LMS/MND/S07395

OU-1 Pump and Treatment System—Groundwater Capture Demonstration Using Rhodamine WT Dye, Mound, Ohio

February 2011

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1.0 Introduction

1.1 Purpose

The purpose of this study was to provide physical data that would demonstrate capture of groundwater from two areas in Operable Unit (OU)-1. Concern about adequate capture of trichloroethene (TCE) impacted groundwater was based on the detection of TCE concentrations greater than the maximum contaminant level in downgradient well 0418 and the reduced extraction rates from wells 0449 and 0450, resulting in subsequently smaller drawdowns compared to those observed in the original pump and treatment system.

Concentrations of volatile organic compounds (VOCs) began to increase significantly in downgradient well 0418 in August 2007 and reached a maximum concentration of 205 micrograms per liter (µg/L) in October 2007. The newer extraction wells have been in operation since July 2007, but the pumping rates were substantially lower than those maintained in the initial extraction wells, which were abandoned in 2007 to support excavation of the landfill. In December 2007, the extraction rates in both wells were significantly increased after redevelopment and installation of new pumps, and the concentrations of VOCs in well 0418 began to decline. Since April 2008, the highest concentration of TCE measured in well 0418 was 27 µg/L, and levels have remained below the 5 µg/L maximum contaminant level since August 2010.

1.2 Scope

The scope of the study was to determine whether TCE impacted groundwater in the vicinity of downgradient well 0418 is captured by extraction wells 0449 and 0450 (Figure 1). Also, this study was used to determine if TCE impacted groundwater at upgradient well P056 is completely captured by extraction wells 0449 and 0450, or whether some of the contaminated groundwater bypasses the two extraction wells and migrates downgradient to well 0418.

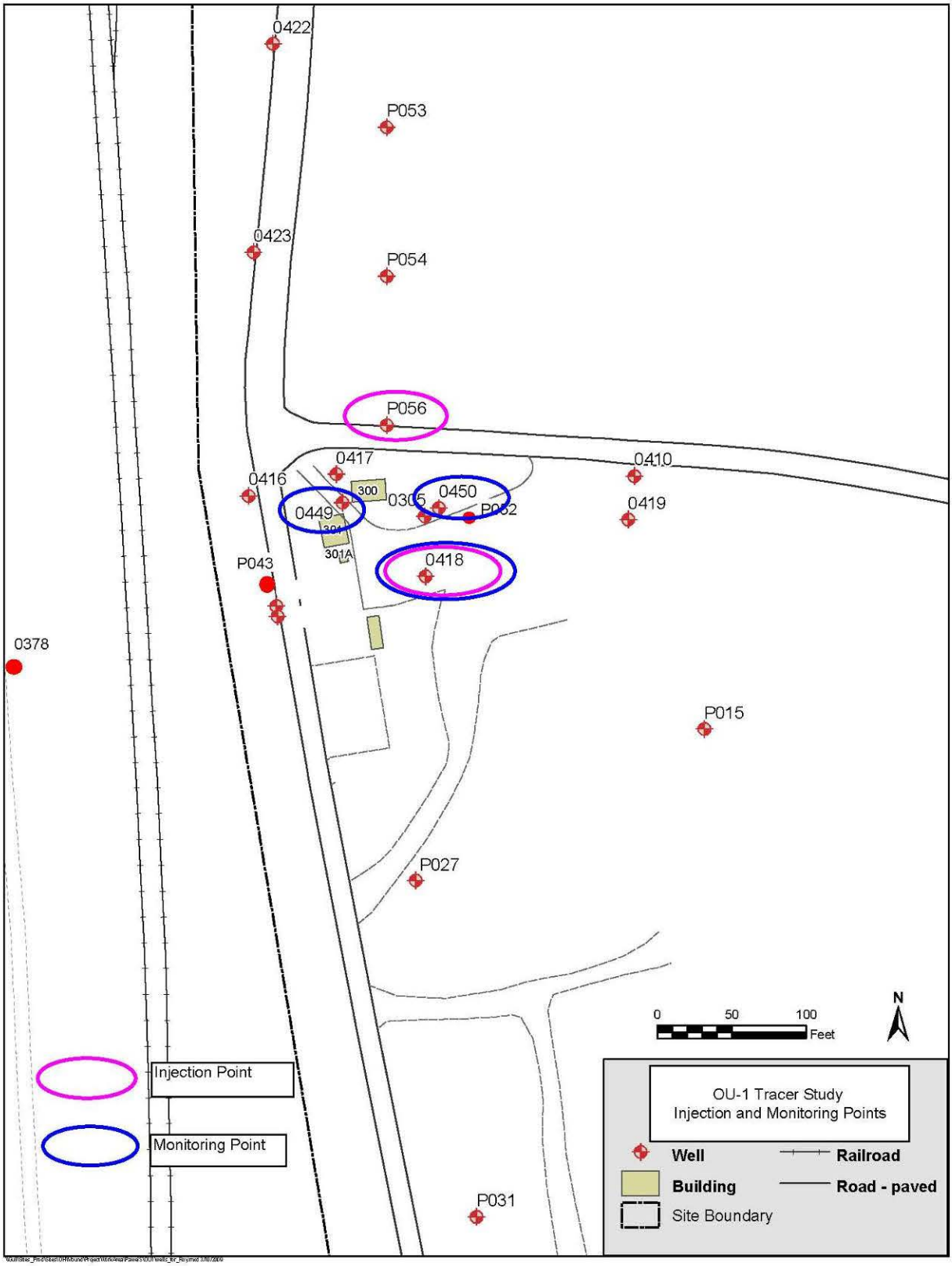

Figure 1. OU-1 Capture Determination Study Area

1.3 Objectives

Two tests were performed under this study. These tests were performed in series while the extraction system was in operation. The objective of the study was to identify if specifics areas of the aquifer are within the capture zone of the two extraction wells.

1.3.1 Test 1—Dye Trace in Well P056

Dye was introduced into well P056, which is located immediately upgradient of the two extraction wells. Well P056 has consistently had the highest concentrations of contaminants of concern in the OU-1 area. The objective of this test was to determine if groundwater originating from this area of highest VOC impact bypasses the extraction wells and migrates to well 0418. Sondes were placed in the two extraction wells and well 0418 to monitor for the presence of rhodamine dye during the test period.

1.3.2 Test 2—Dye Trace in Well 0418

Dye was introduced into well 0418, which is located immediately downgradient of the two extraction wells. Well 0418 has consistently had elevated concentrations of VOCs. The objective of this test was to determine if groundwater in this area is within the capture zone of the extraction wells. Sondes were placed in the two extraction wells to monitor for the presence of rhodamine dye during the test period. No monitoring was performed farther downgradient due to the low groundwater velocities in the OU-1 area. It was estimated that under ideal conditions (average velocity of 1 ft/day), monitoring would have to be performed for 7 to 12 months after introduction of the tracer to determine breakthrough time if capture was not attained.

1.4 Evaluation of Results

The criteria shown below were established to determine if the objectives have been met. These criteria were based on the mass of dye recovered from the extraction wells. A prescribed amount of rhodamine WT dye was placed in each well for these tests. The ranges of mass recovered were established to account for the fact that some mass of dye would be lost through attenuation in the subsurface, and 100 percent recovery of the dye was not possible. Changes to the evaluation of the results are discussed in Section 1.4.

Mass recovered ≥85%	Successful test—adequate capture
70% ≤ Mass recovered < 85%	Unresolved test—data need to be evaluated
Mass recovered < 70%	Unsuccessful test—inadequate capture

1.5 Deviations from the Work Plan

Testing was performed as outlined in the Testing Method for Determining Groundwater Capture by the OU-1 Pump and Treatment System using Rhodamine WT Dye Tracer and a Hydrolab DataSonde with a Rhodamine WT Sensor (Appendix A) except as noted below. These deviations were proposed by the Mound Groundwater Technical Team and approved by the Mound Core Team.

Baseline—The monitoring period was shortened, because the data collected were very consistent in each well.

Tests 1 and 2—The amount of dye put in each well was increased due to the dilution effect caused by water being pulled in by the extraction wells.

Test 1—The mass of dye recovered was not quantified, because it was determined that the capture of clean water was diluting the dye concentrations measured in the two extraction wells and at times resulting in readings that were below the quantification limit of the rhodamine probes.

Test 2—The mass of dye recovered was not quantified.

Tests 1 and 2—Success of the study was based on the concentrations of dye present in the extraction wells and the absence of dye in well 0418 during Test 1.

2.0 Study Activities

2.1 Sensor Calibration

Rhodamine WT was used as a dye tracer to determine capture. Rhodamine WT concentrations were measured using a Hydrolab DataSonde with a rhodamine WT sensor. The probes were calibrated in accordance with the manufacturer's instructions. Calibration curves and documentation are presented in Appendix B.

2.2 Baseline Monitoring

The sensors were placed in wells 0418, 0449, and 0450 on August 17, 2010. Baseline monitoring was performed from 4:00 p.m. August 17 to 9:00 a.m. August 18, 2010. This period was shorter than that outlined in the testing method. However, the Mound Groundwater Technical Team decided the monitoring period was sufficient, as the sensor output voltages and dye concentrations measured during that period were very consistent in each well.

2.3 Test 1—Dye Trace in Well P056

Dye was put into well P056 at 9:00 a.m. August 18, 2010. Dye tablets were used, and a total of five tablets were placed in the well followed by 1 gallon of deionized water, as specified in the testing method.

By August 30, 2010, rhodamine WT dye had not been detected in any of the wells. Although water in a bailer sample taken from P056 on August 24, 2010, had a slight pink color, it was determined likely that the amount of dye placed into the well was insufficient to overcome the dilution effects of the extraction wells. A flow net analysis was performed, and it was determined that the area that incorporated well P056 accounted for only 2 percent of the total volume of water that was captured by the two extraction wells.

The Mound Groundwater Technical Team decided that a larger dose of dye needed to be used for the study. On August 30, 2010, at 10:17 a.m., two pints of liquid rhodamine WT (20 percent by weight) dye was put into well P056 followed by 1 gallon of deionized water. This test was referred to as Test 1B. Detection of dye began in well 0449 on August 31, 2010, and began in well 0450 on September 1, 2010.

In the September 14, 2010, Mound Core Team meeting, the team noted that dye was being detected primarily in well 0450, with some detections in well 0449 early in the test period. No dye had been detected in well 0418. The Core Team concluded from the data to date that water in the vicinity of well P056 was captured by the extraction wells and did not impact the water quality in well 0418. A large amount of dye was still present in well P056, as determined from a water sample collected from the bottom of the well screen. Because Test 2 could not be started until the slug of dye had moved thought the system and concentrations measured in the extraction wells dissipated to baseline levels, the team proposed trying to accelerate the movement of the dye into the aquifer. The Mound Core Team concurred with pushing the dye still present in the well out into the aquifer in order to move on to Test 2.

