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SAND94-1657C

AN OVERVIEW OF THE MIXED WASTE LANDFILL INTEGRATED DEMONSTRATION

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ABSTRACT

The Mixed Waste Landfill Integrated Demonstration (MWLID) focuses on "in-situ" characterization, monitoring, remediation, and containment of landfills in arid environments that contain hazardous and mixed waste. The MWLID mission is to assess, demonstrate, and transfer technologies and systems that lead to faster, better, cheaper, and safer cleanup. Most important, the demonstrated technologies will be evaluated against the baseline of conventional technologies. Key goals of the MWLID are routine use of these technologies by Environmental Restoration Groups throughout the DOE complex and commercialization of these technologies to the private sector. The MWLID is demonstrating technologies at hazardous waste landfills located at Sandia National Laboratories and on Kirtland Air Force Base. These landfills have been selected because they are representative of many sites throughout the Southwest and in other arid climates.

I. INTRODUCTION

The US Department of Energy (DOE) established the Office of Technology Development (OTD) as an element of Environmental Restoration and Waste Management (EM). EM manages wastes generated from current operations and remediation of all DOE sites. OTD has a mission to rapidly develop, demonstrate, and transfer needed environmental technologies to Environmental Restoration, Waste Operations, and Defense Programs. As part of this initiative, OTD is supporting a network of Integrated Programs (IPs) and Integrated Demonstrations (IDs). Integrated Programs focus on technologies to solve specific aspects of environmental or waste management problem. Integrated Demonstrations "integrate" the "demonstration" of innovative technologies that are proposed by federal laboratories/universities/industry research partnerships. Each ID is focused upon a different environmental need aimed at resolving specific problems representative of generic DOE environmental issues.

The MWLID focuses on "in-situ" characterization, monitoring, remediation, and containment of landfills in arid environments that contain hazardous and mixed waste. The MWLID mission is to assess, demonstrate, and transfer technologies and systems that lead to faster, better, cheaper, and safer cleanup. The demonstrated technologies will be evaluated against conventional baseline technologies and systems. Comparisons of cost, efficiency, risk, and feasibility of using these innovative technologies at other sites are being conducted. The MWLID is working to transfer these technologies to environmental restoration groups for the routine cleanup of similarly contaminated landfills throughout the DOE complex and to the private sector for commercialization.

The MWLID is demonstrating technologies at Sandia National Laboratories' Chemical Waste Landfill, Mixed Waste Landfill, Technical Area II Classified Waste Landfill, and an Air Force Weapons Laboratory Hazardous and Solid Waste Amendments (HSWA) site. The Chemical Waste Landfill received chemical hazardous waste from the Laboratories from 1962 to 1985, and the Mixed Waste Landfill received hazardous waste and radioactive wastes (mixed wastes) over a twenty-nine-year period (1959-1988) from various Sandia nuclear research programs. The Technical Area II Classified Waste Landfill contains VOCs, inorganic, and mixed waste, has recently been to added as a demonstration site. These landfills are now closed. The Kirtland Air Force Base Hazardous and Solid Waste Amendments (HSWA) site, operated from 1960 to 1973 by the Air Force Weapons Laboratory, received waste from radio biological experiments.

These sites were selected because they are representative of many sites throughout the Southwest and other arid climates.

The MWLID program is divided into four areas: Characterization and Monitoring, Remediation, Containment, and Technology Integration.

II. CHARACTERIZATION AND MONITORING

Site characterization must include detailed information about the contamination including the source, types, mobility, and amounts as well as the spatial distribution of each contaminant. Quantitative information about the geologic and hydrologic properties of the site also must be determined so environmental scientists can accurately predict how contaminants behave underground. Multiple technologies are needed to fully characterize and monitor a site. One of the MWLID's primary goals is applying innovative technologies to minimize disturbance at landfills while maximizing information gathered by characterization methods. The MWLID utilizes a systems approach that incorporates compatible and complementary technologies for site investigation (Figure 1).

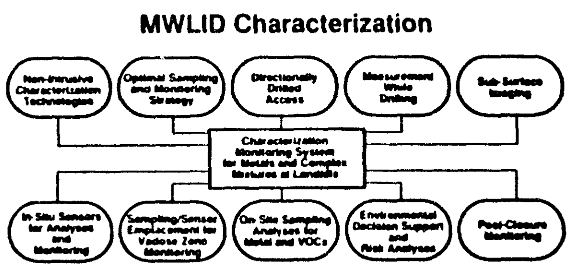

Figure 1

For source characterization, historical data and non-intrusive technologies that do not require holes to be drilled or samples to be taken are used to develop a sampling plan. Non-intrusive methods include electromagnetic (EM) measurements and magnetometry.

