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Permeable Reactive Gate Work Plan
Area 1 – Former Plating Area

Eckles Road Site
Livonia, Michigan

RACER Trust

GHD | 26850 Haggerty Road Farmington Hills Michigan 48331

012607 | Report No 74 | April 2018

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1. Introduction

GHD Services Inc. (GHD), on behalf of Revitalizing Auto Communities Environmental Response Trust (RACER), has prepared this Area 1 Permeable Reactive Gate (PRG) Work Plan (Work Plan) for the RACER property at 12950 Eckles Road in Livonia, Michigan (Site), which is part of the larger RCRA Facility MID005356621.

This Work Plan presents a scope of work for the removal of a portion of the existing Area 1 Barrier Wall and replacement with a permeable mixture of zero-valent iron and sand to polish groundwater as it flows out of the area contained by the Area 1 Barrier Wall. An in-situ chemical reduction (ISCR) treatment program was previously conducted to chemically precipitate dissolved hexavalent chromium (chromium VI) and nickel in groundwater within the former plating area (identified as Area 1).

Figure 1 presents the Site and Facility Location. Figure 2 presents the Site plan.

1.1 Objective of the Permeable Reactive Gate Implementation

It is uncertain if continued long-term operation of the existing groundwater treatment plant (GWTP) will achieve remedial objectives within projected RACER funding. Based on post-ISCR injection groundwater monitoring, the expanded pilot study and full-scale ISCR treatment program realized a signification reduction in dissolved chromium VI and nickel concentrations in groundwater. Active groundwater pump and treat operations with the existing GWTP may no longer be required, other than to manage groundwater elevations within Area 1, currently enclosed by the Area 1 Barrier Wall. A groundwater flow model was developed for the Site (Groundwater Flow Model Report (GHD, 2017) and potential PRG locations and lengths were evaluated and presented in the Permeable Reactive Gate Evaluation Model Report (GHD, 2017).

Although there are no complete exposure pathways and an existing French drain, GWTP and soil-bentonite barrier wall are controlling the migration of impacted groundwater, RACER would like to proactively eliminate the need for ongoing O&M of the GWTP. A series of pilot studies, targeted, and full-scale ISCR injections were conducted to proactively reduce groundwater concentrations of nickel and chromium VI to near their respective drinking water criteria of 0.1 mg/L for each. A reduction to, or below, drinking water criteria was not anticipated at each monitoring location or for all groundwater within Area 1. The objective for the proposed PRG is to allow groundwater to passively flow out of Area 1 and passively treat any residual concentrations of dissolved chromium VI or nickel in groundwater as it leaves Area 1. The installation of the PRG will allow the GWTP to be shut down and significantly reduce require operation and maintenance obligations at the Site.

1.2 Report Organization

The remainder of this report is presented in the following sections:

- **Section 2 – Background Information** – provides details on the physical layout of the Site, historical site characterization reports, interim measures implemented at the Site and applicable cleanup criteria.

- **Section 3 – Groundwater Sampling** - provides details on the Area 1 Groundwater Monitoring activities and results, including additional characterization activities. These details provide the means to define the areas with impacted groundwater and facilitate proper remedial design.
- **Section 4 – Hydrogeologic Conceptual Site Model** (CSM) – utilizes the results of the RFI and ongoing groundwater sampling to update the CSM and includes geology, hydrogeology, hydrology, and groundwater use.
- **Section 5 – Laboratory Treatability Study and Modeling Results -** provides details on the laboratory treatability study and subsequent groundwater modeling and PRG modeling activities conducted to evaluate current groundwater flow conditions and potential PRG design and location alternatives.
- **Section 6 – Permeable Reactive Gate Implementation Scope of Work** - provides details on the proposed Area 1 Barrier Wall removal and PRG installation activities.
- **Section 7 - Performance Monitoring Plan -** provides details on the monitoring and reporting activities that will be performed to evaluate and document the performance of the PRG installation and effectiveness.
- **Section 8 - Schedule** - provides the general sequence of events that are anticipated for installation of the PRG and performance monitoring.
- **Section 9 - References -** provides a listing of reports used to facilitate development of this Work Plan.

2. Background Information

2.1 Historical Site Characterizations

The Site was historically used for the production of vehicle bumpers, leaf springs and strut assemblies, with Area 1 being used for chrome plating. Environmental decommissioning and demolition of the entire Site occurred during the 2000 to 2001 period. Resource Conservation and Recovery Act (RCRA) Corrective Action work was conducted by General Motors before its 2009 bankruptcy and subsequently by RACER pursuant to a 2011 agreement with the United States Environmental Protection Agency (USEPA). A RCRA Facility Investigation (RFI) over several stages was conducted at the Site and included a risk assessment. The results are summarized in the RFI Report (CRA, March 2005) and Supplement to the RFI Report (CRA, April 2005). Following completion of the RFI, a Revised Corrective Measures Proposal (CRA, June 2005) was developed and submitted to the USEPA. USEPA issued a Final Decision and Response to Comments (USEPA, March 2006) selecting final corrective measures for the Site, including continued operation of the groundwater extraction and treatment facility and barrier wall at Area 1.

During the RFI, nickel and chromium impacted groundwater was identified within Area 1. Chromium was not detected at concentrations above generic screening criteria at off-Site locations during any RFI or CA750 sampling events. The chromium-impacted groundwater identified at Area 1 appears to be contained by the French drain collection system and Area 1 Barrier Wall. Nickel-impacted groundwater was identified in some off-site monitoring wells south of Area 1. As described below, the Area 1 Barrier Wall was completed around Area 1 to control the off-Site migration of nickel-impacted groundwater. Groundwater quality in Area 1 has been monitored through MW-OS-3D, MW-OS-4S, MW-OS-4D, MW-OS-5D, MW-OS-6D, MW-OS7D, MW-OS-8D, MW-OS-9S, MW-OS-9D, MW-OS-10D, HA-MW-12, HA-15 and HA-16.

As proposed in the CA750 Report (Environ, October 28, 2004), groundwater samples were collected from off-Site monitoring wells to monitor the concentrations of nickel and chromium in off-Site groundwater. However, as described in a letter to USEPA dated April 13, 2005, monitoring wells MW-OS-9S, MW-OS-9D, and MW-OS-10D were abandoned in February 2005 as requested by the owner of the property where these wells were located. In addition, due to a labor dispute at the facility across the street from Area 1, monitoring wells MW-OS-5D, MW-OS-6D, MW-OS-7D, and MW-OS-8D could not be accessed from May 2005 to January 2006. During this period, groundwater samples were collected from on-Site monitoring wells to evaluate the effectiveness of the Area 1 Barrier Wall.

Analytical results from the on-Site and off-Site groundwater samples have been presented in Quarterly/Semi-Annual Progress Reports and are summarized in the Revised Groundwater Monitoring Plan (CRA, April 2008) (GMP). Nickel was detected in groundwater samples collected from off-Site monitoring wells south of Area 1; however, the concentrations were lower than the site-specific, risk-based criteria for the non-potable groundwater exposures that were reasonably expected for this area (i.e., construction worker ingestion of and dermal contact with groundwater). As discussed in the 2005 RFI Report and the 2005 Supplement to the RFI Report, groundwater in this area is not being used as a drinking water supply and all properties in this area are serviced by a municipal water supply.

The Area 1 Barrier Wall appears to have intercepted the groundwater flow south of Area 1 and limited off-site migration of nickel-impacted groundwater. Chromium has not been detected in off-Site groundwater samples at concentrations greater than generic screening criteria. There has been some variability in the concentrations of nickel in groundwater samples collected from immediately downgradient of Area 1 since the installation of the Area 1 Barrier Wall.

A Revised Groundwater Monitoring Plan (CRA, April 2008) defines ongoing monitoring requirements as part of the Operations, Maintenance, and Monitoring Plan (CRA, July 2007) at the Site. Results of the ongoing GMP sampling and additional characterization activities are discussed below in Section 3.

2.2 Historical Interim Measures

The southern portion of Area 1 contains the existing groundwater extraction and treatment system, which consists of a below grade perforated collection pipe (French drain) and aboveground treatment building. The French drain was installed in 1980/1981 and the alignment runs to the north of the Storm water Clarifier then doglegs to the south of the treatment building and continues for 400 feet parallel to Amrhein Road, ending approximately 80 feet from the eastern edge of Area 1. The collected groundwater was historically treated in the on-Site wastewater treatment plants. The collection/treatment system currently in operation collects groundwater impacted by historical chrome plating operations through the French drain. The current treatment system was constructed in 2000 prior to decommissioning and demolition of the on-Site wastewater treatment plant. The collected groundwater is treated by pH adjustment with sulfuric acid, followed by addition of sodium bisulfite, recycled solids, lime and polymer flocculent in subsequent tanks, the solids are settled in a clarifier, and the effluent passes through a sand filter prior to discharge. When the treatment system is operating, the water is treated continuously at an average rate of approximately 40 gallons per minute (gpm) and accumulated in a tank following clarification. The initially treated water is then polished through the sand filter in approximately 800-gallon batches and discharged to the Great Lakes Water Authority (GLWA), formerly known as City of Detroit Water and Sewerage Department (DWSD), sanitary sewer. Nickel and chromium are precipitated out as sludge and processed in a filter press. The non-hazardous filter cake is collected in a 20-cubic yard roll-off box and disposed of at a local landfill on an as necessary basis (approximately four times per year).

Early RFI data indicated that the French drain may not have been fully effective in cutting off the migration of nickel at the eastern edge of the trench. Therefore, a groundwater cut-off barrier wall (soil-bentonite and jet grout) was installed around Area 1 in 2004 to provide complete physical containment. The groundwater treatment system is currently operated approximately 5 days per week to maintain an inward gradient across the Area 1 Barrier wall and to control the off-Site migration of impacted groundwater.

2.3 Exposure Pathway/Clean-up Criteria Evaluation

Based on the data collected during historical Site characterization activities, exposure pathways were reviewed to identify potentially applicable Part 201 Generic Cleanup Criteria under MDEQ RRD Operational Memorandum No. 1, updated 12/30/2013.

Potentially applicable criteria are based on complete pathways and recognized receptors and are dependent on the current and future land-use of the subject properties. The entire Eckles Road Facility has, or will have, a Declaration of Restrictive Covenant (DRC) recorded with the Wayne County Register of Deeds limiting it to non-residential land uses and prohibiting the use of groundwater. Therefore, non-residential criteria are applicable for this property and the drinking water pathway is not complete (i.e., criteria protective of the drinking water pathway do not apply). In portions of the Facility where impacts may migrate across the Facility boundary, off-Site receptors and pathways are still considered. However, groundwater is not used for drinking water at the properties located downgradient (south/southeast) of Area 1 and the City of Livonia enacted an ordinance in 2009 establishing a Prohibition on Use of Groundwater.

The volatilization to indoor air pathway is considered not applicable at this time and the DRC will provide for soil vapor management should an owner want to build a structure on this Site; further, metals are not likely to volatilize and therefore indoor air inhalation criteria have not been established for chromium VI or nickel.

The nearest surface water body is Newburgh Lake, located approximately 1/3 mile to the south of the Site. Based on analytical results, which have defined plume boundaries to just south of Area 1, no impacts to surface water bodies have been identified. Furthermore, based on the low levels of impact, the current corrective measures, and the alternative corrective measures being proposed, it is unlikely that impacted groundwater will reach surface water at concentrations exceeding groundwater surface water interface (GSI) criteria. Therefore, the GSI pathway is not currently complete and is not expected to become a complete pathway.

3. Groundwater Monitoring

Extensive groundwater quality investigations have been completed in Area 1 as part of the RFI sampling program, Site characterization activities, and performance monitoring conducted as part of ISCR pilot study and full-scale injections. RFI groundwater sample results are provided in the RFI Report and Supplement to the RFI Report. Groundwater impacted by chromium and nickel has been delineated. Groundwater quality is currently monitored as described in the Revised Groundwater Monitoring Plan (CRA, April 2008).

3.1 Groundwater Monitoring Results

Annual groundwater monitoring activities were initiated in 2006 and were based on the results of the extensive groundwater monitoring that was conducted before and during the RFI, and the subsequent groundwater monitoring associated with the CA750 determination. These activities are also consistent with the historic, current, and future DRCs and City of Livonia Groundwater Use Prohibition which restrict groundwater use at the property as identified in the Corrective Measures Proposal (CMP) and Final Decision.

3.2 Area 1 Groundwater Sampling and Results

The Area 1 annual groundwater sampling was completed during December 2017 with additional pilot study and ISCR injection sampling completed throughout 2015, 2016, 2017, and January 2018. Analytical results from 2015 and prior sampling indicates the following:

- Neither total chromium or chromium VI have been detected above generic criteria in off-Site monitoring wells.
- Nickel has been detected at the property boundary and off-Site monitoring wells at concentrations greater than Part 201 Drinking Water Criteria (DWC) and is delineated by off-Site monitoring wells MW-OS-5D, MW-OS-6D, MW-OS-7D, and MW-OS-8D.
- Chromium VI and nickel have been delineated to the north, within the barrier wall, by monitoring wells MW-A1-4S/D, MW-38D-13 and MW-39D-13, MW-40D-13, and MW-A1-3S.
- Chromium VI and nickel concentrations significantly decreased following the expanded pilot study, full-scale, and targeted ISCR injections conducted in 2015, 2016, and 2017.

The Area 1 groundwater results from 2018 and recent prior years are summarized on Figure 3.

3.3 Area 1 Groundwater Treatment Plant Influent Results

The influent to the Area 1 GWTP had been sampled monthly and screened with field test kits to document overall trends within Area 1. Field screening results indicated continuing decreases in influent groundwater concentrations of chromium and nickel since construction of the GWTP in 1999. Beginning in 2017, GWTP influent samples were submitted for laboratory analysis of chromium and nickel to accurately document concentrations and continued reductions. The current GLWA Special Discharge Permit effluent limits for the GWTP are 3.98 mg/L for nickel and 2.77 mg/L for total chromium. Recent GWTP influent concentrations in 2018 have been less than the effluent limits contained in the GLWA Special Discharge Permit. The decreases in GWTP influent concentrations provide additional evidence that the pilot study, targeted, and full-scale ISCR injections were effective at reducing nickel and chromium concentrations in Area 1 groundwater and that continued operation of the GWTP may only be necessary to prevent flooding within the area contained by the Area 1 Barrier Wall. A summary of GWTP influent sample results is provided in Appendix A.

4. Hydrogeologic Conceptual Site Model

The hydrogeologic conceptual site model (CSM) was developed during the RFI to integrate information from historic and current investigations and identify potential exposure risks. This CSM summarizes the Site geology and hydrogeology.

4.1 Geology

Numerous soil borings and monitoring wells have been completed at the Site. A summary of historical soil borings and monitoring wells are presented in Revision 2 of the Current Condition Report (CRA, June 2002) (CCR). Additional soil borings and monitoring wells were completed during the RFI and are presented in the RFI Report (CRA, March 2005) and Supplement to the RFI Report (CRA, April 2005). Geologic data from these soil borings and monitoring wells were used to determine the Site overburden geology and hydrogeology.