From September 20 through September 22, 2010, six small surging efforts were performed in an attempt to push the dye out of the well. These events consisted of introducing 2 or 3 gallons of deionized water into well P056 and surging the well for about 5 minutes. A water sample collected on September 27, 2010, still indicated the presence of a significant amount of dye in the bottom of well P056.

A sampled collected from well P056 on October 11, 2010, still indicated the presence of dye in the bottom on the well. Four flushing events were performed on October 12, October 13, October 14, and October 20, 2010, to flush the dye from the well and the surrounding filter pack. These events consisted of pumping deionized water into the well using a hose with a drain bladder at the end. The bladder was placed about 1.5 to 2.5 ft from the bottom of the well and was used as a packer. Water was pumped into the well at a rate of 3 to 5 gallons per minute for 4 to 6 hours during each event. Samples collected during this period showed that the amount of dye in the well was diminishing.

As of October 25, 2010, some dye was still present in the bottom of well P056. In an effort to begin Test 2, the Ohio Environmental Protection Agency recommended pumping the remaining dye from well P056 and calculating the mass of this dye for the capture demonstration. Two removal events occurred on October 27, 2010. For the first event, 17.5 gallons of water were pumped from well P056 and containerized. The probe from well 0418 was used to measure the rhodamine WT concentration by placing the probe in the container for 5 minutes. The times of placement and removal of the probe were recorded so the data could be accounted for in the 0418 data set. For the second event, 6 gallons of water were removed and allowed to settle overnight, as the water was extremely turbid. The rhodamine WT concentration for this volume of water was measured in the same manner as before.

On December 2, 2010, the Mound Groundwater Technical Team decided that sufficient data and information from Test 1B had been acquired to determine capture. The Technical Team recommended stopping Test 1B and starting Test 2 with some modifications. The Mound Core Team concurred with the recommendation on December 3, 2010.

2.4 Test 2—Dye Trace in Well 0418

The procedure for Test 2 was modified as follows:

- Test 2 would be started before rhodamine WT concentrations in the two extraction wells were similar to baseline values.
- Well 0418 would be redeveloped prior to adding dye to ensure adequate communication with the aquifer.

- The same type and amount of rhodamine WT dye that was used in Test 1B would be used in Test 2.
- The test would pass or fail. Quantification of the mass of dye recovered would not be performed. If dye is detected in one or both extraction wells, it will be concluded that the well is within the capture zone for the extraction well system. If no dye is detected, then a reevaluation of downgradient capture would be performed.
- There are two possibilities for a failed test: either (1) significant dilution decreased the concentrations of dye passing into the extraction wells to levels below the quantification limits for the probes, or (2) well 0418 is not within the capture zone of the two extraction wells.
- If no dye is detected in the extraction wells, the probes will be pulled and moved to downgradient wells P015 and P027.

In preparation for Test 2, well 0418 was redeveloped on December 14 and 15, 2010, to ensure good communication with the aquifer. This work was performed by Terran Corporation. A summary of the fieldwork is provided in Appendix C.

On December 27, 2010, at 10:40 a.m., two pints of liquid rhodamine WR (20 percent by weight) dye was mixed with 30 gallons of deionized water and pumped into well 0418 at approximately 3.5 gallons per minute using a drain bladder placed 2.5 ft from the bottom of the well. An additional 40 gallons of deionized water was used to rinse the container and was then pumped into the well. Detection of dye in well 0450 started at 12:35 a.m. on December 28, 2010.

3.0 Data Evaluation

The objective of each test was to determine if portions of the aquifer were within the capture zone created by extraction wells 0449 and 0450. Criteria were established to determine if the objectives had been met and were based on the mass of dye recovered from the extraction wells. It was determined though the course of testing that the mass of dye recovered could not be used as a criterion for successful capture, as significant dilution resulted in mass recoveries that were lower than expected.

3.1 Baseline

Baseline data were collected for 17 hours prior to the introduction of the dye into well P056. The values collected during this period were stable. The average baseline values for each well are summarized in Table 1. Since these values were so low, they were not subtracted from the data collected during Test 1 for mass determination.

Table 1. Baseline Values of Rhodamine Dye for OU-1 Capture Determination

Well	Baseline Concentration (ppb)[a]
0418	0.068
0449	0.127
0450	0.132

[a]ppb = parts per billion (≈ µg/L)

3.2 Test 1—Dye Trace in Well P056

The mass of dye placed in well P056 during Test 1B was calculated to be 208 grams (g). Monitoring for the presence of dye was performed throughout the duration of Test 1B. Detection of dye greater than two times the baseline values started in well 0449 at approximately 5:00 a.m. August 31, 2010, and in well 0450 at 11:00 p.m. September 1, 2010.

During the initial phases of the study, the concentrations of dye recovered in the two extraction wells were low (Figure 2 and Figure 3), resulting in recovery of dye that was lower than expected. Samples were collected by bailer periodically from well P056, and a pink tint in the sample water indicated that dye was present in the well casing. These earlier samples were collected from the top of the water column. Samples collected later in the study from different depths revealed that the dye was stratified in the water column, and the bulk of the dye had sunk to the bottom of the well.

Data collected from the two extraction wells indicated that the dye was being detected primarily in well 0450 (Figure 2) with some detections in well 0449 early in the test period (Figure 3). The amount of clean water available to well 0449 diluted the concentration of the dye to levels too low to be detected by the rhodamine sensor after the initial high-concentration peak moved to the extraction well. This was determined when the pump in well 0449 stopped working in November, and concentrations of dye measured in well 0449 were higher during that period. It can be concluded that both wells recovered rhodamine dye, but well 0450 may have a more direct hydraulic connection with well P056.

By September 14, only 15.6 g (of the original 208 g) of rhodamine WT dye had been accounted for from the two extraction wells (Figure 4). Between September 20 and October 10, 2010, efforts were implemented to push the dye out of the well casing and into the aquifer to accelerate recovery. As of October 25, only 40.2 g of dye could be accounted for from the two extraction wells. No dye was detected in well 0418 during this time period.

On October 27, water and dye were removed from well P056 in an effort to move to Test 2. Approximately 0.023 g of dye was removed in this effort. This amount is negligible compared to the total amount of 208 g and was not subtracted from the percentage removed calculations.

On December 2, 2010, the Mound Groundwater Technical Team decided that sufficient data and information from Test 1 had been acquired to determine that the portion of the aquifer in the vicinity of well P056 was captured by the two extraction wells and has not affected the water quality in well 0418. However, due to the dilution effect caused by the extraction wells, the mass of dye could not be quantified as specified in the test criteria. By this time, only 48.3 g of dye (Figure 4) could be accounted for and equates to 23.2 percent of the total placed into well P056 (Figure 5). A summary of the mass removed throughout Test 1B is presented in Appendix C. It was recommended to stop Test 1 and start Test 2 with some changes. The Mound Core Team concurred with the recommendations on December 3, 2010.

