A QUALITATIVE RECLAMATION ASSESSMENT HANDBOOK FOR ABANDONED HARDROCK MINE LANDS[1].

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Abstract. The Abandoned Mine Lands Inventory System (AMLIS) includes nearly 1100 abandoned mines in Montana. The Montana offices of the Bureau of Land Management and the U.S. Forest Service as well as the Montana Department of Environmental Quality AML Program have been working to clean up these abandoned mine lands since 1995. The agencies in general have given priority to sites with mill tailings and waste rock dumps situated in stream channels, and in Montana the clean up of impacted lands on a watershed basis through interagency cooperation has been emphasized. There is an emerging desire of the federal agencies to begin monitoring these reclaimed sites in a systematic way. The overall objective for developing the "Qualitative Reclamation Assessment Handbook for Abandoned Hardrock Mine Lands" is to provide a common platform to evaluate reclaimed mine sites so that federal agencies responsible for risk management and land management can easily communicate and work in partnership to accomplish their respective missions. The handbook contains assessment forms and protocol designed to evaluate pertinent attributes found at specific locations within a reclaimed mine site (repository, wetland, etc.). These attributes may include vegetation cover, status of a cap or liner, roads, evidence of AMD, and several others. The outcome envisioned by the agencies includes identifying maintenance needs, generating temporal information for trend analysis, and identifying remedial methods and technologies that have proven to be effective and those that have resulted in poor performance. The data and information collected during a reclamation assessment can then be used to evaluate the status of the reclamation work and whether or not the conditions at the site remain protective of human health and the environment.

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[1] Paper was presented at the 2009 National Meeting of the American Society of Mining and Reclamation, Billings, MT, ***Revitalizing the Environment: Proven Solutions and Innovative Approaches*** May 30 – June 5, 2009. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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Proceedings America Society of Mining and Reclamation, 2009 pp 89-106
DOI: 10.21000/JASMR09010089
http://dx.doi.org/10.21000/JASMR09010089

Introduction

There are over 9600 abandoned mine sites listed in the Abandoned Mine Lands Inventory System (AMLIS). The inventory includes nearly 1100 abandoned mines in Montana (OSMRE, 2008). Federal and state agencies have been working together since 1995 to cleanup these abandoned mine lands. These sites are quite variable, but many have mine waste materials with concentrations of metals that constitute a human health hazard. In addition, these contaminants are frequently released into receiving streams and groundwater (BLM, 2008). Abandoned mines are often located on patented private land while down-gradient mine wastes are deposited on public lands used for recreation, grazing, timber harvest, wildlife habitat, and water resources. Waste materials represent toxicological risks to humans as well as terrestrial and aquatic organisms. In general, state and federal agencies have given priority to sites with mill tailings and waste rock dumps situated in stream channels, and the cleanup of these impacted lands on a watershed basis through interagency cooperation has been emphasized (USGS, 2008). A common strategy for the cleanup of these abandoned sites is to remove waste materials from stream channels, consolidate wastes in on-site repositories, cap wastes with locally available coversoils (generally using some type of a liner), or cap waste materials in place. Mine, mill, smelter, and related structures are sometimes demolished if they are not culturally significant or are unsafe. Mine shafts and adits are backfilled or bat gated.

The purpose of reclamation work on abandoned or reclaimed mine sites is to protect human health and mitigate risk to the environment (BLM, 2008). Restoring and maintaining functioning ecological systems is an overall target for abandoned mine reclamation work. Reclamation activities at hardrock abandoned mines are often complicated, time-consuming and expensive. Specific cleanup goals and objectives are set before work commences and drive the project through completion. Monitoring is required to assure the initial goals and objectives are still being met, as over time, conditions at a reclaimed site will change. Natural processes may change plant communities, water drainage patterns and other attributes of a reclaimed site. These processes are normal and to be expected, however, if reclamation activities are impacted in a negative way, a site that once appeared to be functioning as planned may deteriorate. Examples include undesireable plant species moving into a reclaimed site and disrupting the natural succession of the intended plant community, or gullies forming on recontoured slopes due to erosion caused by stormwater runoff. Generally, these types of negative site conditions

worsen overtime. The overall objective for developing the "Qualitative Reclamation Assessment Handbook for Abandoned Hardrock Mine Lands" is to provide a common platform to evaluate reclaimed mine sites. Routine on-site evaluations of the current condition of reclaimed sites is paramount to assuring past reclamation activities are still meeting the initial goals and objectives and if not, identifying conditions that need attention. Identifying problem areas early typically results in the remedy being less complicated and expensive as opposed to allowing the deteriorating conditions to persist and likely worsen.

