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Closure and Post-Closure Redevelopment of the McColl Superfund Site

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CLOSURE AND POST-CLOSURE REDEVELOPMENT OF THE McCOLL SUPERFUND SITE

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ABSTRACT

The McColl Superfund site was one of the highest-profile hazardous waste sites in the USA in the 1980's. The 12 unlined pits containing refinery waste from World War II presented unique challenges for closure construction and post-closure redevelopment due the caustic nature, low bearing capacity, and high odor potential of the waste, the proximity of residences, and a mandate to restore portions of a golf course over several of the pits. Closure design included special testing to demonstrate the durability of materials that could potentially come in contact with the waste and to evaluate the potential for migration of waste through native subsurface materials, design of a lightweight geosynthetic cap on top of the waste, reconstruction using mechanically stabilized earth of a non-engineered waste-retaining embankments separating the waste, and construction of a slurry wall up a 3H:1V (Horizontal to Vertical) slope. Closure design and construction was originally estimated to cost $18 to $20 million dollars and take three years to complete. However, design and construction was completed in two years at a cost of approximately $13 million dollars through the use of an engineering, procurement, and construction management (EPCM) strategy and a unique "over-the-shoulder" review arrangement with the regulatory agencies.

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INTRODUCTION

The 22 acre McColl site in southern California, home to 12 unlined pits filled with low pH refinery waste from World War II, was one of the highest profile Superfund sites in the USA in the late 1970s and early 1980s. Following rejection of plans for clean closure and for waste stabilization, a contingent remedy consisting of a geosynthetic final cover, mechanically stabilized earth berms, and a soil-bentonite slurry wall was adopted for site closure. Design challenges in implementing the contingent remedy included the caustic nature of the waste (in some cases, a pH less than 1), the low bearing capacity on top of some of the waste pits, the need to stabilize non-engineered embankments that retained the waste, the construction of the soil-bentonite slurry wall up a 3H:1V (3 Horizontal:1 Vertical) slope, the proximity of residences to the non-engineered embankments and slurry wall, the high odor potential of the waste, and a mandate to restore abandoned portions of a golf course constructed over several of the waste pits.

Initial plans to "clean close" the site either by excavating the waste and trucking it to a hazardous waste landfill or by on-site incineration were met by strong opposition from community groups supported by well-known activists. Community opposition centered upon the hazards associated with potentially toxic volatile compounds and noxious odors (e.g. methyl mercaptan, a thiophene compound) released during excavation and incineration of the waste or trucking large quantities of the hazardous waste through adjacent neighborhoods for landfill disposal elsewhere. Following rejection of clean closure, the Environmental Protection Agency (EPA) issued a record of decision (ROD) calling for a preferred remedy consisting of in-place chemical solidification of the waste but with a contingent remedy of containment by capping and construction of a slurry wall around the waste pits, depending upon results of a large scale pilot test.

In the pilot test, conducted at a cost of over $15 million dollars, an attempt was made to stabilize one of the twelve waste pits by mixing the waste with cementitious agents using augers up to 10 ft in diameter while controlling gaseous emissions by enclosing the sump with a large negative-pressure shroud. Gasses generated during stabilization were routed to a 50,000 ft^3/min onsite treatment system. Unfortunately, the heat generated by the reaction between the cementitious agents and the low pH waste heated the sump up to over 240^{o}F, fluidizing and volatilizing waste in the bottom of the pit that had already stabilized naturally along with the viscous waste in the top of the pit. Furthermore, the shroud failed to adequately control odors (mercaptan is objectionable at concentrations of 5 parts per billion).

Following completion of the pilot test, EPA decided to proceed with the contingent remedy of waste containment by capping the pits with a Resource Conservation and Recovery Act (RCRA)–equivalent final cover and construction of a slurry wall around the pits. EPA estimated that the contingent remedy could be constructed in 3 years at a cost of $18 to $20 million dollars. However, by using an engineering, procurement, and construction management (EPCM) contracting approach and inviting EPA and the California Department of Toxic Substances Control (DTSC) to participate in "over-the-shoulder" review during design of the remedy, design and construction of the contingent remedy was completed in two years at a cost of approximately $13 million dollars (Collins et al. 1998). Since the completion of construction of the contingent remedy, the site been removed ("delisted") from the Superfund list and thousands of golfers have played across portions of the cap without incident, most without knowing what lies beneath their feet.

