THE ACID DRAINAGE TECHNOLOGY INITIATIVE[1]

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Abstract. The Acid Drainage Technology Initiative (ADTI) is a coalition of federal and state agencies, industry, academia, and consulting firms working together to promote communications and technology enhancement in the field of prediction and remediation of acid drainage from mining activities, past and present. This joint effort was formed in recognition of the need to address a range of issues dealing with the technical problems of predicting and controlling acid drainage. These include: the legacy of acid mine drainage/acid rock drainage (AMD/ARD) problems throughout the U.S; the development of consensus on improved test methods, particularly for prediction of mine drainage quality prior to mining; avoidance and remediation technology to prevent, treat and abate AMD/ARD pollution in an effective and economical manner and the application of "best science" methods to accomplish these goals. ADTI is subdivided into a coal mining sector and a metal mining sector. The coal mining sector (http://wvwri.nrcce.wvu.edu/ADTI) is organized into two primary working groups, one focused on prediction and the other on avoidance and remediation methods. The metal mining sector (http://www.unr.edu/mines/adti/) is organized around five major technical areas relevant to the particular technical problems it faces: (1) sampling/monitoring, (2) prediction, (3) mitigation, (4) modeling and (5) pit lakes. This paper discusses the formation, goals and major accomplishments of the ADTI, leading to its current activities.

Additional Key Words: acid mine drainage, acid rock drainage.

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Introduction

The Acid Drainage Technology Initiative (ADTI) is an applied science and technology development program that addresses mine drainage issues related to abandoned and active mining activities. These issues include mine drainage prediction, sampling, monitoring, modeling and avoidance and remediation. This paper discusses the formation, goals and major accomplishments of the ADTI.

A number of federal agencies, including the Office of Surface Mining (OSM), Bureau of Land Management (BLM), U.S. Geological Survey (USGS), U.S. Environmental Protection Agency (EPA), the U.S. Army Corps of Engineers (USACE) and the U.S. Bureau of Mines (USBM), joined together with industry, the states and academia in a partnership-based effort to identify, evaluate and develop "best science" practices to remediate existing sources of mine drainage and to prevent its occurrence from active and future mining. The ADTI program provides a central focus on technology development and technology transfer; it is not a regulatory or policy development program. The guiding principle of ADTI is to build consensus among all partners on acid drainage technology development and technology transfer issues.

ADTI is focused on reducing the extent and severity of acid drainage problems from all sources, including acid mine drainage (AMD) related to coal mining and acid rock drainage (ARD) related to metal mining. The former is primarily an issue in the eastern United States, while the latter is primarily an issue the western United States. An example of AMD from an abandoned coal mine is shown in Fig. 1. The magnitude of the AMD problem is illustrated by an EPA survey (EPA 1995), which indicated that approximately 5,100 miles of streams have been impacted by acid mine drainage in five Appalachian region states. Other coal mining regions are also affected by AMD, though not to the same extent, and ARD affects many hard rock mining areas.

Objectives

The overall objectives of ADTI are to identify, evaluate and develop cost-effective and practical acid drainage technologies, develop the best science available in the field of acid drainage and work toward a consensus among industry, federal and state regulatory agencies on mine drainage prediction and remediation methods.

Figure 1. A typical example of acid mine drainage.

Origin and Development of ADTI

The idea for a program that was to become known as ADTI, originated at the 3rd International Conference on Acidic Rock Drainage in Pittsburgh, PA in April 1994, where OSM organized a meeting on mine drainage issues. At this meeting, a cross-section of scientists from federal and state agencies, the coal mining industry and two universities (West Virginia University and Penn State University), discussed the current state of knowledge of the science of mine drainage prediction techniques. The goal of the meeting was to develop consensus on reliable, standard test methods for mine drainage prediction applicable to the Appalachian Coal Basin. The group recognized that this task could not be accomplished in one day and agreed to work together to build consensus on solving mine drainage problems.

