Environmental Consultants
and Contractors

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SCS ENGINEERS

November 7, 2014
File No. 25211343.92

Mr. Jeff Ackerman
Wisconsin Department of Natural Resources
3911 Fish Hatchery Road
Fitchburg, WI 53711

Subject: NR 722 Remedial Options Analysis
Platteville Cleaners
250 West Main Street, Platteville, Wisconsin
BRRTS #02-22-550753

Dear Mr. Ackerman:

On behalf of Platteville Cleaners, SCS Engineers (SCS) is providing this analysis of remedial action alternatives for soil and groundwater contaminated with chlorinated volatile organic compounds (CVOCs) at the Platteville Cleaners, 250 West Main Street, Platteville, Wisconsin. Consistent with NR 722.07, the letter includes a brief project background and a description of the following remedial approaches:

- Soil Excavation (Option 1)
- Soil Chemical Oxidation (Option 2)
- Groundwater Enhanced Anaerobic Bioremediation (Option 3)
- Remediation by Natural Attenuation (Alone) (Option 4)

Table 1 summarizes estimated costs for each option. This letter summarizes the pros and cons for each remedial option and key assumptions associated with remediation and case closure.

Based on overall cost, soil and groundwater remediation effectiveness, technical feasibility, restoration timeframe, and some site-specific concerns, SCS recommends that Platteville Cleaners proceed with enhanced soil treatment through chemical oxidation (Option 2). The proposed treatment area is shown in **Attachment A**, **Figure 7**. The remedy includes 2 years of quarterly groundwater sampling following soil treatment, soil confirmation sampling, and a case closure request.

Once we have agreement from the WDNR regarding the recommended remedial approach, SCS will prepare a more detailed cost estimate and work scope for WDNR's approval.

BACKGROUND

Site Investigation Findings

Site investigation activities were performed at the Platteville Cleaners site to evaluate the degree and extent of chlorinated solvent contamination. The contamination resulted from a release of tetrachloroethylene (PCE) dry cleaning solvent. The date and quantity of the release are not known.

Clay soils in the vicinity of the site extend to the top of sandstone bedrock, which is present at a depth of approximately 20 feet below ground surface (bgs). The water table is present within bedrock at a depth of approximately 40 feet bgs. Groundwater flow is to the south and has a downward flow component.

PCE has migrated through the unsaturated soil and bedrock and into groundwater to a depth of at least 80 feet bgs. The majority of the soil contamination lies under the dry cleaning building at levels exceeding Chapter NR 720 residual contaminant levels (RCLs).

Groundwater contamination exceeding Wisconsin Administrative Code (WAC) Chapter NR 140 enforcement standards extends about 350 feet or more off site to the south. The City of Platteville supplies potable water though municipal wells. The nearest municipal water supply well is located approximately 3,000 feet to the east-southeast. Per communication with the City, there is a private well located approximately 800 feet south of the site, but the well is not used for potable water supply.

Elevated PCE soil gas concentrations in sub-slab samples collected at the dry cleaning building indicate a potential for vapor intrusion from the sub-surface into the building. With the exception of 40 North Chestnut Street, sample results for sub-slab and indoor air samples collected from nearby homes and businesses do not exceed the WDNR's vapor risk screening levels (VRSLs) or indoor air vapor action levels (VALs). Indoor air acrolein and trichloroethylene (TCE) sample results for 40 North Chestnut Street exceed the WDNR's VALs; however, the sources of these contaminants do not appear to be related to the Platteville Cleaners.

For additional site investigation details please see the July 18, 2013 Site Investigation Report on file with the WDNR.

Site-Specific Issues

The following site-specific issues affect remedial action planning at this site:

1. The property limits closely coincide with the Platteville Cleaners building, leaving very little room for access.

2. The greatest soil CVOC concentrations are located directly under the building in an area of active dry cleaning operations. Remediation approaches that minimize business disruption are preferable.

3. The source area is in clay soil and extends into unsaturated bedrock, which is present at a depth of approximately 20 feet bgs. Soil vapor extraction (SVE) treatment methods would be severely limited by the low permeability of the clay soil, and the bedrock cannot be accessed in the source area with conventional drilling methods. Therefore, SVE is not evaluated as an option for remediation.

4. The existing and anticipated future use of the property is expected to remain commercial, using the same building footprint and general processes currently in place. Therefore, regardless of the remedial approach selected, some residual, CVOC-contaminated soil will remain in place when the case is closed.

REMEDIAL ACTION OPTIONS

For the chemical oxidation and bioremediation options discussed below, SCS has used costs and product trade names provided by Regenesis, a specialty vendor based in California that provides advanced technologies for soil and groundwater site remediation. Regenesis documentation for Options 2 and 3 is included in **Attachments A** and **B**.

Option 1 – Soil Excavation

With this option, the goal is to focus on source removal by excavating the soil with greater CVOC concentrations from below the concrete slab within the building, and hauling the materials to a licensed hazardous waste facility for disposal. **Figure 1** outlines a possible soil excavation area. An estimated 120 tons of soil would be removed, based on a 10 milligram per kilogram (mg/kg) or part per million (ppm) cleanup objective for PCE in soil. An area of approximately 340 square feet would be excavated to a depth of approximately 6 feet bgs.

The excavation would be followed by 2 years of quarterly groundwater natural attenuation monitoring. If results are favorable, a case closure would be submitted to the WDNR.

Pros

- Addresses source removal more definitively than in-situ treatment techniques.
- May enhance property value.
- Compared to other approaches, short timeframe for soil remediation.

Cons

- High cost.
- Disruptive to ongoing business and site traffic.
- Excavation alone will have less effect on groundwater contamination.
- Excavation depth is limited to approximately 6 feet bgs.

Assumptions

- There are no access restrictions.
- Remediation is effective and additional excavation is not necessary.
- Waste characterization sampling will be performed to determine if excavated soil will need to be managed as a hazardous waste.
- For scoping purposes, we assume excavated soil is characteristically hazardous and will be managed accordingly.
- See Option 4 assumptions.

Option 2 – Soil Chemical Oxidation

For Option 2, the goal is to chemically treat the primary source area under the building, using a target PCE soil cleanup objective of 10 ppm. The scope of work includes two in-situ chemical oxidation (ISCO) injection events using PersulfOx spaced about 4 weeks apart. The longevity of the chemical oxidation from PersulfOx is expected to be 4 weeks once injected.

The first application will be considered a pilot test to see if the low permeability of the clay soils will limit the injection of remedial fluids. The second application will be applied only if the pilot test is successful.

A total of approximately 2,590 pounds of PersulfOx would be applied to the treatment area over the course of the two injection events. During each event, PersulfOx would be injected into the impacted soils through nine direct-push points between 0 and 20 feet bgs. Injection points would be spaced 6 feet on center for each of the two application events as shown on **Figure 7** of **Attachment A**. The nine injection points for the second application event would be offset from the first set of injection points to optimize distribution within the clay soils. Regenesis estimates that the remediation of the soils would be complete within 6 weeks after the second PersulfOx injection event.

Regenesis estimates that this approach is capable of reducing the soil concentration of PCE by approximately 75 percent or more. SCS will perform post-injection soil confirmation sampling to evaluate the treatment. Four direct-push borings will be advanced to a depth of approximately 20 feet. Four samples from each boring will be collected for analysis of volatile organic compounds (VOCs).

The chemical injection would be followed by 2 years of quarterly groundwater natural attenuation monitoring. If results are favorable, a case closure would be submitted to the WDNR.

Pros

- Lower cost compared to other options.
- Less business disruption compared to excavation activities.
- Reduces the contaminant mass and concentrations in soil.

Cons

- Does not directly address unsaturated bedrock or groundwater impacts.
- Potentially disruptive to anaerobic equilibrium and existing biodegradation patterns.
- Less definitive source area remediation than excavation.

Assumptions

- There are no access restrictions and target injection depths can be reached using standard direct-push drilling methods.
- Remediation is effective and additional injections are not necessary.
- Waste characterization sampling will be performed to determine if on-site drill cuttings will need to be managed as a hazardous waste.
- For scoping purposes, we assume on-site drill cuttings are characteristically hazardous and will be managed accordingly.
- See Option 4 assumptions.

Option 3 – Groundwater Enhanced Anaerobic Bioremediation

This option addresses the groundwater impacts shown in **Attachment B**, **Figure 9** by creating a permeable reactive barrier to prevent migration of CVOCs. The scope of work includes one injection event of 3-D Microemulsion (3DME), Bio-Dechlor Inoculum Plus (BDI Plus) and Chemical Reducing Solution (CRS). 3DME would provide a source of hydrogen (electron donor) for biotic destruction of CVOCs. BDI Plus is a microbial substrate composed partly of Dehalococcoides, which would increase the efficiency of reductive dechlorination. CRS provides abiotic in-situ chemical reduction of CVOCs through the precipitation of iron sulfides and iron oxide/hydroxides. Regenesis estimates that the active life of 3DMe at this site will be approximately 3 years. Additional information for each of these products is included in **Attachment B**.

The 3DME (10,800 pounds), BDI Plus (50 liters), and CRS (4,400 pounds) would be prepared on site and injected into a transect of 10 bedrock injection wells (approximately 1,400 gallons per well). The proposed transect is shown in **Attachment B**, **Figure 9**. The wells would be spaced at approximately 20 feet. Only one injection event will be required due to the longevity of the 3DME. Over the active life of 3DME, the BDI Plus culture will thrive and migrate downgradient with groundwater.

