Linde FUSRAP Site Remediation: Engineering Challenges and Solutions of Remedial Activities on an Active Industrial Facility – 13506

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ABSTRACT

The Linde FUSRAP Site (Linde) is located in Tonawanda, New York at a major research and development facility for Praxair, Inc. (Praxair). Successful remediation activities at Linde combines meeting cleanup objectives of radiological contamination while minimizing impacts to Praxair business operations. The unique use of Praxair's property coupled with an array of active and abandoned utilities poses many engineering and operational challenges; each of which has been overcome during the remedial action at Linde.

The U.S. Army Corps of Engineers – Buffalo District (USACE) and CABRERA SERVICES, INC. (CABRERA) have successfully faced engineering challenges such as relocation of an aboveground structure, structural protection of an active water line, and installation of active mechanical, electrical, and communication utilities to perform remediation.

As remediation nears completion, continued success of engineering challenges is critical as remaining activities exist in the vicinity of infrastructure essential to business operations; an electrical substation and duct bank providing power throughout the Praxair facility. Emphasis on engineering and operations through final remediation and into site restoration will allow for the safe and successful completion of the project.

INTRODUCTION

The Linde site is located in the Town of Tonawanda, a suburb between Niagara Falls and Buffalo, New York. The site is an industrial complex owned and operated by Praxair which serves as its worldwide research and development facility locally employing over 1,400 personnel. The Praxair property encompasses approximately one-half square kilometers and is surrounded by a residential neighborhood, public park and gold course, railroad tracks, and other commercial properties. Commercial and industrial activities have been conducted at the Linde site since the 1930's.

Throughout most of the 1940's, the Linde Air Products Division of Union Carbide Industrial Gas processed uranium ores under contract with the Manhattan Engineer District (MED). Linde was selected to support the MED program as a result of its experience processing uranium to produce salts used to color ceramic glazes. Activities under the MED contract used a three-phase process for separation of uranium dioxide from uranium ores and tailings, and for conversion of uranium dioxide to uranium tetrafluoride. These activities resulted in elevated levels of radionuclides in portions of the property and several buildings. The principle radionuclides of concern are uranium, thorium, and radium.

The Formerly Utilized Sites Remedial Action Program (FUSRAP) was initiated by the federal government in 1974 to identify, investigate, and clean up or control sites throughout the United States previously part of the early atomic energy program. Under its authority for FUSRAP, the U.S. Department of Energy (DOE) conducted several characterization studies at various Tonawanda sites between 1978 and 1992 that formed the basis for future actions at the Linde site. In 1997 the administration and execution of FUSRAP was transferred from DOE to USACE.

In 2009, CABRERA was designated as the prime remedial action contractor for the Linde site. Through the final phases of remediation at the Linde site, USACE and CABRERA have overcome several engineering challenges to successfully complete remediation while maintaining Praxair's business operations.

THE ENGINEERING CHALLENGES

The different engineering challenges are separated by the required remediation activity. Relocation of an aboveground, semi-permanent structure and structural support of an active water line were necessary to complete remediation of an abandoned sanitary sewer and surrounding soils. Complete installation and activation of mechanical, electrical, and communication utilities followed by protection of these utilities via excavation shoring were required for remediation of utility tunnels and surrounding soils.

Sanitary Sewer Remediation

In 1944, one of five buildings in support of MED activities was constructed at the Linde site. This building became known as Building 31. Linde FUSRAP remedial investigations identified contamination inside the building, adhered to foundation walls, and in soils beneath and surrounding the foundation walls. In 2005 the building was demolished and foundation walls and surrounding soils excavated until site cleanup objectives were met. However, an abandoned forty-six centimeter (cm) sanitary sewer originating from Building 31 remained. This sanitary sewer traveled approximately 250 meters due South from Building 31 to a one meter (m) mainline sanitary sewer. Through various data collection efforts the forty-six centimeter sanitary sewer was identified as contaminated which necessitated the need to find and remediate it in entirety. In 2011 a remedial action to excavate the southernmost thirty meters of the forty-six centimeter sanitary sewer and its surrounding soils was initiated.