The subsurface geology in the vicinity of the Site consists of approximately 145 feet of overburden overlying the Antrim Shale bedrock. The Antrim Shale is comprised of hard, dark gray to black or brown, pyritiferous shale that contains abundant silt, making it a confining layer. The shale is generally too impermeable to be an aquifer and the abundance of pyrite restricts the water quality for use as a potable water supply. The shale is located at approximately 145 feet below ground surface (bgs).

The surficial glacial deposits in the area of the Site generally consist of a fine to coarse sand of approximately 22 feet to 28 feet in thickness underlain by a continuous clay layer. The sand unit is comprised of a surficial layer of fill sand that generally varies from 2 to 6 feet in thickness. Below the surficial fill material, the native sand unit is typically poorly graded and interbedded with lenses of coarse sand and gravel to a depth of 22 to 28 feet below ground surface (bgs). The clay layer underlying the glacial sand deposit is approximately 50 feet thick and is a laterally extensive unit that is present beneath the entire Site and throughout the area. The clay is underlain by interbedded gravel, boulders, sands, and clays to approximately 145 feet bgs, to the top of the shale bedrock.

4.2 Hydrogeology

Groundwater exists at the Site at a depth of approximately 5 to 12 feet bgs within the fine to coarse sand, which underlies the Site and generally appears to flow in a southeasterly direction.

Groundwater within the Area 1 Barrier Wall generally appears to flow in a southerly direction towards the French Drain Collection System. Groundwater investigations indicate shallow groundwater at the Site has an approximate saturated thickness of 15 feet. Groundwater in the vicinity of the Site is not used as a drinking water supply.

Slug tests were performed in ten on-Site wells as part of the RFI. The calculated hydraulic conductivity for the surficial water bearing zone is 7.4 x 10-3 centimeters per second (cm/sec). Laboratory permeability tests performed on four soil samples as part of the RFI indicate that the vertical permeability of the continuous clay beneath the Site is 1.55 x 10-8 cm/sec. Based on information obtained from the RFI, the clay aquitard represents a barrier to vertical migration of groundwater.

4.3 Hydrology

No surface water bodies exist at the Site. The nearest surface water bodies are Newburgh Lake located approximately 1/3 mile south of the Site, and the Middle River Rouge located approximately 1/4 mile southwest of the Site.

4.4 Groundwater Use

GLWA provides potable water supply for the Site and surrounding areas from the Springwells Plant located in Dearborn, Michigan. The water source for the Springwells Plant is the Detroit River. Groundwater at the Site is not used as a potable water supply and groundwater use has been, or will be, restricted at the Site. All properties located within approximately ¼ mile south and southeast of Area 1 (downgradient of Area 1) are serviced by a municipal water supply and there are no known current or historical uses of groundwater located south or southeast of Area 1. Current and historical uses of shallow groundwater in the residential area southeast of the Site were also evaluated as part of the RFI activities. All properties in the residential area southeast of the Site are serviced by a municipal water supply. The City of Livonia enacted a prohibition on the use of groundwater during 2009. Details of the ordinance are presented in the 2009 Annual Report (CRA, January 2010).

Based on documents reviewed, one water supply well historically existed on Site. The water supply well was installed in 1954 and was located approximately 135 feet east of Eckles Road on the west side of the Site. The well was used for the lawn sprinkler system at the Site. This well was 145 feet deep, which is well below the impacted surficial water bearing zone that extends to a maximum depth of 28 feet bgs. The screened interval is unknown but is expected to be below the clay layer that extends to approximately 80 feet bgs. No other information is available for this well however, no other water supply wells have been in use on Site since then.

5. Laboratory Treatability Studies and Modelling

A laboratory treatability study was performed in 2013 at the CRA laboratory in Niagara Falls, New York to assess the effectiveness of a permeable reactive gate containing ZVI, identify the optimum media matrix for the barrier, and determine the minimum hydraulic retention time in the barrier required to treat the groundwater. A memorandum describing the laboratory treatability study is presented in Appendix B. The following sections provide brief summaries and recommendations that resulted from the study and modeling.

5.1 Laboratory Treatability Study

The laboratory treatability study was performed using 20 gallons of groundwater collected from well MW-22-2D, which was located near a previously proposed PRG location, 20 gallons of groundwater collected from well OW-24, which was a high chromium VI well, and 20 gallons of groundwater collected from well HA-16, which is a high nickel well. The samples were collected prior to the expanded pilot study, full-scale, and targeted injections, and are representative of worst case scenarios of groundwater migrating through the proposed PRG. The laboratory treatability study consisted, columns tests with identical glass columns packed with 10 percent ZVI and 90 percent sand mixture. Two of the columns that did not achieve treatment goals with 10 percent ZVI were repacked with 20 percent ZVI and 80 percent sand mixture.

Summary

- At a hydraulic residence time (HRT) of 30 hours, chromium and nickel were significantly reduced in all three columns.
- For samples containing high initial concentrations of chromium or nickel (greater than 100,000 ug/L), a column packed with 10 percent ZVI was unable to reduce concentrations to below the target level.
- A column packed with 20 percent ZVI and a 30-hour HRT was required to reduce metals concentrations in these samples to below the 100-ug/L target level.
- When chromium and nickel concentrations in groundwater were lower (less than 100,000 ug/L), 10 percent ZVI and a 30-hour HRT was sufficient to reduce metals concentrations to below the 100-ug/L target level.

Recommendations

Based on the laboratory treatability study results, a 20 percent ZVI and 80 percent sand mixture with a HRT of 30 hours is recommended for the PRG.

5.2 Groundwater Flow Model

GHD develop a Groundwater Flow Model (Groundwater Flow Model Report, February 2017) to represent the existing hydrologic, geologic, and hydrogeologic conditions at the Site and surround area. The groundwater flow model was calibrated under steady-state conditions to provide a reasonable match to groundwater elevations and groundwater flow directions observed in the Site prior to installation of the Area 1 Barrier Wall. The groundwater flow model then was checked under transient conditions. Comparisons of transient groundwater displacement during the GWTP shutdown is a rigorous test of hydraulic conductivity distribution in Area 1. GHD compared simulated drawdown under pumping conditions to the numerical reflection of rebound. The calibrated groundwater flow model and the secondary transient check indicate that the model is appropriate for use for subsequent metals transport simulations as described in Section 5.3. Additional details are provided in the Groundwater Flow Model Report.

5.3 Permeable Reactive Gate Evaluation

GHD evaluated various sizes and locations of potential permeable reactive gates (PRGs) to be installed at the Site as described in the Permeable Reactive Gate Evaluation – Model Development and Application (GHD, September 2017). A proposed PRG that extends approximately 15 feet below ground surface (bgs) was determined to be preferable to a PRG that extends the full depth of the water bearing unit to the underlying clay because it simplifies construction, improves delivery of ZVI media throughout the full depth of the PRG and reduces associated costs. It also takes into account that higher concentrations of chromium VI and nickel were identified in the deeper portion of the saturated thickness of the water bearing unit in the center and south-central portion of Area 1, so it would be preferable to treat shallower groundwater with lower concentrations of chromium or nickel as it exits Area 1.

GHD evaluated the risk of mineral fouling of the proposed PRG. Based on a review of literature and groundwater sample results, the potential rate of porosity loss was not expected to significantly affect the PRG and buffering was not anticipated to be necessary. Additional information is presented in a memorandum provided in Appendix C.

5.4 Laboratory Study and Modeling Summary

Based on the Laboratory Treatability Study and PRG Evaluation using the Groundwater Model, key minimum design features of the proposed PRG system were determined to include:

- The PRG will be installed within the existing 2.5-foot thick barrier wall along the eastern section
- The PRG will be installed to a depth of approximately 15 feet bgs
- The PRG will be constructed of granular ZVI mixed with sands similar to native sands
- Following construction of the PRG, the GWTP will be shut-down
- Groundwater moving through the PRG will have a HRT of at least 30 hours for treatment to be effective
- Groundwater does not daylight/flood in Area 1 or downgradient of the Area 1 barrier wall following shutdown of the GWTP

Based on the evaluation, an off-set southeastern PRG alternative satisfied the criteria for successful gate designs when the PRG length was equal to or greater than 180 feet long as detailed in the *Permeable Reactive Gate Evaluation, Model Development and Application* (GHD, September 2017). The proposed location is located 50 feet north of the southeastern corner of the Barrier Wall and extends for 180 feet to the north. The proposed location and depth of the PRG is presented on Figure 4. The proposed PRG should be implemented as described below.

6. Permeable Reactive Gate Implementation

One PRG is planned to be installed at the offset southeastern location within the existing Area 1 Barrier Wall. The portion of the existing Area 1 Barrier Wall and surrounding soil potentially containing residual bentonite will be removed prior to installation of the PRG. The PRG will consist of one trench approximately 15 feet deep (bottom elevation of approximately 691 feet above mean sea level (AMSL) and 4 feet wide. Based on the results of the treatability study and modeling activities described above, it was recommended that the PRG be 2 feet wide, however, to ensure bentonite associated with the Area 1 Barrier Wall is adequately removed, a 4-foot wide excavation will be centered on the 2-foot wide Area 1 Barrier Wall. To simplify backfilling activities and provide a higher level of certainty of the effectiveness, the ZVI sand mixture will be installed throughout the 4 foot width of the excavation. A benefit of the additional width of installed PRG is that it will significantly increase the HRT to greater than the design time of 30 hours. The trench will be approximately 180 feet long oriented north to south as shown on Figures 4 and 5. The trench will be filled with a mixture of approximately 20 percent ZVI to 80 percent sand by weight. As identified in the laboratory treatability study, a 10 percent ZVI to sand ratio was shown to be adequate for concentrations of chromium VI and nickel in the vicinity of the PRG after the ISCR injections, but due to potential difficulties associated with installation of a precise mix of 10 percent ZVI to 90 percent sand in the field (not laboratory conditions), and a conservative approach to ensure adequate treatment, the field goal will be a minimum mix ratio of 20 percent ZVI to 80 percent sand.

Prior to installation of the PRG, the existing slab, clay cap, and Area 1 Barrier Wall (soil-bentonite wall) will be removed via saw-cutting from the excavation area and any buffer area required and the area will be excavated utilizing a bio-polymer slurry (See Appendix D for additional information), trench boxes, a one-pass trencher, or other means to stabilize the sidewalls of the trench. A 4-foot wide excavation centered on the existing Area 1 Barrier Wall and cap or until native sands are identified, will be removed to ensure permeability adjacent to the PRG is not restricted by remaining barrier wall materials. Bids and alternate proposals will be solicited from contractors and the recommended approach will be reviewed with USEPA prior to implementation. The excavated clay from the existing cap or stockpiled soil-bentonite from the removed Area 1 Barrier Wall, if usable, will be installed in the top 3 feet of the trench to minimize surface water infiltrating/affecting the PRG. If some or all of this material is not re-useable as backfill or for other purposes on-site, it will be properly characterized and disposed off-Site. Sheet-pile or similar supports will be installed at the north and south ends of the PRG trench to a depth of approximately 20 feet bgs to isolate the adjacent Area 1 Barrier Wall from the PRG trench and the sheet-pile will remain at each end of the PRG following construction to prevent short-circuiting at the PRG – Area 1 Barrier Wall interface. The ZVI sand mixture for the PRG will be placed into the trench in an appropriate manner, dependent on the method of excavation/backfilling that is selected. The excavated clay from the existing cap or excavated and stockpiled soil-bentonite from the Area 1 Barrier Wall, if usable, will be installed from 0 to 3 feet bgs on top of the PRG to minimize surface water from infiltrating/affecting the PRG. Any groundwater encountered during installation of the PRG will be applied to the ground surface west of the proposed PRG (within the footprint of the former press pit basement), or managed in the GWTP, if required.

7. Performance Monitoring Plan

7.1 PRG Groundwater Monitoring

In order to monitor the effectiveness of the PRG, groundwater performance monitoring will consist of collection of groundwater samples from eight existing monitoring wells and four new monitoring wells located within the vicinity of the PRG as shown on Figure 4. Additional sampling activities to monitor groundwater conditions within Area 1 will be performed outside of the PRG performance monitoring activities.

The monitoring wells will be installed and sampled prior to installation of the PRG and then tested quarterly for 1 year for total and dissolved metals (chromium, iron, manganese, nickel, and sodium), alkalinity and other total dissolved solids (TDS). Alkalinity testing will provide groundwater quality data to allow for evaluation of precipitation of carbonate minerals in the PRG. TDS analysis will provide a general water-quality parameter also to be used for evaluation of precipitation within the PRG. As identified in the Interstate Technology & Regulatory Council (ITRC) June 2011 document titled Permeable Reactive Barrier: Technology Update "*There is empirical evidence from longer-term column tests that the mass flux of dissolved species through the PRB [Permeable Reactive Barrier] is more important than their absolute concentration in the groundwater (Gavaskar et al. 2002; Parbs, Ebert, and Dahmke 2007). In other words, a site with higher TDS in the groundwater but lower groundwater flow velocity could present the same potential for precipitation (and loss of performance) as a site with low TDS and higher groundwater velocity. Therefore, both the level of TDS in the groundwater and the groundwater velocity at a site are factors in determining expected level of precipitation in a PRB.*"

Low-Flow sampling techniques will be used to collect the groundwater samples. Each monitoring well will be purged at approximately 100-200 milliliters/minute in accordance with low-flow protocols. Field analyses of the purge water will consist of pH, conductivity, temperature, turbidity, dissolved oxygen, and oxidation reduction potential (ORP). These field parameters will be monitored during purging to ensure stabilization of the groundwater within each monitoring well prior to sampling. Upon obtaining stabilization, the groundwater samples will be collected. After 1 year of monitoring, sampling frequency will be re-evaluated and other long-term sampling techniques will be considered including no purge techniques such as passive diffusion bags or HydraSleeves.

The monitoring wells identified above, along with up to 20 additional existing monitoring wells, will also be used for hydraulic evaluations to verify that groundwater is flowing towards and through the PRG in order confirm the ability to shutdown the GWTP. Static water levels will be measured from up to 28 monitoring wells the week prior to, and up to two times during installation of the PRG, depending on the duration of installation activities. Monitoring wells proposed for groundwater elevation monitoring are presented on Figure 4. Groundwater elevations and flow directions will continue to be monitored every two weeks for a period of three months following shutdown of the GWTP, then monthly to confirm significant mounding or flooding does not occur within Area 1. Measuring the groundwater potentiometric surface will provide information to evaluate changes in horizontal and vertical hydraulic gradients, direction of groundwater flow, and the HRT in the PRG. The GWTP may be operated intermittently following installation of the PRG to manage groundwater elevations along the southern portion of the Area 1 Barrier Wall, until such a time that groundwater flow reaches the a new equilibrium.

The groundwater flow direction and hydraulic gradient data along with the alkalinity, TDS and metals data will provide the necessary data to evaluate PRG performance. Following the first year, the sampling protocols and hydraulic measurements will be re-evaluated and any appropriate changes will be recommended to USEPA for approval before altering the monitoring plan.

