impacts are decreasing without intervention.  
            ■ No impacts to cultural resources. |
### APPENDIX F

**COMMON UNIT CONVERSIONS FOR METRIC - ENGLISH MEASURES**


### METRIC UNIT EQUIVALENTS

<table>
<thead>
<tr>
<th>Metric Unit</th>
<th>Multiply By</th>
<th>English Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>kilometer (km)</td>
<td>.6214</td>
<td>mile</td>
</tr>
<tr>
<td>meter (m)</td>
<td>1.0936</td>
<td>yard</td>
</tr>
<tr>
<td>centimeter (cm)</td>
<td>.0328</td>
<td>foot</td>
</tr>
<tr>
<td>millimeter (mm)</td>
<td>.03937</td>
<td>inch</td>
</tr>
<tr>
<td>square kilometer (km²)</td>
<td>1.196</td>
<td>square mile</td>
</tr>
<tr>
<td>hectare (ha)</td>
<td>2.471</td>
<td>acre</td>
</tr>
<tr>
<td>square meter (m²)</td>
<td>10.764</td>
<td>square foot</td>
</tr>
<tr>
<td>square meter (m²)</td>
<td>1550</td>
<td>square inch</td>
</tr>
<tr>
<td>square centimeter (cm²)</td>
<td>.1550</td>
<td>square inch</td>
</tr>
<tr>
<td>cubic centimeter (cm³)</td>
<td>.061</td>
<td>cubic inch</td>
</tr>
<tr>
<td>cubic meter (m³)</td>
<td>1.308</td>
<td>cubic yard</td>
</tr>
<tr>
<td>liter (L)</td>
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<td>cubic yard</td>
</tr>
<tr>
<td>kilometer/hour (km/h)</td>
<td>.621</td>
<td>mph</td>
</tr>
<tr>
<td>liter (L)</td>
<td>2.642</td>
<td>U.S. gallon</td>
</tr>
<tr>
<td>meter (m)</td>
<td>.22</td>
<td>imperial gallon</td>
</tr>
<tr>
<td>metric ton (t)</td>
<td>.984</td>
<td>long ton</td>
</tr>
<tr>
<td>metric ton (t)</td>
<td>1.102</td>
<td>short ton</td>
</tr>
<tr>
<td>kilogram (kg)</td>
<td>2.205</td>
<td>pound, avo.</td>
</tr>
<tr>
<td>gram (g or gr)</td>
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<td>ounce, avo.</td>
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<tr>
<td>kilonewton (kN)</td>
<td>225</td>
<td>pound</td>
</tr>
<tr>
<td>newton (N)</td>
<td>.22</td>
<td>pound</td>
</tr>
<tr>
<td>cubic centimeter (cm³)</td>
<td>.0338</td>
<td>fluid ounce</td>
</tr>
<tr>
<td>kilogram/cu meter</td>
<td>1.868</td>
<td>pound/cu. yd</td>
</tr>
<tr>
<td>kilogram/cu meter</td>
<td>.062</td>
<td>pounds/cu. ft</td>
</tr>
<tr>
<td>kilogram/sq cm (kg/cm²)</td>
<td>14.225</td>
<td>pounds/sq in</td>
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<tr>
<td>kilocalorie (kcal)</td>
<td>3.968</td>
<td>kcal</td>
</tr>
<tr>
<td>kilogram-meter (kg*km)</td>
<td>7.233</td>
<td>foot-pound</td>
</tr>
<tr>
<td>meter-kilogram (m*kg)</td>
<td>7.233</td>
<td>pound-foot</td>
</tr>
<tr>
<td>metric horsepower (CV)</td>
<td>.9863</td>
<td>hp</td>
</tr>
<tr>
<td>kilowatt (kW)</td>
<td>1.341</td>
<td>hp</td>
</tr>
<tr>
<td>kilopascal (kPa)</td>
<td>.145</td>
<td>psi</td>
</tr>
<tr>
<td>bar</td>
<td>14.5</td>
<td>psi</td>
</tr>
<tr>
<td>tons/sq ft</td>
<td>1692</td>
<td>pounds/cu. yd</td>
</tr>
</tbody>
</table>