SITE CONDITIONS

The twelve waste pits at the McColl site were divided into three areas: the Los Coyotes waste pits and the Upper and Lower Ramparts waste pits. These three areas are shown in Fig. 1 as they looked in 1995, after the pilot test but before the start of remedy construction. The waste in the pits was typically 20 to 30 feet deep. The waste in the upper portions of the pits was a tarry viscous material while the waste in the bottom of the pits had hardened since their deposition into a material referred to as char.

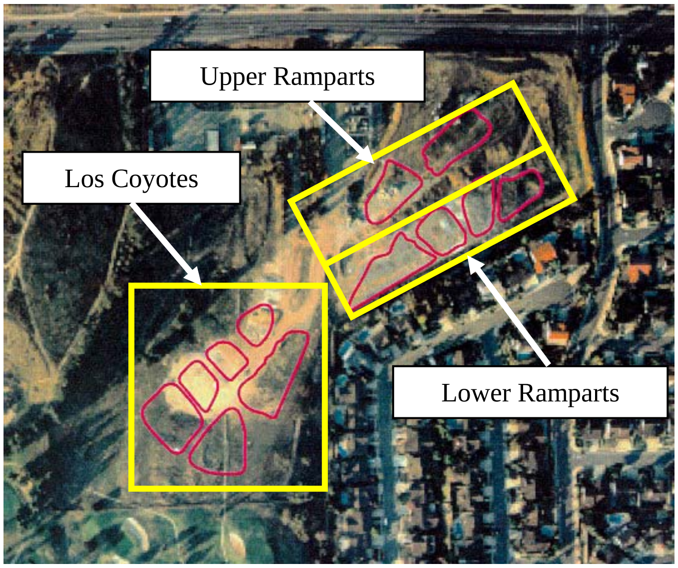

Fig. 1. The McColl site prior to remedy construction (purple lines show approximate boundaries of the waste pits).

The four lower Rampart pits were the most problematic due to their proximity to adjacent homes and the very low bearing capacity of top of the pits. On the southern side of the Lower Ramparts pits the waste was retained by a five to ten ft-tall non-engineered embankment with approximately 1.5H:1V (Horizontal:Vertical) slopes, the toe of which formed the property line with the adjacent residences. The Lower Rampart pits were covered with diesel-based bentonite drilling muds in the 1950s and 1960s.

The Upper Rampart and Los Coyotes pits were on located on a higher elevation terrace than the Lower Ramparts pits. The upper Rampart sumps were also supported by an embankment of unknown construction and integrity on its south side (the boundary between Upper and Lower Ramparts). In the late 1950's the six Los Coyotes sumps were covered with five to eight feet of earthfill and portions of a golf course, since abandoned, were constructed over the top of these sumps. In the 1960s, residential neighborhoods were developed south side of the Lower Ramparts pits and the east side of the Los Coyotes pits.

Subsurface conditions at the site were primarily interbedded sandy silts and clays and silty and clayey sand. The regional groundwater table was more than 140 ft below ground surface. However, isolated lenses of perched water were encountered around the site at elevations higher than the regional water table. While there was no indication of lateral migration of the viscous waste from the pits, a significant amount of lateral migration from the pits of gaseous by-products of the waste, primarily sulfur dioxide, was detected in the subsurface exploration program.

CONTINGENT REMEDY

Following completion of the pilot test, EPA decided to proceed with the contingent remedy of capping and slurry wall construction without waste solidification. The components of this contingent remedy included:

- a multi-layer geosynthetic cap over the top of the waste pits;
- a system to collect and treat gases from beneath the cap;
- a slurry wall to control outward migration of waste and waste by-products from the pits and inward migration of groundwater to the pits;
- mechanically stabilized earth retaining walls to stabilize the non-engineered embankments adjacent to the pits; and
- long-term operations, maintenance, and monitoring.

EPA further mandated a 100-year design life for this remedy.

