WORK PLAN FOR
IN SITU CHEMICAL OXIDATION REMEDIATION OF TRICHLOROETHENE GROUNDWATER PLUME

ECKLES ROAD FACILITY
LIVONIA, MICHIGAN

Prepared for

RACER Trust

Prepared by
HAMP, MATHEWS & ASSOCIATES, INC.
Bath, Michigan

August 23, 2019

Table of Contents

List of Figures

List of Tables

List of Appendices

1.0 INTRODUCTION

This Work Plan presents an in situ chemical oxidation (ISCO) remediation approach for treatment of a trichloroethene (TCE) groundwater plume in a residential neighborhood that originated from a former General Motors plant at 13000 Eckles Road in Livonia, Michigan (**Figure 1**). The environmental liability associated with the subject property is now managed by Revitalizing Auto Communities Environmental Response Trust (RACER). Long-term monitoring of the plume as a potential source for volatilization to indoor air pathway (VIAP) risk to residents has been conducted since 2012. Vapor mitigation systems have been installed for two homes. VIAP risk remains as the TCE plume continues to migrate to additional residential homes.

1.1 Objectives

The proposed treatment approach splits a residual TCE plume into time-manageable sections via degradative mechanisms of ISCO configured in four transects strategically positioned within the highest known areas of the TCE plume (**Figure 2**). The objective of the ISCO program will be to inject oxidant into the four treatment zones to reduce concentrations of TCE in groundwater thereby reducing the potential for long-term VIAP monitoring and mitigation requirements. The injections will be completed with a goal of reducing groundwater concentrations of TCE as close as practical to the U.S. Environmental Protection Agency's (EPA) groundwater vapor screening level of 10 ug/L. It is not anticipated that TCE concentrations will be reduced to the EPA groundwater vapor screening level at each monitoring location nor for groundwater throughout the residential neighborhood. The need for potential subsequent injections will be evaluated after a review of results from each post-injection monitoring event. The following sections present site background on the nature and occurrence of the TCE plume, related VIAP concerns, and technical details regarding the proposed ISCO program. A chart conveying the proposed ISCO strategy and process flow is included as **Figure 3**, while supporting technical details are both included in **Tables 1** through **3** and in **Appendices A** through **E**.

1.2 Site Background

During environmental investigations performed in 2002, soil in the southeast corner of the Site was found to contain TCE and polychlorinated biphenyls (PCBs). The impacted soil, or area of interest (AOI), is shown on **Figure 1** as AOI 31 (Former Fire Training Area). Approximately 715 tons of PCB- and TCE-impacted soil was excavated from AOI 31 and disposed off-Site in 2003. ISCO with potassium permanganate, $KMNO_4$ was also performed on the source groundwater through a series of injections from 2004 through 2005. Post-ISCO treatment sampling in the source area found little to no organic carbon in the soil indicating that remaining TCE in the soil is negligible; TCE was predominantly present dissolved in groundwater.

Numerous groundwater investigations downgradient (southeast) of AOI 31 and annual groundwater monitoring through 2011 demonstrated that the TCE plume had extended approximately 1,500 feet from AOI 31 into an off-Site residential neighborhood. In 2004, a human health risk assessment (HHRA) was performed to assess the VIAP risk to neighborhood residents from the groundwater plume. The VIAP HHRA was reviewed by the U.S. Environmental Protection Agency (EPA), and it was concluded that the groundwater plume would not generate unsafe indoor air vapor concentrations inside homes in the neighborhood.

By 2011, the EPA had revised its HHRA approach for the VIAP and requested that RACER collect soil vapor (and sub-slab vapor for homes with basements) and indoor air samples for homes in the neighborhood where access was granted. The EPA also updated its health risk assessment for TCE in 2011, lowering its health screening values for both soil vapor and indoor air.

In 2012, HMA conducted a VIAP investigation at 10 homes near and overlying the TCE groundwater plume (**Figure 1**); the VIAP sample results are presented in the next section. In addition, groundwater monitoring from 2001 to 2017 has demonstrated that the leading edge of the groundwater plume has migrated approximately 318 to 428 feet over this 16-year period, indicating a plume velocity of approximately 19 to 27 feet per year. This plume velocity will factor significantly into the basis of in situ remediation design, as discussed later in this document.

1.3 VIAP Investigation Results

In the 2012 VIAP investigation, TCE was not detected in indoor air samples from any of the 10 homes, including crawlspace and basement indoor air samples[1]. TCE was detected in sub-slab vapor beneath one home (Home 7; **Figure 1**) at a concentration (230 ug/m^3) above the EPA's soil vapor screening level at the time (21 ug/m^3). The relatively higher TCE concentration in the sub-slab at this home is likely the result of the basement floor being closer to the groundwater source of TCE. Other homes investigated were slab on grade, had shallow crawl spaces, or were situated off the centerline of the plume. A vapor mitigation system was installed at Home 7 in July 2012.

The EPA issued a no further action decision for the VIAP to RACER via e-mail January 10, 2013, but only for the residential properties investigated (**Figure 1**) – not for groundwater as the vapor source. To address TCE in groundwater as a potential on-going VIAP source, EPA requested that a long-term VIAP monitoring program be conducted to account for spatial and temporal changes in the soil vapor plume immediately above the groundwater table at areas containing relatively elevated dissolved-phase concentrations of TCE. The EPA also recommended additional groundwater sampling to delineate the TCE plume edges and toe to assure identification of additional homes for potential VIAP assessment. In 2014, The Michigan Department of Community Health (now Health and Human Services) evaluated data from the 2012 VIAP investigation and concluded that vapor intrusion was likely *not* occurring in the homes sampled in the investigation, but also recommended continued monitoring of groundwater and soil vapor to ensure VIAP conditions remain acceptable.

Following the EPA's release of its final vapor intrusion guidance in June 2015, HMA conducted soil vapor and Geoprobe® groundwater sampling in June-July 2016 and February-July 2017 to delineate the dissolved-phase TCE vapor source and to assess the relationship between dissolved and vapor-phase concentrations of TCE. Sub-slab sampling at Home 8 was also performed in July and December of 2017 based on elevated TCE groundwater sample results from MW-400S, 401S, and 402S, which were installed by GHD in the right-of-way of Grantland Street and sampled in June 2016.

[1] An indoor air sample in an art room at Home 5 contained 3.7 ug/m^3 TCE, while the kitchen/dining room sample was non-detect for TCE. TCE was detected in soil vapor adjacent to the home at a concentration of 1.5 ug/m^3. The VIAP was considered incomplete based on the lack of correlation between soil vapor and indoor air results, the likelihood of an indoor air TCE source in the art room, and follow-up indoor air sampling (included a duplicate) that was non-detect for TCE.

Distribution of TCE in the groundwater, based on groundwater Geoprobe® investigation results from 2016 and 2017 and monitoring well sample results from 2014 through 2016, is shown on **Figure 4**. Soil vapor sample results from 2012 through 2018 above the TCE plume and near/within homes are presented on **Figure 5**, along with time-trend graphs of TCE groundwater concentrations for select monitoring wells from 2005 to 2018. A geological cross-section (A-A') along the full length of the TCE plume within the residential neighborhood is provided on **Figure 6**. The distribution of dissolved-phase TCE laterally and vertically is shown in cross-sections generally perpendicular to the plume on **Figures 7 through 10**.

The general CSM that HMA has developed is a shallow aquifer (8-10 feet) within sand (of variable grain size) in the upper 15 to 20 feet of the soil profile underlain by progressively finer-grained deposits. The groundwater plume is descending to the lower portion of the aquifer as it migrates downgradient. Coarser sand layers with higher permeability may be present in the lower portion of the aquifer. These more conductive layers transmit the higher concentrations of TCE. As noted earlier, long-term groundwater monitoring indicates a plume velocity ranging from 20-30 feet per year. A silty sand marks the base of the more permeable aquifer; although, this silty sand is still water bearing and may also be impacted with TCE.

The 2017 Geoprobe® investigation results (**Figures 4** and **6**) demonstrated that TCE concentrations notably increase with depth, and the plume extends farther downgradient (than previously believed) to the south of Grantland Street under five additional residential properties not investigated in 2012 – Homes 18, 19, 21, 22, and 23. To the north of Grantland Street, TCE is also present in groundwater under portions of Homes 20 and 25, with the northern boundary of the TCE plume delineated by the investigation. Based on the groundwater results, soil vapor sampling for VIAP risk assessment was performed at these homes (except Home 23 and 25 since TCE groundwater results are less than the EPA's groundwater vapor screening level – 10 ug/l), and sub-slab samples were collected from Home 8.

Sub-slab concentrations of TCE at Home 8 on two sample events in 2017 (**Figure 5**) exceeded the EPA soil vapor screening level. A vapor mitigation system was installed January 2018 at Home 8. TCE concentrations in soil vapor samples collected in 2017 and 2018 at homes downgradient of Home 8 (Homes 17 through 22) are below EPA soil vapor screening levels. The homeowner of Home 9 has never allowed access.

While these results indicate that unacceptable VIAP risk is currently not likely at homes south of Grantland Street, TCE groundwater concentrations approximately two-times higher are immediately upgradient in right-of-way monitoring wells, MW-400S (430 ug/l) and MW-402S (330 ug/l) (**Figure 6**). Considering estimated groundwater migration rates of TCE for the geology (discussed later in this plan) and that significant degradation of TCE has not been observed, a potential VIAP risk at the noted homes south of Grantland Street cannot be omitted. Additionally, the 2018 sample from MW-404S immediately upgradient of Home 22, contained a TCE groundwater concentration of 39 ug/l – greater than the EPA groundwater vapor screening level of 10 ug/l. Given well published concerns related to temporal variability in TCE soil vapor concentrations, further monitoring of the homes south of Grantland Street is advisable.

In June 2018, an additional Geoprobe® investigation was performed along the east edge of the Home 6 property to evaluate whether potentially higher TCE concentrations may be present in this portion of the plume. This concern is based on the CSM depictions (**Figures 6 through 10**) derived from the 2017 Geoprobe® investigations. The soil and groundwater TCE sample results from five borings advanced in 2018 are presented on **Figure 11**. The soil and groundwater results

from PB18-4 and PB18-5, relative to TCE concentrations in borings to the north and south, suggest that a significant TCE mass may be somewhat localized vertically and horizontally within the soil at this location along the plume. Concentrations reported in the soil are much higher than in the groundwater at these borings and indicate continued partitioning from adsorbed to dissolved phase, i.e., continued source for the groundwater plume. These locations represent the highest observed TCE concentrations in groundwater along the length of the plume and lie immediately upgradient of the two homes with vapor mitigation systems. Based on these findings and the VIAP risk uncertainties to additional downgradient receptors, consideration for groundwater remediation of the vapor source in this and additional areas was mutually agreed upon between RACER and the EPA and has been the subject of study in 2017-2018.

1.4 Preliminary Technology Screening

Based on the long-term VIAP monitoring results and refinement of the TCE plume CSM summarized above, the HMA technical team sought to answer the question *"Can we do something to treat TCE mass to lessen the potential for future VIAP risk to downgradient residents?"*

In the fall of 2017 through the winter 2018, preliminary technology screening was undertaken. The following key acknowledgements weighed heavily in the HMA technical team's initial screening of technologies:

- Physical location of the plume is logistically challenging with respect to its length and access, i.e., we do not have access to the plume everywhere.
- Redox state of the plume is highly oxic, which does not favor reductive technologies (**Appendix A**).
- Hydrogeologic nature of the plume is favorable for "surgical" treatment in the vertical dimension, i.e., the majority of it resides in a highly conductive layer for targeted treatment, and it moves at a plume velocity amenable to in situ degradative treatment.
- Any in situ technology must be capable of relatively rapid degradation of TCE and yet exhibit sustained concentration decreases of dissolved TCE over time without a substantial rebound in concentrations. The technology selected must be fast acting yet offer some measure of longevity.

Based on these key considerations, ISCO via a sodium persulfate oxidant was preliminarily identified as a viable candidate technology for the site. Reductive technologies such as enhanced reductive dechlorination (ERD) or zerovalent iron (ZVI) were not advanced beyond this preliminary screening because dissolved oxygen (DO) and oxidation-reduction potential (ORP) data from the plume demonstrated the groundwater was highly oxic, which would pose a challenge to reductive technologies. Driving this oxic groundwater to the anoxic reduced conditions required for these reductive technologies seemed preliminarily cost prohibitive and aesthetically undesirable. Furthermore, ERD is generally slow to effect change in TCE concentrations. Thus, ISCO was preliminarily vetted further in mid-2018 via a series of pilot borings, sampling and analysis, and an aquifer pump and recharge test.

1.5 Preliminary Design Data Acquisition

In the summer through fall 2018, HMA undertook a Preliminary Design Data Acquisition phase of work to collect key data to assess if ISCO could be feasible at the site. Key work tasks included:

- Drilling and sampling of two Geoprobe™ boring transects that provided soil and groundwater data and further plume delineation. **Figure 7** conveys the locations of these borings, related soil and groundwater results, and the resulting geologic cross-section.
- Physical saturated soil testing, such as grain size distribution (GSD) and fraction of organic carbon (FOC), the results of which are included in **Appendix B**.
- Aquifer pump tests under extraction and injection only conditions at EW-1 (**Figure 11**).
- Native Persulfate Soil Oxidant Demand sampling and analysis by PeroxyChem (**Appendix C**).

Key results from this Preliminary Design Data Acquisition include:

- Native persulfate soil oxidant demand is low (1.46 g/kg) and should not hinder an ISCO effort to the point of infeasibility.
- Saturated soil is amenable to pumping and injecting water as supported by the GSD data (**Appendix B**) and pump test observations.
- Pump test findings suggest a hydraulic conductivity, K, of the fine to coarse sand layer of 50-100 feet/day.
- Aquifer characteristics predicted an “injection only” zone of influence (ZOI) of over 30 feet in diameter (**Figure 11**) based on MODFLOW predictions with an injection flow rate of 3-5 gallons per minute for 8 hours.
- The oxic state of plume was further confirmed based on additional field groundwater sampling parameters (**Appendix D**).
- Coincident saturated soil and groundwater sampling and analysis revealed more mass on saturated soils and in groundwater than previously expected (**Figure 7** cross section C-C’ and **Table 1**).

These findings, particularly the low persulfate native soil oxidant demand and the reasonable predictions of ZOI under inject only conditions, further supported the feasibility of ISCO as an in situ treatment technology for the TCE plume.

2.0 PRELIMINARY DESIGN

This section highlights key aspects of the current conceptual design of the ISCO treatment system and related monitoring program.

2.1 Multiple Transect Locations and Configuration

The overall remedial objective is to reduce or degrade TCE mass to reduce risk associated with the VIAP and to restrain the spread of the plume. As noted, the current plume resides in a residential neighborhood such that access to the entirety of the plume all at once is not feasible. Based on plume movement over the past 15-16 years, the TCE plume has been documented to

move via groundwater advection at an average velocity of 20-30 feet per year. A plume velocity of 30 feet per year has been assumed in the design of the proposed ISCO program.

In light of these considerations, the technical team proposes to deploy ISCO in four transects (**Figure 2**) in an effort to split or divide the plume into time manageable segments. Chemical oxidant is proposed to be delivered at these locations via direct injection. The delivered oxidant will then create a transect of "clean" groundwater (and saturated soil), i.e., a substantial reduction in TCE concentrations. The treated groundwater will migrate out of the treatment transect(s) and will be replaced with untreated groundwater through natural flow. Thus, the treatment transects will continually degrade the TCE as it moves into and through the treatment window. This degradative treatment process will continue until the delivered oxidant has been consumed. Several other factors will likely influence the longevity of a treatment event, including:

- Native persulfate oxidant demand (which should be most demanding in the first injection events and get progressively less influential over the ISCO treatment program);
- Groundwater and/or plume velocity; and
- Re-sorption of TCE back on to the saturated soil (which was previously "cleaned" or treated by the oxidation).

In light of these factors, TCE rebound in aqueous concentration post-injection will be an important performance metric in determining time interval between events. Once the longevity of the aqueous TCE degradation has expired (to be determined empirically by field monitoring), delivery of additional oxidant will be repeated. These four ISCO transects are selected based on:

- TCE mass in groundwater and adsorbed to soil in the saturated zone.
- Known reliable access with accepting property owners.
- A reasonable travel time for the segmented plume(s) through the established ISCO zones. Each segmented plume will flow through an ISCO treatment transect over the course of the next 4-7 years.

Specifically, each transect was selected as follows:

- Zone 1 – plume width in area of highest known mass (Home 6) and owner relations.
- Zone 2 – treatment of plume center of mass and soil vapor/VIAP area (Home 7/8 boundary) and owner relations.
- Zone 3 – splits plume into manageable segment and takes advantage of access at north ROW of Grantland Street.
- Zone 4 – treatment near the downgradient portion of groundwater plume in area of known TCE soil vapor.

The remainder of the plume that is downgradient of the Zone 4 treatment transect is expected to also reduce in concentration due to treated water flowing from the Zone 4 transect and natural dilution and dispersion within the shallow aquifer.

Are we confident that we don't need injections near the top of the screen?? May need to do localized determinations of screen depth for treatment/delivery

2.2 Delivery Method

Permanent delivery wells are intended to be installed along each transect. Spacing of the delivery wells is a critical aspect and will require field planning to layout each transect. Each well will be completed with a flush-mount protective cover to reduce imposition upon the property owners. Permanent wells are highly recommended for the proposed ISCO treatment based largely on the requirement for repeated oxidant delivery. Permanent wells allow the technical team to perform these repeated oxidant deliveries with minimal heavy equipment and mobilization effort. Wells also allow the treatment to target the vertical zone of interest, which is the medium to coarse sand just overlying the fine silty sand, which generally resides at 15-17 feet below grade in the proposed treatment zones. The proposed delivery wells will be screened at 13-18 feet below grade but will be based on field sampling of the soil and groundwater profile prior to delivery well installation. Should baseline sampling of a proposed transect indicate a longer screened interval is warranted, screen length and placement will be adjusted accordingly. **Figure 12** presents design details on typical well construction. The use of permanent delivery wells also provides monitoring and operational flexibility and ability to address possible contingencies.

Key delivery system design details include:

- Delivery well spacing – approximately 20 feet apart, which provides overlap of injection points based on the 30-foot predicted diameter ZOI.
- Delivery well depth – targeted to lower portion of the aquifer where a layer of higher permeability sand is generally present. Delivery wells will typically be screened from 13-18 feet below grade, pending field review of soil layers and baseline soil/groundwater sampling in the proposed transect locations.
- Delivery well design detail – use of continuous slot screens constructed of chemically resistant polyvinyl chloride (PVC) materials;
- Skid-mounted inject only delivery system – the use of a small, portable skid-mounted inject only delivery system will allow for ease of logistics and handling during delivery in the residential neighborhood. Oxidant delivery for the full system will occur over the course of one week.
- City water will be used for oxidant mixing and delivery. Water will be obtained from a nearby fire hydrant on Grantland Street through cooperation with the City of Livonia. This is desirable because readily available municipal water will be free of solids and should have low to no oxidant demand.

2.3 Oxidant

Klozur® SP, a sodium persulfate product manufactured by PeroxyChem, is proposed as the oxidant (with alkaline activation) for treatment. Degradative mechanisms of this oxidant are known and accepted in the industry (**Appendix E**). TCE is expected to be oxidized to end products of carbon dioxide, chloride ion, and water, with little if any generation of vinyl chloride. The rationale for selection Klozur® SP over other oxidants is as follows:

- Low persulfate native oxidant demand (as noted in Section 1.4),
- Proven effectiveness on TCE,
- Ease of handling and use, and

- Rate of reaction and longevity.

Sodium persulfate is generally longer lasting than other highly reactive oxidants and easier to handle, which offers better and safer logistics in the field. Klozur® SP (with alkaline activation) is expected to last 288 days under ideal, controlled conditions (e.g., laboratory environment). In reality, transient metals, carbonates, organic matter, and TCE, may cause oxidant to be consumed more rapidly than the 288 days, e.g., several months. Analysis of the native soil oxidant demand indicated low demand (1.46 grams / kilogram of soil), but field longevity is difficult to predict and will be assessed as part of post-injection monitoring. Final design data collection will include additional persulfate native soil oxidant demand analyses within the proposed transects.

Based on previous sites, the degradative effects of a Klozur® SP delivery event will likely persist several months. As discussed in Section 2.1, the longevity of a delivery event will be empirically derived based on post-delivery monitoring.

Table 2 summarizes the currently proposed initial delivery event details for each ISCO transect. Note that sodium hydroxide will be used as the alkaline activator, and the sodium hydroxide volume is reflected the Table 2 "Injection Volumes". Note that the Klozur® SP dosages and related PeroxyChem calculations are included in Appendix E. All four treatment zones were based on the 30 feet per year plume velocity and mass/concentration estimates shown in Appendix E. However, in an effort to determine if additional oxidant would provide additional longevity, the dosages or Klozur® SP concentrations for Zones 1 and 3 have been doubled for the first event. The safety data sheet for Klozur® SP and sodium hydroxide are also provided in **Appendix E**.

2.4 Operation, Maintenance, and Monitoring

This section outlines the performance monitoring program and presents an "Adaptive Management" approach for operation, maintenance, and monitoring (OM&M). Monitoring parameters are organized into the following temporal frequencies:

- Baseline conditions before delivery,
- Real-time during delivery,
- Monthly following delivery, and
- Quarterly following delivery.

The monitoring program, including parameter list for each type of monitoring and locations, is summarized in **Table 3**. Monitoring locations are also listed in **Table 3** and are shown on **Figure 2**. Baseline parameters will be a comprehensive list of parameters to track over the lifetime of the ISCO treatment system to document both performance and the minimization of unintended consequences. Real-time operational parameters will serve as "live" metrics of delivery and distribution of oxidant in the intended treatment zones. Monthly monitoring post-oxidant delivery will focus predominantly on the performance metrics of TCE concentration reductions and oxidant longevity. Finally, quarterly monitoring will be performed to track the effects of the ISCO treatment program on the overall plume geometry.

As diagramed in **Figure 3**, operation of the ISCO treatment program will follow an adaptive management approach, i.e., we will deliver, monitor, make adjustments from the feedback data, and repeat the cycle. In particular, oxidant delivery frequency and oxidant dosage per delivery event are anticipated to change over time. As native oxidant demand is overcome by the initial oxidant delivery events, an increase in longevity of the oxidant delivery events may occur, i.e., TCE concentration reductions may be sustained for longer durations. In addition, less oxidant may be required per delivery event over time as the native oxidant demand is likely depleted by the early delivery events.

2.5 Contingency Planning

This section briefly discusses possible contingencies. The primary contingency will be to address poor performance, particularly if we are seeing that the degradative effect of delivery events is too short, i.e., we are having to deliver too frequently. As shown in **Figure 3**, consideration will be made to modifying the delivery locations or spacing and/or adding a low-solubility oxidant Klozur® KP, which has much more longevity (but will react slower) to the existing treatment transects in addition to the much more soluble Klozur® SP. In this way, the augmented ISCO treatment zones would likely last several years without requiring additional delivery events. These contingencies will be assessed based on data acquired during the first two years of operation.

3.0 SCHEDULE

As shown in **Figure 3**, the ISCO treatment process is currently in the Planning Phase. A task schedule for the remainder of 2019 is as follows:

- June 2019
  - Submit a draft ISCO Work Plan to regulatory stakeholders
  - Continued planning and design data acquisition (permitting, additional sampling)
- July – August 2019
  - Regulatory review and engagement
  - Final Work Plan
- September 2019
  - Planning and final design
  - System infrastructure installation (e.g., delivery wells)
  - Neighborhood outreach
  - EGLE (formerly MDEQ) In Situ Review TAPS Team (InSiRT) Meeting
- October 2019 through March 2020
  - Baseline data collection
  - Initial delivery event and performance monitoring
- November 2019 through April 2020
  - Performance monitoring
  - Determination of Delivery Event 1 longevity
  - Planning for Delivery Event 2 in 2020.

FIGURES

MW-G-2S
694.07

MW2-01
692.58

AOI 31

Amrhein Road

Grantland Street

LEGEND

- GROUNDWATER MONITOR WELL LOCATION - ACTIVE
- GROUNDWATER MONITOR WELL LOCATION - ABANDONED
- INDOOR AIR AND/OR SOIL GAS SAMPLED
- PLANNED INVESTIGATION PROPERTY
- APPROXIMATE 10 μg/L TCE GROUNDWATER PLUME OUTLINE - 2017
- INDICATES UNDEFINED BOUNDARY OF AOI 31 OFF SITE

GROUNDWATER ELEVATION 9/8/2010
1-FOOT CONTOUR INTERVAL
TAKEN FROM CRA MAP

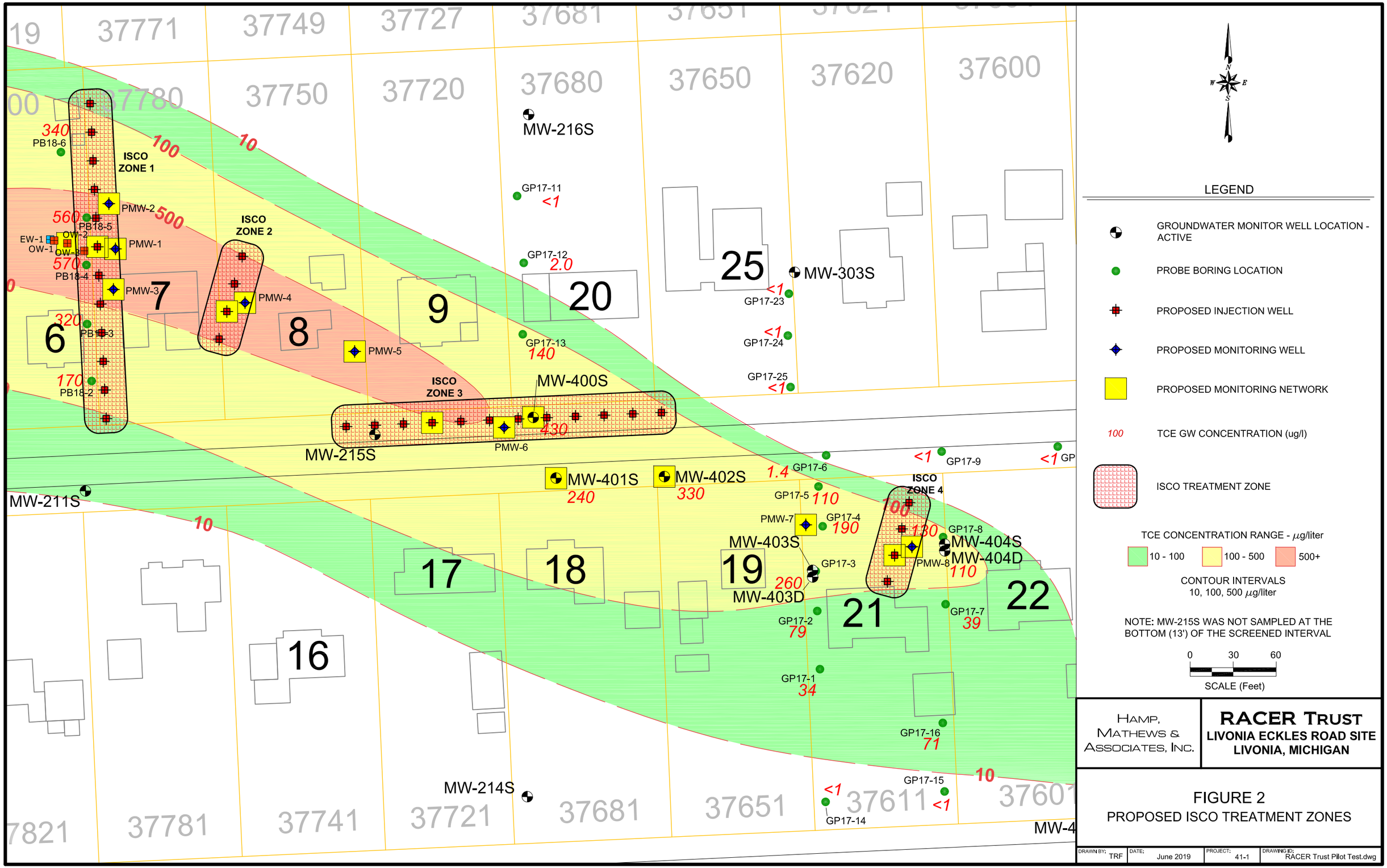
0 100 200
SCALE (Feet)

HAMP, MATHEWS & ASSOCIATES, INC.

RACER TRUST
LIVONIA ECKLES ROAD SITE
LIVONIA, MICHIGAN

FIGURE 1
SITE LOCATION/AOI 31 AND OFF-SITE RESIDENTIAL NEIGHBORHOOD

DRAWN BY:	DATE:	PROJECT:	DRAWING ID:
TRF	May 2019	41-1	RACER Trust Base Map.dwg



HAMP, MATHEWS & ASSOCIATES, INC.