Purpose of the Reclamation Evaluation Handbook

There is a developing interest on the part of federal agencies to begin monitoring reclaimed mine sites in a systematic way (USGS, 2008). Evaluating reclaimed mine sites using a common platform will assist federal agencies responsible for risk management and land management in accomplishing their respective missions. Communication within and among agencies are made easier when all parties use similar methods for collecting data. There are four desired outcomes from instituting a systematic monitoring program.

- Identify when and where there is a need for maintenance on a reclaimed site. It is important that reclamation work performed remains protective of the resources and human health risks are reduced.
- Provide temporal information that will allow trend analysis of cleanup status.
- Identify cleanup methods and technologies that are proven to be effective and identify those that have resulted in poor performance.
- Provide the agencies with data and information that can be used to support the funding of their ongoing remediation programs.

Objectives

The overall objective of this project was to develop evaluation protocols for previously reclaimed abandoned mine sites and to compile these protocols into a handbook that can be used by land management agencies engaged in abandoned mine cleanup activities. The intent is to provide a tool that is straightforward, easy to apply on-site, and results in standardized protocols to assess revegetation success, erosional stability, public safety, maintenance issues, and trend. Using the data collected during the on-site evaluation, land managers should have the

information necessary to determine if remedial objectives continue to be met, or if maintenance is necessary.

Approach

Scientists at the Reclamation Research Unit at Montana State University were charged with development of procedures, performance standards, maintenance triggers, and evaluation systems for reclaimed or remediated areas at several of Montana's CERCLA (EPA Superfund Program) sites. Evaluation systems used at these CERCLA sites include the Land Reclamation Evaluation System (LRES) for the Anaconda Smelter Site (CDM and RRU/MSU, 1999), the Butte Reclamation Evaluation System (BRES) for the Butte Priority Soils Operable Unit of the Silver Bow Creek/Butte site (CDM and RRU/MSU, 2003), and the Riparian Evaluation System (RipES) for the Clark Fork River Operable Unit of the Milltown Reservoir NPS Site (BRI and RRU/MSU, 2004). Using key principals from these systems, a draft set of abandoned hardrock mine reclamation evaluation forms were developed specifically for the U.S. Forest Service in the fall of 2004 and the Bureau of Land Management in 2005.

These draft forms were then field-tested at several reclaimed mines to determine if they could be used to identify key issues addressed in the goals and objectives of the project. Reclaimed mine sites were evaluated using the draft protocols; notes were made and the forms were edited in the field and then taken back to the office for improvement. Several iterations of field forms were repeatedly tested in the field during the development of the evaluation handbook to confirm that the forms were comprehensive enough to adequately determine the current status of past reclamation activities. One of the major requests from the federal land management agency personnel was to keep the forms simple and the evaluation protocol at a level where new evaluators would not require extensive training. Another consideration was the amount of time it would take to complete an evaluation and the expense involved. To keep time and expenses at a minimum, the evaluation system was developed as a qualitative tool, therefore expensive equipment and laboratory analyses are not necessary when evaluating a reclaimed mine site using the "Abandoned Mine Land Post-Remediation Assessment Handbook". However, a site requiring maintenance may require quantitative analyses; procedures to remedy problems at a reclaimed site are not addressed in the evaluation handbook.

The following forms are part of the final Abandoned Mine Land Post-Remediation Assessment Handbook:

- Form No. 1 Public Safety and Maintenance;
- Form No. 2 Summary of Public Safety and Maintenance;
- Form No. 3 Evaluation of Waste Repositories;
- Form No. 4 Evaluation of Waste Rock Dumps:
- Form No. 5 Evaluation of Removal Areas;
- Form No. 6 Evaluation of General Remediated Areas;
- Form No. 7 Evaluation of Wetland Areas;
- Form No. 8 Evaluation of Streambank/Riparian Areas;
- Form No. 9 Evaluation of Adits and Shafts;
- Form No. 10 Evaluation of Borrow Areas;
- Form No. 11 Summary of Evaluated Areas.