Before excavation activities could begin, a semi-permanent, aboveground structure used for salt storage (salt barn) by Praxair needed to be relocated. The salt barn is approximately fourteen meters wide by sixteen meters long with a center height of approximately seven meters and is accessible through a 5 meter wide by 5 meter high opening. Erected by Praxair in 2004, the salt barn was originally located less than one and one-half meters from the forty-six centimeter sanitary sewer and consists of a galvanized tubular steel frame bolted to a reinforced concrete pad and covered with a vinyl tarpaulin. The steel frame includes six arched trusses stabilized by cross bracing and attached to a base beam which is bolted to the concrete pad. While the salt barn could be unbolted from the pad and moved, its structural integrity was a concern. Thus, consideration also was given to demolishing the structure.

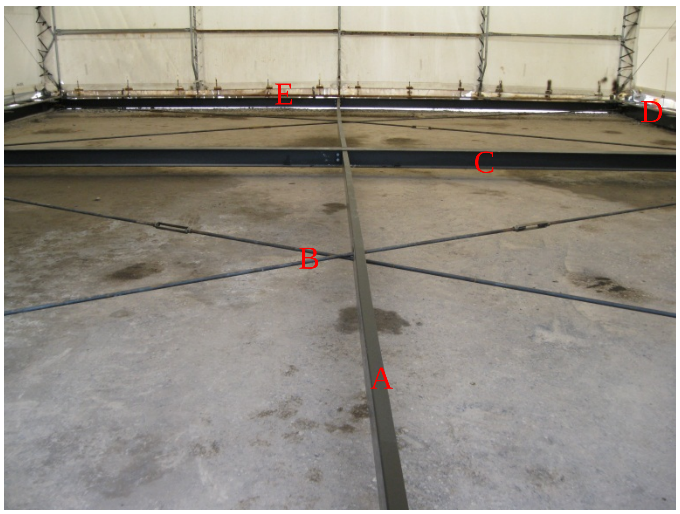
A Professional Engineer (PE) in the State of New York (NYS) evaluated the structural condition of the salt barn in accordance with ANSI International (ANSI), formerly American National Standards Institute, requirements. The engineering survey included a visual inspection and structural assessment of the steel frame to evaluate the possibility of collapse during either salt barn demolition or relocation. From the structural assessment it was concluded the salt barn could be demolished (requiring procurement and construction of a new salt barn for Praxair) or relocated to a nearby area. A cost benefit analysis between demolition and relocation identified relocation as providing best value to the client.

USACE and CABRERA coordinated with Praxair to select the relocation spot. It was agreed the salt barn would be placed on a heavy duty asphalt pad approximately fifty-three meters northeast of its current location while also being rotated approximately 100 degrees. This location positioned the salt barn atop previously remediated areas while providing at least three meter clearance from the nearest active underground utility and eight meter clearance from nearby high voltage power lines. The heavy duty asphalt pad was constructed of thirty centimeters of NYS Department of Transportation (DOT) #2 run-of-crusher stone subbase compacted to ninety-five percent standard proctor density, ten centimeters of NYSDOT Type 3 binder, and five centimeters of NYSDOT Type 7 top coat. The pad was constructed three meters larger than the salt barn in each dimension to provide ample space for positioning. The pad was also constructed approximately thirty centimeters higher than the surrounding grade with a half percent slope to keep surface water off the pad while promoting positive drainage. An asphalt ramp approximately eight meters wide by eight meters long was constructed to provide access for salt storage and loading. The asphalt pad and old salt barn location are shown in Figure 1. An asphalt pad was selected over a reinforced concrete slab-on-grade to maintain the semi-permanent nature of the whole structure.

A: New asphalt pad
B: Salt Barn in old location

Fig. 1. Asphalt pad in relocation spot with salt barn in previously existing location.

The most challenging task was designing a system capable of supporting the salt barn from collapse while allowing it to traverse rugged terrain during the move to its new location. The final design utilized a series of support plates and "I" beams to support the salt barn frame. One W10x49 beam with eight, two centimeter thick support plates welded to it was specified to run each length of the salt barn. Six of the support plates were located where the six trusses attach to the base beam. The remaining two support plates were installed for permanent anchoring in the new location. The base beam was connected to the support plates using two, one centimeter "U" bolts. One W8x35 beam with three welded support plates supported the rear (opposite the opening) of the salt barn. The base beam was attached to these support plates with one, one centimeter "U" bolt. A second W8x35 beam was placed across the width of the salt barn halfway down its length. This beam was bisected with two C8x13.7 channel pieces. The front of the salt barn required two W8x35 beams with two support plates each and one W8x35 beam with no support plates. The beams with support plates were used to support the salt barn frame (similar to the rear) while the beam without support plates spanned across the salt barn opening. Splicing using nuts and bolts and/or welds was required at all locations where beams and channel were joined or intersections existed. The beams and channel were tensioned using cross braces created with two and one-half centimeter diameter threaded rods and turnbuckles. The assembled salt barn frame support system is shown in Figure 2.