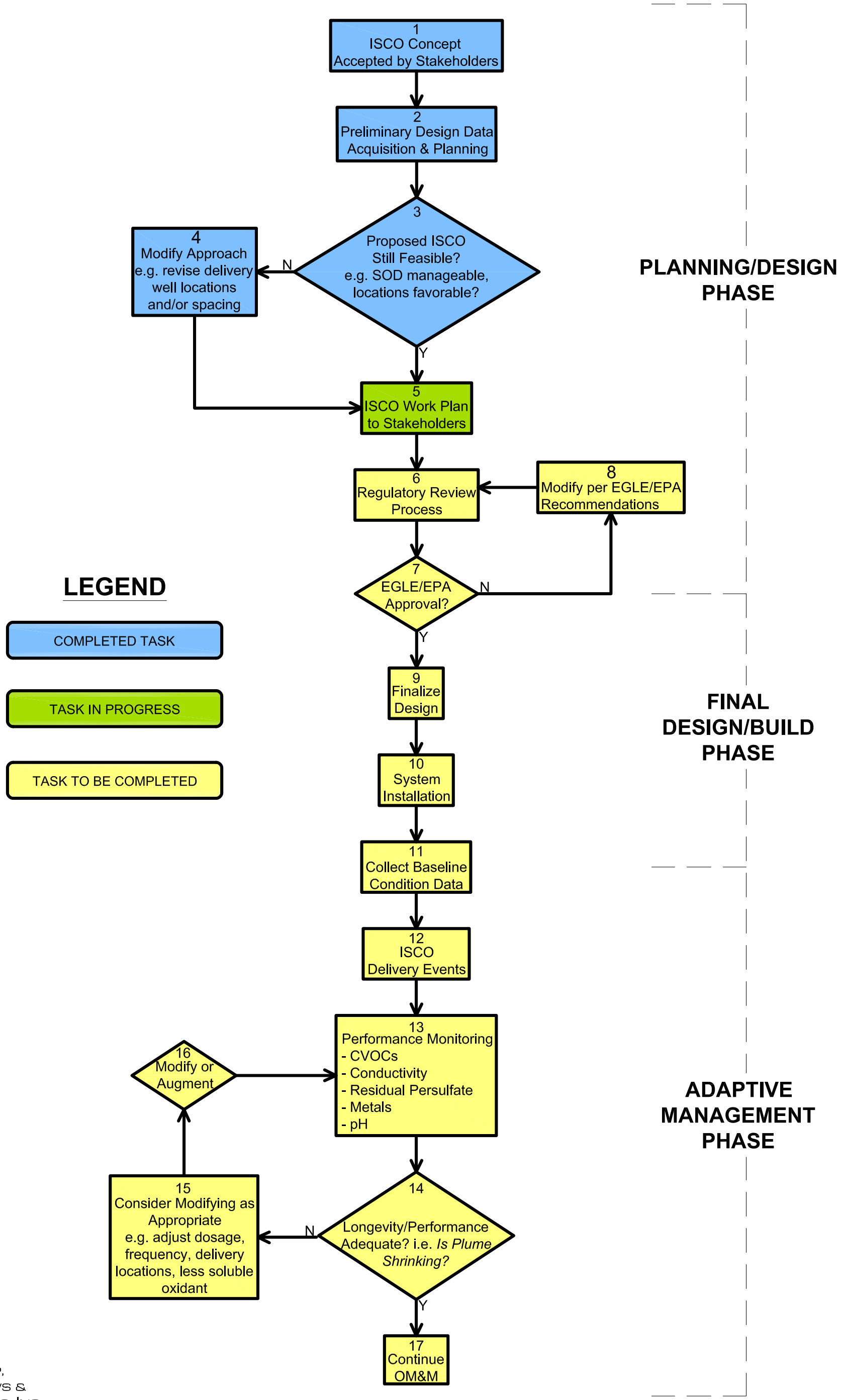
RACER TRUST
LIVONIA ECKLES ROAD SITE
LIVONIA, MICHIGAN

FIGURE 2
PROPOSED ISCO TREATMENT ZONES

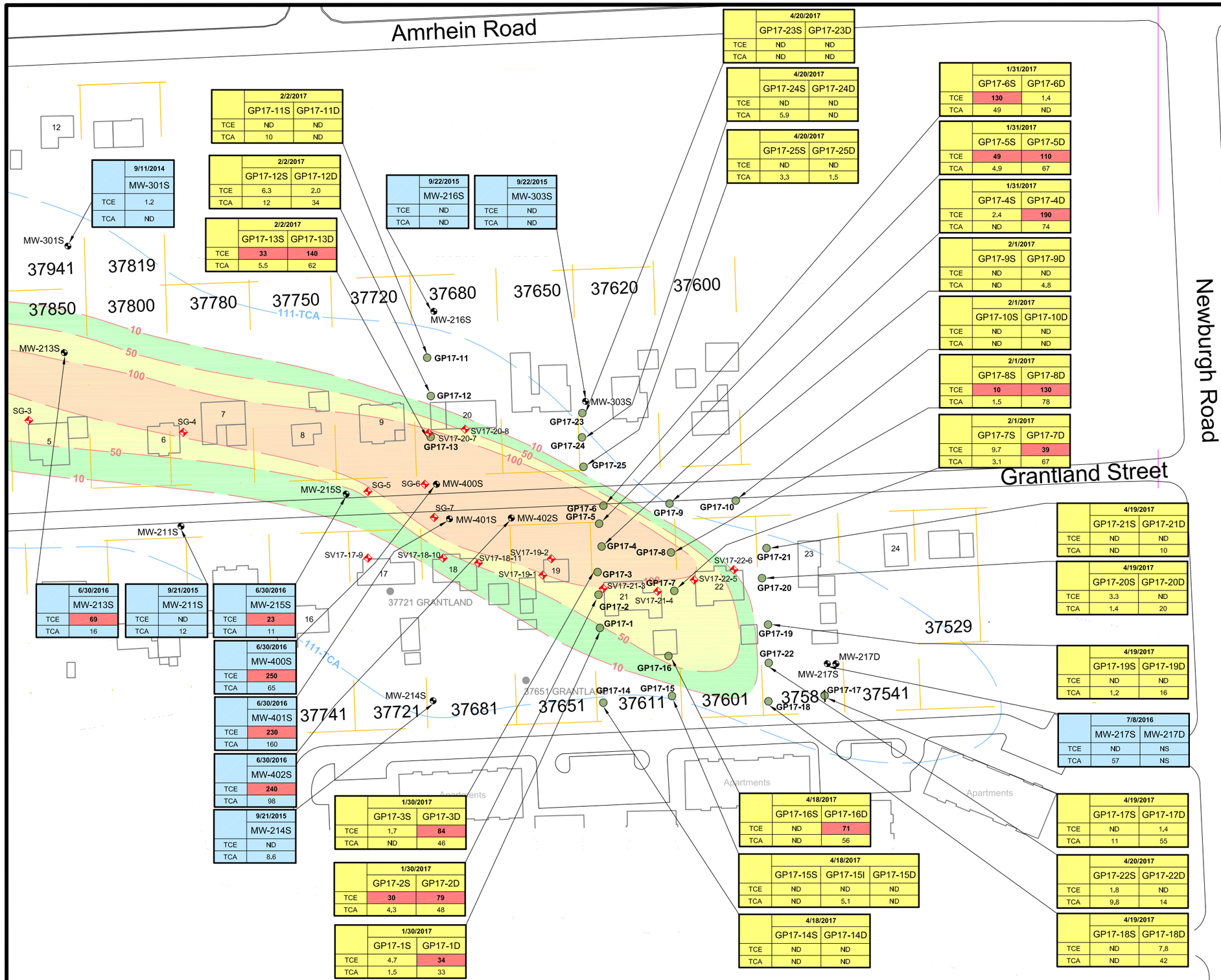
DRAWN BY:	DATE:	PROJECT:	DRAWING ID:
TRF	June 2019	41-1	RACER Trust Pilot Test.dwg

RACER Trust

Figure 3 - ISCO Strategy/Process Flow



Hamp, Mathews & Associates, Inc.



	2/2/2017	
	GP17-11S	GP17-11D
TCE	ND	ND
TCA	10	ND

	2/2/2017	
	GP17-12S	GP17-12D
TCE	6.3	2.0
TCA	12	34

	2/2/2017	
	GP17-13S	GP17-13D
TCE	33	140
TCA	5.5	62

	9/11/2014
	MW-301S
TCE	1.2
TCA	ND

	9/22/2015
	MW-216S
TCE	ND
TCA	ND

	9/22/2015
	MW-303S
TCE	ND
TCA	ND

	4/20/2017	
	GP17-23S	GP17-23D
TCE	ND	ND
TCA	ND	ND

	4/20/2017	
	GP17-24S	GP17-24D
TCE	ND	ND
TCA	5.9	ND

	4/20/2017	
	GP17-25S	GP17-25D
TCE	ND	ND
TCA	3.3	1.5

	1/31/2017	
	GP17-6S	GP17-6D
TCE	130	1.4
TCA	49	ND

	1/31/2017	
	GP17-5S	GP17-5D
TCE	49	110
TCA	4.9	67

	1/31/2017	
	GP17-4S	GP17-4D
TCE	2.4	190
TCA	ND	74

	2/1/2017	
	GP17-9S	GP17-9D
TCE	ND	ND
TCA	ND	4.8

	2/1/2017	
	GP17-10S	GP17-10D
TCE	ND	ND
TCA	ND	ND

	2/1/2017	
	GP17-8S	GP17-8D
TCE	10	130
TCA	1.5	78

	2/1/2017	
	GP17-7S	GP17-7D
TCE	9.7	39
TCA	3.1	67

	4/19/2017	
	GP17-21S	GP17-21D
TCE	ND	ND
TCA	ND	10

	4/19/2017	
	GP17-20S	GP17-20D
TCE	3.3	ND
TCA	1.4	20

	4/19/2017	
	GP17-19S	GP17-19D
TCE	ND	ND
TCA	1.2	16

	7/8/2016	
	MW-217S	MW-217D
TCE	ND	NS
TCA	57	NS

	4/19/2017	
	GP17-17S	GP17-17D
TCE	ND	1.4
TCA	11	55

	4/20/2017	
	GP17-22S	GP17-22D
TCE	1.8	ND
TCA	9.8	14

	4/19/2017	
	GP17-18S	GP17-18D
TCE	ND	7.8
TCA	ND	42

	6/30/2016	
	MW-213S	
TCE	69	
TCA	16	

	9/21/2015	
	MW-211S	
TCE	ND	
TCA	12	

	6/30/2016	
	MW-215S	
TCE	23	
TCA	11	

	6/30/2016
	MW-400S
TCE	250
TCA	65

	6/30/2016
	MW-401S
TCE	230
TCA	160

	6/30/2016
	MW-402S
TCE	240
TCA	98

	9/21/2015
	MW-214S
TCE	ND
TCA	8.6

	1/30/2017	
	GP17-3S	GP17-3D
TCE	1.7	84
TCA	ND	46

	1/30/2017	
	GP17-2S	GP17-2D
TCE	30	79
TCA	4.3	48

	1/30/2017	
	GP17-1S	GP17-1D
TCE	4.7	34
TCA	1.5	33

	4/18/2017	
	GP17-16S	GP17-16D
TCE	ND	71
TCA	ND	56

	4/18/2017		
	GP17-15S	GP17-15I	GP17-15D
TCE	ND	ND	ND
TCA	ND	5.1	ND

	4/18/2017	
	GP17-14S	GP17-14D
TCE	ND	ND
TCA	ND	ND

LEGEND

- GEOPROBE SAMPLE LOCATIONS
- MONITOR WELL LOCATIONS - ACTIVE
- SOIL VAPOR SAMPLE LOCATIONS
- ESTIMATED TRICHLOROETHENE (TCE) ISOCONCENTRATION LINE - μg / LITER
- ESTIMATED 1,1,1-TRICHLOROETHANE (TCA) ISOCONCENTRATION LINE - 5 μg / LITER
- PROPERTY BOUNDARY LINE
- 24 HOME NUMBER

MONITORING WELL GROUNDWATER SAMPLE RESULTS	SAMPLE DATE
	WELL ID
TRICHLOROETHENE (TCE)	23
1,1,1 TRICHLOROETHANE	ND

GEOPROBE GROUNDWATER SAMPLE RESULTS	SAMPLE DATE	
	SAMPLED INTERVAL	
	SHALLOW (4.5' - 10')	DEEP (13' - 19')
TRICHLOROETHENE (TCE)	4.9	39
1,1,1 TRICHLOROETHANE (TCA)	ND	100

NOTE:
- ND = Not Detected
- NS = Not Sampled
- Units = μg/Liter

Detected over 10 μg/Liter

ESTIMATED TCE CONCENTRATION RANGE - μg / LITER

10* - 50 | 50 - 100 | 100+

* **NOTE:** 10 μg / LITER IS THE USEPA GROUNDWATER VAPOR INTRUSION SCREENING LEVEL (VISL-GW).

0 60 120

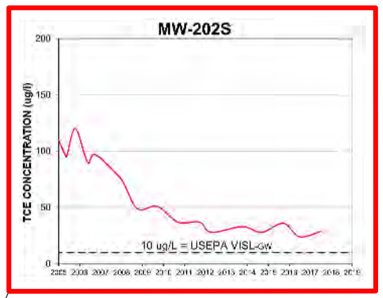
SCALE (Feet)

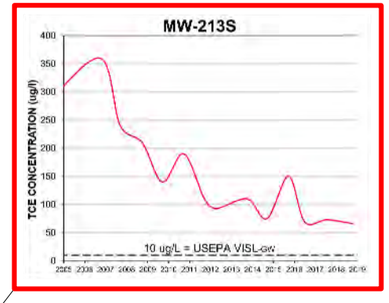
HAMP, MATHEWS & ASSOCIATES, INC.

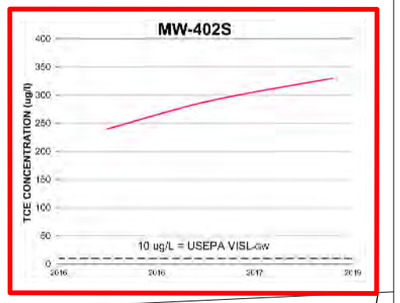
RACER TRUST
LIVONIA ECKLES ROAD SITE
LIVONIA, MICHIGAN

FIGURE 4
GEOPROBE INVESTIGATION GROUNDWATER SAMPLE RESULTS (2016-2017)

DRAWN BY:	DATE:	PROJECT:	DRAWING ID:
HGH, JLB, DJR	May 2019	41-1	GeoprobeGWMaps.dwg







SOIL VAPOR - HOME 1		
DATE	SS-1	SS-2
2/24/12	ND	ND
4/17/12	ND	0.74
5/15/12	ND	ND
11/19/18	3.2	18

SOIL VAPOR - HOME 1		
DATE	SS-1	SG-2
2/24/12	4.9	-
4/17/12	3.7	-
5/15/12	-	ND
6/27/16	-	ND
11/19/18	ND	ND

SOIL VAPOR	
DATE	SG-1
6/27/16	102.1
7/18/17	97

SOIL VAPOR	
DATE	SG-2
5/15/12	ND
6/27/16	ND
7/18/17	ND
11/19/18	ND

SOIL VAPOR - HOME 20		
DATE	SV-20-7	SV-20-8
7/19/17	ND	ND
11/20/18	ND	ND

SOIL VAPOR	
DATE	SG-5
6/27/16	3.3
7/18/17	11
11/19/18	ND

SOIL VAPOR	
DATE	SG-6
6/27/16	12.8
7/18/17	ND
11/19/18	ND

SOIL VAPOR	
DATE	SG-7
6/27/16	ND
7/18/17	ND
11/19/18	ND

SOIL VAPOR	
DATE	SG-3
2/27/12	ND
4/19/12	1.5
6/27/16	11.3
7/18/17	9.0
11/19/18	3.1

SOIL VAPOR - HOME 8		
DATE	SS-1	SS-2
2/24/12	11	ND
4/19/12	4.9	ND
7/18/17	240 / 240	12
12/5/17	210	31

SOIL VAPOR	
DATE	SG-4
3/2/12	ND
4/16/12	ND
5/2/12	ND
6/27/16	ND
7/18/17	ND
11/19/18	ND / ND

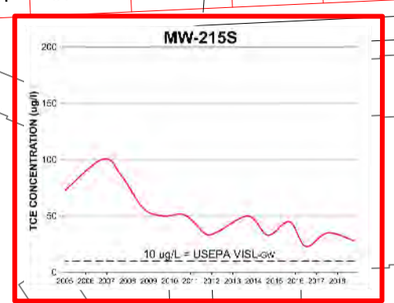
SOIL VAPOR	
DATE	SV-17-9
3/2/12	ND
4/16/12	ND
7/18/17	ND

SOIL VAPOR - HOME 18		
DATE	SV-18-10	SV-18-11
7/19/17	ND	ND
11/19/18	ND	ND

SOIL VAPOR - HOME 19		
DATE	SV-19-1	SV-19-2
7/19/17	ND	ND
11/20/18	4.3	ND

SOIL VAPOR - HOME 21				
DATE	SV-21-3	SV-21-4	VP-21-1	VP-21-2
7/19/17	ND	ND	ND	ND
12/14/18	NS	NS	ND / ND	ND
12/20/18	ND	ND	NS	NS

SOIL VAPOR - HOME 22				
DATE	SV-22-5	SV-22-6	VP-22-1	VP-22-2
7/19/17	ND / ND	ND	ND	ND
11/20/18	ND	ND	ND / ND	ND



Amrhein Road

Grantland Street

MW-202S MW-203S MW-205S MW-206S MW-211S MW-213S MW-214S MW-215S MW-216S MW-301S MW-303S MW-400S MW-401S MW-402S MW-403S MW-403D MW-404S MW-404D MW-405S MW-405D MW-406D MW-406S MW-217D

111-TCA 10ug/l

LEGEND

- SOIL VAPOR MONITORING LOCATION
- MONITOR WELL LOCATION - ACTIVE
- MONITOR WELL LOCATION - ABANDONED
- TRICHLOROETHENE ISOCONCENTRATION CONTOUR LINE

TCE CONCENTRATION RANGE - μg/liter

10 - 100 | 100 - 500 | 500+

* **NOTE:** 10 μg / LITER IS THE USEPA GROUNDWATER VAPOR INTRUSION SCREENING LEVEL (VISL-GW).

TCE SOIL VAPOR CONCENTRATIONS
μg/m³

SOIL VAPOR	
DATE	NS-1
6/27/16	ND

NS - NEAR SLAB **SS** - SUB-SLAB
ND - NON DETECT **SG** - DEEP SOIL GAS

* **NOTE:** 70 μg / m³ IS THE USEPA SOIL VAPOR SCREENING LEVEL.

0 75 150
SCALE (Feet)

HAMP, MATHEWS & ASSOCIATES, INC.

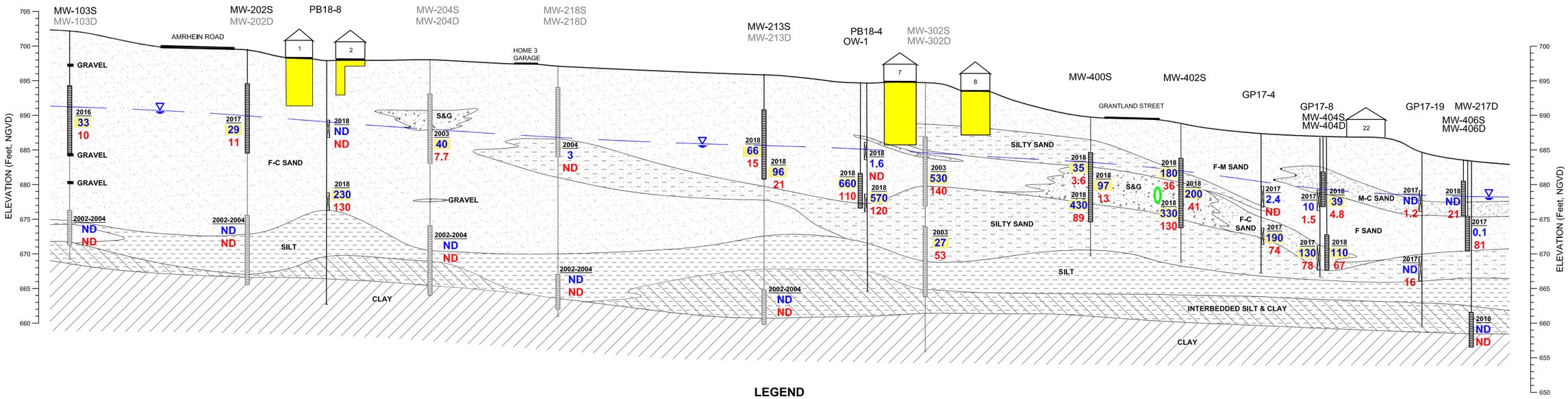
RACER TRUST
LIVONIA ECKLES ROAD SITE
LIVONIA, MICHIGAN

FIGURE 5
TRICHLOROETHENE SOIL VAPOR (2012-2018) AND APPROXIMATE GROUNDWATER PLUME (2017-2018)

DRAWN BY:	DATE:	PROJECT:	DRAWING ID:
HGH/TRF	April 2019	41-1	Soil Vapor-GW Plume 2017.dwg

A
NORTHWEST

A'
SOUTHEAST



LEGEND

CLAY

SAND (F=FINE) (M=MEDIUM) (C=COARSE)

SAND & GRAVEL

SILT

SILTY SAND

SILT & CLAY

ACTIVE WELL SCREEN

ABANDONED WELL SCREEN

DATA YEAR
TRICHLOROETHENE TCE(µg/L) 60
1,1,1 TRICHLOROETHANE TCA(µg/L) 60

ND - NOT DETECTED

0 SANITARY SEWER

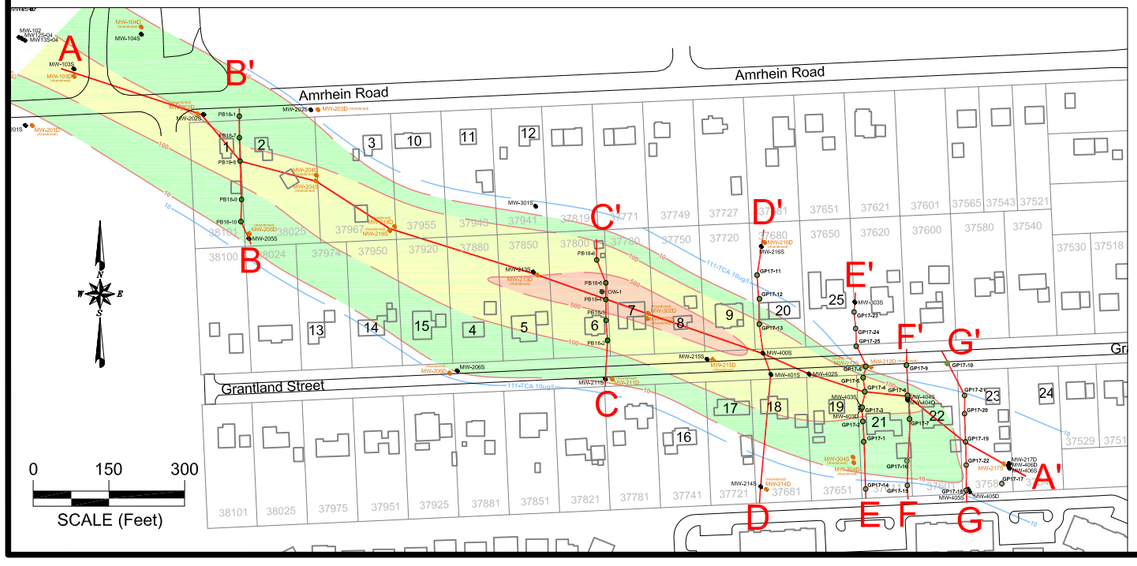
GROUNDWATER LEVEL (7-2017)

21 * **NOTE:** HIGHLIGHTED VALUES EXCEEDS 10 µg / LITER, THE USEPA GROUNDWATER VAPOR INTRUSION SCREENING LEVEL (VISL-GW).

GP - GEOPROBE® BORING

MW - MONITOR WELL

PB - PILOT BORING FOR GROUNDWATER TREATMENT



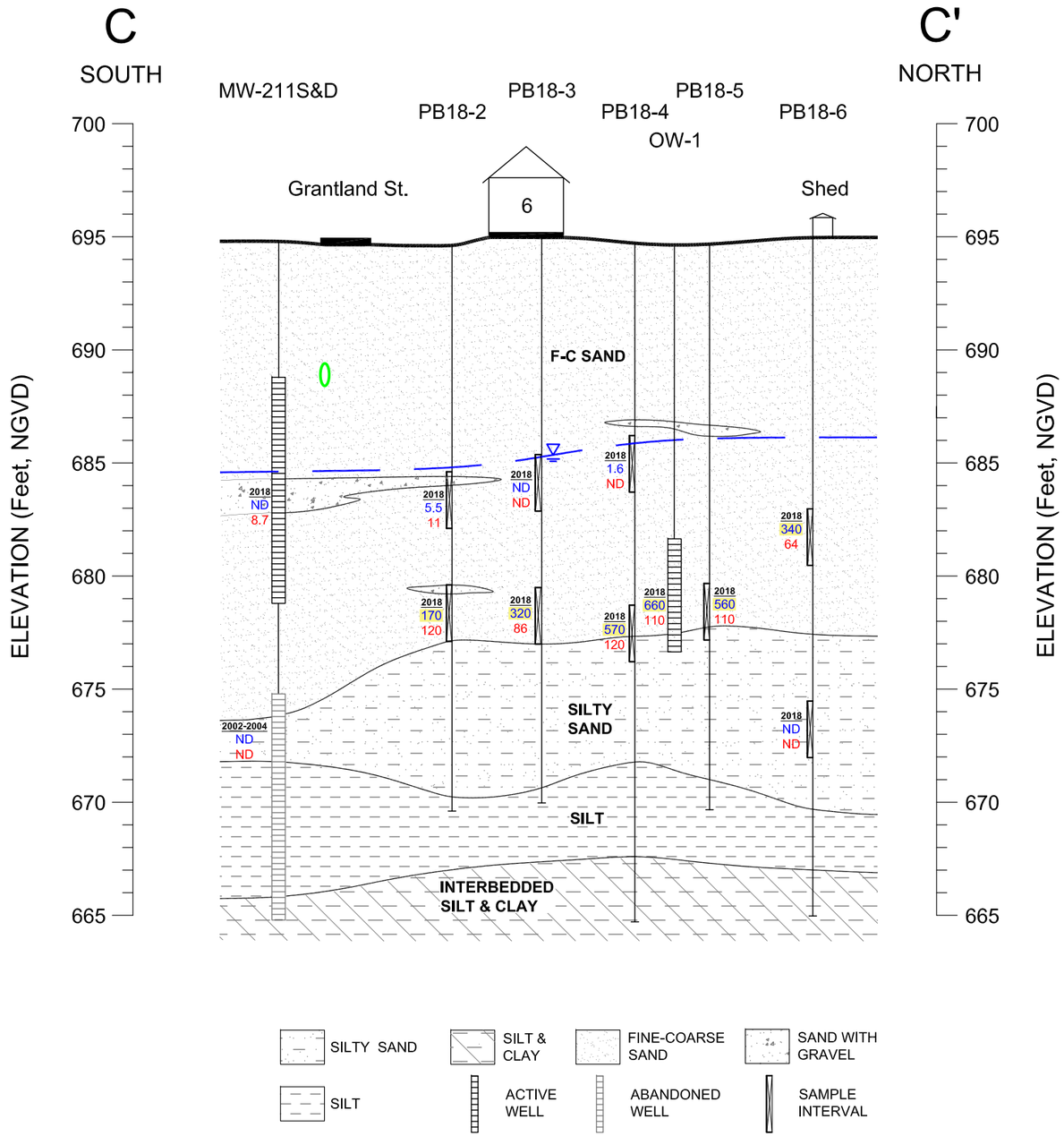
Horizontal Scale 1" = 150'
Vertical Scale 1" = 15'
Vertical Exaggeration 10X

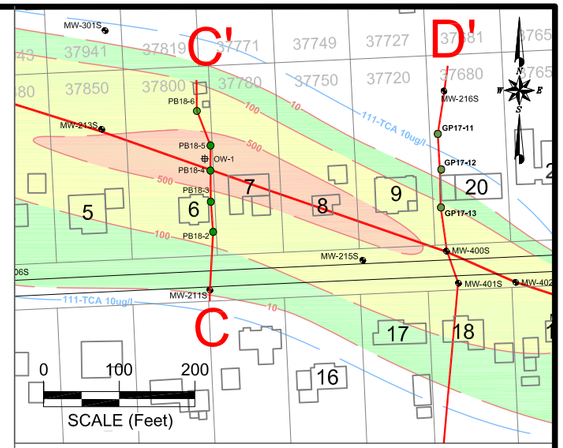
HAMP, MATHEWS & ASSOCIATES, INC.