7.2 Reporting

A PRG Implementation summary report will be prepared following installation of the PRG to document the activities completed and any recommendations. The report will include, at a minimum, as-built drawings showing the location of the PRG and details of the construction materials, details for performance monitoring wells that were installed, results of baseline sampling, results of groundwater elevation monitoring, and a written summary of activities completed.

7.3 Contingency Planning

The PRG has been designed using conservative assumptions, and proposed along the eastern alignment of the Area 1 Barrier Wall where elevated concentrations of nickel and chromium are not present in groundwater, however, unforeseen conditions may be encountered that could require modification to the proposed scope of work identified in this Work Plan. Some potential conditions that would require adjustments in the field, continued operation of the GWTP, or supplemental PRG installation activities include the following:

- Bentonite from the existing Area 1 Barrier Wall may extend more than the 4-foot wide excavation proposed for the PRG which could require additional removal of soils and backfilling with PRG material
- Unexpected voids/former infrastructure may exist in the area of excavation which could require additional PRG material
- Measured hydraulic gradients across the PRG may indicate inadequate flow through the PRG
- Groundwater mounding/flooding could occur within Area 1 following shutdown of the GWTP which would indicate an inadequate volume of groundwater is flowing through the PRG

Significant conditions encountered in the field, or identified as a result of the performance monitoring activities, along with proposed corrective actions, will be communicated to USEPA.

8. Schedule

The following general sequence of events and target dates are anticipated for implementation of the proposed full scale ISCR activities:

Task:	*Target Date:*
Meet with USEPA to review this Work Plan	May 2018
Begin Contractor procurement and order ZVI (Initiated upon preliminary USEPA/MDEQ approval May 2018)	June/July 2018
Install New Monitoring Wells and complete baseline monitoring (Dependent upon receipt of USEPA approval)	July/August 2018
Remove existing section of Area 1 Barrier wall and Install PRG (Dependent upon receipt of USEPA/MDEQ approvals)	September/October 2018
Initiate Performance Monitoring	November 2018
Reduce GWTP Operation	October/November 2018
PRG Implementation Summary Report	February 2019
3 Month Post-Installation Monitoring	February 2019

9. References

"Current Conditions Report 13000 Eckles Road Livonia, Michigan";
Conestoga-Rovers & Associates; June 21, 2002.

"RCRA Facility Investigation Work Plan 13000 Eckles Road Livonia, Michigan" Conestoga-Rovers & Associates; September 2002.

"Remedial Technologies Assessment Area 1 13000 Eckles Road, Livonia Michigan" Conestoga-Rovers & Associates; January 2003.

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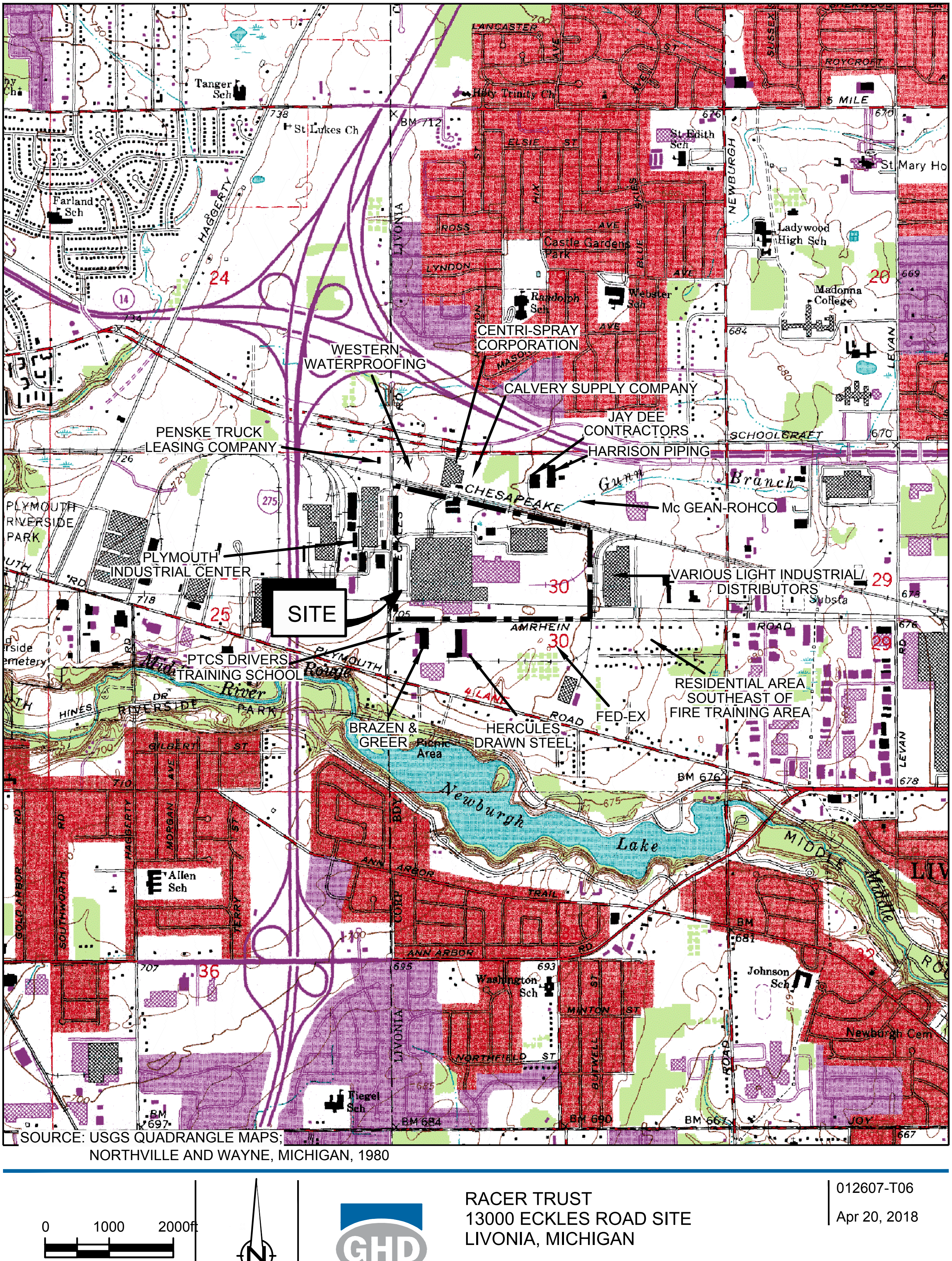

RACER TRUST
13000 ECKLES ROAD SITE
LIVONIA, MICHIGAN

012607-T06
Apr 20, 2018

SITE LOCATION

FIGURE 1

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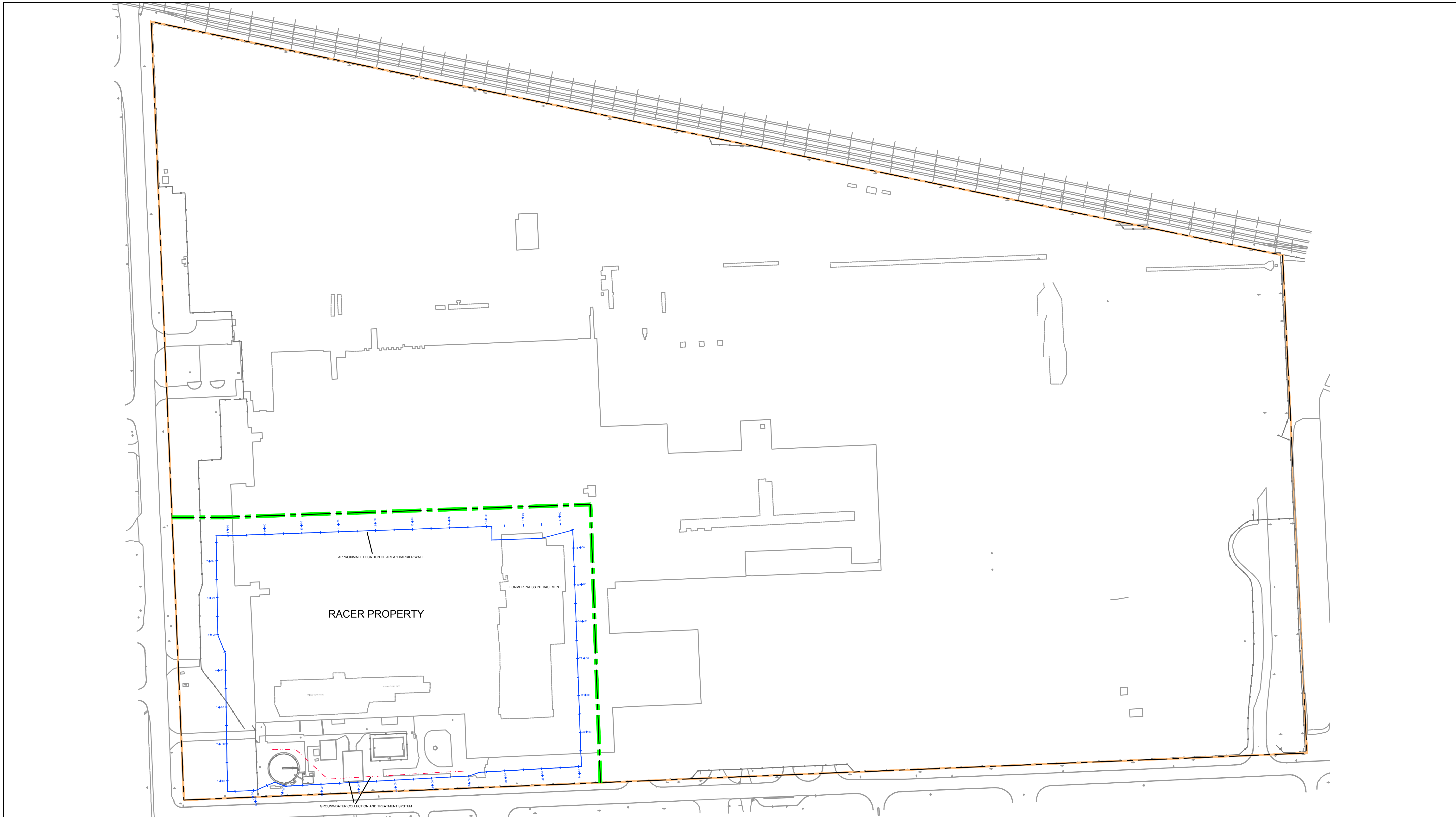


0 125 250ft

N

LEGEND

SITE BOUNDARY

RACER PROPOERTY BOUNDARY

FENCE

CONCRETE

AREA BARRIER WALL

GHD

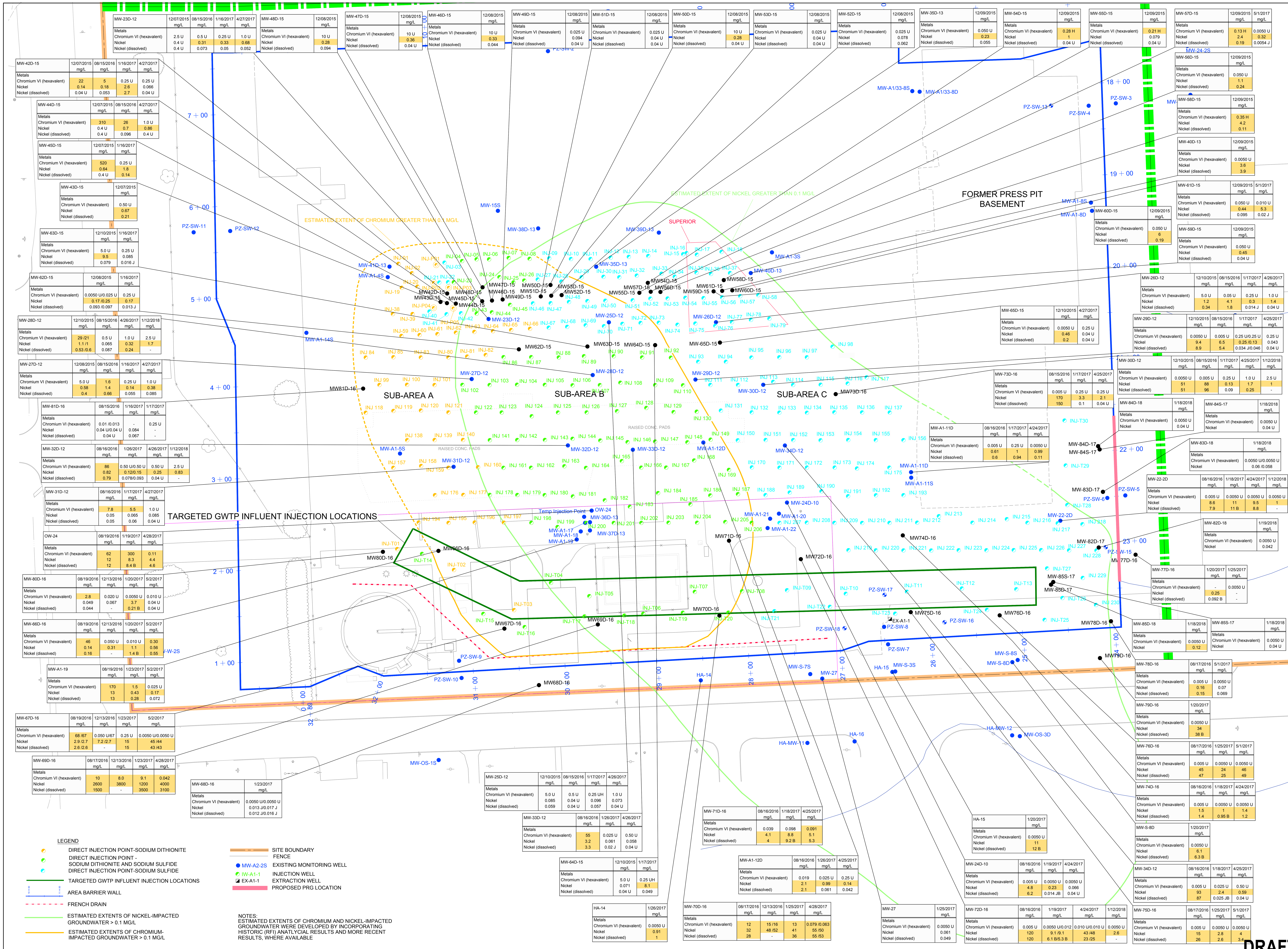
RACER TRUST
13000 ECKLES ROAD SITE
LIVONIA, MICHIGAN

SITE PLAN

012607-T06
Apr 20, 2018

FIGURE 2

CAD File: I:\drawings\12000s\12607\12607-REPORTS\012607-T06(074)\012607-T06(074)GN\012607-T06(074)GN-DE005.dwg



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Parameter	Non-Residential Health-Based Drinking Water Criteria (mg/L)	Site-Specific Risk-Based Groundwater Criteria (mg/L)
Chromium	0.1	28
Chromium VI (hexavalent)	0.1	28
Nickel	0.1	2400

