Lessons Learned From a Decade of Design, Construction, and Operations of the Environmental Management Waste Management Facility in Oak Ridge, Tennessee – 12062

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ABSTRACT

The Environmental Management Waste Management Facility (EMWMF) is the Department of Energy's on-site disposal facility for radioactive and hazardous waste generated by the CERCLA cleanup of the Oak Ridge Reservation (ORR). EMWMF recently completed building out to its maximum site capacity and is approaching a decade of operating experience. In meeting the challenges of design, construction, and operation of a mixed waste and low-level radioactive waste disposal facility within the framework of CERCLA, the Bechtel Jacobs Company LLC (BJC) project team learned valuable lessons that may be beneficial to other disposal facilities. Since project inception in 1998, the scope of the effort includes five regulator-approved designs, four phases of construction, and utilization of half of EMWMF's 1.63M m^3 of airspace during disposal of waste streams from across the ORR. Funding came from the broadest possible range of sources – privatization, American Recovery and Reinvestment Act, and two funding appropriation accounts.

INTRODUCTION

On-site disposal facilities have become the catalysts for accelerating site clean ups across the Department of Energy (DOE) complex by providing additional funding for footprint reduction projects as a result of the site-wide lifecycle cost savings they produce. These savings start accruing beyond the break-even waste volume at which the fixed capital and annual operating costs of the on-site facility are offset by higher unit transportation and unit disposal costs for off-site waste disposition. Thus the benefit from an on-site facility is derived in two primary ways:

- Maximize the percentage of the total site waste stream disposed in the on-site facility, and,
- Maximize efficiencies of design, construction, and operations.

The evolution of EMWMF from a concept to the catalyst of the ORR cleanup has spawned many practices relevant to the latter point (the former point being worthy of its own dedicated discussion).

DESIGN

As each phase of EMWMF was constructed, and operating experience accumulated, the knowledge gained was used to improve the next design. Each design was issued as an addendum to the Remedial Design Report to provide a CERCLA vehicle for regulatory approval. Of the five designs approved by the regulators, only four were actually built. The original design for Cell 5 as the final cell was retracted when consensus was reached with the regulators to expand EMWMF to six cells to maximize the utilization of the available space on site. The lessons learned applicable to facility design include:

Core Team. Even before the November 1999 approval of the Record of Decision (ROD) for an on-site disposal facility for the ORR, the project convened a Core Team with representatives from the Tennessee Department of Environment and Conservation (TDEC), the US Environmental Protection Agency (EPA) Region IV, DOE, and BJC. The Core Team quickly became, and continues to be, an effective forum for general communication, inter-agency rapport building, and resolving issues to sustain the momentum of the project.

Lesson Learned: Establish a Core Team as soon as possible. Empower the Core Team members to the extent each participating entity will allow to maximize the Core Team's effectiveness. Even if the Core Team members are not authorized to make decisions, having a venue for two-way real-time communication fosters better understanding of each entity's positions and priorities, which enables better decisions to be made faster, in most cases.

Lesson Learned: Anticipate turnover of the Core Team members by documenting Core Team interactions with meeting minutes and formalizing all agreements and decisions with official correspondence that is entered in the Administrative Record.

As the design commenced, the project faced several design challenges that stemmed from the site selection criteria for EMWMF that included practical considerations as well as technical considerations.

Site Access. The site for the facility is on the side of a steep ridge just inside the ORR boundary (see Fig 1) which precluded access from the north and provided over 35 m of topographic relief across the 300m north-south dimension of the footprint. To the east and west, the footprint was constrained by blue line tributaries which could not be impinged upon.