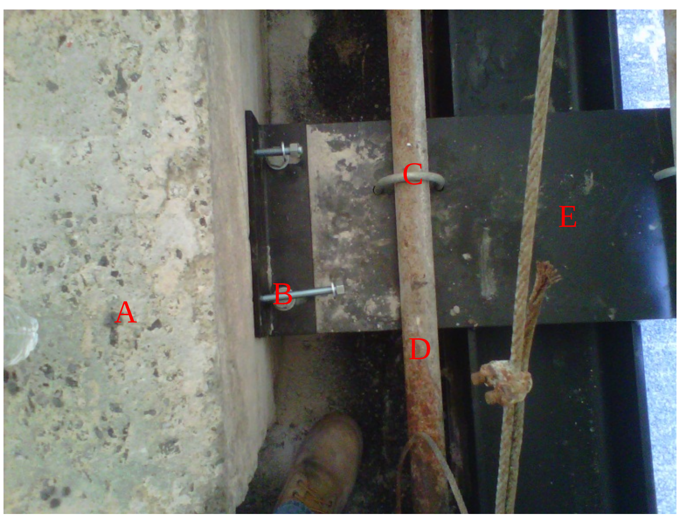
A: C8x13.7 channel
B: Threaded rod cross brace
C: W8x35 beam
D: W10x49 beam with support plates
E: W8x35 beam with support plates

Fig. 2. Salt barn frame support system.

To move the salt barn, skid plates were welded to the bottom of the four corners and midpoints of the support beams. The skid plates were one centimeter thick steel with thirty to forty degree upward bends which allowed the beams to ride over the terrain instead of plowing through it. Moving the salt barn required two pieces of heavy equipment and would be completed in three phases. In phase one, each piece of heavy equipment pulled from the rear of the salt barn with parallel and equal tension. This moved the salt barn approximately thirty meters due East from its former location. Phase two was the most difficult part of the move; rotating the salt barn. The heavy equipment were placed at opposite corners of the salt barn and pulled with equal tension in opposite directions thus rotating the salt barn approximately 100 degrees. The rotation properly oriented the salt barn with the new asphalt pad. Phase three, like phase one, pulled with parallel and equal tension except the pull was made from the front of the salt barn in a northern direction for approximately thirty-eight meters to the new asphalt pad. The three phases of the salt barn move are shown in Figure 3.

Fig. 3. From left to right, phase one, phase two, and phase three of the salt barn move.

Anchoring the salt barn to the asphalt pad was not desired so a new permanent anchoring system would need to be designed. When properly anchored, the salt barn is designed to withstand wind loads of 145 kilometers per hour and snow loads of two and one-half newtons per square meter with the cover attached. The new anchoring system would need to allow the salt barn to at least meet these design criteria and is shown in Figure 4. The support plates required for supporting the salt barn during transport were anchored to a concrete block (anchor block). Each anchor block is approximately one-half meter by one-half meter by two meters and weighs roughly 1,600 kilograms. The support plate was anchored to the block using two, one centimeter anchor bolts and Hilti HIT HY 150 concrete adhesive. While a single anchor block at each truss location was capable of securing the salt barn, additional blocks were placed on the anchor blocks for increased factor of safety.



A: Anchor block
B: Anchor bolt
C: “U” bolt
D: Salt barn base beam
E: Support plate

Fig. 4. New permanent anchoring system.