RACER TRUST
13000 ECKLES ROAD SITE
LIVONIA, MICHIGAN

FIGURE 6
CROSS SECTION A - A'

DRAWN BY:	DATE:	PROJECT:	DRAWING ID:
JLB/HGH	December 2018	41-1	RACER X-Sections 2018.dwg





LEGEND

- GEOPROBE SAMPLE LOCATIONS
- MONITOR WELL LOCATIONS - ACTIVE
- 21 HOME NUMBER
- 21 * **NOTE:** HIGHLIGHTED VALUES EXCEEDS 10 μg / LITER, THE USEPA GROUNDWATER VAPOR INTRUSION SCREENING LEVEL FOR TCE (VISL-GW).
- TCE TRICHLOROETHENE (μg/L)
- TCA 1,1,1 TRICHLOROETHANE (μg/L)
- 0 SANITARY SEWER PIPE

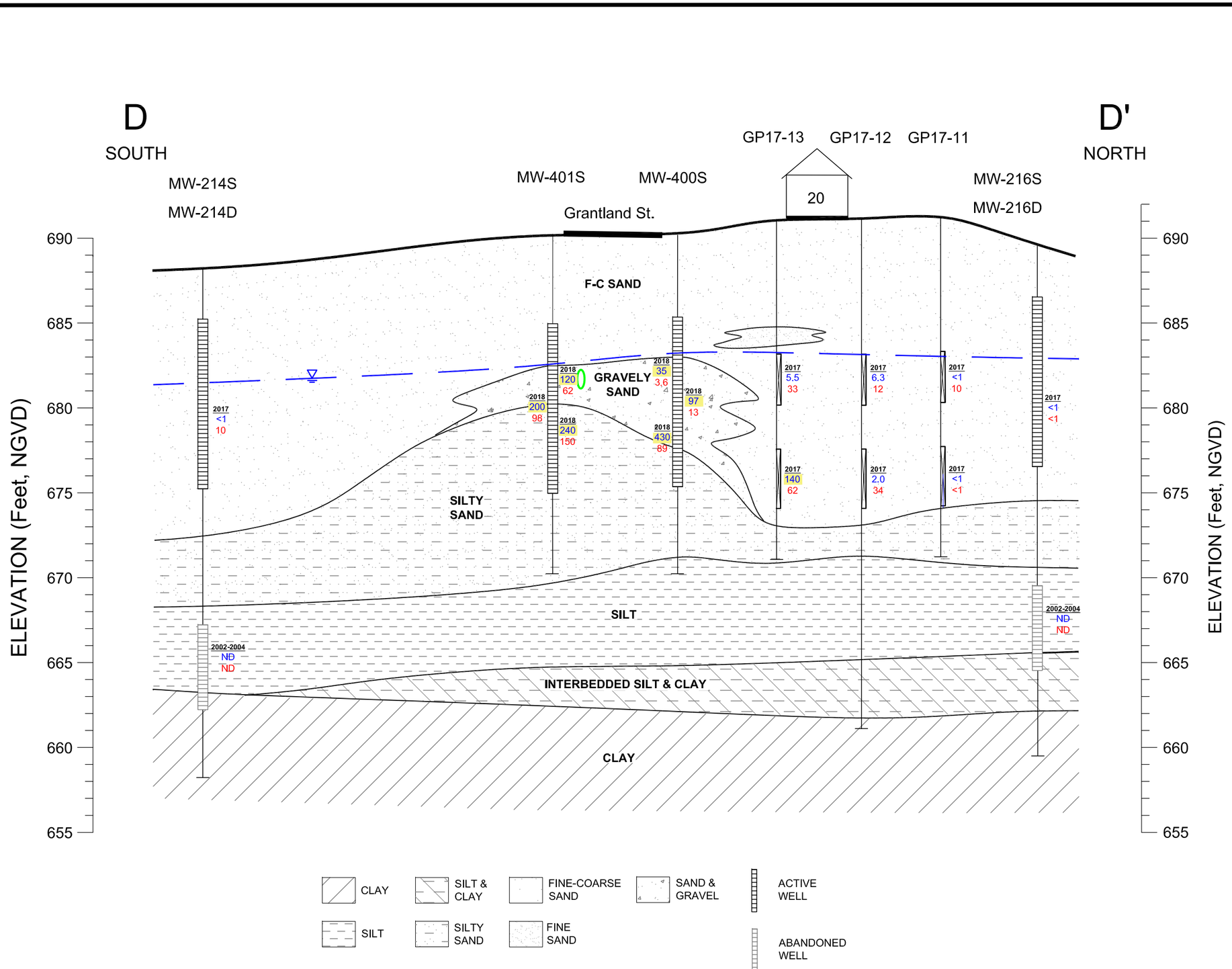
Horizontal Scale 1" = 60'
Vertical Scale 1" = 6'
Vertical Exaggeration 10X

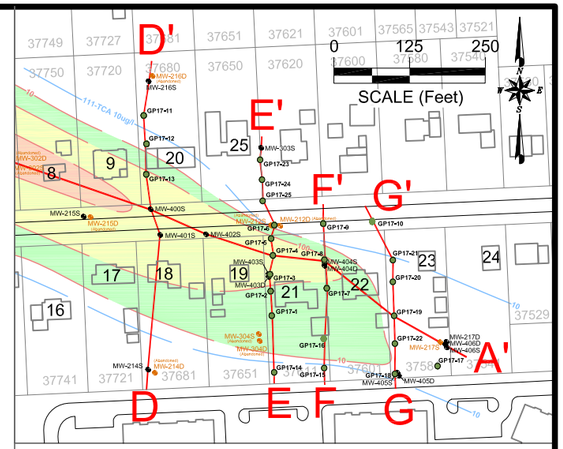
HAMP, MATHEWS & ASSOCIATES, INC.

RACER TRUST
13000 ECKLES ROAD SITE
LIVONIA, MICHIGAN

FIGURE 7
CROSS SECTIONS C-C'
2018 GROUNDWATER CONCENTRATIONS

DRAWN BY:	DATE:	PROJECT:	DRAWING ID:
DJR/HGH	December 2018	41-1	RACER X-Sections 2018.dwg





GEOPROBE SAMPLE LOCATIONS

MONITOR WELL LOCATIONS - ACTIVE

MONITOR WELL LOCATIONS - ABANDONED

PROPERTY BOUNDARY LINE

21 HOME NUMBER

SANITARY SEWER PIPE

21 * **NOTE:** HIGHLIGHTED VALUES EXCEEDS 10 μg / LITER, THE USEPA GROUNDWATER VAPOR INTRUSION SCREENING LEVEL (VISL$_{GW}$).

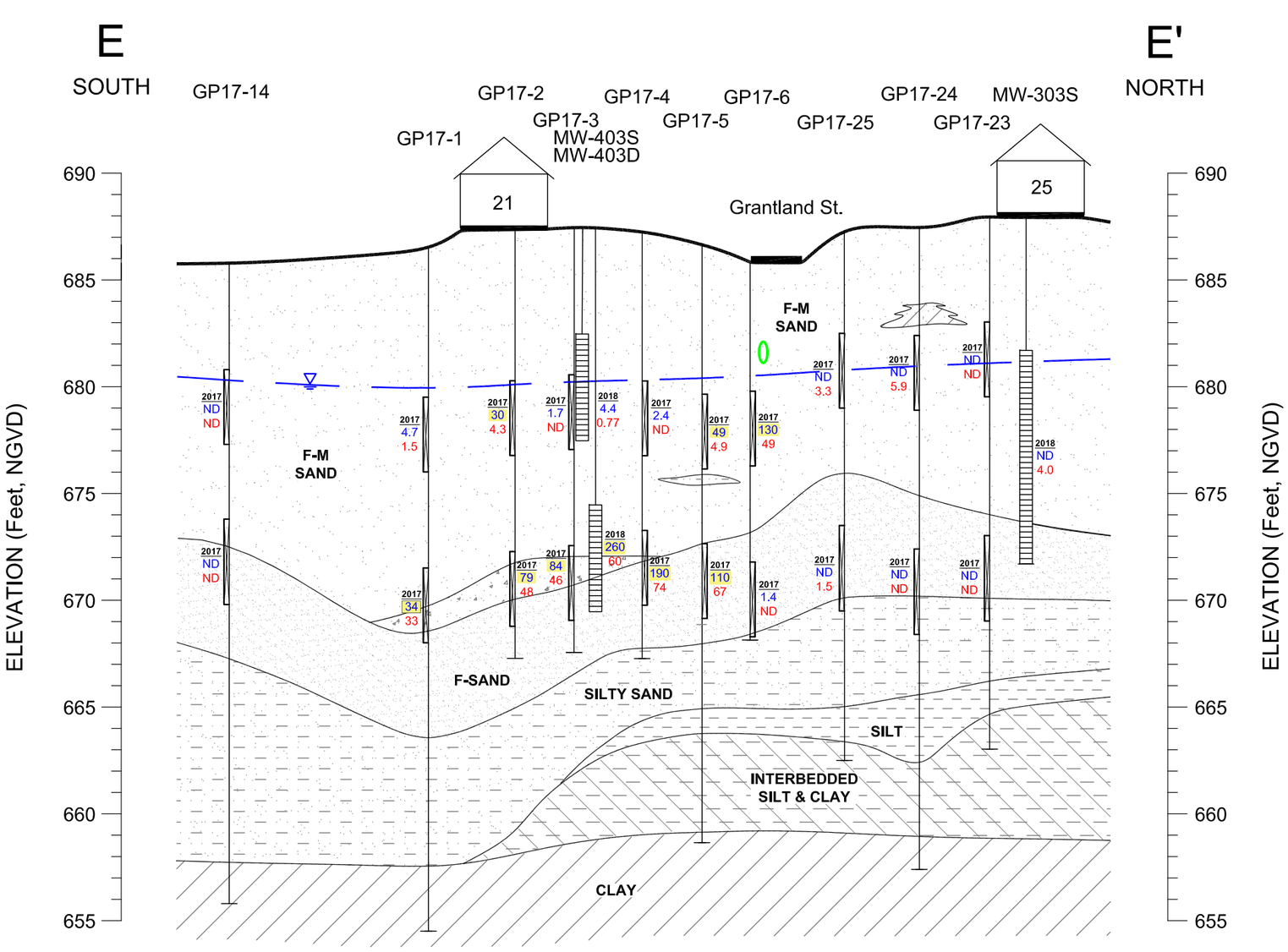
Horizontal Scale 1" = 60'
Vertical Scale 1" = 6'
Vertical Exaggeration 10X

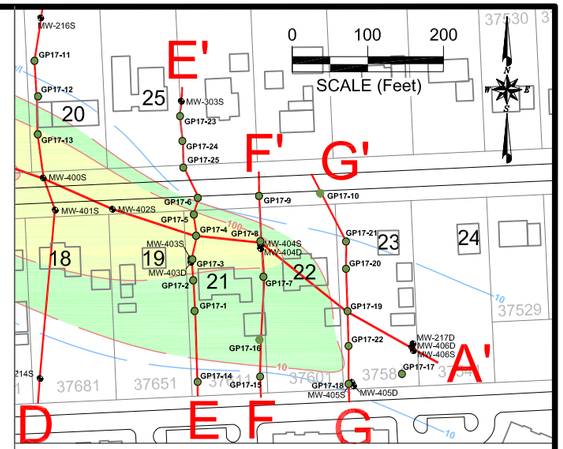
HAMP, MATHEWS & ASSOCIATES, INC.

RACER TRUST
13000 ECKLES ROAD SITE
LIVONIA, MICHIGAN

FIGURE 8
CROSS SECTIONS D-D'
2017-2018 GROUNDWATER CONCENTRATIONS

DRAWN BY:	DATE:	PROJECT:	DRAWING ID:
JLB/HGH	December 2018	41-1	RACER X-Sections 2018.dwg





LEGEND

- GEOPROBE SAMPLE LOCATIONS
- MONITOR WELL LOCATIONS - ACTIVE
- 21 HOME NUMBER
- 21 * **NOTE:** HIGHLIGHTED VALUES EXCEEDS 10 μg / LITER, THE USEPA GROUNDWATER VAPOR INTRUSION SCREENING LEVEL (VISL$_{GW}$).
- TCE TRICHLOROETHENE (μg/L)
- TCA 1,1,1 TRICHLOROETHANE (μg/L)
- 0 SANITARY SEWER PIPE

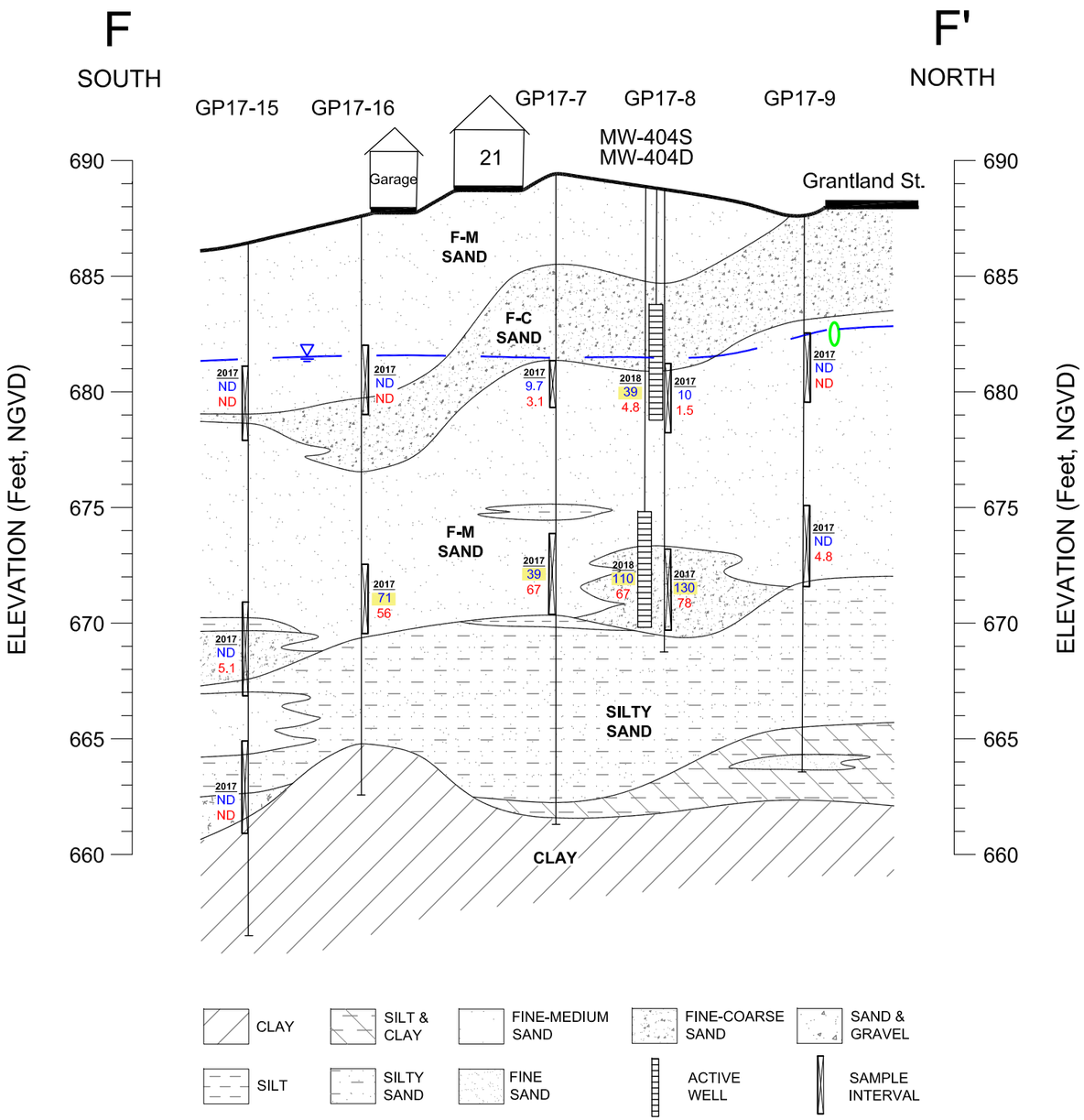
Horizontal Scale 1" = 60'
Vertical Scale 1" = 6'
Vertical Exaggeration 10X

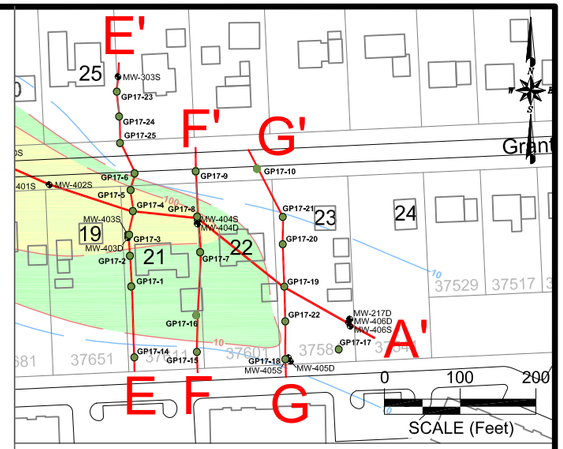
HAMP, MATHEWS & ASSOCIATES, INC.

RACER TRUST
13000 ECKLES ROAD SITE
LIVONIA, MICHIGAN

FIGURE 9
CROSS SECTIONS E-E'
2017-2018 GROUNDWATER CONCENTRATIONS

DRAWN BY:	DATE:	PROJECT:	DRAWING ID:
JLB/HGH	December 2018	41-1	RACER X-Sections 2018.dwg





LEGEND

- GEOPROBE SAMPLE LOCATIONS
- MONITOR WELL LOCATIONS - ACTIVE
- 21 HOME NUMBER
- 21 * **NOTE:** HIGHLIGHTED VALUES EXCEEDS 10 μg / LITER, THE USEPA GROUNDWATER VAPOR INTRUSION SCREENING LEVEL (VISL-gw).
- TCE TRICHLOROETHENE (μg/L)
- TCA 1,1,1 TRICHLOROETHANE (μg/L)
- 0 SANITARY SEWER PIPE

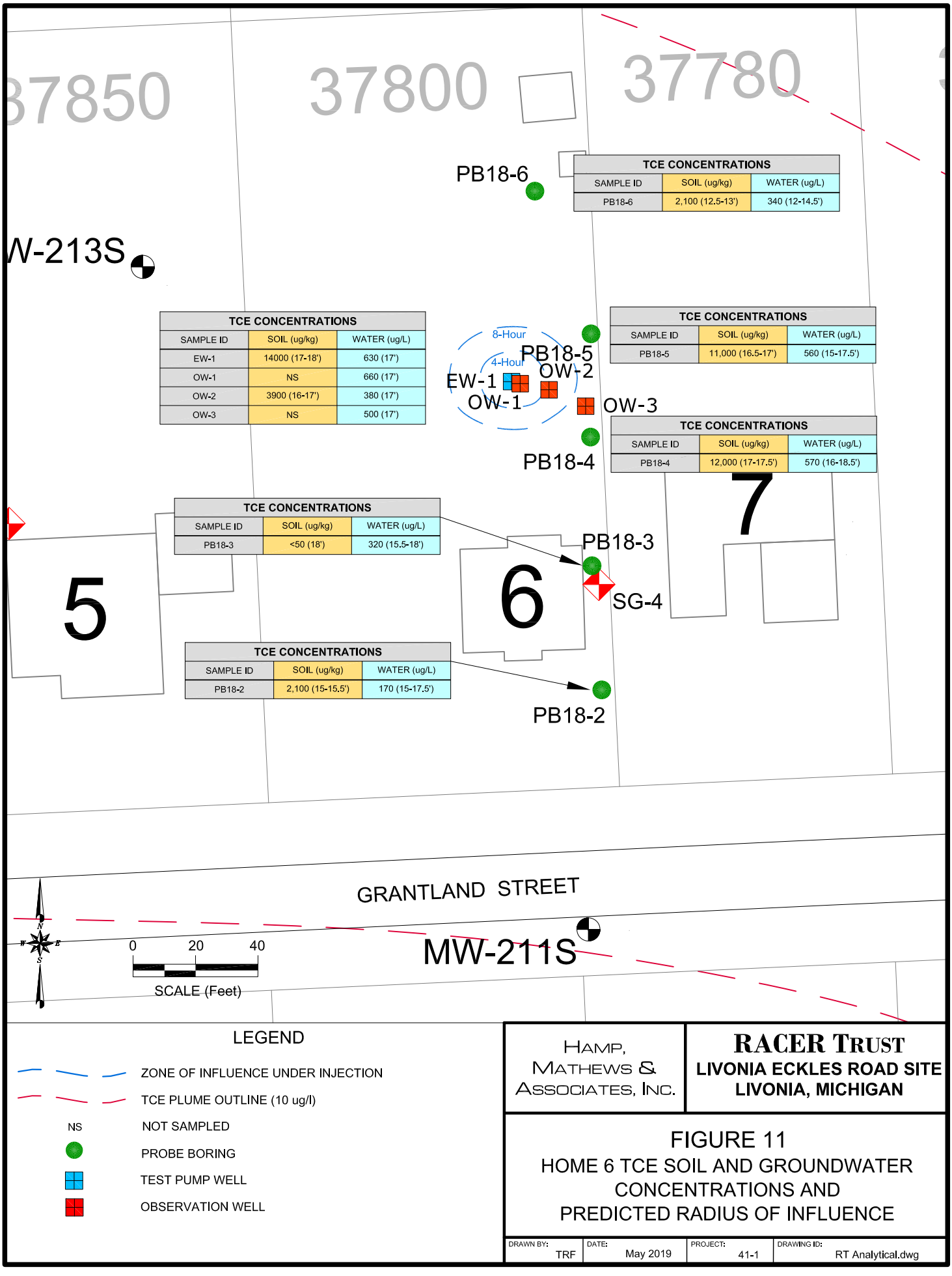
Horizontal Scale 1" = 60'
Vertical Scale 1" = 6'
Vertical Exaggeration 10X

HAMP, MATHEWS & ASSOCIATES, INC.

RACER TRUST
13000 ECKLES ROAD SITE
LIVONIA, MICHIGAN

FIGURE 10
CROSS SECTIONS F-F'
2017-2018 GROUNDWATER CONCENTRATIONS

DRAWN BY:	DATE:	PROJECT:	DRAWING ID:
HGH	December 2018	41-1	RACER X-Sections.dwg

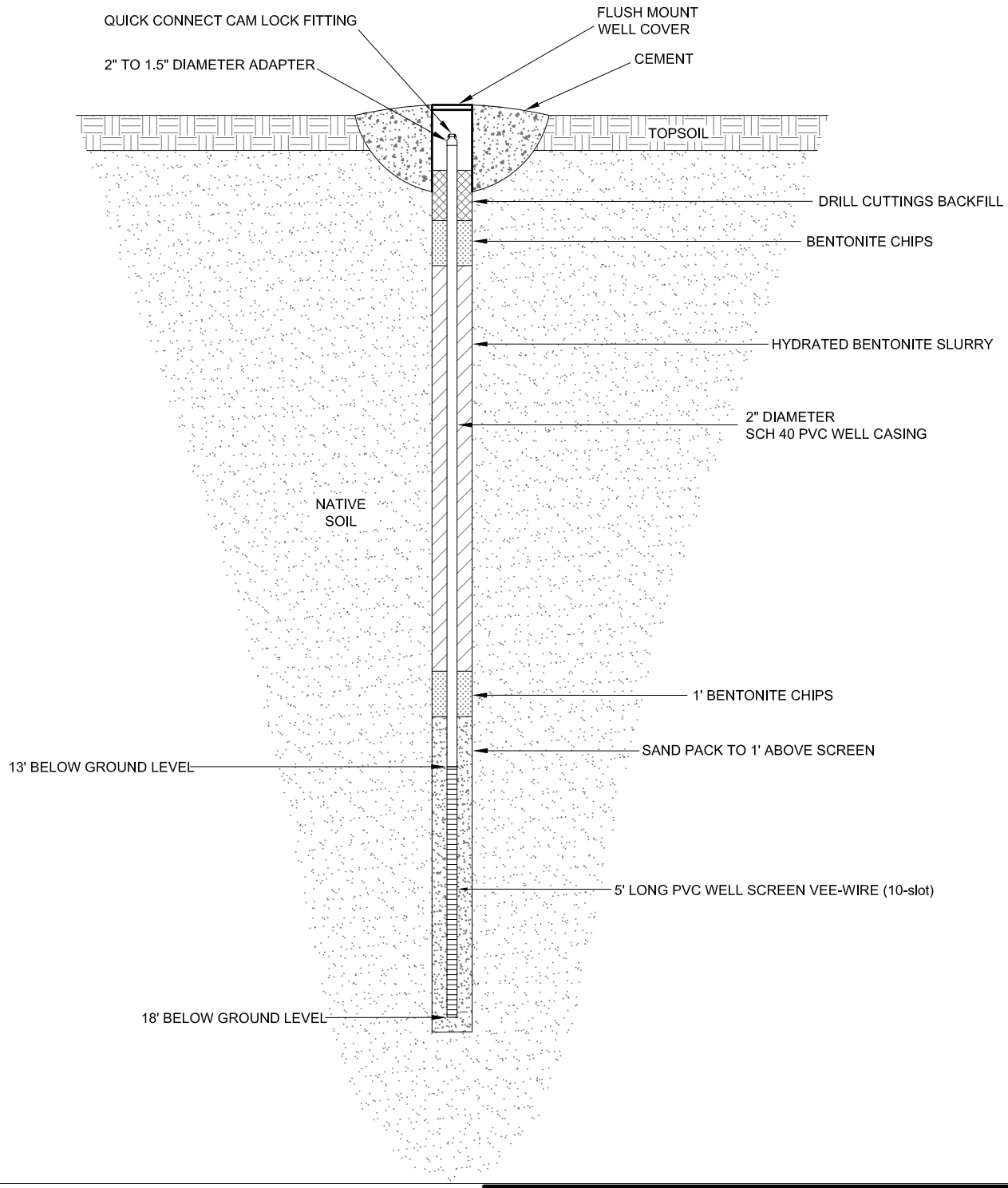


HAMP, MATHEWS & ASSOCIATES, INC.

RACER TRUST
LIVONIA ECKLES ROAD SITE
LIVONIA, MICHIGAN

FIGURE 11
HOME 6 TCE SOIL AND GROUNDWATER CONCENTRATIONS AND PREDICTED RADIUS OF INFLUENCE

DRAWN BY:	DATE:	PROJECT:	DRAWING ID:
TRF	May 2019	41-1	RT Analytical.dwg



HAMP, MATHEWS & ASSOCIATES, INC.

RACER TRUST
LIVONIA ECKLES ROAD SITE
LIVONIA, MICHIGAN

FIGURE 12
ISCO DELIVERY WELL DESIGN

DRAWN BY:	DATE:	PROJECT:	DRAWING ID:
TRF	May 2019	41-2	ISCO Delivery Well Design.dwg

Tables

Table 1 - Coincident Soil-Groundwater TCE Concentrations
RACER Trust - Eckles Road TCE Plume
Livonia, MI

Parameter(s)	PB18-2			PB18-4			EW-1			OW-2			PB18-5			PB18-6				
	Soil	Water	Ratio Soil to GW	Soil	Water	Ratio Soil to GW	Soil	Water	Ratio Soil to GW	Soil	Water	Ratio Soil to GW	Soil	Water	Ratio Soil to GW	Soil	Water	Ratio Soil to GW	Soil	Water
	15'-15.5'	15'-17.5'		17'-17.5'	16'-18.5'		17'-18'	17'		16'-17'	17'		16.5'-17'	15'-17.5'		12.5'-13'	12'-14.5'		22.5'-23'	20.5'-23'
1,1,1-Trichloroethane	810	120	27:4	1800	120	15:1	1900	120	95:6	410	64	32:5	3700	110	269:8	320	64	5:1	<65	<1.0
Trichloroethene	2100	170	***12:1***	12000	570	***21:1***	14000	630	***22:1***	3900	380	***10:1***	11000	560	***20:1***	2100	340	***6:1***	<50	<1.0
Soil Lithology:	Fine to medium sand, little medium gravel, WG			Medium to coarse sand, F. gravel, WG			Coarse to medium grained sand, Mod. P.G.			Medium to fine grained sand, poorly graded.			Fine to coarse sand, WG			M-F sand, Little F-C gravel, WG			Silty Sand	

Soil ug/kg
Groundwater ug/L

Table 2. ISCO Delivery Event Summary - RACER Eckles Road

Zone	Klozur SP Dosage		Injection Details			Klozur SP Quantities Per Injection Location	
	Mass of Klozur SP (lbs)	Concentration in Total Pore Volume (g/L)	# of Injection Locations	Total Injected Volume (gal)	Klozur SP Injection Concentration (g/L)	Klozur SP (lbs)	Injection Volume (gal)
1	35,264	52	12	28,300	149	2,939	2,358
2	6,612	29	4	9,400	84	1,653	2,350
3	33,060	50	12	28,300	140	2,755	2,358
4	6,612	31	4	9,100	87	1,653	2,275

Table 3. Proposed Groundwater Monitoring Plan
RACER Trust - Livonia Eckles Road Site, Livonia, Michigan

Sample Type	Sample Frequency	Sample Parameters	Field Parameters	Sample Locations (See Figure 2)
Baseline Parameters	Prior to Initial Delivery Event; Annually	1. Total Organic Carbon 2. Sodium 3. Chloride 4. Sulfate 5. Iron (Total) 6. Manganese 7. Alkalinity 8. Total VOCs 9. Residual Persulfate 10. Michigan 10 Metals	1. ORP 2. pH 3. Dissolved Oxygen 4. Specific Conductivity 5. Temperature 6. Turbidity 7. Water Level	Select Delivery Wells Located Within: Zone 1 Zone 2 Zone 3 Zone 4 OW-2, PMW-1, PMW-2, PMW-3, PMW-4, PMW-5, PMW-6, PMW-7, PMW-8, MW-400S, MW-401S, MW-402S
Delivery Event	During Delivery Events	1. Soil Vapors for CVOCs (PID) 2. Residual Persulfate	1. Temperature 2. Dissolved Oxygen 3. Water Levels 4. ORP 5. pH	Delivery Wells
Monthly Events	Monthly for 2 Months Post-Injection	1. CVOCs 2. Residual Persulfate 3. Sulfate	1. ORP 2. pH 3. Dissolved Oxygen 4. Specific Conductivity 5. Temperature 6. Turbidity 7. Water Level	Select Delivery Wells Located Within: Zone 1 Zone 2 Zone 3 Zone 4 OW-2, PMW-1, PMW-2, PMW-3, PMW-4, PMW-5, PMW-6, PMW-7, PMW-8, MW-400S, MW-401S, MW-402S
Quarterly Events	Quarterly Beginning 3rd Month After Delivery Event	1. CVOCs 2. Chloride 3. Sulfate 4. Michigan 10 Metals 5. Total Organic Carbon	1. ORP 2. pH 3. Dissolved Oxygen 4. Specific Conductivity 5. Temperature 6. Turbidity 7. Water Level	

Appendix A

2016 Low-Flow Sampling Logs

Hamp, Mathews &
Associates, Inc.

Monitoring Well Record for Low w Purging
(Form SP-09)

Project Data:

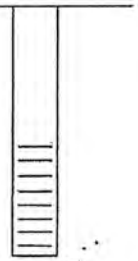
Project Name: [redacted]
Ref. No.: 012607

Date: 6/30/16
Personnel: D. Campbell

Monitoring Well Data:

Well No.: MW2135
Vapour PID (ppm):
Measurement Point:
Constructed Well Depth (m/ft):
Measured Well Depth (m/ft):
Depth of Sediment (m/ft):

Saturated Screen Length (m/ft):
Depth to Pump Intake (m/ft)[1]:
Well Diameter, D (cm/in):
Well Screen Volume, V_s (L)[2]:
Initial Depth to Water (m/ft): 9.77



Start: 12107

Time	Pumping Rate (mL/min)	Depth to Water (m/ft)	Drawdown from Initial Water Level[3] (m/ft)	Temperature °C	Conductivity (mS/cm)	Turbidity NTU	DO (mg/L)	pH	ORP (mV)	Volume Purged, Vp (L)	No. of Well Screen Volumes Purged[4]
Precision Required:				±3 %	±0.005 or 0.01[5]	±10 %	±10 %	±0.1 Units	±10 mV		
13:00	150	9.80		12.77	0.828	0.98	3.49	5.06	118.9		
13:05	↓			12.74	0.820	0.23	3.45	5.15	116.1		
13:10	↓	↓		12.72	0.817	0.20	3.36	5.37	107.9		
	Sample @	13:10									

Notes:

(1) The pump intake will be placed at the well screen mid-point or at a minimum of 0.6 m (2 ft) above any sediment accumulated at the well bottom.