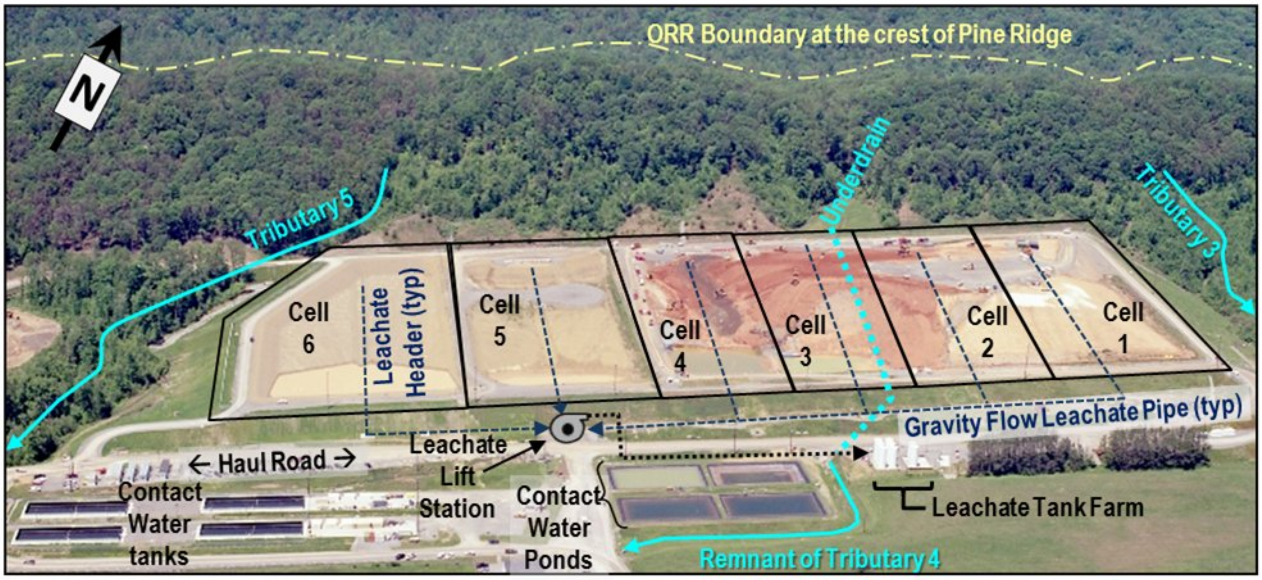

Fig 1. EMWMF facility layout showing the progression of cell construction from east to west and significant site features. .

For the sake of maximizing available space for future build-out, the first phase of the disposal facility was positioned as far to the east as possible without impacting the tributary or compromising the structural integrity of the facility. As a result, waste shipments could access the controlled area only from the south and west. However, each of the 3 times the facility was expanded to the west, construction precluded access from that direction, leaving the south access as the single access point.

Lesson Learned: Include site access during all phases of construction and operations as a siting criterion and a design criterion. Maintain multiple access points to increase through-put and provide multiple paths for access and egress in emergency conditions.

Site Topography. The site topography was used to benefit the facility's leachate collection system. The floor of the EMWMF is sloped at 5% from north to south with a leachate collection header running in that direction along the centerline of each cell. At the custom-designed penetrations at the sump in the south berm of each cell, the perforated collection headers transition to solid, double-wall pipes which flow by gravity underground into manholes, which then flow by gravity underground to the lift station for transfer to the central leachate storage tanks (refer back to Fig 1). This passive configuration has eliminated the cost and maintenance associated with leachate lift pumps, and more importantly, the undesirable consequences of pump failure – excessive head on the liner and the personnel dose and risk during pump repair/replacement – during the removal of 70,000 m^3 of leachate from EMWMF.

Lesson Learned: Where topography is conducive, gravity-draining leachate systems provide a reliable, passive, low-maintenance means of removing leachate from waste cells.