Client
RACER TRUST

Project
13000 ECKLES ROAD SITE
LIVONIA, MICHIGAN

No.	Issue	Drawn	Approved	Date

Drawn DRAWN — Designer
Drafting Check — Design Check
Project Manager CM — Date Apr 24, 2018
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Original Size ANSI D — Bar is one inch on original size drawing

Project No. 012607-T06

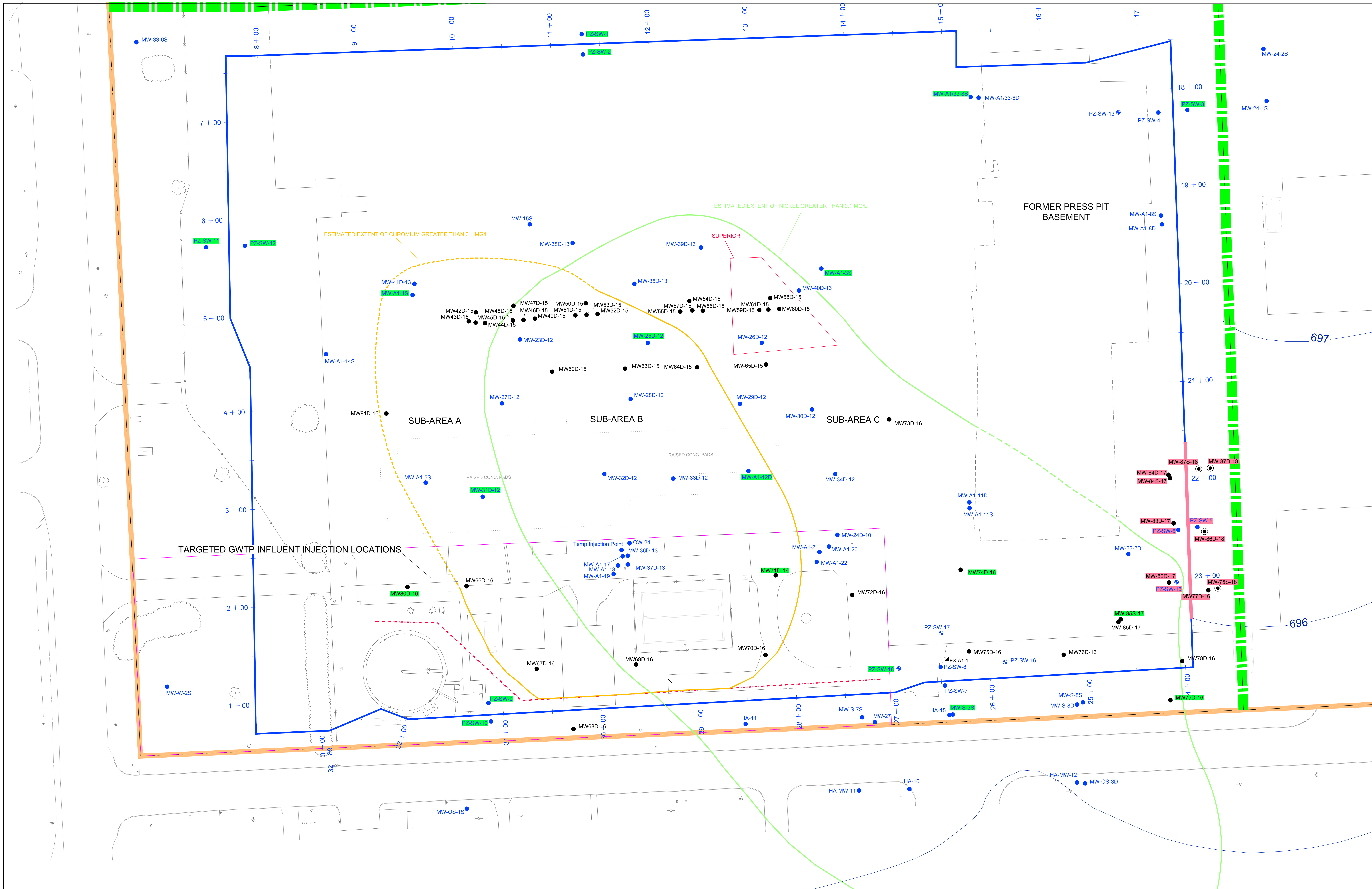
Title
AREA 1 ISCR INJECTION LOCATIONS & GROUNDWATER SAMPLE RESULTS

Sheet No.
FIGURE 3

DRAFT

Sheet 1 of 1

Plot Date: 24 April 2018 - 8:33 PM Plotted By: Chris Meincke CAD File: I:\drawings\12000s\12607\12607-REPORTS\012607-T06(074)\012607-T06(074)GN\012607-T06(074)GN-DE003.dwg



LEGEND

AREA BARRIER WALL

FRENCH DRAIN

ESTIMATED EXTENTS OF NICKEL-IMPACTED GROUNDWATER > 0.1 MG/L PRE-ISCR INJECTIONS

ESTIMATED EXTENTS OF CHROMIUM-IMPACTED GROUNDWATER > 0.1 MG/L PRE-ISCR INJECTIONS

SITE BOUNDARY

FENCE

MW-A2-2S EXISTING MONITORING WELL

MW-75S-18 PROPOSED WELL LOCATION

EX-A1-1 EXTRACTION WELL

PROPOSED PRG LOCATION

PRG PERFORMANCE MONITORING LOCATION

GW ELEVATION MONITORING LOCATION

NOTES:
ESTIMATED EXTENTS OF CHROMIUM AND NICKEL-IMPACTED GROUNDWATER WERE DEVELOPED BY INCORPORATING HISTORIC (RFI) ANATLYCIAL RESULTS AND MORE RECENT RESULTS, WHERE AVAILABLE

DRAFT

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Project

13000 ECKLES ROAD SITE LIVONIA, MICHIGAN

No.	Issue	Drawn	Approved	Date
-	-	-	-	-

Drawn DRAWN	Designer
Drafting Check	Design Check
Project Manager CM	Date Apr 24, 2018
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Original Size ANSI D	Bar is one inch on original size drawing 0 1"

Project No. 012607-T06

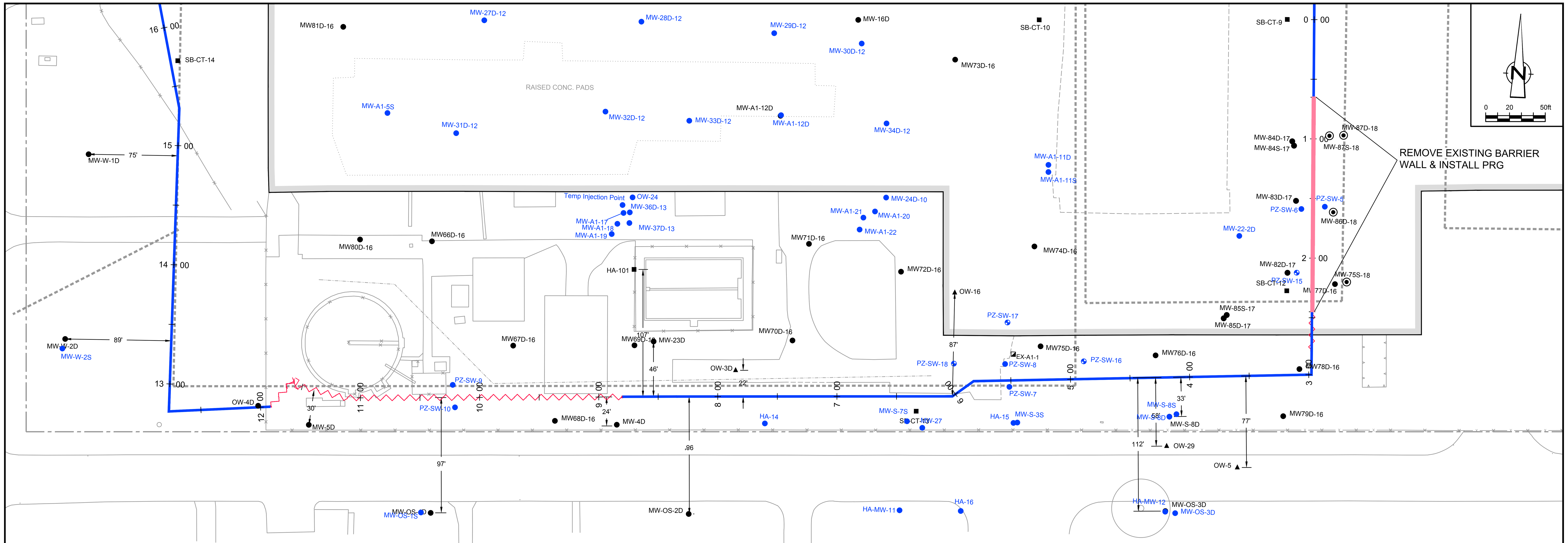
Title

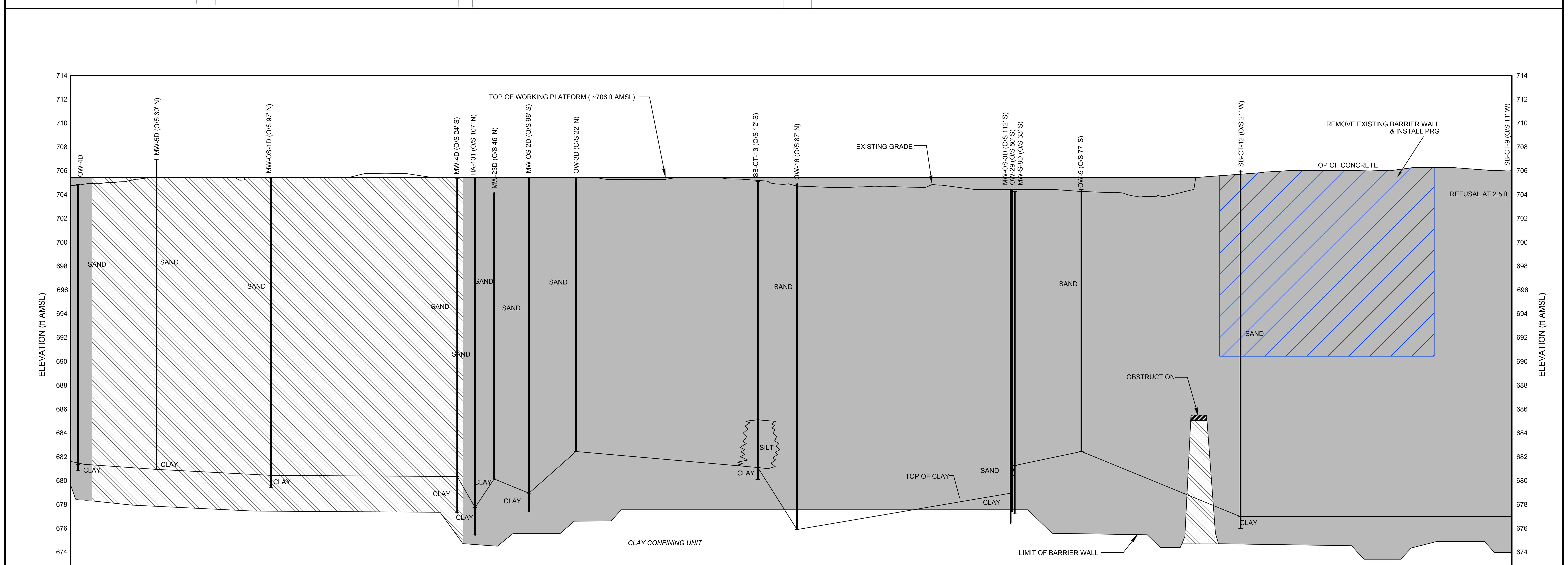
PROPOSED AREA 1 PRG LOCATION PERFORMANCE MONITORING LOCATIONS

Sheet No.

FIGURE 4

Sheet 1 of 1





CHAINAGE	GROUND	CLAY
12+01.9	705.4	681.9
12+00	705.4	
11+50	705.9	
11+39.7	705.8	682.5
11+00	706.0	
10+50	706.0	
10+41	706.0	681.0
10+00	706.0	
9+50	706.3	
9+00	706.0	
8+84.7	706.0	680.9
8+69.7	706.0	678.3
8+53.7	706.0	680.7
8+50	706.0	
8+24.5	706.0	679.5
8+00	706.0	
7+85	706.0	683.0
7+50	705.8	
7+00	706.0	
6+50	705.9	
6+47.8	705.9	681.7
6+03.2	705.5	676.5
6+00	705.3	
5+50	705.2	
5+00	705.2	
4+50	705.0	
4+20	705.0	679.5
4+18.8	705.0	681.0
4+17	705.0	681.8
4+00	705.0	
3+61	704.9	683.0
3+50	704.8	
3+00	704.4	
2+50	706.1	
2+27.5	706.3	677.53
2+00	706.5	
1+50	706.6	
1+00	706.6	
0+50	706.8	
0+00	706.5	

Nº	Revision	Date	Initial

LEGEND

- SITE BOUNDARY
- BARRIER WALL ALIGNMENT
- JET GROUTED BARRIER WALL
- CONCRETE SLAB
- FRENCH DRAIN COLLECTION SYSTEM
- FENCE
- AOI AREA
- LOCATION INDICATING DEPTH TO CLAY ALONG BARRIER WALL
- SOIL-BENTONITE BARRIER WALL
- JET GROUT BARRIER WALL
- EXISTING MONITORING WELL LOCATION
- EXTRACTION WELL

KEY MAP

SCALE: 1"=700'

SCALE VERIFICATION

THIS BAR MEASURES 1" ON ORIGINAL. ADJUST SCALE ACCORDINGLY.

Approved

DRAWING STATUS

Status	Date	Initial
ISSUED TO CLIENT FOR REVIEW	FEB/2018	C.M.