(2) The well screen volume will be based on a 1.52 metres (5-foot) screen length (L). For metric units, $V_s=\pi*(r^2)*L$ in mL, where r (r=D/2) and L are in cm.
For Imperial units, $V_s=\pi*(r^2)*L*(2.54)^3$, where r and L are in inches

(3) The drawdown from the initial water level should not exceed 0.1 m (0.3 ft). The pumping rate should not exceed 600 mL/min.

(4) Purging will continue until stabilization is achieved or until 20 well screen volumes have been purged (unless purge water remains visually turbid and appears to be clearing, or unless stabilization parameters are varying slightly outside of the stabilization criteria and appear to be stabilizing), No. of Well Screen Volumes Purged= Vp/Vs.

(5) For conductivity, the average value of three readings <1 mS/cm ±0.005 mS/cm or where conductivity >1 mS/cm ±0.01 mS/cm.

Sample ID
GL-12607-063016-DC-001

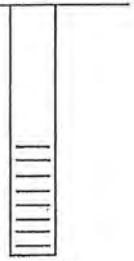
Monitoring Well Record for Low-Flow Purging
(Form SP-09)

Project Data:

Project Name: [redacted] Eckles Rd
Ref. No.: 012607
Date: 6/30/16
Personnel: D. Campbell

Monitoring Well Data:

Well No.: MW-2155
Vapour PID (ppm):
Measurement Point:
Constructed Well Depth (m/ft):
Measured Well Depth (m/ft):
Depth of Sediment (m/ft):
Saturated Screen Length (m/ft):
Depth to Pump Intake (m/ft)[1]:
Well Diameter, D (cm/in):
Well Screen Volume, V_s (L)[2]:
Initial Depth to Water (m/ft): 8.07



Start: 13:20

Time	Pumping Rate (mL/min)	Depth to Water (m/ft)	Drawdown from Initial Water Level[3] (m/ft)	Temperature °C	Conductivity (mS/cm)	Turbidity NTU	DO (mg/L)	pH	ORP (mV)	Volume Purged, Vp (L)	No. of Well Screen Volumes Purged[4]
Precision Required:				±3 %	±0.005 or 0.01[5]	±10 %	±10 %	±0.1 Units	±10 mV		
13:45	150	8.10		15.57	0.772	2.19	5.21	6.31	48.8		
13:50				15.54	0.773	1.42	5.07	6.39	38.2		
13:55	"	"		15.53	0.773	1.57	5.07	6.43	37.2		
	Sampled @	13:55									

Notes:

(1) The pump intake will be placed at the well screen mid-point or at a minimum of 0.6 m (2 ft) above any sediment accumulated at the well bottom.
(2) The well screen volume will be based on a 1.52 metres (5-foot) screen length (L). For metric units, $V_s=\pi*(r^2)*L$ ln mL, where r (r=D/2) and L are in cm.
For Imperial units, $V_s=\pi*(r^2)*L*(2.54)^3$, where r and L are in inches
(3) The drawdown from the initial water level should not exceed 0.1 m (0.3 ft). The pumping rate should not exceed 600 mL/min.
(4) Purging will continue until stabilization is achieved or until 20 well screen volumes have been purged (unless purge water remains visually turbid and appears to be clearing, or unless stabilization parameters are varying slightly outside of the stabilization criteria and appear to be stabilizing), No. of Well Screen Volumes Purged= Vp/Vs.
(5) For conductivity, the average value of three readings <1 mS/cm ±0.005 mS/cm or where conductivity >1 mS/cm ±0.01 mS/cm.

Sample ID
GW-12607-063016-DC-002

Monitoring Well Record for Low-Flow Purging
(Form SP-09)

Project Data:

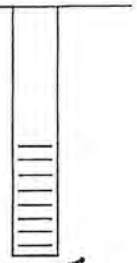
Project Name: [redacted] Eckles Rd
Ref. No.: 012607

Date: 6/30/16
Personnel: D. Conrad

Monitoring Well Data:

Well No.: MW-4005
Vapour PID (ppm):
Measurement Point:
Constructed Well Depth (m/ft):
Measured Well Depth (m/ft):
Depth of Sediment (m/ft):

Saturated Screen Length (m/ft):
Depth to Pump Intake (m/ft)[1]:
Well Diameter, D (cm/in):
Well Screen Volume, V_s (L)[2]:
Initial Depth to Water (m/ft): 6.41



Start: 13:25

Time	Pumping Rate (mL/min)	Depth to Water (m/ft)	Drawdown from Initial Water Level[3] (m/ft)	Temperature °C	Conductivity (mS/cm)	Turbidity NTU	DO (mg/L)	pH	ORP (mV)	Volume Purged, Vp (L)	No. of Well Screen Volumes Purged[4]
			Precision Required:	±3 %	±0.005 or 0.01[5]	±10 %	±10 %	±0.1 Units	±10 mV		
14:15	150	6.43	0.02	16.94	0.817	1.64	5.32	7.19	2.6		
14:20				16.96	0.818	0.51	4.44	7.17	3.2		
14:25				16.75	0.820	0.40	2.45	7.15	4.2		
14:30				16.76	0.819	1.19	3.23	7.10	4.9		
14:35				16.63	0.823	0.69	4.05	7.15	7.1		
14:40	↓	↓		16.59	0.823	0.60	3.76	7.13	8.5		
	Sampled	14:40									

Notes:

(1) The pump intake will be placed at the well screen mid-point or at a minimum of 0.6 m (2 ft) above any sediment accumulated at the well bottom.
(2) The well screen volume will be based on a 1.52 metres (5-foot) screen length (L). For metric units, $V_s=\pi*(r^2)*L$ in mL, where r (r=D/2) and L are in cm. For Imperial units, $V_s=\pi*(r^2)*L*(2.54)^3$, where r and L are in inches
(3) The drawdown from the initial water level should not exceed 0.1 m (0.3 ft). The pumping rate should not exceed 600 mL/min.
(4) Purging will continue until stabilization is achieved or until 20 well screen volumes have been purged (unless purge water remains visually turbid and appears to be clearing, or unless stabilization parameters are varying slightly outside of the stabilization criteria and appear to be stabilizing), No. of Well Screen Volumes Purged= Vp/Vs.
(5) For conductivity, the average value of three readings <1 mS/cm ±0.005 mS/cm or where conductivity >1 mS/cm ±0.01 mS/cm.

Sample ID:
GL-12607-063016-DC-003

Monitoring Well Record for Low-Flow Purging
(Form SP-09)

Project Data:

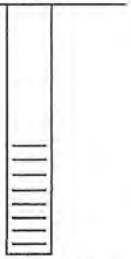
Project Name: [redacted] Eckles Rd
Ref. No.: 012607

Date: 6/30/16
Personnel: D. Canfield

Monitoring Well Data:

Well No.: MW-405
Vapour PID (ppm):
Measurement Point:
Constructed Well Depth (m/ft):
Measured Well Depth (m/ft):
Depth of Sediment (m/ft):

Saturated Screen Length (m/ft):
Depth to Pump Intake (m/ft)[1]:
Well Diameter, D (cm/in):
Well Screen Volume, V_s (L)[2]:
Initial Depth to Water (m/ft): 6.60



Start: 14:00

Time	Pumping Rate (mL/min)	Depth to Water (m/ft)	Drawdown from Initial Water Level[3] (m/ft)	Temperature °C	Conductivity (mS/cm)	Turbidity NTU	DO (mg/L)	pH	ORP (mV)	Volume Purged, Vp (L)	No. of Well Screen Volumes Purged[4]
Precision Required:				±3 %	±0.005 or 0.01[5]	±10 %	±10 %	±0.1 Units	±10 mV		
15:00	150	6.65		14.25	1.107	1.20	1.95	6.49	17.0		
15:05	"	"		14.32	1.383	0.99	0.61	6.51	17.0		
15:10	"	"		14.35	1.367	1.05	0.57	6.61	10.8		
15:15	"	"		14.29	1.354	0.74	0.74	6.65	9.2		
	Sampled @	15:15									

Notes:

(1) The pump intake will be placed at the well screen mid-point or at a minimum of 0.6 m (2 ft) above any sediment accumulated at the well bottom.
(2) The well screen volume will be based on a 1.52 metres (5-foot) screen length (L). For metric units, $V_s=\pi*(r^2)*L$ in mL, where r (r=D/2) and L are in cm.
For Imperial units, $V_s=\pi*(r^2)*L*(2.54)^3$, where r and L are in inches
(3) The drawdown from the initial water level should not exceed 0.1 m (0.3 ft). The pumping rate should not exceed 600 mL/min.
(4) Purging will continue until stabilization is achieved or until 20 well screen volumes have been purged (unless purge water remains visually turbid and appears to be clearing, or unless stabilization parameters are varying slightly outside of the stabilization criteria and appear to be stabilizing), No. of Well Screen Volumes Purged= Vp/Vs.
(5) For conductivity, the average value of three readings <1 mS/cm ±0.005 mS/cm or where conductivity >1 mS/cm ±0.01 mS/cm.

Sample ID:
GW-12607-063016-DL-004
-005 (Dup)

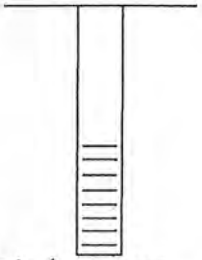
Monitoring Well Record for Low w Purging
(Form SP-09)

Project Data:

Project Name: [redacted] Eckles Rd
Ref. No.: 012607
Date: 6/30/16
Personnel: D. Canfield

Monitoring Well Data:

Well No.: MW-402S
Vapour PID (ppm):
Measurement Point:
Constructed Well Depth (m/ft):
Measured Well Depth (m/ft):
Depth of Sediment (m/ft):
Saturated Screen Length (m/ft):
Depth to Pump Intake (m/ft)[1]:
Well Diameter, D (cm/in):
Well Screen Volume, V_s (L)[2]:
Initial Depth to Water (m/ft): 5.98



Start: 14:45

Time	Pumping Rate (mL/min)	Depth to Water (m/ft)	Drawdown from Initial Water Level[3] (m/ft)	Temperature °C	Conductivity (mS/cm)	Turbidity NTU	DO (mg/L)	pH	ORP (mV)	Volume Purged, Vp (L)	No. of Well Screen Volumes Purged[4]
			Precision Required:	±3 %	±0.005 or 0.01[5]	±10 %	±10 %	±0.1 Units	±10 mV		
15:35	150	6.00		11.62	1.072	2.12	3.24	7.06	14.4		
15:40	"	"		14.59	1.063	1.32	3.13	7.05	16.9		
15:45	"	"		14.46	1.058	2.42	2.81	7.02	19.0		
	Sample @	15:45									

Notes:

(1) The pump intake will be placed at the well screen mid-point or at a minimum of 0.6 m (2 ft) above any sediment accumulated at the well bottom.
(2) The well screen volume will be based on a 1.52 metres (5-foot) screen length (L). For metric units, $V_s=\pi*(r^2)*L$ in mL, where r (r=D/2) and L are in cm. For Imperial units, $V_s=\pi*(r^2)*L*(2.54)^3$, where r and L are in inches
(3) The drawdown from the initial water level should not exceed 0.1 m (0.3 ft). The pumping rate should not exceed 600 mL/min.
(4) Purging will continue until stabilization is achieved or until 20 well screen volumes have been purged (unless purge water remains visually turbid and appears to be clearing, or unless stabilization parameters are varying slightly outside of the stabilization criteria and appear to be stabilizing), No. of Well Screen Volumes Purged= Vp/Vs.
(5) For conductivity, the average value of three readings <1 mS/cm ±0.005 mS/cm or where conductivity >1 mS/cm ±0.01 mS/cm.

Sample ID: 6W-12607-06.30.16-DC-006

Monitoring Well Record for Low w Purging
(Form SP-09)

Project Data:

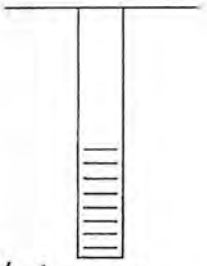
Project Name: [redacted] Eckles Rd
Ref. No.: 01267

Date: 6/30/16
Personnel: D. Cousineau

Monitoring Well Data:

Well No.: MW-2025
Vapour PID (ppm):
Measurement Point:
Constructed Well Depth (m/ft):
Measured Well Depth (m/ft):
Depth of Sediment (m/ft):

Saturated Screen Length (m/ft):
Depth to Pump Intake (m/ft)[1]:
Well Diameter, D (cm/in):
Well Screen Volume, V_s (L)[2]:
Initial Depth to Water (m/ft): 8.40



Start: 16:30

Time	Pumping Rate (mL/min)	Depth to Water (m/ft)	Drawdown from Initial Water Level[3] (m/ft)	Temperature °C	Conductivity (mS/cm)	Turbidity NTU	DO (mg/L)	pH	ORP (mV)	Volume Purged, Vp (L)	No. of Well Screen Volumes Purged[4]
Precision Required:				±3 %	±0.005 or 0.01[5]	±10 %	±10 %	±0.1 Units	±10 mV		
16:30	150	8.40		16.37	1.286	1.85	2.84	6.34	31.4		
16:35	↓	↓		16.56	1.317	0.73	2.00	6.11	24.2		
16:40				16.27	1.355	0.79	1.22	6.49	19.2		
16:45				16.25	1.370	1.19	1.00	6.48	18.3		
16:50	↓	↓		16.28	1.366	0.40	1.11	6.51	15.4		
	Sampled	16:50									

Notes:

(1) The pump intake will be placed at the well screen mid-point or at a minimum of 0.6 m (2 ft) above any sediment accumulated at the well bottom.
(2) The well screen volume will be based on a 1.52 metres (5-foot) screen length (L). For metric units, $V_s=\pi*(r^2)*L$ in mL, where r (r=D/2) and L are in cm. For Imperial units, $V_s=\pi*(r^2)*L*(2.54)^3$, where r and L are in inches
(3) The drawdown from the initial water level should not exceed 0.1 m (0.3 ft). The pumping rate should not exceed 600 mL/min.
(4) Purging will continue until stabilization is achieved or until 20 well screen volumes have been purged (unless purge water remains visually turbid and appears to be clearing, or unless stabilization parameters are varying slightly outside of the stabilization criteria and appear to be stabilizing), No. of Well Screen Volumes Purged= Vp/Vs.
(5) For conductivity, the average value of three readings <1 mS/cm ±0.005 mS/cm or where conductivity >1 mS/cm ±0.01 mS/cm.

Sample ID:
GW-1267-063016-DL-007

012607

Monitoring Well Record for Low-Flow Purging

(Form SP-09)

Project Data:

Project Name: [redacted]

Ref. No.: 12607

Date: 7/8/16

Personnel: Meincke

Monitoring Well Data:

Well No.: MW-103S

Vapour PID (ppm): _____

Measurement Point: _____

Constructed Well Depth (m/ft): _____

Measured Well Depth (m/ft): _____

Depth of Sediment (m/ft): _____

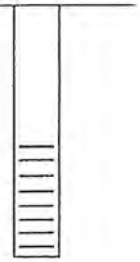
Saturated Screen Length (m/ft): _____

Depth to Pump Intake (m/ft)[1]: _____

Well Diameter, D (cm/in): _____

Well Screen Volume, V_s (L)[2]: _____

Initial Depth to Water (m/ft): _____



Time	Pumping Rate (mL/min)	Depth to Water (m/ft)	Drawdown from Initial Water Level[3] (m/ft)	Temperature °C	Conductivity (mS/cm)	Turbidity NTU	DO (mg/L)	pH	ORP (mV)	Volume Purged, Vp (L)	No. of Well Screen Volumes Purged[4]
Precision Required:				±3 %	±0.005 or 0.01[5]	±10 %	±10 %	±0.1 Units	±10 mV		
12:07		10.81		13.44	~~0.853~~ 0.672	47.9	4.49	6.25	175.4		
12:25	100	10.79		18.89	0.741	32.8	1.56	6.84	124.7		
12:44		10.80		14.98	.689	~~5.89~~	1.04	6.86	109.1		
12:55		10.86		15.38	0.709	2.20	0.83	6.83	103.2		
13:03		10.80		15.94	0.725	1.92	0.74	6.82	98.9		

Notes:

(1) The pump intake will be placed at the well screen mid-point or at a minimum of 0.6 m (2 ft) above any sediment accumulated at the well bottom.

(2) The well screen volume will be based on a 1.52 metres (5-foot) screen length (L). For metric units, $V_s=\pi*(r^2)*L$ in mL, where r (r=D/2) and L are in cm. For Imperial units, $V_s=\pi*(r^2)*L*(2.54)^3$, where r and L are in inches

(3) The drawdown from the initial water level should not exceed 0.1 m (0.3 ft). The pumping rate should not exceed 600 mL/min.

(4) Purging will continue until stabilization is achieved or until 20 well screen volumes have been purged (unless purge water remains visually turbid and appears to be clearing, or unless stabilization parameters are varying slightly outside of the stabilization criteria and appear to be stabilizing), No. of Well Screen Volumes Purged= Vp/Vs.

(5) For conductivity, the average value of three readings <1 mS/cm ±0.005 mS/cm or where conductivity >1 mS/cm ±0.01 mS/cm.

Sample ID

GW-12607-070816-CM-001

10 ml/15 sec

13:05

Monitoring Well Record for Low Purging
(Form SP-09)

Project Data:
Project Name: [redacted]
Ref. No.: 12607-
Date: 7/8/16
Personnel: MCinnes

Monitoring Well Data:
Well No.: MW17-S
Vapour PID (ppm):
Measurement Point:
Constructed Well Depth (m/ft):
Measured Well Depth (m/ft):
Depth of Sediment (m/ft):
Saturated Screen Length (m/ft):
Depth to Pump Intake (m/ft)[1]:
Well Diameter, D (cm/in):
Well Screen Volume, V_s (L)[2]:
Initial Depth to Water (m/ft):

Time	Pumping Rate (mL/min)	Depth to Water (m/ft)	Drawdown from Initial Water Level[3] (m/ft)	Temperature °C	Conductivity (mS/cm)	Turbidity NTU	DO (mg/L)	pH	ORP (mV)	Volume Purged, Vp (L)	No. of Well Screen Volumes Purged[4]
Precision Required:				±3 %	±0.005 or 0.01[5]	±10 %	±10 %	±0.1 Units	±10 mV		
1340	120	5.74		17.48	0.702	1.15	3.20	6.99	129.2		
1400		5.7		17.05	0.713	0.88	2.35	7.03	110.2		
1410		5.73		16.76	0.722	1.33	1.95	7.04	103.2		
1420		5.72		16.97	0.731	1.19	1.81	7.06	94		

Notes:

14:25

GW-12607-070816-CM-002

(1) The pump intake will be placed at the well screen mid-point or at a minimum of 0.6 m (2 ft) above any sediment accumulated at the well bottom.
(2) The well screen volume will be based on a 1.52 metres (5-foot) screen length (L). For metric units, $V_s=\pi*(r^2)*L$ in mL, where r (r=D/2) and L are in cm.
For Imperial units, $V_s=\pi*(r^2)*L*(2.54)^3$, where r and L are in inches
(3) The drawdown from the initial water level should not exceed 0.1 m (0.3 ft). The pumping rate should not exceed 600 mL/min.
(4) Purging will continue until stabilization is achieved or until 20 well screen volumes have been purged (unless purge water remains visually turbid and appears to be clearing, or unless stabilization parameters are varying slightly outside of the stabilization criteria and appear to be stabilizing), No. of Well Screen Volumes Purged= Vp/Vs.
(5) For conductivity, the average value of three readings <1 mS/cm ±0.005 mS/cm or where conductivity >1 mS/cm ±0.01 mS/cm.

Appendix B

Physical Soil Testing Results

Hamp, Mathews &
Associates, Inc.

Professional Service Industries, Inc.
3120 Sovereign Drive, Suite C
Lansing, MI 48911

Phone: (517) 394-5700
Fax: (517) 394-5796

Report No: MAT:04081992-2-S1
Issue No: 1

Material Test Report

Client: HAMP, MATHEWS & ASSOCIATES **CC:** JOEL PARKER
15266 ANN DRIVE
BATH, MI 48808

Project: LABORATORY TESTING SERVICES

Approved Signatory: Joel Walter (Branch Manager)
Date of Issue: 9/5/2018

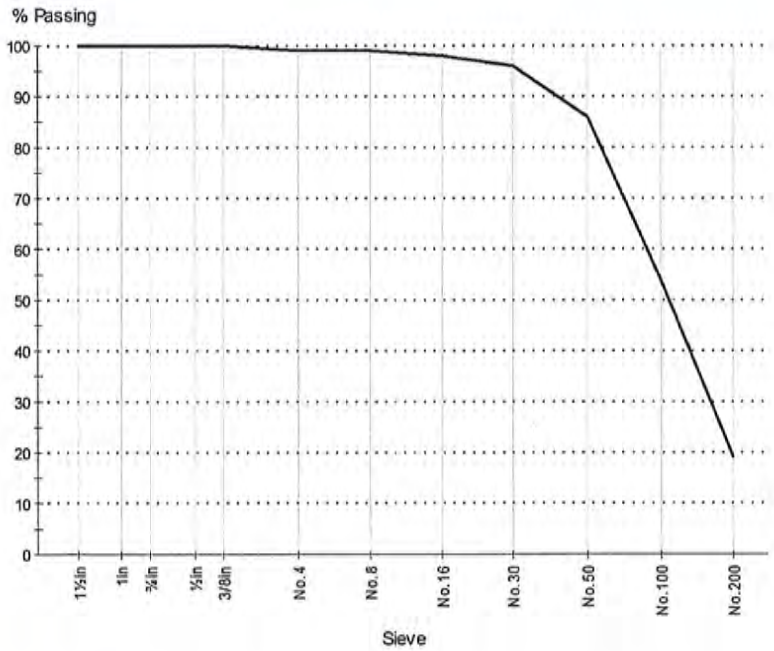
Sample Details

Sample ID:	04081992-2-S1
Client Sample ID:	N/A
Date Sampled:	08/29/18
Sampled By:	Joel Walter
Specification:	Sieve-Results-Curve
Supplier:	N/A
Source:	N/A
Material:	Brown fine SAND with silt/clay
Sampling Method:	Sampled by Client
Soil Description:	Moist
General Location:	PB18-10, 8' to 10.5'

Sample Description:

Moist

Particle Size Distribution



COBBLES	GRAVEL		SAND			FINES (19.0%)	
	Coarse	Fine	Coarse	Medium	Fine		
(0.0%)	(0.0%)	(1.0%)	(0.2%)	(7.7%)	(72.0%)	Silt	Clay

Grading: ASTM C 136, ASTM C 117

Drying by: Oven
Date Tested: 9/5/2018
Tested By: Matthew Ranney

Sieve Size	% Passing	Limits
1½in (37.5mm)	100	
1in (25.0mm)	100	
¾in (19.0mm)	100	
½in (12.5mm)	100	
3/8in (9.5mm)	100	
No.4 (4.75mm)	99	
No.8 (2.36mm)	99	
No.16 (1.18mm)	98	
No.30 (600µm)	96	
No.50 (300µm)	86	
No.100 (150µm)	54	
No.200 (75µm)	19	

D85: 0.2936 **D60:** 0.1708 **D50:** 0.1386
D30: 0.0933 **D15:** N/A **D10:** N/A

Professional Service Industries, Inc.
3120 Sovereign Drive, Suite C
Lansing, MI 48911

Phone: (517) 394-5700
Fax: (517) 394-5796

Report No: MAT:04081992-2-S2
Issue No: 1

Material Test Report

Client: HAMP, MATHEWS & ASSOCIATES **CC:** JOEL PARKER
15266 ANN DRIVE
BATH, MI 48808

Project: LABORATORY TESTING SERVICES

Approved Signatory: Joel Walter (Branch Manager)
Date of Issue: 9/5/2018

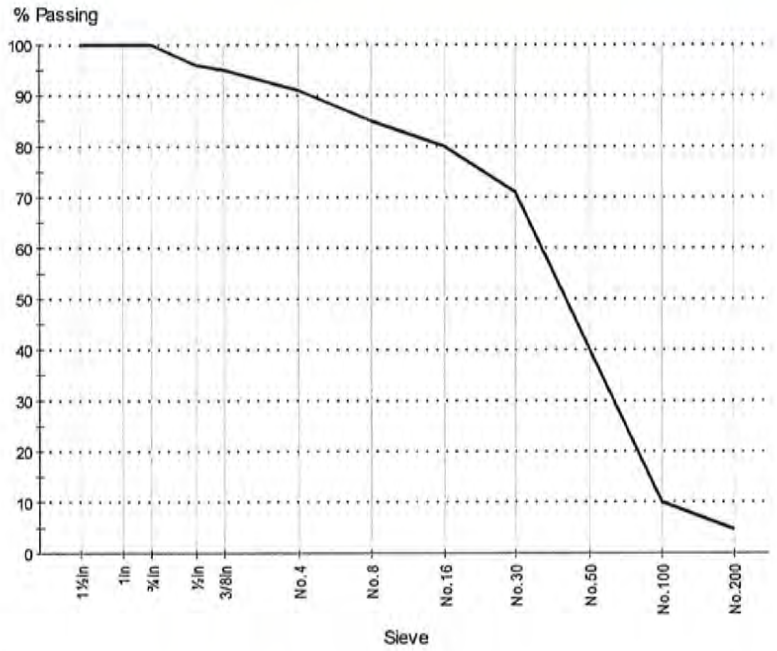
Sample Details

Sample ID:	04081992-2-S2
Client Sample ID:	N/A
Date Sampled:	08/29/18
Sampled By:	Client
Specification:	Sieve-Results-Curve
Supplier:	N/A
Source:	N/A
Material:	Brown fine to medium SAND
Sampling Method:	Sampled by Client
Soil Description:	Moist
General Location:	PB18-10, 17.5' to 20'

Sample Description:

Moist

Particle Size Distribution



COBBLES	GRAVEL		SAND			FINES (4.7%)	
	Coarse	Fine	Coarse	Medium	Fine		
(0.0%)	(0.0%)	(9.0%)	(7.2%)	(28.2%)	(50.9%)	Silt	Clay

Grading: ASTM C 136, ASTM C 117

Drying by: Oven
Date Tested: 9/5/2018
Tested By: Matthew Ranney

Sieve Size	% Passing	Limits
1½in (37.5mm)	100	
1in (25.0mm)	100	
¾in (19.0mm)	100	
½in (12.5mm)	96	
3/8in (9.5mm)	95	
No.4 (4.75mm)	91	
No.8 (2.36mm)	85	
No.16 (1.18mm)	80	
No.30 (600µm)	71	
No.50 (300µm)	40	
No.100 (150µm)	10	
No.200 (75µm)	4.7	

D85: 2.3600 **D60:** 0.4692 **D50:** 0.3752
D30: 0.2381 **D15:** 0.1684 **D10:** 0.1500
Cu: 3.13 **Cc:** 0.81

Brighton Analytical L.L.C. ™

2105 Pless Drive Brighton, Michigan 48114 Phone (810)229-7575 Fax (810)229-8650 E-mail bai-brighton@sbcglobal.net

September 24, 2018

Intertek-PSI
3120 Sovereign Drive
Suite C
Lansing, MI 48911

Subject: Eckles Road
021081992

Dear Mr. Walter :

Thank you for making Brighton Analytical, L.L.C. your laboratory of choice. Attached are the results for the samples submitted on 08/31/2018 for the above mentioned project. NELAP/TNI Accredited Analysis and MDEQ Drinking Water Certified Analysis will be identified in their respective reporting formats. Hard copies can be supplied at your request for a fee of $20.00 per copy.

The invoice for this project will be emailed separately. If you have any questions concerning the data or invoice, please don't hesitate to contact our office. We welcome your comments and suggestions to improve our quality systems. Please reference Brighton Analytical, L.L.C. Project ID 52534 when calling or emailing. We thank you for this opportunity to partner with you on this project and hope to work with you again in the future.

Sincerely,
Brighton Analytical, L.L.C.

Brighton Analytical, L.L.C.™

email: bai-brighton@sbcglobal.net
2105 Pless Drive Phone: 810-229-7575
Brighton, MI 48114 FAX: 810-229-8650

BA PROJECT #: 52534

ABBREVIATIONS FOR MATRIX
S = Solid
L = Liquid
DW = Drinking H_2O
O = Oil
P = Wipes
A = Air (Tedlar Bag)
F = Filter
T = Tube M = Misc.