Shallow Groundwater. Groundwater is shallow over much of the site and is frequently expressed as surface water in the form of seeps, intermittent streams, and blue-line streams. The initial EMWMF design called for up to 15 m of fill in the channel of the blue-line tributary that bisected the footprint. Modeling predicted that the water table would rise with the backfill, but under-predicted the magnitude of the rise. By the time groundwater stabilized after Cells 1 and 2 were constructed, the water table in the future development footprint immediately adjacent to Cell 2 along the path of the former tributary channel was 1.5 m higher than the maximum allowable level. This level was established to maintain a dry 3-meter thick buffer zone between the water table and the base of the low permeability clay liner. Sporadic seasonal groundwater incursion into this buffer zone had been anticipated and was permissible, but a sustained incursion violated the design basis. To restore the dry buffer zone, a facsimile of the former stream was constructed in the form of a 325-meter long French drain at a nominal depth of 7.6 m below the grade of the future clay liner in Cell 3. The Underdrain (refer back to Fig 1) was composed of 3 increasingly fine gradations (railroad ballast to sand, from core to periphery) of durable aggregate in a 4 m x 2 m cross section, then backfilled with hydraulically compacted manufactured sand to the base of the buffer zone. Select material meeting the buffer specification was then used to bring the site back to grade.

Lesson Learned: Unless 100% of groundwater recharge can be diverted or an outlet is provided, the potentiometrtic surface in fine-grained soils will be a subdued replica of the surface topography. This experience also validated the benefit of the Core Team. Using the CERCLA process, multiple options were evaluated and the optimum solution was designed and implemented within 9 months of confirmation of the groundwater incursion.

Water Management. The primary reason for the abundant groundwater at the site is the average annual precipitation of 130 cm. A weather enclosure for disposal operations was considered early in the project but was rejected because of the need to accommodate simultaneous receipt of multiple waste types at multiple locations across the site, including visually classified waste that has to be placed a considerable distance from other waste deliveries by non-classified drivers. With a cumulative working face reaching 6 ha and a desire to avoid consuming airspace with daily clean cover, water management has been a perpetual challenge. To the extent possible, storm water falling within the waste containment structure berms is directed away from waste to manage it as clean runoff. However, the naturally low permeability of the native soil coming into EMWMF either as waste or clean void filler, made it operationally impractical to allow the balance of rain water to percolate through the waste into the leachate collection system. An agreement was reached with the Core Team to add a third category of site water – contact water – which is surface water collected within an active disposal that may have come in contact with waste. Per the agreement, this water would be collected in in-cell catchments and pumped to lined surface impoundments for sampling (refer back to Fig 1). Cumulative annual sum-of-the-fraction release criteria were negotiated to allow discharge of untreated contact water through the site storm water retention pond to adjacent surface waters. Since operations started in 2002, over 90,000 m^3 of contact water (81% of the total collected) has been discharged. Absent the negotiated category for contact water, that water would have been handled as leachate, which would have required over 5,000 tanker loads transported by road 16 km across the ORR to a liquid waste treatment facility.

Lesson Learned: Negotiate the simplest options possible for water management to minimize the burden on site resources.

Admixed Clay for the Liner. The multi-component liner for EMWMF includes a 0.9 m thick compacted clay liner, which is the critical component for attenuating the release of contamination over the 1,000 year post-closure design life of the facility. During the first construction phase, the project tried to take advantage of the availability of native clay soils for the liner. In spite of the construction of a test pad that produced a viable moisture-density zone for clay liner placement to meet the 1 x 10^{-7} cm/sec permeability requirement, the variability of the native clays caused 15 of the 93 Shelby tube samples of constructed liner to fail permeability requirements. The expensive, time-consuming, and frustrating rework motivated the development of a bentonite-admixture for the clay liner in Phase 2. The addition of 3% bentonite (by dry weight) in a pugmill broadened the optimum moisture-density zone for placement and yielded field permeabilities that averaged 1.7 x 10^{-8} cm/sec which is almost an order of magnitude better than the regulatory standard. The reliability of field moisture-density results to predict acceptable laboratory permeability results enabled placement of the next 15 cm lift in the clay liner without a hold point to wait 3 to 4 days for laboratory Shelby tube permeability tests. The schedule acceleration and reduced maintenance of completed liner lifts compensated for the additional costs for production of the admixed material. Further benefits included: the test pad and superior clay liner quality in Phase 2 qualified the clay borrow source and admix process for Phase 3 and Phase 4, eliminating additional test pads and saving an estimated $250,000 and 2 months of schedule each time; and, the admixing process included a 10 cm bar grate and a 2.5 cm x 2.5 cm screen to prepare the material for the pugmill (see Fig 2) which completely eliminated the need for hand-picking oversize material from clay liner soil as it was spread.