The next step occurred in September 1995 when a Planning Committee was formed. The Planning Committee consisted of representatives from the National Mining Association (NMA), the Interstate Mining Compact Commission (IMCC), the National Mine Land Reclamation Center (NMLRC), OSM, BLM and EPA. The Planning Committee coined the term: *Acid Drainage Technology Initiative* to include acid drainage issues related both to coal mining as well as to metal mining. The Planning Committee designated the NMLRC at West Virginia

University to be the initial Secretariat for ADTI, which was consistent with NMLRC's Congressional mandate to: "coordinate research activities and technology development with industry, state and federal agencies and trade organizations." Thus, an integral part of the organization of ADTI is the participation of the academic community.

In December 1995, a "White Paper," that served as the foundation for the ADTI joint venture, was prepared by the NMLRC and the Planning Committee. The White Paper outlined the roles of a newly formed *Operations Committee*, which was set up to replace the Planning Committee. The roles of the Operations Committee are to coordinate the work of the ADTI Working Groups, provide guidance to them, monitor their progress and facilitate the consensus-building process. The history and development of the ADTI was extensively detailed in a paper by Roger Hornberger at the 5th International Conference on Acid Rock Drainage (ICARD) in June 2000 (Hornberger et al., 2000), which along with updated material, forms the basis for this discussion.

Organization and Structure of ADTI

ADTI became operational in April, 1996. The original organizational structure of ADTI consisted of two working groups supervised by the Operations Committee. Working Group 1 focused on prediction. It had three subgroups: Overburden Analysis Test Methods, Sampling and Alternate Sources of Information and Field Validation. Working Group 2 addressed Avoidance and Remediation; it had four Subgroups: Active Treatment Technologies, Passive Treatment Technologies, Alkaline Addition and Overburden and Refuse Reclamation, and Engineered Structural Techniques.

For the first two years, Working Groups 1 and 2 consisted of members working in and/or representing the coal and metal mining sectors. Initial and subsequent Work Group meetings showed that members from a variety of backgrounds (the mining industry, federal and state agencies and academia), were able to work well together on common problems confronting both industries. However, as there are major differences in geology, climate, mining practices and regulatory practices between metal mining and coal mining, the working groups and the Operations Committee recognized that it was necessary to change ADTI's structure and some of its initial goals. The Prediction Group realized that a single prediction report would not

adequately address the specific concerns and issues of both the metal and coal mining sectors. Therefore, it was decided to produce two prediction reports, one addressing coal mining and one addressing metal mining. In a similar vein, the Avoidance and Remediation Working Group, which was working on one comprehensive handbook, also realized the need for two reports, one on coal mining and one on metal mining, with the coal mining volume to be prepared first.

These developments led to the organization of a metal mining sector (MMS) within ADTI to better address issues and problems faced by the metal mining industry, and the federal and state agencies associated with the industry and the remediation of abandoned metal mine sites. The MMS was organized in August 1998. In April, 1999, four MMS members were added to the Operations Committee, including one as MMS Chairperson. The MMS Steering Committee solicited proposals for a Western university center for ADTI as the counterpart of NMLRC at WVU. In October, 1999, the University of Nevada at Reno was approved as the Western center. With the establishment of the MMS, the current organizational structure of ADTI became set, as shown in Fig. 2.

The CMS appointed a Chairperson, which it previously had not had, to balance the organizational structure and communications functions with those of the Chairperson of the MMS. These re-organizational developments have helped shape ADTI into a more balanced organization with better capabilities for technology development and technology transfer for both coal and non-coal mining than at the outset. The current organizational structure of the CMS is the same as the original ADTI structure, that is, two major working groups, Prediction and Avoidance and Remediation, each with several subgroups.