PROJECT NAME: ECKLES ROAD
PROJECT #: 01CP1992
PO #: (PLEASE NOTE IF DIFFERENT BILLING ADDRESS) 01081992-2

Sample Collected By: CLIENT

REQUESTED TURNAROUND: (circle one)
Rush: 1 -3 business days (verify with lab & specify date needed)
1 Day =2.5X Cost 2 Day= 2X Cost 3 Day = 1.5X Cost
Standard: 5 business days

If RUSH, approved by: _____

Analysis Requested/Method

Brighton ID #	Sample Description	Sample Coll. Date	Sample Coll. Time	Container/Quantity: VOA'S (PRES) Y N N/A	HDPE UNPRESERVED	HDPE HNO3	HDPE H2SO4	HDPE NAOH	AMBER Preserved?	GLASS NO PRESERVATIVE	STERILIZED BACTERIA	MEOH Preserved Y N	Sample Matrix	
CLO 1) 1725	PB 18-10, 8-10.5'	8/29			1								S	
2) 1726	PB 18-14, 17.5-20'	8/29			1								S	
3)														
4)														
5)														
6)														
7)														
8)														
9)														
10)														

Special Instructions: RFQ-08291FJW

PAGE ___ OF ___
COMPANY/MAILING ADDRESS:
INTERFER-PSI
3120 MARRIAN DRIVE
LANSING, MI 48911
ATTN: JOEL WALTER
PHONE: 517-394-3700
FAX OR EMAIL: JOEL.WALTER@PSIUSA.COM

Samples received within hold time? yes no
Temperature of samples °C:
pHs verified in login? yes no
Headspace/bubbles in VOA's? yes no n/a
Sample containers and COC match? yes no
NO MATCH
BILLING ADDRESS (IF REQUIRED):
SAME
Drinking H2O: FAX TO LCHD yes no
Chlorinated Water Supply? yes no AMT.: _____
MCL failure: yes no
Client notified (date/time/initials):

Please fill out the Chain of Custody completely and review. Incorrect or incomplete information will result in a "hold" on all analyses.

Trans. #	RELINQUISHED BY:	RECEIVED BY:	DATE:	TIME:	Trans. #	RELINQUISHED BY:	RECEIVED BY:	DATE:	TIME:
1			8.31.18	1410	3				
2					4				

RTI LABORATORIES, INC.

RTI Laboratories
31628 Glendale St.
Livonia, MI 48150
TEL: (734) 422-8000
Website: www.rtilab.com

Monday, September 24, 2018

Deb Hoffner
Brighton Analytical Labs
2105 Pless Dr
Brighton, MI 48116-9463
TEL: (810) 229-7575
FAX: (810) 229-8650

RE: 52534

Work Order #: 1809069

Dear Deb Hoffner:

There were no problems with the analytical events associated with this report unless noted in the Case Narrative.

This report may only be reproduced in its entirety. Individual pages, reproduced without supporting documentation, do not contain related information and may be misinterpreted by other data reviewers.

Quality control data is within laboratory defined or method specified acceptance limits except if noted.

If you have any questions regarding these tests results, please feel free to call.

Sincerely,

Katherine Jones

Project Manager

RTI Laboratories, Inc. - Workorder Sample Summary

WO#: 1809069

Date Reported: 9/24/2018
Original

Client: Brighton Analytical Labs

Project: 52534

Lab Sample ID	Client Sample ID	Tag No	Date Collected	Date Received	Matrix
1809069-001A	CI01725		8/29/2018 12:00 AM	9/5/2018 10:29 AM	Soil
1809069-002A	CI01726		8/29/2018 12:00 AM	9/5/2018 10:29 AM	Soil

RTI Laboratories, Inc. - Case Narrative

WO#: 1809069

Date Reported: 9/24/2018
Original

Client: Brighton Analytical Labs

Project: 52534

Concentrations reported with a J flag in the Qual field are values below the reporting limit (RL) but greater than the established method detection limit (MDL). There is greater uncertainty associated with these results and data should be considered as estimated. These analytes are not routinely reviewed nor narrated below as to their potential for being laboratory artifacts.

Concentrations reported with an E flag in the Qual field are values that exceed the upper quantification range. There is greater uncertainty associated with these results and data should be considered as estimated.

All sample analyses included a Method Blank, LCS/LCSD, MS/MSD, Duplicates, post digestion spikes, serial dilutions, and all method specified quality control, as applicable. All QC parameters were within established control limits except where noted on the QC report and/or below. Initial and continuing calibration results were within method specifications, except as noted below.

Any comments or problems with the analytical events associated with this report are noted below.

Sample Receipt:
Receipt No. 1: Samples were received at the RTI Laboratories, Inc. via Client delivery on 09/05/2018. Total number of samples received are 2.

Sample Analysis:
Samples were analyzed at the RTI Laboratories
Organic Carbon, Walkley-Black - TOCWB

RTI Laboratories, Inc. - Analytical Report

WO#: 1809069

Date Reported: 9/24/2018
Original

Client:	Brighton Analytical Labs	**Collection Date:**	8/29/2018 12:00:00 AM
Project:	52534		
Lab ID:	1809069-001	**Matrix:**	Soil
Client Sample ID:	CI01725		

Analysis	Result	RL	Qual	Units	DF	Date Analyzed
Organic Carbon, Walkley-Black	**Method: TOCWB**					**Analyst: NK**
Organic Carbon, Fractional	ND	0.10		%	1	9/17/2018 4:00 PM

RTI Laboratories, Inc. - Analytical Report

WO#: 1809069

Date Reported: 9/24/2018
Original

Client:	Brighton Analytical Labs	**Collection Date:**	8/29/2018 12:00:00 AM
Project:	52534		
Lab ID:	1809069-002	**Matrix:**	Soil
Client Sample ID:	CI01726		

Analysis	Result	RL	Qual	Units	DF	Date Analyzed
Organic Carbon, Walkley-Black	**Method: TOCWB**					**Analyst: NK**
Organic Carbon, Fractional	ND	0.10		%	1	9/17/2018 4:00 PM

RTI Laboratories, Inc. - DATES REPORT

WO#: 1809069

Date Reported: 9/24/2018
Original

Client: Brighton Analytical Labs

Project: 52534

Sample ID	Client Sample ID	Collection Date	Matrix	Test Name	Leachate Date	Prep Date	Analysis Date
1809069-001A	CI01725	8/29/2018 12:00 AM	Soil				
				TOC_WB-Organic Carbon, Walkley-Black		9/17/2018 4:00 PM	9/17/2018 4:00 PM
1809069-002A	CI01726	8/29/2018 12:00 AM	Soil				
				TOC_WB-Organic Carbon, Walkley-Black		9/17/2018 4:00 PM	9/17/2018 4:00 PM

RTI Laboratories, Inc. - Definitions and Acronyms

WO#: 1809069

Date Reported: 9/24/2018
Original

DEFINITIONS:

DF: Dilution factor; the dilution factor applied to the prepared sample.

DUP: Duplicate; aliquots of a sample taken from the same container under laboratory conditions and processed and analyzed independently, used to calculate Precision (%RPD).

LCS: Laboratory Control Sample; prepared by adding a known amount of target analytes to a specified amount of clean matrix and prepared with the batch of samples, used to calculate Accuracy (%REC).

LCSD: A duplicate LCS sample, used to calculate both Accuracy (%REC) and Precision (%RPD)

MBLK: Method Blank; a sample of similar matrix that does not contain target analytes or interference that may impact the analytical results and is processed simultaneously with and under the same conditions as samples through all steps of the analytical procedure, used to assess and verify that the analytical process is free of contamination.

MDL: Method Detection Limit; The lowest concentration of analyte that can be detected by the method in the applicable matrix.

Mg/Kg or mg/L: Units of part per million (PPM) – milligram per Kilogram (W/W) or milligram per Liter (W/V).

MS: Matrix Spike; prepared by adding a known amount of target analytes to a specified amount of matrix sample for which an independent estimate of target analyte concentration is available, used to calculate Accuracy (%REC)

MSD: A duplicate MS sample, used to calculate both Accuracy (%REC) and Precision (%RPD)

% REC: Percent Recovery of a known spike (SPK); a measure of accuracy expressed as a percentage of a measured (recovered) concentration compared to the known concentration (SPK) added to the sample. This is compared to the Low Limit and High Limit.

% RPD: Relative Percent Difference; a measure of precision expressed as a percentage of the difference between two duplicates relative to the average concentration. This is compared to the RPD Limit.

PL: Permit limit:; Not included on all reports. Used primarily for wastewater discharge permits.

PQL: Practical Quantitation Limit; The lowest verified limit to which data is quantified without qualifications. Analyte concentrations below PQL are reported either as ND or as a number with a "J" qualifier.

Qual: Qualifier that applies to the analyte reported

RL: Reporting Limit: See PQL

SPK: Spike; used in the QC section for both SPK Value and SPK Ref Val

Ug/Kg or ug/L: Units of part per billion (PPB) – microgram per Kilogram (W/W) or microgram per Liter (W/V).

QUALIFIERS:

*/X: Reported value exceeds the maximum allowed concentration by regulation or permit

B: Analyte detected in the associated Method Blank at a concentration > RL.

E: Analyte concentration reported that exceeds the upper calibration standard. Greater uncertainty is associated with this result and data should be considered estimated.

H: Holding time for preparation or analysis has been exceeded

J: Analyte concentration is reported, and is less than the PQL and greater than or equal to the established MDL. Greater uncertainty is associated with this result and data reported is estimated. These analytes are not routinely reviewed nor narrated as to their potential for being laboratory artifacts.

M: Manual Integration used to determine area response

ND: Analyte concentration is less than the Reporting Limit.

P: Second column RPD exceeds 40%

R: % RPD exceeds control limits

S: % REC exceeds control limits

T: MBLK result is greater than 1/2 of the LOQ

U: The analyte concentration is less than the DL.

TO: RTI

Brighton Analytical, L.L.C.™
Email: bai-brighton@sbcglobal.net
2105 Pless Drive — Phone: 810-229-7575
Brighton, MI 48114 — Fax: 810-229-8650

BA PROJECT #:

ABBREVIATIONS FOR MATRIX
S = Solid
L = Liquid
DW = Drinking H_2O
O = Oil
P = Wipe
A = Air (Tedlar Bag)
F = Filter
T = Tube
M = Misc.

PROJECT NAME: 52534
PROJECT #: 52534 1809069
PO #: (PLEASE NOTE IF DIFFERENT BILLING ADDRESS)

Sample collected by:

REQUESTED TURNAROUND: (circle one)
Rush: 1-3 business days (verify with lab & specify date needed)
1 Day = 2.5X Cost 2 Day = 2X Cost 3 Day = 1.5X Cost
Standard: 5 business days

If RUSH, approved by: _____

Analysis Requested/Method

Brighton ID #	Sample Description	Sample Coll. Date	Sample Coll. Time	Container Type & Quantity: VOA'S (PRES) Y N N/A	HDPE UNPRESERVED	HDPE HNO_3	HDPE H_2SO_4	HDPE NAOH	AMBER PRESERVED?	GLASS, NO PRESERVATIVE	STERILIZED BACTERIA	MEOH Preserved Y N	Sample Matrix	TOC
1)	CI01725	8.29.18			1								WS	X
2)	CI01726	8.29.18			1								WS	X
3)														
4)														
5)														
6)														
7)														
8)														
9)														
10)														

Special Instructions: 10-11°C on ice

PAGE ___ OF ___

COMPANY/MAILING ADDRESS:
Brighton Analytical
2105 Pless Dr.
Brighton MI 48114
ATTN: Deb Hoffner
PHONE: 8102297575 X160
FAX OR EMAIL: bai-brighton@sbcglobal.net

Samples received within hold time? yes ☐ no ☐
Temperature of samples °C:
pHs verified in login? yes ☐ no ☐
Headspace/bubbles in VOA's? yes ☐ no ☐ n/a ☐
Sample containers and COC match? yes ☐ no ☐

BILLING ADDRESS (IF REQUIRED):

Drinking H_2O:
Fax to LCHD? yes ☐ no ☐
Chlorinated Water Supply? yes ☐ no ☐
AMT.: _____

MCL Failure: yes ☐ no ☐
Client Notified (date/time/initials): _____

Please fill out the Chain of Custody completely and review. Incorrect or incomplete information will result in a "hold" on all analyses.

Trans. #	RELINQUISHED BY:	RECEIVED BY:	DATE:	TIME:	Trans. #	RELINQUISHED BY:	RECEIVED BY:	DATE:	TIME:
1			9.5.18	10:29	3				
2					4				

Appendix C

Native Persulfate Soil Oxidant Demand Analysis

Hamp, Mathews &
Associates, Inc.

Klozur® Persulfate Demand Test and Base Buffering Capacity test

Client: Hamp, Mathews & Assoc.
15226 Ann Drive
Bath, MI, 48808
Contact Person: Joel Parker
Phone: 517-896-1288
Email: jparker@hampmathews.com

Performing Lab: PeroxyChem Environmental Solutions USA
Tonawanda, New York, 14150

Date **September 17, 2018**

I. Background

Klozur® activated persulfate is a strong oxidant capable of mineralizing a wide range of contaminants, including chlorinated solvents, petroleum hydrocarbons, polyaromatic hydrocarbons, gasoline additives, pesticides, and many others. Activation of the persulfate anion generates the sulfate radical, the primary species that drives the rapid destruction of the contaminants of concern. Activation can be accomplished by several methods[1]: heat, transition metals, addition of hydrogen peroxide, or utilizing high pH. Choice of the activation method will depend on the contaminant of concern and site characteristics.

A chemical oxidant is not specific as to what it will oxidize. As a result, activated persulfate will not only mineralize the contaminant of concern, but a portion of the oxidant will be used in oxidizing soil organics, reduced metals, and organic species that are not of concern. In addition, activated persulfate will undergo auto-decomposition, which will be a function of temperature, concentration and activation method. The demand upon the activated persulfate from all of these components is captured in a coarse screening test termed, “Klozur Demand Test”. It is dependent upon the site characteristics, such as the organic content of the soil, the mineral loading, and soil type and collectively must be considered for estimating the magnitude of oxidant dosing during field application.

[1] PeroxyChem is the owner of licensee under various patents relating to the use of activation chemistries

The Klozur® Persulfate KDT test measures the loss of persulfate in the presence of soil, groundwater and activator over a period of 48 and 168 hours. The resulting KDT values can then be used as a guide to develop appropriate persulfate dosing for subsequent treatability testing and field applications.

When high pH is chosen as a means of activation, a Base Buffering Capacity (BBC) test is recommended. The goal of a BBC test is to determine the amount of sodium hydroxide (NaOH) needed to raise the pH of a soil to pH 10.5, which is necessary for Klozur persulfate activation. This report contains the results and observations from both a KDT and BBC test.

II. Sample Handling

Client Sample Identification

Site Identification: Site X
Soil ID: PB 18-6 (9-15')
GW ID: DiH2O

Site Identification: Site X
Soil ID: PB 18-7 (9-11.5')
GW ID: DiH2O

Handling Procedures

- The samples were received on 08/30/2018. Soil was transferred into a stainless steel bowl and mixed well. Soil PB 18-6 (9-15') was brown in color and very fine moist sand in texture with no odor. No groundwater was provided. Soil PB 18-7 (9-11.5') was brown in color and fine sand with small stones and shells throughout with no odor.
- The remaining soil was put into its original container and stored at ambient lab temperature.
- On 09/05/2018, the tubes were prepared according to the PeroxyChem Tonawanda KDT protocol using the provided soil and groundwater. Additional tubes were prepared according to the PeroxyChem Tonawanda BBC protocol using the provided soil and groundwater.
- The experimental samples were stored at room temperature and each sample was inverted several times once per day.
- The unused soil will be disposed of responsibly after about one month.

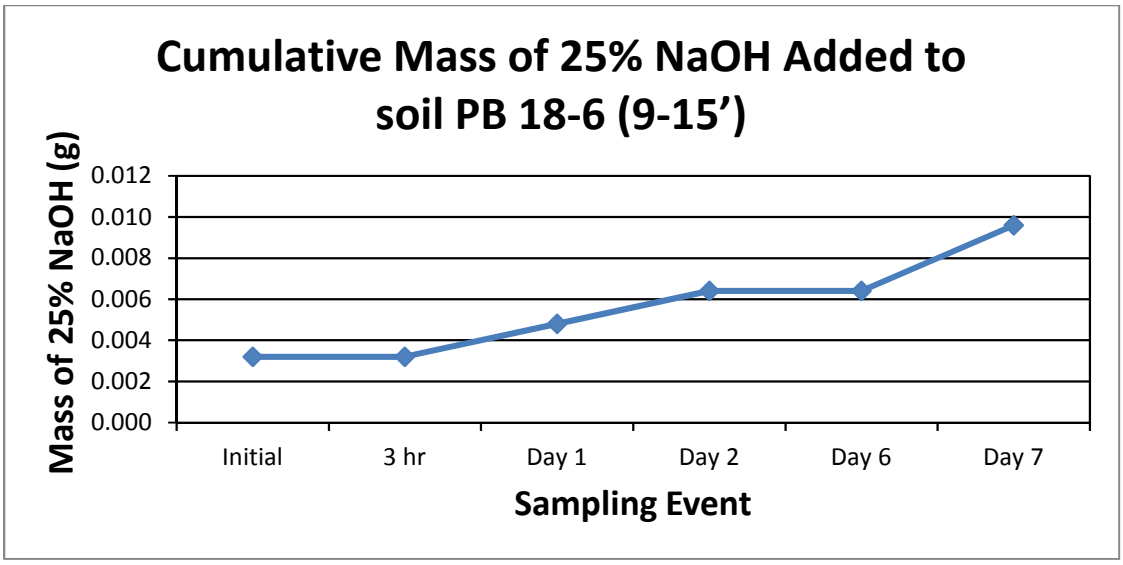
III. Results

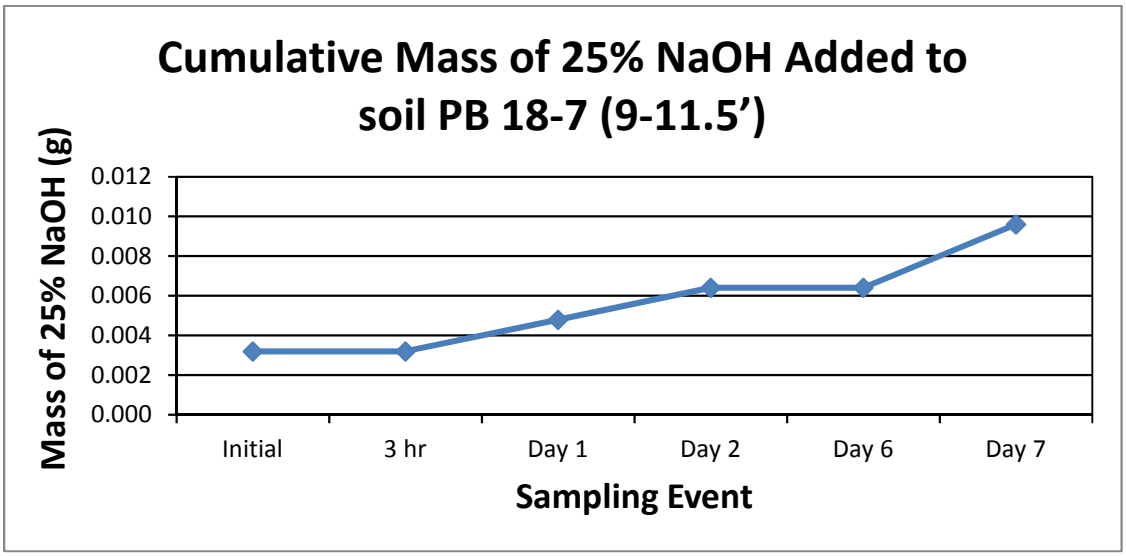
Sample ID	Trial Activator	Soil Wt. (g)	Water Vol. (mL)	Klozur Dosage (g/Kg Soil) t=0 hrs.	Slurry pH	Klozur Consumption (g persulfate / kg dry soil)	
						t=48hr	t=168 hr
Soil: PB 18-6 (9-15') GW: DiH2O	High pH 25% NaOH	10	30	15	12.45	0.49	1.00

Sample ID	Trial Activator	Soil Wt. (g)	Water Vol. (mL)	Klozur Dosage (g/Kg Soil) t=0 hrs.	Slurry pH	Klozur Consumption (g persulfate / kg dry soil)	
						t=48hr	t=168 hr
Soil: PB 18-7 (9-11.5') GW: DiH2O	High pH 25% NaOH	10	30	15	12.41	0.96	1.46

Sample ID	pH	Initial Dosing	7 days	Total mass of 25% NaOH added over 7 days (g)	BBC (g 25% NaOH / kg dry soil)
Soil: PB 18-6 (9-15')	Initial pH	9.66	10.40	0.010	0.36
GW: DiH2O	Final pH	10.71	10.87		

Sample ID	pH	Initial Dosing	7 days	Total mass of 25% NaOH added over 7 days (g)	BBC (g 25% NaOH / kg dry soil)
Soil: PB 18-7 (9-11.5')	Initial pH	9.58	10.47	0.006	0.24
GW: DiH2O	Final pH	10.67	10.71		





IV. Conclusions

The Klozur® Persulfate demand with high pH activation for the PB 18-6 (9-15') sample was 0.49 g persulfate / kg dry soil after 48 hours and 1.00 g persulfate / kg dry soil after 168 hours.

The BBC for the provided soil and groundwater was 0.36 g 25% NaOH / kg dry soil.

The Klozur® Persulfate demand with high pH activation for the PB 18-7 (9-11.5') sample was 0.96 g persulfate / kg dry soil after 48 hours and 1.46 g persulfate / kg dry soil after 168 hours.

The BBC for the provided soil and groundwater was 0.24 g 25% NaOH / kg dry soil.

V. Photos from BBC test

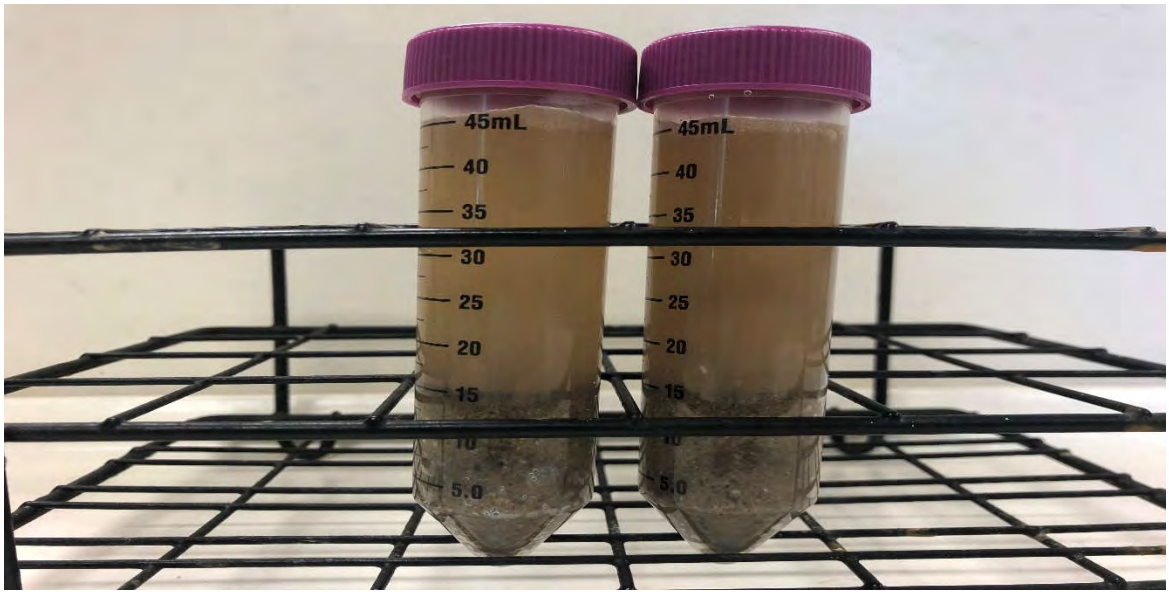


Photo 1: PB 18-6 (9-15'): Day 0, before initial dosing. From left to right: Tube #1 and #2

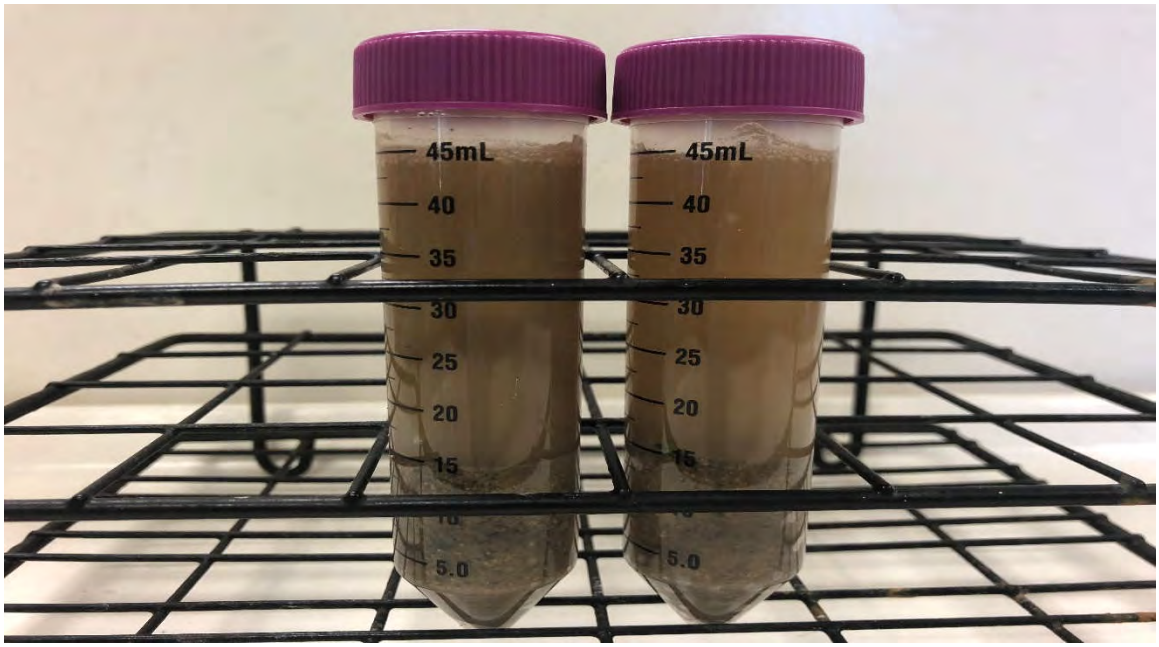


Photo 2: PB 18-7 (9-11.5'): Day 0, before initial dosing. From left to right: Tube #1 and #2

VI. Authorizing Signatures

This report contains the results as determined by PeroxyChem laboratory protocol and are accurately represented herein.

Note: 1. PeroxyChem recommends performing suitable treatability testing and field pilot demonstration to determine the effectiveness of Klozur® activated persulfate on the contaminants of concern. KDT testing provides only an indication of the minimum amount of oxidant required to overcome the demands of soil, groundwater and other secondary species that contribute to the usage of the oxidant. The KDT results do not imply a guarantee of efficacy of the activated persulfate in actual field situations. 2. ANY SUCH QUANTITY OR WARRANTY IS EXPRESSLY DISCLAIMED.

Appendix D

2018 Low-Flow Sampling Logs

Hamp, Mathews &
Associates, Inc.

LOW FLOW
MINIMUM DRAWDOWN
SAMPLE DATA SHEET

Project Name: _____ **Date:** 11/8/18

Project Number: _____ **Well ID:** OW-3

Location: _____

Personnel: _____

Equipment: _____

Parameters: _____

_____

Weather Conditions

Temp: 40°

Wind: NW @ 8mph

Humidity: 61%

Baro: 30.38 in Hg

PURGING INFORMATION

Start Purging: 12:48

End Purging: 13:11

Purge Rate: 150 mL/min.

Purge Volume (gal): 1.5

Static Water Level (TOC): 9.10'

Tubing Elevation: 17'

Total Depth: 18'

Purge Method: Peristaltic

Well Condition: ✓

Casing Diameter: 2"

Casing Type: PVC

Screen Length: 5'

TIME	SWL / Δ	pH	Cond.	ORP	D.O.	Turbidity	Temp.	COMMENTS
12:51	9.16 / Ø	7.63	1248	-32.1	2.54		12.97	
12:54	9.16 / Ø	7.43	1248	-52.9	1.47		13.19	
12:57	9.16 / Ø	7.41	1245	-57.4	1.28		13.25	ORP, DO off
13:00	9.16 / Ø	7.38	1241	-60.6	1.14		13.23	DO off
13:03	9.16 / Ø	7.35	1238	-63.1	1.07		13.25	DO off
13:06	9.16 / Ø	7.33	1234	-65.6	1.07		13.24	✓
13:09	9.16 / Ø	7.31	1233	-66.4	1.01		13.23	✓
13:12	/							
13:15	/							
13:18	/							
13:21	/							

SAMPLING INFORMATION

Time: 13:~~09~~ 12

Color: Clear

Odor: No

Filtered: No

pH: _____

Cond.: _____

ORP: _____

D.O.: _____

Turbidity: _____

Temp: _____

NOTES _____

_____

_____

Blind Duplicate: _____ Signiture: _____

LOW FLOW
MINIMUM DRAWDOWN
SAMPLE DATA SHEET

Project Name: _____ **Date:** 11/8/18

Project Number: _____ **Well ID:** OW-2

Location: _____

Personnel: _____ **Weather Conditions**

Equipment: _____ Temp: _____

Parameters: _____ Wind: _____

_____ Humidity: _____

PURGING INFORMATION

Start Purging: 13:21 Static Water Level (TOC): 8.97' Well Condition: _____

End Purging: _____ Tubing Elevation: 17' Casing Diameter: _____

Purge Rate: 150mL/min Total Depth: 18' Casing Type: _____

Purge Volume (gal): 2 Purge Method: Peristaltic Screen Length: _____

TIME	SWL / Δ	pH	Cond.	ORP	D.O.	Turbidity	Temp.	COMMENTS
13:24	9.00 /	7.31	1246	-64.4	0.58		12.91	
13:27	9.00 / Ø	7.31	1251	-70.1	0.54		12.96	
13:30	9.00 / Ø	7.32	1218	-66.7	1.01		12.97	DO off
13:33	9.00 / Ø	7.32	1182	-56.7	1.34		13.03	DO off
13:36	9.00 / Ø	7.36	1150	-51.4	1.54		13.06	DO OFF
13:39	9.00 / Ø	7.32	1143	-47.4	1.57		13.02	
13:42	9.00 / Ø	7.32	1138	-43.4	1.62		13.05	
13:45	9.00 / Ø	7.32	1132	-39.1	1.64		13.04	
13:48	/							
13:51	/							
13:54	/							

SAMPLING INFORMATION

Time: 13:48 Odor: No pH: _____ D.O.: _____

Color: Clear Filtered: No Cond.: _____ Turbidity: _____

ORP: _____ Temp: _____

NOTES _____

_____

_____

Blind Duplicate: _____ Signiture: _____

LOW FLOW
MINIMUM DRAWDOWN
SAMPLE DATA SHEET

Project Name: _____ **Date:** 11/8/18

Project Number: _____ **Well ID:** OW-1

Location: _____

Personnel: _____ **Weather Conditions**

Equipment: _____ Temp: _____

Parameters: _____ Wind: _____

_____ Humidity: _____

PURGING INFORMATION

Start Purging: 13:55 Static Water Level (TOC): 8.92' Well Condition: ✓

End Purging: 14:14 Tubing Elevation: 17' Casing Diameter: 2"

Purge Rate: 150 mL/min. Total Depth: 18' Casing Type: PVC

Purge Volume (gal): 1.5 Purge Method: Peristaltic Screen Length: 5'

TIME	SWL / Δ	pH	Cond.	ORP	D.O.	Turbidity	Temp.	COMMENTS
13:59	8.95 /	7.32	1144	-36.6	1.36		12.61	
14:02	8.95 / Ø	7.32	1152	-33.6	1.05		12.53	
14:05	8.95 / Ø	7.35	1152	-25.5	0.91		12.51	
14:08	8.95 / Ø	7.35	1157	-14.8	0.79		12.59	ORP, DO off.
14:11	8.95 / Ø	7.35	1158	-6.5	0.77		12.63	
14:14	8.95 / Ø	7.36	1156	-2.2	0.75		12.66	
14:17	/							
14:20	/							
14:23	/							
14:26	/							
14:29	/							

SAMPLING INFORMATION

Time: 14:17 Odor: No pH: _____ D.O.: _____

Color: Clear Filtered: No Cond.: _____ Turbidity: _____

ORP: _____ Temp: _____

NOTES _____

_____

_____

Blind Duplicate: _____ Signiture: _____

LOW FLOW
MINIMUM DRAWDOWN
SAMPLE DATA SHEET

Project Name: RACER - Eckles Rd. **Date:** 11/8/18

Project Number: 41-2 **Well ID:** EW-1 (14')

Location: 37800 Grantland

Personnel: D.S. / J.C.