A. Cross-Borehole Electromagnetic (EM) Imaging

Cross-borehole EM Imaging can be used to map the subsurface of site by measuring the attenuation and phase shift of radio frequency signals propagated between boreholes. Since electrical properties, such as resistivity or electrical conductivity, are directly related to the chemical composition of the fluid passing through the geologic medium, contaminant source and plume detection may be possible.

B. Magnetometer Towed Array

The Magnetometer Towed Array or *STOLS* employs an array of seven magnetometers mounted on a buggy to rapidly survey a site. The vehicle and sensor platform have been designed to exhibit low magnetic signature to minimize interference with the magnetometers. An on-board computer accepts magnetic data simultaneously with precise positioning data and outputs positions for every magnetic data point. Displayed on a video monitor, the magnet map of the surveyed area provides the user interface to semi-automated target analysis. A magnetic anomaly can be selected for a iterative least-squares model matching to determine the best fit of the magnetic moment and depth to the anomaly.

C. Optimization of Sampling Strategies

The ID is employing a *computerized sampling plan* using geostatistics that optimizes historical and non-intrusive field data to aid in the formulation of a sampling strategy. The objective of Optimization of Sampling Strategies is to develop software for the optimization of sampling strategies, also known as "Smart Sampling." The software, SitePlanner and PLUME, combine data visualization, data management, and geostatistics to optimize the number and location of drilling and sampling locations needed to characterize a hazardous waste site. The system can be used in the field as data are collected, such as geologic and on-site chemical analytical information, to support real-time decision making during a site characterization process. Using this methodology to optimize the number and location of borings, wells, and samples can result in significant savings in time and costs for site characterization. This sampling strategy provides guidance in sample placement for contaminant delineation. The plan assists in siting vertical and directionally-drilled boreholes and sampling locations along the boreholes.

D. Hybrid Directional Boring and Horizontal Drilling

New methods of directional drilling (drilling at an angle), and horizontal boring are being demonstrated to eliminate the problem of drilling-induced contaminant migration and contaminated drilling by-products. In addition, worker safety is enhanced because the drilling equipment can often be located at the periphery of the landfill. Two industry partners for these drilling projects are Charles Machine Works, (Oklahoma) and Water Development Corporation (California). This drilling program seeks to minimize the environmental impact of the drilling process and provide a low cost but high quality alternative to more costly, conventional directional methods at shallow depths and vertical peripheral drilling. The project has involved the end users of the equipment in testing and evaluation. Successful demonstrations of the technology have been conducted at Savannah River Site, Hanford, Sandia National Laboratories, and Kirtland Air Force Base.

E. Measurement While Drilling

The Measurement While Drilling (MWD) project is a downhole screening technique that combines a downhole sensor with a drilling tool in order to detect contamination while a borehole is being drilled and without bringing a sample to the surface. Contaminant detection and quantification, data transmission, and navigation are some of the important issues to be mastered and integrated in this project. The first combination sensor and drilling technique to be developed is a gamma spectrometer for radionuclide detection and quantification linked to a steerable "push" drilling method. Subsequent sensors may include detection of metal or organic contaminants. Using MWD techniques site characterization can be achieved in less time and at lower costs since sample collection and analysis can be minimized or eliminated.

F. Absorptive Stripping Voltammetry (ASV)

New Mexico State University and Pacific Northwest Laboratory are partners in demonstrating a rapid field screening method, stripping voltammetry for the detection of heavy metals in soil samples retrieved through drilling. This method can analyze four metals simultaneously at parts-per-billion (ppb) levels within several hours of collection. Results are as good or better than comparable laboratory techniques. Significant cost savings can be achieved using ASV to support field characterization and remediation activities. This technique provides results in the field in a near real-time fashion and can be used as a screening method for site worker safety, to direct field activities quickly and efficiently, and to minimize the number of samples that must be sent to a laboratory for conformation analyses.