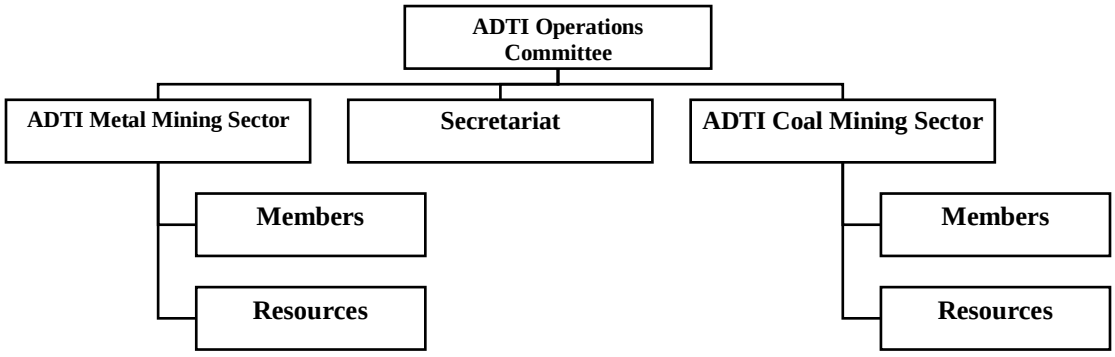

Figure 2. Current ADTI Organizatonal Structure.

The MMS structure (Fig. 3) is considerably more complex than that of the CMS, since it reflects the diversity of issues confronting the metal mining industry. There are five

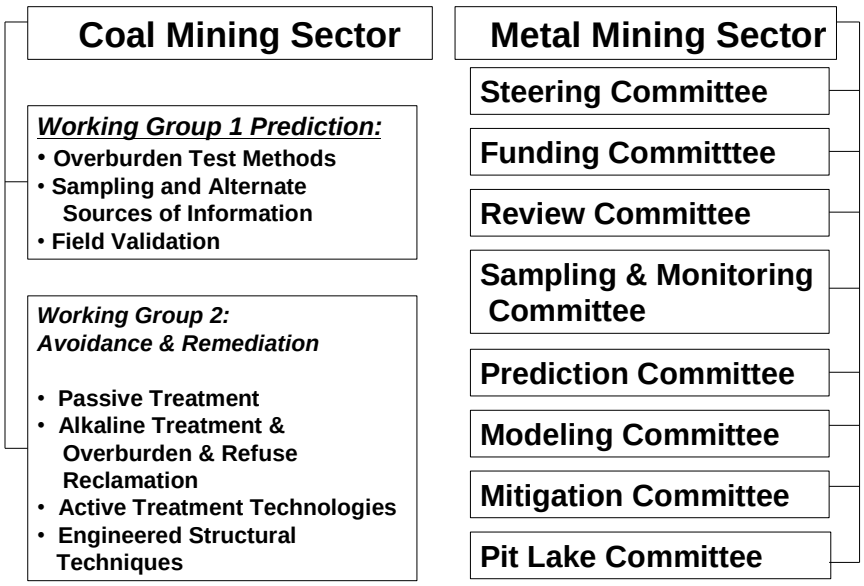

Figure 3. ADTI Sector Organization

technical committees: 1) prediction, 2) sampling and monitoring, 3) mitigation, 4) modeling, and 5) pit lakes. Each of the technical committees selects their own chairperson and membership. The technical committees are ultimately responsible for producing their respective sections of an MMS Acid Drainage Workbook. The MMS Steering Committee is responsible for overall guidance of the five technical committees. The MMS Steering Committee appoints the Chairman and the representatives to the Operations Committee. There are also two administrative committees, Funding and Review. These assist the Steering Committee by working on funding issues and coordinating activities and review/consensus functions in developing an MMS Workbook. There may also be additional topics to be added as new technical committees by the MMS Steering Committee if future interest dictates.

The ADTI membership is made up of volunteer experts. Members of both ADTI Sectors usually include specialists from industry, academia, and state and federal agencies. The make-up of the ADTI Operations Committee is shown in Table 1. The positions held by the various Operations Committee members are shown in the first column, and their regular professional

affiliations (i.e. places of employment) are shown in column three. The technical working groups and committees of the CMS and MMS, respectively, are essentially separate entities, as shown in Fig. 3. Because of this, the Operations Committee has at least two important new roles beyond those delineated in the ADTI White Paper: (1) to ensure consistency between the activities and work products of the CMS and MMS, and (2) to support, to the maximum extent possible, equal and adequate funding for the CMS and MMS programs and for all CMS and MMS committees and research priorities. Both Sectors maintain close communication with each other through the Operations Committee to optimize technology transfer on topics common to both types of mining.