Regenesis estimates that this anaerobic bioremediation approach is capable of reducing groundwater concentrations of PCE an order of magnitude or more and will also destroy daughter products in groundwater within the treatment area.

The chemical injection would be followed by 2 years of quarterly natural attenuation groundwater monitoring. If the results are favorable, closure request would be submitted to the WDNR.

Pros

- Less disruptive to business operations.
- Enhances, rather than disrupts, existing anaerobic equilibrium.
- Reduces contaminant mass and concentrations in groundwater.

Cons

- Does not address source area.
- Longer remediation timeframe than other options.
- Higher cost compared to other options.

Assumptions

- There are no access restrictions.
- Injection points are installed using standard rotary drilling methods.
- Remediation is effective and additional injections are not necessary.
- Waste characterization sampling will be performed to determine if off-site drill cuttings will need to be managed as a hazardous waste.
- We assume the off-site drill cuttings from the injection points can be disposed of as non-hazardous, because drill cuttings from similar wells in the vicinity of the proposed injection points were determined not to be characteristically hazardous.
- See Option 4 assumptions.

Option 4 – Remediation by Natural Attenuation (Alone)

Option 4 is included in **Table 1** primarily as a "least cost" placeholder for comparison with active remediation approaches. For costing purposes, SCS assumed 4 years of semiannual groundwater monitoring, with regular reports to the WDNR. The monitoring includes the following for each of the 10 site monitoring wells:

- Semiannual water level measurements.
- Semiannual VOC sampling.
- Annual natural attenuation sampling for iron, ethane, ethane, methane, and sulfate.
- Annual field measurement for dissolved oxygen, REDOX potential, and pH.

Pros

- Least disruptive to business operations.
- Lowest cost.

Cons

- Does not address source area.
- Longer remediation timeframe than other options.

Assumptions

- Monitoring wells remain accessible for sampling.
- The groundwater CVOC plume is stable within 2 years and additional monitoring is not necessary.
- The Platteville wastewater treatment plant will accept well development and purge water.
- Costs do not include monitoring well repairs or abandonment.

Based on overall cost, soil and groundwater remediation effectiveness, technical feasibility, restoration timeframe, and some site-specific concerns, SCS recommends that Platteville Cleaners proceed with enhanced soil treatment through chemical oxidation (Option 2). As shown in **Table 1**, SCS estimates a total project cost for Option 2 of $108,990.00. All the costs summarized in this Remedial Options Analysis are preliminary. As mentioned previously, SCS will prepare a more detailed cost estimate and work scope for the selected remedy, once WDNR has reviewed and provided input on this letter.

Please contact me at (608) 216-7329 if you have any questions concerning this letter.

Sincerely,

Robert E Langdon

Robert Langdon
Senior Project Manager
SCS ENGINEERS

REL/lmh/JBT

cc: Tim Koeller, Platteville Cleaners

Attachments: Table 1 – Platteville Cleaners Remedial Options and Costs
Figure 1 – Option 1 – Excavation
Attachment A – Regenesis October 28, 2014 Proposal
Attachment B – Regenesis June 23, 2014 Technical Memorandum

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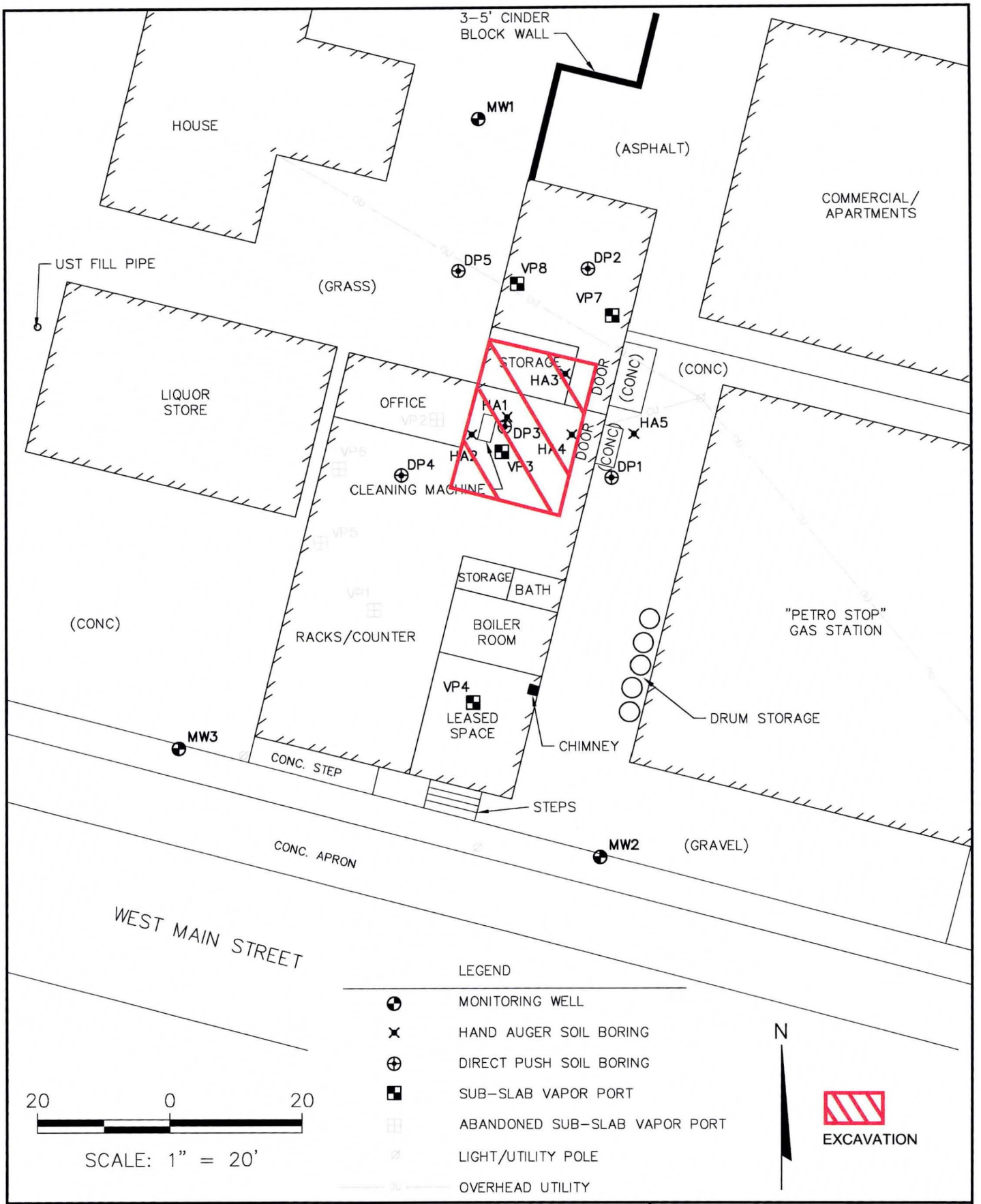
Table 1. Platteville Cleaners Remedial Options and Costs
SCS Project #25211343.92

Option Number	Remedial Options	Cost Estimate
1	Excavation (120 tons with 2 years of quarterly groundwater monitoring)	$175,980
2	Soil Chemical Oxidation (two injection events with 2 years of quarterly groundwater monitoring)	$108,990
3	Groundwater Enhanced Anaerobic Bioremediation (10 injection wells, one injection event, 2 years of quarterly groundwater monitoring)	$171,240
4	Natural Attenuation Alone (2 years of quarterly groundwater monitoring)	$53,260

Note: Costs include both DERF-eligible and non-eligible costs.

I:\3439A\Budgets\CO_7\[Remedial Action Options Cost Estimate_141105.xlsx]Table 1



CLIENT	PLATTEVILLE CLEANERS 250 WEST MAIN STREET PLATTEVILLE, WISCONSIN	SITE	PLATTEVILLE CLEANERS 250 WEST MAIN STREET PLATTEVILLE, WISCONSIN

OPTION 1 - EXCAVATION

PROJECT NO.	25211343.92	DRAWN BY:	SAS/KP	ENGINEER	SCS ENGINEERS 2830 DAIRY DRIVE MADISON, WI 53718–6751 PHONE: (608) 224–2830
DRAWN:	05/04/11	CHECKED BY:	REL		FIGURE 1
REVISED:	07/11/13	APPROVED BY:	REL 07/18/13		

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ATTACHMENT A

Regenesis October 28, 2014 Proposal

Proposal for Site Remedy

REGENESIS
Advanced Technologies for Groundwater Resources

To: Robert Langdon – SCS Engineers **October 28, 2014**

From: Doug Davis, Ryan Moore and Steve Barnes - REGENESIS

RE: Platteville Cleaners – Proposal for ISCO Application, Platteville, WI

Thank you for the opportunity to work with SCS Engineers at the above-referenced project. We have provided the attached design and cost estimate for REGENESIS Remediation Services (RRS) application of our sodium persulfate-based in situ chemical oxidation (ISCO) technology, PersulfOx, to treat perchloroethylene (PCE) in vadose zone soils.

