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A Novel Approach to Remediation of a Waterfront Chromium Facility

Christian Lavallee
Black & Veatch Corp., Philadelphia, Pennsylvania

Raj Rajaram
Black & Veatch Corp., Chicago, Illinois

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Mr. Christian Lavallee, P.E.
Black & Veatch Corp.
Philadelphia, Pennsylvania-USA-19106

Dr. Raj Rajaram, P.E.
Black & Veatch Corp.
Chicago, Illinois-USA-60606

ABSTRACT

A chromium ore processing facility in Maryland was mandated by the State to undertake remedial steps to prevent further migration of contaminants to the soil, groundwater and surface water. The owner of the facility entered into a Consent Decree (CD) with the U.S. Environmental Protection Agency (EPA) and Maryland Department of the Environment (MDE) to submit and execute a remedial design based on findings of site investigations. These investigations found that the soils were contaminated with hexavalent chromium. Additionally, both the shallow and deep aquifers, and surface water were found to be contaminated with chromium.

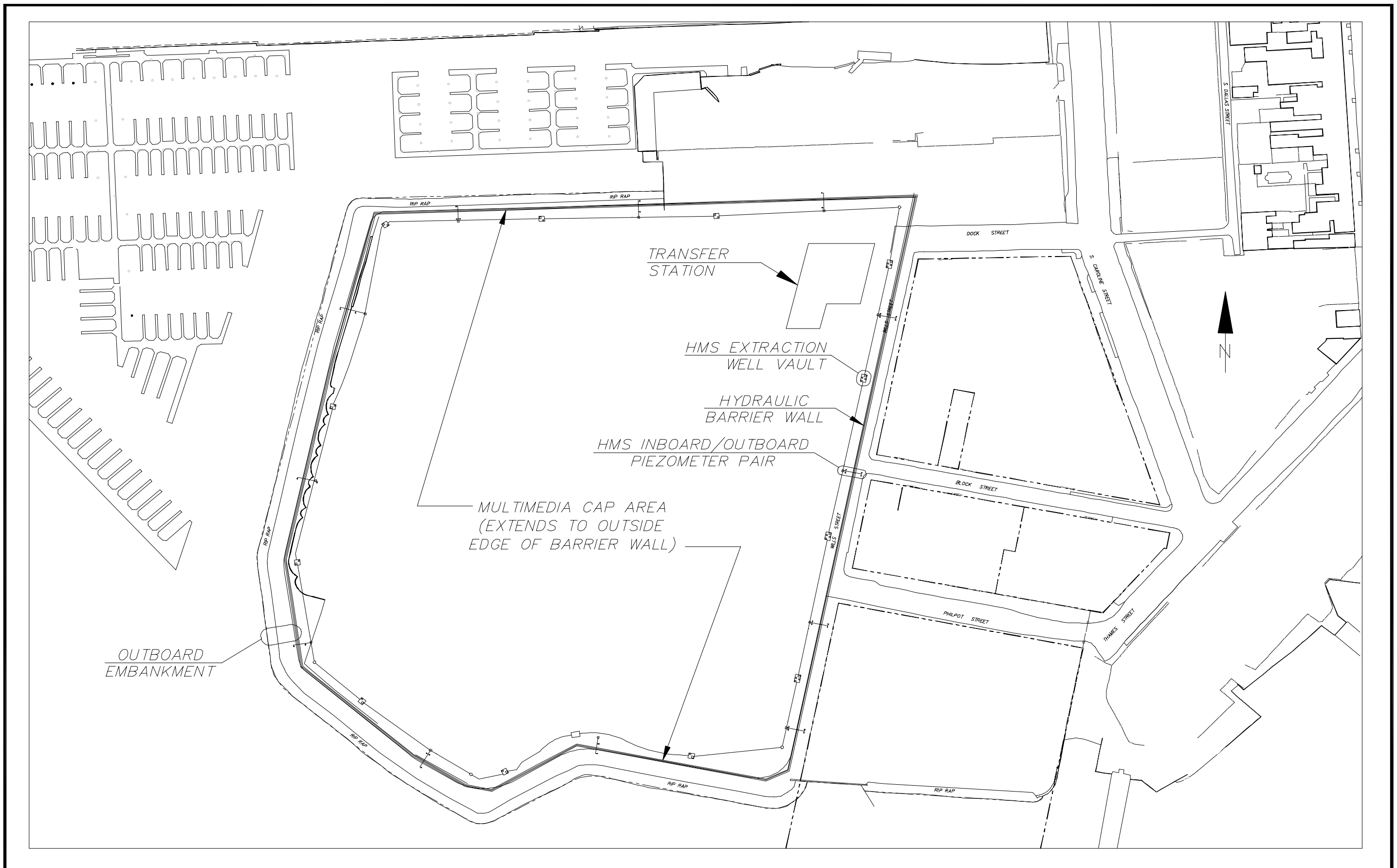
The remedial action completed at this site is designed to minimize the future releases of contaminants to the air, adjacent soils, surface water and groundwater, while allowing for potential site redevelopment. The corrective measures included: (1) installation of a new perimeter bulkhead and a deep vertical hydraulic barrier (slurry wall) as a containment structure; (2) installation and operation of a groundwater withdrawal system within the containment structure; (3) construction of a multimedia cap over the containment area; and (4) a comprehensive surface and groundwater monitoring system. In addition, the site remediation activities were conducted in a manner to prevent any significant cross-media transfer of pollutants during site preparation and installation of containment structures at the site.