Work and Functioning of ADTI

The work of the main operational units of ADTI, the CMS and MMS, is performed primarily by the respective committees, technical committees or working groups and by the University Centers. The two University Centers have been active in performing research identified by either the Operations Committee or by the CMS and MMS. The Eastern University Center at West Virginia University, through the National Mine Land Reclamation Center, has worked closely with other academic institutions, such as Pennsylvania State University and Indiana University of Pennsylvania on research projects, and has also worked closely with OSM on AMD remediation at abandoned mine sites and on other projects.

The University of Nevada, Reno, the Western University Center for ADTI, collaborates with the other schools involved in the Western University Consortium (WUC), which includes the University of Alaska, Fairbanks, University of Idaho, University of Utah and the New Mexico Institute for Mining and Technology. The MMS also includes a university network, among which requests for proposals are circulated. In addition to the consortium universities, the network presently consists of: Northern Arizona University, University of California (Berkeley), Colorado School of Mines, Desert Research Institute, University of Missouri (Rolla), Montana State University – Bozeman, Montana Tech of the University of Montana, University of New Mexico, and South Dakota School of Mines and Technology.

MMS has also worked closely in the past with the Western Governors Association, (WGA), which has common interests in some of the same acid drainage issues ADTI has worked on. The

MMS has maintained contact with the Canadian Mine Environment Neutral Drainage (MEND) group as well as close contacts and coordination with the International Network for Acid Prevention (INAP), an industry acid initiative.

Table 1. ADTI Operations Committee

Name	Position	Affiliation
Paul Ziemkiewicz	Chairperson	NMLRC, West Virginia University
Dennis Turner	Secretariat	Arizona DEQ
Coal Mining Sector (CMS):		
John Craynon	Chairperson	OSM
Ken Johnson	Industry Representative	CONSOL Energy
Roger Hornberger	State Representative	IMCC; Pennsylvania DEP
Barry Scheetz	Avoidance/Remediation Chairperson	Pennsylvania State University
Jeff Skousen	Prediction Chairperson	West Virginia University Eastern University Center
Metal Mining Sector (MMS):		
Virginia McClemore	Chairperson	New Mexico Bureau of Mines
Charles Bucknam	Industry	Newmont Mining Corp.
David Williams	Federal Representative	BLM, Montana
Harry Posey	State Representative	Colorado DNR
Dirk Van Zyl	Western Univ. Center	University of Nevada, Reno

Statement of Mutual Intent

A Statement of Mutual Intent (SMI) was developed to formalize participation in ADTI by federal and state agencies and organizations, academic institutions, and industry to foster cooperation and partnership among all stakeholders. The goals of the SMI are to protect and improve water quality that may be adversely impacted by acid mine drainage from coal and metal mining, to increase cooperation and partnership, and to develop cost-effective controls for acid drainage to protect and restore streams and watersheds. At this time, the SMI has been signed by the Interstate Mining Compact Commission, Mining Life Cycle Center, Mackay School of Mines, University of Nevada, Reno, National Mine Land Reclamation Center, University of West Virginia, National Mining Association, Great Basin Minewatch, and the U.S. Department of the Interior, on behalf of participating Departmental bureaus, including BLM,

FWS, OSM and USGS. Others expected to sign include the Environmental Protection Agency and, U.S. Army Corps of Engineers.

Coal Mining Sector (CMS)

Funding

Funding for CMS has been provided from a relatively few sources. OSM has provided the majority of the funding. OSM has provided $200-250,000 per year over the last four years (FY99–FY03). $200,000 is also included in the OSM budget for fiscal year 2004. Other funding has come from EPA, WVU and the mining industry.

Initial Projects

The initial projects identified by the CMS were to produce state-of-the-art summaries of AMD prediction and remediation technology. The first ADTI product was "***A Handbook of Technologies for Avoidance and Remediation of Acid Mine Drainage*"** (Skousen et al., 1998). The second ADTI CMS product was: "***Prediction of Water Quality at Surface Coal Mines***" (Kleinmann, 2000).