PROPOSED PRG LOCATION
AREA 1 BARRIER WALL CROSS SECTION

PERMEABLE REACTIVE GATE WORK PLAN

13000 ECKLES ROAD SITE
LIVONIA, MICHIGAN

GHD

Source Reference:

Project Manager:	Reviewed By:	Date:	
C.M.	T.K.	APRIL 2018	
Scale: HORZ. 1"=50' VERT. 1"=5'	Project Nº: 012607-T06	Report Nº: 074	Drawing Nº: FIGURE 5

012607-T06(074)GN-DE002 APR 24, 2018

Appendix A
Summary of GWTP Influent Sample Results

Table A.1

Analytical Results of GWTP Influent Samples
Eckles Road Site
Livonia, Michigan

Sample Location:		**GLWA**	**GWTP Influent**	**GWTP Influent**	**GWTP Influent**	**GWTP Influent**	**GWTP Influent**	**GWTP Influent**
Sample Identification:		**Special Discharge Permit**	**WT-012607-122116-EE-002**	**WT-012607-011717-EE-002**	**WT-012607-021517-EE-001**	**WT-012607-030817-EE-002**	**WT-012607-041917-EE-002**	**WT-012607-052417-EE-002**
Sample Date:		**Effluent Limits**	12/21/2016	1/17/2017	2/15/2017	3/8/2017	4/19/2017	5/24/2017
Sample Type:								
Parameters	**Units**							
Metals								
Chromium	mg/L	2.77	5.40	4.80	5.40	5.10	4.40	3.50
Chromium VI (hexavalent)	mg/L		5.20	--	4.40	4.20	3.80	3.30
Nickel	mg/L	3.98	2.90	3.30	3.60	3.90	2.90	2.70

Notes:
U - Not detected at the associated reporting limit.
H - Sample was prepped or analyzed beyond the specified holding time.
"--" - Parameter was not analyzed for in specified sample

Table A.1

Analytical Results of GWTP Influent Samples
Eckles Road Site
Livonia, Michigan

Sample Location:		**GWTP Influent**	**GWTP Influent**	**GWTP Influent**	**GWTP Influent**	**GWTP Influent**	**GWTP Influent**	**GWTP Influent**
Sample Identification:		**WT-012607-062817-EE-002**	**WT-012607-071217-EE-002**	**WT-012607-080217-EE-002**	**WT-012607-090617-EE-002**	**WT-012607-101117-EE-002**	**WT-012607-111517-EE-002**	**WT-012607-120617-EE-002**
Sample Date:		6/28/2017	7/12/2017	8/2/2017	9/6/2017	10/11/2017	11/15/2017	12/6/2017
Sample Type:								
Parameters	**Units**							
Metals								
Chromium	mg/L	3.50	4.00	3.10	2.80	3.30	4.50	4.00
Chromium VI (hexavalent)	mg/L	2.50	0.0050 U	2.10	2.7 H	--	4.10	2.80
Nickel	mg/L	3.00	3.00	2.90	2.60	3.40	2.80	2.30

Table A.1

Analytical Results of GWTP Influent Samples
Eckles Road Site
Livonia, Michigan

Sample Location:		**GWTP Influent**	**GWTP Influent**	**GWTP Influent**	**GWTP Influent**	**GWTP Influent**	**GWTP Influent**	**GWTP Influent**	**GWTP Influent**
Sample Identification:		**WT-012607-011018**	**WT-012607-012418-EE-002**	**WT-012607-013118-EE-002**	**WT-012607A-020718-EE-002**	**WT-012607-021418-EE-002**	**WT-012607-022818-EE-002**	**WT-012607-030718-EE-002**	**WT-012607-031418-EE-002**
Sample Date:		1/10/2018	1/24/2018	1/31/2018	2/7/2018	2/14/2018	2/28/2018	3/7/2018	3/14/2018
Sample Type:									
Parameters	**Units**								
Metals									
Chromium	mg/L	1.80	2.80	2.30	2.60	1.60	0.38	2.20	2.60
Chromium VI (hexavalent)	mg/L	1.10	2.40	2.30	2.40	--	0.30	0.038	2.4
Nickel	mg/L	1.20	3.00	2.70	2.90	2.20	2.50	2.80	2.60

Table A.1

Analytical Results of GWTP Influent Samples
Eckles Road Site
Livonia, Michigan

Sample Location:		**GWTP Influent**	**GWTP Influent**	**GWTP Influent**	**GWTP Influent**	**GWTP Influent**
Sample Identification:		**WT-012607-032118-EE-102**	**WT-012607-032818-EE-002**	**WT-012607-040418-EE-002**	**WT-012607-041118-EE-002**	**WT-012607-041818-EE-002**
Sample Date:		3/21/2018	3/28/2018	4/4/2018	4/11/2018	4/18/2018
Sample Type:						
Parameters	**Units**					
Metals						
Chromium	mg/L	2.60	2.40	2.10	2.60	1.10
Chromium VI (hexavalent)	mg/L	2.10	2.10	1.90	1.70	0.76
Nickel	mg/L	2.40	2.50	2.40	1.80	1.00

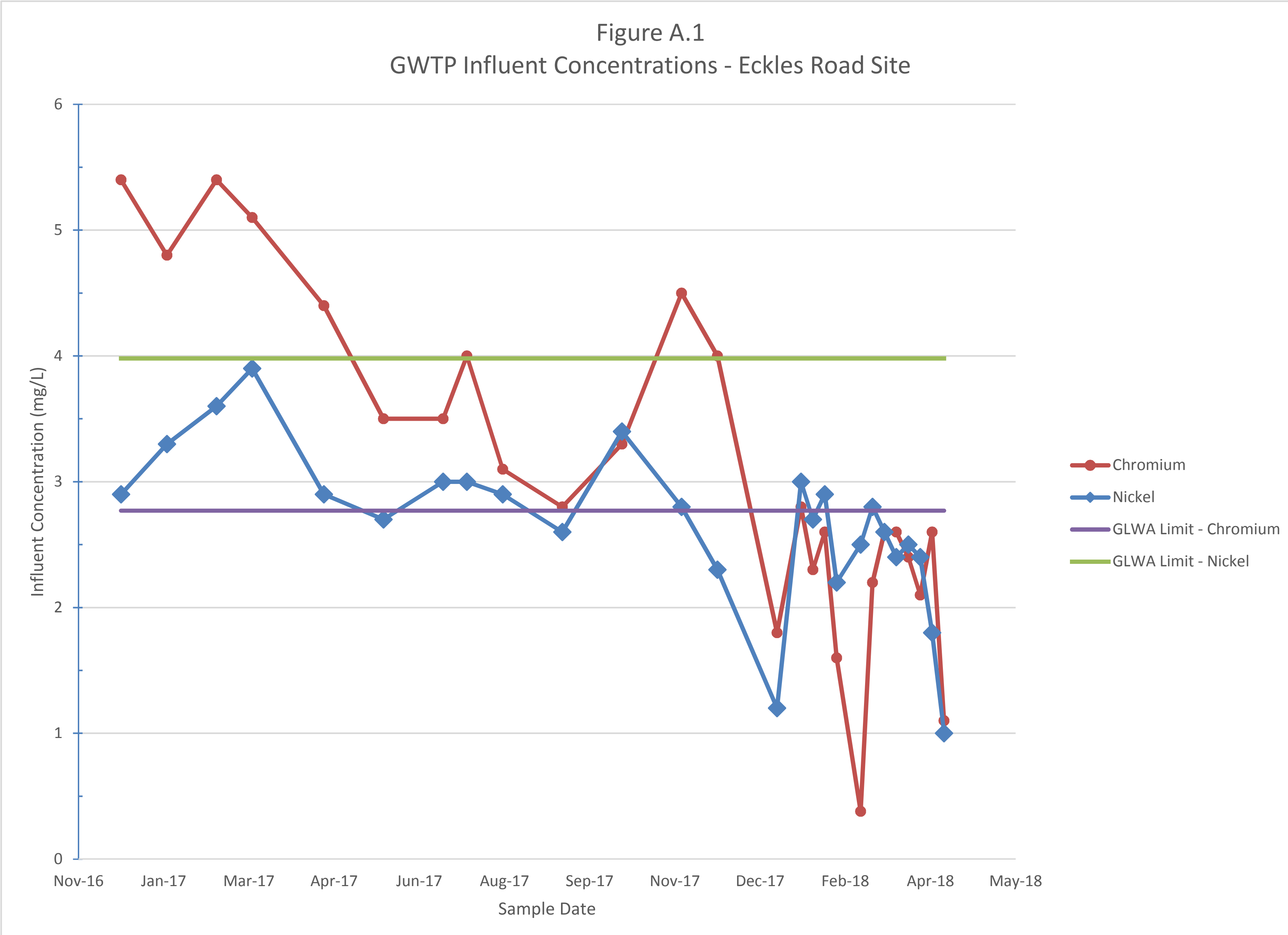


Figure A.1
GWTP Influent Concentrations - Eckles Road Site
Influent Concentration (mg/L)
0
1
2
3
4
5
6
Nov-16
Jan-17
Mar-17
Apr-17
Jun-17
Aug-17
Sep-17
Nov-17
Dec-17
Feb-18
Apr-18
May-18
Sample Date
Chromium
Nickel
GLWA Limit - Chromium
GLWA Limit - Nickel

Appendix B
Memorandum – ZVI PRB Treatability Study

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www.CRAworld.com

DRAFT MEMORANDUM

TO:	Chris Meincke	REF. NO.:	012607
FROM:	Alan Weston/Sophia Dore/Christa Nunn/adh/6	DATE:	January 24, 2014
RE:	**Zero Valent Iron Permeable Reactive Barrier Treatability Study Area 1 – Former Plating Area, 13000 Eckles Road Site, Livonia, Michigan**		

Introduction

Chromium and nickel from former plating operations are present in groundwater at Area 1 – the Former Plating Area at the 13000 Eckles Road Site, Livonia, Michigan (Site). The on-Site areas with groundwater that contains chromium and nickel are currently enclosed by a soil-bentonite barrier wall. Groundwater from within the barrier wall is extracted and treated on Site.

The Conestoga-Rovers & Associates (CRA) Innovative Technology Group (ITG) performed a remedial technology assessment to assess treatment options for in situ treatment of the groundwater. The most promising technology was the installation of a zero valent iron (ZVI) permeable reactive barrier (PRB) gate in the barrier wall to treat groundwater as it flowed from the area. The goal of the PRB would be to reduce concentrations of chromium and nickel to below 100 micrograms per liter (μg/L). A laboratory treatability study was performed to test potential PRB matrices and to confirm that ZVI would be effective. This memo contains the results from the treatability study.

Permeable Reactive Barrier

A PRB is a passive treatment that relies on the natural flow of groundwater to bring contaminants to the reactive media. It is a permanent structure, rarely relocated or modified. The barrier serves as a reactive zone to intercept and treat contaminated groundwater. Physical, chemical, and/or biological processes can be used as removal mechanisms for contaminants. When the contaminants make contact with the reactive media, chemical reactions take place to degrade or alter the contaminants and allow treated groundwater to pass through. In conventional trench PRB, the reactive medium must be more permeable than the surrounding soil matrix to ensure it is the preferred flow pathway. Hydraulic flow modeling is advisable to ensure that the barrier is not overtopped or bypassed. Inorganic compounds, such as soluble metal salts, can precipitate in the PRB. This precipitation may cause the barrier material to become less reactive, reduce the hydraulic conductivity, and result in clogging of the barrier or breakthrough of the plume. PRB can also consist of lines of wells for injection of the reactive media. Commonly used trench reactive media include ZVI, zeolites, granular activated carbon (GAC), organic media, and proprietary substrates such as EHC®, which is a mixture of iron and an organic substrate. Injection well reactive media include emulsified vegetable oil (EVO) and other organic substrates, chemical oxidizing agents, chemical reducing agents, and emulsified zero valent iron (EZVI). A PRB is a passive treatment technology with very low operation and maintenance requirements; the major costs are the installation of the PRB and regeneration of replacement of the active medium when it becomes exhausted. ZVI PRBs have been shown to have a life of at least 20 years. GAC PRBs are likely to need replacement after 10 years. An EVO injection well PRB requires regeneration every 2 years.

REGISTERED COMPANY FOR ISO 9001 ENGINEERING DESIGN

EQUAL EMPLOYMENT OPPORTUNITY EMPLOYER

Hydraulic flow modeling is advisable during the design stage to ensure that the barrier is not overtopped or bypassed if a PRB option is selected.

Treatability Study

Objectives

The primary objectives of the treatability studies were to gather the data necessary to:

i) Assess the effectiveness of selected treatment media including ZVI for treatment of Site groundwater
ii) Identify the optimum media matrix for the barrier
iii) Determine the minimum hydraulic retention time in the barrier required to treat the groundwater

Sample Acquisition

This treatability study was performed using 20 gallons of groundwater collected from well MW-22-2D, which is located near the initially proposed location of the PRB; 20 gallons of groundwater collected from well OW-24, which is a high chromium well; and 20 gallons of groundwater collected from well HA-16, which is a high nickel well. These samples were received at the CRA laboratory in Niagara Falls, New York on October 10, 2013.

Task 1: Initial Characterization

The groundwater sample was analyzed for:

i) pH
ii) total and dissolved metals
iii) Total suspended solids (TSS)

For well HA-16, the high nickel well, the groundwater had a pH of 6.26 standard units (S.U.) and TSS of 66 milligrams per liter (mg/L). Total chromium was 25.7 μg/L, total iron was 27,300 μg/L, total manganese was 2,240 μg/L, total nickel was 503,000 μg/L, and total zinc was 887 μg/L. Dissolved chromium was 32.1 μg/L, dissolved iron was 253,000 μg/L, dissolved manganese was 2,790 μg/L, dissolved nickel was 533,000 μg/L, and dissolved zinc was 1,140 μg/L. A comparison of the total and dissolved metals data showed that the metals were primarily in their dissolved forms in this groundwater sample.

For well MW-22-2D, the well located near the proposed PRB location, groundwater had a pH of 7.15 S.U. and TSS of 4.00 mg/L. Total chromium was 1.11 μg/L, total iron was 2,170 μg/L, total manganese was 165 μg/L, total nickel was 38,100 μg/L, and total zinc was 73.4 μg/L. Dissolved chromium was 0.159 μg/L, dissolved iron was 91.8 μg/L, dissolved manganese was 167 μg/L, dissolved nickel was 39,200 μg/L, and dissolved zinc was 65.4 μg/L. These data showed that some of the chromium and iron were in the suspended form while most of the manganese, nickel, and zinc were in the dissolved form.

For well OW-24, the high chromium well, groundwater had a pH of 6.52 S.U. and TSS of 10 mg/L. Total chromium was 298,000 μg/L, total iron was 10.8 μg/L, total manganese was 100 μg/L, total nickel was 20,700 μg/L, and total zinc was 52.7 μg/L. Dissolved chromium was 199,000 μg/L, dissolved iron was 5.76 μg/L, dissolved manganese was

129 μg/L, dissolved nickel was 30,600 μg/L, and dissolved zinc was 54.7 μg/L. These data showed that as with well MW-22-2D, some of the chromium and iron were in the suspended form while most of the manganese, nickel, and zinc were in the dissolved form. These results are shown in Table 1.

Task 2: Column Tests

Three identical glass columns were packed with 10 percent ZVI, 90 percent sand, and groundwater from one of the wells was passed through the column as follows:

Column 1: Well HA-16

Column 2: Well MW-22-2D

Column 3: Well OW-24

Initially, the groundwater was pumped into the bottom of each of the columns using a multi-channel pump at a flow rate of 2 milliliters per minute (mL/min). The water from the top of the columns was collected after water had been flowing through the columns for 8 hours, when approximately 2 pore volumes of water had passed through each column, and analyzed for dissolved metals.

Column 1 (HA-16, High Nickel Well)

At a flow rate of 2 mL/min, which corresponds to a hydraulic residence time (HRT) of 90 minutes, the effluent from the column contained dissolved chromium at 22.8 μg/L, dissolved nickel at 33,200 μg/L, and dissolved zinc at 910 μg/L. Although a reduction in the nickel concentration of 94 percent was achieved, the nickel in the column effluent still exceeded the 100-μg/L target. The HRT was increased to 3 hours and then to 30 hours; however, although nickel removal was increased to 97 percent, the nickel concentration in the column effluent remained above 100 μg/L. Since a 30-hour HRT was the practical lower limit for the pumping rate of groundwater into the column, the column was repacked with 20 percent ZVI. An additional 2 pore volumes of water were pumped through the column using a rate that gave an HRT of 30 hours, and the effluent from the column was sampled and analyzed. The column effluent contained 27.9 μg/L of dissolved chromium, 243 μg/L of dissolved nickel, and 108 μg/L of dissolved zinc. The results showed that greater than 99.9 percent removal of nickel had been achieved, but the nickel concentration remained slightly above the 100-μg/L target level. Significant chromium removal was not observed in this column, likely due to kinetics. The nickel concentration was so much higher than the chromium concentration that the nickel uses all the active ZVI sites, and the chances of a chromium making contact with a ZVI active site are very small. The Column 1 results are shown in Table 2.