INTRODUCTION

In 1991, a Corrective Measures Implementation Program Plan (CMIPP) was submitted by the owner of a 140-year old chromium ore processing facility in Maryland to prevent further migration of contaminants to the soil, groundwater and surface water. Figure 1 provides the layout of the facility and the surrounding harbor. The owner of the facility had stopped manufacturing operations in 1985 and entered into a CD with the EPA and MDE in 1989 to investigate the nature and extent of contamination at the 20-acre facility and submit the CMIPP based on the findings of their investigations. These investigations found that the soils were contaminated with hexavalent chromium above the action level of 10 parts per million. Both the shallow aquifer (0-20 feet below the ground surface) and deep aquifer (23-70 feet below the ground surface) were found to be contaminated with chromium, with concentrations exceeding 5,000 mg/l near the former manufacturing area at the facility. The surface water in the harbor surrounding the facility was also found to be contaminated with chromium above regulated levels.

The proposed corrective measure alternatives (CMAs) presented in the Consent Decree, and detailed in the CMIPP, included: the installation of a new perimeter outboard embankment; a deep vertical hydraulic barrier (slurry wall) within the new embankment as a containment structure to prevent the release of contamination into the harbor and groundwater surrounding the facility; installation and operation of a groundwater withdrawal system inboard of the containment structure to maintain an inward hydraulic gradient of groundwater at the site; construction of a multimedia cap over the containment area to prevent any future exposure to the contaminated soil and minimize the generation of contaminated leachate from any infiltration of precipitation at the site; and a comprehensive surface and groundwater monitoring system to confirm that all the site remediation goals are being achieved.

In preparation for implementing these CMAs, the facility owner dismantled the manufacturing plant existing at the facility. The implementation of the CMIPP commenced in 1992 after dismantling the plant and placing an asphalt cover over the former manufacturing areas at the site. Prior to the construction of containment structures, sediments were dredged from the harbor surrounding the facility, and a new outboard embankment was constructed. The deep vertical hydraulic barrier consisting of a slurry wall constructed using a mixture of soil and bentonite encompasses 15 acres of the site. A multimedia cap of capillary break stone, geosynthetic clay liner, geomembrane, geocomposite drainage layer and clean fill covers the area enclosed by the slurry wall. The groundwater extraction system, with off-site treatment and disposal, is now operational. This system is programmed maintain an inward hydraulic gradient of 0.072 feet across the barrier wall.



BLACK & VEATCH | REMEDIATION OF CHROMIUM FACILITY | SITE LAYOUT | FIGURE 1

Groundwater, surface water, and sediment are monitored on a regular basis to confirm the remedial components are performing as intended. Tide and groundwater levels are monitored continuously and dictate the rate of groundwater extraction from the site. The concentration of chromium in the wells and surface water outside the barrier wall reflects the performance of the containment. Additional parameters are monitored for continued compliance. This site remediation and its design elements are also intended to permit future redevelopment of the site as a mixed-use, non-residential zone.