Both publications were published by the National Mine Land Reclamation Center (NMLRC) at West Virginia University and are available from the NMLRC website: **http://wvwri.nrcce.wvu.edu/publications.php - adti**. Printed copies are also available at no cost. To obtain a printed copy, contact the West Virginia Water Resources Institute, West Virginia University, 202 NRCCE Building PO Box 6064 Morgantown, WV 26506-6064, Attn: E. Nelson; Phone: (304) 293-2867 x 5450; email: Eleanor.Nelson@mail.wvu.edu .

Avoidance/Remediation Handbook. The first publication, *A Handbook of Technologies for Avoidance and Remediation of Acid Mine Drainage*, was prepared by the Avoidance and Remediation Working Group. This working group consisted of 31 experts who worked under the direction of Chairman Charles Miller. Table 2 gives the makeup of this Working Group.

Table 2. Makeup of Working Group 2, Avoidance and Remediation.

Affiliation	No. of Members
Federal Government	8
State Government	6
Academia	7
Industry/Consultants	10

The Avoidance and Remediation Handbook is a comprehensive resource that describes the many applicable technologies, including generalized design and performance criteria. It also describes failures to enable the user to avoid repeating inadequate and inappropriate methods. It includes a series of case studies to provide information on the applicability and limitations of each technique to enable the user to select the best technique for a particular situation. Table 3 below, gives the four major technical sections and the topics covered in each.

Prediction Report. The second ADTI CMS publication, *Prediction of Water Quality at Surface Coal Mines* (Kleinmann, 2000) was prepared by the Prediction Working Group. This working group consisted of 27 experts who worked under the direction of Chairman Robert Kleinmann. The makeup of this Working Group is shown in Table 4.

The Prediction report is a comprehensive treatment of all aspects of coal mine drainage prediction at surface mines. The report contains chapters on: How Geology Affects Mine Drainage Prediction, the Hydrology of the Appalachian Bituminous Coal Basin, Static Tests for Coal Mining AMD Prediction in the Eastern U.S., Guidelines and Recommendations for Use of Kinetic Tests for Coal Mining AMD Prediction in the Eastern U.S, Overburden Sampling Considerations and Mine Drainage Prediction, a Summary of Concepts and Processes.

Table 3. Major Technical Subjects in ADTI Avoidance/Remediation Handbook

Alkaline Addition and Overburden/Refuse Reclamation	**Active Treatment Technologies**
Bactericides	Aeration/oxidation
Alkaline addition	Neutralizers
Sewage sludge	Flocculants/coagulants
Encapsulation	Reverse osmosis .
Removal of toxic materials (remining and reprocessing)	Ion exchange resins
Selective handling	Electrodialysis .
Reclamation (regrading and revegetation)	Natural zeolites .
Daylighting underground mines	Metals recovery from AMD sludge
Synergistic effects	**Passive Systems Technologies**
New techniques	Natural wetlands
Engineered Structural Techniques	Constructed wetlands
Water management	Anoxic limestone drains
Inundation (saturation)	Vertical flow systems
Dewatering	Limestone ponds
Drains	Open limestone channels
Impervious soil cover or membrane	Bioremediation
Underground mine seals	Diversion wells
	Limestone sand treatment

Table 4. Makeup of Working Group 1, Prediction.

Affiliation	**No. of Members**
Federal Government	10
State Government	7
Academia	6
Industry/Consultants	4

The key findings, recommendations and conclusions in the report are summarized below:

- Mine drainage prediction should be considered as the integration of chemical, geologic, hydrologic and biologic processes needed to arrive at an overall estimate of water quality.
- If site characterization is adequate, it is generally possible to predict post-mining water quality.

