Oppenheimer's Box of Chocolates: Remediation of the Manhattan Project Landfill at Los Alamos National Laboratory - 12283

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ABSTRACT

Material Disposal Area B (MDA B) is the oldest radioactive waste disposal facility at Los Alamos National Laboratory. Operated from 1944-48, MDA B was the disposal facility for the Manhattan Project. Recognized as one of the most challenging environmental remediation projects at Los Alamos, the excavation of MDA B received $110 million from the American Recovery and Reinvestment Act of 2009 to accelerate this complex remediation work. Several factors combined to create significant challenges to remediating the landfill known in the 1940s as the "contaminated dump." The secrecy surrounding the Manhattan Project meant that no records were kept of radiological materials and chemicals disposed or of the landfill design. An extensive review of historical documents and interviews with early laboratory personnel resulted in a list of hundreds of hazardous chemicals that could have been buried in MDA B. Also, historical reports of MDA B spontaneously combusting on three occasions —with 50-foot flames and pink smoke spewing across the mesa during the last incident in 1948—indicated that hazardous materials were likely present in MDA B. To complicate matters further, though MDA B was located on an isolated mesa in the 1940s, the landfill has since been surrounded by a Los Alamos commercial district. The local newspaper, hardware store and a number of other businesses are located directly across the street from MDA B. This close proximity to the public and the potential for hazardous materials in MDA B necessitated conducting remediation work within protective enclosures. Potential chemical hazards and radiological inventory were better defined using a minimally intrusive sampling method called direct push technology (DPT) prior to excavation. Even with extensive sampling and planning the project team encountered many surprises and challenges during the project. The one area where planning did not fail to meet reality was safety. There were no serious worker injuries and the minor injuries recorded were those common to construction type activities. Extensive monitoring along the site boundary demonstrated that no hazardous chemicals were released and radiological dose to the public was within administrative limits.

INTRODUCTION

Material Disposal Area (MDA) B is an inactive subsurface disposal site, designated Solid Waste Management Unit 21-015, located in Technical Area (TA) 21 adjacent to DP Road at Los Alamos National Laboratory (LANL) (Fig. 1). MDA B is a narrow strip of land with an overall length of 594 m and ranges in width from 22 m to 91 m. It covers an area of approximately 24,400 m^2 (6 acres). MDA B is comprised of 10 discrete pits or trenches ranging in depth from 5 m to 12 m in depth. Adjacent properties on DP Road include municipal land and private properties in a local commercial zone. When remediation is complete DOE will transfer the MDA B property to the County. Los Alamos County and the Los Alamos School District plan on

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development of the transferred properties in the next few years as part of urban improvements that include retail stores and residential housing projects.

Known in the 1940s as the “contaminated dump”, MDA B received both hazardous and radioactively contaminated wastes from the Laboratory from 1944 until it closed in June 1948 after a fire. In 2009 the MDA B Project received funding from the American Recovery and Reinvestment Act (ARRA) to remediate the landfill. Disposal trenches were completely excavated, and all wastes and contaminated environmental media were characterized and shipped to multiple approved waste disposal facilities. The work was performed in accordance with the Compliance Order on Consent with the New Mexico Environment Department (NMED) and 10 CFR 830, “Nuclear Safety”. Engineering and administrative controls to comply with the nuclear safety requirements constituted the greatest efforts for the 2 years of remediation of MDA B.

Figure 1. Aerial view of TA 21 circa 1995. MDA B is parallel to DP road at top left of photo

SITE CHARACTERIZATION

Planning for the safe implementation of the MDA B waste retrieval project required information on the location and evolution of the disposal trenches and the nature of the wastes disposed. No waste disposal records were kept and no construction drawings or site engineering diagrams have been found that show the locations of the trenches when they were in use. Thus, understanding the context of the historic operations at MDA B between 1944 and 1948 was

essential to understanding what wastes would and would not have been disposed of at MDA B and what hazards these would pose during retrieval.

A report was compiled [1] that reviewed the available documents and information relevant to site operations at MDA B at the time the disposal facility was in use, including historic records and reports; some previously classified, historic memoranda and other correspondence; and aerial photographs taken in the 1940s, as well as retiree interviews. The report addressed the following questions in lieu of disposal records.