### ENGLISH UNIT EQUIVALENTS

<table>
<thead>
<tr>
<th>English Unit</th>
<th>Multiply By</th>
<th>Metric Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>mile, statute (m)</td>
<td>1.609</td>
<td>kilometer</td>
</tr>
<tr>
<td>yard (yd)</td>
<td>.9144</td>
<td>meter</td>
</tr>
<tr>
<td>foot (ft)</td>
<td>.3048</td>
<td>meter</td>
</tr>
<tr>
<td>inch (in)</td>
<td>25.4</td>
<td>millimeter</td>
</tr>
<tr>
<td>square mile (m²)</td>
<td>2.590</td>
<td>square kilometer</td>
</tr>
<tr>
<td>acre</td>
<td>.4047</td>
<td>hectare</td>
</tr>
<tr>
<td>square foot (ft²)</td>
<td>.0929</td>
<td>square meter</td>
</tr>
<tr>
<td>square inch (in²)</td>
<td>.000045</td>
<td>square meter</td>
</tr>
<tr>
<td>cubic yard (yd³)</td>
<td>.7645</td>
<td>cubic meter</td>
</tr>
<tr>
<td>cubic inch (in³)</td>
<td>16.387</td>
<td>cubic centimeter</td>
</tr>
<tr>
<td>cubic foot (ft³)</td>
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<td>cubic foot</td>
</tr>
<tr>
<td>cubic yard (yd³)</td>
<td>.0164</td>
<td>cubic yard</td>
</tr>
<tr>
<td>cubic yard (yd³)</td>
<td>764.55</td>
<td>cubic yard</td>
</tr>
<tr>
<td>ton — ton</td>
<td>1.459</td>
<td>ton</td>
</tr>
<tr>
<td>U.S. gallon (US Gal)</td>
<td>3.785</td>
<td>liter</td>
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<tr>
<td>U.S. gallon</td>
<td>.833</td>
<td>imperial gallon</td>
</tr>
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<td>long ton (l)</td>
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<td>metric ton</td>
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<td>short ton (st)</td>
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<td>metric ton</td>
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<td>pound (lb)</td>
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<td>kilogram</td>
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<td>ounce (oz)</td>
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<td>gram</td>
</tr>
<tr>
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<td>kilonewton</td>
</tr>
<tr>
<td>fluid oz (fl oz)</td>
<td>29.57</td>
<td>cu centimeter</td>
</tr>
<tr>
<td>pound (lb)</td>
<td>16.018</td>
<td>kg/cu meter</td>
</tr>
<tr>
<td>liquid lb (liq lb)</td>
<td>.5933</td>
<td>kg/cu meter</td>
</tr>
<tr>
<td>pounds/sq in.</td>
<td>.0703</td>
<td>kilogram/sq cm</td>
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<tr>
<td>psi</td>
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<td>bar</td>
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<td>psi</td>
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<td>kilogram-calorie</td>
</tr>
<tr>
<td>foot-pound (ft-lb)</td>
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<td>kilogram-meter</td>
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<td>horsepower (hp)</td>
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<td>metric horsepower</td>
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<tr>
<td>horsepower (hp)</td>
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<td>kilowatt</td>
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<tr>
<td>pounds/cu yd</td>
<td>.0005928</td>
<td>pounds/sq ft</td>
</tr>
<tr>
<td>pounds (No. 2 diesel fuel)</td>
<td>.1413</td>
<td>U.S. gallon</td>
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</table>

**NOTE:** Some of the above factors have been rounded for convenience. For exact conversion factors please consult International System of Units (SI) table.
AML INVENTORY FORM

TITLE BLOCK

NPS Unit________________ Inspector________________ Date______________.
Mine/District________________ Revised By________________ Date______________.
Access__________________________________________________________.

LOCATION BLOCK

State____ County_________ USGS 7.5' Quad__________________________.
UTM Coordinates _____________N _________________E
T______ R______ Sec______ _____1/4 _____1/4

LOCATION MAP
GENERAL DESCRIPTION

Type: Pit/Quarry__ Underground__ Placer__ Mill__ Buildings___.
Historic Resources: y/n  Threatened or Endangered Species: y/n
Hazard Rating__________  Environmental Rating__________.
Description__________________________________________.