The contingent remedy required restoration of the golf course on top of the Los Coyotes cap and required design and construction of a surface water control system to direct surface water off the top of and away from the pits. In negotiations with the golf course owner, it was agreed that the reconstructed holes for the golf course would also extend over the Upper Ramparts cap and the golf course would be provided with two new water hazards. In exchange, the golf course owner provided the borrow soil necessary for remedy construction and the use of golf course property (i.e. one of the new water hazards) for the surface water control system.

DESIGN AND CONSTRUCTION CHALLENGES

Implementation of the contingent remedy for the McColl Superfund site faced a number of geotechnical challenges, including:

- design and construction of a stable cap over the layer of diesel-based bentonite drilling muds that had been placed on top of the Lower Ramparts waste pits;
- design of a cap compatible with golf course restoration on top of the Los Coyotes waste pits;
- tying the geosynthetic cap into the soil-bentonite slurry wall to provide a continuous barrier on top of and around the pits;
- demonstrating that the integrity of the remedy would not be adversely affected by the caustic waste or waste by-products over the 100-year design life;
- demonstrating that a soil-bentonite slurry wall would adequately contain laterally-migrating waste and waste by-products;
- stabilization of the non-engineered embankments retaining the waste in the Lower and Upper Ramparts;
- construction of the slurry wall and stabilized embankment along the south side of Lower Ramparts without encroaching on the adjacent residences; and
- construction of the soil-bentonite slurry wall up the 3H:1V slopes between Lower and Upper Ramparts.

RCRA-EQUIVALENT CAP DESIGN

RCRA standards prescribe a final cover (cap) comprised of, from bottom to top:

- a foundation layer;
- a gas collection layer, if needed;
- a 2 ft thick low permeability soil barrier layer with a saturated hydraulic conductivity equal to or less than 1×10^{-7} cm/s;
- a geomembrane barrier layer equal to or greater than 0.02 in. (20 mil) in thickness;
- a 1 ft-thick drainage layer with a saturated hydraulic conductivity equal to or greater than 1×10^{-2} cm/s;
- a biological intrusion (biotic) barrier; and
- a vegetated erosion control layer with a minimum thickness of 2 ft.

In the Los Coyotes and Upper Ramparts areas the cap shown in Figure 2, a cap closely mimicking the prescriptive RCRA cap, was used. The primary difference between the cap shown in Fig. 2 and the RCRA prescriptive cap is the use of a geomembrane-backed geosynthetic clay liner (GCL) in lieu of the low permeability soil layer beneath the high density polyethylene (HDPE) geomembrane barrier layer. The geosynthetic clay liner employed in this case consisted of a 0.25 in. layer of sodium bentonite adhered to a 0.03 in. (30 mil) HDPE geomembrane. The GCL was placed with the geomembrane backing on the bottom. Hence the bentonite layer was encapsulated between two HDPE geomembranes. Other features of the cap for the Los Coyotes and Upper Ramparts areas included a combined drainage / biotic barrier layer (referred to as the mechanical barrier layer in Fig. 2) composed of cobbles filled with sand, two layers of geogrid reinforcement in the foundation layer, and 7 ft or more of vegetative cover soil to accommodate golf course grading and landscaping.

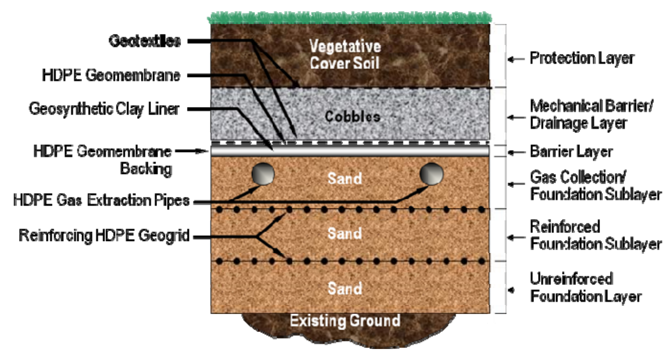

Fig. 2. RCRA-equivalent cap for the golf course (Los Coyotes and Upper Ramparts) areas.