DISMANTLEMENT AND DECONTAMINATION

Dismantlement was performed in accordance with the Dismantlement Plan incorporated into the Consent Decree, and included building classification, deconstruction and waste handling.

The dismantlement work started in November 1989 and was completed in early 1993. The activities included 21 buildings, 240,000 square feet of transite roofing, 15,000 tons of decontaminated equipment and steel for recycling, and 35,000 tons of construction debris that was sampled, classified and shipped to appropriate off-site disposal facilities. An office building, warehouse with water treatment equipment, and two storage tanks totaling 900,000 gallons were left onsite to support the remedial component construction.

Building classification fell into three categories:

- Type A – non-contaminated
- Type B – contaminated with chrome or asbestos
- Type C – partially contaminated with chrome or asbestos

Type A facilities were demolished using standard demolition techniques. Methods for Type B facilities included negative air systems, interior targeted deconstruction to remove specific materials and contamination, followed by exterior decontamination and deconstruction. Type C facilities were decontaminated as a Type B facility, but then could be reclassified as Type A depending on sample results. Building foundations were left in-place.

Waste handling procedures were dependent on the building classifications and materials removed. Materials from Type B and C structures were presumed hazardous unless testing indicated otherwise. Contaminated materials that could not be cleaned were sent to a hazardous waste landfill. Steel materials were cleaned onsite using existing equipment and processes, and then were sent offsite for recycling. Asbestos was handled and disposed according to regulatory requirements. Typical contaminated construction debris was sent to a hazardous waste landfill. The onsite water treatment facility removed chromium from contaminated water before discharging to the City sewer.

IMPLEMENTATION OF THE REMEDIAL PLAN

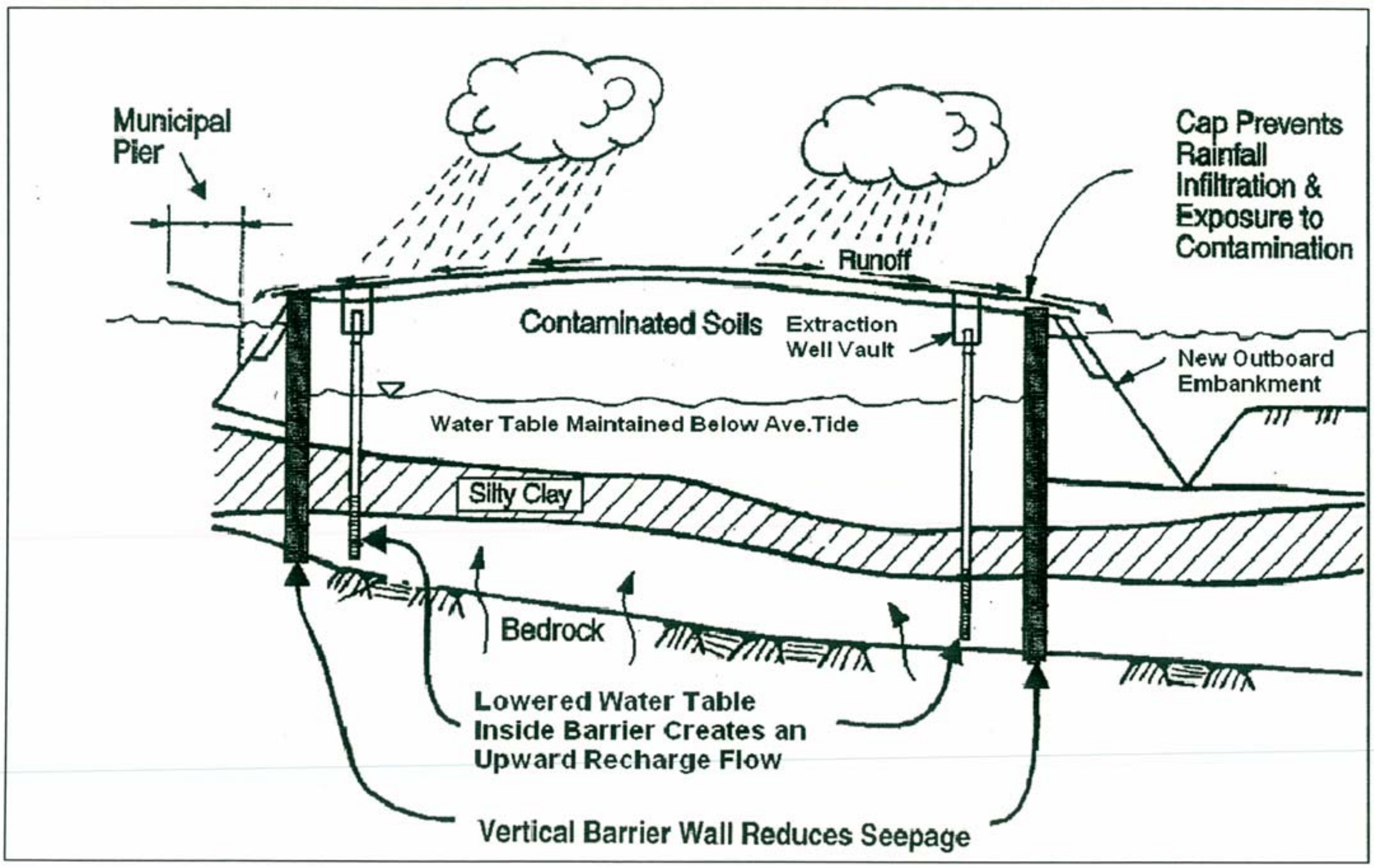
The CMA components were divided into distinct design and construction phases: 1. new outboard embankment, 2. hydraulic barrier wall, and 3. multimedia cap and groundwater extraction system. The extraction system is also known as the head maintenance system (HMS) because extraction is based on head differential across the hydraulic barrier wall. Each phase was performed by separate contractors. The Owner managed the dismantlement contract directly. Black & Veatch and Mueser Rutledge Consulting Engineers combined design and field efforts for the new outboard embankment, hydraulic barrier wall, and multimedia cap and groundwater extraction system phases, as depicted in Fig. 2.