Equipment: Peristaltic pump, static, YSI, tubing, Fibertec jars

Parameters:

Weather Conditions

Temp:

Wind:

Humidity:

PURGING INFORMATION

Start Purging: 14:30

End Purging: 14:47

Purge Rate: 150 mL/min.

Purge Volume (gal): 1.5

Static Water Level (TOC): 8.94'

Tubing Elevation: 14' bgs

Total Depth: 18' screen 20' w/ sump

Purge Method: Peristaltic

Well Condition: ✓

Casing Diameter: 4"

Casing Type: PVC

Screen Length: 5'

TIME	SWL / Δ	pH	Cond.	ORP	D.O.	Turbidity	Temp.	COMMENTS
14:32	8.95 /	7.35	1132	33.0	1.74		12.67	
14:35	8.95 / Ø	7.34	1144	37.6	1.45		12.88	
14:38	8.95 / Ø	7.33	1153	39.4	1.37		12.90	
14:41	8.95 / Ø	7.31	1162	39.9	1.18		12.93	
14:44	8.95 / Ø	7.30	1167	40.8	1.12		12.86	
14:47	8.95 / Ø	7.31	1170	41.8	1.09		12.92	
14:50	/							
14:53	/							
14:56	/							
14:59	/							
15:02	/							

SAMPLING INFORMATION

Time: 14:50

Color: Clear

Odor: No

Filtered: No

pH:

Cond.:

ORP:

D.O.:

Turbidity:

Temp:

NOTES

Blind Duplicate:

Signiture:

LOW FLOW
MINIMUM DRAWDOWN
SAMPLE DATA SHEET

Project Name: _____ **Date:** 11/8/18

Project Number: _____ **Well ID:** EW-1 (17')

Location: _____

Personnel: _____ **Weather Conditions**

Equipment: _____ Temp: _____

Parameters: _____ Wind: _____

_____ Humidity: _____

PURGING INFORMATION

Start Purging: 14:58 Static Water Level (TOC): _____ Well Condition: _____

End Purging: 15:14 Tubing Elevation: 17' bgs Casing Diameter: _____

Purge Rate: 150 mL/min Total Depth: 18' screen 20' w/sump Casing Type: _____

Purge Volume (gal): 1.5 gal. Purge Method: Peristaltic Screen Length: _____

TIME	SWL / Δ	pH	Cond.	ORP	D.O.	Turbidity	Temp.	COMMENTS
15:02	8.95 /	7.34	1214	45.0	0.45		12.60	
15:05	8.95 / 0	7.36	1219	42.5	0.45		12.61	
15:08	8.95 / 0	7.38	1220	38.6	0.35		12.61	
15:11	8.95 / 0	7.37	1220	38.4	0.28		12.62	
15:14	8.95 / 0	7.38	1220	36.8	0.26		12.63	
15:17	/							
15:20	/							
15:23	/							
15:26	/							
15:29	/							
15:32	/							

SAMPLING INFORMATION

Time: 15:17 Odor: No pH: _____ D.O.: _____

Color: Clear Filtered: No Cond.: _____ Turbidity: _____

ORP: _____ Temp: _____

NOTES _____

_____

_____

Blind Duplicate: _____ Signiture: _____

APPENDIX E

KLOZUR® SP SUPPORTING DOCUMENTATION

HAMP, MATHEWS &
ASSOCIATES, INC.

Environmental Solutions

KLOZUR® KP
Case Study

Klozur® KP Reduces CVOC and BTEX Contamination Concentrations by >99% at a Former Industrial Site in Germany

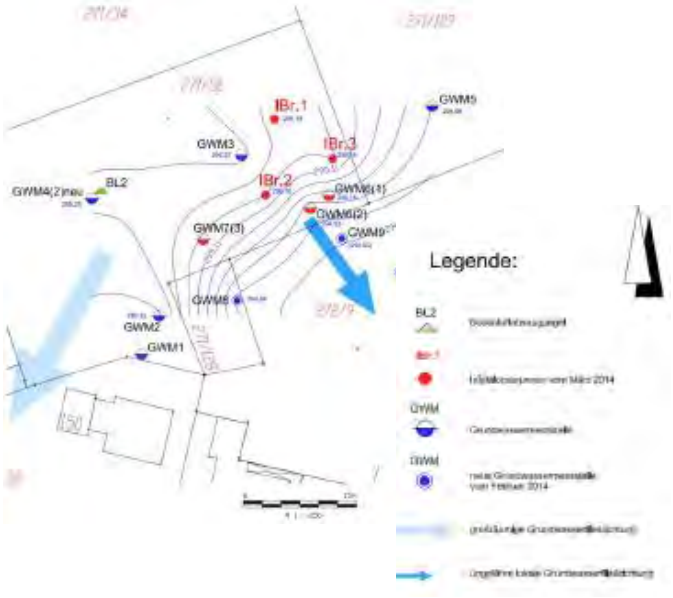
Summary

Consultant: Riskcom
Contractor: TOTERRA Ltd.

The drum storage area of a former industrial site in Germany was contaminated with naphthalene, BTEX, and CVOC's including tetrachloroethene (PCE), trichloroethene (TCE), and cis-1,2-dichloroethene (DCE). The contamination was found mainly in the low permeable sandstone up to 12 m (39.4 ft) below ground surface (bgs).
It was determined that pump & treat was not practical and that it was not possible to excavate, therefore the preferred approach was hydraulically placed Klozur® KP with a patented chelated iron activator[1].

Pilot Project

The pilot design targeted the areas with the highest levels of groundwater impacts; approximately between 7 – 11 m (23 – 36 ft) bgs. Three areas were targeted for treatment with 5 vertical injection intervals in each area via hydraulic fracturing technology.
Approximately 1,350 kg (2976 lbs) of Klozur KP was injected activated by 200 kg (441 lbs) of ferrous lactate.



Conclusions

The Klozur KP and activator were successfully distributed over a 200 m^2 (2,152 ft^2) throughout the three injection area locations. Post application monitoring 6 months after the injections showed that the activated Klozur KP resulted in up to 99% treatment of target contaminants of concern (COCs).

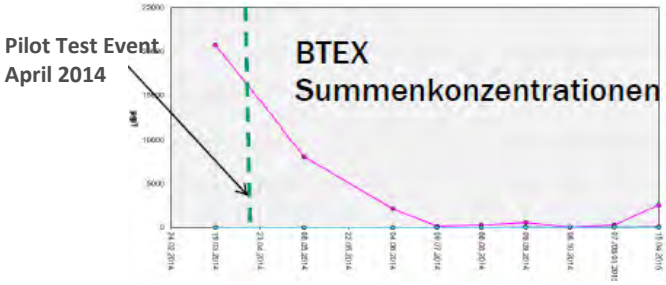


Figure 1 – BTEX Total Concentration after the Klozur KP injection event

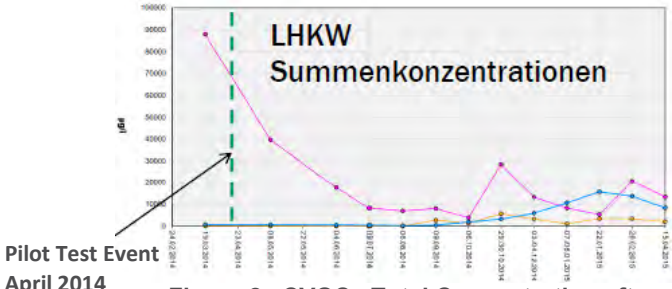


Figure 2 –CVOCs Total Concentration after the Klozur KP injection event

Above in Figures 1 and 2 it can be seen from the primary monitoring wells that the concentrations rapidly reduced post injection and the Klozur KP allowed for treatment over time as it slowly dissolved through the treatment area.

Table 1 shows most concentrations dropped to >99% reduction for most COC's within 6 months after the injection in the target area. After one year the PCE and TCE concentrations remained low while DCE, BTEX, and PAH concentrations increased. Secondary site parameters, including conductivity, indicate that this increase in concentration is due to upgradient contaminated groundwater moving back into the target interval of the pilot treatment area.

Date	Contaminant (µg/L)				
	PCE	TCE	cDCE	BTEX	PAH
3/19/2014	13,000	22,000	52,000	20,713	98
10/7/2014	8	23	3,800	47	5
Percent Reduction 6 months post application	**99.9%**	**99.9%**	**92.7%**	**99.8%**	**94.5%**
4/15/2015	4	6	13,000	2,570	104
Percent Reduction 12 months post application	**99.97%**	**99.97%**	**75.0%**	**87.6%**	**-5.3%**

Table 1 – Total Contaminant Concentration and reduction 6 to 12 months after the Klozur KP injection event

1. US patent 9,375,768 B2

13-Jun-2019

Customer:	**Hamp Mathews**	**Prepared by:**	
Contact:	**Joel Parker**	**John Valkenburg, PE**	
Site Location:	**Livonia**	**1-517-669-5400**	
Proposal Number:	**CRM 21370**	**John.Valkenburg@peroxychem.com**	

Klozur® SP Demand Calculations

PROPOSAL ATTACHMENTS

PRODUCT OVERVIEW

Klozur® SP is an environmental grade sodium persulfate which has been delivered safely and cost effectively to treat a wide variety of common contaminants of concern with an unmatched combination of power and control. With proper activation, Klozur SP can generate both oxidative and reductive pathways delivering the power to destroy the most recalcitrant of contaminants.

For more information on activated Klozur SP, please contact your PeroxyChem representative or www.klozur.com.

SITE INFORMATION

	Value	Unit	Note
Area of Treatment	7,200	ft2	customer supplied
Treatment Zone Thickness	5	ft	customer supplied
Treatment Volume	36,000	ft3	calculated value
Porosity	30	%	default value
Ground Water Volume	80,779	USG	calculated value
Soil Density	100	lbs/ft3	default value
Soil Mass	3,600,000	lb	calculated value
Fraction Soil Mass Contacted*	100	%	default value
Base Buffering Capacity (Alkaline Activation only)	0.36	g 25 percent NaOH / kg soil	estimated value, it is recommend that this be analytically determined
Soil Oxidant Demand	1.46	g Klozur / kg soil	estimated value, it is recommend that this be analytically determined

* Fraction soil mass contacted may be less for sites with contact limitations such as fractured bedrock or those with low permeable materials.

Disclaimer:

The estimated dosage and recommended application methodology described in this document are based on the site information provided to PeroxyChem, but are not meant to constitute a guaranty of performance or a predictor of the speed at which a given site is remediated. Klozur® persulfate and activator demand calculations do not take into account the kinetics, speed of the reaction, or ability to establish contact between the reagents and contamination in the subsurface. These calculations represent the minimum anticipated amount needed to treat the contaminants of concern (COCs). As a result, these calculations should be used as a general approximation for purposes of an initial economic assessment. PeroxyChem recommends that oxidant demand and treatability testing be performed to verify the quantities of oxidant needed.

CONTAMINANTS OF CONCERN* (COCs)

Concentrations:

The following are estimates of the contaminant concentration in soil and groundwater within the target area. The total COC mass was calculated including estimated COC mass in groundwater, soil and NAPL, if present, within the targeted area.

Contaminant	GW (mg/L)	Soil (mg/kg)	NAPL (lbs)	Total COC Mass** (lb)
TCE	0.5	10.0	0.0	36.3

Remedial Goals and Target Mass Reductions:

The target demand is determined by also accounting for remedial goals for each contaminant and represents the estimated mass reductions targeted for each contaminant.

Contaminant	GW (mg/L)	Soil (mg/kg)	NAPL (lbs)	Total COC Mass Targeted*** (lbs)
TCE	0	0	0	36.3

*Unless provided, sorbed concentrations were roughly estimated based on expected groundwater concentrations, foc and Koc values. For a more refined estimate, it is recommended that actual values be verified via direct sampling of the targeted treatment interval.

** Includes estimated contaminant mass in soil, groundwater, and NAPL (if provided) at the site.

*** Includes estimated contaminant mass in soil, groundwater, and NAPL (if provided) at the site with the remedial goals subtracted from the total mass onsite.

KLOZUR PERSULFATE DEMAND

The estimated mass of Klozur SP accounts for target demand with the COCs, non-target demand associated with the soils (SOD) and a safety factor applied to each. The safety factor is intended to account for potential variability in the COC and SOD estimates and any other uncertainties associated with the application or site.

The demand from COCs was estimated using: **Degradation Ratio**

The degradation ratio should be determined/verified in a bench or field test

	Klozur SP Demand	Safety Factor	Klozur SP Demand with Factor	
Demand from COCs	436	4.0	1,744	lb
Demand from SOD	5,256	6.0	31,536	lb

Total Klozur SP Demand: **33,280** **lb** **To be applied in** **1** **application**

KLOZUR SP PACKAGING OPTIONS AND PRICING

Klozur SP can be delivered to your site in a variety of packages including in bags, or two sizes of super sacks for your handling convenience. Pricing below is exclusive of shipping and any applicable taxes.

Estimate for : **Total Klozur SP Demand**

Packaging Type: **55.1 lb bags**

Packaging Type	# of packages / pallet	lb Klozur® SP / pallet	# of packages needed
55.1 lb bags	40	2,204	640

KLOZUR ACTIVATION CHEMISTRIES

Klozur activation chemistries are used to convert Klozur SP into the highly reactive radicals. Choosing the right activator chemistry for your contaminants of concern is important in obtaining a successful site remediation. The choice of activator will be dependent upon the target contaminants, site lithology and hydrogeology, and other site conditions. While activator demand quantities for all methods are given, not all activation methods are recommended for your given contaminant or site conditions. Please consult with an PeroxyChem Environmental Solutions technologist for proper selection of activation chemistry.

Note: Only one type of activator is typically needed.

Recommended methods to activate Klozur SP: **high pH**

***PeroxyChem LLC is the owner or licensee under various patent applications relating to the use of activation chemistries**

Alkaline (High pH) Activation

Alkaline demand = Alkalinity to neutralize generate HSO_4^- from persulfate decomposition + amount needed to raise ground water / soil to a pH > 10.5

Calculation for NaOH (high pH) demand:

Sodium hydroxide is a highly soluble form of alkalinity that is commonly used for injection events with Klozur SP.

NaOH demand for HSO4 neutralization	11,853	lb @ 100% basis
Soil buffering amount	324	lb @ 100% basis
Total NaOH demand	12,177	lb @ 100% basis

PeroxyChem recommends using a 25 wt% or less NaOH concentration **

Amount of	25	wt% solution needed	4,595	gal
			48,710	lb

** note: the addition of concentrated NaOH to water is very exothermic. Add NaOH slowly to water, and allow for excess heat to dissipate.

INSTALLATION VIA INJECTION

Klozur SP will be delivered as a dry powder, packaged in 55.1-lb (25 Kg) bags, 1,102 lb (500 Kg), and 2,204 lb (1,000 Kg) supersacks. Klozur SP is highly soluble in water and can be injected via fixed wells, open boreholes or using direct push technology (DPT). Klozur SP is typically batched at a concentration of between 50 to 450 g/L (5 to 35%) and PeroxyChem recommends injecting at a concentratipn of between 50 and 250 g/L, depending upon site design and conditions.

Effective treatment requires establishing contact between a sufficient amount of activated persulfate and the contaminant in the subsurface. A key element of establishing this contact in a source zone is the injection volume used to inject the activated persulfate reagents. Depending on the application method employed and site conditions, between 20% and 100% (with >50% typical) of the effective porosity is normally targeted during Klozur SP injection, with a higher percent pore fill normally targeted for sites with slow groundwater velocities.

Below is an example injection scenario for the proposed mass Klozur SP for this site. The suggested injection volumes may be altered based on the site specific conditions.

Number of Applications	1	
Klozur SP Dosage		
Mass of Klozur SP	35,264	lb
Concentration in Total Pore Volume	52	g/L
	5.0	% w/w
Application rate by soil mass (dry weight)	9.8	g/kg
Injection Locations		
Number of Injection Locations	12	
Radius of Influence		
Design[1]	15	ft
Injection[2]	*11.6*	*ft*
Overlapping Design ROI[3]	13	%
Transect Layout		
Approximate Spacing between locations[4]	20	ft
2x Injection ROI	*23.1*	*ft*
Overlapping of Injection ROI (%)	*16%*	
Injection Details (per application)		
Total Injection Volume	28,300	gal
Percentage of Effective Pore Volume	70	%
Klozur SP Injection Concentration	149	g/L
	13.7	% w/w
Klozur SP Quantities Per Injection Location:		
Klozur SP	2,939	lb
Injection Volume	2,358	gal

Design parameters should be considered approximations and suggestions. Site design engineers and contractors are ultimately responsible for the field application and design.

Values are based upon client supplied data and other assumed values. Changes in any of the input values will affect and alter other values.

Notes:

1. Design radius of influence corresponds to the desired treatment radius from each injection location.
2. Injection radius of influence corresponds to the distance from each injection point the injection volume would distribute assuming uniform (cylindrical) distribution in the effective pore volume.
3. Approximate percentage of overlap between the Design ROI from the various injection locations. Actually percent overlap will depend upon injection location layout.
4. Approximate distance between injection locations. Actual distance will depend upon site layout.

13-Jun-2019

Customer:	**Hamp Mathews**	**Prepared by:**	
Contact:	**Joel Parker**	**John Valkenburg, PE**	
Site Location:	**Livonia**	**1-517-669-5400**	
Proposal Number:	**CRM 21370**	**John.Valkenburg@peroxychem.com**	

Klozur® SP Demand Calculations

PROPOSAL ATTACHMENTS

PRODUCT OVERVIEW

Klozur® SP is an environmental grade sodium persulfate which has been delivered safely and cost effectively to treat a wide variety of common contaminants of concern with an unmatched combination of power and control. With proper activation, Klozur SP can generate both oxidative and reductive pathways delivering the power to destroy the most recalcitrant of contaminants.

For more information on activated Klozur SP, please contact your PeroxyChem representative or www.klozur.com.

SITE INFORMATION

	Value	Unit	Note
Area of Treatment	2,400	ft2	customer supplied
Treatment Zone Thickness	5	ft	customer supplied
Treatment Volume	12,000	ft3	calculated value
Porosity	30	%	default value
Ground Water Volume	26,926	USG	calculated value
Soil Density	100	lbs/ft3	default value
Soil Mass	1,200,000	lb	calculated value
Fraction Soil Mass Contacted*	100	%	default value
Base Buffering Capacity (Alkaline Activation only)	0.36	g 25 percent NaOH / kg soil	estimated value, it is recommend that this be analytically determined
Soil Oxidant Demand	1.46	g Klozur / kg soil	estimated value, it is recommend that this be analytically determined

* Fraction soil mass contacted may be less for sites with contact limitations such as fractured bedrock or those with low permeable materials.

Disclaimer:

The estimated dosage and recommended application methodology described in this document are based on the site information provided to PeroxyChem, but are not meant to constitute a guaranty of performance or a predictor of the speed at which a given site is remediated. Klozur® persulfate and activator demand calculations do not take into account the kinetics, speed of the reaction, or ability to establish contact between the reagents and contamination in the subsurface. These calculations represent the minimum anticipated amount needed to treat the contaminants of concern (COCs). As a result, these calculations should be used as a general approximation for purposes of an initial economic assessment. PeroxyChem recommends that oxidant demand and treatability testing be performed to verify the quantities of oxidant needed.

CONTAMINANTS OF CONCERN* (COCs)

Concentrations:

The following are estimates of the contaminant concentration in soil and groundwater within the target area. The total COC mass was calculated including estimated COC mass in groundwater, soil and NAPL, if present, within the targeted area.

Contaminant	GW (mg/L)	Soil (mg/kg)	NAPL (lbs)	Total COC Mass** (lb)
TCE	0.4	8.0	0.0	9.7

Remedial Goals and Target Mass Reductions:

The target demand is determined by also accounting for remedial goals for each contaminant and represents the estimated mass reductions targeted for each contaminant.

Contaminant	GW (mg/L)	Soil (mg/kg)	NAPL (lbs)	Total COC Mass Targeted*** (lbs)
TCE	0	0	0	9.7

*Unless provided, sorbed concentrations were roughly estimated based on expected groundwater concentrations, foc and Koc values. For a more refined estimate, it is recommended that actual values be verified via direct sampling of the targeted treatment interval.

** Includes estimated contaminant mass in soil, groundwater, and NAPL (if provided) at the site.

*** Includes estimated contaminant mass in soil, groundwater, and NAPL (if provided) at the site with the remedial goals subtracted from the total mass onsite.

KLOZUR PERSULFATE DEMAND

The estimated mass of Klozur SP accounts for target demand with the COCs, non-target demand associated with the soils (SOD) and a safety factor applied to each. The safety factor is intended to account for potential variability in the COC and SOD estimates and any other uncertainties associated with the application or site.

The demand from COCs was estimated using: **Degradation Ratio** The degradation ratio should be determined/verified in a bench or field test

	Klozur SP Demand	Safety Factor	Klozur SP Demand with Factor	
Demand from COCs	116	2.0	233	lb
Demand from SOD	1,752	3.0	5,256	lb

Total Klozur SP Demand: **5,489** **lb** **To be applied in** **1** **application**

KLOZUR SP PACKAGING OPTIONS AND PRICING

Klozur SP can be delivered to your site in a variety of packages including in bags, or two sizes of super sacks for your handling convenience. Pricing below is exclusive of shipping and any applicable taxes.

Estimate for : **Total Klozur SP Demand**

Packaging Type: **55.1 lb bags**

Packaging Type	# of packages / pallet	lb Klozur® SP / pallet	# of packages needed
55.1 lb bags	40	2,204	120

KLOZUR ACTIVATION CHEMISTRIES

Klozur activation chemistries are used to convert Klozur SP into the highly reactive radicals. Choosing the right activator chemistry for your contaminants of concern is important in obtaining a successful site remediation. The choice of activator will be dependent upon the target contaminants, site lithology and hydrogeology, and other site conditions. While activator demand quantities for all methods are given, not all activation methods are recommended for your given contaminant or site conditions. Please consult with an PeroxyChem Environmental Solutions technologist for proper selection of activation chemistry.

Note: Only one type of activator is typically needed.

Recommended methods to activate Klozur SP: **high pH**

***PeroxyChem LLC is the owner or licensee under various patent applications relating to the use of activation chemistries**

Alkaline (High pH) Activation

Alkaline demand = Alkalinity to neutralize generate HSO_4^- from persulfate decomposition + amount needed to raise ground water / soil to a pH > 10.5

Calculation for NaOH (high pH) demand:

Sodium hydroxide is a highly soluble form of alkalinity that is commonly used for injection events with Klozur SP.

NaOH demand for HSO4 neutralization	2,223	lb @ 100% basis
Soil buffering amount	108	lb @ 100% basis
Total NaOH demand	2,331	lb @ 100% basis

PeroxyChem recommends using a 25 wt% or less NaOH concentration **

Amount of	25	wt% solution needed	879	gal
			9,322	lb

** note: the addition of concentrated NaOH to water is very exothermic. Add NaOH slowly to water, and allow for excess heat to dissipate.

INSTALLATION VIA INJECTION

Klozur SP will be delivered as a dry powder, packaged in 55.1-lb (25 Kg) bags, 1,102 lb (500 Kg), and 2,204 lb (1,000 Kg) supersacks. Klozur SP is highly soluble in water and can be injected via fixed wells, open boreholes or using direct push technology (DPT). Klozur SP is typically batched at a concentration of between 50 to 450 g/L (5 to 35%) and PeroxyChem recommends injecting at a concentratipn of between 50 and 250 g/L, depending upon site design and conditions.

Effective treatment requires establishing contact between a sufficient amount of activated persulfate and the contaminant in the subsurface. A key element of establishing this contact in a source zone is the injection volume used to inject the activated persulfate reagents. Depending on the application method employed and site conditions, between 20% and 100% (with >50% typical) of the effective porosity is normally targeted during Klozur SP injection, with a higher percent pore fill normally targeted for sites with slow groundwater velocities.

Below is an example injection scenario for the proposed mass Klozur SP for this site. The suggested injection volumes may be altered based on the site specific conditions.

Number of Applications	1	
Klozur SP Dosage		
Mass of Klozur SP	6,612	lb
Concentration in Total Pore Volume	29	g/L
	2.9	% w/w
Application rate by soil mass (dry weight)	5.5	g/kg
Injection Locations		
Number of Injection Locations	4	
Radius of Influence		
Design[1]	15	ft
Injection[2]	*11.6*	*ft*
Overlapping Design ROI[3]	13	%
Transect Layout		
Approximate Spacing between locations[4]	20	ft
2x Injection ROI	*23.1*	*ft*
Overlapping of Injection ROI (%)	*16%*	
Injection Details (per application)		
Total Injection Volume	9,400	gal
Percentage of Effective Pore Volume	70	%
Klozur SP Injection Concentration	84	g/L
	8.0	% w/w
Klozur SP Quantities Per Injection Location:		
Klozur SP	1,653	lb
Injection Volume	2,350	gal

Design parameters should be considered approximations and suggestions. Site design engineers and contractors are ultimately responsible for the field application and design.

Values are based upon client supplied data and other assumed values. Changes in any of the input values will affect and alter other values.

Notes:

1. Design radius of influence corresponds to the desired treatment radius from each injection location.
2. Injection radius of influence corresponds to the distance from each injection point the injection volume would distribute assuming uniform (cylindrical) distribution in the effective pore volume.
3. Approximate percentage of overlap between the Design ROI from the various injection locations. Actually percent overlap will depend upon injection location layout.
4. Approximate distance between injection locations. Actual distance will depend upon site layout.

13-Jun-2019

Customer:	**Hamp Mathews**	**Prepared by:**	
Contact:	**Joel Parker**	**John Valkenburg, PE**	
Site Location:	**Livonia**	**1-517-669-5400**	
Proposal Number:	**CRM 21370**	**John.Valkenburg@peroxychem.com**	

Klozur® SP Demand Calculations

PROPOSAL ATTACHMENTS

PRODUCT OVERVIEW

Klozur® SP is an environmental grade sodium persulfate which has been delivered safely and cost effectively to treat a wide variety of common contaminants of concern with an unmatched combination of power and control. With proper activation, Klozur SP can generate both oxidative and reductive pathways delivering the power to destroy the most recalcitrant of contaminants.

For more information on activated Klozur SP, please contact your PeroxyChem representative or www.klozur.com.

SITE INFORMATION

	Value	Unit	Note
Area of Treatment	7,200	ft2	customer supplied
Treatment Zone Thickness	5	ft	customer supplied
Treatment Volume	36,000	ft3	calculated value
Porosity	30	%	default value
Ground Water Volume	80,779	USG	calculated value
Soil Density	100	lbs/ft3	default value
Soil Mass	3,600,000	lb	calculated value
Fraction Soil Mass Contacted*	100	%	default value
Base Buffering Capacity (Alkaline Activation only)	0.36	g 25 percent NaOH / kg soil	estimated value, it is recommend that this be analytically determined
Soil Oxidant Demand	1.46	g Klozur / kg soil	estimated value, it is recommend that this be analytically determined

* Fraction soil mass contacted may be less for sites with contact limitations such as fractured bedrock or those with low permeable materials.

Disclaimer:

The estimated dosage and recommended application methodology described in this document are based on the site information provided to PeroxyChem, but are not meant to constitute a guaranty of performance or a predictor of the speed at which a given site is remediated. Klozur® persulfate and activator demand calculations do not take into account the kinetics, speed of the reaction, or ability to establish contact between the reagents and contamination in the subsurface. These calculations represent the minimum anticipated amount needed to treat the contaminants of concern (COCs). As a result, these calculations should be used as a general approximation for purposes of an initial economic assessment. PeroxyChem recommends that oxidant demand and treatability testing be performed to verify the quantities of oxidant needed.

CONTAMINANTS OF CONCERN* (COCs)

Concentrations:

The following are estimates of the contaminant concentration in soil and groundwater within the target area. The total COC mass was calculated including estimated COC mass in groundwater, soil and NAPL, if present, within the targeted area.