In general the forms contain multiple questions regarding relevant attributes that are found at specific locations within a reclaimed mine site such as repositories, wetlands, waterways, and removal areas. The attributes may include vegetation cover, status of a cap or liner, roads, erosion status, evidence of acid mine drainage (AMD), weed infestations, and more. The responses are qualitative in nature and agency personnel can be trained to accurately and precisely (repeatedly) provide the required information.

The evaluation forms included in the handbook are briefly summarized below.

Form No. 1 Public Safety and Maintenance

Public safety is one of the driving forces behind reclaiming abandoned mine sites. These areas are often visited by people interested in the history of mining in the area or may be easily accessed for recreation activities such as off-road vehicle driving. Safety issues range from physical dangers such as open adits or dilapidated structures to exposure to hazardous waste materials. Public safety issues at reclaimed mines include identifying whether a safety issue requires immediate maintenance or routine maintenance. The Public Safety and Maintenance evaluation is an assessment of the entire site. Site attributes addressed include:

- Fences, gates, signs
- Roads ,culverts, bridges
- Erosion geotechnical
- Adits and shafts
- Fire

- Waste repositories
- Monitoring wells
- Exposed waste materials
- Historical structures
- Surface waters
- Land use issues
- Weeds
- Storm water control
- Site boundaries
- Supplemental information

Figure 1. Gated adit protecting public safety, untreated water is a source of acid mine drainage.

Figure 2. Dilapidated historic structure poses risk to public safety.

Form No. 2 Summary of Public Safety and Maintenance

Public safety and maintenance issues for the entire site are summarized using form No. 2. The form also prompts the evaluator to determine the degree of urgency related to the maintenance issues; is the problem of a nature that it can wait until the next routine maintenance trip is scheduled for that site, or does it require immediate attention in order to protect human health and the environment?

Form No. 3 Evaluation of Waste Repositories

A repository is an engineered disposal cell similar to a landfill (Ford and Walker 2002). Many abandoned mine cleanup activities include the construction of a repository either at the site or nearby. Design of a repository depends largely on site conditions but should remain stable in the long-term and prevent migration of contaminants into the environment (Lottermoser, B. 2003). Repository concerns include; vegetation community and cover, condition of diversion structures, drainage or seepage, erosion, and stability including signs of slope failure or

subsidence. Repositories may be located away from the abandoned mine site, therefore the evaluators must be knowledgeable of the locations of these repositories.

Figure 3. Repository with poor vegetation cover and rills and gullies caused by erosion.

Form No. 4 Evaluation of Waste Rock Dumps:

A waste rock dump is typically a historic pile of overburden that may be environmentally innocuous or contain contaminated materials and produce runoff water of poor quality. Waste rock dumps are generally not highly engineered, rather unwanted (of low economic value) rock was simply dumped in a convenient location that often included steep slope areas. The type of reclamation work occurring on waste rock dumps is variable and can range from no action to installing a constructed cap.

Figure 4. Waste rock and other material were dumped down the side of a steep slope. Erosion and surface water runoff quality are of concern at this site.

Form No. 5 Evaluation of Removal Areas

This form is used to assess locations where mine waste has been removed. These areas are generally covered with borrow soil and revegetated, but not always. Several attributes are assessed in removal areas, examples include: vegetation community, remaining waste, erosion, water diversion features, acid mine drainage, metal salts, seeps, and impacts of/to adjacent land.

Figure 5. Waste material left in place adjacent to removal area. Run-on from the contaminated area is affecting the reclaimed area.

Figure 6. Poor vegetation establishment in removal area.

Form No. 6 Evaluation of General Remediated Areas

General remediated areas refer to reclaimed areas within the site that are not assessed using the other feature-specific evaluation forms. These areas may have been treated in-place, graded, revegetated, or had other reclamation activities occur. This form asks the evaluator to assess attributes that include, but are not limited to; vegetation community, erosion, weeds, instability of slopes, acid mine drainage, exposed waste, and impact of/to adjacent land.