Relocating the salt barn was only part of the engineering efforts needed to remediate the forty-six centimeter sanitary sewer. Another effort involved an active domestic water line. In the area of sanitary sewer remediation, the water line is fifteen centimeter ductile iron and travels perpendicular to the alignment of the sanitary sewer. At almost four meters below grade, the sanitary sewer was deeper than the water line which is approximately one meter below grade. To maintain safe excavation conditions, benching or sloping at no less than one-half to one-third (0.50 meters horizontal to 0.33 meters vertical) was necessary. Remediating the sanitary sewer required the excavation at the surface to be approximately twelve meters wide and the excavation at water line elevation to be approximately eight meters wide. The ductile iron water line would not be capable of supporting itself across such a large span. Initial consideration was given to cutting and capping the water line at the limits of excavation for the time required to perform remediation and data collection. However, after discussions with Praxair, it was determined the water line could not be cut and capped as this water line was used to feed Praxair's boilers to produce steam for heating and experiments. Remediation was dependent upon two workaround options, installing temporary bypass piping or engineering a method to support the water line.

After investigating the level of effort required to install bypass piping, it was determined structurally supporting the water line was a more cost effective option. The designed support system needed to provide a safe working zone below the water line as well as maintain the integrity of the pipe. However, before the support system could be designed and constructed the water line integrity needed to be evaluated. This was accomplished by removing the overburden and exposing the top of the water line. Once exposed, a NYS PE inspected the line and deemed it structurally capable of being supported. The designed support system included a series of nylon slings hung from a steel beam supported by steel plates. The beam was a W8x35 "I" beam previously used during salt barn relocation. At each end, the beam was welded to one meter by two meter by two and one-half centimeter thick steel bearing plates. The beam and attached plates were placed on one and one-half meter wide excavation benches and centered over the water line. To act as counterbalance, one-half meter by one-half meter by two meter concrete blocks were placed on each bearing plate. With the beam in place the nylon slings could be installed. Each nylon sling was five centimeters wide with a ratcheting mechanism and had a 225 kilogram minimum capacity. The slings were spaced approximately one meter apart and ratcheted to apply just a slight amount of tension to the water line. At this point the underlying soils and sanitary sewer could be remediated as shown in Figure 5. After remediation was complete backfilling operations began. Backfilling immediately under the water line (less than one-half meter) would not be possible, however it was very important to provide a firm and uniform bearing surface before slings were removed.

A: W8x35 beam
B: Active water line
C: Nylon sling
D: Concrete block
E: Steel bearing plate

Fig. 5. Structural support of an active ductile iron water line.

Beneficial reuse material (firm silty-clay) was placed and compacted to ninety-five percent standard proctor density to a depth approximately one-half meter below the water line. To complete backfilling and provide support, pea gravel was evenly distributed under and around the sides of the water line. The slings were then removed and backfilling over the water line was completed.

Sanitary sewer remediation required ingenious structural engineering designs to relocate the salt barn and support the active water line. Successfully implementing the engineered designs in the field enabled remedial activities to continue while not disrupting Praxair's business operations.

Utility Tunnel Remediation

From 1942 to 1943, pilot plant and laboratory studies were conducted at Linde in support of MED activities. From 1943 to 1948, full scale uranium ore processing occurred at Linde resulting in about 25,000 metric tons of ore being processed. The principal solid waste from ore processing was a solid, gelatinous filter cake which was temporarily stored in piles scattered around the Linde property. Another waste product from ore processing was a liquid effluent containing dissolved uranium oxide. The effluent was discarded by direct injection to the Linde subsurface through seven injection wells or storm and sanitary sewers.

In 1937, the first series of utility tunnels were installed at the Linde site to provide underground pathways of utilities and personnel. In 1957, and again in 1961, additional utility tunnels were installed on the property. Although the tunnel network is in the proximity of buildings once used for uranium ore processing, no process piping was ever installed inside the tunnels. However, throughout the Linde FUSRAP Project, several dose assessments inside the tunnel network and analysis of soils surrounding the utility tunnels show concentrations of MED radionuclides exceeding site cleanup objectives. Also in the vicinity of part of the tunnel network was the contaminated forty-six centimeter sanitary sewer (described above).

Two lengths of the utility tunnel network were included in the remedial activities. The first length removed was a series of two meter inside diameter reinforced precast concrete tunnel sections approximately 170 meters long traveling the site in an East-West direction (E-W tunnel). The second length removed was a series of two and one-half meter inside diameter reinforced precast concrete tunnel sections approximately 110 meters long traveling in a North-South direction (N-S tunnel). The tunnel lengths across the site are connected via cast-in-place reinforced concrete junction boxes. An active electrical vault and three junction boxes were involved in the removal of the E-W and N-S tunnels; junction boxes (JB) 7, 8, and 9. Many abandoned and active utilities were present in the E-W and N-S tunnels and indicated structures. Abandoned utilities included nitrogen, high pressure steam, telephone, and fiber optic. Active utilities included water, low pressure steam and condensate, air, low and high pressure gas, fire alarm, communication, and 4160 volt electric providing power throughout the entire Praxair site. Prior to remediating the tunnels and structures all active utilities had to be relocated without disrupting service to Praxair.