Fig 2. EMWMF used a pugmill for admixing bentonite with clay to produce superior quality material for the compacted clay liner.

Lesson Learned: Design and specification of high quality materials can pay off in the field by eliminating delays, rework, and maintenance. Qualify the borrow source and admix process for multiple phases of construction. A high quality finished product builds the confidence of the regulators in the overall competence and caliber of the project.

Modular Design. When the ROD for EMWMF was approved, the CERCLA decision processes for the remedial action and D&D projects that would generate waste were so immature that the capacity needed at EMWMF could only be estimated between 273,000 m^3 and 1,300,000 m3. A modular approach allowed the project to proceed with an initial 305,000 m^3 capacity (2 cells) to provide an assured disposal outlet to drive the imminent CERCLA decisions for the waste generating projects with the capability to expand EMWMF as other CERCLA decisions were made. Many of the site features in the first phases were designed to accommodate future expansion – e.g., surplus capacity for water management infrastructure and extension of each of the 7 liner layers well into the future Cell 3 footprint for ease of continuation. Some important features, however, should have been included to enhance expandability. First, Y's should have been installed for future Cells 3 and 4 in the gravity header that ran outside the south berm to collect leachate flowing from the individual cell leachate manholes to the lift station (refer back to Fig 1). Breaching that contaminated header when the manholes for Cells 3 and 4 were connected required radiological training and work permits for the otherwise clean construction work. Second, the leachate collection stone in the liner should have been discontinued at the top of the intercell berm to eliminate a pathway for contact water when the south-end catchments were full. The water percolated through the protective cover, into the leachate collection stone, and over the top of the berm into an uncontrolled area. The Cell 2 west intercell berm was modified in 2003 to remove the stone layer from the segment adjacent to the catchment. Subsequent intercell berm designs also accounted for this.

Lesson Learned: For a modular facility development plan, each phase of design should account for future expansion in each affected system and component, without compromising operations.

CONSTRUCTION

Facility construction was accomplished in four increments – Phase 1 developed the site and Cells 1 and 2 to provide 305,000 m^3 of airspace; Phase 2 added Cells 3 and 4 to bring the capacity to 840,000 m^3; Phase 3 added Cell 5 to increase the capacity to 1,246,000 m^3; and Phase 4 added Cell 6 (refer back to Fig. 1) to complete facility capacity at 1,631,500 m^3, which was 331,500 m^3 more than the 1,300,000 m^3 maximum capacity approved in the ROD. An Explanation of Significant Difference amended the ROD to add Cell 6. Each construction phase lasted just over a year and thus spanned the seasons each time. Twice the construction was executed by subcontractors and twice it was directly executed by BJC. The first two phases used privatization funding, the third phase used ARRA funding, and the last phase was split funded from two funding appropriation accounts. The most notable lessons learned from construction are:

Project Schedule. Every outdoor construction project is motivated to take advantage of good weather by working extra hours. This is even more important for disposal facility construction which includes weather-sensitive liner components such as low permeability clay and geomembranes with rigid quality standards. These are also the components most critical to operational and post-closure facility performance. During each EMWMF construction phase, the grading and earthwork started as soon as possible in the Spring to allow completion of the clay and geomembrane liner components by late fall before the onset of cold, wet winter weather could have a significant impact on progress and quality. A base schedule of 4 ten-hour days per week provided the opportunity to use Fridays as a weather make-up day each week. In addition, during periods of favorable weather, the project proactively worked some Fridays to generate schedule float as insurance against prolonged periods of bad weather later.