Figure 7. Area treated in-place (in-situ) remediation. Lime and organic matter were tilled into the contaminated soil and the area was revegetated.

Form No. 7 Evaluation of Wetland Areas

Wetland areas may be original to the site or may have been constructed as part of the reclamation design. Assessment attributes include looking at the seasonal water level of the wetland, determining if acid drainage discharges into the wetland, plant community health, sedimentation, water diversion features, and more.

Figure 8. Wetland in a reclaimed area; silt fence needs maintenance or removal depending on erosional characteristics of adjacent area.

Form No. 8 Evaluation of Streambank/Riparian Areas

Many reclaimed mine sites have small streams running through the area and these waterways are generally impacted by mining activities to some degree. Assessing the condition of reclamation work on streambanks and/or riparian areas is important because these areas can degrade rapidly if problems arise. Attributes evaluated at streambank/riparian areas at reclaimed sites include; vegetation community and health, lateral cutting of the streambank, evidence of acidic drainage, exposed waste, sedimentation in waterway, and impacts on or from adjacent land.

Figure 9. Acid mine drainage discharging into a clear stream. Notice vegetation is poorly established on the streambank near the acid water.

Figure 10. Dead and dying streambank vegetation in reclaimed area.

Form No. 9 Evaluation of Adits and Shafts

Abandoned mine sites require the closure of unsafe mine adits and shafts. These mine features can pose a serious risk to the public. Additionally, adits and shafts commonly discharge water from the old mine workings. Assessment attributes include the condition of the water being discharged, the path of the discharged water, and condition of the device used to close the adit/shaft.

Figure 11. Temporarily closed mine shaft.

Figure 12. The mine adit closure bulkhead at this reclaimed site is located several feet inside of opening creating an attractive nuisance and risk to site visitors.

Form No. 10 Evaluation of Borrow Areas

Borrow areas are evaluated using Form No. 10, these are areas where uncontaminated soil or fill material was removed, creating a pit that generally requires recontouring and revegetation. Borrow sites may be located some distance from the abandoned mine site. In some cases following removal of borrow material, the pit may be used as a repository. Attributes addressed at borrow areas include vegetation conditions, erosion characteristics, impacts of or to adjacent land, water diversion features and slope stability. If the pit was filled with waste material, the borrow pit would then be assessed using the repository or waste rock dump form.

Figure 13. Revegetated borrow area.

Form No. 11 Summary of Evaluated Areas

The last form is used to summarize the results of the on-site reclamation evaluation. This information is then used for the final evaluation report.

Conducting an Evaluation

Pre- Fieldwork Preparations

Before the site visit and actual fieldwork begins, field assessment packets are be assembled for each remediated abandoned mine site to be assessed. If possible, this packet of information includes the following: a construction completion report, as-built drawings, construction change orders, and any maintenance work completed after initial remediation. If these documents are not available, the construction bid documents can be helpful in gaining an understanding of the

remediation activities that were to be completed. Hard copy maps of the site, recent aerial photos, and any GIS files should also be included in the packet. If a person familiar with the work that occurred at the site is available for an interview, it is recommended the evaluator contact that person and discuss the site and implementation of remedial or reclamation actions. The evaluation forms mentioned in the section above are used during the field assessments. Any issues related to access onto private property need to be resolved prior to entry by evaluators. Written access agreements may be required and should be part of the packet.

Evaluator Qualifications and Training

Evaluation of these sites is based on a range of qualitative estimates and observations from simple physical attributes to complex ecological associations (e.g. estimating the percent canopy cover within a plant community). Therefore, training in the use of the forms is required. The purpose of the training is to achieve precise (repeatable) assessments by evaluators. Training at selected field sites should be conducted on a regular and continuing basis to help calibrate the evaluator's qualitative estimates of site conditions. Evaluators should have knowledge of basic ecology. Some knowledge of ecological and environmental field measurement methods, as well as land reclamation techniques is required. Field experience in range condition assessments, vegetation community measurements, geology, soil remediation, phytotoxicity, and evaluations of erosion is desirable. Persons with Bachelor of Science degrees in land rehabilitation, range science, or soil science typically have acceptable combinations of experience and knowledge.