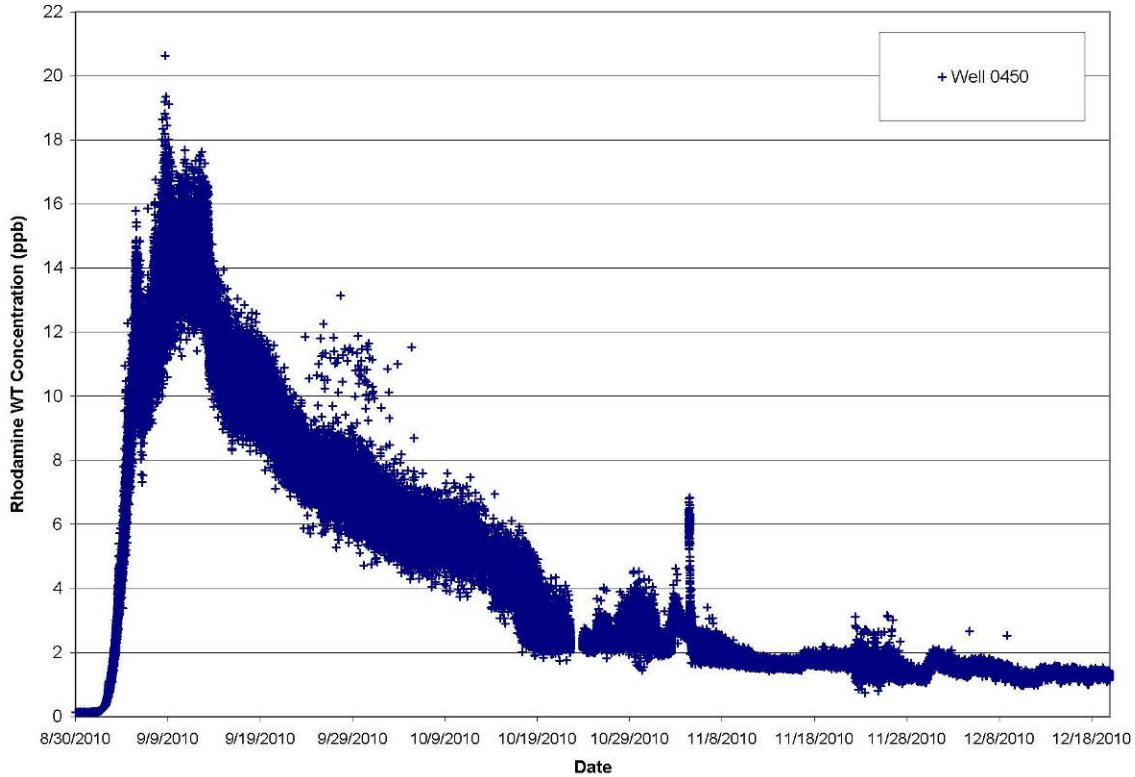

Figure 2. Rhodamine WT Concentrations in Well 0450 During Test 1B

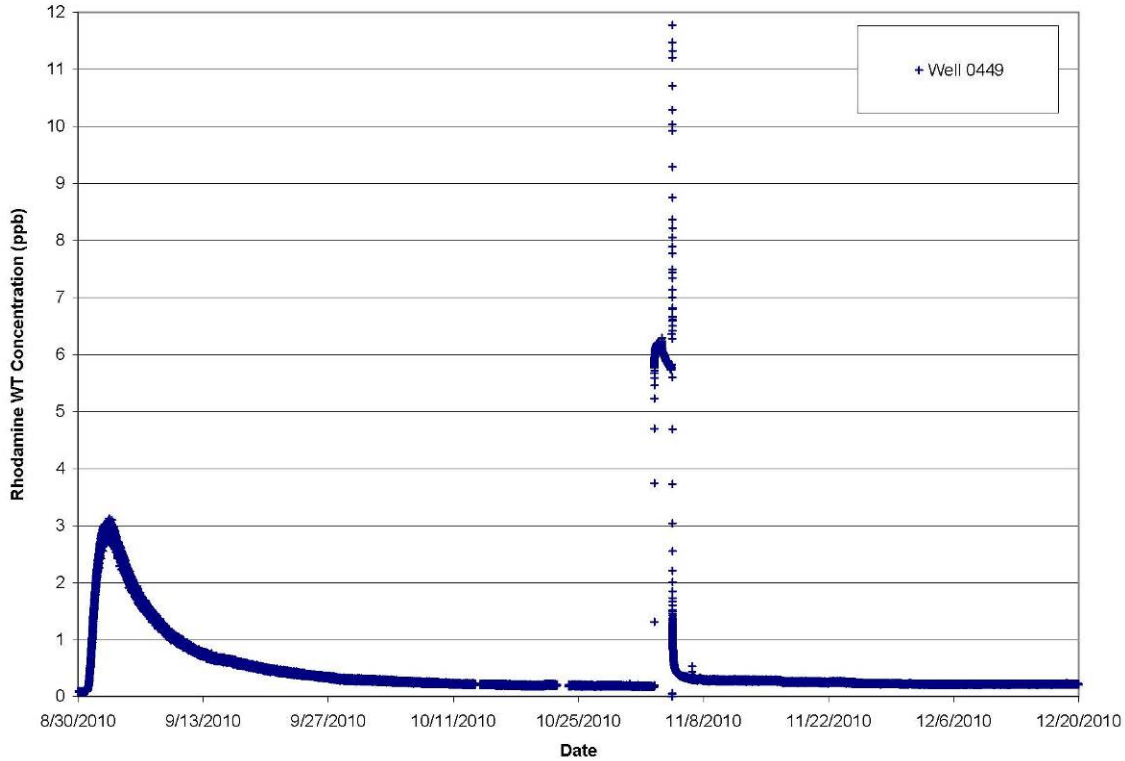

Figure 3. Rhodamine WT Concentrations in Well 0449 During Test 1B

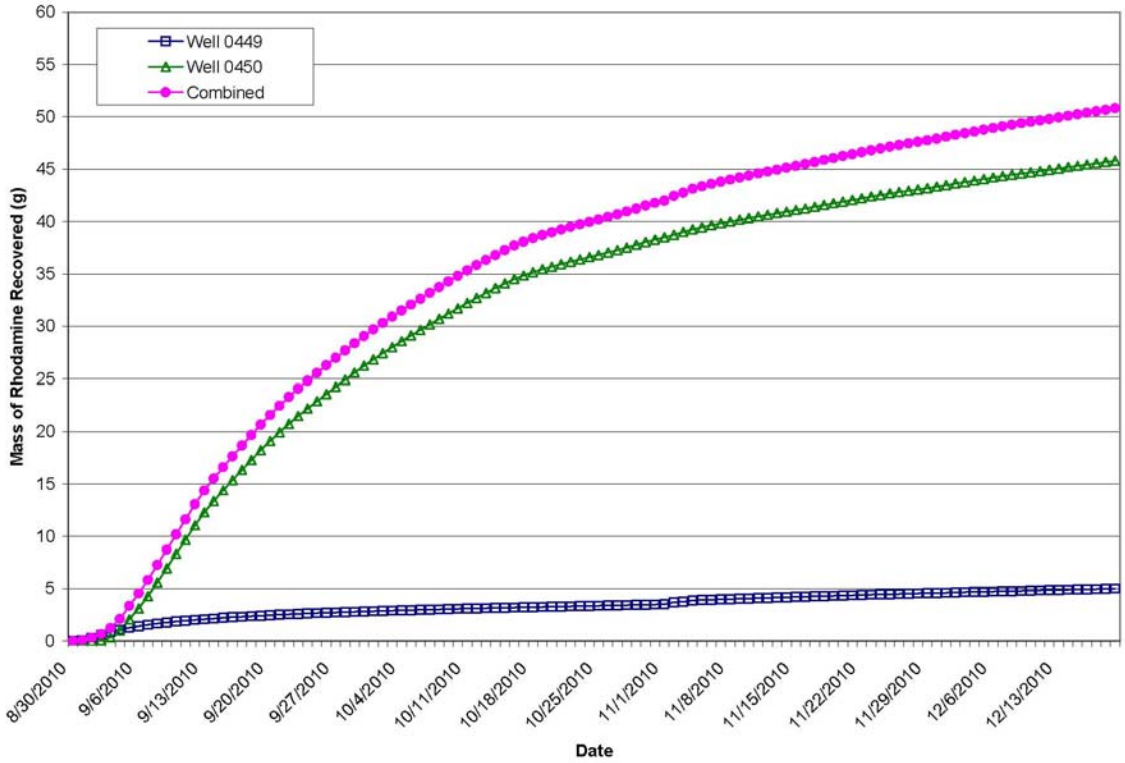

Figure 4. Mass of Rhodamine WT Recovered During Test 1B

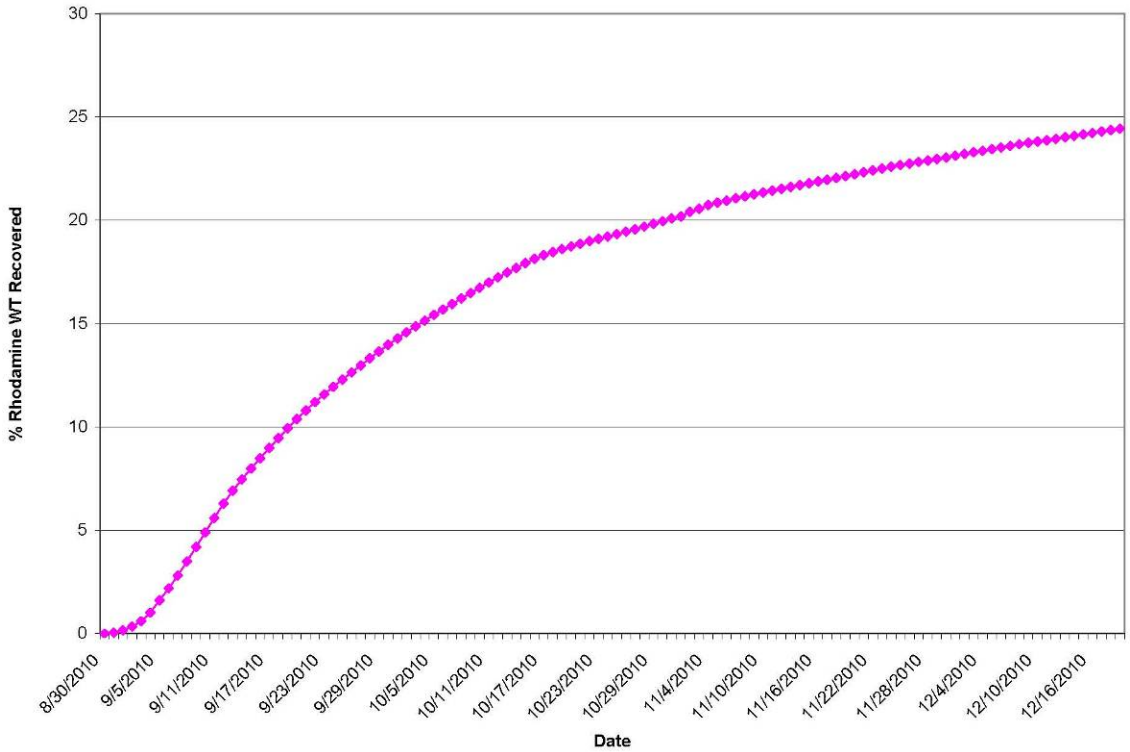

Figure 5. Percentage of Total Mass Recovered During Test 1B

3.3 Test 2—Dye Trace in Well 0418

The mass of dye placed in well 0418 during Test 2 was 208 g. Monitoring for the presence of dye was performed throughout the duration of Test 2. Detection of dye in well 0450 started at 12:35 a.m. December 28, 2010 (Figure 6). Dye was detected only in extraction well 0450 during this test. A well-defined peak was observed on December 29, 2010 (Figure 6), and the concentrations slowly tailed off. No measureable concentrations of dye were detected in extraction well 0449. It was determined that the revised criteria for a successful test were attained, and on January 6, 2011, Test 2 was declared complete.

4.0 Conclusions

It can be concluded from these two tests that wells 0418 and P056 are within the capture zone of the two extraction wells. Also, it can be concluded that the two extraction wells provide containment for the area of highest TCE impact beneath the southwest corner of the former landfill. Groundwater from this area is contained by the extraction wells and does not migrate to well 0418.

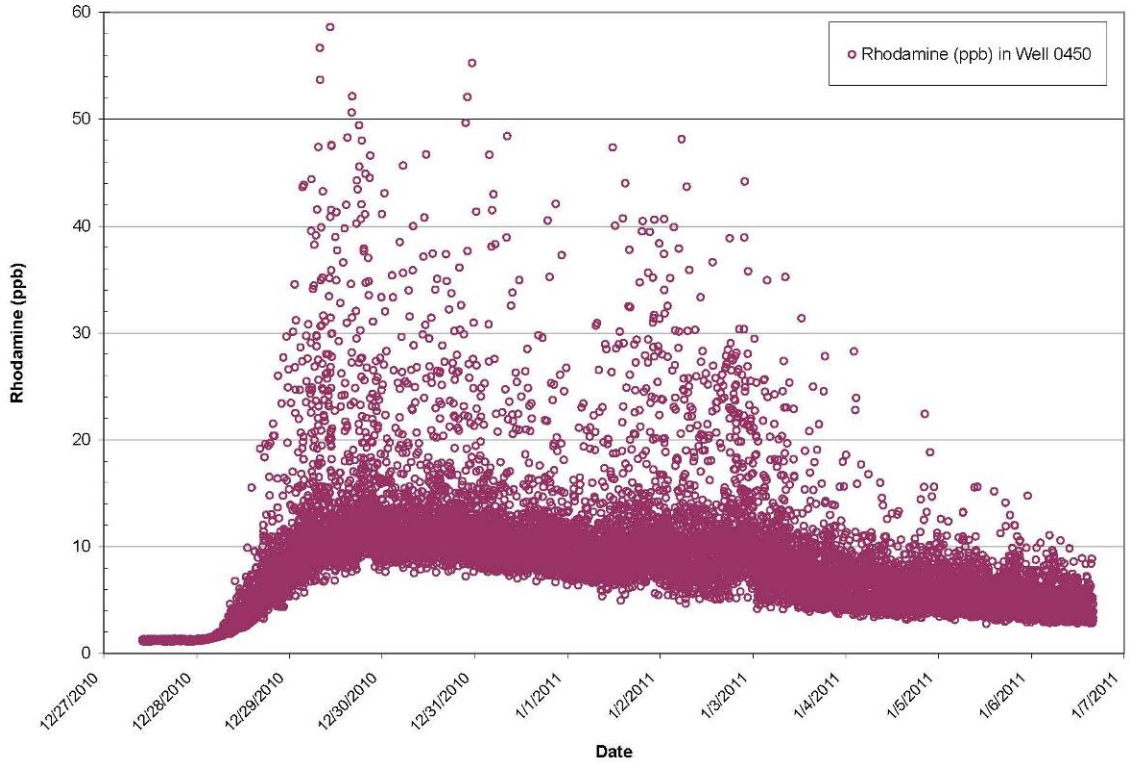

Figure 6. Rhodamine WT Concentrations in Well 0450 During Test 2

Appendix A

Testing Method for Determining Groundwater Capture by the OU-1 Pump and Treatment System Using Rhodamine WT Dye Tracer and a Hydrolab DataSonde with a Rhodamine WT Sensor

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A1.0 Purpose and Scope

This document outlines the testing method for determining groundwater capture by the OU-1 pump and treatment system for several nearby wells. Rhodamine WT will be used as a dye tracer to determine capture. Rhodamine WT concentrations will be measured using a Hydrolab DataSonde with a rhodamine WT sensor.