Lesson Learned: Create the schedule with due consideration to the impact of weather on quality and schedule recovery. During clay liner construction, a rain day in September creates a 1 to 2 day delay; a rain day in November can create a week-long delay because of longer time to dry out and the likelihood of another storm. Wet or freezing weather precludes welding of geomembranes. Work overtime when weather is good and the project is going well to get ahead of schedule and avoid the pressure and frustration of trying to catch up when the weather makes that difficult or impossible.

Recycling of Vegetation from Site Clearing. During the initial site clearing, the organic material was burned in pits, which was an effective, though not-so-green, means of disposal. No clearing was required for Phase 2, but when the clearing effort was being planned for Phase 3 construction, the project reflected on the challenges of controlling sediment in storm water runoff during the two previous phases. The fine-grain site soil that readily suspends in runoff and the site topography that creates high volume storm flows combined to reduce the effect of silt fence and check dams. During intense storms, these runoff controls were frequently overwhelmed by heavy sediment loading and heavy flow. Consequently, the vegetation cleared at the start of Phase 3 construction was mulched and generously placed on the downstream side of silt fence to both buttress the fence and provide a tortuous flow path to slow the flow and remove suspended solids before the flow entered drainage channels. Mulch was also used in small gabions as energy dissipaters at flow concentration points, and as interim cover for bare areas that were going to be worked intermittently prior to final grading and seeding.

Lesson Learned: Beneficially reuse cleared vegetation by mulching it for use as an erosion control medium. The improvement in the quality of runoff and the green approach was well-received by TDEC and EPA.

Long-Lead and Performance Critical Items. Throughout the four construction phases, schedule delays were caused by late delivery or out-of-specification condition of items ranging from clay liner soil to geosynthetics to leachate tanks. While some of these delays can be avoided simply by earlier acquisition, other constraints can limit the ability to mitigate this risk. The project baseline must include funding for early acquisition (which can be problematic if the project spans multiple fiscal years); adequate warehouse or laydown space must be available; and, inspection and testing of quality items must be done upon manufacture or delivery to allow time for replacement of failing items.

Lesson Learned: Identify critical acquisitions so they can be funded and scheduled as early as practical, then ensure other support is also appropriately planned – e.g. crane and laydown space to off-load leachate tanks, environmentally controlled storage, etc.

Integration of Construction Quality Control and Construction Quality Assurance. The EMWMF quality program included a construction quality control (CQC) subcontractor working with the construction team and an independent construction quality assurance (CQA) subcontractor reporting to the project engineer. CQC performed the testing and observations to document satisfactory completion of work in compliance with the specifications. CQA verified proper CQC testing methods and frequencies, replicated a percentage of CQC tests, and prepared the Construction Completion Report that TDEC and EPA approved to authorize use of the facility. With each phase of construction, CQC and CQA were increasingly integrated into the team. By the third and fourth phases, CQC and CQA conferred to split samples or co-locate sampling/testing sites as much as possible. Both entities were co-located with the construction team and attended the morning plan-of-the-day meetings and the evening end-of-the-day meetings to discuss testing and acceptance standards for scheduled work and to provide feedback from recent testing. Integrating the efforts of CQA with CQC, and integrating both entities closely with the construction team minimized discrepancies between CQC and CQA test results and thus retesting, minimized delays to perform tests or acquire samples, minimized repairs from destructive testing, and provided an opportunity to praise the whole team each time acceptable testing results were announced.

Lesson Learned: Fully integrate quality personnel (but maintain the necessary degree of separation to ensure independence). Integrate CQC and CQA testing and broadcast passing test results to provide positive feedback.

