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From:  
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Date:  
March 28, 2018

Arcadis Project No.:  
WA000804.2018

Subject:  
Sulfate Application Field Memorandum, Kinder Morgan Energy Partners,  
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 Energy Partners Harbor Island Terminal, located at 2720 13<sup>th</sup> 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 and October 2016. 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, 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 asymptote 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, a supplemental sulfate application was completed in September 2015, which consisted of 16,000 pounds of Epsom salt dispersed across 19,650 square feet, approximately 0.8 pounds per square foot (lbs/ft<sup>2</sup>). A second supplemental sulfate application was completed in October 2016 and consisted 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<sup>2</sup> over a 5,000 ft<sup>2</sup> area in the C and D yards, and 0.85 lbs/ft<sup>2</sup> over a 12,500 ft<sup>2</sup> area in the B yard. 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 monthly through the collection of in situ conductivity readings from each of the performance monitoring wells.

Recent ABOx performance monitoring indicates sulfate concentrations are approaching 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 the months of April and October 2018. In April 2018, approximately 5,000 pounds of Epsom salt will be applied to the ground surface across 5,000 square feet in the C and D yards and 5,000 pounds of Epsom salt will be applied to the ground surface across 10,000 square feet in the B yard. In October 2018, approximately 5,000 pounds of Epsom salt will be applied across the same 5,000 square foot area in the C and D yards. The application of Epsom salt will deliver approximately 1.0 pound of Epsom salt per square foot to the C and D yard application areas in April and October 2018 and approximately 0.5 pound per square foot to the B yard application area in April 2018.

## **Field Implementation**

### *Mobilization*

Epsom salt is scheduled for delivery by Univar, Inc. by April 3, 2018. 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 be mobilized to the site on April 3, 2018 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 C and D yard application areas and two 50-pound bags will be applied to 200 square foot application cells in the B yard application area. 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.

### *Storage of Epsom*

The remaining 5,000 lbs of Epsom will be stored in an area in the D yard designated as appropriate by Kinder Morgan personnel. 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.

### *Secondary Application*

Arcadis will remobilize at a date to be determined in October 2018 to apply the remaining 5,000 lbs of Epsom in the C and D yard application areas. Application and phasing will follow the same steps outlined in the Field Implementation section above. Grid size, application area, and application density will mirror the April event.

### **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**

April 3, 2018 through April 4, 2018 – Apply Epsom in B, C, and D yards

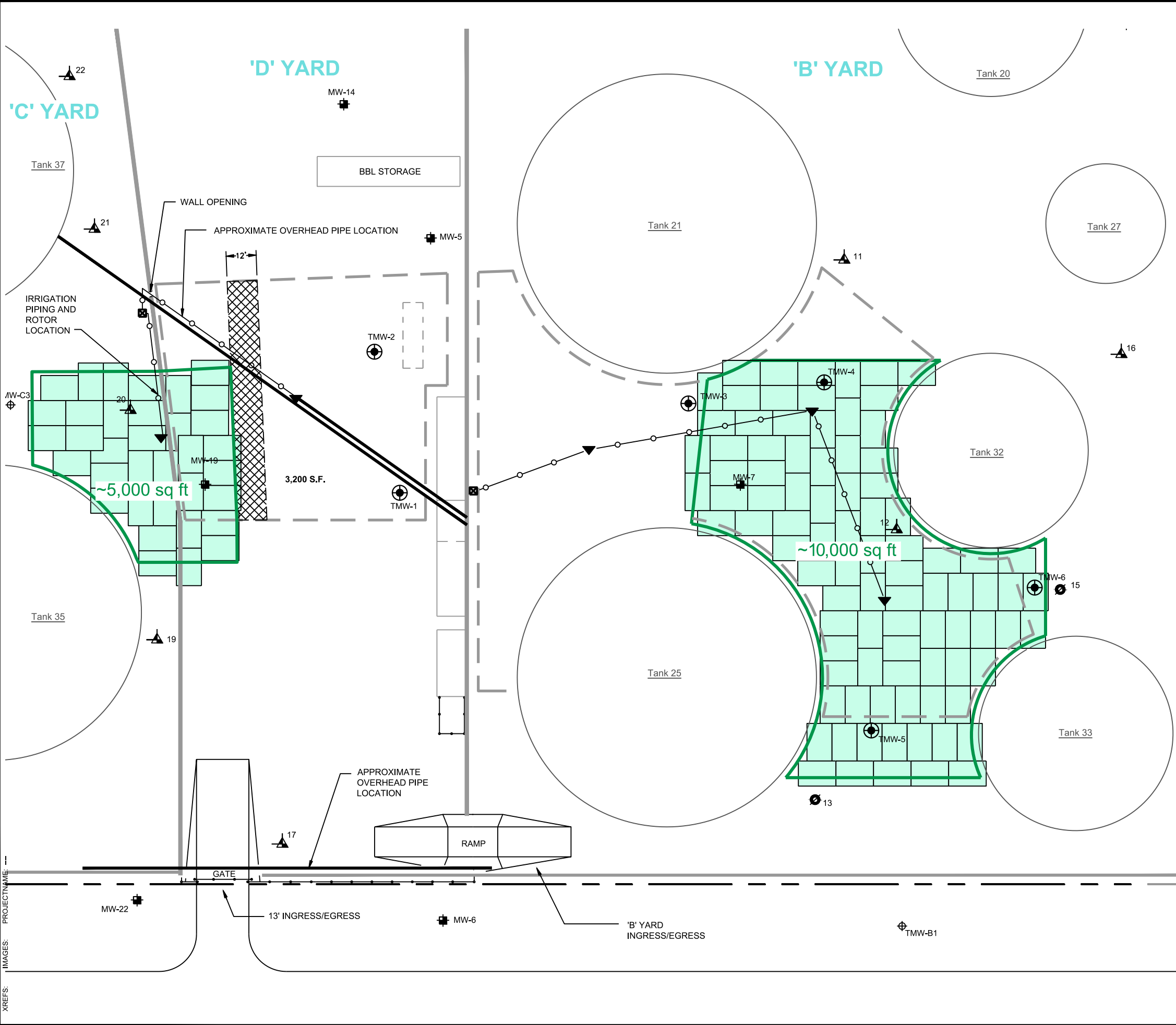
October 2018 – Apply Epsom in C and D yards

### **Figures**

Figure 1 – Land Application and Epsom Distribution Cells

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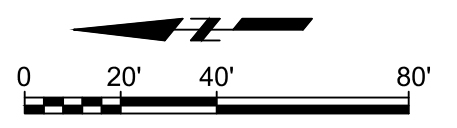
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### LEGEND

- 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; 2016

- ### DESIGN SPECIFICATION
- APPROXIMATELY 1.0 POUND PER SQUARE FOOT OF EPSOM DELIVERED TO C AND D YARD APPLICATION AREA IN APRIL AND OCTOBER 2018
  - APPROXIMATELY 0.5 POUNDS PER SQUARE FOOT OF EPSOM DELIVERED TO B YARD APPLICATION AREA IN APRIL 2018



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## LAND APPLICATION AND EPSOM DISTRIBUTION CELLS