Please find the following attachments:

1) Application map depicting treatment area
2) Remedial design summary table
3) PersulfOx ISCO technology description

Project Goals and Remedial Scope

We understand the goal for this project is to reduce PCE concentrations in the source area utilizing an ISCO approach. We have designed for application of our all-in-one activated sodium persulfate technology (PersulfOx®) within an approximate 330 square ft area which correlates to the 10 mg/kg PCE shallow soil (0 to 6 ft bgs) isocontour and the 1 mg/kg deep soil (6 to 20 ft) isocontour line. We propose two applications of PersulfOx. The first application would be used to test the efficacy/feasibility of the approach given the fine grained nature of the soils which could potentially hinder injection of remedial fluids. We anticipate two applications are necessary within the target area to achieve sufficient pore space occupancy in order to significantly reduce PCE concentrations. Nine (9) injection points are estimated for each application for a total of 18 injection points.

RRS Scope of Services

As mentioned, RRS will implement the turn-key application of the proposed ISCO treatment. The implementation of this scope of work includes:

- RRS will provide and ship the specified quantities of remedial agents to the site prior to personnel mobilization.
- CLIENT will receive product delivery at the site prior to mobilization and arrange for secure storage near the work area during product application.
- RRS will provide the injection trailer with a project manager, direct push rig and operator, and perform product application, which will include the following:
    - Mix and prepare remedial reagents for application
    - Injection trailer apparatus (equipped with pumps, mixing tanks, injection heads with flow & pressure gauges, safety bypass valves, first aid station, etc.)

  - PPE and safety equipment for RRS personnel
- Collect empty containers, used PPE and RRS generated refuse daily. This nonhazardous material will be placed in the property's onsite refuse container for disposal.
- Utilize up to 1,500 gallons of water per day for the application.
- Perform real-time reagent distribution diagnostics to allow for field modifications, as needed.
- After completion of the full scale application, prepare and submit a Post-Application Summary Report including application depths, material quantities applied, injection pressures, surfacing of material and other noteworthy field observations.

Health and Safety

RRS will develop and implement a site specific health and safety plan (HASP) for this project. The safety of all site personnel is a priority on all RRS projects. Tailgate safety meetings will be conducted each morning to review the HASP requirements, identify the location of first aid stations to site personnel, review activities planned for the day, discuss safety concerns and modify plans, as needed. All on-site personnel will be up to date with Occupational Safety and Health Administration (OSHA) 1910.120 HAZWOPER training requirements.

The injection equipment utilized by RRS is specifically designed to monitor and handle the chemical reagents being applied. Pressure bypass lines, pressure relief valves, and sufficiently rated equipment are just a few of the engineering controls installed within the injection unit to mitigate potential health and safety issues. All RRS personnel are trained to properly operate the injection unit and maintain the equipment within acceptable ranges.

Project Cost Information

The cost to implement this scope of work is $33,742 and includes product, sales tax and delivery to the site. One product shipment for each application (two total) is assumed. A breakout of costs for each application event is provided as follows:

PersulfOx Event #1 (1,292 lbs)	
PersulfOx Cost	$ 3,237
RRS Application	$11,850
Tax and Freight	$ 1,784
Event #1 Cost	***$16,871***
PersulfOx Event #2 (1,292 lbs)	
PersulfOx Cost	$ 3,237
RRS Application	$11,850
Tax and Freight	$ 1,784
Event #2 Cost	***$16,871***
Total Project Cost	***$33,742****

**** This pricing is contingent upon completion of this scope of work without delays or work stoppages once mobilization occurs. Payment terms are net thirty (30) days from date of each invoice. It is estimated that 2 days in the field will be required for each application. A daily rate adjustment of $4,700 will be applied to the invoice if the if work is completed prior to or exceeds this daily-rate estimate.***

RRS Standard Assumptions and Qualifications

- In generating this preliminary estimate, REGENESIS relied upon professional judgment and site specific information provided by others. Using this information as input, we performed calculations based upon known chemical and geologic relationships to generate an estimate of the mass of product and subsurface placement required to affect remediation of the site.
- CLIENT personnel will take delivery of the remedial products prior to RRS mobilization and arrange for secure storage in an environment that will prevent exposure to inclement weather (i.e., freezing temperatures, rain, etc.). If material is stored off-site, CLIENT personnel will coordinate the delivery of the material to the site.
- RRS will call in a public utility locate for area in or near the injection zones. All private, on-site underground utilities and any known subsurface features (i.e., piping, storage tanks, septic systems, etc.) will be clearly marked/cleared by CLIENT prior to RRS mobilization to the site. RRS is not responsible for damage to any unmarked utilities or subsurface features.
- RRS will collect project related refuse, empty product containers and used PPE on a daily basis to keep the site clean. This nonhazardous refuse will be placed in an on-site refuse container provided by others.
- A high volume water source (i.e. hydrant) capable of producing at least 40 gpm will be available to RRS for the duration of the project, within 300 feet of the work area, at no cost to RRS. RRS will utilize this water for the injection activities.
- RRS will have access to the site for equipment operation and storage of materials and equipment.
- CLIENT is responsible for securing injection permits prior to mobilizing to the site.
- CLIENT is responsible for any soil, air and/or groundwater sampling and analysis (as required).
- This proposal does not account for concrete coring, if applicable. DPI points will be bentonite grouted to surface after use.
- RRS will not be responsible for any treatment chemistry infiltration into undesired locations (e.g., subsurface utility corridors). Damage to utilities via infiltration will not be the responsibility of RRS.
- Proposal assumes probing and drilling will begin at ground surface. If hand augering, concrete coring or air knife services will be required, additional charges will apply.
- This proposal assumes work will be performed within the building and no special geoprobe equipment is needed to gain access to the work area.

REGENESIS appreciates the opportunity to present you with this proposal. If you need any additional information please do not hesitate to contact Doug Davis at 614-447-0492 or Ryan Moore at 219-286-4838.

REGENESIS

Steven R. Barnes
Remediation Services Project Manager

Doug Davis
Central Region Technical Manager

Attachment: Site Map Depicting the Proposed Treatment Area

Please sign below to acknowledge acceptance of proposal #49571 for the Platteville Cleaners Site in Platteville, WI and authorize RRS to perform stated work:

SCS Engineers

_____ _____

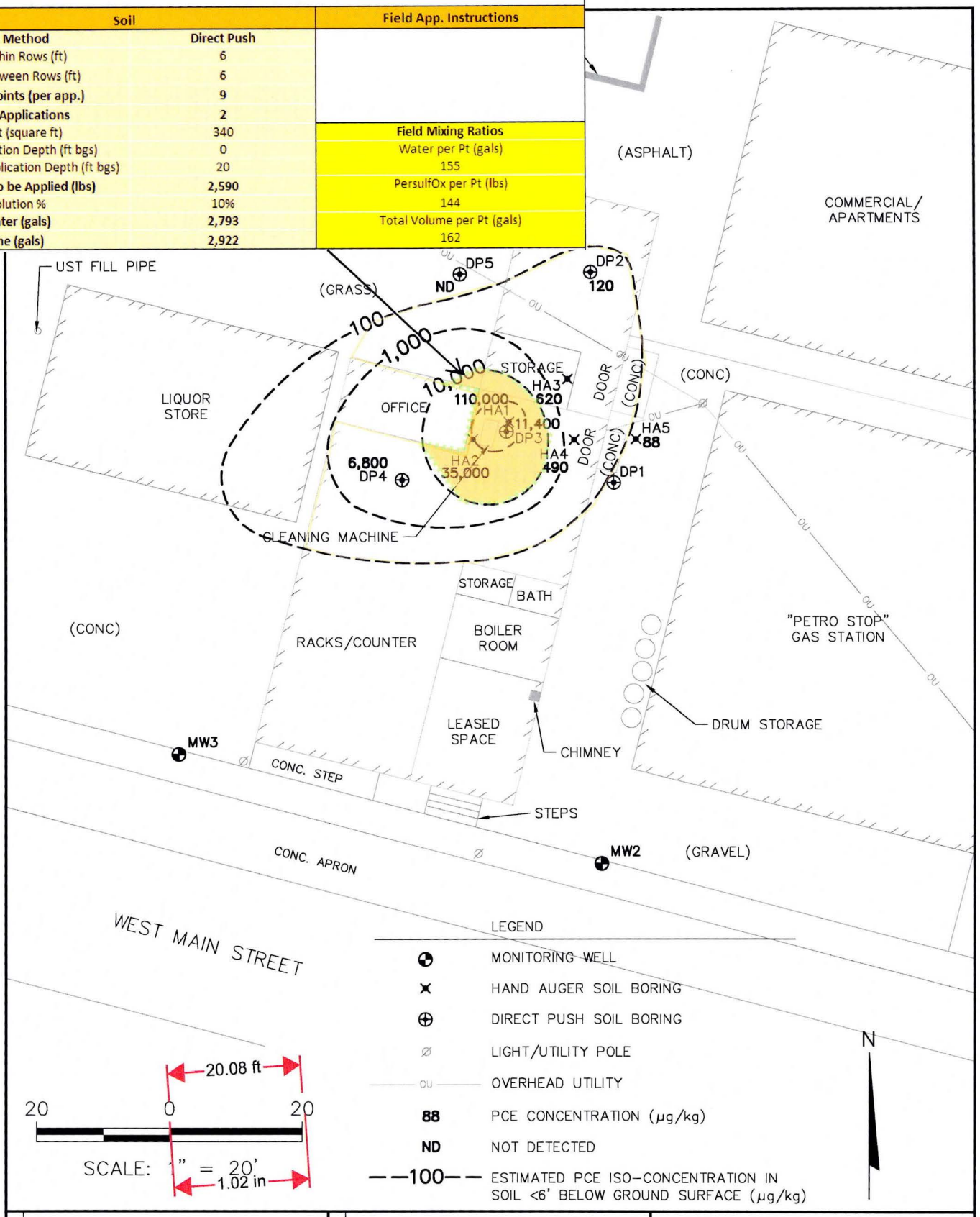
Authorized Signature | Date

_____ _____

Name (print) | P.O. or Project Number

PersulfOx® Application Design Summary

Soil		Field App. Instructions
Application Method	**Direct Push**	
Spacing Within Rows (ft)	6	
Spacing Between Rows (ft)	6	
Injection Points (per app.)	**9**	
Number of Applications	**2**	
Areal Extent (square ft)	340	**Field Mixing Ratios**
Top Application Depth (ft bgs)	0	Water per Pt (gals)
Bottom Application Depth (ft bgs)	20	155
PersulfOx to be Applied (lbs)	**2,590**	PersulfOx per Pt (lbs)
PersulfOx Solution %	10%	144
Volume Water (gals)	**2,793**	Total Volume per Pt (gals)
Total Volume (gals)	**2,922**	162