Column 2 (MW-22-2D, Well Near Proposed PRB Location)

At a flow rate of 2 mL/min, which corresponds to a HRT of 90 minutes, the effluent from the column contained dissolved chromium below its analytical detection limit, dissolved nickel at 14,900 μg/L, and dissolved zinc at 30.7 μg/L. Nickel concentrations exceeded the target level of 100 μg/L. The HRT was increased to 3 hours. Although the 3-hour HRT resulted in a 91-percent removal of nickel, the nickel concentration was still not reduced to below the 100-μg/L target. Therefore, the HRT was then increased to 3 hours; however, although nickel removal was increased to 97 percent, the nickel concentration in the column effluent remained above 100 μg/L. Therefore, the pumping rate was reduced to 0.1 mL/min (HRT of 30 hours), and 2 pore additional pore volumes of water were pumped through the column prior to sampling the effluent. The results from this sampling showed 41.8 μg/L of dissolved chromium, 30.5 μg/L of dissolved nickel, and 12.8 μg/L of dissolved zinc; therefore, both chromium and nickel were below the 100-μg/L target. In order to determine whether a shorter HRT could be used, the HRT was reduced to

15 hours. At this flow rate, the column effluent contained dissolved chromium below its analytical detection limit, 1,450 μg/L of dissolved nickel and 9.39 μg/L of dissolved zinc. Therefore, nickel exceeded the 100-μg/L target when the HRT was reduced to 15 hours. The Column 2 results are shown in Table 3.

Column 3 (OW-24, High Chromium)

At a flow rate of 2 mL/min, which corresponds to a HRT of 90 minutes, the effluent from the column contained dissolved chromium at 195,000 μg/L, dissolved nickel at 11,400 μg/L, and dissolved zinc at 35.9 μg/L. Although reductions in chromium and nickel concentrations were achieved, chromium and nickel in the column effluent both exceeded the 100-μg/L target. The HRT was increased to 3 hours and then to 30 hours; however, although chromium removal was increased to 62 percent and nickel to 96 percent, the concentrations of both metals in the column effluent remained above 100 μg/L. Since a 30-hour HRT was the practical lower limit for the pumping rate of groundwater into the column, the column was repacked with 20 percent ZVI. An additional 2 pore volumes of water were pumped through the column with an HRT of 30 hours, and the effluent from the column was sampled and analyzed. The effluent contained 23.4 μg/L of dissolved chromium, 3.78 μg/L of dissolved nickel, and 8.69 μg/L of dissolved zinc. Both chromium and nickel were below their 100-μg/L target levels. In order to determine whether a shorter HRT could be used, the HRT was reduced to 15 hours. At this HRT, the column effluent contained 87,700 μg/L of dissolved chromium and 108 μg/L of dissolved nickel; therefore, the 100-μg/L target level for chromium and nickel was exceeded when the HRT was reduced to 15 hours. The Column 3 results are shown in Table 4.

Summary

- At a HRT of 30 hours, chromium and nickel were significantly reduced in all three columns.
- For samples containing high initial concentrations of chromium or nickel (greater than 100,000 μg/L), a column packed with 10 percent ZVI was unable to reduce concentrations to below the target level.
- A column packed with 20 percent ZVI and a 30-hour HRT was required to reduce metals concentrations in these samples to below the 100-μg/L target level.
- When chromium and nickel concentrations in groundwater were lower (less than 100,000 μg/L), 10 percent ZVI and a 30-hour HRT was sufficient to reduce metals concentrations to below the 100-μg/L target level.

Recommendations

The PRB gate would be installed in the area of well MW-22-2D; however, currently the groundwater containment barrier prevents high concentration groundwater from migrating to this area. Once the previously contained groundwater is allowed to migrate through the PRB, chromium and nickel concentrations in the area of well MW-22-2D may increase. If source area treatment is performed, then this increase may not be observed.

To be conservative, it is assumed that high concentrations of chromium and nickel will reach the PRB. Currently, 300,000-500,000 gallons of groundwater are pumped from the containment area each month. Therefore, the gate would need to accommodate this volume of water. It is assumed that 500,000 gallons of groundwater would flow through the gate per month, which is 694 gallons per hour. Based on the results of this study, the groundwater would require a hydraulic residence time of at least 30 hours in the gate in order for treatment below the target level to occur. Therefore, the gate would need a volume of at least 9,275 cubic feet. A gate 25 feet deep and 10 feet wide and 37 feet long would be the minimum size capable of accommodating the volume. If a 2X safety factor is applied, the gate would need to be 74 feet long. A 74-foot section of the barrier wall would be removed, and a mixture containing 20 percent ZVI and 80 percent sand would be placed in the excavation. Approximately 414,400 pounds of ZVI and 15,000 cubic feet of sand would be placed in the excavated trench between 5 feet below ground surface (bgs) and 30 feet bgs. The top 5 feet of the trench would be backfilled with clean common fill. The cost for the ZVI is estimated at $203,100.

The rate at which the ZVI in the barrier would be consumed by the chromium and nickel in the groundwater was calculated. The calculations were performed using the stoichiometric demand of the nickel and chromium with a 10-time safety factor and the assumption that the surface area of each ZVI particle would contain 22.5 percent of the ZVI and would, therefore, be available to treat the metals in the groundwater.

Based on this model, the consumption rate of the ZVI in the barrier due to treatment of the metals passing through the barrier would be 2.13 cubic feet of the PRB per pound of chromium and 4.89 cubic feet of the PRB per pound of nickel.

TABLE 1

INITIAL GROUNDWATER CHARACTERIZATION
ZVI PERMEABLE REACTIVE BARRIER TREATABILITY STUDY
AREA 1 - FORMER PLATING AREA
13000 ECKLES ROAD SITE, LIVONIA, MICHIGAN

Parameters	***Units***	***001***	***002***	***003***
General Chemistry				
pH	S.U.	6.26	7.15	6.52
Total Suspended Solids (TSS)	mg/L	66.0	4.00	10.0
Total Metals				
Aluminum	µg/L	137	116	138
Antimony	µg/L	5.67 J	10.0 J	1190
Arsenic	µg/L	24.1 J	10.7 J	73.2
Barium	µg/L	17.5	20.7	10.0
Beryllium	µg/L	0.195 J	0.218 J	0.169 J
Cadmium	µg/L	2.97 J	1.75 J	1.27 J
Calcium	µg/L	1190000	149000	1090000
Chromium	µg/L	25.7	1.11 J	298000
Cobalt	µg/L	40.6	4.97 J	7.03 J
Cupper	µg/L	ND (20)	ND (20)	ND (20)
Iron	µg/L	27300	2170	10.8
Lead	µg/L	17.6 J	15.8 J	ND (50)
Magnesium	µg/L	52100	12300	59300
Manganese	µg/L	2240	165	100
Molybdenum	µg/L	0.671 J	14.2	7.58 J
Nickel	µg/L	503000	38100	20700
Potassium	µg/L	10700	10400	5540
Selenium	µg/L	ND (100)	ND (100)	13.0 J
Silver	µg/L	4.14 J	1.99 J	13.7
Sodium	µg/L	329000	360000	198000
Thallium	µg/L	36.7 J	35.8 J	111
Vanadium	µg/L	4.40 J	1.74 J	22.5
Zinc	µg/L	887	73.4	52.7
Dissolved Metals				
Dissolved Aluminum	µg/L	127	70.3	139
Dissolved Antimony	µg/L	3.06 J	10.5 J	1650
Dissolved Arsenic	µg/L	28.2 J	7.67 J	90.2
Dissolved Barium	µg/L	26.7	20.1	12.4
Dissolved Beryllium	µg/L	0.193 J	0.151 J	0.179 J
Dissolved Cadmium	µg/L	3.97 J	1.10 J	0.667 J
Dissolved Calcium	µg/L	1160000	158000	1370000
Dissolved Chromium	µg/L	32.1	0.159 J	199000
Dissolved Cobalt	µg/L	51.1	2.99 J	7.22
Dissolved Cupper	µg/L	ND (20)	ND (20)	ND (20)
Dissolved Iron	µg/L	25300	91.8	5.76 J
Dissolved Lead	µg/L	ND (50)	ND (50)	ND (50)
Dissolved Magnesium	µg/L	65400	14300	71800
Dissolved Metals - Continued				
Dissolved Manganese	µg/L	2790	167	129

TABLE 1

INITIAL GROUNDWATER CHARACTERIZATION
ZVI PERMEABLE REACTIVE BARRIER TREATABILITY STUDY
AREA 1 - FORMER PLATING AREA
13000 ECKLES ROAD SITE, LIVONIA, MICHIGAN

Parameters	*Units*	*001*	*002*	*003*
Dissolved Molybdenum	µg/L	3.04 J	13.7	10.8
Dissolved Nickel	µg/L	533000	39200	30600
Dissolved Potassium	µg/L	12100	9480	6830
Dissolved Selenium	µg/L	ND (100)	10.9 J	6.78 J
Dissolved Silver	µg/L	1.35 J	1.14 J	15.5
Dissolved Sodium	µg/L	316000	317000	240000
Dissolved Thallium	µg/L	24.2 J	28.6 J	175
Dissolved Vanadium	µg/L	5.36 J	0.929 J	29.9
Dissolved Zinc	µg/L	1140	65.4	54.7

Notes:
ND (x) - Not detected at reporting limit.
J - Estimated result.

TABLE 2

COLUMN STUDY GROUNDWATER ANALYSIS COLUMN 1 - HA-16 - HIGH NICKEL WELL
ZVI PERMEABLE REACTIVE BARRIER TREATABILITY STUDY
AREA 1 - FORMER PLATING AREA
13000 ECKLES ROAD SITE, LIVONIA, MICHIGAN

Parameters	*Units*	*Initial*	*1st Sampling*	*2nd Sampling*	*3rd Sampling*	*4th Sampling**
Flow Rate	mL/min	-	2.00	1.00	0.100	0.100
HRT	hours	-	1.50	3.00	30.000	30.000
Volume of GW Passed Through	mL	-	570	460	810	270*
Dissolved Metals						
Dissolved Chromium	µg/L	32.1	22.8	18.4	10.5	27.9
Dissolved Nickel	µg/L	533000	33200	253000	17213	243
Dissolved Zinc	µg/L	1140	910	729	100	108
Percent Removal of Chromium	%		29.0	42.7	67.3	13.1
Percent Removal of Nickel	%		93.8	52.5	96.8	>99.9
Percent Removal of Zinc	%		20.2	36.1	91.2	90.5

Notes:
ND (x) - Not detected at reporting limit.
J - Estimated result.
*Columns were repacked with 20% ZVI.

TABLE 3

COLUMN STUDY GROUNDWATER ANALYSIS COLUMN 2 - MW-22-2D - WELL NEAR PROPOSED PRB LOCATION
ZVI PERMEABLE REACTIVE BARRIER TREATABILITY STUDY
AREA 1 - FORMER PLATING AREA
13000 ECKLES ROAD SITE, LIVONIA, MICHIGAN

Parameters	***Units***	***Initial***	***1st Sampling***	***2nd Sampling***	***3rd Sampling***	***4th Sampling***
Flow Rate	mL/min	-	2.00	1.00	0.100	0.200
HRT	hours		1.5	3.0	30	15
Volume of GW Passed Through	mL	-	540	450	490	1055
Dissolved Metals						
Dissolved Chromium	µg/L	0.159 J	ND (10)	ND (10)	41.8	ND (10)
Dissolved Nickel	µg/L	39200	14900	3540	30.5	1450
Dissolved Zinc	µg/L	65.4	30.7	7.16 J	12.8	9.39 J
Percent Removal of Chromium	%		n/a	n/a	n/a	n/a
Percent Removal of Nickel	%		62.0	91.0	99.9	96.3
Percent Removal of Zinc	%		53.1	89.1	80.4	85.6

Notes:
ND (x) - Not detected at reporting limit.
J - Estimated result.

TABLE 4

COLUMN STUDY GROUNDWATER ANALYSIS COLUMN 3 - OW-24 - HIGH CHROMIUM
ZVI PERMEABLE REACTIVE BARRIER TREATABILITY STUDY
AREA 1 - FORMER PLATING AREA
13000 ECKLES ROAD SITE, LIVONIA, MICHIGAN

Parameters	***Units***	***Initial***	***1st Sampling***	***2nd Sampling***	***3rd Sampling***	***4th Sampling****	***5th Sampling***
Flow Rate	mL/min	-	2.0	1.0	0.1	0.1	0.2
HRT	hours		1.5	3.0	30.0	30.0	15.0
Volume of GW Passed Through	mL	-	570	460	820	250*	1140
Dissolved Metals							
Dissolved Chromium	µg/L	199000	195000	106000	75033	23.4	87732
Dissolved Nickel	µg/L	30600	11400	9360	1094	3.78 J	108
Dissolved Zinc	µg/L	54.7	35.9	29.3	21.6	8.69	ND (20)
Percent Removal of Chromium	%		2.0	46.7	62.3	>99.9	55.9
Percent Removal of Nickel	%		62.7	69.4	96.4	>99.9	99.6
Percent Removal of Zinc	%		34.4	46.4	60.5	84.1	91.9

Notes:
ND (x) - Not detected at reporting limit.
J - Estimated result.
*Columns were repacked with 20% ZVI.

Appendix C
Memorandum – Potential for Fouling of Proposed PRG

Memorandum

March 7, 2018

To:	Chris Meincke, Tom Kinney	Ref. No.:	012607
From:	Sophia Dore/Ryan Thomas/mkd	Tel:	716-205-1978

Subject: **Potential for Fouling of Proposed Permeable Reactive Gate**
13000 Eckles Road Site
Livonia, Michigan

1. Introduction

The installation of a permeable reactive gate (PRG) has been proposed for the 13000 Eckles Road Site located in Livonia Michigan (Site). The risk of mineral fouling of the PRG was evaluated. This evaluation involved the collection of samples from the area in which the PRG will be installed and the analysis of groundwater from this area for parameters pertinent to mineral fouling.

2. Mineral Fouling

Mineral fouling of zero-valent iron (ZVI) Permeable Reactive Barriers (PRBs) can cause adverse reactions to the hydraulic behavior of the system. Geochemical interactions between groundwater and zero-valent iron can lead to mineralization processes that through time can have an impact on contaminant removal and hydraulic throughput. The types of processes include oxidation and mineralization involving iron, sulfate, calcium, and inorganic carbon.