- Prediction is best achieved by using a variety of tools, including, hydrologic data, geologic data, and data from prior mining sites with equivalent properties. An integral part of the evaluation should be whether predicted water quality is likely to have unacceptable effects on local water quality (i.e., resource sensitivity), and if so, what can be done during mining and reclamation to avoid or negate any such adverse effects.
- Implicit in prediction is the requirement that the samples collected be representative of the site being evaluated; i.e., geologic variability within a site must be captured through adequate sampling. The effect of weathering on the sampled strata must also be considered.
- Acid Base Accounting (ABA) remains the preferred static overburden mine drainage prediction test. The use of ABA for accurate prediction of mine water quality depends on obtaining representative overburden samples.
- There is an uncertain or "gray zone" for ABA overburden analyses, between analytical results clearly associated with alkaline drainage and those that are clearly associated with acidic drainage. Neutralization Potential (NP) values less than 10 tons/1000 tons, or Net Neutralization Potential (NNP) values less that 0 tons/1000 tons are considered potentially acid producing. NP values greater than 21 tons/1000 tons or NNP values greater than 12 tons/1000 tons are considered alkaline. The gray zone was defined as the region between these values.
- Modified ABA procedures are recommended to account for sources of error due to the presence of the mineral siderite and to the subjective nature of the "fizz" test (see Chapter 4). The presence of the mineral siderite is known to cause overestimation of alkalinity levels reported in ABA results.
- ABA analyses should use total (rather than pyritic) sulfur; since this overestimates acid potential, it will provide a margin of safety.
- Overburden analysis may not be necessary, if equivalent information is available from adjacent mining, pre-mining water quality and other site characterization data. The most effective predictor of AMD potential has been found to be previous mining in the same seam and general location as the proposed operation.
- Many recommendations were made for improving and standardizing kinetic (simulated weathering) testing (see Chapter 5). Kinetic testing is especially appropriate when ABA results fall into the gray zone.

- The importance of overburden sampling considerations was emphasized (see Chapter 6). A practical approach to overburden sampling was outlined, using a toolbox of useful information and an experience-oriented understanding of overburden sampling. Overburden sampling considerations include: a sound sampling plan based on geologic knowledge, preliminary drilling, the size, shape and layout of the mine, depth of overburden, depth of the weathered zone, topography and facies changes.
- The ADTI Coal Mining Sector supports the work done in Pennsylvania (see Chapter 6), which indicates that a minimum of three and more typically six to seven drill holes are needed per 100 acres to capture the geologic variability of a site. But, as each site is different, no hard and fast rule can be stated.
- Finally, and most importantly is the need to evaluate each mine site on a case-by-case basis, as each mine site is unique, which precludes the use of a simple cookbook approach.

Subsequent and Ongoing CMS Activity

Subsequent CMS activity has focused on the following general areas:

Monitoring and Evaluation of Acid Mine Drainage Remediation Projects. The purpose of this activity is to determine the overall performance of AMD remediation technologies.

Selenium in Coal Mine Overburden and Surface and Ground Water. This is a project to identify potential sources, strategies for preventing mobilization and offsite transport, and treatment methods.

Field Verification of the Acid-Base Accounting Method to Predict AMD. This project compares pre-mining and post-reclamation water quality data at reclaimed mine sites. This will help determine which parameters most accurately predict post-mining water quality; i.e., how well the pre-mining ABA results compare to water quality actually produced from a reclaimed site.

Development of standardized kinetic test procedures. This is a project to develop a standardized simulated-weathering laboratory test procedure to predict coal mine drainage quality resulting from coal-mine overburden by more realistically simulating the chemical conditions under which

AMD forms.

Other projects. There are a variety of other projects. These include monitoring of in-situ underground mine treatment sites and providing technical assistance to watershed AMD remediation projects.

These activities are discussed in more detail in Parsons et al., (2004), which follows this paper. The future planned activities of the CMS will also be discussed in Craynon (2004) also in this session.

Metal Mining Sector (MMS)

Funding

Funding for the MMS has involved a variety of funding sources, as the MMS group does not have a dedicated source of funding in the same manner as the CMS does through OSM. MMS funds have come from OSM, EPA, which has provided $20,000 for general support over the last two years, and project specific funding from the US Army Corps of Engineers through its Restoration of Abandoned Mines (RAMS) project. It is estimated that the volunteer time and agency/company support has amounted to approximately $100,000 for the MMS group. The MMS is aggressively pursuing funding from a variety of sources, including private as well as government sources.