Pipe Locators. The leachate and contact water piping at EMWMF is high density polyethylene (HDPE). This material is desirable for its flexibility, weldability, and corrosion resistance, but when buried, it cannot be detected with conventional pipe locators. The first phase design included 15-cm wide foil tape 0.3 m above the buried pipe as a locating device. The tape primarily serves as a visual indicator of vertical proximity to piping during subsequent excavation, but under favorable conditions it provides a signal to magnetic pipe locators. An attempt after Phase 1 to magnetically locate the tape above the HDPE leachate pressure header between the lift station and the tank farm proved unsuccessful resulting in a breach of the outer wall of the double-wall leachate header by an excavator. To prevent a recurrence, a 6.5 mm diameter bare metal cable was affixed to all buried HDPE pipe (see Fig 3) in subsequent phases (in addition to the foil tape). At-grade terminations were provided for each pipe/cable run so a signal from the pipe locator could be induced to improve the instrument response. No further damage has been done to buried HDPE pipes during excavations.

Fig 3. To ensure buried HDPE pipe can be located, conductive wire was affixed to each pipe and metallic locator tape was placed 0.3 m above each pipe starting at the point the leachate headers exited the cell under the south berm.

Lesson Learned: Use conductive wire with surface terminations to provide a high-reliability means of locating buried non-conductive pipe in addition to conventional locator tape.

OPERATIONS

The goal of waste disposal facility operations is maximizing the return on the investment in design, construction, and eventual closure of the airspace through operational efficiency and optimization of airspace consumption. From the start of waste disposal operations in May 2002 through July 2011, EMWMF received 1,183,000 tonnes of waste from across the ORR. Six DOE prime contractors using dozens of subcontractors generated and shipped 134 waste lots to EMWMF. Accommodating each of these waste generators and their waste lots while preserving the operational goal often meant a new learning curve for EMWMF, the generator, or both. The most relevant lessons related to operations include:

Safety. The best way to sustain efficient and effective operations is to operate safely. Thanks to the dedication and perseverance of the entire crew, during the 3,351 days that BJC operated EMWMF, there were no lost work day cases. The number of consecutive safe work days was a continual source of pride among the crew and cause for periodic recognition and celebration. It is particularly impressive considering the type of work and hazards at the site – up to 200 deliveries per day amidst on-the-ground spotters and radcon technicians; steel debris that can suddenly release stored energy while being pushed and compacted by heavy equipment; over 5,000 tankers of leachate and contact water loaded and hauled 32 km (round trip) to the ORR liquid waste treatment facility; and the requirement for year-round facility operations and maintenance. This accomplishment was the result of a team commitment to implement Integrated Safety Management every day.

Lesson Learned: Safety first. Safe work requires an unwavering project-wide commitment to safety and recognition of those who make it happen.

Waste Generation Forecast. A key component of the ORR cleanup baseline and the EMWMF project baseline was the Waste Generation Forecast (WGF). As cleanup projects were initially identified and scoped, estimates by quarter of waste volumes by type and destination (on-site or off-site) were posted on the WGF. When the cleanup project acquired more information to refine the volume estimate, a baseline change proposal was required to document the basis for the change and maintain configuration control of the WGF. EMWMF used the WGF on a long range basis to maintain the project lifecycle baseline to ensure project resource levels were synchronized with the rate of waste deliveries. The process to add manual staff included position posting, hiring, training, and security clearance, which took 3 to 6 months. Similarly, adding heavy equipment to the fleet included specifications, bidding, manufacture, and operator training – a duration of 2 to 4 months. Most importantly, adding airspace capacity required a 2-year lead time for subcontract preparation, design, construction, and approval of the Construction Completion Report. For operational planning within a 6-month horizon, a higher resolution component of the WGF called the Waste Load Forecast was utilized to increase the resolution of the quarterly cleanup project waste volumes by identifying loads per week and per day by individual waste lot. The additional detail was used to schedule project support to assist startup of shipping campaigns as well as resource deliveries, such as clean fill, gravel, or grout and a concrete pump truck for void space filling.

Lesson Learned: Maintain configuration control of the waste generation forecast and communicate the importance of doing so to the waste generators. Require multiple levels of resolution to facilitate planning for long-term and short-term horizons. To the extent possible, sequence complimentary waste streams to foster efficiency – delivery of adequate quantities of soil waste concurrent with debris to fill the voids; concurrent or sequential delivery of waste streams requiring similar special handling equipment or hazard controls, etc.