CLIENT	PLATTEVILLE CLEANERS 250 WEST MAIN STREET PLATTEVILLE, WISCONSIN	SITE	PLATTEVILLE CLEANERS 250 WEST MAIN STREET PLATTEVILLE, WISCONSIN

SHALLOW SOIL RESULTS MAP

PROJECT NO.	3439A	DRAWN BY:	SAS/KP
DRAWN:	04/03/09	CHECKED BY:	REL
REVISED:	07/18/13	APPROVED BY:	REL 07/18/13

ENGINEER

SCS ENGINEERS
2830 DAIRY DRIVE MADISON, WI 53718-6751
PHONE: (608) 224-2830

FIGURE 7

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REGENESIS

Project Information

Platteville Cleaners
Platteville, WI
Soil

Prepared For:
Robert Langdan (SCS)

Target Treatment Zone (TTZ) Info	Unit	Value
Treatment Area	ft^2	340
Top Treat Depth	ft	0.0
Bot Treat Depth	ft	20.0
Vertical Treatment Interval	ft	20.0
Treatment Zone Volume	ft^3	6,800
Treatment Zone Volume	cy	252
Soil Type	---	clay
Porosity	cm^3/cm^3	0.45
Effective Porosity	cm^3/cm^3	0.10
Treatment Zone Pore Volume	gals	22,890
Treatment Zone Effective Pore Volume	gals	5,087
Fraction Organic Carbon (foc)	g/g	0.010
Soil Density	g/cm^3	1.5
Soil Density	lb/ft^3	94
Soil Weight	lbs	6.4E+05
Hydraulic Conductivity	ft/day	0.0
Hydraulic Conductivity	cm/sec	3.53E-07
Hydraulic Gradient	ft/ft	0.100
GW Velocity	ft/day	0.00
GW Velocity	ft/yr	0
Sources of Oxidant Demand	**Unit**	**Value**
Sorbed Phase Contaminant Mass	lbs	70
Dissolved Phase Contaminant Mass	lbs	0.0
Total Contaminant Mass	lbs	70
Stoichiometric PersulfOx Demand	lbs	233
Efficiency/Safety Factor	---	**5.0**
Stoichiometric PersulfOx Required	lbs	1,167
SOD PersulfOx Required	lbs	1,415
Total PersulfOx Required	**lbs**	**2,582**

Application Dosing

PersulfOx Required	**lbs**	**2,590**

PersulfOx® Application Design Summary

Soil		Field App. Instructions
Application Method	**Direct Push**	
Spacing Within Rows (ft)	6	
Spacing Between Rows (ft)	6	
Injection Points (per app.)	**9**	
Number of Applications	**2**	
Areal Extent (square ft)	340	**Field Mixing Ratios**
Top Application Depth (ft bgs)	0	Water per Pt (gals)
Bottom Application Depth (ft bgs)	20	155
PersulfOx to be Applied (lbs)	**2,590**	PersulfOx per Pt (lbs)
PersulfOx Solution %	10%	144
Volume Water (gals)	**2,793**	Total Volume per Pt (gals)
Total Volume (gals)	**2,922**	162
		8
		Volume per vertical ft gals)

Technical Notes/Discussion

Prepared By:

Date: 6/19/2014

Assumptions/Qualifications

In generating this preliminary estimate, Regenesis relied upon professional judgment and site specific information provided by others. Using this information as input, we performed calculations based upon known chemical and geologic relationships to generate an estimate of the mass of product and subsurface placement required to affect remediation of the site.

PersulfOx™
CATALYZED PERSULFATE

A Sodium Persulfate - Based *In Situ* Chemical Oxidant with Built-In Activation

DESCRIPTION

PersulfOx™ is an *in situ* chemical oxidation reagent that destroys organic contaminants found in groundwater and soil through powerful yet controlled chemical reactions. PersulfOx is a sodium persulfate ($Na_2S_2O_8$) - based technology which employs a uniquely patented catalyst to enhance oxidative destruction of both hydrocarbon and chlorinated contaminants in the subsurface.

Traditionally, sodium persulfate is activated with the addition of heat, chelated metals, hydrogen peroxide, or base in order to generate sulfate radicals. These activation processes are inherently complex, costly and can pose additional health and safety risks. In comparison, PersulfOx is a relatively safe and easy-to-use ISCO agent.

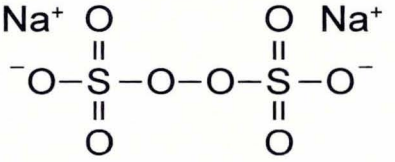


FIGURE 1:
SODIUM PERSULFATE CHEMICAL STRUCTURE

In short, PersulfOx contains a built-in catalyst which activates the persulfate component and generates contaminant destroying free radicals without the need for the addition of a separate activator.

FEATURES & BENEFITS

- Promotes rapid and sustained *in situ* oxidation of a wide-range of organic contaminants
- Provides a unique catalytic surface on which oxidants and contaminants react in a process known as "surface mediated oxidation."
- Contains built-in activation: eliminates complex and potentially hazardous chemical addition required to achieve traditional persulfate activation
- Fewer health and safety concerns than with use of traditional activation methods such as heat, chelated metals, hydrogen peroxide or base
- Single component product results in simplified logistics and application. No additional containers and/or multi-step mixing ratios required prior to application
- Contaminant oxidation performance equivalent to best alternative persulfate activation methods

FUNCTION

PersulfOx is an all-in-one product that provides powerful and highly efficient chemical oxidation performance. It is easily mixed with water and applied into the contaminated matrix using subsurface injection techniques or soil mixing tools.

The PersulfOx catalyst is a silica based, microscopic surface on which oxidants and contaminants can come together and react in a distinct process known as "surface mediated oxidation." During this process, oxidation reactions occur repeatedly on the surface of the catalyst serving several contaminant-reducing functions:

- The generation of sulfate radical and other oxidizing species
- Accelerated oxidation through the adsorption of contaminant molecules and other oxidizing species
- Catalyzes direct and free-radical-mediated oxidation by sodium persulfate

The equation below shows the net complete oxidation of toluene, a constituent of gasoline, by PersulfOx:

For a Free Consultation and Application Design for the use of PersulfOx visit www.regenesis.com

REGENESIS
Advanced Technologies for Contaminated Site Remediation

REGENESIS / 1011 Calle Sombra / San Clemente / CA 92673-6244 / USA / T: 949.366.8000 / F: 949.366.8090 / www.regenesis.com

ATTACHMENT B

Regenesis June 23, 2014 Technical Memorandum

TECHNICAL MEMORANDUM

REGENESIS
Advanced Technologies for Groundwater Resources

From: Doug Davis - REGENESIS June 23, 2014

To: Robert Langdon – SCS Engineers

RE: Platteville Cleaners - Preliminary Remedial Design and Cost Estimates, Platteville, WI

Thank you for the opportunity to work with SCS Engineers at the above-referenced project. We have provided the attached ***preliminary*** design and cost estimates for REGENESIS Remediation Services (RRS) application of our sodium persulfate-based in situ chemical oxidation (ISCO) technology, PersulfOx, to treat perchloroethylene (PCE) in vadose zone soils and installation of a permeable reactive barrier (PRB), along the north edge of West Main Street, utilizing 3-D Microemulsion, Bio-Dechlor INOCULUM Plus (BDI Plus) and CRS ISCR Solution to promote reductive dechlorination and prevent migration of chlorinated solvents further downgradient. The attached application maps depict the layouts of these treatment areas and provide design specifications (# of points, injection volumes, etc.).

Project Goals and Remedial Scope

We understand the goal for this project is to reduce PCE concentrations in the source area utilizing an in situ chemical oxidation (ISCO) approach. We have designed for application of our all-in-one activated sodium persulfate technology (PersulfOx®) within an approximate 330 square ft area which correlates to the 10 mg/kg PCE shallow soil (0 to 6 ft bgs) isocontour and the 1 mg/kg deep soil (6 to 20 ft) isocontour line. We propose two applications of PersulfOx. The first application would be used to test the efficacy/feasibility of the approach given the fine grained nature of the soils which could potentially hinder injection of remedial fluids. We anticipate two applications are necessary within the target area to achieve sufficient pore space occupancy in order to significantly reduce PCE concentrations.