The low strength and high compressibility of drilling muds that had been placed on top of the Lower Ramparts cap presented a unique design challenge. Analysis indicated that the cap could not sustain the loads associated with the cap shown in Fig. 2. Both bearing capacity and long term settlement considerations mandated that the loads imposed by the cap on the Lower Ramparts pits had to be minimized. To accommodate these constraints, the cap design shown in Fig. 3 was developed. Key features of the Lower Ramparts cap design included:

- limiting the vegetation on the cap to shallow-rooted grasses and the thickness of the vegetative cover layer to 1 ft (the minimum thickness advised by the landscape architect);
- employing a geosynthetic drainage geocomposite on top of the geomembrane;
- employing geocell reinforcement in the foundation layer rather than the geogrid reinforcement employed in the golf course areas (due to the low overburden pressure, which would limit the effectiveness of geogrid reinforcement); and
- relying on institutional controls rather than a biotic barrier for intrusion protection.

Institutional controls employed to mitigate the potential for inadvertent intrusion in the Lower Ramparts area included physical separation from the Upper Ramparts and Los Coyotes area and from adjacent residences by fences and a steep MSE slope. Furthermore, the irrigation system in Lower Ramparts was placed above grade to minimize the potential for inadvertent intrusion. Upon completion of construction, the Lower Ramparts area was dedicated to the Audubon Society as a wildlife sanctuary.

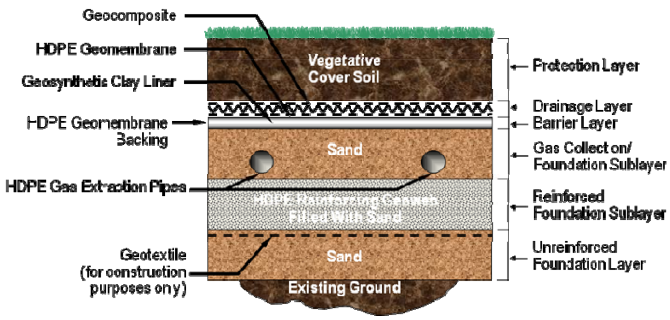

Fig. 3. RCRA-equivalent cap for the Lower Ramparts area.

An important design consideration for both RCRA-equivalent cap cross sections was the ability of geosynthetic elements of the cap to maintain their integrity over their 100-year design life. This was of particular concern for the cap elements below the primary geomembrane barrier, e.g. the geogrid and geocell reinforcement and geomembrane backing of the GCL, as these elements were most likely to come in contact with caustic waste and waste by-products. Therefore, the geocell and geomembrane elements of the cap were subject to chemical compatibility testing for a period of four months. Due to its excellent chemical resistance, HDPE was employed for all of these geosynthetic elements of the cap. The geogrid was not subject to compatibility testing as it had a higher density than the geomembrane or geocell materials and hence was considered to be more resistant. However, it was agreed that any strength reduction observed in the geomembrane or geocell materials would also be applied to the geogrid. The materials selected for compatibility testing were purchased prior to the start of construction, stockpiled on site, and then subjected to compatibility testing to be sure that the material used in construction had the same chemical composition as the material subject to compatibility testing.

In the compatibility testing program (Hendricker et al., 1998), conducted in accordance with EPA 9090 protocols, coupons of the geocell and geomembrane materials were immersed in viscous waste (TAR) and a waste-derived liquid (WDL) at two temperatures, 23^{o} C and 50^{o} C, for periods of up to 4 months and periodically removed and subjected to testing for mass, thickness, puncture resistance, trapezoidal tear strength, and stress crack resistance. The waste derived liquid, generated by agitating tar and distilled water together for over an hour and then siphoning off the liquid, was employed to model potential contact with gas condensate form the waste. This liquid actually had a lower pH (pH on the order of 0.6) than the waste itself. The principle of time-temperature superposition, i.e. Arrhenius modeling (Koerner, 2005), was used to project test results out over the 100-year design life. Figure 4 shows some of the results of the testing on the HDPE geomembrane. These results suggest some softening of the HDPE materials upon initial contact with the waste but no time dependent trend was observed. Similar results were obtained on geocell specimens. Notched constant tensile load environmental stress crack resistance tests using a load equal to 30 percent of the yield strength of the material were contact on specimens exposed to waste and waste-derived liquid for 120 days. These tests were terminated after 400 hours with no tensile breaks. Based upon the results of the chemical compatibility testing, a reduction factor of fifty percent was applied to HDPE materials deemed likely to come in contact with waste or waste by-products.