Relocation began by developing a utility system design and work plan encompassing all active utilities. The design included construction of three new cast-in-place reinforced concrete junction boxes (JB 7A, 8A, and 9A) with direct buried utilities between the junction boxes. It also included construction of an enlargement to the electrical vault with a new concrete electrical duct bank. Junction boxes 8A and 9A were doweled into the existing tunnel network, replacing JB 8 and extending the function of JB 9. This required excavation of soils immediately adjacent to active utility tunnels followed by controlled saw cutting of those tunnel sections. With saw cutting complete the new junction boxes were formed and poured. The electrical vault enlargement (extension) also was a cast-in-place reinforced concrete structure doweled into the existing electrical vault. However, saw cutting to remove a wall separating the existing vault from the extension could not take place with live 4160 volt (4160V) electrical lines. The saw cutting would need to take place during scheduled electrical system shutdowns (more discussion to follow). JB 7A was constructed as a stand-alone structure near the existing JB 7. With the vault extension and JB 7A in place, a new concrete electrical duct bank connecting the vault and JB 7A was formed and poured with electrical conduits embedded. The new junction boxes and electrical duct bank are shown in Figure 6.

Fig. 6. From top left to bottom right, JB 7A, electrical vault (with extension) and conduits for duct bank, JB 8A, and JB 9A.

The direct buried utilities were slightly offset from the tunnel lengths slated for remediation but followed the same alignment; North-South between JB 7A and JB 8A and East-West between JB 7A and JB 9A. This required nearly 260 meters of direct buried utility installation. Direct buried utilities consisted of twenty-five centimeter low pressure steam, fifteen centimeter low pressure condensate, fifteen centimeter domestic water, fifteen centimeter compressed air, ten centimeter low pressure gas, ten centimeter high pressure gas (the mechanical utilities), ten distinct 4160V electrical circuits, and various communication utilities (the electrical utilities). Of the ten electrical circuits, five circuits traveled between JB 7A and JB 9A and five circuits traveled between JB 7A and JB 8A. The mechanical utilities were placed on native soils and buried with approximately one-half meter of sand before backfilling to grade with beneficial reuse material or imported stone. Mechanical utilities were installed and tested to the appropriate standards and specifications as the excavation for direct buried utilities progressed. Concrete duct banks were formed and poured with embedded conduits for all electrical utilities. The electrical utilities could not be installed or tested until the duct banks between junction boxes were complete. Once the direct buried activities were complete, piping, valves, and other appurtenances for mechanical utilities were installed inside the junction boxes while wires and cables for the electrical utilities were pulled through the embedded conduits. Installation of the new direct buried utilities is shown in Figure 7.

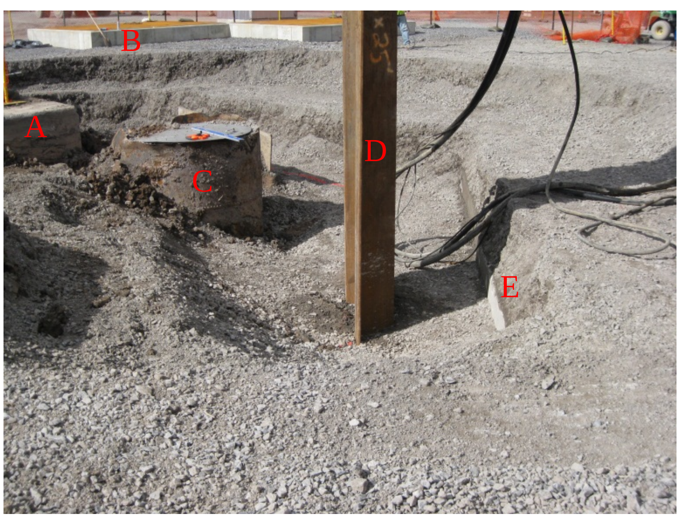
Connecting new and existing utilities to de-energize all active utilities in the E-W and N-S tunnels required tie-ins inside the new junction boxes and electrical vault. Coordination between USACE, Praxair, CABRERA, and involved subcontractors was critical. Utilities feeding Praxair operations simply could not be shut down and relocated. Each shut down required precise scheduling and involvement between all parties; typically occurring on weekends and holidays.