Physical WAC Variances. EMWMF's physical WAC (e.g., size, weight, and void space) were based on the compaction specifications, the capabilities of the equipment fleet, and the resources customarily utilized to place waste. When a net cost saving to DOE could be demonstrated between the cleanup project and EMWMF, these criteria were waived and special arrangements made to accommodate variant waste. As cleanup projects began making repetitive requests for variances to the physical WAC, the most common variances were documented by EMWMF as blanket variances that cleanup projects could invoke during the waste stream approval process and implement the special conditions during generation of a waste lot. Examples include bundling rebar instead of cutting into 1.2 m lengths, stacking and banding intact transite panels in lieu of double bagging in $\leq$ 18 kg packages, and oversized equipment that would not fit within a 45 cm-thick lift. For these common variances, the necessary accommodations were easy to implement and well-practiced. Other waste items, however, required one-of-a-kind variances. These were negotiated with the cleanup project to reach an optimum accommodation based on a long-standing charging practice determination that held the waste generator responsible for the cost of materials and equipment (but not labor) beyond the resources normally utilized in EMWMF operations. Thus, equipment or containers that exceeded the physical WAC for $\leq$ 10% internal void space were accepted and subsequently grouted by EMWMF, with the generator paying for the grout, the concrete pump truck, and other dedicated supplies such as HEPA filters for container exhaust ports. Similarly, oversized and overweight equipment or debris was off-loaded and placed using a rented crane paid for by the waste generator.

Lesson Learned: Establish reasonable physical WAC based on the equipment, systems, and specifications for the facility. Also establish a process for variances to those WAC including the fiscal responsibility for the resources required to accommodate the variant waste.

Special Waste Streams. Operational efficiency is best achieved by standardization of the waste deliveries in terms of content and mode. Unfortunately, the cleanup of a 60 year legacy of radioactive and hazardous materials production, usage, and experimentation does not always allow for standardization. The ideal delivery to EMWMF was bulk LLW soil or debris in an end-dump truck. The 130,000 deliveries made to EMWMF, however, also included side-dump trailers, intermodal containers, articulated off-road dump trucks, and flatbeds. Delivered waste forms included drums, boxes, and cargo containers; wrapped equipment; bulk equipment; soil and debris containing asbestos or beryllium in super-sacks; classified waste; PCB waste, and treated Resource Conservation and Recovery Act waste. Each of these non-standard deliveries required some measure of special accommodation – a dedicated dump ramp (see Fig 4), off-loading equipment, worker training, worker and environmental monitoring, void filler, or security. With proper planning, symbiotic benefits were derived from some special waste streams. For example, stainless steel boxes containing lead waste were lined up around the periphery of high-void equipment to create a form to contain the grout used as void filler; and, a mulch-based spray-on fixative originally deployed to mitigate airborne asbestos hazards was also sprayed on classified waste for visual concealment (the bright green area adjacent to the classified dump ramp in Fig 4).

Lesson Learned: Standardize operations to the extent possible but anticipate non-standard deliveries. Explore ways to achieve some measure of commonality among special waste streams and take advantage of beneficial reuse of waste.

Fig 4. EMWMF facility infrastructure was developed to accommodate the standard and special waste streams being delivered.

Dedicated Waste Haul Road. After an improperly solidified waste leaked during transportation to EMWMF over a public road on the ORR, a haul road was constructed from the East Tennessee Technology Park, where most of the EMWMF-bound waste would subsequently originate, to EMWMF. An 8-km-long gravel road was built to connect to an existing 4.8-km-long road segment that ran through EMWMF. The new road crossed 2 public highways, 13 blue-line streams, the habitats of 2 protected species, wetlands, floodplains, the rights of way of a high pressure gas line and a 161kV power line, and the jurisdiction of all 3 major DOE prime contractors on the ORR. Overcoming these difficulties was justified by the benefits this dedicated-use road provided for waste transportation to EMWMF:

- reducing cycle time;
- eliminating risk to the public from a traffic accident or a waste spill;
- allowing a more efficient radiological survey protocol for waste vehicles;
- enhancing the security of classified waste shipments;
- allowing the installation of a radio frequency identification system to track waste shipments and automatically compile a waste database; and
- simplifying transportation paperwork since shipments were not "in commerce."