Remedial construction activities, including dismantlement, took 10 years and cost about $60 million, not including engineering and other project expenses. The 1987 Feasibility Study's economic analysis indicated the 1987 present worth for the selected CMAs was in the range of $46 million to $188 million.

Perimeter dredging for the new bulkhead was performed in 1992. Approximately 216,000 cubic yards of sediment were transported for disposal. Additionally, an unused one acre slip was filled and surcharged to consolidate sediments. About 2500 wick drains were installed on 4-foot centers to relieve porewater pressure, and provide a route for collection and removal of the water. Filling the slip eliminated about 600 feet of additional dredging and new embankment construction.

The new outboard embankment construction was performed in 1992-93 to stabilize the various existing bulkhead structures and provide a competent zone to install the deep hydraulic barrier. The embankment is a zoned fill ranging from sand at the bulkhead to large rip rap outboard in the splash zone. The new bulkhead length is 1900 feet, averaging 35 feet in depth, with nearly 300,000 tons of sand and stone material.

The soil bentonite hydraulic barrier wall was installed over a two year period from 1994 to 1996. Excavation beyond 55 feet deep



BLACK & VEATCH | REMEDIATION OF CHROMIUM FACILITY | SITE CROSS SECTION | FIGURE 2 was performed by backhoe with an extended boom and stick, allowing a maximum reach of 93 feet. Equipment was supported by an elevated soil platform and timber mats.

The barrier wall is 3200 feet long, 3 feet wide, and installed to an average depth of 68 feet, with a 3 foot key into bedrock. Average permeability, based on more than 50 analyzed samples, is 4x10-9 cm/sec.

The head maintenance system (HMS) and multimedia cap were installed concurrently between 1996 and 1999. The HMS is comprised of 4 shallow and 12 deep extraction wells, using a pneumatic pumping system, and housed in 12 vaults. The extraction wells are matched with 16 pairs of inboard and outboard piezometers to monitor groundwater extraction results. Water is pumped and collected in two storage tanks housed in the transfer station, which was built over the multimedia cap. The HMS is controlled and monitored by programmable logic controllers and a master computer system.

The transfer station, which houses office and meeting space, two 10,000 gallon groundwater storage tanks, and tanker truck loading facilities, has a slab foundation over a mud-mat protecting the multimedia cap components. The transfer station facilities and HMS computer control system became operational in 1999. When the transfer station became operational, the remaining original site facilities, including the water treatment building and a 750,000 gallon storage tank, were dismantled and removed from the site.