- What information is available concerning the physical boundaries, characteristics, and timing of waste burials at MDA B?
- What programs and organizations were active at Los Alamos in the mid- to late 1940s that may or may not have contributed wastes to MDA B?
- What specific process information is available that describes the types and quantities of wastes produced?
- What program, organization, or process information is available to exclude wastes from MDA B?

The operational history of MDA B is tied to the earliest history of the Laboratory, the scope and urgency of World War II, the transition to the Atomic Energy Commission in January 1947, and the start of the cold war. The resulting report summarized the development of the process chemistry, metallurgy, and other research and production activities at the Laboratory during the 1944 to 1948 timeframe to provide a perspective of the work conducted at the Laboratory; the scale of those processes; and the handling of spent chemicals, obsolete process equipment, and contaminated items. Monthly reports compiled by the operating groups of the period described the application of significant resources and research efforts to the recovery of the then-priceless new materials plutonium and enriched uranium and addressed the measures to ensure that the materials sent for disposal were not recoverable and that recoverable solutions were stored until a method to recover them could be developed. These monthly reports documented the development of new and revised processes, the refit and renovation of laboratories, the decontamination and dismantlement of old laboratory areas, and the disposal of items and equipment that did not meet release criteria after decontamination efforts.

Waste generator sites that used MDA B would have been the original technical area (TA-01), Delta Prime (DP) Site at TA-21, the contaminated laundry, the Bayo Canyon radiolanthanum project, the Omega Site (TA-02) boiling water reactor, and a few other radiological experimental areas of the early Laboratory. This assessment is confirmed by monthly reports and correspondence of the operating groups, as well as log books kept by the drivers of a truck that picked up contaminated trash and debris from these sites and delivered them to MDA B. Explosives wastes were not thought to be disposed of at MDA B because Anchor Ranch, S Site and other explosives production and test areas used what is now known as TA 16 MDA R for these types of wastes. During the war, the technical area contained virtually all plutonium and enriched-uranium research, purification, recovery and metal fabrication operations. After the war, DP West assumed operations for pilot plant scale plutonium purification, reduction, metal fabrication and recovery operations. Polonium operations moved to DP East. D Building

retained operations with enriched uranium, but converted to plutonium research and analytical support.