Fig. 7. Performing direct buried utility installation.

Mechanical utilities were shut down and relocated individually with a weekend devoted to each utility. These shut downs required finishing installation inside the junction boxes as well as performing final testing before initializing the new system. The 4160V circuits were cut and spliced on two separate shut downs; the five E-W circuits (JB 7A to JB 9A) during the Memorial Day weekend and the five N-S circuits (JB7A to JB 8A) during the Labor Day weekend. The wall separating the existing electrical vault from the vault extension was saw cut and removed during the Memorial Day shutdown. This provided the means to pull new electrical cables from JB 7A, through the new duct bank, and into the electrical vault to complete splicing during the appropriate shut down event. After all utilities had been relocated and re-energized the E-W and N-S tunnels could be remediated.

Part of the tunnel remediation included removal of JB 7. Historical figures indicated the contaminated forty-six centimeter sanitary sewer passed just below and outside this structure. The proximity of JB 7 to JB 7A and the recently energized concrete duct bank prompted the need for excavation shoring as opposed to conventional sloping or benching. Any attempt to utilize sloping or benching would likely have resulted in the undermining and potential failure of the duct bank. Therefore the most effective excavation shoring method was selected; sheet piling. Before a NYS PE could design the shoring system (type of sheet piling, depth of sheet piling, etc.), the engineering properties including plastic limit, liquid limit, plasticity index, and soil classification needed to be determined. A drilling rig was employed to collect soil samples to a depth of six meters in two separate locations where sheet piling would be installed. Gradation and soil testing described the soil as clayey-silt with moist and stiff to very stiff properties; effective for sheet piling.

The sheet piling design needed to protect the active electrical duct bank and JB 7A while excavating to a depth of approximately five and one-half meters to remove JB 7 and an abandoned storm drainage lift station. The final design specified sixteen linear meters of AZ 26 sheet pile installed to a depth approximately nine meters below grade using a crane and vibratory hammer. Vibration from the hammer was immediately a concern considering sheet pile installation was very near Praxair's electrical substation, electrical vault, electrical duct bank, and JB 7A. Too much vibration from the hammer could greatly weaken the concrete foundation of the substation as well as crack the vault, duct bank, and JB 7A concrete leading to other problems. To ensure vibratory damage would not occur, vibration monitoring was performed at various locations throughout sheet piling installation. The monitoring recorded peak particle velocity and vibration frequency. As long as peak particle velocity remained under five centimeters per second, no damage would occur to the surrounding concrete structures. Monitoring records indicated at no time during installation did peak particle velocity exceed five centimeters per second. Installation of the first sheet pile is shown in Figure 8. With sheet piling installed the final phase of remediation began.



A: JB 7
B: JB 7A
C: Abandoned lift station
D: Sheet piling
E: Active electrical duct bank

Fig. 8. Protecting active electrical duct bank using sheet piling.

Utility tunnel remediation was a multi-disciplinary engineering effort. Structural, mechanical, and electrical engineering designs were employed to develop the direct buried utility system. The new junction boxes and vault extension were designed and constructed in accordance with structural engineering requirements. The mechanical utilities (air, gas, water, steam, and condensate) were designed and installed based on mechanical engineering standards while the electrical utilities (4160V circuits, communication utilities, and duct banks) were designed and installed using electrical engineering specifications. The final engineering feat to install sheet piling for protection of the active duct bank utilized principles and practices associated with geotechnical and civil engineering.

CONCLUSION

As remediation nears conclusion and site wide restoration begins, engineering challenges will continue to exist. Much of the infrastructure removed during remediation was installed during the 1950's and 1960's when codes and standards were not as expansive as today's requirements. Restoring infrastructure to today's standards while not making existing infrastructure obsolete will prove difficult. Each remediation activity had its own challenges, and while some were greater than others, successful completion of every engineering challenge was integral to conducting a remedial action on an active industrial facility.