Per our conversation we have also provided an estimated scope and cost for installation of a PRB along West Main Street as depicted on the attached ERD Application Map. The purpose of the PRB would be to prevent migration of chlorinated solvents downgradient of the line. 3-D Microemulsion will provide a source of hydrogen for approximately 3 years via a staged-release profile. CRS is added to provide in situ chemical reduction (ISCR) through the precipitation of iron sulfides and iron oxides/hydroxides. BDI Plus is a microbial substrate comprised largely of Dehalococcoides (DHC) and is proposed here to increase the efficiency of reductive dechlorination. As a portion of the 3-D Microemulsion is mobile, there will be some treatment emanating downgradient of the PRB. Product quantities and product/application estimates have been calculated assuming application through 10 injection wells at approximate 20 ft spacing.

Technology Description

Technology descriptions sheets for the proposed products are attached.

RRS Scope of Services

As mentioned, RRS will implement the turn-key application of the proposed remedial technologies. The implementation of this scope of work includes:

- RRS will provide and ship the specified quantities of remedial agents to the site prior to personnel mobilization.
- CLIENT will receive product delivery at the site prior to mobilization and arrange for secure storage near the work area during product application.
- RRS will provide the injection trailer with a project manager, direct push rig and operator, and perform product application, which will include the following:
    - Mix and prepare remedial reagents for application
    - Injection trailer apparatus (equipped with pumps, mixing tanks, injection heads with flow & pressure gauges, safety bypass valves, first aid station, etc.)
    - PPE and safety equipment for RRS personnel
- Collect empty containers, used PPE and RRS generated refuse daily. This nonhazardous material will be placed in the property's onsite refuse container for disposal.
- Utilize up to 1,500 gallons of water per day for the application.
- Perform real-time reagent distribution diagnostics to allow for field modifications, as needed.
- After completion of the full scale application, prepare and submit a Post-Application Summary Report including application depths, material quantities applied, injection pressures, surfacing of material and other noteworthy field observations.

Health and Safety

RRS will develop and implement a site specific health and safety plan (HASP) for this project. The safety of all site personnel is a priority on all RRS projects. Tailgate safety meetings will be conducted each morning to review the HASP requirements, identify the location of first aid stations to site personnel, review activities planned for the day, discuss safety concerns and modify plans, as needed. All on-site personnel will be up to date with Occupational Safety and Health Administration (OSHA) 1910.120 HAZWOPER training requirements.

The injection equipment utilized by RRS is specifically designed to monitor and handle the chemical reagents being applied. Pressure bypass lines, pressure relief valves, and sufficiently rated equipment are just a few of the engineering controls installed within the injection unit to mitigate potential health and safety issues. All RRS personnel are trained to properly operate the injection unit and maintain the equipment within acceptable ranges.

Project Cost Information

The cost information for the scope items are provided as follows:

PersulfOx Injection Event #1 (Pilot Test)

PersulfOx Required 1,292 lbs
Injection Points - 9
PersulfOx Cost - $3,237
Estimated 15% Tax and Freight - $486
RRS Application Cost - $11,430
Total Cost - $15,243

PersulfOx Injection Event #2

PersulfOx Required 1,292 lbs
Injection Points - 9
PersulfOx Cost - $3,237
Estimated 15% Tax and Freight - $486
RRS Application Cost - $11,430
Total Cost - $15,243

PRB – 3-D Microemulsion, CRS and BDI Plus – application via 10 injection wells (cost for injection wells not included)

3DME Required – 10,800 lbs
CRS Required – 4,400 lbs
BDI Plus Required – 50 Liters

3DME Cost – $31,320
CRS Cost - $11,000
BDI Plus Cost – $8,500
Estimated 15% Tax and Freight - $7,623
RRS Application Cost - $10,140
Total Cost - $68,583

RRS Standard Assumptions and Qualifications

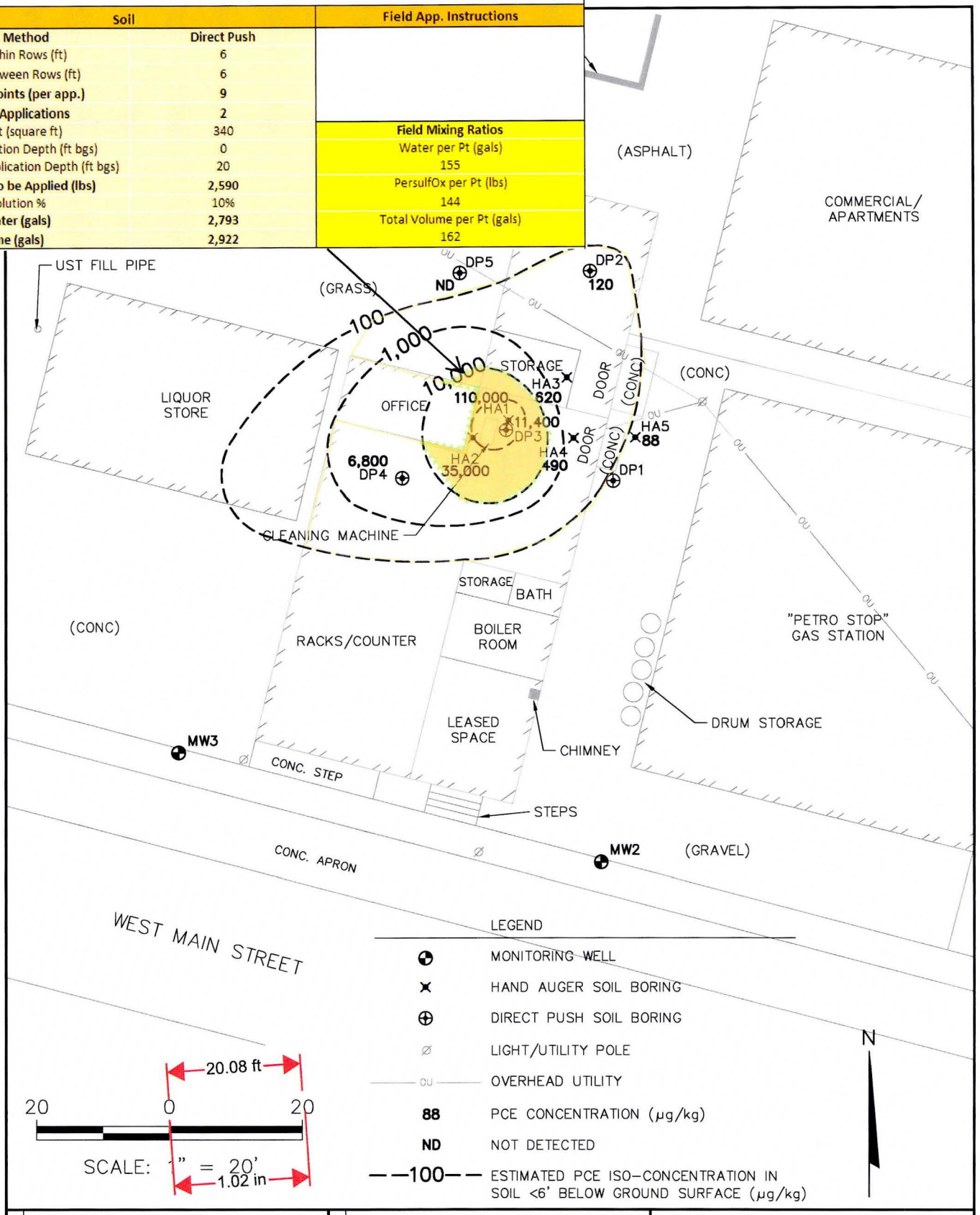
- In generating this preliminary estimate, REGENESIS relied upon professional judgment and site specific information provided by others. Using this information as input, we performed calculations based upon known chemical and geologic relationships to generate an estimate of the mass of product and subsurface placement required to affect remediation of the site.

- CLIENT personnel will take delivery of the remedial products prior to RRS mobilization and arrange for secure storage in an environment that will prevent exposure to inclement weather (i.e., freezing temperatures, rain, etc.). If material is stored off-site, CLIENT personnel will coordinate the delivery of the material to the site. All of the products will be shipped to the site in one (1) delivery.
- RRS will call in a public utility locate for area in or near the injection zones. All private, on-site underground utilities and any known subsurface features (i.e., piping, storage tanks, septic systems, etc.) will be clearly marked/cleared by CLIENT prior to RRS mobilization to the site. RRS is not responsible for damage to any unmarked utilities or subsurface features.
- RRS will collect project related refuse, empty product containers and used PPE on a daily basis to keep the site clean. This nonhazardous refuse will be placed in an on-site refuse container provided by others.
- A high volume water source (i.e. hydrant) capable of producing at least 40 gpm will be available to RRS for the duration of the project within 100' of the project staging area, at no cost to RRS. RRS will utilize this water for the injection activities.
- RRS will have access to the site for equipment operation and storage of materials and equipment.
- CLIENT is responsible for securing injection permits prior to mobilizing to the site.
- CLIENT is responsible for any soil, air and/or groundwater sampling and analysis (as required).
- This proposal does not account for concrete coring, if applicable. DPI points will be bentonite grouted to surface after use.
- RRS will not be responsible for any treatment chemistry infiltration into undesired locations (e.g., subsurface utility corridors). Damage to utilities via infiltration will not be the responsibility of RRS.
- CLIENT will provide a field water quality meter similar to a YSI 556 with a down-hole sensor while on-site for injection activities (PRB area only).
- Proposal assumes probing and drilling will begin at ground surface. If hand augering, concrete coring or air knife services will be required, additional charges will apply.

