MEMO

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From:
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Date:
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Arcadis Project No.:
30018857

Subject:
Sulfate Application Field Memorandum, Kinder Morgan Liquid Terminals, Harbor Island Terminal

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The following Sulfate Application Field Memorandum describes the procedures for field activities related to the reapplication of sulfate at the Kinder Morgan Liquid Terminals' Harbor Island Terminal, located at 2720 13th Avenue SW, Seattle, Washington (site). Arcadis U.S., Inc. (Arcadis) will perform the reapplication of sulfate.

Objective

The objective of the field event is to reapply sulfate (in the form of magnesium sulfate [Epsom salt]) to the ground surface within the B, C and D yards to supplement the initial remedial sulfate application completed in June 2013 and the supplemental sulfate applications completed in September 2015, October 2016, April 2018 and October 2018. This supplemental sulfate application will provide additional electron acceptors for continued anaerobic biological oxidation (ABOx) of petroleum impacts within site groundwater.

Remedial Design

Epsom salt, a highly soluble form of sulfate, will be applied to the ground surface in select areas within the B, C and D yards (**Figure 1**). Precipitation will act as the primary mechanism to dissolve the Epsom and residual gypsum from the initial sulfate application and allow infiltration through the unsaturated soils and into groundwater, delivering sulfate to support ABOx of petroleum compounds in groundwater. Approximately 900 milligrams per liter (mg/L) of dissolved sulfate is targeted to maintain ABOx in the application area. During dry periods of the year (typically May through September), precipitation is supplemented with surface irrigation supplied from the irrigation system installed in the B, C, and D yards.

The initial sulfate application, completed in June 2013, consisted of 264,000 pounds of gypsum and 42,000 pounds of Epsom salt dispersed across 30,000 square feet. Performance monitoring indicated that the trend of dissolved sulfate concentration in groundwater was decreasing toward an asymptotic concentration above background levels but below the target level of 900 mg/L. The asymptotic trend is attributed to the dissolution of Epsom and apparent residual gypsum. In response, additional remedial actions to supply supplemental sulfate for ABOx have been implemented as follows:

- During September 2015, consisting of 16,000 pounds of Epsom salt dispersed across 19,650 square feet, which was approximately 0.8 pounds per square foot (lbs/ft^2).
- During October 2016, consisting of 15,000 pounds of Epsom dispersed across the B, C, and D yards. The application density applied in 2016 was 1.0 lbs/ft^2 over a 5,000 ft^2 area in the C and D yards, and 0.85 lbs/ft^2 over a 12,500 ft^2 area in the B yard.
- During April 2018, consisting of 10,000 pounds of Epsom dispersed across the B, C and D yards. The application density applied in April 2018 was 1.0 lbs/ft^2 over a 5,000 ft^2 area in the C and D yards and 0.5 lbs/ft^2 over a 10,000 ft^2 area in the B yard.
- During October 2018, consisting of 5,000 pounds of Epsom dispersed across the C and D yards at an application density of 1.0 lbs/ft^2 over a 5,000 ft^2 area.

Sulfate concentrations in the sulfate application areas are assessed semi-annually via groundwater laboratory analysis to determine if an additional sulfate application is required to support ABOx. ABOx performance is also monitored by analyzing biodegradation trends following semi-annual groundwater monitoring, which indicate that hydrocarbon concentrations within the remedial footprint are generally decreasing due to the remedial action. Additional monitoring of sulfate concentrations is completed monthly through the collection of in situ conductivity readings from each of the performance monitoring wells.

Recent ABOx performance monitoring indicates sulfate concentrations are generally less than the target threshold level. To maintain the target sulfate concentration in groundwater, a supplemental application of approximately 15,000 pounds of Epsom salt will be applied to the application area during /December 2019. Approximately 15,000 pounds of Epsom salt will be applied to the ground surface across approximately 15,000 square feet in the B, C, and D yards. The application of Epsom salt will deliver approximately 1.0 pound of Epsom salt per square foot to the application area to support sulfate concentrations greater than the target threshold level.

Field Implementation

Mobilization

Epsom salt is scheduled for delivery by Univar, Inc. by December 3, 2019. The total delivery will consist of 7 pallets of Epsom salt packaged in 50-pound bags for a total of 300 bags. Pallets will be off-loaded by terminal personnel identified by the terminal operator. The pallets will be staged on the asphalt area in the southwest portion of the D yard prior to the application event. The pallets will be covered with water-proof tarpaulin and will be staged so as not to inhibit ingress/egress of any doors, gates, ramps or emergency equipment. Arcadis field personnel, materials, and equipment will mobilize to the site on December 04, 2019 to initiate the supplemental sulfate application field event.