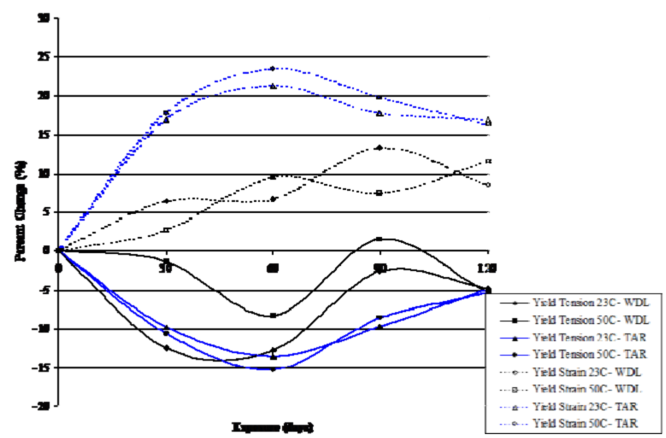

Fig. 4. Chemical compatibility testing of HDPE geomembrane using viscous waste (TAR) and waste-derived liquid (WDL).

SLURRY WALL DESIGN AND CONSTRUCTION

Design and construction concerns regarding the soil-bentonite slurry wall included establishing the performance requirements for the wall, chemical compatibility between the wall backfill and migrating waste or waste by-products, and wall constructability. The remedy called for the wall to contain waste and waste by-products from the waste pits within its confines and serve as a barrier to lateral migration of groundwater from outside of the slurry wall into the pits. Exploration and testing conducted to determine what wastes and waste by-products needed to be contained by the slurry wall system encountered no evidence of lateral migration of the viscous (tarry) waste in the subsurface. To conclusively eliminate the need for the slurry wall to be relied upon for retention of migrating viscous waste a unique laboratory test was developed. In this test, a hole was drilled along the axis of a cylindrical specimen from the top of the specimen to mid-height, an open tube was inserted into the hole, the tube was filled with tarry waste, and a pressure head equal to the overburden pressure at the bottom of the pits was applied to the waste in the tube for 30 days. At the end of the 30 day period, the sample was dissected and examined for evidence of waste migration into the soil. When no indication of viscous waste migration was observed, retention of migrating viscous waste was eliminated as a performance requirement for the slurry wall.

Elimination of containment of laterally migrating viscous waste as a performance requirement for the slurry wall left retention of laterally migrating gases and waste-derived liquids from the pit and lateral migration of groundwater into the pits as the performance requirements for the slurry wall. The primary concerns with respect to these performance requirements were loss of effectiveness of the slurry wall as a barrier due to degradation of the saturated hydraulic conductivity of the soil-bentonite wall following permeation with migrating waste-derived liquids and desiccation of the wall in the arid environment. The potential for degradation of the saturated hydraulic conductivity of the soil-bentonite wall following permeation with waste derived liquids was evaluated by conducting hydraulic conductivity compatibility testing in accordance with EPA 9100 protocols.

The EPA 9100 protocol for evaluating the saturated hydraulic conductivity of soils subject to permeation with waste liquids and leachate is similar to the ASTM D5084 procedure for evaluating the saturated hydraulic conductivity of soils except that in the EPA method the soil is subjected to permeation with at least two pore volumes of the liquid in question and until the saturated hydraulic conductivity reached an asymptotic value. To evaluate the potential for degradation of the saturated hydraulic conductivity of the soil-bentonite wall backfill following permeation with waste derived liquids, the same waste-derived liquid used in the chemical compatibility testing of the geosynthetic materials was used in the EPA 9100 tests. Figure 5 presents the results of one of the chemical compatibility tests on native soil mixed with sodium bentonite. The results presented in Fig. 5 showed some slight degradation in the saturated hydraulic conductivity due to permeation with the waste derived liquid, with its value increasing from about 2 x 10^{-8} cm/s to about 3.5 x 10^{-8} cm/s over the 3 month duration of the test. This was considered to be acceptable performance for the slurry wall (assuming as it remained saturated).