Contaminants in a ZVI PRB are treated through redox conditions created by the corrosion of iron. These corrosion reactions can result in pH conditions that induce precipitation of secondary minerals that may precipitate in the pores of the PRB. Some minerals precipitating under higher pH conditions include iron oxides, iron (oxy)-hydroxides, and carbonates. Reductions in the concentration of major ions such as calcium (2+) and magnesium (2+) will occur in response to the mineral precipitation. As groundwater flows through a PRB, the iron will be corroded by dissolved oxygen (DO) and water causing elevation of the pH and subsequent precipitation of oxides and carbonates (Li et al. 2005).

The most common minerals observed in column and field studies from ZVI PRBs are aragonite or calcite in the form of calcium carbonate ($CaCO_3$), siderite in the form of ferrous carbonate ($FeCO_3$), and ferrous hydroxide ($Fe(OH)_2$). Other minerals are possible such as carbonates and hydroxides versions of magnesium and manganese, but calculations and field studies have shown these minerals resulted in negligible changes in porosity reduction. (Li et al. 2005, Li et al. 2006, Wilkin et al. 2003). Wilkin has noted (Wilkin, 2003) that elevated concentrations of sulfate in groundwater entering a PRB coupled with moderately to highly reducing conditions in a PRB can lead to the reduction of sulfate and production of sulfide, which may precipitate in a PRB as iron sulfide.

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3. Evaluation of the Potential for Fouling in the Proposed PRG

Iron corrosion typically happens in a pH range of 10-11 for a PRB that contains 100 percent ZVI. The pH in the proposed PRG is expected to be between pH 8 and 9 due to the lower ZVI content of 10-20 percent. Although this pH may result in some precipitation of minerals, less precipitation will occur at pH 8-9 than at pH 10-11; therefore, the lower iron content will reduce the potential for fouling.

Data pertinent to fouling was collected from wells that are near the proposed location of the PRG. To assess the risk of mineral fouling of the proposed PRG, concentrations of calcium, iron, and magnesium were key. These parameters were measured directly and also contribute to hardness which was a parameter measured for some wells. Injections of sodium sulfide were performed at this Site to treat source area metals; therefore, some elevated sulfate and sulfide concentrations have been measured at the Site therefore, sulfate and sulfide concentrations were also evaluated.

Concentrations of the relevant parameters at two wells located close to the proposed PRG location are shown in Table 1 and the ranges are summarized in the table below.

Table 3.1 Post Sodium Sulfide Injection Groundwater Data Ranges in Wells Located Close to the Proposed PRG

Parameters	Units	Range	Typical Range for Groundwater*
Total Calcium	mg/L	86-160	0.100 - 1002
Total Iron	mg/L	0.19-0.99	< 50.2
Total Magnesium	mg/L	11-20	0.1-100
Total Manganese	mg/L	0.079-1.1	<0.9882
Sulfate	mg/L	38-130	3.1 – 170 (Southeast Michigan)
Sulfide	mg/L	<3.0	
Notes:			
mg/L - Milligrams per liter			

*Representative natural groundwater ions concentrations from Li et al., Freeze and Cherry (1979), Hem (1985), Dumouchelle et al. (1987), and Langmuir (1997)

The data collected from the wells close to the proposed PRG shows that groundwater in this area contains low concentrations of calcium, iron and magnesium when compared to the typical range for natural groundwater concentrations. Sulfate concentrations are in the mid to high end of the range for groundwater in the area. Since sodium sulfide was injected at the Site it was expected that elevated sulfate concentration might be present, however these data show that sulfate concentrations in the area of the proposed PRG are within the expected range for the area.

Li et al. (2005) presents a summary of field observations regarding geochemical conditions and the effects of mineral fouling of PRBs.

In that study, nine ZVI PRB systems were evaluated for chemistry of influent groundwater, secondary materials formed in the ZVI, and impacts on hydraulics. The greatest calcium and magnesium levels found in the influent groundwater were 341 mg/L and 19.4 mg/L, respectively.

At this elevated calcium level, the impact on the PRB was found to take place in the first 30 months with a lifespan of ZVI estimated as 8 years in the more corroded entrance section and 15 years for the other sections. Since calcium levels in the area of the proposed PRG are 25-50 percent of the level in this case study, based on these data the lifespan of the entire PRG is expected to be greater than 15 years.

A 22-percent ZVI PRB from Canadian Forces Base (CFB) Borden located in Ontario, Canada presented by Li et al. had 280 mg/L of calcium and 2.4 mg/L of magnesium in the influent groundwater. Trace amounts of iron oxides, calcium carbonate, and iron carbonate were observed within the first few millimeters from the entrance face after 4 years; however, no decline in performance was observed over 5 years. Given that the levels of calcium found in groundwater in the area of the proposed PRG are 30-60 percent of those found at CFB Borden and the iron content of the PRG will be similar, it is reasonable to infer less fouling at the current Site. Therefore, the risk of mineral fouling of the proposed ZVI PRG at the Site is expected to be low.

Wilkin et al (2003) looked at the role of ions such as calcium and iron on reduction of PRB porosity but also looked at sulfate and sulfide. This is relevant because the source area treatments have increased sulfate and sulfide at the Site. A funnel and gate system at the Denver Federal Center in Colorado, one of the sites evaluated in this article, had groundwater that contained calcium at 100 mg/L and sulfate at 286 mg/L. Mineral deposits at a thickness of 10-50 microns (µm) were observed at up to 8 centimeters (cm) from the upgradient edge of the PRB; however, at a distance of greater than 8 cm, the coating was discontinuous and less than 5 µm thick. The loss of porosity for this PRB was calculated at 0.56 percent per year. Therefore, after 20 years, only 11 percent of the pore volume of the PRB would have been lost. At the current Site, calcium concentrations were similar, however sulfate concentrations were 13-45 percent of those at the Colorado Site therefore the loss of porosity of the PRB is expected to be less.

In the worst-case scenario that all of the mentioned total calcium and magnesium precipitates to their carbonate minerals at the Site, there are strategies to limit their impact on the ZVI PRG. Such strategies are pH adjustment that adds buffering materials to the reactive medium to decrease the elevated pH (Li and Benson 2010). However, due to the fact that the PRG at the Site will contain a mixture of ZVI and sand resulting in a less elevated pH, and due to the relatively low concentrations of calcium and magnesium in the influent groundwater, it is not expected that buffering will be required.

4. References

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Table 1
Parameters Pertinent to PRG Fouling
Potential for Fouling of Proposed Permeable Reactive Gate
13000 Eckles Road Site
Livonia, MI

Sample Location:		**Typical Concentration**	**MW-82D-18**	**MW-83D-18**	**MW-83D-18**	**MW-84D-18**	**MW-84S-17**	**MW-85D-18**	**MW-85S-17**
Sample Identification:		**in Groundwater**	**GW-12607-011918-SK-012**	**GW-12607-011818-SK-008**	**GW-12607-011818-SK-009**	**GW-12607-011818-SK-007**	**GW-12607-011818-SK-006**	**GW-12607-011818-SK-010**	**GW-12607-011818-SK-011**
Sample Date:			**1/19/2018**	**1/18/2018**	**1/18/2018**	**1/18/2018**	**1/18/2018**	**1/18/2018**	**1/18/2018**
Sample Type:					**Duplicate**				
	Units								
Metals									
Calcium	mg/L	0.1-1002	87	130	130	160	140	86	120
Chromium	mg/L		0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U
Chromium III (trivalent)	mg/L		--	0.0050 U	0.0050 U	0.0050 U	0.0050 U	0.0050 U	0.0050 U
Chromium VI (hexavalent)	mg/L		0.0050 U	0.0050 U	0.0050 U	0.0050 U	0.0050 U	0.0050 U	0.0050 U
Iron	mg/L	<50.2	**0.49**[ab]	0.26	0.19	**0.38**[ab]	**0.99**[ab]	**0.52**[ab]	**0.75**[ab]
Magnesium	mg/L	0.1-100	14	11	11	11	12	14	20
Manganese	mg/L	<0.9882	**1.1**[ab]	**0.31**[ab]	**0.31**[ab]	**0.47**[ab]	**0.079**[ab]	**0.63**[ab]	**0.58**[ab]
Nickel	mg/L		0.042	0.06	0.058	0.04 U	0.04 U	**0.12**[ab]	0.04 U
Sodium	mg/L		32	11	11	6.4	16	56	7.2
General Chemistry									
Alkalinity, total (as CaCO3)	mg/L		340	290	290	330	340	230	300
Hardness	mg/L		270	350	380	430	410	280	380
Sulfate	mg/L		64	47	49	130	31	130	38
Sulfide	mg/L		3.0 U	3.0 U	3.0 U	3.0 U	3.0 U	3.0 U	3.0 U
Field Parameters									
Conductivity, field	mS/cm		0.64	0.69	0.69	0.79	0.75	0.73	0.69
Dissolved oxygen (DO), field	mg/L		0	0	0	0	4.6	0.46	0.51
Oxidation reduction potential ((	millivolts		16.5	32.9	32.9	93.9	51.6	28.5	28.7
pH, field	s.u.		7.51	7.11	7.11	7.12	7.00	7.54	7.25
Temperature, field	Deg C		10.33	10.01	10.01	11.61	9.13	9.16	8.33
Turbidity, field	NTU		14	9.59	9.59	17.6	26.3	13.9	24.2

Notes:

U - Not detected at the associated reporting limit.

(1) Groundwater - MDEQ Generic cleanup criteria for residential and nonresidential category, administrative rule R 299.44 effective December 30, 2013, pursuant to Part 201 of 1994 PA 451 as amended

Appendix D
Bio-Polymer Slurry Information

Quality Polymers from

RANTEC CORPORATION
PO Box 729
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Phone (307) 655-9565
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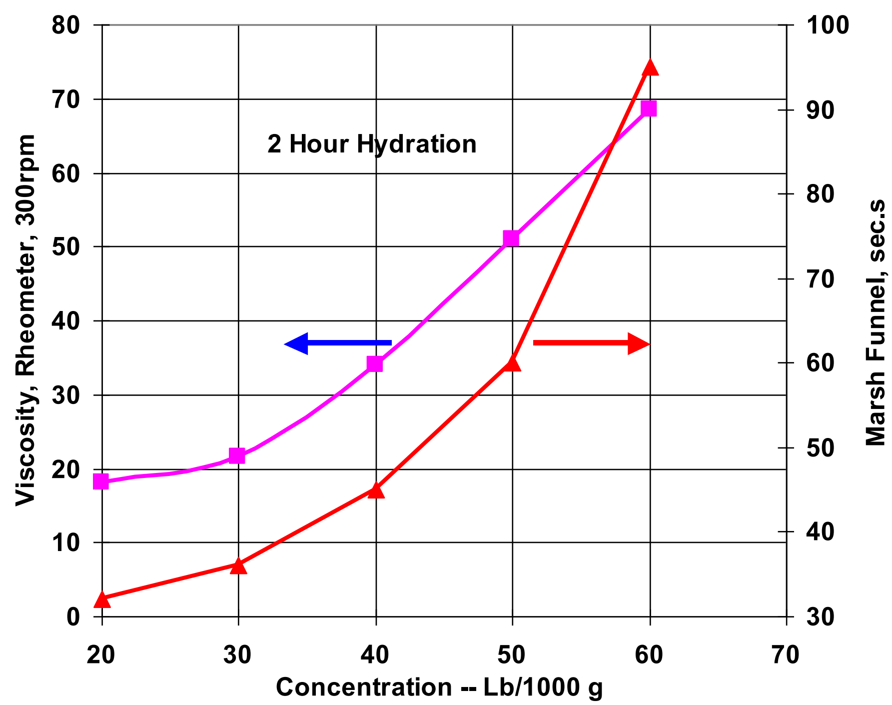
Email: rantec@ranteccorp.com

28 Years of Innovation

Rantec G150™ BioPolymer

DESCRIPTION

G150 is Rantec's guar gum-based natural polymer (galacto-mannan) for biopolymer liquid shoring fluids (BLSF) and drilling muds. Molecular weight is in the range of 1.5 to 2.0 million. **G150** BLSF has been used extensively for geo-technical stabilization of extraction trenches during excavation and construction and well bores during drilling. **G150** is biodegradable and can be broken down completely thus maintaining the permeability of those soils and producing formations. Rantec has more than 16 years of experience in supplying **G150** for use in liquid shoring and drilling applications. As part of Rantec's continued improvement program **G150** in now easier to mix, less dusty and produces more viscosity per pound.



’.XLS,CONC

Figure 1: Viscosity with Concentration shows fresh water viscosity for a range of concentrations of Rantec **G150** biopolymer.

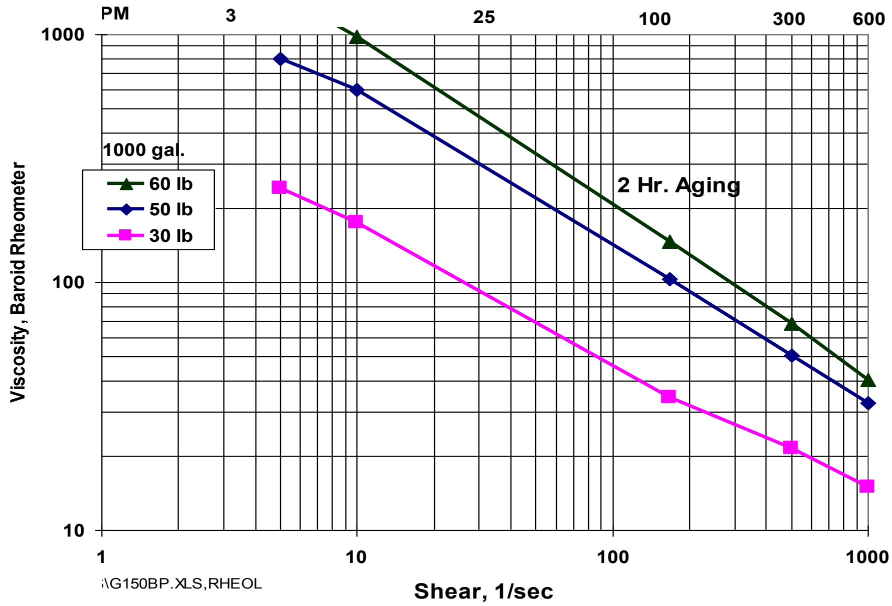
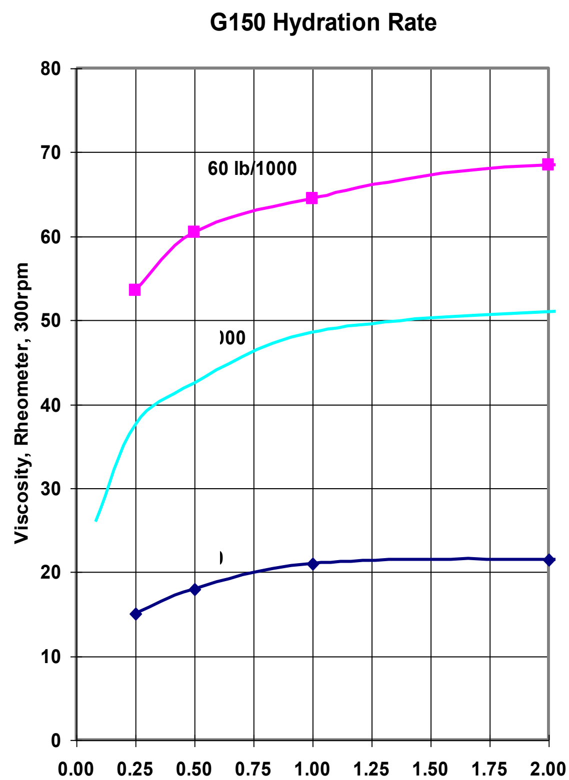


Figure 2: Rheology

Rantec **G150** BLSF is a non-Newtonian "shear-thinning" fluid. At low shear rates a gel is apparent, while under high shear, viscosity is very low.
Figure 2: Rheology demonstrates these rheological characteristics of the fluid.