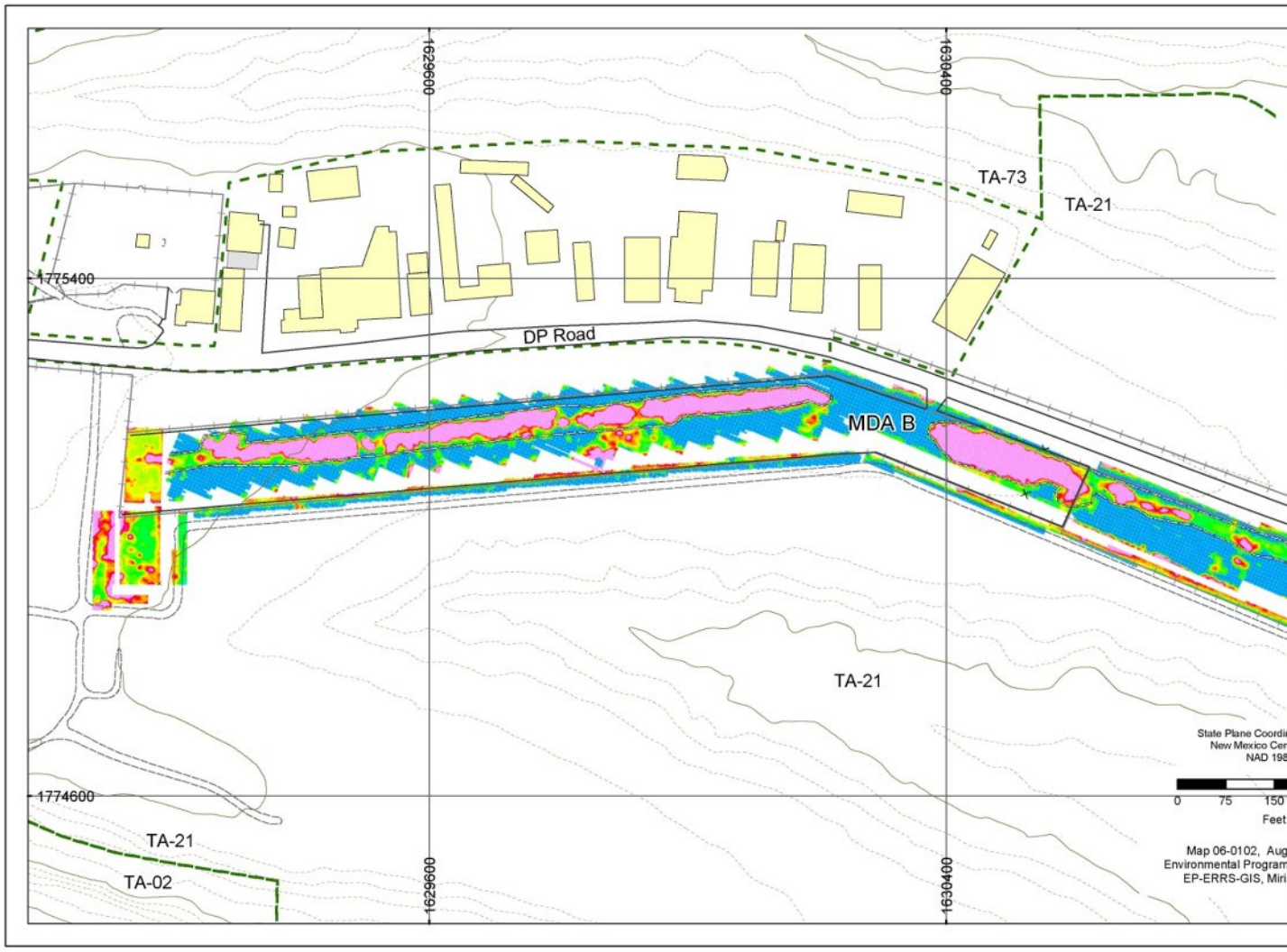
The MDA B pits and trenches are interpreted to be approximately located as shown on the geophysics map (Fig. 2). These pits/trenches were constructed by progressive eastward expansion of a series of semi- contiguous trenches during the 1944 to 1948 period. The earliest trenches were on the far western end of MDA B. Aerial photographs taken in 1946 and 1947 were interpreted to document which trenches were active during those years. By 1947, all laboratories had established waste disposal procedures that required laboratory and salvage wastes to be boxed and sealed. Large items or equipment were to be wrapped with paper or placed in wooden crates and tagged to indicate waste status. Operational wastes were generally placed in cardboard boxes and were simply piled into the active trench. Using a bulldozer, workers subsequently covered the material with fill dirt on a weekly basis. No effort was made to segregate waste types or loads, nor to compact the waste beyond the soil cover compaction efforts.

The vast majority of waste disposed of at MDA B waste was radioactively contaminated, including routine laboratory waste, contaminated glassware, obsolete equipment, wooden laboratory furniture, demolition debris, building materials, clothing, trash, compressed gas cylinders, and chemicals from the laboratory areas. All waste from the chemical and metallurgical laboratories (plutonium, uranium and polonium) was considered contaminated trash and all waste and trash was to be thrown into the “hot waste” receptacles placed in each laboratory. The largest waste contributors were the contaminated laundry and building demolition debris as most laboratory structures were upgraded after the war.

An extensive review of historical documents and interviews with retired Laboratory employees by project personnel guided development of a potential chemical and radiological inventory of MDA B. This inventory was used as the basis for development of safety documentation and for work planning. Over 170 hazardous chemicals were identified as being used in processes that would have sent waste to MDA B. Reports on plutonium research and recovery activities were used to estimate the potential inventory in MDA B and both the chemical and radiological inventories were incorporated into the safety documentation for the project.

In 2008 the DOE Los Alamos Site Office (LASO) approved a Documented Safety Analysis (DSA) and Technical Safety Requirements (TSR) for MDA B [2] as a hazard category (HC) 3 nuclear facility. The total quantity of material at MDA B was estimated to be 12 plutonium-equivalent Curies (PE-Ci) dispersed throughout approximately 18000 m^3 of environmental media and debris. Subsequently, LANL determined that they could segment operations and carry out the remediation of MDA B below HC 3 nuclear facility limits. LANS submitted a revised hazard categorization and in March of 2009 LASO approved the HC revision. The MDA B Project implemented essentially all of the engineered and administrative controls from the DSA and TSRs plus segmentation and material-at-risk (MAR) controls through the Facility Safety Plan (FSP) [3] to maintain MDA B below HC 3 threshold quantities.