Contaminant	GW (mg/L)	Soil (mg/kg)	NAPL (lbs)	Total COC Mass** (lb)
TCE	0.4	8.0	0.0	29.1

Remedial Goals and Target Mass Reductions:

The target demand is determined by also accounting for remedial goals for each contaminant and represents the estimated mass reductions targeted for each contaminant.

Contaminant	GW (mg/L)	Soil (mg/kg)	NAPL (lbs)	Total COC Mass Targeted*** (lbs)
TCE	0	0	0	29.1

*Unless provided, sorbed concentrations were roughly estimated based on expected groundwater concentrations, foc and Koc values. For a more refined estimate, it is recommended that actual values be verified via direct sampling of the targeted treatment interval.

** Includes estimated contaminant mass in soil, groundwater, and NAPL (if provided) at the site.

*** Includes estimated contaminant mass in soil, groundwater, and NAPL (if provided) at the site with the remedial goals subtracted from the total mass onsite.

KLOZUR PERSULFATE DEMAND

The estimated mass of Klozur SP accounts for target demand with the COCs, non-target demand associated with the soils (SOD) and a safety factor applied to each. The safety factor is intended to account for potential variability in the COC and SOD estimates and any other uncertainties associated with the application or site.

The demand from COCs was estimated using: **Degradation Ratio** The degradation ratio should be determined/verified in a bench or field test

	Klozur SP Demand		Safety Factor	Klozur SP Demand with Factor	
Demand from COCs	349		4.0	1,395	lb
Demand from SOD	5,256		6.0	31,536	lb

Total Klozur SP Demand: **32,931** **lb** **To be applied in** **1** **application**

KLOZUR SP PACKAGING OPTIONS AND PRICING

Klozur SP can be delivered to your site in a variety of packages including in bags, or two sizes of super sacks for your handling convenience. Pricing below is exclusive of shipping and any applicable taxes.

Estimate for : **Total Klozur SP Demand**

Packaging Type: **55.1 lb bags**

Packaging Type	# of packages / pallet	lb Klozur® SP / pallet	# of packages needed
55.1 lb bags	40	2,204	600

KLOZUR ACTIVATION CHEMISTRIES

Klozur activation chemistries are used to convert Klozur SP into the highly reactive radicals. Choosing the right activator chemistry for your contaminants of concern is important in obtaining a successful site remediation. The choice of activator will be dependent upon the target contaminants, site lithology and hydrogeology, and other site conditions. While activator demand quantities for all methods are given, not all activation methods are recommended for your given contaminant or site conditions. Please consult with an PeroxyChem Environmental Solutions technologist for proper selection of activation chemistry.

Note: Only one type of activator is typically needed.

Recommended methods to activate Klozur SP: **high pH**

***PeroxyChem LLC is the owner or licensee under various patent applications relating to the use of activation chemistries**

Alkaline (High pH) Activation

Alkaline demand = Alkalinity to neutralize generate HSO_4^- from persulfate decomposition + amount needed to raise ground water / soil to a pH > 10.5

Calculation for NaOH (high pH) demand:

Sodium hydroxide is a highly soluble form of alkalinity that is commonly used for injection events with Klozur SP.

NaOH demand for HSO4 neutralization	11,113	lb @ 100% basis
Soil buffering amount	324	lb @ 100% basis
Total NaOH demand	11,437	lb @ 100% basis

PeroxyChem recommends using a 25 wt% or less NaOH concentration **

Amount of	25	wt% solution needed	4,315	gal
			45,746	lb

** note: the addition of concentrated NaOH to water is very exothermic. Add NaOH slowly to water, and allow for excess heat to dissipate.

INSTALLATION VIA INJECTION

Klozur SP will be delivered as a dry powder, packaged in 55.1-lb (25 Kg) bags, 1,102 lb (500 Kg), and 2,204 lb (1,000 Kg) supersacks. Klozur SP is highly soluble in water and can be injected via fixed wells, open boreholes or using direct push technology (DPT). Klozur SP is typically batched at a concentration of between 50 to 450 g/L (5 to 35%) and PeroxyChem recommends injecting at a concentratipn of between 50 and 250 g/L, depending upon site design and conditions.

Effective treatment requires establishing contact between a sufficient amount of activated persulfate and the contaminant in the subsurface. A key element of establishing this contact in a source zone is the injection volume used to inject the activated persulfate reagents. Depending on the application method employed and site conditions, between 20% and 100% (with >50% typical) of the effective porosity is normally targeted during Klozur SP injection, with a higher percent pore fill normally targeted for sites with slow groundwater velocities.

Below is an example injection scenario for the proposed mass Klozur SP for this site. The suggested injection volumes may be altered based on the site specific conditions.

Number of Applications	1	
Klozur SP Dosage		
Mass of Klozur SP	33,060	lb
Concentration in Total Pore Volume	49	g/L
	4.7	% w/w
Application rate by soil mass (dry weight)	9.2	g/kg
Injection Locations		
Number of Injection Locations	12	
Radius of Influence		
Design[1]	15	ft
Injection[2]	*11.6*	*ft*
Overlapping Design ROI[3]	13	%
Transect Layout		
Approximate Spacing between locations[4]	20	ft
2x Injection ROI	*23.1*	*ft*
Overlapping of Injection ROI (%)	*16%*	
Injection Details (per application)		
Total Injection Volume	28,300	gal
Percentage of Effective Pore Volume	70	%
Klozur SP Injection Concentration	140	g/L
	12.9	% w/w
Klozur SP Quantities Per Injection Location:		
Klozur SP	2,755	lb
Injection Volume	2,358	gal

Design parameters should be considered approximations and suggestions. Site design engineers and contractors are ultimately responsible for the field application and design.

Values are based upon client supplied data and other assumed values. Changes in any of the input values will affect and alter other values.

Notes:

1. Design radius of influence corresponds to the desired treatment radius from each injection location.
2. Injection radius of influence corresponds to the distance from each injection point the injection volume would distribute assuming uniform (cylindrical) distribution in the effective pore volume.
3. Approximate percentage of overlap between the Design ROI from the various injection locations. Actually percent overlap will depend upon injection location layout.
4. Approximate distance between injection locations. Actual distance will depend upon site layout.

13-Jun-2019

Customer:	**Hamp Mathews**	**Prepared by:**	
Contact:	**Joel Parker**	**John Valkenburg, PE**	
Site Location:	**Livonia**	**1-517-669-5400**	
Proposal Number:	**CRM 21370**	**John.Valkenburg@peroxychem.com**	

Klozur® SP Demand Calculations

PROPOSAL ATTACHMENTS

PRODUCT OVERVIEW

Klozur® SP is an environmental grade sodium persulfate which has been delivered safely and cost effectively to treat a wide variety of common contaminants of concern with an unmatched combination of power and control. With proper activation, Klozur SP can generate both oxidative and reductive pathways delivering the power to destroy the most recalcitrant of contaminants.

For more information on activated Klozur SP, please contact your PeroxyChem representative or www.klozur.com.

SITE INFORMATION

	Value	Unit	Note
Area of Treatment	2,310	ft2	customer supplied
Treatment Zone Thickness	5	ft	customer supplied
Treatment Volume	11,550	ft3	calculated value
Porosity	30	%	default value
Ground Water Volume	25,917	USG	calculated value
Soil Density	100	lbs/ft3	default value
Soil Mass	1,155,000	lb	calculated value
Fraction Soil Mass Contacted*	100	%	default value
Base Buffering Capacity (Alkaline Activation only)	0.36	g 25 percent NaOH / kg soil	estimated value, it is recommend that this be analytically determined
Soil Oxidant Demand	1.46	g Klozur / kg soil	estimated value, it is recommend that this be analytically determined

* Fraction soil mass contacted may be less for sites with contact limitations such as fractured bedrock or those with low permeable materials.

Disclaimer:

The estimated dosage and recommended application methodology described in this document are based on the site information provided to PeroxyChem, but are not meant to constitute a guaranty of performance or a predictor of the speed at which a given site is remediated. Klozur® persulfate and activator demand calculations do not take into account the kinetics, speed of the reaction, or ability to establish contact between the reagents and contamination in the subsurface. These calculations represent the minimum anticipated amount needed to treat the contaminants of concern (COCs). As a result, these calculations should be used as a general approximation for purposes of an initial economic assessment. PeroxyChem recommends that oxidant demand and treatability testing be performed to verify the quantities of oxidant needed.

CONTAMINANTS OF CONCERN* (COCs)

Concentrations:

The following are estimates of the contaminant concentration in soil and groundwater within the target area. The total COC mass was calculated including estimated COC mass in groundwater, soil and NAPL, if present, within the targeted area.

Contaminant	GW (mg/L)	Soil (mg/kg)	NAPL (lbs)	Total COC Mass** (lb)
TCE	0.4	8.0	0.0	9.3

Remedial Goals and Target Mass Reductions:

The target demand is determined by also accounting for remedial goals for each contaminant and represents the estimated mass reductions targeted for each contaminant.

Contaminant	GW (mg/L)	Soil (mg/kg)	NAPL (lbs)	Total COC Mass Targeted*** (lbs)
TCE	0	0	0	9.3

*Unless provided, sorbed concentrations were roughly estimated based on expected groundwater concentrations, foc and Koc values. For a more refined estimate, it is recommended that actual values be verified via direct sampling of the targeted treatment interval.

** Includes estimated contaminant mass in soil, groundwater, and NAPL (if provided) at the site.

*** Includes estimated contaminant mass in soil, groundwater, and NAPL (if provided) at the site with the remedial goals subtracted from the total mass onsite.

KLOZUR PERSULFATE DEMAND

The estimated mass of Klozur SP accounts for target demand with the COCs, non-target demand associated with the soils (SOD) and a safety factor applied to each. The safety factor is intended to account for potential variability in the COC and SOD estimates and any other uncertainties associated with the application or site.

The demand from COCs was estimated using: **Degradation Ratio** The degradation ratio should be determined/verified in a bench or field test

	Klozur SP Demand	Safety Factor	Klozur SP Demand with Factor	
Demand from COCs	112	2.0	224	lb
Demand from SOD	1,686	3.0	5,059	lb

Total Klozur SP Demand: **5,283** **lb** **To be applied in** **1** **application**

KLOZUR SP PACKAGING OPTIONS AND PRICING

Klozur SP can be delivered to your site in a variety of packages including in bags, or two sizes of super sacks for your handling convenience. Pricing below is exclusive of shipping and any applicable taxes.

Estimate for : **Total Klozur SP Demand**

Packaging Type: **55.1 lb bags**

Packaging Type	# of packages / pallet	lb Klozur® SP / pallet	# of packages needed
55.1 lb bags	40	2,204	120

KLOZUR ACTIVATION CHEMISTRIES

Klozur activation chemistries are used to convert Klozur SP into the highly reactive radicals. Choosing the right activator chemistry for your contaminants of concern is important in obtaining a successful site remediation. The choice of activator will be dependent upon the target contaminants, site lithology and hydrogeology, and other site conditions. While activator demand quantities for all methods are given, not all activation methods are recommended for your given contaminant or site conditions. Please consult with an PeroxyChem Environmental Solutions technologist for proper selection of activation chemistry.

Note: Only one type of activator is typically needed.

Recommended methods to activate Klozur SP: **high pH**

***PeroxyChem LLC is the owner or licensee under various patent applications relating to the use of activation chemistries**

Alkaline (High pH) Activation

Alkaline demand = Alkalinity to neutralize generate HSO_4^- from persulfate decomposition + amount needed to raise ground water / soil to a pH > 10.5

Calculation for NaOH (high pH) demand:

Sodium hydroxide is a highly soluble form of alkalinity that is commonly used for injection events with Klozur SP.

NaOH demand for HSO4 neutralization	2,223	lb @ 100% basis
Soil buffering amount	104	lb @ 100% basis
Total NaOH demand	2,326	lb @ 100% basis

PeroxyChem recommends using a 25 wt% or less NaOH concentration **

Amount of	25	wt% solution needed	878	gal
			9,306	lb

** note: the addition of concentrated NaOH to water is very exothermic. Add NaOH slowly to water, and allow for excess heat to dissipate.

INSTALLATION VIA INJECTION

Klozur SP will be delivered as a dry powder, packaged in 55.1-lb (25 Kg) bags, 1,102 lb (500 Kg), and 2,204 lb (1,000 Kg) supersacks. Klozur SP is highly soluble in water and can be injected via fixed wells, open boreholes or using direct push technology (DPT). Klozur SP is typically batched at a concentration of between 50 to 450 g/L (5 to 35%) and PeroxyChem recommends injecting at a concentratipn of between 50 and 250 g/L, depending upon site design and conditions.

Effective treatment requires establishing contact between a sufficient amount of activated persulfate and the contaminant in the subsurface. A key element of establishing this contact in a source zone is the injection volume used to inject the activated persulfate reagents. Depending on the application method employed and site conditions, between 20% and 100% (with >50% typical) of the effective porosity is normally targeted during Klozur SP injection, with a higher percent pore fill normally targeted for sites with slow groundwater velocities.

Below is an example injection scenario for the proposed mass Klozur SP for this site. The suggested injection volumes may be altered based on the site specific conditions.

Number of Applications	1	
Klozur SP Dosage		
Mass of Klozur SP	6,612	lb
Concentration in Total Pore Volume	31	g/L
	3.0	% w/w
Application rate by soil mass (dry weight)	5.7	g/kg
Injection Locations		
Number of Injection Locations	4	
Radius of Influence		
Design[1]	15	ft
Injection[2]	*11.4*	*ft*
Overlapping Design ROI[3]	13	%
Transect Layout		
Approximate Spacing between locations[4]	19	ft
2x Injection ROI	*22.7*	*ft*
Overlapping of Injection ROI (%)	*18%*	
Injection Details (per application)		
Total Injection Volume	9,100	gal
Percentage of Effective Pore Volume	70	%
Klozur SP Injection Concentration	87	g/L
	8.2	% w/w
Klozur SP Quantities Per Injection Location:		
Klozur SP	1,653	lb
Injection Volume	2,275	gal

Design parameters should be considered approximations and suggestions. Site design engineers and contractors are ultimately responsible for the field application and design.

Values are based upon client supplied data and other assumed values. Changes in any of the input values will affect and alter other values.

Notes:

1. Design radius of influence corresponds to the desired treatment radius from each injection location.
2. Injection radius of influence corresponds to the distance from each injection point the injection volume would distribute assuming uniform (cylindrical) distribution in the effective pore volume.
3. Approximate percentage of overlap between the Design ROI from the various injection locations. Actually percent overlap will depend upon injection location layout.
4. Approximate distance between injection locations. Actual distance will depend upon site layout.

Preprint: Proceedings of the Fourth International Conference on the Remediation of Chlorinated and Recalcitrant Compounds (2004)

Novel Activation Technologies for Sodium Persulfate *In Situ* Chemical Oxidation

Philip A. Block (philip_block@fmc.com) (FMC Corporation, Philadelphia, PA)
Richard A. Brown (dick.brown@erm.com) (ERM, Inc., Ewing, NJ)
David Robinson (david.robinson@erm.com) (ERM, Inc., Ewing, NJ)

ABSTRACT: Persulfate oxidation chemistry is an emerging technology for the *in situ* chemical oxidation of chlorinated and non-chlorinated organics. Activation of persulfate to form sulfate radicals is a potent tool for the remediation of a wide variety of contaminants, including chlorinated solvents (ethanes, ethanes and methanes), BTEX, MTBE, 1,4-dioxane, PCB's and PAH's. Several new activation technologies now exist to catalyze the formation of sulfate radicals, including persulfate combined with chelated-metal complexes, persulfate combined with hydrogen peroxide and alkaline persulfate. The breadth of activator systems allows for the proper choice of persulfate technology for given contaminants and site conditions.

Introduction

Persulfates (specifically dipersulfates) are strong oxidants that have been widely used in many industries for initiating emulsion polymerization reactions, clarifying swimming pools, hair bleaching, micro-etching of copper printed circuit boards, and TOC analysis. In the last few years there has been increasing interest in sodium persulfate as an oxidant for the destruction of a broad range of soil and groundwater contaminants. Persulfates are typically manufactured as the sodium, potassium, and ammonium salts. The sodium form is the most commonly used for environmental applications.

The persulfate anion is the most powerful oxidant of the peroxygen family of compounds and one of the strongest oxidants used in remediation. The standard oxidation – reduction potential for the reaction

$$S_2O_8^{-2} + 2H^+ + 2e^- \rightarrow 2HSO_4^- \qquad \textbf{Equation 1}$$

is 2.1 V, as compared to 1.8 V for hydrogen peroxide (H_2O_2) and 1.4 V for the peroxymonosulfate anion (HSO_5^-). This potential is higher than the redox potential for the permanganate anion (MnO_4^-) at 1.7 V, but slightly lower than that of ozone at 2.2 V.

In addition to direct oxidation, sodium persulfate can be induced to form sulfate radicals, thereby providing free radical reaction mechanisms similar to the hydroxyl radical pathways generated by Fenton's chemistry. The generation of sulfate radicals is

$$S_2O_8^{-2} + initiator \rightarrow SO_4^{\bullet -} + (SO_4^{\bullet -} \text{ or } SO_4^{-2}) \qquad \textbf{Equation 2}$$

The sulfate radical is one of the strongest aqueous oxidizing species with a redox potential estimated to be 2.6 V, similar to that of the hydroxyl radical, 2.7 V.

In addition to its oxidizing strength, persulfate and sulfate radical oxidation has several advantages over other oxidant systems. First, it is kinetically fast. Second, the sulfate radical is more stable than the hydroxyl radical and thus able to transport greater

distances in the sub-surface. Third, persulfate has less affinity for natural soil organics than does the permanganate ion (Brown 2003) and is thus more efficient in high organic soils. These attributes combine to make persulfate a viable option for the chemical oxidation of a broad range of contaminants.

Conventional Persulfate Activation

In the early 1960's, a significant body of work examined the kinetics and mechanisms associated with persulfate oxidation (House, 1962 and Haikola, 1963). While the persulfate anion by itself was found to be a strong oxidizer, it's reaction rates are kinetically slow for the more recalcitrant contaminants, such as trichloroethylene. However, the kinetics of persulfate oxidation can be significantly enhanced by the generation of sulfate radicals.

Sulfate radical initiation (Equation 2) can be achieved through the application of heat, transition metal catalysts or UV radiation. These processes are reviewed in several references (House, 1962; Behrman, 1980; Balazs, 2000). With transition metal activation, Balazs points out that while the mechanism is dependent on catalyst type, organic substrate and oxidant concentration, the rate equation can be generally stated as:

$$d[S_2O_8^{-2}]/dt = -k[S_2O_8^{-2}]^x[catalyst]^y \qquad \textbf{Equation 3}$$

where ½ < x < 3/2 and 0 < y < 3/2. This suggests that the reaction rate is independent of the contaminant loading. Several recent patents have specifically disclosed the activation of persulfate for the oxidation of organic contaminants by either heat or transition metals. Pugh (1999) discusses both metal catalysis and heat activation, at temperatures above 20^0C, to oxidize organic contaminants. Hoag (2000, 2002) discusses divalent metal catalysis and the application of heat in the range of 40 to 99^0C to oxidize VOCs. This body of literature basically leads one to conclude that the effective use of persulfate for environmental applications necessitates the use of either heat activation of the addition of iron II.

In the laboratory, heat-activated persulfate has been demonstrated in aqueous systems to be applicable to a wide range of contaminants. The activation temperature required varies by compound. Table 1 lists the oxidation of various compounds as a function of temperature. At 45 ºC and above all the compounds tested were oxidized. Bruell (2001) has shown that heat-catalyzed persulfate oxidation of organics in a soil environment requires higher temperatures than in aqueous systems.

For activation by transition metal catalysis, ferrous iron (Fe^{+2}) is the most common and readily available activator, with common forms being ferrous sulfate ($FeSO_4$) and ferrous chloride ($FeCl_2$). Generally, 100 to 250 mg / L of iron is required to effectively activate persulfate. Additions of ferrous iron in excess, greater than 750 mg / L, can lead to the rapid decomposition of persulfate and a loss

Table 1
List of Contaminants With > 90% Decomposition Treated with Persulfate @ 20^0 C
Toluene, Ethylbenzene; Xylene; 1,1-DCE; 1,2-Dichlorobenzene; 1,3-Dichlorobenzene, 1,2,4-Trichlorobenzene
List of Additional Contaminants With > 90% Decomposition Treated with Persulfate @ 35^0 C
1,2-DCE, PCE, TCE, Vinyl Chloride, Carbon Tetrachloride, 1,1-DCA; 1,2-DCA, Benzene, Chlorobenzene, MTBE
List of Additional Contaminants With > 90% Decomposition Treated with Persulfate @ 45^0 C
Methylene Chloride, Chloroform, 1,1,1-TCA

in remediation performance. If significant amounts of reduced metals are available in the subsurface, addition of metal catalysts may not be necessary to catalyze the persulfate. Divalent iron activated persulfate effectively oxidizes many of the compounds susceptible to the heat-activated persulfate, including BTEX, chlorobenzene, dichlorobenze, DCE, TCE, and PCE. However, its effectiveness against chlorinated ethanes, such as TCA, and chlorinated methanes, such as chloroform, is limited.

While heat and iron II activation of persulfate are effective in bench scale oxidation studies, they both have limitations for field application. Heat activation requires installation of a parallel heating system to heat the aquifer matrix to the desired temperature. This entails both capital expenditures as well as additional operating expense. The options for *in situ* heating include steam or hot air injection, electrical resistance (joule) heating, or radio frequency heating. Generally heating is best applied for source treatment where the target area is limited. *In situ* heating, with an external heating source, is impractical for treating large groundwater plumes.

The problem with the use of iron II as an activator is its transportability. Iron II is eventually oxidized by the persulfate to iron III, which, at a pH above 4, is insoluble. The net reaction is:

$$2Fe^{+2} + S_2O_8^{-2} \rightarrow 2Fe^{+3} + 2SO_4^{-2}; Fe^{+3} + 3H_2O \rightarrow Fe(OH)_3\downarrow + 3H^+ \qquad \textbf{Equation 4}$$

Meyers (Meyers, 2002) discussed the affect of the precipitation of iron on the loss of persulfate activation in field applications. As an example, in a pilot treatment test of TCE with persulfate, a persulfate and iron mixture (10% sodium persulfate and 174 mg/L of available Fe^{+2}) was injected into a sandy silt. Nine days after the injection, a monitoring point 1.5 M down-gradient of the injection point was sampled, and the iron concentration was found to be 0.3 mg/L, and the TCE concentration was 9.3 mg/L. Groundwater samples from the monitoring point were collected and re-dosed with either iron alone or with persulfate without additional iron. After 7 days the re-dosed samples were reanalyzed for TCE. The results are shown in Table 2. Greater reduction in TCE levels was achieved when additional Fe^{+2} was added, as compared to when only additional persulfate was added, suggesting a lack of available catalyst, and not oxidant, in the subsurface at the down-gradient monitoring point.

Table 2: TCE @ 7 Days

Dosing Material	TCE, µg/L
Control – no dose	8,700
1 g/L Persulfate	7,500
250 mg/L Fe^{+2}	4,240

Novel Activation Technologies

Practical constraints in sulfate radical formation by heating or addition of ferrous iron indicate a need for improved persulfate activation systems. Such technologies should:

- be transportable in a groundwater system
- increase the reactivity of persulfate with a broad range of organic contaminants
- be easy to apply in a variety of subsurface conditions.

Several new persulfate activation systems have recently been developed (FMC - ERM, 2002; FMC - Orin, 2003) that address these issues. A few of these technologies use non-

metal routes to generate sulfate radicals. The following is a discussion of these novel activators.

A. Chelated Metal Catalysts

Chelated metal catalysts are complexes of transition metals bound to strong chelating agents. Examples of chelating agents include: ethylenediaminetetraacetic acid (EDTA), citrate, polyphosphate, glycolic acid, catechol, nitrotriacetic acid (NTA), Tetrahydroquinine (THQ) and others in this class of materials. Previous work (Pignatello, 1992) demonstrated the benefit of chelated iron complexes to activate hydrogen peroxide for the destruction of complex pesticides. Chelated trivalent iron (Fe^{+3}), in addition to Fe^{+2}, was found to have excellent oxidation performance.

Laboratory tests were conducted to test the efficacy of chelated iron catalysts for persulfate activation utilizing several different iron – chelant complexes. The best performing complex, Fe(III) – EDTA will be highlighted for discussion purposes. All samples were prepared as aqueous solutions in VOA bottles with zero headspace. A standard contaminant mixture was used: twenty-eight different VOCs were dissolved in DI water to attain individual VOC concentrations of 10-20 mg/L. The Fe-EDTA complex was generated by reacting equimolar concentrations of ferric chloride and EDTA. The Fe -EDTA complex was dosed to provide 550 mg / L of available iron to the solution. An oxidant dosage level of 10 % sodium persulfate was used. Samples were taken at time zero, and at 7, 14 and 21 days and analyzed via GC-MS. All studies were conducted at room temperature and ambient pH.

Table 3
Performance of Persulfate + Iron Catalysts, Ambient pH, 21-Day Results

µg / L	Control	Persulfate	Persulfate Fe(II)	Persulfate Fe(III)	Persulfate Fe(III)-EDTA
Chloromethanes	35000	34000	29100	35000	32000
Chloroethanes	50000	52000	37600	50000	48000
Chloroethenes	32700	9830	0	660	0
Chlorobenzenes	34800	9300	0	3100	360
BTEX	43700	1370	0	0	0
Oxygenates	46000	44000	830	17600	3550
pH	6.9	2.2	2.3	2.3	2.2

The 21-day results are shown in Table 3, which compares persulfate alone and persulfate with: iron II (unchelated), Fe(III) (unchelated), and Fe(III)-EDTA. A DI water control was also run. The table displays the results for different classes of contaminants. Several observations can be made from the data. First, none of the persulfate / iron catalysts are effective with the chloroethanes or chloromethanes. Second, all persulfate solutions resulted in a low pH. Third, Fe(II) was the most effective catalyst. The second best performing catalyst was the Fe-EDTA complex. Fourth, BTEX oxidation was effective with persulfate alone. And fifth, Fe(III), at a low pH, is a moderately effective catalyst. It should be noted that the results in Table 3 are at a pH of 2, where metal solubility and activity is not an issue.

Under the neutral pH conditions that may be found in the field, chelating the transition metal catalyst provides protection from hydration and subsequent precipitation (see Eq. 4). Table 4 shows the results for different iron catalysts with persulfate at a controlled pH of 7-8. The experimental conditions were similar to those used to generate Table 3, except: 1) a commercial Fe (III) -EDTA (Aldrich) was used with the dosing

level at 100 mg/L iron, and 2) the persulfate concentration was 2.5% (instead of 10%). As can be seen from Table 4, at a pH of 7 - 8, only the Fe-EDTA catalyst with persulfate was effective; whereas the un-chelated iron catalysts had reduced activity.

Table 4
Performance of Iron Catalysts with Persulfate, Controlled pH (7-8), 21-Day Results

µg / L	Control	Persulfate Ctrl pH	Fe (II) Amb pH	Fe (II) Ctrl pH	Fe (III) Ctrl pH	Fe-EDTA Ctrl pH
Ethenes	34,083	32,606	0	27,730	31,230	9,870
Ethanes	67,115	62,379	61,908	63,702	64,756	50,246
Methanes	51,983	48,180	42,261	45,597	49,664	44,900
BTEX	40,119	3,963	0	13,538	13,560	647
Chlorobenzenes	56,089	36,990	0	31,824	34,662	7,428
Oxygenates	60,908	53,923	11,639	56,444	57,187	26,931
pH	6.7	8.5	2	7.5	8	7.6

The solubility and availability of the transition metal catalysts are critical factors in the activation of persulfate. Chelation is an effective means of maintaining metal activity at neutral or alkaline groundwater conditions.

B. Dual Oxidant System: Sodium Persulfate & Hydrogen Peroxide

Hydrogen peroxide technology, known as Fenton's reagent, has been widely applied in treating groundwater contaminants with varying results. In general, it is highly reactive and is able to oxidize a wide range of contaminants. However, the limitation of peroxide is its stability in some soil matrixes, where it rapidly decomposes, limiting its transport and effectiveness. A dual oxidant system (FMC - Orin, 2003) utilizing hydrogen peroxide and sodium persulfate has been developed that combines the reactivity of peroxide in the reduction of compounds of concern with the enhanced stability of persulfate. It is hypothesized that hydrogen peroxide and persulfate may have several synergistic attributes. First, hydroxyl radicals can initiate persulfate radical formation. Similarly, sulfate radicals can stimulate formation of hydroxyl radicals. Secondly, hydrogen peroxide may react with a significant portion of the more reactive contaminants, allowing the sulfate radicals to destroy the more recalcitrant compounds of concern. Finally, a combination of peroxide and sulfate radicals may provide a multi-radical attack mechanism, yielding either a higher efficiency in destroying contaminants, or allowing for recalcitrant compounds to be more readily degraded.

Initial laboratory testing by Orin RT (FMC - Orin, 2003) was performed by adding chlorinated solvents to an aqueous solution at room temperature. Two grams of sodium persulfate and 8 mL of 12.5% hydrogen peroxide were added per 100 grams of contaminated solution. Samples were taken on Day 8 and analyzed by GC-MS. Table 5 displays the results from the study. Significant reductions were measured not only for chlorinated ethenes, but chlorinated ethanes as well.