Initial Field Assessment

Evaluations should be conducted during the optimal phenological time for seeded plant species, which is generally between mid June and mid September for most abandoned mine sites in Western Montana. When scheduling site visits, evaluators should consider the location, including elevation, of the reclaimed sites. Snow cover will take longer to melt at high elevation locations.

A preliminary walkthrough of the entire remediated site is performed to: 1) confirm boundaries of the remediation; 2) ascertain and/or confirm the locations where different reclamation techniques were implemented; 3) identify locations of historical features, creeks, repositories, adits and shafts, wetlands, and other features specific to the remediated site.

The site is then assessed using Form No.1 – Public Safety and General Maintenance. This form asks questions in thirteen categories and stresses issues relating to public safety and the

need for routine or immediate maintenance to protect human health and/or to protect remediated landscapes. Form No. 1 is an assessment of the entire site; additional evaluation forms are used to evaluate specific reclaimed areas within the site. After Form No. 1 is completed and appropriate notes, digital photos, and GPS coordinates are recorded, a summary of the findings is recorded on Form No.2.

Photographic documentation of the reclaimed sites is required. During evaluation of the site, GPS coordinates mated with digital images are required when problems are encountered, especially those that may constitute a public safety or critical maintenance issues. Digital images should also be used to document overall site conditions; during the first site visit, at least two permanent photo points should be established. Permanent photo points can be used to represent conditions at the site over a multi-year period. An overview perspective of the entire site is preferred for the permanent points. Images captured in subsequent years should be matched to the same field of view.

A dry erase board with date, location and comments can be included in the photos of features. dry erase board can also be used to index field photos and notes to images downloaded from the digital camera. An electronic file naming convention is recommended for downloaded images to match year, site, and feature.

Evaluations of Site-Specific Features and Areas

As summarized above, site-specific features of a remediated abandoned mine may include waste repositories, constructed wetlands, adit discharge channels, removal/replacement areas, treated areas, reconstructed streambanks or channels, and other remediated locations. Feature specific evaluation forms were previously discussed in this document. In general, these forms ask questions pertaining to landscape stability, vegetation integrity, water quality, and evidence of adverse impacts of the remediation on adjacent lands. At the end of each form, a narrative of feature-specific problems, associated digital photos, and GPS coordinates are recorded. A new form is used for each feature. For example, if there are two repositories at the site, a separate field form should be completed for each repository. A final Form No. 11 asks if any feature-specific problems are identified that may inhibit the long-term effectiveness and permanence of the remediation.

Site Sketch or Map

A depiction of the location and areas evaluated is required. A site sketch is generally acceptable. The preferred site map is a printed, recent aerial photograph that can be drawn on to depict areas evaluated. If possible, each area evaluated should be marked or sketched on the aerial photo.

Reclamation Evaluation Reports

A Reclamation Evaluation Report for each site should be prepared and at a minimum each report should contain the following:

- A narrative of findings which includes identification of any immediate threats to public safety, identification of high priority maintenance needs to protect the remediation, and a synopsis of the comments and notes recorded in the field as exhibited on the evaluation forms;
- Completed field forms;
- Digital photos and GPS coordinates of problem areas;
- Maps and aerial photos used in the field to depict boundaries of site-specific features (e.g. repositories, wetlands, removal areas).

Summary

Developing systematic reclamation evaluation protocol provides a common platform to evaluate reclaimed mine sites so that agencies responsible for land and risk management can easily communicate and work in partnership to accomplish their respective missions. The data and information collected during a reclamation assessment can be used for trend analysis and to evaluate the status of the reclamation work and whether or not the conditions at the site remain protective of human health and the environment. Another advantage of reclamation monitoring is the ability to identify cleanup methods and technologies that are proven to be effective and identify those that have resulted in poor performance.

Following completion of the "Qualitative Reclamation Assessment Handbook for Abandoned Hardrock Mine Lands" in 2006, a BLM summer intern applied the evaluation system to 12 reclaimed sites in southwestern Montana. The Forest Service hired a contractor to evaluate 18 sites in Montana in 2008 and in the summer of 2009 several BLM sites will be evaluated in Montana and South Dakota.

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