G. Borehole Permeameter for Site Monitoring

The borehole permeameter is a probe designed to measure in-situ unsaturated hydraulic conductivity of various geologic media. Understanding the hydraulic conductivity of various geologic units beneath a contaminated site is crucially important since conductivity is a principle controlling factor in the transport of contaminants in the subsurface. The borehole permeameter is versatile in its applications, can fit inside a five-inch diameter borehole, and can be deployed at depths up to 300 feet. In addition, the permeameter is being developed to collect in-situ measurements of soil moisture. Future development is planned to use the permeameter in the saturated zone.

H. Metal Detection by X-Ray Fluorescence

Downhole X-ray fluorescence spectroscopy (XRF) is a project designed to detect and quantify metals in a lined borehole in real time using two XRF techniques. Depending on site-specific objectives and constraints, the XRF probe can use either a radio-isotope source or an X-ray generating tube to detect metal contamination in the subsurface. Downhole detection and quantification of metal contamination minimizes the number of samples that must be collected and subsequently analyzed on-site or shipped off-site to a laboratory. In-situ analysis can greatly speed the characterization process and support near real-time decision making in the field leading to savings in cost and time.

I. SEAMIST ™ and Vadose Zone Monitoring Technology

The SEAMIST™ membrane liner, developed by Science Engineering Associates and demonstrated at the MWLID, is a promising technology that, for many applications, can replace the rigid casing found in most boreholes. SEAMIST™ can be used for sample collection, in situ measurements, and transporting sensors downhole without allowing contact between the instruments and the contaminated soils. Sensors which operate downhole to detect contamination or measure soil properties reduce the number of soil samples which have to be obtained and sent offsite for analysis.

An integrated pressure and gas sampling system using the SEAMIST™ borehole liner has been built by Sandia National Laboratories and Science and Engineering Associates. This system is a stand alone field system that performs real time measurement at up to 45 sampling ports in either a single well or multiple wells. The wells used can range from test holes one to two inches in diameter created by a hydraulic "punch," to existing full size boreholes eight inches in diameter. The sampling system utilizes a Bruel and Kjaer gas analyzer, a barometric pressure sensor, a differential pressure sensor (to determine the pressure difference between the surface and sampling point), and a solenoid valve system to sequentially connect each sampling port to a sensor. Also, temperature sensors and thermocouple psychrometers (TCPs) that measure soil water potential are located in selected wells. The Vadose Zone Monitoring System can be used to characterize and monitor contaminant transport in soils with deep vadose zones.

J. Post-Closure Monitoring

The objective of this project is to design, field test, and evaluate an automated state-of-the-art soil moisture monitoring system for measuring the hydraulic performance of covers and subsurface barriers used for landfill closure. Three brands of Time Domain Reflectrometry (TDR) technology are planned to be compared with conventional neutron technology to measure the moisture content changes in various covers and barriers currently under development and testing.

K. Environmental Decision Support System

The Environmental Decision Support System (EDSS) is a user-friendly, interactive, computer code that facilitates the environmental decision-making process. The system is being designed to provide access to site data through a geographic information system (GIS); provide a set of analysis tools to evaluate site conditions; and provide a platform for graphically displaying and documenting the results of these analyses. The EDSS is a tool that can be used by site managers and regulators for developing conceptual models of a site, running numerical simulations, risk analysis, and optimizing sampling locations.

L. Landfill Characterization and Monitoring System

The Landfill Characterization and Monitoring System (LCMS) is an integrated systems approach for characterizing and monitoring contaminants in and beneath landfills. The system uses the best of emerging and existing technologies that are compatible and complementary. The emphasis of the system is on minimally-intrusive technologies and downhole sensors that require minimal development work. The synergy of this approach can produce superior results in a safer fashion while reducing costs and time for field investigation as much as 80% to 90%. The demonstration, evaluation, and rapid transfer and commercialization of these technologies throughout the DOE complex and to the private sector are primary goals of the LCMS. To date the LCMS has several commercialization successes including the Magnetometer Towed Array, Optimization of Sampling Strategies, Angled and Directional Drilling, Absorptive Stripping Voltammetry, and the *SEAMIST*™ Liner.

III. REMEDIATION

Site characterization provides the information necessary for the MWLID to tackle the technology development for remediation of mixed waste landfills using in-situ technologies that will minimize the risk from the landfill contents without excavating the waste materials and contaminated soils (Figure 2). This innovative remediation mission is based on the premises that (1) moving the landfill to another location only transfers the risk and (2) the national capacity for permitted mixed waste is limited, thus encouraging management of mixed waste landfills at their current location.