The multimedia cap covers about 15 acres and is tied into the hydraulic barrier around the perimeter. The cap is comprised of, from top to bottom, 30 inches of cover soil embedded with a visual warning barrier, high flow composite drainage layer, 60-mil LDPE geomembrane, geosynthetic clay layer (GCL), geotextile, and a capillary break stone layer to deter upward migration of contamination. The visual barrier is an orange high visibility HDPE geogrid fence intended to provide a warning of the synthetic layers 12 inches below it. The capillary break stone is intended to prevent existing site contamination from migrating up and contacting the synthetic layers.

BEST MANAGEMENT PRACTICES USED DURING REMEDIATION

The remedial action completed at this site is designed primarily to minimize the future releases of contaminants from the soils to the air, surface water and groundwater. In addition, the site remediation activities were conducted in a manner to prevent any significant cross-media transfer of pollutants during site preparation and installation of containment structures at the site. The containment structures were also designed to minimize the possibility of improper operation during the future development and use of site for recreational or commercial purposes. Descriptions of 12 selected best management practices (BMPs) used at the site to address cross-media transfer of pollutants follow below.

Perimeter and Personnel Monitoring of Air Quality.

The facility installed six air sampling stations at the site perimeter that operated continuously to provide samples for analysis of chromium and asbestos concentrations. The sample results were then compared with previously determined background standards for each pollutant. The action levels were set at each background level's second standard deviation. In addition to monitoring air quality in the perimeter of the site, personnel monitoring for chromium and asbestos was conducted to assure the health and safety of personnel working on site during the dismantling and disposal of the plant, and construction of the remedial measures.

Covering Debris Generated During Construction

Piles of debris generated during construction activities were kept covered under sheets of plastic. This practice was followed on the site mainly due to concerns of wind carrying over any dust or other debris from open piles to the harbor or nearby neighborhoods.

Providing Temporary Sumps for Collecting Stormwater Run-Off

Temporary sumps were provided with a pumping system to collect and transfer any run-off from the site to the tanks being used for storing groundwater extracted on-site. This arrangement prevented a transfer of site pollutants to the surface water during construction. During construction of the cap, a permanent system was constructed to divert stormwater run-on to the site and collecting stormwater run-off from the site.

Preventing Surface Water Pollution During Construction of the Slurry Wall

In addition to the detailed specifications and inspections required to assure a high quality construction of the slurry wall at the site, a few precautions were taken to prevent cross-media transfer of pollutants during construction. For example, the trench construction spoils were placed at levels above the 100-year level of high tide, and were also covered by a sheet of plastic. These spoils were tested for the presence of high concentrations of chromium and were provided with an appropriate management of stormwater run-on/run-off. Fugitive dust emission from the spoils was controlled during periods of dry weather by sprinkling water over the spoils.

Arrangements for Trucks Crossing Over the Slurry Walls

During construction of the multimedia cap over the site, a short bridge of concrete was placed over the slurry wall at several points to permit the occasional travel of trucks. This arrangement prevented damage to the slurry wall.

Checking the Integrity of Slurry Wall

The containment performance of the slurry wall was assessed after its construction using a series of hydraulic tests and monitoring. For the purpose of testing, paired piezometers were designed to the same specification as the final groundwater extraction wells. Water levels in the shallow aquifer outside the slurry wall rose at an average rate of 0.35 foot of head per month during and immediately after slurry wall construction. Individual pumping tests were performed in the deep aquifer and at four locations inside the site perimeter. In these locations, even with 25 feet of drawdown, the outside piezometers did not indicate the influence from the pumping well. Several interior piezometers were then pumped simultaneously to simulate the groundwater withdrawal after remedial construction. Tests confirming earlier pumping test results showed rapid drawdown propagation in the confined aquifer within the slurry wall. As a visual indicator of any settlement of slurry wall contents occurring after construction, temporary steel plates were embedded in the slurry wall at several locations and used for direct measurement of subsidence. The hydraulic tests confirmed the integrity of the slurry wall.

Providing Standby Well-Heads for Future Groundwater Extraction

In anticipation of future well performance needs or operation problems, such as screen clogging, and maintaining needed capacity at the designated extraction locations, standby well-heads (without pumps) were installed for future as needed use. This feature minimizes the need to penetrate and potentially damage the multimedia cap to drill new wells for an upgrade of the groundwater extraction system after site development.