Figure 2. Results of geophysical surveys conducted in 1998 at MDA B depicting locations of burial pits and trenches.



The unknown nature of the waste in the trenches and the close proximity of the public required extensive safety controls to protect both workers and the public. Controls were needed to address radiological, chemical and compressed gas hazards. Fires had started spontaneously in the landfill on at least three occasions. Excavation of all waste was required to be performed in HEPA filtered enclosures with fire protection, seismic, and blast overpressure requirements. (Figure 3). Excavation was accomplished using blast shielded excavators and workers were only allowed in enclosures when the excavator was not operating. Multiple enclosures were allowed to operate simultaneously but the MAR in each enclosure was limited and carefully monitored.

Figure 3. Excavation enclosures at MDA B

The safety controls established for the project prohibited open air excavation and therefore had prevented attempts to characterize the waste directly. Prior to start of excavation direct push technology (DPT) sampling was employed to provide both chemical and radiological data for waste characterization and MAR estimation. The DPT core sampling technique did not bring any waste material to the surface other than what was contained within the sampling tube and was considered the only acceptable method to obtain direct waste samples. Three specific objectives were defined for the DPT sampling:

1. Provide operational data for safely performing waste-retrieval and sorting activities by establishing correlations between field instrument readings and laboratory analysis before actual excavation begins;

2. Provide operational data for revising the estimated quantity and distribution of radioactive MAR; and

3. Provide operational data for analyzing waste samples for hazardous materials before excavation to aid in initial waste-sorting activities.

Previous geophysical data was used to select 87 DPT locations for sampling. The work plan specified obtaining samples at multiple depths from each location. Laboratory analysis was performed for radioisotopic distribution, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), metals, and toxicity characteristic analytes. Figure 3 shows the geophysical mapping of the MDA B site.

For the first objective the primary correlation sought was between field gamma assay and laboratory analytical results for the radionuclides Am-241 and Pu-239. Correlation was also sought between Am-241 and Pu-239 in both sets of data. Nuclear safety requirements limited core sampling to a maximum diameter core of 5 cm, which did not provide adequate sample volume for the required suite of analyses. For each depth interval sampled, multiple cores had to be obtained in order to achieve adequate sample volume and in some locations adequate volume was not obtained. In practice, the field and laboratory results could not be correlated because the field results were obtained for each individual core as it came out of the exclusion zone while the laboratory results were obtained for each sample, which usually was composited from multiple cores. A correlation between Am-241 and Pu-239 in the data was expected based on an expected uniform starting ratio of Pu-239 to Pu-241 in the weapons-grade plutonium material of the late 1940s and on Am-241 in-growth from the decay of Pu-241 over 60+years or about four half-lives of Pu-241. However, due to a wide variation in analyzed isotopic ratio a correlation could not be calculated with certainty. The ratio of the two isotopes was examined informally in all data sets and found to vary by over two orders of magnitude and in the analytical data the percentage of detects for Am-241 relative to Pu-239 was low such that the data set was very limited.

Radionuclide data for the second objective confirmed that Pu-239 is the dominant radiological contaminant. Radiological detects were also reported for Am-241, H-3, Cs-137, Pu-238, Sr-90, Th-228, Th-230, and U-238. Activities were within the expected range with the exception of one sample that was an order of magnitude higher for Pu-239. The calculated radionuclide inventory for MDA B was not revised based on the DPT sample data due to the small data set and variability in concentrations.

The third objective, to characterize the waste for hazardous constituents, required retrieving samples of the waste matrix.. Sample recovery suffered gaps of no recovery and limited recovery for a significant number of the cores retrieved. Problems with recovery suggest that waste was deflected from the 5 cm diameter core tube. Most cores contained only soil with little or no waste matrix. The minimal waste retrieval provided little insight into the wastes buried in MDA B. Although several metals and organics exceeded residential screening levels, only one sample contained mercury above the RCRA TCLP limit. Previous historical document reviews did not identify any sources for RCRA listed chemicals therefore TCLP metals were considered the only likely source of mixed waste.