The scope of the study is to determine whether trichloroethene (TCE) impacted groundwater in the vicinity of downgradient well 0418 is captured by extraction wells 0449 and 0450. Also, this study will determine if TCE impacted groundwater at upgradient well P056 is completely captured by extraction wells 0449 and 0450, or whether some of the contaminated groundwater bypasses the two extraction wells and migrates downgradient to well 0418.

A2.0 Personnel Responsibilities

S.M. Stoller Corporation (Stoller), the Legacy Management Support (LMS) contractor, will provide field oversight of the study. Stoller staff or representatives of the Ohio Environmental Protection Agency or MMCIC will operate the sampler and collect samples. The following responsibility matrix provides a summary of project responsibilities.

Responsibility Matrix

Title	Personnel	Responsibilities
Project Manager	Bob Ransbottom	Overall project oversight and coordination.
aRc Contact	Bob Ransbottom	Coordination with aRc remediation contractor
Safety Lead	Roy Mowen	Safety oversight
Compliance Lead	Chuck Friedman	Compliance issues
Project Hydrogeologist	Becky Cato	Dye tracer oversight, including data acquisition and evaluation.
OEPA Representative	Mike Proffitt	Study evaluation—OU-1 Technical Team member
MMCIC Representative	Mike Clinch	Study evaluation—OU-1 Technical Team member

A3.0 Equipment and Supplies

A3.1 Equipment

- Hydrolab MS5 DataSonde fitted with a Rhodamine WT sensor (specification sheet in Attachment A).
- Laptop computer
- Communications cable
- Hydrolab communications program

A3.2 Supplies

- Rhodamine WT dye (specification sheet in Attachment B)
- Volume measuring device
- Field notebook
- Hydrolab MS5 DataSonde User Manual
- Rhodamine WT sensor Instruction Sheet
- Hydrolab Hydras 3 LT Quick Start Software Manual

A4.0 Health and Safety

All field activities will be conducted in accordance with the project-specific Job Safety Analysis (JSA) and the Stoller Health and Safety Manual. Field screening for organic vapors or radiological exposure, personal protective equipment, and special training requirements will be specified in the JSA, as required.

Users of Rhodamine WT should take special precautions to avoid direct contact with the dye. Wear proper personal protective equipment (PPE) when handling dye products. Immediately wash any areas that come in contact with dye.

A documented pre-job briefing will be conducted with all project participants in attendance. Additionally, a daily Plan of the Day meeting will be held at the job site.

A5.0 Summary of Testing Method

A5.1 Rhodamine WT Sensor Calibration

The rhodamine WT sensor will be calibrated in accordance with the manufacturer's specifications (Attachment C).

A5.2 Background Fluorescence Determination

The sondes will be deployed at the three locations that will be monitored during the tests (Figure A1). Measurements will be collected for 1 to 2 days to identify the background fluorescence in the OU-1 area.

Sondes will be programmed to collect measurements every 10 minutes. This data collection interval will be used for all subsequent tests.

A5.3 Determination of Dye Amount

One dye tracer tablet contains 228 milligrams of Rhodamine WT dye.

Information from methods discussed in EPA guidance (Ref 8.4) and methods developed by Worthington and Smart (Ref. 8.5) indicate that five tablets are needed for each test to provide sufficient mass to develop a breakthrough curve.

A5.4 Test 1: Dye Trace in Well P056

- Place five dye tablets into well P056 followed by 1 gallon of deionized water to ensure that the tablets have not bridged inside the well casing.
- Record the time that the dye was introduced into well.
- Monitor sondes in the two extraction wells and well 0418 for recovery of the dye.
- Continue monitoring for dye at the remaining locations for a time period equal to 3 times the period it took for the peak concentration of dye to arrive in the extraction wells.

A5.5 Test 2: Dye Trace in Well 0418

- Place five dye tablets into well 0418 followed by 1 gallon of deionized water to ensure that the tablets have not bridged inside the well casing.
- Record the time that the dye was introduced into well.
- Monitor sondes in the two extraction wells for recovery of the dye.
- Continue monitoring for dye at the remaining locations for a time period equal to 5 times the period it took for the peak concentration of dye to arrive in the extraction wells.

A6.0 Data Acquisition

Data from each sonde will be downloaded weekly throughout the study.

Data from each sonde also will be available on the LMS System Operation and Analysis at Remote Sites (SOARS) for review throughout the study.

A7.0 Figures and Attachments

Figure 1—Dye Injections Points and Rhodamine WT Measurement Locations

Attachment A.	Specification Sheet for Hydrolab MS5 DataSonde fitted with a Rhodamine WT sensor
Attachment B.	Technical Data Bulletin—Bright Dyes Water Tracing Dye, FWT Red Products
Attachment C.	Calibration of Hydrolab DataSonde with a Rhodamine WT Sensor

A8.0 References

Hydrolab MS5 DataSonde User Manual

Hydrolab Rhodamine WT sensor Instruction Sheet

Hydrolab Hydras 3 LT Quick Start Software Manual

U.S. Environmental Protection Agency, 2003. Tracer-Test Planning Using the Efficient Hydrologic Tracer-Test Design (EHTD) Program, EPA/600/R-03/034, National Center for Environmental Assessment, April.

Worthington, S.R.H., and C.C. Smart, 2003. "Empirical Determination of Tracer Mass for Sink to Spring Tests in Karst," in Sinkholes and the Engineering and Environmental Impacts on Karst, B.F. Beck, ed., Geotechnical Special Publication No. 122, American Society of Civil Engineers, pp 287–295.

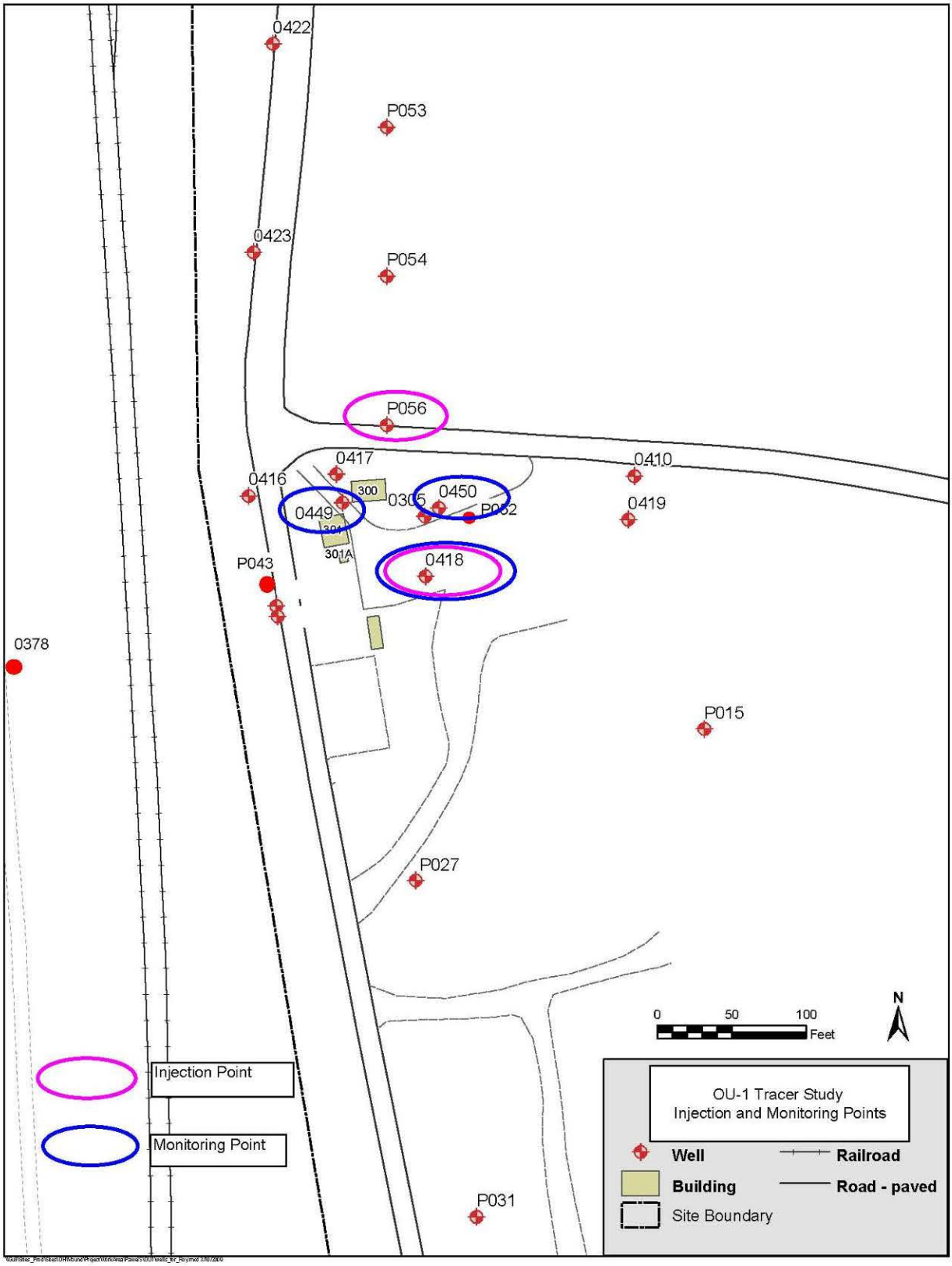

Figure A1. Dye Injections Points and Rhodamine WT Measurement Locations

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Attachment A

Specification Sheet for Hydrolab MS5 DataSonde fitted with a Rhodamine WT sensor

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SPECIFICATIONS

Sondes

Size
DataSonde:
Outer diameter – 3.5"/8.9 cm
Length – 23"/58.4 cm
MiniSonde:
Outer diameter – 1.75"/4.4 cm
Length – 29.5"/74.9 cm (with battery pack)

Weight
DataSonde:
7.4 lbs/3.35 kg (typical)
MiniSonde:
2.9 lbs/1.3 kg
(typical with battery pack)