We sincerely appreciate the opportunity to present you with this proposal and look forward to working with you further on this project. If you need any additional information please do not hesitate to contact me (Doug Davis at 614-447-0492) or Ryan Moore at 219-286-4838.

PersulfOx® Application Design Summary

Soil		Field App. Instructions
Application Method	**Direct Push**	
Spacing Within Rows (ft)	6	
Spacing Between Rows (ft)	6	
Injection Points (per app.)	**9**	
Number of Applications	**2**	
Areal Extent (square ft)	340	**Field Mixing Ratios**
Top Application Depth (ft bgs)	0	Water per Pt (gals)
Bottom Application Depth (ft bgs)	20	155
PersulfOx to be Applied (lbs)	**2,590**	PersulfOx per Pt (lbs)
PersulfOx Solution %	10%	144
Volume Water (gals)	**2,793**	Total Volume per Pt (gals)
Total Volume (gals)	**2,922**	162



CLIENT	SITE	
PLATTEVILLE CLEANERS 250 WEST MAIN STREET PLATTEVILLE, WISCONSIN	PLATTEVILLE CLEANERS 250 WEST MAIN STREET PLATTEVILLE, WISCONSIN	SHALLOW SOIL RESULTS MAP

PROJECT NO.	3439A	DRAWN BY:	SAS/KP	ENGINEER	SCS ENGINEERS 2830 DAIRY DRIVE MADISON, WI 53718-6751 PHONE: (608) 224-2830
DRAWN:	04/03/09	CHECKED BY:	REL		FIGURE 7
REVISED:	07/18/13	APPROVED BY:	REL 07/18/13		

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REGENESIS

Project Information

Platteville Cleaners
Platteville, WI
Soil
Prepared For:
Robert Langdan (SCS)

Target Treatment Zone (TTZ) Info	Unit	Value
Treatment Area	ft^2	340
Top Treat Depth	ft	0.0
Bot Treat Depth	ft	20.0
Vertical Treatment Interval	ft	20.0
Treatment Zone Volume	ft^3	6,800
Treatment Zone Volume	cy	252
Soil Type	---	clay
Porosity	cm^3/cm^3	0.45
Effective Porosity	cm^3/cm^3	0.10
Treatment Zone Pore Volume	gals	22,890
Treatment Zone Effective Pore Volume	gals	5,087
Fraction Organic Carbon (foc)	g/g	0.010
Soil Density	g/cm^3	1.5
Soil Density	lb/ft^3	94
Soil Weight	lbs	6.4E+05
Hydraulic Conductivity	ft/day	0.0
Hydraulic Conductivity	cm/sec	3.53E-07
Hydraulic Gradient	ft/ft	0.100
GW Velocity	ft/day	0.00
GW Velocity	ft/yr	0
Sources of Oxidant Demand	**Unit**	**Value**
Sorbed Phase Contaminant Mass	lbs	70
Dissolved Phase Contaminant Mass	lbs	0.0
Total Contaminant Mass	lbs	70
Stoichiometric PersulfOx Demand	lbs	233
Efficiency/Safety Factor	---	**5.0**
Stoichiometric PersulfOx Required	lbs	1,167
SOD PersulfOx Required	lbs	1,415
Total PersulfOx Required	**lbs**	**2,582**

Application Dosing

PersulfOx Required	**lbs**	**2,590**

PersulfOx® Application Design Summary

Soil		Field App. Instructions
Application Method	**Direct Push**	
Spacing Within Rows (ft)	6	
Spacing Between Rows (ft)	6	
Injection Points (per app.)	**9**	
Number of Applications	**2**	
Areal Extent (square ft)	340	**Field Mixing Ratios**
Top Application Depth (ft bgs)	0	Water per Pt (gals)
Bottom Application Depth (ft bgs)	20	155
PersulfOx to be Applied (lbs)	**2,590**	PersulfOx per Pt (lbs)
PersulfOx Solution %	10%	144
Volume Water (gals)	**2,793**	Total Volume per Pt (gals)
Total Volume (gals)	**2,922**	162
		8
		Volume per vertical ft gals)

Technical Notes/Discussion

Prepared By:

Date: 6/19/2014

Assumptions/Qualifications

In generating this preliminary estimate, Regenesis relied upon professional judgment and site specific information provided by others. Using this information as input, we performed calculations based upon known chemical and geologic relationships to generate an estimate of the mass of product and subsurface placement required to affect remediation of the site.

PersulfOx™
CATALYZED PERSULFATE

A Sodium Persulfate - Based *In Situ* Chemical Oxidant with Built-In Activation

DESCRIPTION

PersulfOx™ is an *in situ* chemical oxidation reagent that destroys organic contaminants found in groundwater and soil through powerful yet controlled chemical reactions. PersulfOx is a sodium persulfate ($Na_2S_2O_8$) - based technology which employs a uniquely patented catalyst to enhance oxidative destruction of both hydrocarbon and chlorinated contaminants in the subsurface.

Traditionally, sodium persulfate is activated with the addition of heat, chelated metals, hydrogen peroxide, or base in order to generate sulfate radicals. These activation processes are inherently complex, costly and can pose additional health and safety risks. In comparison, PersulfOx is a relatively safe and easy-to-use ISCO agent.

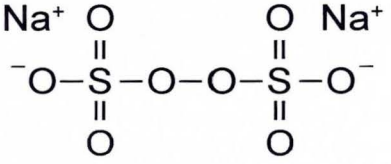

FIGURE 1:
SODIUM PERSULFATE CHEMICAL STRUCTURE

In short, PersulfOx contains a built-in catalyst which activates the persulfate component and generates contaminant destroying free radicals without the need for the addition of a separate activator.

FEATURES & BENEFITS

- Promotes rapid and sustained *in situ* oxidation of a wide-range of organic contaminants
- Provides a unique catalytic surface on which oxidants and contaminants react in a process known as "surface mediated oxidation."
- Contains built-in activation: eliminates complex and potentially hazardous chemical addition required to achieve traditional persulfate activation
- Fewer health and safety concerns than with use of traditional activation methods such as heat, chelated metals, hydrogen peroxide or base
- Single component product results in simplified logistics and application. No additional containers and/or multi-step mixing ratios required prior to application
- Contaminant oxidation performance equivalent to best alternative persulfate activation methods

FUNCTION

PersulfOx is an all-in-one product that provides powerful and highly efficient chemical oxidation performance. It is easily mixed with water and applied into the contaminated matrix using subsurface injection techniques or soil mixing tools.

The PersulfOx catalyst is a silica based, microscopic surface on which oxidants and contaminants can come together and react in a distinct process known as "surface mediated oxidation." During this process, oxidation reactions occur repeatedly on the surface of the catalyst serving several contaminant-reducing functions:

- The generation of sulfate radical and other oxidizing species
- Accelerated oxidation through the adsorption of contaminant molecules and other oxidizing species
- Catalyzes direct and free-radical-mediated oxidation by sodium persulfate

The equation below shows the net complete oxidation of toluene, a constituent of gasoline, by PersulfOx:

For a Free Consultation and Application Design for the use of PersulfOx visit www.regenesis.com

REGENESIS
Advanced Technologies for Contaminated Site Remediation

REGENESIS / 1011 Calle Sombra / San Clemente / CA 92673-6244 / USA / T: 949.366.8000 / F: 949.366.8090 / www.regenesis.com

3-D Microemulsion®, BDI® Plus, CRS® Application Design Summary

Barrier		Field App. Instructions
Application Method	**Injection Wells**	Injection quantities confirmed here are estimated. A pre-application injection test may be needed to confirm volumetric rates into the sandstone as proposed here.
Spacing Within Rows (ft)	One row of injection wells at 20-ft (nominal) spacing.	
Spacing Between Rows (ft)		
Application Points	**10**	
Areal Extent (square ft)	6,000	
Top Application Depth (ft bgs)	35	**Field Mixing Ratios**
Bottom Application Depth (ft bgs)	55	3DME Concentrate per Pt (lbs)
3DME to be Applied (lbs)	**10,800**	1080
3DME to be Applied (gals)	1,294	Mix Water per Pt (gals)
3DME Mix %	10%	1165
Volume Water (gals)	**11,648**	3DME Mix Volume per Pt (gals)
3DME Mix Volume (gals)	12,942	1294
CRS to be Applied (lbs)	**4,400**	CRS Volume per Pt (gals)
CRS Volume (gals)	502	50
BDI Plus to be Applied (L)	**50**	BDI Volume per Pt (L)
BDI Mix Water Volume (gals)	500	5.0
HRC Primer to be Applied (lbs)	**0**	HRC Primer per Pt (lbs)
HRC Primer Volume (gals)	0	0
Total Application Volume (gals)	**13,957**	Volume per pt (gals)
Estimated Radius of Injection (ft)	12.2	1396