Metal Mining Sector Activities

The MMS, through its various technical committees, has been active with several projects, many of which are conducted through the University Center for the ADTI-MMS, the Mining Life-Cycle Center at the Mackay School of Mines, University of Nevada, Reno. Also participating is the Western Universities Consortium, a cooperative venture of several western universities. The ADTI-MMS also includes a university network, among which requests for proposals will be circulated in addition to the Consortium universities.

Standardized Testing Methods. MMS is working with the American Society for Testing and Materials (ASTM) on test methods standardization, “ruggedness testing” and alternatives to existing ASTM methods for several aspects of acid drainage testing. In cooperation with BLM,

MMS is working on the development of long-term dissolution tests for various waste rock lithologies. MMS is also working with USGS, National Institute of Standards and Technology (NIST) and the Canada Center for Mineral and Energy Technology (CANMET) to develop standard reference materials for mine waste and for toxic release inventory and quality control.

Restoration of Abandoned Mine Sites Database. The Mining Life-Cycle Center at the University of Nevada, Reno is working with the Western Region Restoration of Abandoned Mine Sites (RAMS) program administered by the U.S. Army Corps of Engineers (USACE), to develop two information databases. These databases will be for the State of Nevada and will include a GIS database for the collection and evaluation of site specific data from abandoned mine sites and a technology database for the summary and evaluation of appropriate technologies that can be used for abandoned mines.

Satellite broadcast on acid drainage. On January 24, 2002 the MMS group presented a Bureau of Land Management (BLM) training course on Acid Rock Drainage, Prediction and Treatment. This course was a day long live satellite broadcast covering all aspects of acid drainage that was developed, prepared and presented by members of ADTI-MMS with the support and assistance of the BLM training center staff in Phoenix, Arizona. The broadcast received good reviews from viewers across the country.

Coordination and support for corporate research. In 2002 Molycorp approached the ADTI-MMS for assistance in developing and soliciting a research proposal for the purpose of investigating the potential effect of chemical and physical weathering on the stability of waste rock piles at its molybdenum mine located near Questa, New Mexico. The ultimate goal of this research is to develop a model to assess the risk of failure of existing waste rock piles based on the physical, chemical and mineralogical composition and weathering of the rock. ADTI-MMS has coordinated the distribution of a Request for Proposal (RFP) and has worked with Molycorp to review proposals submitted. A team from the University of Utah was selected by Molycorp and a review team of ADTI-MMS members will be working with Molycorp as the project gets underway in 2004.

INAP Coordination. ADTI has been actively involved in coordination with the International Network for Acid Prevention (INAP), an international industry group, on a range of acid drainage issues. INAP will help fund some of the ADTI-MMS projects.

Incorporation as a formal Non-Profit Corporation. In order to more effectively pursue long term goals, the MMS steering committee has supported incorporation as a non-profit corporation. This will give ADTI-MMS a more formal legal status which can help in several aspects of the group's mission.

Other Projects. West Virginia University and the University of Nevada, Reno are completing an engineers manual: *Guidelines for the Design of Abandoned Mine Land Restoration* for the US Army Corps of Engineers, Engineering Research and Development Center. The report focuses on the development of engineering standards for coal and hard rock mine land remediation and the treatment of mine drainage.

MMS Workbooks

Each of the MMS technical groups is developing a workbook for their area of responsibility. The Introduction and Mitigation chapters are both currently available on the ADTI-MMS website for review. The Prediction chapter has received funding and is being written. Progress on the other workbooks continues as funding and time permit. See the MMMS website below for additional information on the workbooks.

ADTI Websites

Each of the ADTI sectors has its own website. The MMS website is http://www.unr.edu/mines/adti/. It is maintained by the Mining Life-Cycle Center at the University of Nevada, Reno. The website contains information about ADTI, Committees, Workbooks, Consensus Review, Projects, Presentations, Research and Links as well as information about how to join. The website also serves as access for review of workbooks. Contacts can be made through the website to gain access to the review process.

The CMS web site, http://wvwri.nrcce.wvu.edu/ADTI is administered by the NMLRC; it has background information, project listings and a list of contacts.

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