Communication Interface
RS-232, SDI-12, RS-485

Memory
Up to 120,000 measurements

Battery Supply
DataSonde: 8 C batteries
MiniSonde: 8 AA batteries

Operating Temperature
-5 to 50 °C

Maximum Depth
200 m

Sensors

	Range	*Accuracy*	*Resolution*
Hach LDO™*	0 to 60* mg/L *Exceeds maximum natural concentrations	± 0.1 mg/L @ ≤ 8 mg/L ± 0.2 mg/L @ > 8 mg/L ± 10% reading > 20 mg/L	0.01 mg/L
Polarographic DO	0 to 50 mg/L	± 0.2 mg/L @ ≤ 20mg/L ± 0.6 mg/L @ > 20 mg/L	0.01 mg/L
Conductivity	0 to 100 mS/cm	± (0.5% of reading + 0.001 mS/cm)	
Salinity	0 to 70 ppt	± 0.2 ppt	0.01 ppt
pH	0 to 14 pH units	± 0.2 units	0.01 units
Turbidity, Self-Cleaning	0-3000 NTU	*Compared to StabCal* ± 1% up to 100 NTU ± 3% from 100-400 NTU ± 5% from 400-3000 NTU	0.1 NTU from 0-400 NTU; 1 NTU for >400 NTU
Turbidity, 4-Beam	0-1000 NTU	± (5% of reading + 1 NTU)	0.1 NTU from 0-100 NTU; 1 NTU for > 100 NTU
Depth	0 to 10m (Vented Level) 0 to 25m 0 to 100m 0 to 200m	± 0.003 meters ± 0.05 meters ± 0.05 meters ± 0.1 meters	0.001 meters 0.01 meters 0.01 meters 0.1 meters
Chlorophyll a	*Dynamic Range* Low sensitivity: 0.03-500 µg/L Med. sensitivity: 0.03-50 µg/L High sensitivity: 0.03-5 µg/L	± 3% for signal level equivalents of 1 ppb rhodamine WT dye or higher using a rhodamine sensor	0.01 µg/L
Blue-Green Algae (fresh water or marine)	*Dynamic Range* Low sensitivity: 150-2,000,000 cells/mL Med. sensitivity: 150-200,000 cells/mL High sensitivity: 150-20,000 cells/mL	± 3% for signal level equivalents of 1 ppb rhodamine WT dye or higher using a rhodamine sensor	20 cells/mL
Rhodamine WT	*Dynamic Range* Low sensitivity: 0.04-1000 ppb Med. sensitivity: 0.04-100 ppb High sensitivity: 0.04-10 ppb	± 3% for signal level equivalents of 1 ppb rhodamine WT dye or higher using a rhodamine sensor	0.01 ppb
Ion Selective Electrodes			
Ammonia Max Depth: 15 meters	0 to 100 mg/L-N	Greater of ± 5% of reading, or ± 2 mg/L-N	0.01 mg/L-N
Nitrate Max Depth: 15 meters	0 to 100 mg/L-N	Greater of ± 5% of reading, or ± 2 mg/L-N	0.01 mg/L-N
Chloride Max Depth: 15 meters	0.5 to 18000 mg/L	Greater of ± 5% of reading, or ± 2 mg/L	4 digits
TDG (Total Dissolved Gas)	400 to 1400 mmHg	± 1.5 mmHg	1.0 mmHg
ORP	-999 to 999 mV	± 20 mV	1 mV
PAR	0 to 10,000 µmol $s^{-1}m^{-2}$	± 5% of reading	1 µmol $s^{-1}m^{-2}$
Temperature	-5 to 50 °C	± 0.10 °C	0.01 °C

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Attachment B

Technical Data Bulletin
Bright Dyes—Water Tracing Dye, FWT Red Products

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Division of Kingscote Chemicals

WATER TRACING DYE
FWT RED PRODUCTS

TECHNICAL DATA BULLETIN

Bright Dyes FWT Red products are specially formulated versions of Rhodamine WT dye for convenient use in water tracing and leak detection studies. This bright, fluorescent red dye is certified by NSF International to ANSI/NSF Standard 60 for use in drinking water. It may be detected visually, by ultraviolet light and by appropriate fluorometric equipment. Today it is most often used visually. Visually the dye appears bright pink to red, depending on its concentration and under ultraviolet light as bright orange.

The dye is resistant to absorption on most suspended mater in fresh and salt water. Compared to Bright Dyes FLT Yellow/Green products it is significantly more resistant to degradation by sunlight and when used in fluorometry, stands out much more clearly against background fluorescence. As always the use and suitability of these products for any specific application should be evaluated by a qualified hydrologist or other industry professional.

General Properties	Tablets	FWT Red 25 Liquid	Powders
Detectability of active ingredient [1]	Visual <100 ppb	Visual <100 ppb	Visual <100 ppb
Maximum absorbance wavelength [2]	550/588 nm	550/588 nm	550/588 nm
Appearance	Dark red convex 1.6cm diameter	Clear dark red aqueous solution	Dark red fine powder
NSF (Max use level in potable water)	0.3 ppb	0.8 ppb	0.1 ppb
Weight	1.05 gms ± 0.05		
Dissolution Time [3]	50% < 3 minutes 95% < 6 minutes		50% < 3 minutes 95% < 6 minutes
Specific Gravity		1.03 ± 0.05 @ 25° C	
Viscosity [4]		1.3 cps	
pH		8.7 ± 0.5 @ 25° C	

Coverage of Products	One Tablet	One Pint Liquid	One Pound Powder
Light Visual	604 gallons	31,250 gallons	604,000 gallons
Strong Visual	60 gallons	3,125 gallons	60,400 gallons

Caution: These products may cause irritation and/or staining if allowed to come in contact wit the skin. The use of gloves and goggles is recommended when handling this product, as with any other dye or chemical.

To our best knowledge the information and recommendations contained herein are accurate and reliable. However, this information and our recommendations are furnished without warranty, representation, inducement, or license of any kind, including, but not limited to the implied warranties and fitness for a particular use or purpose. Customers are encouraged to conduct their own tests and to read the material safety data sheet carefully before using.

[1] In deionized water in 100 ml flask. Actual detectability and coverage in the field will vary with specific water conditions.
[2] No significant change in fluorescence between 6 and 11 pH.
[3] (One tablet, 1 gram of powder), in flowing deionized water in a 10 gallon tank.
[4] Measured on a Brookfield viscometer, Model LV, UL adapter, 60 rpm @ 25° C.

Kingscote Chemicals, 3334 S. Tech Blvd., Miamisburg, Ohio 45342
Telephone (937) 886-9100 Fax (937)886-9300 Web:www.brightdyes.com

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Attachment C

Calibration of Hydrolab DataSonde with a Rhodamine WT Sensor

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Instruction Sheet

00722789

Rhodamine WT Sensor

Safety Precautions

Please read this entire instruction sheet before operating this sensor. Pay particular attention to all danger and caution statements. Failure to do so could result in serious injury to the operator or damage to the sensor.

Do not use or install this sensor in any manner other than that which is specified in this instruction sheet.

Use of Hazard Information
If multiple hazards exist, this instruction sheet will use the signal word (Danger, Caution, Note) corresponding to the greatest hazard.

DANGER
Indicates a potentially or imminently hazardous situation which, if not avoided, could result in death or serious injury.

CAUTION
Indicates a potentially hazardous situation that may result in minor or moderate injury or instrument damage.

Note: *Information that requires special emphasis.*

Precautionary Labels
Read all labels and tags attached to the instrument. Personal injury or damage to the instrument could occur if not observed.

This symbol, if noted on the instrument, references the instruction sheet for operational and/or safety information.

Introduction

The Rhodamine WT sensor is available as an option on the DS5, DS5X, or MS5. The sensor is an in-situ optical fluorometer that determines rhodamine concentration in a given water sample. The sample is irradiated using green (550 nm) light. The Rhodamine WT sensor absorbs the green light energy and fluoresces or emits red (590–715 nm) light.

The sensor directly measures the amount of red light emitted by the rhodamine in the water sample. The multiprobe can either display the rhodamine signal as a scaled voltage from 0–5 V or as a concentration from 0–1000 ppb.

Maintenance

Important Note: *Do not use organic solvent solutions such as acetone or methanol with the Rhodamine WT sensor. These solvents will damage the plastic housing cap.*

The Rhodamine WT sensor requires periodic maintenance to remove contaminants such as oil, biological growth, dirt, etc. Sensor maintenance should be conducted after every deployment cycle, adjusting the deployment cycle length to account for the degree of fouling that occurs in the area. Maintenance should also be done before and after calibration.

1. Flush the entire instrument with clean fresh water. Use soapy water and a soft brush to clean the outside surfaces of the instrument.
2. Soak the entire instrument in freshwater for at least 30 minutes.
3. Visually inspect the optical windows. Use optical tissue or a cotton swab with soapy water to clean the optical windows. Rinse with freshwater.

Parameter Setup

Important Note: *The Rhodamine WT sensor has been characterized at the factory to display linear behavior between the gain zones. DO NOT change the values stored in the Sensor Setup tab. This may result in non-linear readings.*

The Rhodamine WT sensor functions using one of three gain settings:

- X1 gain provides a range of 0 to 1000 ppb
- X10 gain provides a range of 0 to 100 ppb
- X100 gain provides a range of 0 to 10 ppb

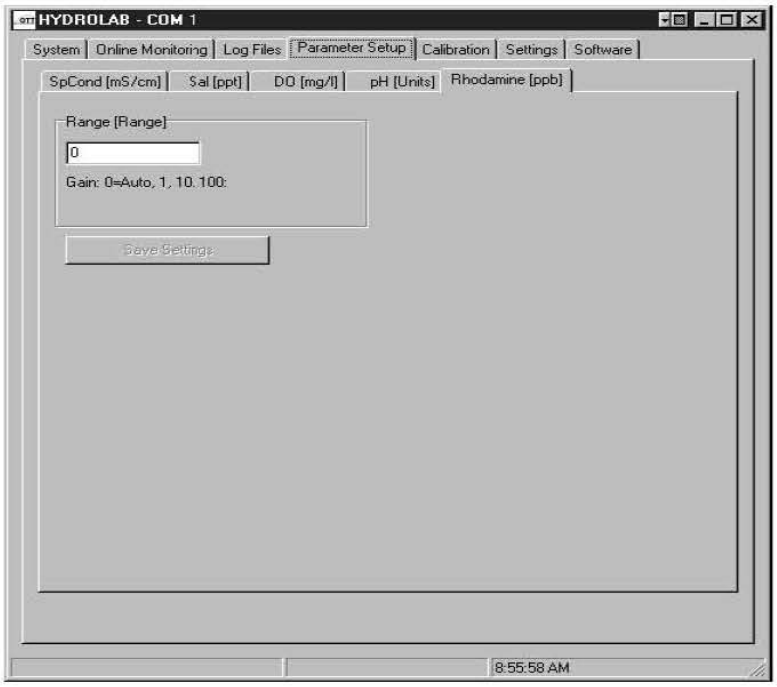
The factory-default will automatically switch the gain as needed. If necessary, the gain settings may be fixed to one of the three gain settings described above.