Table 5
Degradation of Contaminants with Persulfate + Peroxide

(mg/L)	**Time 0**	**Day 8**
1,1-DCE	4.5	0.1
TCE	2.8	non-detectable
1,1-DCA	1.1	non-detectable
1,1,1-TCA	12.0	0.6

A second laboratory study was run using soils from an MGP site. A slurry was made using 400 g of processed soil and 1.08 L of distilled water. Sodium persulfate was then added to a concentration of 11.5 g/L and allowed to mix. 120 mL of 50% peroxide was then added. The slurry was then analyzed via GC-MS. The results are pictured in

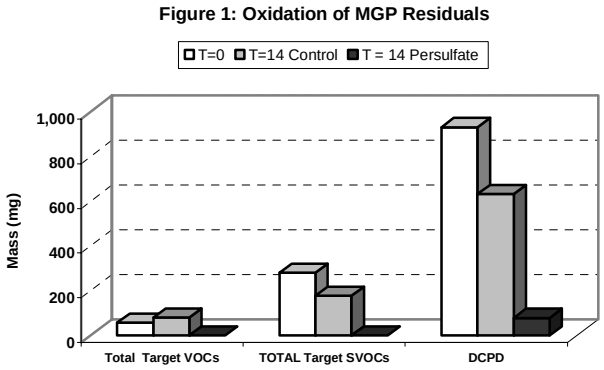


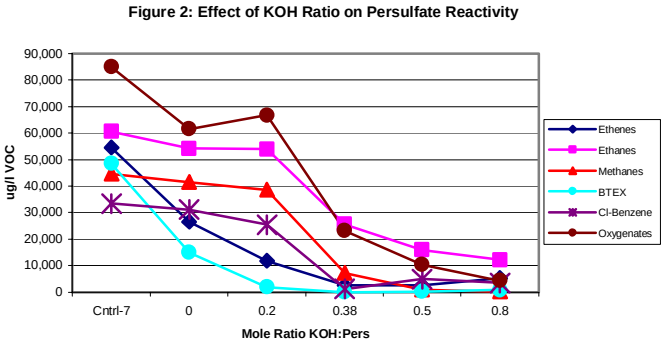
Figure 1. The VOCs present were BTEX and styrene. The SVOCs were 3 to 5 ring PAHs. Dicylcopentadiene (DCPD) was present as the major constituent. As can be seen from Figure 1, the combined peroxide-persulfate system was effective against all of these contaminants.

The combined peroxide-persulfate reaction system appears to have a broad range of applicability. It not only oxidizes compounds generally amenable to persulfate oxidation, but also oxidizes compounds not readily oxidized by conventional persulfate technology.

D. Alkaline Persulfate

Persulfate is known to be highly reactive at low pH (<3), but it is also highly reactive at pH's greater than 10. It should thus be possible to "activate" persulfate by increasing the pH to high values. Initial laboratory testing indicated the persulfate oxidation of contaminants was not just a matter of high pH, but of the buffering capacity as well (mole ratio of pH modifier to persulfate).

Studies were conducted in VOA vials with zero headspace. While a variety of pH modifiers were observed to activate persulfate, KOH will be used for discussion. Samples were prepared by adding persulfate at a concentration of 25 g/L and KOH to achieve mole ratios of 0.2, 0.4, 0.5 and 0.8 KOH : persulfate. The samples were analyzed after 7 days by GC-MS. A control with no persulfate or KOH was also run. No other catalysts were added to the samples. The activation of persulfate that was observed is solely due to the added base. The results of these studies are pictured in Figure 2. The data are grouped by class of contaminant.



Several observations can be made from these results. First persulfate reactivity increases with increasing levels of KOH. Second, there appears to be a threshold effect in the oxidation of some chlorinated VOCs. The mole ratio needs to be 0.4 or above for the persulfate to effectively react with the recalcitrant chlorinated VOCs (ethanes and methanes). The effect of the amount of KOH on the oxidation of

BTEX and oxygenates (MTBE, TBA, 1,4-dioxane) is more gradual. The amount oxidized increases with increasing KOH.

Table 6 lists the pH observed at 7 and 14 days for the different mole ratios of KOH and persulfate. The pH appears to have a breakpoint similar to that observed for the reactivity. A mole ratio of 0.4 or above is needed to achieve a pH above 10.0.

Table 6: pH versus KOH mole Ratio		
Mole Ratio	pH, 7-days	pH, 14-days
0	1.3	0.5
0.2	4.3	4.5
0.38	11.5	10.4
0.5	11.5	10.5
0.8	12.2	13

An interesting result for this study is the effect of the alkaline pH on historically difficult to destroy compounds, such as chlorinated ethanes and methanes. Table 7 displays the 14 day results from the study for a selection of compounds for two different KOH : persulfate mole ratios. In most cases, there was complete destruction of these compounds

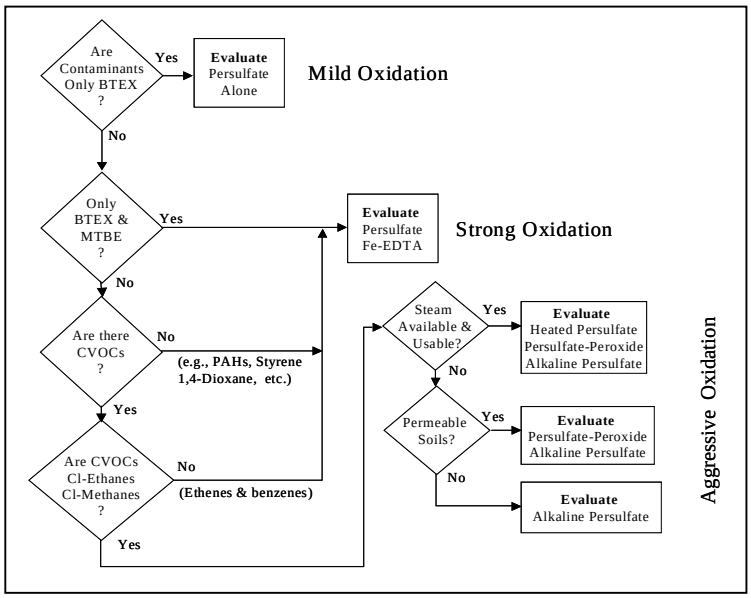
Table 7: Destruction of Recalcitrant Compounds with Alkaline Persulfate – Day 14 Results			
µg / L	Control Day 14	0.5 mol KOH : Persulfate	0.8 mol KOH : Persulfate
1,1,1-TCA	19,000	14,400	3,400
1,1,2-TCA	25,000	ND	ND
1,2-DCA	22,000	ND	ND
1,1-DCA	17,000	1,600	ND
Carbon Tetrachloride	18,000	ND	ND
Methylene Chloride	20,000	ND	ND
Vinyl Chloride	195	ND	ND
	ND – non detect		

A number of conclusions can be drawn from these studies. First, alkaline persulfate has a broad reactivity. Second, the alkaline activation of persulfate appears to be possible with a number of different bases. Each base may have a different optimal ratio and/or breakpoint. Third, in applying the alkaline-persulfate activator technology it is important to add sufficient base (excess buffering capacity). The quantity of base needs to take into account any acidity in the soil. Fourth, there are reaction pathways for persulfate that are not currently well understood and can potentially be further optimized. The reaction of persulfate under basic conditions is a novel technology deserving further study.

Summary

Persulfate oxidation chemistry is an emerging technology for the *in situ* chemical oxidation of chlorinated and non-chlorinated organics. Activation of persulfate to form sulfate radicals yields a very potent tool for the remediation of a wide variety of contaminants, including chlorinated solvents (ethenes, ethanes and methanes), BTEX, MTBE, 1,4-dioxane, PCB's and polyaromatic hydrocarbons.

Figure 3: Choosing the Right Activator



There now exists a

variety of chemistries from which to choose to catalyze the formation of sulfate radicals. Choosing which activator system to use is key to maximizing the efficacy of persulfate oxidation. Figure 3 provides a logic-flow for assessing the different activator systems. There are three levels of persulfate activators that can be used. These include "Mild Oxidation," in which persulfate alone is used. This may be appropriate for BTEX sites. If MTBE is present, then the "Strong Oxidation" system, which is persulfate activated with Fe-EDTA, is appropriate. This "Strong Oxidation" system is also appropriate for sites with only chlorinated ethenes (PCE, TCE, DCE) or chloro-benzenes. If there are chlorinated ethanes or methanes present that need treatment, then the "Aggressive Oxidation" systems should be evaluated. These include the alkaline-persulfate, combined peroxide and persulfate, and heated persulfate. These aggressive activation chemistries may be applied also for BTEX and chlorinated ethene sites if faster remediation is desired, or if there is a high contaminant load.

Proper evaluation of the site conditions is also needed for the effective application of the appropriate persulfate technology. Site geology, hydrogeology, soil properties, soil oxidant demand, and the remedial goals are all key factors to evaluate. Persulfate technology is not a "one-size-fits-all" technology. There is a rich and varied chemistry that can be brought to bear on a wide variety of contaminant problems.

References

Balazs, G.B., J.F. Cooper, P.R. Lewis and G.M. Adamson. *Emerging Technologies in Hazardous Waste Management 8*, ed. Tedder and Pohland, Kluwer Academic / Plenum Publishers, New York, 2000.

Behrman, E.J. and J.O. Edwards. *Reviews in Inorganic Chemistry*, 2, p 179 (1980)

Brown, R.A., D. Robinson and G. Skladany. "Response to Naturally Occurring Organic Material: Permanganate versus Persulfate", ConSoil 2003, Ghent Belgium, (2003)

Bruell, C. J. "Kinetics of Thermally Activated Persulfate Oxidation of Trichloroethylene (TCE) and 1,1,1- Trichloroethane (TCA)," The First International Conference on Oxidation and Reduction Technologies for In-Situ Treatment of Soil and Groundwater, Niagara Falls, Ontario, Canada, June 25-29, 2001

Elmendorf, C., F. Sessa. Poster at the 4th Annual Batelle Conference On the Remediation of Chlorinated and Recalcitrant Compounds, Panther Technologies and FMC Corporation (2004)

FMC Corporation and Environmental Resources Management, patent pending technology (2002)

FMC Corporation and Orin RT, patent pending technology (2003)

Hakoila, E. *Ann. Univ. Turku*, Ser A, 66, (1963).

Hoag, G.E., P.V. Chhedda, B.A. Woody and G.M. Dobbs. US Patent 6,019,548 (2000)

Hoag, G.E., P.V. Chhedda, B.A. Woody and G.M. Dobbs. US Patent 6,474,908 (2002)

House, D.A. *Chem Rev*, 62, p 185 (1962).

Huang, K.C., R.A. Couttenye, and G.E. Hoag. *Chemosphere*, 49, p 413 (2002)

Meyer, M., "Sodium Persulfate Oxidation of TCE Plume In Belgium", The Second International Conference on Oxidation and Reduction Technologies for In-Situ Treatment of Soil and Groundwater, Toronto, Ontario, November 19-22, 2002

Pugh, J.R., US Patent 5,976,348 (1999)

Pignatello, J.J and Y. Sun. *J. Agr. Food Chem.*, 40, p 322 (1992)

CASE STUDY:
TREATMENT OF SHALLOW SOIL CONTAMINATION USING HIGH PH ACTIVATION OF SODIUM PERSULFATE INDUSTRIAL SITE, ILLINOIS

INTRODUCTION

JAG Consulting Group recently implemented an in-situ chemical oxidation (ISCO) application at an active industrial site in Illinois to treat the shallow soil contaminated with PCE, TCE, methylene chloride, toluene, and xylenes.

Use of sodium hydroxide (caustic) provided the high pH activation of sodium persulfate. High pH activation was selected as the optimal ISCO technology because of its treatment effectiveness on both chlorinated and petroleum hydrocarbons, the rapid cleanup timeframe, and its relative low cost application.

DESIGN OF FIELD INJECTION PARAMETERS

Prior to the field injections, JAG Consulting performed a soil buffering test in the laboratory in order to determine the amount of sodium hydroxide needed to raise the pH of the soil to above 10.5 pH units and maintain it for 2 weeks.

Because chemical oxidation requires an aqueous media, an infiltration gallery was constructed to slowly percolate water into the shallow soil (1 to 15 ft) to create saturated soil conditions. The full scale field injection consisted of 12 injection wells located in two Treatment Areas. Due to the low permeability silts and clays, each injection well had an estimated radius of influence of 10 feet. Approximately 4,700 gallons of sodium hydroxide (25%) and 11,500 pounds of sodium persulfate were injected into the wells.

FIELD AND ANALYTICAL RESULTS

The following results were achieved in this ISCO project:

- Analytical sampling results indicate that PCE, TCE, methylene chloride, xylenes, and toluene levels were generally reduced from 88% to 99% within 6 months following treatment.
- The ISCO injections attained the soil cleanup criteria established by the State of Illinois EPA and "No Further Action" has been granted for Area #2. A second injection is planned for Area #1.

Boring No.	Constituent	Initial Concentration (ug/kg)	After ISCO Concentration (ug/kg)	Percent Reduction
SB-17	PCE	160,000	180	99.9%
	TCE	5,900	10	99.8%
	Methylene Chloride	360	1	99.7%
	Xylenes	1,200	82	93.2%
	Toluene	52,000	1,400	97.3%
SB-20	PCE	220,000	1,900	99.1%
	TCE	4,500	280	93.8%
	Methylene Chloride	620	10	98.4%
	Xylenes	1,900	10	99.5%
	Toluene	1,900	10	99.5%
SB-8	PCE	1,700,000	190,000	88.8%
	TCE	16,000	4,200	73.8%
	Methylene Chloride	5,900	10	99.8%
	Xylenes	220,000	7,000	96.8%
	Toluene	200,000	22,000	89.0%

CONTACT INFORMATION

JAG Consulting Group
Phone: 714-241-7722
Email: gary@JAGConsultingGroup.com
Web Site: www.JagConsultingGroup.com

SAFETY DATA SHEET
Klozur® SP

SDS # : 7775-27-1-12
Revision date: 2018-07-13
Format: NA
Version 1.04

1. PRODUCT AND COMPANY IDENTIFICATION

Product Identifier

Product Name Klozur® SP

CAS-No 7775-27-1

Synonyms Sodium Persulfate; Sodium Peroxydisulfate; Disodium Peroxydisulfate; Peroxydisulfuric acid, disodium salt; Peroxydisulfuric acid, sodium salt.

Alternate Commercial Name Klozur® Persulfate

Recommended use of the chemical and restrictions on use

Recommended Use: In situ and ex situ chemical oxidation of contaminants and compounds of concern for environmental remediation applications

Restrictions on Use No uses to be advised against were identified.

Manufacturer/Supplier

PeroxyChem LLC
2005 Market Street
Suite 3200
Philadelphia, PA 19103
Phone: +1 267/ 422-2400 (General Information)
E-Mail: sdsinfo@peroxychem.com

Emergency telephone numbers

For leak, fire, spill or accident emergencies, call:
1 800 / 424 9300 (CHEMTREC - U.S.A.)
1 703 / 527 3887 (CHEMTREC - Collect - All Other Countries)
1 303/ 389-1409 (Medical - U.S. - Call Collect)

2. HAZARDS IDENTIFICATION

Classification

OSHA Regulatory Status
This material is considered hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200)

Acute toxicity - Oral	Category 4
Skin corrosion/irritation	Category 2
Serious eye damage/eye irritation	Category 2B
Respiratory sensitization	Category 1
Skin sensitization	Category 1
Specific target organ toxicity (single exposure)	Category 3
Oxidizing Solids	Category 3

GHS Label elements, including precautionary statements

EMERGENCY OVERVIEW

Danger

Hazard Statements
H334 - May cause allergy or asthma symptoms or breathing difficulties if inhaled
H335 - May cause respiratory irritation
H319 - Causes serious eye irritation
H315 - Causes skin irritation
H317 - May cause an allergic skin reaction
H302 - Harmful if swallowed
H272 - May intensify fire; oxidizer

Precautionary Statements - Prevention
P261 - Avoid breathing dust/ fume/ gas/ mist/ vapors/ spray
P285 - In case of inadequate ventilation wear respiratory protection
P271 - Use only outdoors or in a well-ventilated area
P280 - Wear protective gloves/ protective clothing
P264 - Wash face, hands and any exposed skin thoroughly after handling
P210 - Keep away from heat/sparks/open flames/hot surfaces. - No smoking
P220 - Keep/Store away from clothing/combustible materials
P221 - Take any precaution to avoid mixing with combustibles

Precautionary Statements - Response
P305 + P351 + P338 - IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing
P337 + P313 - If eye irritation persists: Get medical advice/ attention
P302 + P352 - IF ON SKIN: Wash with plenty of water.
P333 + P313 - If skin irritation or rash occurs: Get medical advice/ attention
P362 - Take off contaminated clothing and wash before reuse
P304 + P340 - IF INHALED: Remove person to fresh air and keep comfortable for breathing
P342 + P311 - If experiencing respiratory symptoms: Call a POISON CENTER or doctor
P301 + P312 - IF SWALLOWED: Call a POISON CENTER or doctor if you feel unwell
P330 - Rinse mouth
P370 + P378 - In case of fire: Use water for extinction

Precautionary Statements - Storage
P403 + P233 - Store in a well-ventilated place. Keep container tightly closed

Hazards not otherwise classified (HNOC)
No hazards not otherwise classified were identified.

Other Information
Risk of decomposition by heat or by contact with incompatible materials

Unknown acute toxicity
0% of the mixture consists of ingredient(s) of unknown toxicity

3. COMPOSITION/INFORMATION ON INGREDIENTS

Formula Na2O8S2

Chemical name	CAS-No	Weight %
Sodium Persulfate	7775-27-1	> 99
Sodium sulfate	7757-82-6	< 2

4. FIRST AID MEASURES

General Advice May produce an allergic reaction.

Eye Contact Rinse thoroughly with plenty of water for at least 15 minutes, lifting lower and upper eyelids intermittently. Consult a physician. If symptoms persist, call a physician.

Skin Contact Wash off immediately with soap and plenty of water while removing all contaminated clothes and shoes. Get medical attention if irritation develops and persists.

Inhalation Remove from exposure, lie down. If breathing is irregular or stopped, administer artificial respiration. Call a physician immediately.

Ingestion Do NOT induce vomiting. Call a physician or poison control center immediately. Rinse mouth. Drink 1 or 2 glasses of water.

Most important symptoms and effects, both acute and delayed Itching; Redness; Coughing and/ or wheezing.

Indication of immediate medical attention and special treatment needed, if necessary Treat symptomatically

5. FIRE-FIGHTING MEASURES

Suitable Extinguishing Media Water. Cool containers with flooding quantities of water until well after fire is out.

Unsuitable extinguishing media Do not use carbon dioxide or other gas filled fire extinguishers; they will have little effect on decomposing persulfate.

Specific Hazards Arising from the Chemical Decomposes under fire conditions to release oxygen that intensifies the fire.

Flammable properties Contact with combustible material may cause fire

Explosion data
Sensitivity to Mechanical Impact Not sensitive.
Sensitivity to Static Discharge Not sensitive.

Protective equipment and precautions for firefighters As in any fire, wear self-contained breathing apparatus pressure-demand, MSHA/NIOSH (approved or equivalent) and full protective gear.

6. ACCIDENTAL RELEASE MEASURES

Personal Precautions Keep off any unprotected persons. Avoid contact with the skin and the eyes. Avoid breathing dust. Wear personal protective equipment.

Other Never add other substances or combustible waste to product residues.

Environmental Precautions Prevent material from entering into soil, ditches, sewers, waterways, and/or groundwater. See Section 12, Ecological Information for more detailed information.

Methods for Containment Vacuum, shovel or pump waste into a drum and label contents for disposal. Avoid dust formation. Store in closed container.

Methods for cleaning up Clean up spill area and treat as special waste. Dispose of waste as indicated in Section 13.

7. HANDLING AND STORAGE

Handling Wear personal protective equipment. Use only in area provided with appropriate exhaust ventilation. Avoid dust formation. Handle product only in closed system or provide appropriate exhaust ventilation at machinery. Avoid contact with skin and eyes. Avoid breathing dust. Remove and wash contaminated clothing before re-use. Reference to other sections.

Storage Keep containers tightly closed in a dry, cool and well-ventilated place. Keep away from heat. Do not store near combustible materials. Avoid contamination of opened product. Keep away from food, drink and animal feedingstuffs. Avoid formation and deposition of dust.

Incompatible products Acids, Alkalis, Halides, Combustible materials, Organic material, Reducing agents. Acids, alkalis, halides (fluorides, chlorides, bromides), combustible materials, reducing agents and organic compounds.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Control parameters

Exposure Guidelines .

Chemical name	ACGIH TLV	OSHA PEL	NIOSH	Mexico
Sodium Persulfate 7775-27-1	TWA: 0.1 mg/m³	-	-	-
Chemical name	**British Columbia**	**Quebec**	**Ontario TWAEV**	**Alberta**
Sodium Persulfate 7775-27-1	TWA: 0.1 mg/m³	-	TWA: 0.1 mg/m³	TWA: 0.1 mg/m³

Appropriate engineering controls

Engineering measures Provide local exhaust or general ventilation adequate to maintain exposures below permissable exposure limits.

Individual protection measures, such as personal protective equipment

Eye/Face Protection Eye protection recommended. Chemical goggles consistent with EN 166 or equivalent.

Skin and Body Protection Wear long-sleeved shirt, long pants, socks, and shoes.

Hand Protection Protective gloves: Neoprene gloves, Polyvinylchloride, Natural Rubber.

Respiratory Protection If exposure limits are exceeded or irritation is experienced, NIOSH/MSHA approved respiratory protection should be worn: particulate filtering facepiece respirators.

Hygiene measures Keep away from food, drink and animal feeding stuffs. Do not eat, drink or smoke when using this product. Wash hands before breaks and after shifts. Keep work clothes separate, remove contaminated clothing - launder after open handling of product.

General information Protective engineering solutions should be implemented and in use before personal protective equipment is considered.

9. PHYSICAL AND CHEMICAL PROPERTIES

Information on basic physical and chemical properties

Appearance	Crystalline solid
Physical State	Solid
Color	White
Odor	odorless
Odor threshold	Not applicable
pH	6.0 (1% solution)
Melting point/freezing point	180 °C (Decomposes)
Boiling Point/Range	Decomposes upon heating
Flash point	Not flammable
Evaporation Rate	No information available
Flammability (solid, gas)	Not flammable
Flammability Limit in Air	Not applicable
Upper flammability limit:	No information available
Lower flammability limit:	No information available
Vapor pressure	6.07E-30 mm Hg at 25ºC
Vapor density	No information available
Density	2.59 g/cm³ (crystal density)
Specific gravity	No information available
Water solubility	42 % @ 25 °C
Solubility in other solvents	No information available
Partition coefficient	No information available (inorganic)
Autoignition temperature	No evidence of combustion up to 600°C No evidence of combustion up to 600 °C
Decomposition temperature	> 100 °C (assume)
Viscosity, kinematic	No information available (Solid)
Viscosity, dynamic	No information available
Explosive properties	Not explosive
Oxidizing properties	oxidizer
Molecular weight	238.1
VOC content (%)	Not applicable
Bulk density	1.12 g/cm³ (loose)

10. STABILITY AND REACTIVITY

Reactivity None under normal use condtions. Oxidizer. Contact with other material may cause fire.

Chemical Stability Stable.

Possibility of Hazardous Reactions None under normal processing.

Hazardous polymerization Hazardous polymerization does not occur.

Conditions to avoid Heat. Moisture.

Incompatible materials Acids, alkalis, halides (fluorides, chlorides, bromides), combustible materials, reducing agents and organic compounds. . Acids, Alkalis, Halides, Combustible materials, Organic material, Reducing agents.

Hazardous Decomposition Products Oxygen which supports combustion.

11. TOXICOLOGICAL INFORMATION

Product Information

Unknown acute toxicity 0% of the mixture consists of ingredient(s) of unknown toxicity

LD50 Oral	Sodium Persulfate: 895 mg/kg (rat)
LD50 Dermal	Sodium Persulfate: > 10 g/kg
LC50 Inhalation	Sodium Persulfate: >5.10 mg/L (4h) (rat)

Serious eye damage/eye irritation Irritating to eyes.
Skin corrosion/irritation Minimally irritating.

Sensitization Sodium Persulfate:. May cause sensitization by inhalation and skin contact.

Component Information

Chemical name	LD50 Oral	LD50 Dermal	LC50 Inhalation	NOAEL Oral Value
Sodium Persulfate (7775-27-1)	895 mg/kg (Rat)	> 10000 mg/kg (Rabbit)	> 21.6 mg/L (Rat) 4 h	
Sodium sulfate (7757-82-6)	> 10000 mg/kg (Rat)			

Information on toxicological effects

Symptoms Symptoms of allergic reaction may include rash, itching, swelling and trouble breathing.

Delayed and immediate effects as well as chronic effects from short and long-term exposure

Irritation Irritating to eyes, respiratory system and skin.
corrosivity None.

Carcinogenicity Contains no ingredient listed as a carcinogen.

Mutagenicity Did not show mutagenic effects in animal experiments

Neurological effects Not neurotoxic

Reproductive toxicity This product is not recognized as reprotox by Research Agencies.
Developmental toxicity None known.
Teratogenicity Not teratogenic in animal studies.

STOT - single exposure May cause respiratory irritation.
STOT - repeated exposure Not classified.

Target organ effects Eyes, Lungs.

Aspiration hazard No information available.

12. ECOLOGICAL INFORMATION

Ecotoxicity

Ecotoxicity effects

Sodium Persulfate (7775-27-1)				
Active Ingredient(s)	Duration	Species	Value	Units
Sodium Persulfate	96 h LC50	Rainbow trout	163	mg/L
Sodium Persulfate	48 h LC50	Daphnia magna	133	mg/L
Sodium Persulfate	96 h LC50	Grass shrimp	519	mg/L
Sodium Persulfate	72 h EC50	Algae Selenastrum capricornutum	116	mg/L

Persistence and degradability Biodegradability does not pertain to inorganic substances.

Bioaccumulation Does not bioaccumulate.

Mobility Dissociates into ions.

Other Adverse Effects None known.

13. DISPOSAL CONSIDERATIONS

Waste disposal methods This material, as supplied, is a hazardous waste according to federal regulations (40 CFR 261). It must undergo special treatment, e.g. at suitable disposal site, to comply with local regulations.

Contaminated Packaging Empty remaining contents. Dispose of in accordance with local regulations.

14. TRANSPORT INFORMATION

DOT

UN/ID no UN 1505
Proper Shipping Name SODIUM PERSULFATE
Hazard class 5.1
Packing Group III

TDG

UN/ID no UN 1505
Proper Shipping Name SODIUM PERSULFATE
Hazard class 5.1
Packing Group III

MEX

UN/ID no UN 1505
Proper Shipping Name SODIUM PERSULFATE
Hazard class 5.1
Packing Group III

ICAO

UN/ID no UN 1505
Proper Shipping Name SODIUM PERSULFATE
Hazard class 5.1
Packing Group III

ICAO/IATA

UN/ID no UN 1505
Proper Shipping Name SODIUM PERSULFATE
Hazard class 5.1

Packing Group III

IMDG/IMO

UN/ID no	UN 1505
Proper Shipping Name	SODIUM PERSULFATE
Hazard class	5.1
Packing Group	III

ADR/RID

UN/ID no	UN 1505
Proper Shipping Name	SODIUM PERSULFATE
Hazard class	5.1
Packing Group	III

ADN

Proper Shipping Name	SODIUM PERSULFATE
Hazard class	5.1
Packing Group	III

15. REGULATORY INFORMATION

U.S. Federal Regulations

SARA 313
Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA). This product does not contain any chemicals which are subject to the reporting requirements of the Act and Title 40 of the Code of Federal Regulations, Part 372

SARA 311/312 Hazard Categories
This product is not subject to reporting under the Emergency Planning and Community Right-to-Know rule.

Clean Water Act
This product does not contain any substances regulated as pollutants pursuant to the Clean Water Act (40 CFR 122.21 and 40 CFR 122.42)

CERCLA/EPCRA
This material, as supplied, does not contain any substances regulated as hazardous substances under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) (40 CFR 302) or the Superfund Amendments and Reauthorization Act (SARA) (40 CFR 355). There may be specific reporting requirements at the local, regional, or state level pertaining to releases of this material

US State Regulations

U.S. State Right-to-Know Regulations
This product contains the following substances regulated under state Right-to-Know laws:

Chemical name	Massachusetts	New Jersey	Pennsylvania	Illinois	Rhode Island
Sodium Persulfate		X			
Sodium sulfate	X		X		

California Proposition 65
This product does not contain any Proposition 65 chemicals

CANADA

Environmental Emergencies
This product contains no substances listed under Canada's Environmental Emergency regulations.

Canadian National Pollutant Release Inventory

This product contains no substances reportable under Canada's National Pollutant Release Inventory regulations.

International Inventories

Component	TSCA (United States)	DSL (Canada)	EINECS/ELINCS (Europe)	ENCS (Japan)	China (IECSC)	KECL (Korea)	PICCS (Philippines)	AICS (Australia)	NZIoC (New Zealand)
Sodium Persulfate 7775-27-1 (> 99)	X	X	X	X	X	X	X	X	X
Sodium sulfate 7757-82-6 (< 2)	X	X	X	X	X	X	X	X	X

Mexico

Mexico - Grade Slight risk, Grade 1

16. OTHER INFORMATION

NFPA	**Health Hazards** 1	**Flammability** 0	**Stability** 1	**Special Hazards** OX
HMIS	**Health Hazards** 1	**Flammability** 0	**Physical hazard** 1	**Special precautions** J

NFPA/HMIS Ratings Legend Special Hazards: OX = Oxidizer
Protection=J (Safety goggles, gloves, apron, combination dust and vapor respirator)

Revision date: 2018-07-13
Revision note SDS sections updated: 3.
Issuing Date: 2017-03-17

Disclaimer

PeroxyChem believes that the information and recommendations contained herein (including data and statements) are accurate as of the date hereof. NO WARRANTY OF FITNESS FOR ANY PARTICULAR PURPOSE, WARRANTY OF MERCHANTABILITY OR ANY OTHER WARRANTY, EXPRESSED OR IMPLIED, IS MADE CONCERNING THE INFORMATION PROVIDED HEREIN. The information provided herein relates only to the specified product designated and may not be applicable where such product is used in combination with any other materials or in any process. Further, since the conditions and methods of use are beyond the control of PeroxyChem, PeroxyChem expressly disclaims any and all liability as to any results obtained or arising from any use of the products or reliance on such information.

Prepared By:

PeroxyChem

End of Safety Data Sheet