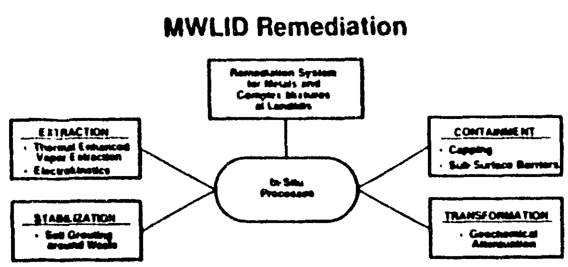

Figure 2

Few in-situ technologies are available to remediate contamination located in the area between the landfill and the groundwater. The vadose zone is an important area because it provides a barrier between the landfill and groundwater. While the vadose zone can effectively isolate and contain some contaminants, other contaminants may move quickly through this zone. When the vadose zone becomes contaminated with fast-moving pollutants, such as volatile organics, there is concern that pollutants may reach groundwater before intervention can take place. The MWLID focuses on safe, efficient, and effective new methods to remediate *fast-moving* contamination in the vadose zone and containment of the *slow-moving* contaminants to minimize their long-term migration. These remediation technologies can provide the basis for an advanced clean-up strategy.

The MWLID remediation technologies include extraction of fast moving VOCs and the transformation of heavy metal contaminants to nonmobile forms. Removal of the most rapidly moving constituents will then allow for long-term remediation and/or containment and monitoring of the site.

A. Remedial Options Evaluation

This project will identify and evaluate innovative remedial technologies that should be pursued by the Mixed Waste Landfill ID and will present the results in topical reports. Successful completion of this project will provide a basis for Environmental Restoration to select innovative technologies as part of the RCRA Corrective Measures Studies and compare them with existing proven baseline remediation methods.

B. Thermal Enhanced Vapor Extraction

The MWLID is demonstrating an innovative extraction technology. *Thermal Enhanced Vapor Extraction System* (TEVES) will demonstrate vacuum technology combined with soil heating methods and off-gas treatment to remediate volatile organic wastes that often are found at mixed waste landfills. The soil contaminants are volatilized by electrical and microwave heating. The electrical heating will raise the soil temperature to approximately 100° C and allow for removal of low boiling contaminants as well as water. Removal of the water makes further use of electrical heating impossible. The microwave heating is then used to raise the soil temperature to approximately 250° C to remove higher boiling contaminants. Since soils have interconnected spaces between each particle, contaminated air and vapors can be removed from the soil by applying a vacuum to a pipe placed in the ground. The hazardous vapors that are extracted are treated in a catalytic oxidation process that destroys the contaminants similar to an automobile catalytic converter. The output of the offgas treatment is passed through an NaOH scrubber so that only CO_2 and H_2O are vented to the atmosphere.

C. Electrokinetic Remediation

There are currently no viable in situ methods for remediating heavy metal contamination from unsaturated soils. The MWLID is demonstrating the feasibility of electrokinetic removal of chromate contamination from an unlined chromic acid pit at the Chemical Waste Landfill at Sandia National Laboratories, where the chromium contamination has been detected to a depth of 75 feet, a depth at which excavation is not economically feasible. *Electrokinetics* is a method where subsurface chromium contamination is moved through the soils by the application of a small electric field.

D. Chromium Transformation

Some soil contaminants, such as chromium (Cr), can exist in more than one redox state, with one more mobile than the other. This project will investigate the behavior of Cr waste under chemical conditions typical of the unsaturated zone. Cr chemistry in natural systems is not understood, particularly in the unsaturated zone in arid environments, where pore water chemistry fluctuates in response to cyclic saturation and evaporation.

It is imperative to identify and quantify the appropriate chemical reactions that must be considered during selection of remediation methodologies, in order to improve clean-up efficiency. Alternatively, results may obviate the need for extensive remediation by demonstrating the immobility of precipitated insoluble Cr. Technologies are being evaluated to find ways to transform more mobile chromium to a less mobile state by a chemical reduction process.

IV. CONTAINMENT

Once the immediate threat of fast-moving contaminants is under control, the remaining landfill debris must be contained to minimize the long-term migration of slow-moving contaminants. Containment technologies involve (1) the placement of surface covers to minimize precipitation infiltration into the landfill and leaching wastes into the surrounding soil; and (2) the placement of subsurface barriers to contain slow-moving soil contaminants.