To evaluate the potential for desiccation of the slurry wall, the saturation of the native soils adjacent to the waste pits was evaluated. Near surface (i.e. within 10 ft of the ground surface) silty and clayey soils had a degree of saturation on the order of 85%. However, the degree of saturation of deeper clay layers was close to 100%. As the slurry wall would typically have at least 10 feet of overburden, the design called for embedding the geomembrane to a depth of at least 5 ft into the wall with low permeability soil placed over the top of the geomembrane, and the cap would be irrigated to support vegetation, the potential for desiccation impacting the performance of the slurry wall barrier was considered to be acceptably small.

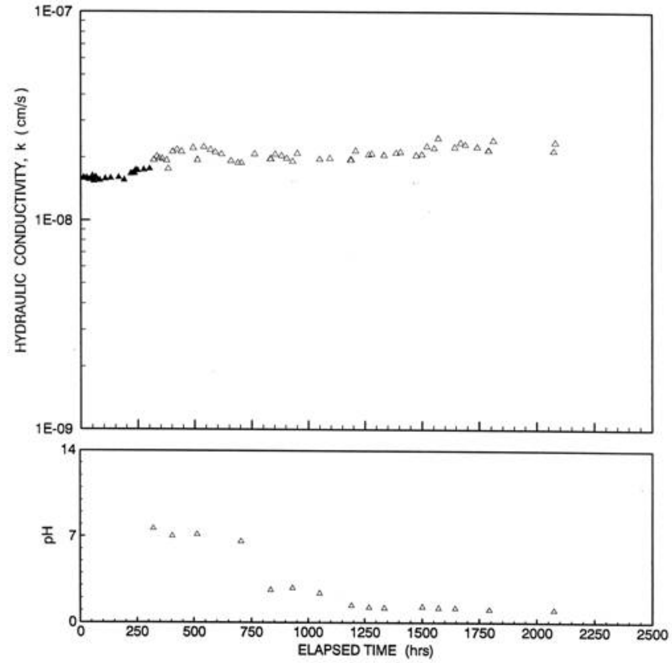

Fig. 5. Chemical compatibility testing of slurry wall soil-bentonite backfill.

There was no continuous low permeability soil layer to key the base of the wall into, as dictated by best practices for containment of contaminated groundwater. However, the groundwater investigation indicated that vertical migration of waste and waste by-products to groundwater at the site was minimal and could be controlled by natural attenuation. Therefore, the primary function of the wall at this site was established to be containment of gases that were migrating laterally from the pits and then upwards to the ground surface and containment of liquids that were migrating laterally on top of discontinuous silty and clayey soil layers. On this basis, it was determined that the bottom of the slurry wall needed to be a minimum of 5 ft below the bottom of the adjacent waste pits.

An important consideration in design of the soil-bentonite slurry wall subsurface barrier was constructability of the wall. Constructability concerns included construction of the wall up the 3H:1V slope separating Upper and Lower Ramparts as well as construction along the south boundary of the site adjacent to the Lower Ramparts area and east boundary adjacent to the Los Coyotes area. Provisions were made to use earthen berms along the wall alignment on the slope between Upper and Lower Ramparts in order to build up the wall above grade and then trim it back after the soil-bentonite backfill had consolidated. However, by using the large pipe "stop logs" like the one shown in Fig. 7 to partition the wall into short sections and allowing the backfill time to set up before proceeding, the slurry wall contractor was able to construct the slurry wall up the slope without using the berms.

Fig. 7. Slurry wall construction between Upper and Lower Ramparts.

MSE WALL DESIGN AND CONSTRUCTION

Design of the remedy for the McColl site included three MSW walls: along the east side of the Lower Ramparts area, along the east side of Los Coyotes area, and in between the Lower and Upper Ramparts areas. The key issues associated with design and construction of these MSE walls were integration of the MSE walls with the geosynthetic cover system and the slurry wall and construction of the MSE wall along the south boundary of the Lower Ramparts pits, where toe of the 1.5H:1V slope for the non-engineered embankment that retained the waste coincided with the property line for the adjacent residences. Because the MSE walls were outside of the cap, they were not expected to come in contact with the waste or waste by-products and the reduction factor from chemical compatibility testing was not employed in MSE wall design.