Providing a Capillary Break Layer in Multimedia Cap

A capillary break gravel layer was used to prevent any capillary rise of contaminated water from the site's subsoils to the low-permeability layer (containing geosynthetic clay liner and geomembrane) above. Upward migration of site contaminants is thus prevented.

Preparing Multimedia Cap for Future Site Development

As the site is permitted for development as a multi-use zone, concept designs were prepared for the cap in areas to be used in the future. The multimedia cap's 30-inch cover soil layer included a hi-visibility geogrid material about 18 inches beneath the surface to alert future developers of the site that a penetration of the cap cover soil below this point might result in damage to the geosynthetic layers. Original site conditions, such as slip and foundation locations, are also documented to facilitate planned development.

Environmental Monitoring Plan for Checking Containment

Monitoring of chromium in surface water and groundwater levels both inside and outside the slurry wall will be continued on a regular basis to ensure compliance with the performance criteria of the Consent Decree.

Dredging of Contaminated Sediments from the Harbor

As part of the embankment construction, dredging and disposal of the sediments was accomplished under stringent environmental controls. Testing of every load of dredged spoils was required. Dredging was also performed completely within a full-depth turbidity curtain. Water sampling and analysis for chromium was conducted inside and outside the curtain to check it's effectiveness in reducing migration of chromium in the surrounding harbor waters. In one area of the site where limited space would have made dredging very problematic, the sediments were stabilized and capped in place subsequent to construction of the rock embankment at this location.

Dismantling the Chromium Plant Under Negative Pressure

The dismantling of the plant was conducted with a series of controls designed to assure worker health and safety. The buildings at the site were categorized according to pollutant concerns (i.e., only asbestos, asbestos and chromium, and only chromium) and the dismantling plan required development and fabrication of enclosures for creating a negative pressure during the dismantlement of some buildings. One of the buildings, for example, used nine HEPA filters with a capacity of 18,000 cubic feet per minute each, as well as the use of water curtains and air seals during dismantling operations. This plant building was 300 feet long and 70 feet wide with a maximum roof height of 100 feet. There was another large building with similar dimensions and several smaller buildings that were dismantled under negative air pressure.

POST-CLOSURE MONITORING

The CD signed between the Owner, the EPA, and the MDE required that the site performance be monitored for a period of 1 year to verify compliance with the Performance Standards specified in the CD. Black & Veatch performed monitoring between July 1, 1999, through June 30, 2000, to verify compliance. The performance standards to be met were: 1). Surface water quality for total chromium shall be less than 50 parts per billion (ppb), calculated for each sample location by arithmetically averaging the samples taken at all depths over 4 consecutive days; and 2). Average groundwater head differential across the hydraulic barrier shall be at least 0.01 ft, and an inward flow of groundwater into the site is maintained. The data monitored by Black & Veatch to ensure compliance with the performance standards are briefly discussed below.

Surface Water Quality Performance

Surface water monitoring was completed around the perimeter of the site at 18 predetermined stations. Samples were collected at each station on four consecutive days each month and analyzed for total dissolved chromium. Every station's chromium concentration has lowered significantly since completion of the barrier wall, head maintenance system, and multimedia cap. Surface water chromium concentrations during the verification period were below the performance standard of 50 ppb total dissolved chromium. During the verification period's 12 monthly sampling events, only 2 of the 216 reported averages were above the 10 ppb detection limit, and those two were reported at less than 11 ppb.

Groundwater Gradient Performance

The groundwater gradient was measured at sixteen piezometer pairs along the deep vertical hydraulic barrier. The head maintenance system (HMS) at the site initiates pumping from within the hydraulic barrier whenever the piezometer pair's hourly gradient falls below the programmed gradient setpoint. The performance standard for the head difference between the piezometer pair was 0.01 feet plus 2 times the HMS water level measurement error, which is (0.01 + 2*(0.031)) = 0.072 feet. The HMS 30-day running average gradient chart for the quarter ending June 30, 2000, is presented in Fig. 3.

The chart shows that the performance standard was met at all times, and the actual head differential maintained around the barrier wall varied from 0.3 to 2.3 feet.