In addition to the three primary objectives the DPT was also used to better define the depth and footprint of the trenches. The depth of the waste layer was determined to range from 1 m to 4.5 m. Two areas at the far east end of MDA B previously thought to contain waste were determined to not have a waste layer. Based on geophysical and DPT data the total volume of material to be excavated was estimated to be 18,150 m^3.

The disposition path for the primary waste stream, radioactive soil and debris, was also an important consideration in determining characterization requirements. Due to the large volume of waste to be retrieved and the short duration of the project, the decision was made to not use the limited space available in the LANL low level radioactive waste disposal facility but to request DOE approval for use of a non-DOE disposal facility. DOE HQ approved an exemption to DOE O 435.1 to allow the project to use a commercial disposal facility in Utah.

Characterization requirements identified in the Investigation/Remediation Work Plan (IRWP) for MDA B [4], various commercial TSD facilities Waste Acceptance Criteria (WAC), and the DPT results [5] were used to develop the sampling and analysis plan (SAP) [6] for retrieval of the buried waste in MDA B. Waste characterization required a composite sample of each 40 m^3 of waste removed to be analyzed for both radioisotopic and chemical constituents. In addition to the routine characterization, sampling of any identified anomalies was also required. The FSP required a MAR sample be analyzed for each waste container prior to the container being removed from the enclosure.

SITE REMEDIATION

Two different types of enclosures were constructed over the trench areas at MDA B. Ten Quonset hut type fixed metal enclosures and two wheeled movable enclosures were constructed over the life of the project. All enclosures included HEPA filtration systems as required by the FSP. As excavation of trench sections progressed either the wheeled enclosures were moved along the line of the trench or additional fixed enclosures were constructed and connected to form one continuous structure.

Excavation of buried waste began in the first two enclosures at MDA B in June of 2010. With potentially significant chemical hazards such as nickel carbonyl and many unknowns progress was initially slow. Each scoop of material from the dig face was placed into the bottom of the trench and spread out for visual examination prior to being placed in a waste container. Multiple visible and infrared cameras, radiation detectors and chemical monitors were viewed remotely from a control room during excavation. Waste technicians assigned to the control rooms used the video cameras to identify any anomalies that required segregation and additional sampling. Video recordings were archived to document all waste retrieval. After obtaining a composite sample and segregating anomalies, soil and debris waste was packaged into reusable bulk roll off containers. The FSP required a sample from each container to be analyzed by gamma spectroscopy at the MDA B field laboratory and a MAR value assigned to the container prior to removal from the enclosure.

Despite careful application of the FSP controls, on two separate occasions, material at MDA B temporarily exceeded HC 3 threshold quantities. The increased Pu-239 levels challenged the original assumption of minimal Pu-239 disposal at MDA B. Because of the uncertainties associated with the excavation of material at MDA B, it was not possible to guarantee that HC 3 threshold quantities would not be exceeded in the future. All excavation work at MDA B was halted until the nuclear safety issues could be resolved. To allow the project to meet the Consent Order deadline for completion, LASO submitted an exemption request from 10 CFR 830, Subpart B, "Safety Basis Requirements" on October 18, 2010. The exemption request allowed MDA B to continue to operate in accordance with the FSP while raising the facility MAR limit to 56 PE-Ci. The exemption request was approved by DOE-HQ on October 20, 2010. Excavation at MDA B resumed on October 24, 2010.

Three days after excavation resumed two drums of a white crystalline powder were recovered from one of the trenches. The drums were corroded and breached upon retrieval resulting in a high VOC alarm and a strong chemical odor. The area was evacuated and excavation halted again until the unknown chemical could be identified. Subsequent analysis identified the compound as naphthalene (moth balls) and excavation was resumed. This was one of only two times during the project that excavation was halted due to discovered chemical hazards. The second instance occurred when several dozen mason jars of beryllium (Be) shavings were unearthed in Enclosure 9. Several of the glass containers were broken resulting in the enclosure being declared a beryllium contamination area. Extensive sampling was initiated and Be was detected in other enclosures resulting in additional work delays. Further investigation determined that the local soil contained unusually high levels of naturally occurring Be. Work was resumed except in enclosure 9 which was inactive for several weeks until Be training and monitoring could be implemented for the workers.