1. Connect the sensor to a PC.

Note: *If a Hydrolab Surveyor is used to display the voltage in the X10 or X100 fixed gain settings or if the user changes the gain settings, then the Surveyor may require a RESET:HISTORY reset in order to display the proper resolution.*

2. Start Hydras 3LT. Wait for Hydras 3LT to establish communications with the sensor. Click the **OPERATE SONDE** button.

3. Click the Parameter Setup tab and select Rhodamine ppb.



4. To enable auto gain, enter zero. To enable a fixed gain, enter 1 for X1, 10 for X10, or 100 for X100. In most cases, it is recommended to leave the sensor in auto gain mode for maximum dynamic range.

5. Click the **SAVE SETTINGS** button.

Rhodamine WT Sensor Calibration

Rhodamine concentration is associated with an output voltage. This output voltage from the sensor may be displayed directly or scaled to reflect a user-defined concentration in ppb.

There are two standard methods for calibrating the Rhodamine WT sensor. Each method requires a 2-point calibration. The first point must be 0 ppb. The second point should be a non-zero value which is at least three times larger than the zero sample but within the linear range of the sensor. It is recommended that the non-zero sample represents an average or approximately 50% of the range of concentration the user expects to monitor. A Solid Standard is recommended for defining repeated non-zero samples.

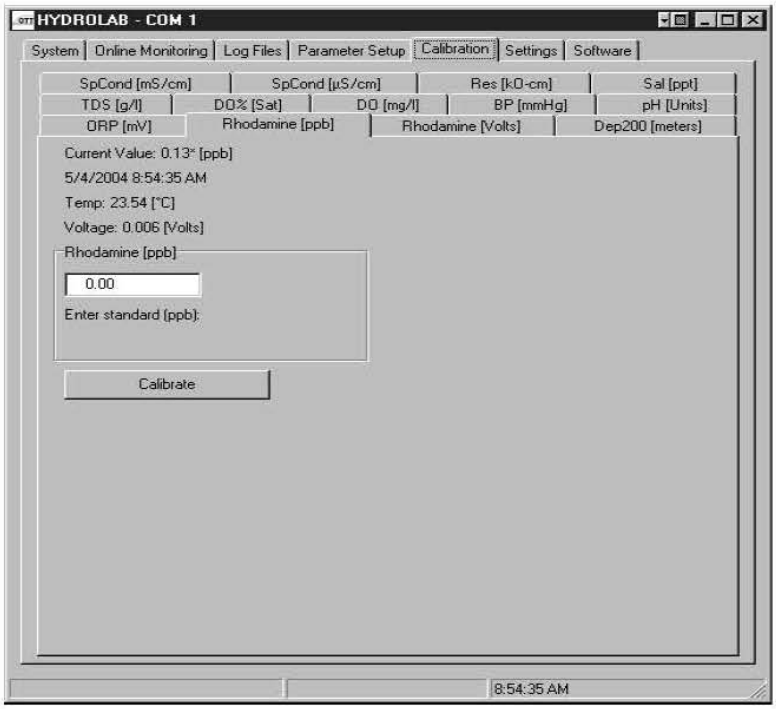
Method 1

Use this method when a known calibration standard is applied to the sensor.

1. Connect the sensor to a PC.

2. Start Hydras 3LT. Wait for Hydras 3LT to establish communications with the sensor. Click the **OPERATE SONDE** button.

3. Click the Calibration tab and select Rhodamine ppb.



4. Place the sensor into a 0 ppb baseline solution. Enter zero in the Rhodamine ppb field.

5. Press **CALIBRATE.** "Calibrate Successful!" screen will be displayed.

6. Place the sensor into a known ppb solution or use the Solid Standard. Enter the rhodamine value in the Rhodamine ppb field.

7. Press **CALIBRATE**. A "Calibrate Successful!" screen will be displayed.

Method 2

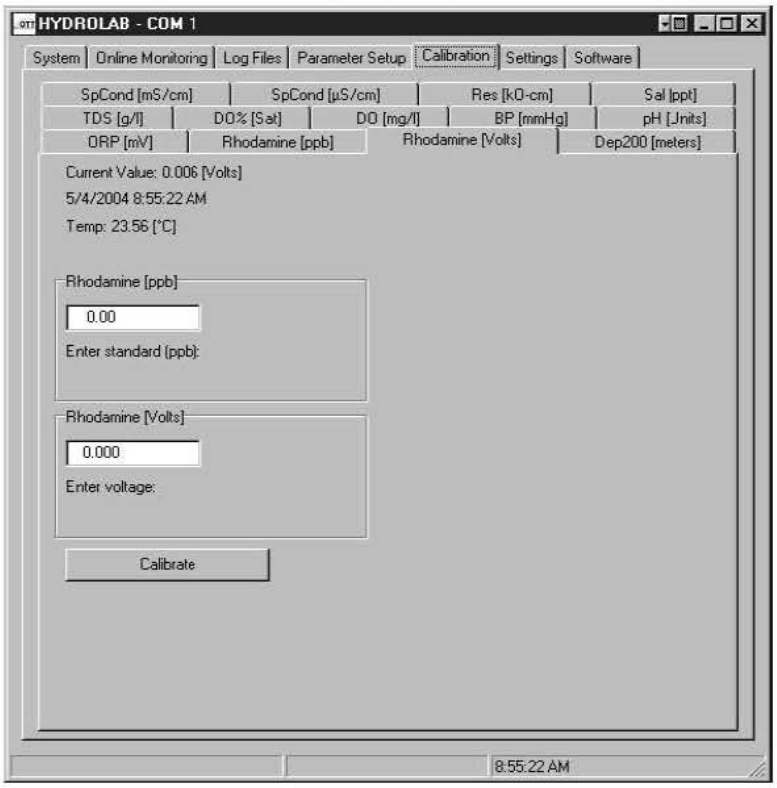
Note: *Voltage values for zero and non-zero ppb rhodamine samples are similar between different sensors, but not identical. When using Method 2, every sensor will have a unique voltage value for a given concentration.*

Use this method when you have voltage values for both a "zero" and "non-zero" ppb rhodamine sample. Typically, both zero and non-zero samples are measured using the sensor to get voltages and then the same samples are measured using a calibrated laboratory fluorometer to get "true" values for the rhodamine concentration.

1. Connect the sensor to a PC.

2. Start Hydras 3LT. Wait for Hydras 3LT to establish communications with the sensor. Click the **OPERATE SONDE** button.

3. Click the Calibration tab and select Rhodamine Volts.



4. Enter zero into the Rhodamine ppb field.

5. Enter the corresponding voltage into the Voltage field.

6. Press **CALIBRATE**. A "Calibrate Successful!" screen will be displayed.

7. Enter the non-zero value into the Rhodamine ppb field.

8. Enter the corresponding voltage into the Voltage field.

9. Press **CALIBRATE**. A "Calibrate Successful!" screen will be displayed.

Calibration Performance Check

The optional Solid Standard can be used as a calibration performance check. The Solid Standard can establish a correlation between a know concentration found from laboratory measurement of a sample whose signal output voltage from the Rhodamine WT sensor is also known. The Solid Standard can also be used to check the sensor stability periodically.

The Solid Standard is a solid fluorescent device placed over the optical head. A flat head screwdriver is used to adjust the magnitude of the fluorescent response from 0 to approximately 1000 ppb. The Solid Standard can be used to establish a correlation between a known concentration and the fluorometer output voltage. It can also be used to check the sensors stability and/or check for the effects of bio-fouling.

Using the Solid Standard

Note: *Solid Standards give unique responses for a given sensor. A given setting on a Solid Standard should only be used for the sensor on which it was calibrated.*

1. Make sure the optical surface of the sensor is clean and dry.
2. Immerse the sensor into a known Rhodamine WT dye solution. Note the sensor output voltage.
3. Clean and dry off the sensor. Place the Solid Standard on the optical end of the sensor.
4. Rotate until the Solid Standard is properly aligned with the indexing mark on the sensor. A "clicking" noise will be heard when aligned properly.
5. Adjust the Solid Standard to produce the same output voltage from the sensor as in step two. Use the provided screwdriver to adjust the screw located on the side of the cube. Adjust the screw clockwise to increase the signal, and counter-clockwise to decrease the signal.
6. For future use, this Solid Standard can be used as a verification device for this sensor.

Specifications

Specifications are subject to change without notice.

Minimum Detection Limit	0.1 ppb
Dynamic Range	Low sensitivity: 0–1000 ppb; Medium Sensitivity: 0–100 ppb; High Sensitivity: 0–10 ppb
Linearity	0.99 R^2
Resolution	0.01 ppb
Range	0–1000 ppb
Accuracy[1]	± 3% of reading or ± 0.1 ppb, whichever is greater
Resolution	0.01 ppb
Warranty	The sensor is covered by a one-year warranty.

[1] The following exceptions are taken to the specified accuracy under IEC 1000-4-3:1996: Vertically-oriented radiated interference of 10V/m between 20 and 600 MHz has been observed to cause measurement shifts up to 5V (with corresponding shifts in the analyte reading) when the Sonde with this sensor was exposed to the stated field. Horizontally-oriented radiation interferences of 10V/m between 50 and 150 MHz and between 450 and 600 MHz has been observed to cause measurement shifts up to 140 mV (with corresponding shifts in the analyte reading) when the Sonde with this sensor was exposed to the stated field. Radiated interference testing was performed in air. Normal operation of the Sonde under water is expected to decrease the impact of the radiation interference.

Accessories

Description	Cat. No.
Solid Standard	007205
Dye-Rhodamine, 8 oz. 21.33% ± 2.5% (w/w)	007273

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Appendix B

Sensor Calibration

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12 Aug 2010 - Calibration performed by Chris Holmes, S.M. Stoller Corp.

Configuration of Rhodamine WT probes for Mound, OH, tracer test

The MS5 probes from Hydrolab/Hach measure temperature, rhodamine concentration in parts per billion (ppb), and battery voltage. I had good results calibrating these probes from 0 to 500 ppb. Anything above 500 ppb did not give good results, and I had extensive conversations with Hydrolab about the problem. The plan is to get these probes into the field and recording data, and Hydrolab is going to send us new probes that we can swap out when it is convenient.

Communication

The probes are set up for SDI-12 communication.

Probe serial Number	SDI-12 Address	Delay (seconds)
49432	3	7
49433	1	5
49434	5	10

I originally had all three probes set up with a 10 second delay for probe warm up, but it seemed like the probes were “talking” over one another so I staggered the warm up delays. The order of the SDI-12 output is as follows.

TempC, Rhodamine_Volts, Rhodamine_ppb, and Internal_battery.