LEGEND

- APPROXIMATE PROPERTY LINE
- FENCE
- LIGHT/UTILITY POLE
- OVERHEAD UTILITY
- MONITORING WELL
- PIEZOMETER
- PCE — TETRACHLOROETHENE (µg/l)
- TCE — TRICHLOROETHENE (µg/l)
- VC — VINYL CHLORIDE (µg/l)
- cis — cis–1,2–DICHLOROETHENE (µg/l)
- trans — trans–1,2–DICHLOROETHENE (µg/l)
- ESTIMATED EXTENT OF GROUNDWATER PCE GREATER THAN ENFORCEMENT STANDARD

DATE	PCE	TCE	VC	cis	trans
3/31/09	**49**	<0.20	<0.20	<0.50	<0.50
6/30/09	**64**	<0.20	<0.20	<0.50	
5/17/10	**42.5**	<3.00	<2.00	<4.00	
9/23/10	**15**	<0.20	<0.20	<0.50	
8/9/11	**26**	<0.20	<0.20	<0.50	
12/1/11	**13**	<0.20	<0.20	<0.50	
4/30/13	**410**	<10	<10	<10	

	TCE	VC	cis	trans
	0.22	<0.20	<0.50	<0.50
	<0.20	**0.48**	<0.50	<0.50
	0.54	<0.50	<0.50	<0.50

	PCE	TCE	VC	cis	trans
1	**20**	<0.20	<0.20	<0.50	<0.50
1	**9.1**	<0.20	<0.20	<0.50	<0.50
3	**7.6**	<0.50	<0.50	<0.50	<0.50

DATE	PCE	TCE	VC	cis	trans
3/31/09	**2,700**	**11**	<0.20	2.9	<0.50
6/30/09	**2,700**	**10**	<10	<25	<25
5/17/10	**2,700**	<40.0	<20.0	<40.0	<50.0
9/23/10	**1,800**	**5.3**	<5.0	<13	<13
8/9/11	**1,600**	4.6	<3.2	<8.0	<8.0
12/1/11	**1,300**	<4.0	<4.0	<10	<10
4/30/13	**660**	<10	<10	<10	<10

DATE	PCE	TCE	VC	cis	trans
5/17/10	**55**	<4.00	<2.00	<4.00	<5.00
9/23/10	**59**	0.41	<0.20	<0.50	<0.50
8/9/11	**110**	0.81	<0.20	<0.50	<0.50
12/1/11	**93**	0.80	<0.20	<0.50	<0.50
4/30/13	**92**	<2.5	<2.5	<2.5	<2.5

DATE	PCE	TCE	VC	cis	trans
5/17/10	**74.3**	**5.26**	<2.00	<4.00	<5.00
9/23/10	**110**	**6.1**	<0.40	<1.0	<1.0
8/9/11	**18**	0.92	<0.20	<0.50	<0.50
12/1/11	**9.5**	0.47	<0.20	<0.50	<0.50
4/30/13	**200**	**12**	<2.5	<2.5	<2.5

DATE	PCE	TCE	VC	cis	trans
5/17/10	0.74	<0.40	<0.20	<0.40	<0.50
9/23/10	**48**	0.31	<0.20	<0.50	<0.50
8/9/11	2.3	<0.20	<0.20	<0.50	<0.50
12/1/11	**14**	<0.20	<0.20	<0.50	<0.50
4/30/13	**11**	<0.50	<0.50	<0.50	<0.50

DATE	PCE	TCE	VC	cis	trans
5/17/10	<0.30	<0.40	<0.20	<0.40	<0.50
9/23/10	<0.50	<0.20	<0.20	<0.50	<0.50
8/9/11	<0.50	<0.20	<0.20	<0.50	<0.50
12/1/11	1.2	<0.20	<0.20	<0.50	<0.50
4/30/13	0.57	<0.50	<0.50	<0.50	<0.50

NOTES:

1. PROPERTY LINE AND BUILDING LOCATIONS ARE APPROXIMATE. LOCATIONS BASED ON AERIAL PHOTOGRAPH DOWNLOADED FROM GRANT COUNTY GIS.
2. BOLD VALUES EXCEED NR 140 ENFORCEMENT STANDARDS.

N

50 0 50

SCALE: 1" = 50'

PROJECT NO.	3439A	DRAWN BY:	SAS/KP/JB
DRAWN:	09/20/10	CHECKED BY:	REL
REVISED:	07/18/13	APPROVED BY:	REL 07/18/13

ENGINEER: SCS ENGINEERS, 2830 DAIRY DRIVE MADISON, WI 53718-6751, PHONE: (608) 224-2830

CLIENT: PLATTEVILLE CLEANERS, 250 WEST MAIN STREET, PLATTEVILLE, WISCONSIN

SITE: PLATTEVILLE CLEANERS, 250 WEST MAIN STREET, PLATTEVILLE, WISCONSIN

GROUNDWATER ANALYTICAL RESULTS MAP

FIGURE 9

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REGENESIS

Project Information

Platteville Cleaners
Platteville, WI
Barrier

Prepared For:
Robert Langdan (SCS)

Target Treatment Zone (TTZ) Info	Unit	Value
Treatment Area	ft^2	6,000
Top Treat Depth	ft	35.0
Bot Treat Depth	ft	55.0
Vertical Treatment Interval	ft	20.0
Treatment Zone Volume	ft^3	120,000
Treatment Zone Volume	cy	4,444
Soil Type	---	sandstone
Porosity	cm^3/cm^3	0.40
Effective Porosity	cm^3/cm^3	0.15
Treatment Zone Pore Volume	gals	359,065
Treatment Zone Effective Pore Volume	gals	134,649
Fraction Organic Carbon (foc)	g/g	0.002
Soil Density	g/cm^3	1.67
Soil Density	lb/ft^3	104
Soil Weight	lbs	1.3E+07
Hydraulic Conductivity	ft/day	1.0
Hydraulic Conductivity	cm/sec	3.53E-04
Hydraulic Gradient	ft/ft	0.028
GW Velocity	ft/day	0.19
GW Velocity	ft/yr	68
Sources of 3-D Microemulsion Demand	**Unit**	**Value**
Dissolved Phase Mass	lbs	0
Sorbed Phase Contaminant Mass	lbs	0
Competing Electron Acceptor Mass	lbs	270
Stoichiometric 3DME Demand	**lbs**	**279**
TTZ Groundwater Mass Flux	L/day	3,146
CVOC Mass Flux through TTZ	lb/yr	0
CEA Mass Flux through TTZ	lb/yr	228
Total Mass Flux through TTZ	lb/yr	228
Total Mass Flux 3DME Demand	**lbs**	**3,542**

Application Dosing

3-D Microemulsion to be Applied	**lbs**	**10,800**
CRS to be Applied	**lbs**	**4,400**
BDI Plus to be Applied	**liters**	**50**
HRC Primer to be Applied	**lbs**	**0**

3-D Microemulsion®, BDI® Plus, CRS® Application Design Summary

Barrier		Field App. Instructions
Application Method	**Injection Wells**	Injection quantities confirmed here are estimated. A pre-application injection test may be needed to confirm volumetric rates into the sandstone as proposed here.
Spacing Within Rows (ft)	One row of injection wells at	
Spacing Between Rows (ft)	20-ft (nominal) spacing.	
Application Points	**10**	
Areal Extent (square ft)	6,000	
Top Application Depth (ft bgs)	35	**Field Mixing Ratios**
Bottom Application Depth (ft bgs)	55	3DME Concentrate per Pt (lbs)
3DME to be Applied (lbs)	**10,800**	1080
3DME to be Applied (gals)	1,294	Mix Water per Pt (gals)
3DME Mix %	10%	1165
Volume Water (gals)	**11,648**	3DME Mix Volume per Pt (gals)
3DME Mix Volume (gals)	12,942	1294
CRS to be Applied (lbs)	**4,400**	CRS Volume per Pt (gals)
CRS Volume (gals)	502	50
BDI Plus to be Applied (L)	**50**	BDI Volume per Pt (L)
BDI Mix Water Volume (gals)	500	5.0
HRC Primer to be Applied (lbs)	**0**	HRC Primer per Pt (lbs)
HRC Primer Volume (gals)	0	0
Total Application Volume (gals)	**13,957**	Volume per pt (gals)
Estimated Radius of Injection (ft)	12.2	1396
		Volume per vertical ft (gals)
		70

Technical Notes/Discussion

Injection quantities confirmed here are estimated. A pre-application injection test may be needed to confirm volumetric rates into the sandstone as proposed here.

Prepared By: D.Davis
Date: 6/19/2014

3-D MicroEmulsion® FACTORY EMULSIFIED

Assumptions/Qualifications

In generating this preliminary estimate, Regenesis relied upon professional judgment and site specific information provided by others. Using this information as input, we performed calculations based upon known chemical and geologic relationships to generate an estimate of the mass of product and subsurface placement required to affect remediation of the site.

3-D Microemulsion® – Factory Emulsified Product Technical Description

Chemical Composition

- Hydrogen Release Compound Partitioning Electron Donor – CAS #823190-10-9
- Sodium Lactate – CAS# 72-17-3
- Water – CAS# - 7732-18-5

Properties

- Density – Approximately 1.0 grams per cubic centimeter (relative to water)
- pH - Neutral (approximately 6.5 to 7.5 standard units)
- Solubility – Soluble in Water
- Appearance – White emulsion
- Odor – Not detectable
- Vapor Pressure – None
- Non-hazardous

Packaging and Material Concentration Specification

3-D Microemulsion® – Factory Emulsified is provided to the site in either 2,000 lb-capacity (~240 gallons of product) reinforced plastic totes or 400-lb capacity (~48 gallons of product) high-density polyethylene drums. The active ingredient constitutes 60% of the weight and volume, the rest of which is water.