Although there was much work being conducted with high explosives at Los Alamos during and after the Manhattan Project, explosives were not expected to have been disposed in MDA B because there was a designated explosives disposal area (MDA R) available at the time MDA B was operational. However, 29 items that appeared to be artillery shells were discovered in the trenches. (Fig, 4) The shells were identified as World War II era 5 inch Navy artillery rounds, Type 54. These shells, although thought to be inert, were required to be managed as potentially dangerous and warranted special handling and storage. The ordinance was transferred to an Army Explosives Ordinance Disposal team for demilitarization.

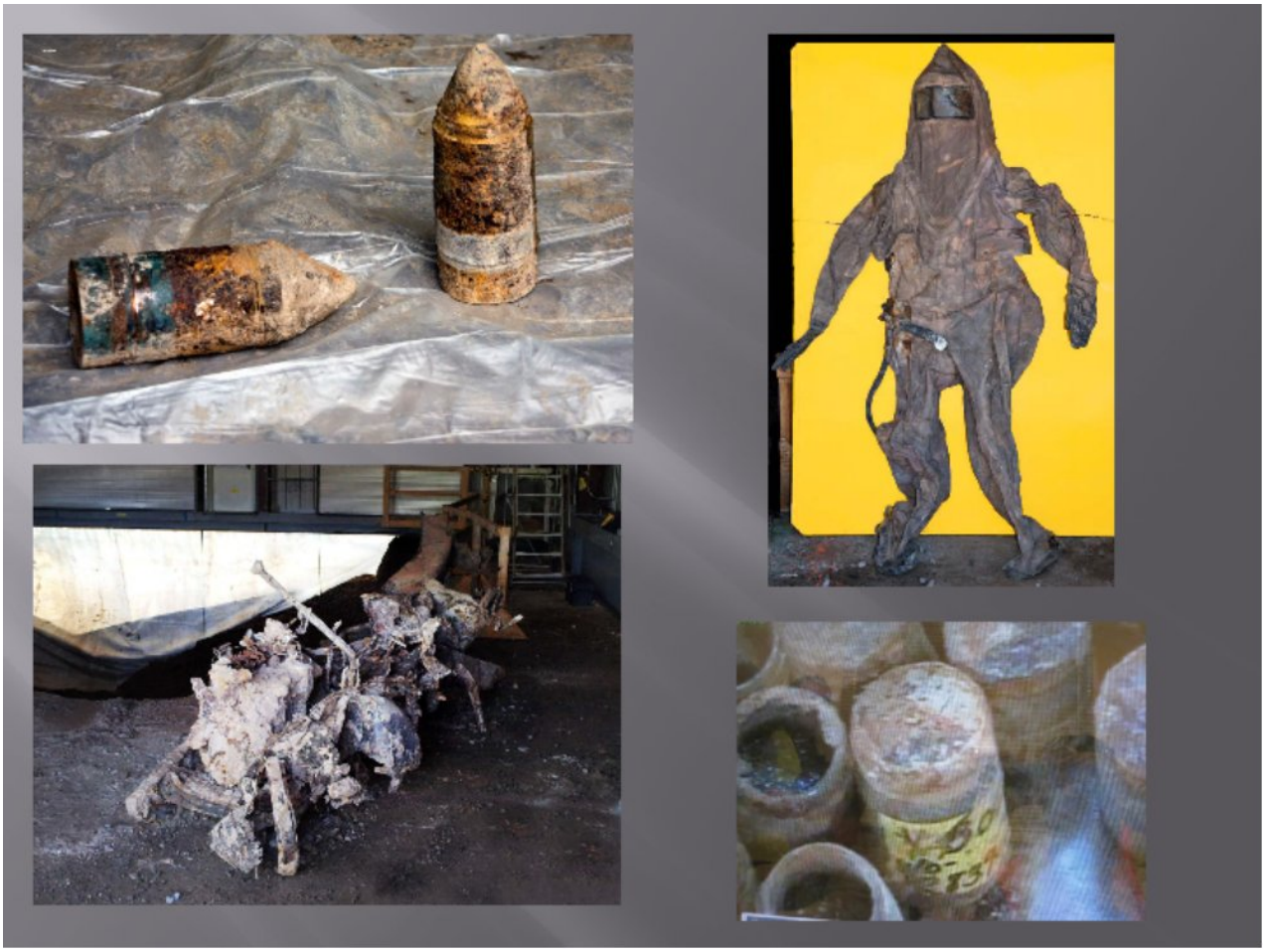
Two key project planning assumptions were determined to not be accurate as excavation of the trenches progressed:

1. waste was being excavated at depths exceeding the expected 4.5 m, and
2. Pu-239 concentrations were much higher than estimated.