Integration of the MSE wall with the geosynthetic cover provided both challenges and opportunities. Challenges included constructing the MSE wall on top of the slurry trench and geosynthetic cover system along the south boundary of the Lower Ramparts area. Opportunities included using the MSE wall to create a working platform for construction of the slurry wall along the eastern boundary of the Los Coyotes area. Figure 8 illustrates the slurry wall construction procedure employed along the east side of the Los Coyotes waste pits, where the MSE wall was used to create the working platform for slurry wall construction.

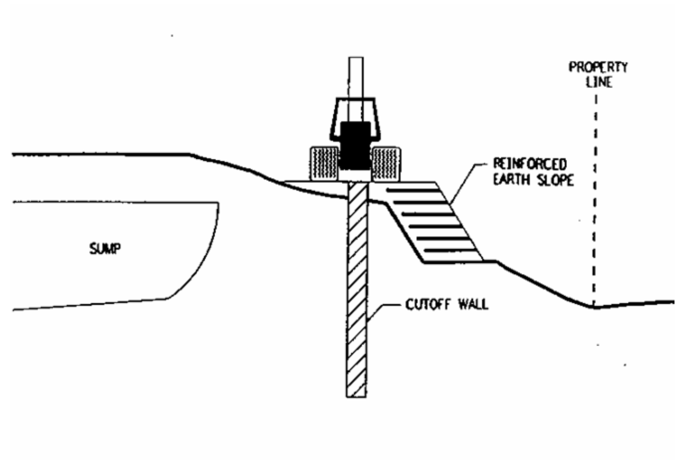

Fig. 8. Slurry wall construction scheme on the east side of Los Coyotes.

Figure 9 illustrates integration of the MSE wall with the slurry trench and geosynthetic cover on the southern boundary of the Lower Ramparts area, where the wall was constructed on top of the slurry wall and where the toe of the wall coincided with the property line. A soldier pile and lagging wall was used to support the waste pit while the non-engineered embankment was removed and the slurry wall and MSE wall were constructed. The GCL and geomembrane barrier layers and the geosynthetic drainage layers on the geosynthetic cover system were draped over the soldier pile wall and tied in with the top of the slurry wall 5 ft below grade after the slurry wall was constructed.   The top 5 ft of the slurry trench was then backfilled with low permeability soil. The backfilled trench was then capped with a concrete-filled geocell support platform prior to construction of the MSE wall. The soldier pile and lagging wall was abandoned in place.

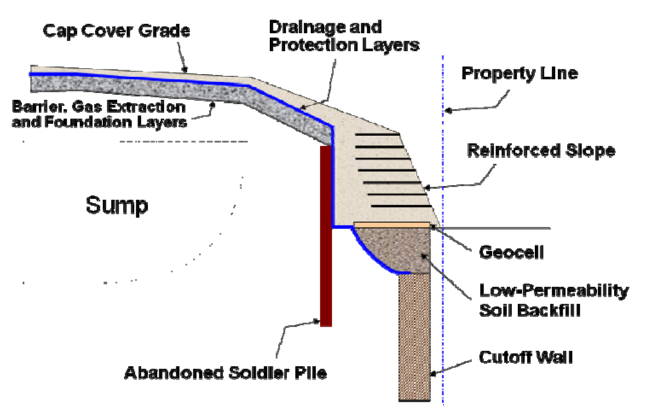

Fig. 9. Integration of the MSE wall, cover system, and slurry wall along the south side of Lower Ramparts.

In order to construct the slurry trench and MSE wall along the Lower Ramparts area it was necessary to encroach upon the backyards of the adjacent homes. Occupants of these homes were relocated at the expense of the responsible parties for construction of the remedy. The fenced construction zone occupied about half of the backyards of the adjacent homes, which were typically 40 to 50 ft in width. Figure 10 illustrates the slurry wall construction scheme along the south side of the Lower Ramparts area and Figure 11 shows construction of the slurry wall in this area.