3-D Microemulsion® – Factory Emulsified (3DME) is comprised of a patented molecular structure containing oleic acids (i.e., oil component) and lactates/polylactates (lactate component) which are molecularly bound to one another. As such the 3DME molecule contains both a soluble (hydrophilic) and in-soluble (lipophilic) region. These two regions of the molecule are designed to be in balance in size and relative strength. The balanced hydrophilic/lipophilic regions of 3DME result in an electron donor with physical properties that allow it to initially adsorb to the aquifer material in the area of application then slowly redistribute via very small 3DME "bundles" called micelles. These 3DME micelles spontaneously form within sections of the aquifer where concentrations of 3DME reach several hundred parts per million.

The micelles small size and mobility allow it to move with groundwater flow through the aquifer matrix passing easily through the pore throats in between soil grains resulting in the further redistribution of 3DME within the aquifer. This allows for advective distribution of the oleic acids which are otherwise insoluble and not able to distribute in this manner. This also allows for increased persistence of the lactate/polylactates component due to their initial attachment to the oleic acids. Due to 3DME's patented molecular structure, we have observed far greater transport when compared to blended emulsified vegetable oil (EVO) products (which don't distribute beyond the limits of pumping) and much greater persistence when compared to soluble substrates such as lactates or simple sugars. In essence, the 3DME molecular structures capitalizes on the best features of the two electron-donor types while at the same time, minimizing their limitations.

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3-D MicroEmulsion®
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3-D Microemulsion is delivered to the site as a ready-to-apply emulsion that is simply diluted with water to generate a large volume of a 3DME colloidal suspension. The actual suspension of 3DMe generated by this mixing ranges in size from micelles on the order of .02 microns to .05 microns in diameter to "swollen" micelles, also termed "microemulsions", which are on the order of .05 to 5 microns in diameter (see Figure 1 below).

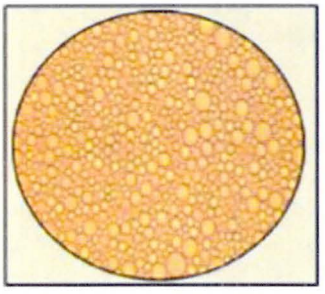
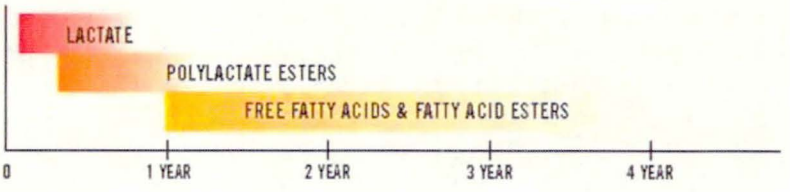


Figure 1: Microscopic view of factory emulsified 3-D Microemulsion.

Once injected into the subsurface in high volumes, the colloidal suspension mixes and dilutes in existing pore waters. The micelles/microemulsions on the injection front will then begin to sorb onto the surfaces of soils as a result of zeta potential attraction and organic matter within the soils themselves. As the sorption continues, the 3DMe will "coat" pore surfaces developing a layer of molecules (and in some cases a bilayer). This sorption process continues as the micelles/microemulsion moves outward and disassociates into their hydrophilic/hydrophobic components.

The specialized chemistry of 3DME results in a staged release of electron donors: free lactate (immediate); polylactate esters (mid-range) and free fatty acids & fatty acid esters (long-term). Material longevity of 3 years or greater has been seen at most sites as determined from biogeochemical analyses.



Applications

Typically 3DME is diluted with water prior to application. Resulting emulsion has viscosity similar to water. Easily injects into formation through direct push injection points, injection wells or other injection delivery systems. Application instructions for this product are contained here→ 3DME Application Instructions.

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Health and Safety

Material is food grade and relatively safe to handle. We recommend avoiding contact with eyes and prolonged contact with skin. OSHA Level D personal protection equipment including vinyl or rubber gloves, eye protection is recommended when handling this product. The Material Safety Data Sheet should be reviewed prior to handling→ MSDS.

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Bio-Dechlor INOCULUM Plus (BDI PLUS™) Product Technical Description

Chemical Composition

- Non-hazardous, naturally-occurring, non-altered anaerobic microbes and enzymes in a water-based medium.

Properties

- Appearance – Murky, yellow to grey water; must odor
- Odor - Musty
- pH 6.0 to 8.0
- Density – Approximately 1.0 grams per cubic centimeter (0.9 to 1.1 g/cc)
- Solubility – Soluble in Water
- Vapor Pressure – None
- Non-hazardous

Packaging and Material Concentration Specification

BDI Plus is provided to the site in a pressurized, stainless-steel soda canister with capacity to hold 18.5 liters of culture. The concentration of culture delivered in the keg is 1×10^{11} cells per liter for standard applications. Kegs containing concentrated cultures are available by special request.

Storage/Usage Requirements

Material may be stored for up to 3 week at 2 to 4 degrees Celsius without aeration.

Bio-Dechlor INOCULUM Plus (BDI PLUS™) is an enriched natural consortium containing species of Dehalococcoides sp. (DHC). BDI PLUS has been shown to simulate the rapid and complete dechlorination of chlorinated solvents such as tetrachloroethene (PCE), trichloroethene (TCE), dichloroethene (DCE) and vinyl chloride (VC) to non-toxic end products, ethene, carbon dioxide and water. The current culture also contains microbes capable of dehalogenating halomethanes (e.g., carbon tetrachloride and chloroform) and haloethanes (e.g., 1,1,1-TCA and 1,1-DCA) as well as mixtures of these contaminants.

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Applications

BDI PLUS is delivered to the site in liquid form and is designed to be injected directly into the saturated zone requiring treatment. It is most often diluted with de-oxygenated water prior to injection into either hydraulic push injection points or properly constructed injection wells. The typical dilution rate of the injected culture is 10 gallons of deoxygenated water to 1 liter of standard BDI PLUS culture. Application instructions for this product are contained here→ BDI PLUS Application Instructions.

Health and Safety

Material is non-hazardous and relatively safe to handle. For handling best practices, one should avoid contact with eyes and prolonged contact with skin. OSHA Level D personal protection equipment including vinyl or rubber gloves safety goggles or a splash shield is recommended when handling this product. An eyewash station is recommended for use of this product. The Material Safety Data Sheet should be reviewed prior to handling→ BDI PLUS MSDS.

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CRS™ ISCR Solution

Ferrous Iron for Enhanced Abiotic *In Situ* Chemical Reduction

Chemical Reducing Solution (CRS™) is an iron-based, liquid amendment used for the *in situ* chemical reduction (ISCR) of chlorinated contaminants, including ethenes and ethanes, in groundwater. The CRS material is a pH neutral, dark blue-green solution that is directly applied with the 3-D Microemulsion®, controlled-release electron donor into contaminated groundwater. CRS provides a soluble, source of ferrous iron (Fe^{2+}), which, in combination with enhanced anaerobic conditions, can precipitate reduced iron sulfides, oxides, and/or hydroxides as shown generally in equation 1. These minerals are capable of destroying chlorinated contaminants via abiotic, chemical reduction pathways (equation 2), thus improving the efficiency of the overall enhanced reductive dechlorination process and decreasing the formation of partially-reduced daughter products in the site groundwater.

CRS (Fe^{2+}) + Anaerobic Groundwater ⟶ FeS + FeS_2 + Fe_xO_y + $Fe_xO_y(OH)_z$ (1)

Reduced Iron Minerals + PCE ⟶ Ethene + Ethane + Iron Chlorides (2)

There are indications that the incorporation of iron as metallic particles or ferrous salts (Fe^{2+}) can enhance anaerobic biological reductive dechlorination of chlorinated solvent contamination by enabling chemical reduction pathways. The overall combination of biological and chemical processes displayed in equations 1 and 2 is referred to as "biogeochemical" reduction of contaminants. Biogeochemical reduction utilizes the biologically-generated reducing environment to create reduced iron precipitates that may then go on to chemically reduce chlorinated compounds.

CRS is used in conjunction with the 3-D Microemulsion electron donor to provide the necessary iron to enable abiotic chemical reduction pathways (including the β-elimination pathway) of chlorinated organic groundwater contaminants like perchloroethene, trichloroethene, dichloroethene, and vinyl chloride (PCE, TCE, DCE, and VC). Products of these biogeochemical reductions are ethene and ethane – dechlorinated organics with low toxicity profiles. CRS provides the following benefits for groundwater remediation:

- Facilitates biogeochemical *In Situ* Chemical Reduction (ISCR) of chlorinated contaminants
- Provides potential incremental remediation performance benefit over enhanced anaerobic bioremediation alone
- Can accelerate chlorinated contaminant remediation by activating abiotic ISCR pathways
- Liquid form provides better distribution than can be achieved by directly injecting a solid zero-valent iron (ZVI) material
- Pairs seamlessly with enhanced anaerobic bioremediation using 3-D Microemulsion
- Reduces the quantity of toxic daughter products formed
- Easy to handle and apply

For a Free Consultation and Application Design for the use of CRS visit www.regenesis.com or e-mail us at info@regenesis.com

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Advanced Technologies for Contaminated Site Remediation