A. Subsurface Barriers

The ID is evaluating the feasibility of emplacement of *subsurface containment structures* to contain slow-moving soil contaminants.

1. In-Situ Containment and Stabilization of Buried Waste. This project is developing, demonstrating, evaluating, and implementing advanced grouting materials for in-situ stabilization and containment of contaminated soils. A variety of different cementitious compounds have been tested for durability, freeze-thaw cycle effects, and evaluating the stabilizing effects on certain contaminants. Information from this project will be transferred to the sub-surface barrier emplacement project.

2. Subsurface Barrier Emplacement. This technology will work to evaluate, test, and demonstrate the emplacement of horizontal barriers beneath waste sites from directionally drilled boreholes, using advanced barrier materials. A review of potential barrier emplacement techniques will be carried out with consideration given to practicality, economy, and compatibility with drilling, barrier materials, and site characteristics. Selected emplacements may be tested and evaluated in the field at a benign site, and finally a selected waste site at Sandia National Labs.

These barriers emplaced under waste sites will provide interim containment of contaminants, thereby confining the volume of waste; allowing time for the development of rational remediation options. And protecting precious groundwater. A barrier system may prove satisfactory for permanent waste containment or could enhance the effectiveness of other in-situ remediation techniques.

3. Verification of Sub-Surface Barriers. A technology is needed that will aid in the development of subsurface barriers by providing regulators with a way to ensure barrier integrity after emplacement. This project is evaluating technologies which could be used to help verify barrier continuity and designing a system for possible field trials in conjunction with the Sub-Surface Barrier project.

4. Effects of Site Capping. This technology has taken measurements under an existing cement cover in a series of boreholes to develop what effects a cap has on the soil beneath. Temperature and moisture readings were taken for a year and this data is being interpreted to provide information for other cover and barrier projects.

B. Surface Covers

Above ground technologies, termed covers or caps, are required for the closure of all landfills in order to reduce the amount of water which leaches the waste out of the landfill. Alternative cover designs that offer cost and technical advantages in arid and semi-arid regions are being demonstrated by the MWLID at Sandia National Laboratories and Los Alamos National Laboratory.

1. Prototype Decision Support System (DSS) to Select MWL Barrier Cover Systems. A PC-based prototype DSS software package, running under Windows, is under development. It will be a user-friendly coupling between symbolic processing and numerical near-surface hydrologic modeling. It will provide risk managers with an objective way to select capping alternatives for remediating radioactive and mixed waste landfills.

2. Migration Barrier Covers. This project will design a migration barrier cover system for a mixed waste landfill using results from and ongoing migration barrier field demonstration and a technology status review. Tasks include gathering data from Hill AFB in Utah pertaining to hydrologic performance of 4 different cover barrier designs. This information will be used to develop an advanced cover for demonstration as part of the Advanced Landfill Cover Demonstration project for the MWLID.

3. Dry Barrier Applications. The objective of this project is to develop and demonstrate an air-enhanced dry barrier for application to landfills in arid environments. This technology is based on the well-founded capillary barrier concept—the contrast in unsaturated hydraulic conductivity of a coarse layer (barrier) and an overlying finer layer will limit downward water flow. This technology goes beyond the conventional capillary barrier in that the coarse layer is dried with lateral air flow through the layer,

preventing moisture accumulation in the layer and ensuring that its unsaturated hydraulic conductivity remains low. The drying of the barrier by air can be accomplished by passive or active means, in order to ensure that the air flow is sufficient to load and transport any net recharge to the atmosphere. The dry barrier may also have application as a method for stripping gas-phase contaminants.

4. Advanced Landfill Cover Demonstration. This demonstration project involves the construction, testing, and evaluation of a number of intermediate-scale landfill cover designs. One cover design will be the present conventional design as governed by EPA guidance. Two alternative designs will be tested for comparison to the conventional cover: a bio-engineered capillary barrier cover and an enhanced capillary barrier cover.

The test design will emphasize measurement of the water balance for each design option, consisting of data for runoff, erosion, movement through the cover, lateral drainage, change in water storage, and evaporation. The demo will use a new cover technology to optimize designs. Success is defined as demonstrating alternative designs from the conventional EPA design that may be more applicable for arid and semi arid sites.