Visitation (site and underground)__________________________

HAZARDS AND ENVIRONMENTAL IMPACTS

<table>
<thead>
<tr>
<th>Ref/HR/ER*</th>
<th>Description</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

*Sketch Reference Number/Hazard Ranking/Environmental Ranking
### HAZARDS AND ENVIRONMENTAL IMPACTS

Use the same reference numbers as on the AML Inventory Form.

#### UNDERGROUND CLOSURES

<table>
<thead>
<tr>
<th>Ref</th>
<th>Closure Type</th>
<th>Dimensions/Quantities &amp; Units</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Measure to applicable construction limits of closure type. For depth use:
- Actual depth, if measured or known from records.
- ">15 ft", if unknown and it appears open.
- "C", if opening is collapsed.

#### SURFACE REMEDIATION

<table>
<thead>
<tr>
<th>Map Symbol</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clearing and grubbing_______ acres</td>
</tr>
<tr>
<td></td>
<td>Earthmoving and backfilling_______ cu yd</td>
</tr>
<tr>
<td></td>
<td>Rock blasting_______ cu yd</td>
</tr>
<tr>
<td></td>
<td>Lime treatment_______ acres</td>
</tr>
<tr>
<td></td>
<td>Reshaping and dozing_______ cu yd</td>
</tr>
<tr>
<td></td>
<td>Structure demolition_______ cu yd</td>
</tr>
</tbody>
</table>

Mine drainage (Ref/qpd) 

---

#### EROSION AND SEDIMENTATION CONTROL

<table>
<thead>
<tr>
<th>Ref</th>
<th>Impact</th>
<th>Item/Quantity</th>
<th>Item/Quantity</th>
</tr>
</thead>
<tbody>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
AML RECONNAISSANCE FORM

REVEGETATION

Map Symbol/Ref Mitigation

- Topsoil replacement ______ cu yd
- Fertilization ______ acres Neutralization? yes/no
- Seeding ______ acres Mulching? yes/no
- Transplanting ______ acres
- Irrigation ______ acres

SITE CHARACTERIZATION

Map Symbol/Ref Investigation

- Air monitoring station: yes/no (circle answer)
- Soils study area ______ acres
- Surface water monitoring sites ______ ea
- Groundwater monitoring wells ______ ea
- Vegetation study area ______ acres

Potential for threatened or endangered species _________________.

Describe environment and impact trends _________________.

Describe access for construction _________________.

HISTORIC/CULTURAL ALTERNATIVES TO REMEDIATION

Alternatives _________________.

Describe general condition _________________.

Evidence of subsurface features? yes/no (circle answer)
### PHOTOGRAPHS

<table>
<thead>
<tr>
<th>Ref</th>
<th>Roll</th>
<th>Frame</th>
<th>Azimuth</th>
<th>Title/Comments</th>
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</thead>
<tbody>
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</tr>
</tbody>
</table>

### DETAIL SKETCHES

[Blank page]

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AML RECONNAISSANCE FORM

Page 4/4
TITLE BLOCK

NPS Unit________________ Inspector________________ Date________.
Mine/District___________ Revised By____________ Date________.
UTM Coordinates ___________N _____________E

HAZARD CONDITIONS

Describe original mitigation of hazards__________________________

Condition:
  Is mitigation functioning? ________________________________
     Yes___ No___ N/A___
  Is there evidence of visitation? _____________________________
     Yes___ No___ N/A___
  Is there evidence of vandalism? _____________________________
     Yes___ No___ N/A___
  Are warning signs in place and functioning? ______
     Yes___ No___ N/A___

Describe current conditions____________________________________

ENVIRONMENTAL CONDITIONS

Describe original reclamation__________________________

Trends:

<table>
<thead>
<tr>
<th>Resource</th>
<th>Improving</th>
<th>Deteriorating</th>
<th>No Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetation</td>
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<tr>
<td>Soils</td>
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<td>Water</td>
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<tr>
<td>Structures</td>
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<td>Other</td>
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</tbody>
</table>

Describe current conditions____________________________________