Site Preparation

The Epsom application area density will be regulated by generating a grid layout within the application area. Three 50-pound bags will be applied to 150 square foot application cells in the B, C and D yard

application areas, approximately 1.0 lb/ft^2 of Epsom salt. Based on this ratio, a grid will be developed and laid out in the B, C, and D yards using white ground-marking spray paint. The appropriate grid shape will be determined by field staff to adapt to infrastructure within the application area and maintain the respective application cell area density. Grids will be developed and laid out immediately prior to field application to minimize distortion of the grid layout from rain and weathering.

Surface Application

A small four-wheel utility vehicle will be used to transport bags of Epsom from the staging location to the application areas within the B and D yards. A truck will be utilized to transport the required Epsom to the application area within the C yard because the four-wheel utility vehicle is not licensed for road use. Arcadis will place the established number of bags in each grid space prior to application. The Epsom bags shall be distributed by the field team utilizing hand tools, including some or all of the following pieces of equipment, to apply the sulfate to the ground surface:

- Wheeled broadcast spreader, filled with Epsom and walked over each grid square;
- Wheelbarrow, filled with Epsom and roughly spread out across grid square and finely spread using a rake or broom; and
- Manual spreading by cutting the bag and pouring in each grid square followed by spreading with a rake or broom.

The application method used in the field will be determined by the field team based on efficiency and facility operations and equipment with consideration to health and safety.

Phasing

Given the repetitive nature of carrying out these tasks sequentially, the field team may phase the tasks at their discretion. Carrying out the tasks of marking the grid, distributing Epsom salt sacks, and spreading in a phased manner to provide variations in job task and limits the potential for injury from repetitive lifting, bending, and spreading. Given that the Epsom salt will be delivered on approximately 7 pallets, work will be segmented into areas that roughly correspond to the coverage area of each pallet. Grid marking, Epsom salt staging and spreading will be conducted sequentially in each area. This will ensure that repetitive tasks are varied frequently enough to reduce the potential for injury.

Health and Safety

Refer to the Site-Specific Health and Safety Plan for general personal protective equipment requirements for the site and other health and safety considerations. Epsom salt is generally considered to be non-hazardous, but care should still be taken to ensure that dust is minimized during handling and spreading. Additionally, back braces may be used while loading and unloading Epsom salt bags, but they do not protect the wearer from potential back injuries sustained from poor lifting technique. Maintaining good body positioning, both with and without back braces, and taking adequate breaks are crucial to ensuring that the potential for back injuries is minimized.

Schedule

December 04 – December 06, 2019 – Apply Epsom in B, C, and D yards

Figures

Figure 1 – Land Application and Epsom Distribution Cells

'C' YARD

'D' YARD

'B' YARD

Tank 37

Tank 35

Tank 21

Tank 25

Tank 20

Tank 27

Tank 32

Tank 33

BBL STORAGE

WALL OPENING

APPROXIMATE OVERHEAD PIPE LOCATION

12'

IRRIGATION PIPING AND ROTOR LOCATION

MW-14

MW-5

TMW-2

TMW-1

MW-19

20

3,200 S.F.

~5,000 sq ft

11

TMW-4

TMW-3

MW-7

12

~10,000 sq ft

TMW-6

15

TMW-5

13

APPROXIMATE OVERHEAD PIPE LOCATION

RAMP

GATE

MW-22

13' INGRESS/EGRESS

MW-6

'B' YARD INGRESS/EGRESS

TMW-B1

LEGEND

- SH-02 — GROUNDWATER MONITORING WELL (INSTALLED BEFORE 1993)
- MW-7 — GROUNDWATER MONITORING WELL (INSTALLED AFTER 1993)
- MW-12R — REPLACEMENT GROUNDWATER MONITORING WELL (INSTALLED BETWEEN JANUARY 31 AND FEBRUARY 21, 2002)
- MW-25 — MONITORING WELLS (INSTALLED SEPTEMBER 30, 2003)
- 3 — FORMER GROUNDWATER MONITORING WELL (ABANDONED JUNE 2003)
- SULFATE APPLICATION AREA; JUNE 2013
- ASPHALT REMOVAL AREA
- WATER SOURCE LOCATION
- PERFORMANCE MONITORING WELL LOCATION (INSTALLED JUNE 2013)
- IRRIGATION ROTOR LOCATION
- IRRIGATION PIPING
- CONCRETE WALL
- ASPHALT RESTORATION AREA
- APPLICATION CELL
- APPROXIMATE BOUNDARY OF SUPPLEMENTAL SULFATE APPLICATION AREA

DESIGN SPECIFICATION

- APPROXIMATELEY 1.0 POUNDS PER SQUARE FOOT OF EPSOM SALT SHALL BE APPLIED TO THE APPLICATION AREA.

0 20' 40' 80'

KINDER MORGAN LIQUID TERMINALS, LLC
HARBOR ISLAND TERMINAL
2720 13TH AVENUE SOUTHWEST, SEATTLE, WASHINGTON

LAND APPLICATION AND EPSOM DISTRIBUTION CELLS

ARCADIS Design & Consultancy for natural and built assets

FIGURE 1