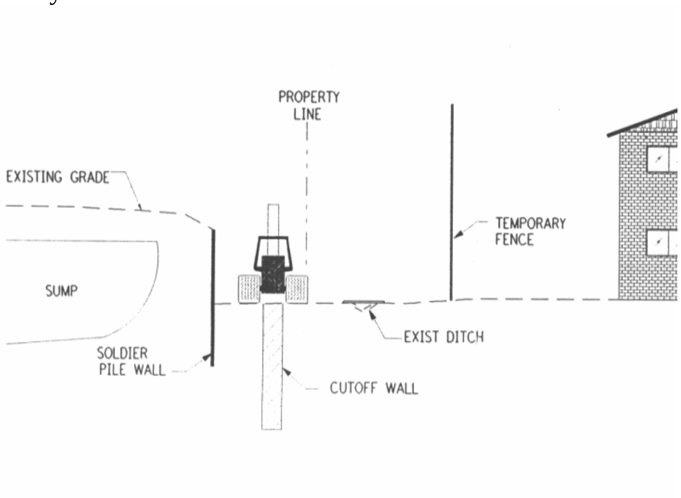

Fig. 10. Slurry wall construction scheme on the south side of Lower Ramparts.

Fig. 11. Slurry wall construction along the south side of Lower Ramparts.

The facing for the MSE walls was constructed using wire frames lined with geosynthetics and filled with top soil to facilitate establishment of vegetation on the face of the wall. Figure 12 shows the facing for the MSE wall along the east side of Lower Ramparts immediately after the end of wall construction.

Fig. 12. MSE wall on the south side of Lower Ramparts immediately following the end of construction.

In the area between Lower and Upper Ramparts, the barrier layer and drainage layer components of the geosynthetic cover system were placed on the graded slope of unknown engineering provenance that separated these two areas. The MSE wall was then constructed in front of the cover system components to provide support for the Upper Ramparts waste pits. Figure 13 shows the MSE wall under construction in this area.

Fig. 13. The MSE wall between Lower and Upper Ramparts under construction.

ADDITIONAL DESIGN CONSIDERATIONS

Design considerations for the final remedy at the McColl Superfund site included surface water control and erosion control. The surface water control system included lined (to minimize infiltration) perimeter channels to collect runoff from the caps and convey it from the Lower Ramparts area into a storm drain and from the Upper Ramparts and Los Coyotes areas into a storm water basin that also served as a water hazards for the golf course.

Post-construction (i.e. post-closure) operations, maintenance, and monitoring are important considerations in closure of any site where waste is left in place. The post-closure monitoring system included survey monuments on the MSE walls and settlement plates on top of the cap, subsurface gas probes inside and outside of the vertical barrier, and groundwater monitoring wells adjacent to the waste pits. "Warning levels" that triggered an evaluation of performance of the remedy were established for each type of monitoring. The operations, maintenance, and monitoring plan called for periodic formal inspections, inspections after extreme events (e.g. earthquakes, severe rainstorms), and comprehensive reviews of remedy performance at 5-year intervals.

CONCLUSION

The cooperative working relationship between the engineers and regulators, including the "over-the-shoulder" review process, enabled the engineering team to beat EPA's preliminary estimates of cost and duration by $5 million to $7 million dollars and one year. Construction of the remedy was completed in slightly over 2 years, in November 1997, at a cost of approximately $13 million dollars. Figure 14 shows a view from Upper Ramparts at the end of construction. In August 1998, EPA officially recognized that closure of the site was complete, removing the site from the National Priorities List (the Superfund list), and the first round of golf was played across the restored portions of the golf course. Figure 15 presents an aerial view of the site following closure. Remedy performance has been so satisfactory since closure that EPA has a reduction in the frequency of monitoring at the site.

ACKNOWLEDGEMENTS

Engineering, procurement, and construction management (EPCM) for closure of the McColl Superfund site was conducted by a Parsons Engineering Science – GeoSyntec Consultants team under contract to the McColl Site Group, a consortium of five petrochemical companies deemed by EPA to be the responsible parties for site closure. Oversight of EPCM activities was conducted by EPA, the California Department of Toxic Substances Control, and EPA's oversight contractor ICF Kaiser Engineers. Many individuals from these organizations made substantial contributions to successful closure of the site.

Fig. 14. View from Upper Ramparts at the completion of closure construction.

Fig. 15. The McColl site after completion of closure construction.

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