Several trenches were found to have waste buried at depths exceeding 12 m. The increased depth resulted in a doubling of the waste volume (35000 m^3) from the original project baseline. Operations were extended to 7 days a week and a second shift was added to maintain the project schedule.

Several pieces of process equipment were found to exceed the transuranic (TRU) waste threshold and required special handling and packaging. Large areas of soil near the process equipment, although not TRU waste, also had elevated concentrations of TRU nuclides. This posed two significant problems for the project. Excavation of the soil greatly increased the MAR in storage and the waste exceeded the DOT limits for packaging in roll off containers used by the project. With limited options for DOT compliant containers to ship the waste the MAR continued to increase and in August 2011 exceeded the operational limit of 45 PE-Ci established by LASO. To reduce to total MAR at MDA B the highest MAR containers were selected to be transported to the LANL onsite disposal facility at TA-54. Since the waste containers were not DOT compliant transfer of the material required a road closure in accordance with the LANL Transportation DSA. Several road closures utilizing 30 or more trucks occurred over the next few months and reduced the MAR well below the operational limit.

Figure 4. Artillery shells, truck, jars of Be and radiation suit excavated from MDA B



Waste transportation was a challenge throughout the duration of the project. In addition to the remediation at MDA B, 24 production and research buildings at TA-21 were being demolished and the waste shipped off site at the same time. Both the D&D project and MDA B were competing for space on the very limited footprint of DP mesa. Over 1100 bulk waste containers

were staged at TA-21 awaiting shipment at the peak of the project. The waste disposition strategy was altered to allow shipment of waste to the onsite LANL disposal facility and to include shipments to the Nevada Nuclear Security Site (NNSS). The high MAR soils excavated could be compliantly packaged in 7 m^3 soft sided containers meeting DOT industrial packaging 2 (IP-2) requirements. This waste exceeded the Class A limits for acceptance at the commercial disposal facility but were acceptable for shipment to NNSS. During the peak of the shipping campaign over 40 trucks were in rotation shipping 100 bulk waste containers per week and logging over 100,000 miles without any accidents.

Near the end of June 2011 the Las Conchas Fire, the largest wildfire in New Mexico history, forced the closure of LANL and evacuation of the town for a week. Work resumed at MDA B after the July 4 holiday but activities were limited due to heavy smoke in the air which affected the enclosure ventilation systems. Due to the fire and other delays beyond the control of LANL, a request for extension of the completion date milestone, based on the force majeure clause in the Compliance Order on Consent, was submitted to NMED. The milestone date was subsequently extended from September 30 to October 27, 2011. Although the extension request was granted the project team was determined to complete the milestone by the original milestone date. Confirmation samples were obtained as excavation was completed in each grid section and the remediation report was drafted pending the last few confirmation sample results. Despite flawed assumptions and a major wildfire, on September 30, 2011 LANL submitted the MDA B remediation report to NMED to meet the original Compliance Order on Consent milestone.

SUMMARY

More than three years of effort by the LANL project team went into the planning for remediation of Material Disposal Area B. Hundreds of historical documents were reviewed; retired personnel were extensively interviewed and noninvasive techniques were used to characterize the site. The information collected was incorporated into the safety requirements, cost estimate, schedule and primary execution plan for the project. Ultimately the waste volume managed by the project approached 40000 m^3, more than double the original project estimate. This increase had a major impact on both project cost and schedule. Nuclear safety requirements for the project were based on an estimated MDA B radionuclide inventory of 12 PE-Ci. When excavation was complete over 123 PE-Ci had been removed from the trenches. The radionuclide inventory at MDA B was an order of magnitude higher than estimated. Work at MDA B could not have proceeded without the safety basis exemption from DOE-HQ. The one area where planning did not fail to meet reality was safety. There were no serious worker injuries and the minor injuries recorded were those common to construction type activities. Extensive monitoring along the site boundary demonstrated that no hazardous chemicals were released and radiological dose to the public was within administrative limits.

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