CONCLUSIONS

The CMIPP outlined the design and implementation basis for an intricate and integrated corrective action. The phased design and best management practice construction approach enabled a process that could accommodate unexpected construction conditions, minimize cross contamination, maintain protection of the public and the environment, control costs to the low end of the feasibility study estimate, maintain a reasonable schedule, and complete an effective remedial response. Post construction verification met all performance requirements, and groundwater extraction volumes are significantly below original projections, reducing annual O&M costs.

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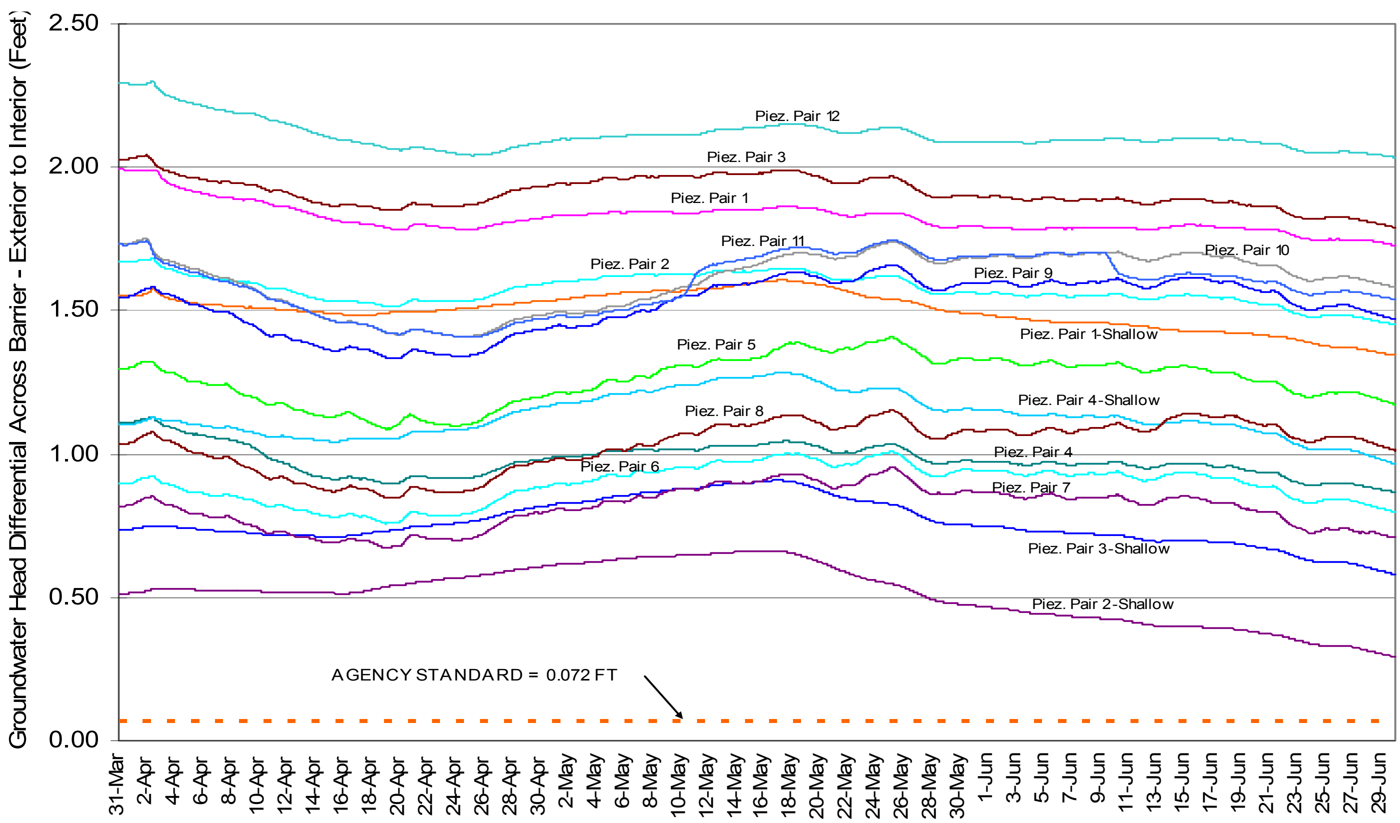

Fig. 3. Thirty Day Running Hourly Average of Head Differential Across the Hydraulic Barrier Wall - Quarter Ending June 30, 2000

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