Lesson Learned: A dedicated haul road is an effective means of mitigating the risk of waste transportation and increasing throughput at the disposal facility.

Airspace Efficiency. A risk-driven cleanup, such as the one for the ORR, usually targets the buildings first because of the higher concentration of contaminants there versus the underlying and surrounding soils. On the ORR this produced a composite waste stream that is soil waste deficient and debris waste rich over most of the lifecyle, requiring that the excess void space in the debris be filled with clean soil. Since disposal facility airspace is a precious commodity and imported clean fill costs $8 to $10/tonne, the project constructed a test pad to determine the minimum ratio of soil to debris to meet the specifications for density of the waste matrix. The testing determined that 1 m^3 of debris properly mixed and compacted with 1 m^3 of soil (waste or clean) will fill > 90% of the void space and result in the consumption of 1.7 m^3 of airspace. The integrity of the facility cap that must remain intact 1,000 years depends on the compliant construction of its support structure, the waste matrix, so the optimum soil to debris ratio is a critical parameter. Other clean fill austerity measures included recovery and reuse of fill from clean in-cell roads and storm water diversion berms and acceptance from ORR construction projects of spoils that were clean but preferentially retained on the ORR. As of July 2011, airspace usage was exactly what was originally forecast in the ROD, which had anticipated a debris rich waste stream – 65% waste, 35% clean fill.

Lesson Learned: Establish targets for airspace utilization and track metrics (but never compromise on meeting compaction and void specifications). Reuse clean in-cell materials as much as possible, use "suspect spoils" that might not be suitable for off-site fill, and seek out sources of free fill.

Equipment Maintenance. Void space is not the only challenge presented by a debris rich waste stream. The equipment that pushes the steel and concrete debris from the dump ramp across other steel and concrete debris to the active placement grid is subject to the harshest possible operating conditions. In spite of the special waste-handling features installed on the D-8 dozers at EMWMF to protect them, the D-8's have experienced damage to almost every external component. Suspension of waste receipts due to equipment failure is not an option so maintenance was a top priority. Preventative maintenance was the best way to enhance equipment reliability. With the understanding that some equipment failures were inevitable, EMWMF took steps to minimize the impact. Vendor mechanics and back-ups were badged, trained, and cleared to allow them full access to the equipment in the controlled area. A dedicated maintenance pad was constructed in the controlled area (refer back to Fig 4) to alleviate hazards from performing repairs on waste and to avoid the need to decontaminate and free-release the equipment or damaged parts (which can be virtually impossible) for repair off-site. A spare parts inventory based on frequency of damage was maintained on-site to reduce the delays from parts acquisition. When new equipment was purchased in 2009 and 2010, the best of the old equipment was refurbished for use as stand-by spares.

Lesson Learned: Heavy equipment operating in contaminated areas, especially tracked equipment, is difficult or impossible to free-release so bring the maintenance program to the equipment. Fixed price subcontracting presents a temptation to increase profit by skipping maintenance. Explicit subcontract terms and a robust maintenance assessment program can eliminate that temptation.

Final Lesson Learned: Document lessons learned after each major phase of a project to benefit successive phases. This is especially important for iterative scope such as modular disposal cell design and construction or repetitive scope such as disposal campaigns by large D&D or remedial action projects.

CONCLUSION

In the process of becoming the cost effective disposal outlet for the majority of the ORR cleanup waste, EMWMF overcame numerous challenges. Lessons learned were a key factor in achieving that success. Many of EMWMF’s challenges are common to other disposal facilities. Sharing the successes and lessons learned will help other facilities optimize design, construction, and operations.