High viscosity in the gel state or low shear condition is important for prevention of soil or water movement, while low viscosity is important under higher shear conditions such as mixing and pumping.

G150 fluids immediately recover original viscosity as soon as shear is relieved. High shear will not destroy the **G150** polymer molecule as can occur with many synthetic polymers.



YIELD AND MIXING

Typical design mix for G150 in difficult conditions would be:

G150	50 to 70 lb/1000 gallons
Busan 1059WS	1.2 to 2.0 lb/1000 gallons
Soda Ash	5 to 8 lb/1000 gallons to maintain pH 10
Lime	1 to 3 lb/1000 gallons if required to maintain pH 10

Rantec **G150** is designed to provide easy mixing and good yield of viscosity. **G150** yields workable viscosity in about 1 hour and is fully yielded in about 4 hours. **Figure 3: Viscosity Development** demonstrates the development of viscosity through a period of 24 hours. In 1 hour **G150** has yielded 90% of its viscosity. **G150** responds well to high shear mixing. Additional shear will accelerate the rate of viscosity yield.

Rantec will provide assistance in choosing equipment suited for good mixing of **G150** fluid. Systems can be engineered for a wide range of capabilities from manual addition to fully automated systems.

IN USE CHARACTERISTICS

Typical Use Rate – 60 lb/1000 gallons (0.72% w/w)
Odor of Broken Slurry – Not noticeable under aerobic conditions. May become putrid under anaerobic conditions.
BOD of Broken Slurry – Typically approximately 1200 ppm.
Useful Life of Slurry – 3 to 10 days depending upon temperature, soil conditions and additives
Degradability – Approximately 10 to 12% insoluble residue after enzyme break

PACKAGING

Rantec **G150** is available in packaging from 20 lb pails to 2000 lb super sacks. The most common packaging is 50 lb multi-wall paper bags. All packages are loaded on pallets and stretch wrapped to protect the product. For outside storage pallet covers can be provided on request.

SAFETY

G150 is a natural organic polymer often used in food ingredients as well as industrial applications. It is non-polluting and non-toxic. It is totally biodegradable, so disposal problems are reduced. Preservative can be used for long term applications. **G150** is non-mineral: therefore, it does not contaminate trenches, surroundings or assays.

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MATERIAL SAFETY DATA SHEET

Guar Gum
08/31/11

1. Product and Company Information

Product Name:	**Rantec® G150™ Guar Gum**
Manufacturer/Supplier:	Rantec Corporation
Address:	17 Kukuchka Lane Ranchester, WY 82839
Phone Number:	(307) 655-9565
Fax Number:	(307) 655-9528
e-mail:	rantec@ranteccorp.com

2. Composition / Information on Ingredients

Ingredient	CAS Number	% Weight	Exposure Limits
Guar Gum	9000-30-0	100	5 mg/m^3 (respirable) PEL-TWA 3 mg/m^3 (respirable) TLV-TWA 10 mg/m^3 (inhalable dust) TLV-TWA

Chemical Family: Carbohydrate
Formula: Approximately $(C_6H_{10}0_5)n$

3. Hazards Identification

OSHA Hazardous Material: Yes
OSHA Hazard Categories:

1. Carcinogen – NO
2. Corrosive – NO
3. Highly Toxic – NO
4. Irritant – Yes
5. Sensitizer – Yes
6. Toxic – NO
7. Target Organ Effect Lung and Cutaneous -- Yes

Emergency Overview:

Concentrations of dust suspended in the air present a fire and explosion hazard.

Inhalation of dust may cause respiratory irritation and possible lung injury with symptoms of shortness of breath and reduced lung function.

Guar gum is very slippery when wet.

Acute Health Effects:
Eye Contact: Contact may cause irritation based on studies with laboratory animals.

Skin Contact: Contact may cause dryness.

Inhalation: Inhalation of dust may cause irritation of the nose, throat and respiratory passages. Symptoms include coughing, sore throat, nasal congestion, sneezing wheezing and shortness of breath. Guar gum may cause life-threatening allergic reaction in susceptible individuals.

3. Hazards Identification (continued)

Ingestion: DO NOT INGEST. While this product is not toxic by ingestion, swallowing small amounts could cause complete blockage of the mouth, pharynx, trachea, esophagus and/or gastrointestinal system which may cause choking, suffocation and/or other life threatening medical conditions. Get medical attention immediately.

Chronic (long-term exposure) Health Effects:

- **Inhalation:** Overexposure to any nuisance dust may cause lung injury. Symptoms include cough, shortness of breath, difficulty breathing and reduced pulmonary function. Repeated exposures may cause allergic sensitization.
- **Carcinogenicity:** None of the components of this product are listed as carcinogens or suspected carcinogens by OSHA, IARC or NTP.
- **Medical Conditions Aggravated by Exposure:** Persons with pre-existing skin and respiratory disorders may be at an increased risk from exposure.

Physical Hazards:

- **Dust:** It is well documented that a dust cloud will fuel an explosion in a confined area with sufficient oxygen and an ignition source. Surface (passive) and airborne (active) dust (fuel) is a potential hazard and the appropriate protective measures should be taken when handling guar outside of the bag in confined work spaces, dust collectors, dryers, mills, sifters, blender, pneumatic conveyance systems, storage tanks, etc. Utilize good housekeeping to remove surface dust from floors, walls, beams, around equipment, etc.
- **Slick Surfaces:** It is possible that an employee will be exposed to guar powder or dust in combination with water on work platform, floor or stair, which will result in a slippery surface.

4. First Aid Measures

Eye: Flush immediately with large amounts of water. Eyelids should be held away from the eyeball to ensure thorough rinsing. If irritation persists get medical attention.

Skin: First aid is not normally needed. Wash exposed skin with soap and water after use. If irritation or rash develops get medical attention. Use skin lotion if dryness occurs.

Inhalation: If symptoms of irritation or allergy develop, remove person from source of exposure to fresh air. If symptoms persist get medical attention.

Ingestion: Swallowing even small amounts may have serious, life-threatening effects. Get immediate medical attention.

5. Firefighting Measures

Flashpoint: Not Applicable
Auto-Ignition Temperature: Not Determined

Lower Explosion Limit: 0.040 oz/cf
Upper Explosion Limit: Not determined

Extinguishing Media: Use water fog, dry chemical, carbon dioxide or foam. Do not use streams of water as dust dispersed by water streams can explode.

Special Fire Fighting Procedures: Wear positive pressure, self-contained breathing apparatus and full protective clothing.
Unusual Fire and Explosion Hazards: Powder has the potential to form explosive mixtures with air. It is well documented that a dust cloud will fuel an explosion hazard. Surface (passive) and airborne (active) dust (fuel) are a potential hazard and the appropriate protective measures should be taken when handling guar gum outside of the original packaging. Avoid creating dust. Keep away from heat, sparks and open flames. As with all dusty materials,

use preventative measures including spark proof motors and ventilation to control dust. Utilize good housekeeping to remove surface dust from floors, walls, beams, around equipment, etc.

Combustion Products: Oxides of carbon and nitrogen.

6: Accidental Release Measures

Wear appropriate protective clothing and equipment. Caution: Guar gum is ***very slippery when wet***. Suspended dust may present a serious dust explosion hazard. Sweep up or vacuum, avoiding the creation of airborne dust. Keep spilled product away from flammable and combustible materials. Use vacuum equipment specifically designed for combustible dusts. Collect into a suitable container for disposal. Wash residual traces with hot water after sweep-up is complete. Test area for residual slippery conditions.

7. Handling and Storage

Handling: Avoid generating and breathing dust. Avoid eye contact. Use with adequate local exhaust ventilation and dust collection to maintain the concentration of airborne dust below the exposure limits. If clothing becomes contaminated, remove and launder before re-use. Wash thoroughly after handling. Keep product away from oxidizers and all sources of ignition including flames, electrical sparks, hot surfaces, pilot lights, etc.

Storage: Keep product dry. Store in a cool, dry area. Keep containers closed to avoid moisture absorption.

8. Exposure Controls / Personal Protection

Engineering Controls: Consult a qualified engineer for evaluation of materials handling and explosion protection system(s).

Personal Protective Equipment (PPE):

- **Eye Protection:** Safety glasses or goggles recommended.
- **Skin Protection:** Rubber, plastic or leather gloves recommended.
- **Respiratory Protection:** If the concentrations exceed the Threshold Value Limit (TLV), a NIOSH approved dust respirator, supplied air respirator or self-contained breathing apparatus is recommended. Select appropriate respiratory protection for respirable particulates based on consideration of the airborne workplace concentrations and duration of exposure. Select and use respirators in accordance with 29 CFR 1910.134 http://www.access.gpo.gov/nara/cfr/cfr-retrieve.html#page1 , ANSI Z88.2 http://www.ansi.org/, the NIOSH Respirator Decision Logic and good industrial hygiene practice http://www.cdc.gov/niosh/homepage.html. To simplify selection of the appropriate respirator, OSHA has developed the Advisor Genius. Available online, the advisor genius allows a safety professional to input the conditions under which the respirator will be used and receive a recommendation of the type of respirator to use. The advisor also contains information about types of respirators and factors that affect respirator use. The online advisor contains a set of options as to the use of the respirator (firefighting, welding, escape purposes, confined areas) and then generates a report with the relevant OSHA standard indicated. The advisor is available at http://www.osha.gov/SLTC/etools/respiratory/respirator_selection.html.

9. Physical and Chemical Properties

Boiling Point: Not Applicable
Melting Point: Decomposes
Vapor Pressure: Not Applicable
Vapor Density (Air=1): Not Applicable
% Solubility in Water: Complete

Specific Gravity: Not applicable
% Volatile: Not applicable
Evaporation Rate (Butyl Acetate=1): Not Applicable
pH: 5-8
Octanol/Water Partition Coefficient: Not Applicable

Odor/Appearance: Creamy white powder with a bean-like odor.

10. Stability and Reactivity

Stability: Material is stable.
Incompatibility: Avoid high temperatures, sparks, open flames and moisture. Avoid contact with strong oxidizing agents.
Hazardous Reactions-Decomposition Products: Combustion may produce carbon dioxide, carbon monoxide and oxides of nitrogen.
Hazardous Polymerization: Will not occur.

11. Toxicological Information

Guar Gum: Oral rat LD50: 9.4g/kg

Guar gum is a natural food additive, although direct use in powder or pill form is banned by the FDA due to the risk of respiratory or gastrointestinal blockage

12. Ecological Information

No ecotoxicity data is available at this time.

13. Disposal Considerations

Dispose in compliance with all applicable federal, state and local regulations. Do not dump down sewers or drains as this may cause blockage.

14. Transport Information

U.S. Department of Transportation (DOT)
Proper Shipping Name: Not Regulated
Hazard Class: N/A
UN/NA Code: N/A
Packing Group: N/A
Labels Required: N/A
IMDG CODE
Proper Shipping Name: NOT REGULATED
Hazard Class: N/A
UN/NA Code: N/A
Packaging Group: N/A
Labels Required: N/A

15. Regulatory Information

Regulatory Information
The United States Food and Drug Administration, the European Economic Community and the World Health Organization accept guar gum as a food additive/ingredient providing it meets specified purity standards and dosage limitations. Maximum usage levels permitted may vary from country to country. Guar gum has been affirmed as GRAS by the United States Food & Drug Administration under title 21, CFR, part 184.1339; it is listed

as item G.3 of Table IV, Division 16, of the Canadian Food and Drug Regulations and is referenced E-412 under the EEC Council Directives.

Comprehensive Environmental Response and Liability Act of 1980 (CERCLA) Reportable Quantity:
This product is not subject to CERCLA reporting requirements as it is sold.

OSHA Hazard Categories: Irritant, Sensitizer, Target Organ Effect.

Superfund Amendments and Reauthorization Act (SARA) Title III Information:
SARA Section 311/312 Hazard Categories: Fire Hazard, Acute Health
This product contains the following toxic chemical(s) subject to reporting requirements of SARA Section 313: None

15. Regulatory Information (continued)

California Proposition 65: Guar gum is not a chemical known to the State of California to cause cancer or reproductive toxicity under the “Safe Drinking Water and Toxic Enforcement Act of 1986”.

Toxic Substances Control Act (TSCA): All components of this product are listed on the TSCA inventory or exempt from notification requirements.

Canadian Environmental Protection Act: All of the components of this product are listed on the Canadian Domestic Substances List or exempt from notification requirements.

European Inventory of Existing Commercial Chemical Substances (EINECS): All of the components of this product are listed on the EINECS Inventory or exempt from notification requirements.

Japan MITI: All of the components of this product are existing chemical substances as defined in the Chemical Substance Control Law.

Australian Inventory of Chemical Substances: All of the components of this product are listed on the AICS Inventory or exempt from notification requirements.

Canadian WHMIS Classification: Class B, Division 4 (Flammable Solid)

16. Other Information

NFPA Hazard Ratings:
NFPA® Flammable (combustible dust) with representative diameter less than 420 microns (40 mesh).

Health: 1	Flammability: 2	Reactivity: 0

HMIS Hazard Ratings:

Health: 1	Flammability: 1	Reactivity: 0

Abbreviations:

ACGIH	American Conference Of Governmental Industrial Hygienists
ANSI	American National Standards Institute

CAS	Chemical Abstracts Service
CDC	Centers for Disease Control and Prevention
CFR	The Code of Federal Regulations
EEC	European Economic Community
EINECS	European Inventory of Existing Commercial Chemical Substances
EPA	United States Environmental Protection Agency
FDA	United States Food and Drug Administration
HMIS	Hazardous Materials Identification System
IARC	International Agency for Research on Cancer
IMDG	International Maritime Dangerous Goods
LD50	Lethal Dose expected to cause death in 50% of the test animals
MITI	Ministry of International Trade and Industry
NFPA	National Fire Protection Association
NIOSH	CDC - National Institute for Occupational Safety
NTP	National Toxicological Program

16. Other Information -- Abbreviations (continued)

OSHA	U.S. Department of Labor, Occupational safety and health administration
PEL	OSHA - permissible exposure limit
TLV	ACGIH - threshold limit value
TWA	Time weighted average
UN/NA	United Nations / North America
US	United States
WHMIS	Workplace Hazardous Materials Information System

NOTICE:

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