V. TECHNOLOGY INTEGRATION

Technology Integration is an integral part of the MWLID mission. The focus of the technology integration effort is to facilitate the involvement of outside participants in the ID activities, to expedite the transfer of the technologies to the private sector for commercialization, and to hasten the adoption of successfully demonstrated technologies throughout the DOE complex and by other Federal agencies. The ID is working with federal, state, municipal, and tribal governmental agencies to expedite the regulatory approval and the use of these technologies. The MWLID is aggressively developing partnerships with the State, municipalities, tribal groups, and private industry to broaden the knowledge and use of its achievements. The ID is working with The New Mexico Environmental Alliance to apply innovative technical solutions to industrial environmental problems. The MWLID is an active participant in the DOE-sponsored Waste Management Education and Research Consortium (WERC), a research partnership among the New Mexico universities, national laboratories, and the Navajo Community College. The ID provides internships and graduate research opportunities for students and educators to challenge them to become involved with innovative solutions to environmental problems.

VI. SUMMARY

The Office of Technology Development has identified performance measures or metrics for technology development. The metrics (in italics) and how the ID measures up is as follows:

A. *Identify "Improved Technologies" (that show improvement over baseline technologies) that lower costs, reduce risk to workers and the public, provide cleaner final site, and are safer.*

The ID's technologies have reduced the number of boreholes and samples needed for site characterization. There have been over sixty field demonstrations of ID technologies that have resulted in no personal injuries or exposures. There have been no releases or episodes which have placed the public or the environment at risk. The concept of identifying and then remediating the fastest moving constituents and containing the remaining contaminants will allow for a cleaner final site with reduced costs compared to conventional remediation.

B. *To develop technologies that meet engineering and economic criteria after bench and pilot phases.*

The ID is demonstrating several technologies which come from the remediation Integrated Program and will be demonstrating another in FY95.

C. *It is essential to have user involvement in the development process.*

The ID has in the past and will continue to work with Environmental Restoration (ER) in identifying needs and evaluating new proposals. ID technologies have been field tested on Sandia ER sites to assist in characterization and partial remediation of hazardous landfills.

D. *Assure availability of technologies for transfer with full documentation and insure they meet the requirements of stakeholders.*

The ID has worked with OTD Headquarters Program Managers and Operations Office program personnel in identifying deliverables, milestones, final reports and conducting commercialization workshops to ensure that transfer of technologies can be done smoothly and efficiently. The ID has beta-tested PROTECH, a technology database, and been instrumental in collecting information for inclusion into it.

E. *Technologies must meet the requirements of stakeholders and final decision documents.*

Stakeholders are constantly being made aware of progress of ID technology development through technology reviews, mid-years and during the technical reviews for future funded projects. The OTD also includes stakeholders in their mid-year reviews and publishes monthly status reports from the IDs and IPs.

F. *Provide mechanisms for "Private Sector" to use their creativity and entrepreneurial spirit. Pull together the best talent and innovation available, leverage DOE dollars with private investment and improve technology transfer and implementation.*

The MWLID has twenty-five industrial partners working on FY94 projects. Two of these partners have CRADAs currently in place with two more close to signing agreements. The ID has seven national laboratories, multiple research laboratories, and six universities participating on technical projects. WERC, as previously mentioned, has also been very active on several different technology demonstrations. Leveraging of over $1 million from industrial partners since the ID was started has reinforced their commitment to develop technologies to the OTD mission. To ensure that technologies are transferred the MWLID will conduct commercialization workshops to aid the private sector in marketing their technologies. Small business workshops have been conducted to help those from the private sector understand the ways they can partner with the national labs.

MWLID technologies that have been commercialized are (1) magnetometer towed array, a non-intrusive characterization technology; (2) Siteplanner™ and PLUME, sampling strategy software; (3) SEAMIST™, a membrane used for sampling, sensor transport and maintaining borehole integrity; and (4) Cross-Borehole Electromagnetic Imaging.

The MWLID will continue to work closely with the Office of Technology Development to ensure that we continue to strive to meet their metrics throughout the lifetime of this demonstration.

ACKNOWLEDGMENTS

This work is funded by the Department of Energy-Office of Technology Development, EM-55 under the Mixed Waste Landfill Demonstrations Technical Task Plans and EM-52 Technical Task Plan No. AL2-3-41-05

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