Wiring

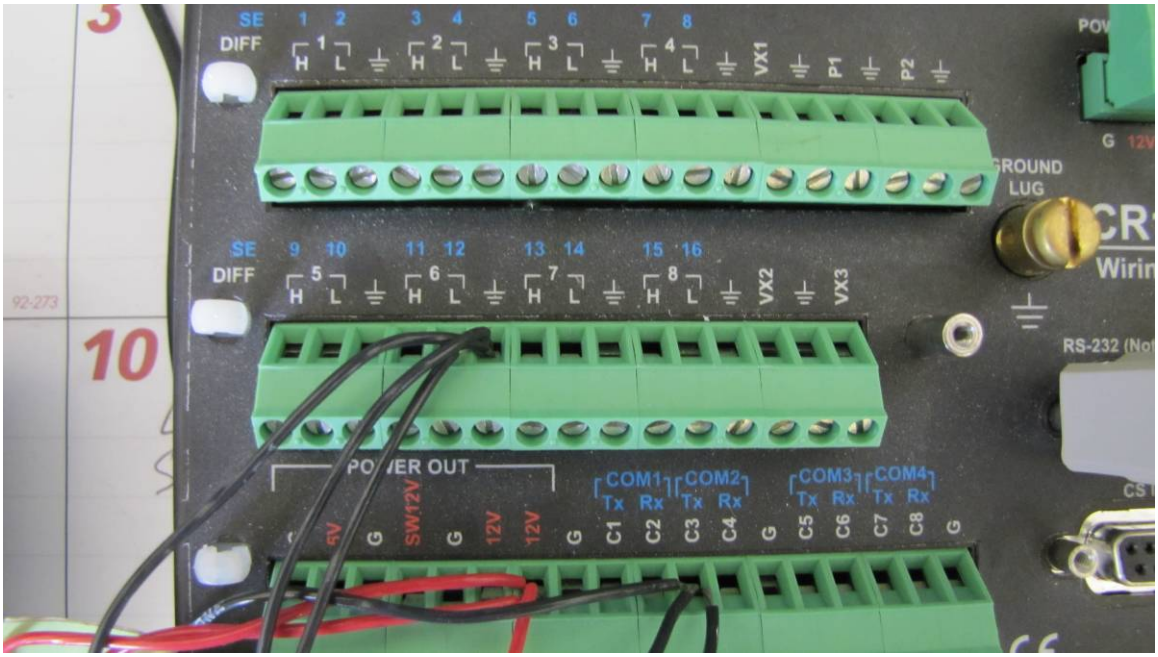
I have labeled all wires with green tags that identify the cable as well as where to insert the wire in the datalogger. The Beldon cable that is spliced to the factory cable has two sets of red, black, shield wires. Each set has “one” or “two” printed on the insulation of the individual wires. The current program wiring diagram indicates that C1 and C2 are being used on the datalogger, so we will use C3 for these probes. The wiring diagram is as follows:

'Well 418
'Red (one) -> 12v
'Black (one) -> C3 (control port 3)
'Black (two) -> Ground

'Well 449
'Red (one) -> 12v
'Black (one) -> C3 (control port 3)
'Black (two) -> Ground

'Well 450
'Red (one) -> 12v
'Black (one) -> C3 (control port 3)
'Black (two) -> Ground

Below is a picture of the test setup in the lab.

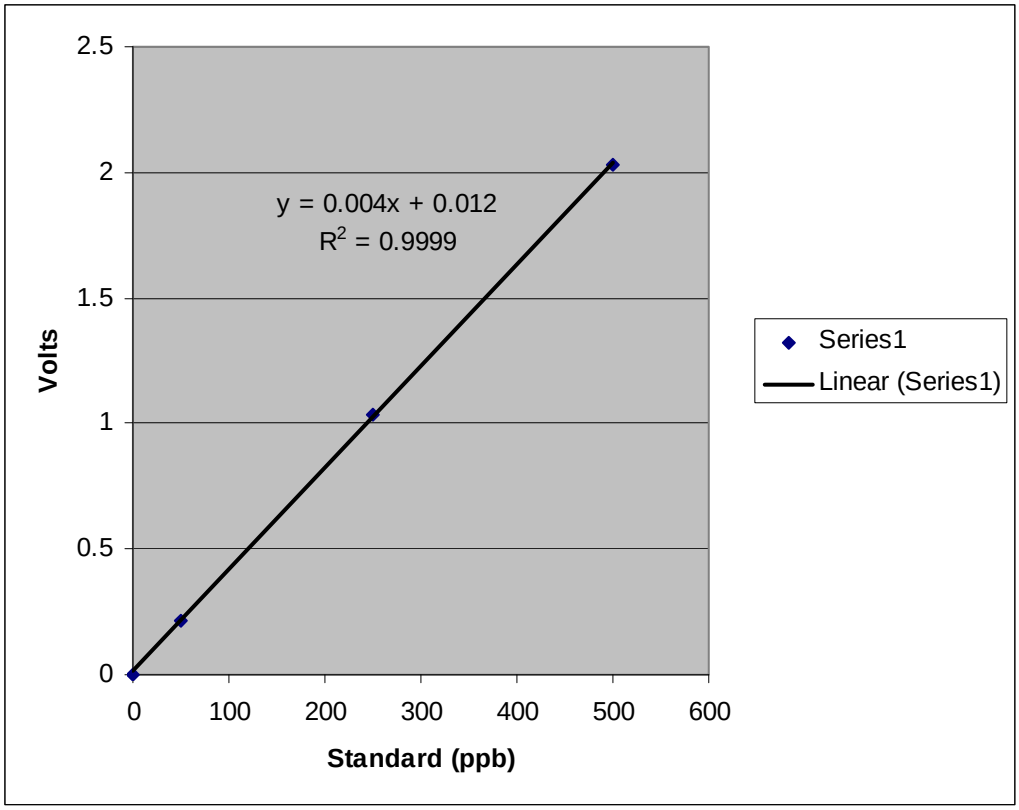


Calibration:

These probes are calibrated from 0 to 500 ppb and gave good results over this range. I also tried to come up with a lower range for these probes. I got reliable results at 0.5 ppb. I was able to detect rhodamine at 0.1 ppb, but not very accurately. I will include the calibration graphs below.

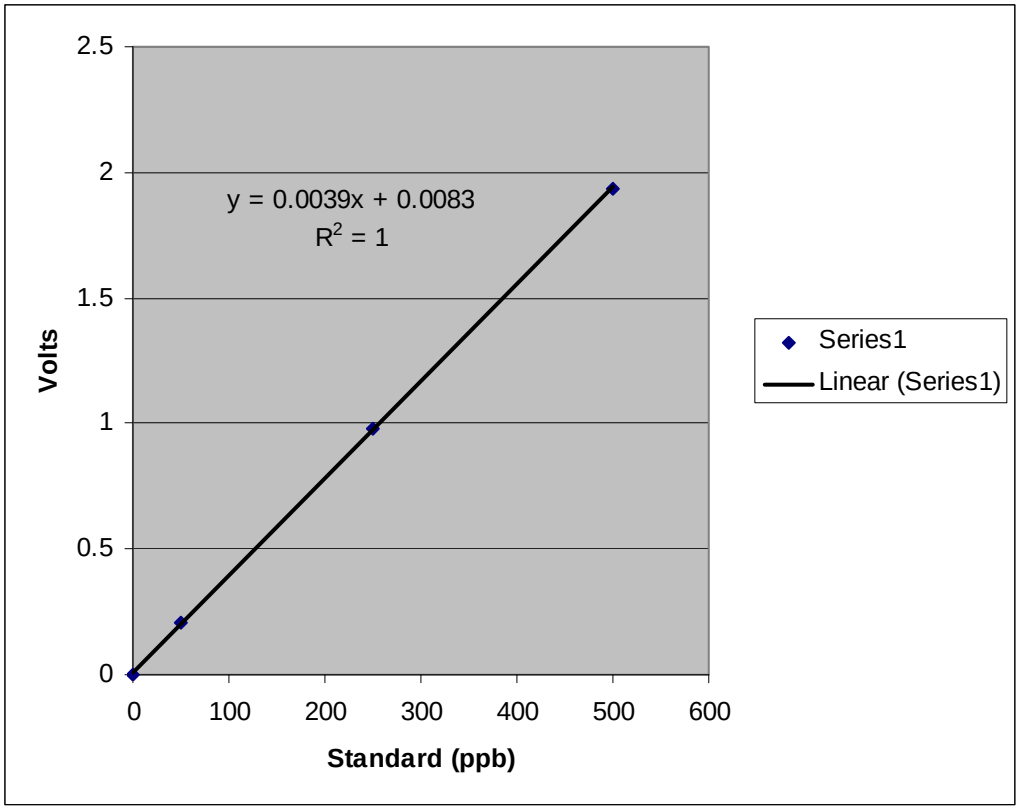
Calibration of Probe 49432, Well 0449

SN = 49432	Standard (ppb)	ppb	v
	0	0	0.0037
	50	53.08	0.2187
	250	253.98	1.0322
	500	500.49	2.0301



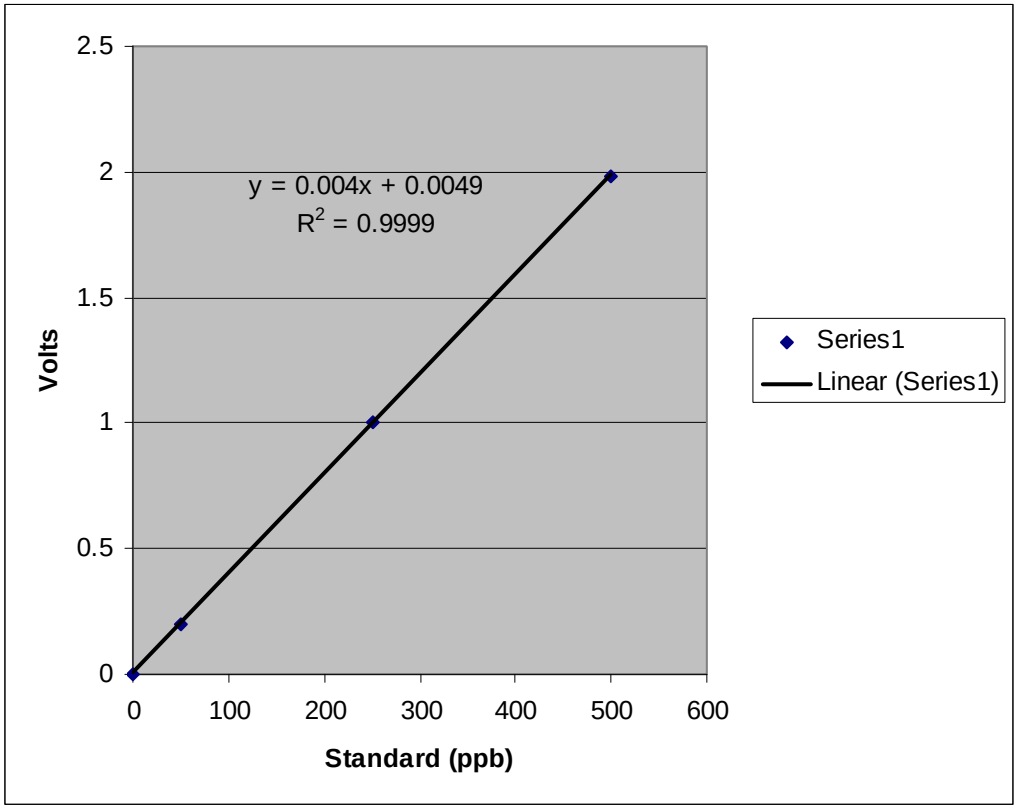
Calibration of Probe 49433, Well 0418

SN = 49433	Standard (ppb)	ppb	v
	0	0	0.0033
	50	52.53	0.2062
	250	251.69	0.9754
	500	500.85	1.9385



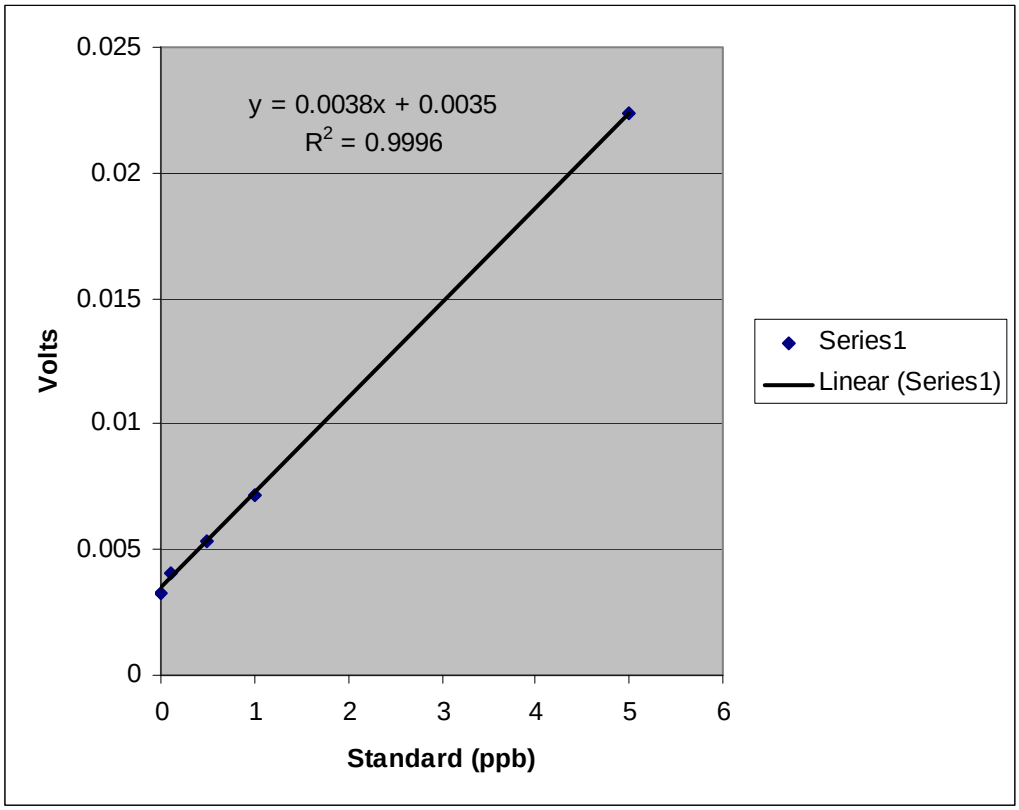
Calibration of Probe 49434, Well 0450

SN = 49434	Standard (ppb)	ppb	v
	0	0	0.0037
	50	49.28	0.1988
	250	253.34	1.0071
	500	499.85	1.9837



Detection limits with probe SN=49433, Well 0418

SN = 49433	Standard (ppb)	ppb	v
	0	0	0.0033
	0.1	0.2	0.0041
	0.5	0.52	0.0053
	1	1.03	0.0072
	5	4.93	0.0224



Appendix C

Development of Well 0418
December 2010

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Cato, Becky

From:	Brent E. Huntsman [behuntsman@terrancorp.com]
Sent:	Monday, December 20, 2010 4:42 PM
To:	Cato, Becky; Ransbottom, Robert
Cc:	Mowen, Roy; Chris J. Ruef; Dan Wagel
Subject:	Well #418 Redevelopment - Mound
Attachments:	MW- 0418 2010-12-14 Step Test Analysis Summary.pdf; MW-418 Mound Redevelopment Recovery.pdf

MW- 0418 10-12-14 Step Test

MW-418 Mound :edevelopment Rec..

All,

Last week Terran's crew redeveloped Well # 418 following the protocol I submitted 12/13/10. At the start of the cleaning process, the well contained about 0.5 feet of silt and sediment in the bottom. Upon measuring static water level, about five feet of water was standing at the bottom of a 10-foot long well screen. During the pre-development step drawdown test, the well contained sufficient water to pump up to 6 gpm, but at 10-minute intervals. Water during pumping remained turbid.
Results of the step test analysis are attached to this note. An average specific capacity for this test is about 4.5 gpm/ft with calculated apparent aquifer transmissivity around 3,600 gal/day/ft.

For approximately three hours, the crew alternated surging and pumping Well # 0418, adding 30 gallons of reverse osmosis treated water in the process. The amount of sediment removed was significant, as was evident by the very turbid discharge. Unfortunately, the well capacity for recharge was greatly diminished, probably due to dewatering the shallow aquifer during the redevelopment process. The turbidity of the water remained high at the end of the day on 12/14, necessitating additional redevelopment.

On 12/15/10, Terran's crew resumed redevelopment. The well was quickly dewatered regardless of the pumping rate. Another 30 gallons of reverse osmosis treated water was used to help flush the fines from the well and used a primer to adjust the pump to a continuous flow rate. The best sustained yield we could maintain was approximately 2.5 gpm with a five foot drawdown. This calculates to a specific capacity of 0.5 gpm/ft. The post-development step drawdown test was not attempted since the well continued to go dry. However, a recovery test was performed after we were able to maintain pumping at ~2.5 gpm for 30 minutes. The analysis of the recovery test is shown in the attachment. Note that the calculated transmissivity is about 200 gal/day/ft, or about ten times less that before development. Also note the calculated ratio of storage during pumping versus storage values during recovery (S/S') is about 13 times greater. Both of these values suggest the small, semi-confined aquifer in the vicinity of Well # 418 was dewatered and recharge is very slow and limited.

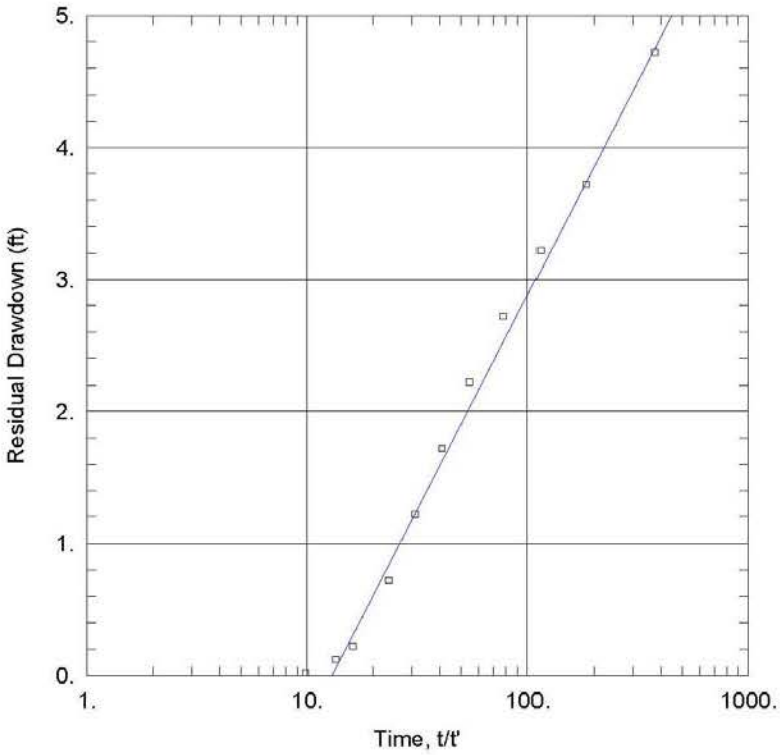
It is my understanding the intended purpose of the redevelopment of Well # 418 was to ensure the well was in direct communication with the aquifer and to determine the recharge rate a tracer solution could be injected into the well. Based upon the amount of fines removed from the well during the redevelopment process and sustainable yield at low pump rates, I believe there is no question good hydraulic communication exists. As for what would be a reasonable injection rate, I would estimate approximately 5 gpm, based on the pre-development step drawdown test.

1

Please call me at (937) 320-3601 if you would like to discuss these results in greater detail or other tasks associated with your upcoming tracer test. Thank you for this opportunity to once again assist Stoller and DOE at Mound.

Brent

2



POST-DEVELOPMENT RECOVERY TEST

Data Set: \\Fileserver\clients\Stoller\SMS09A\MW-418 Mound.aqt
Date: 12/17/10 Time: 13:35:43

PROJECT INFORMATION

Company: Terran Corporation
Client: S.M. Stoller
Project: SMS09A
Location: Miamisburg, OH
Test Well: MW-418
Test Date: 12/14/10

AQUIFER DATA

Saturated Thickness: 6. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
MW-418	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ MW-418	0	0

SOLUTION

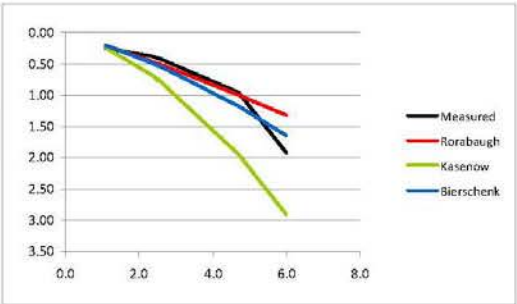
Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 202.9 gal/day/ft S/S' = 13.01

Not corrected for partial penetration

	B	C	n
Rorabaugh	0.1500	2.919E-02	1.49
Kasenow	0.1582	5.450E-02	
Bierschenk	0.1596	1.911E-02	

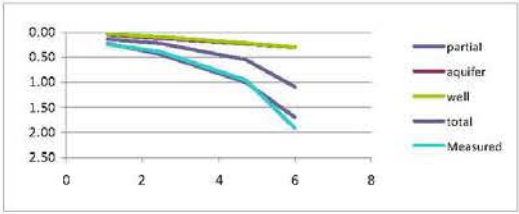
Discharge (gpm)	Drawdown Measured (feet)	Rorabaugh (feet)	Kasenow (feet)	Bierschenk (feet)	Specific Capacity (gpm/ft)
1.1	0.25	0.20	0.24	0.20	4.4
2.4	0.38	0.47	0.69	0.49	6.3
4.7	0.96	1.00	1.95	1.17	4.9
6.0	1.92	1.32	2.91	1.65	3.1
0.0	0.00	0.00	0.00	0.00	#DIV/0!



Corrected for partial penetration

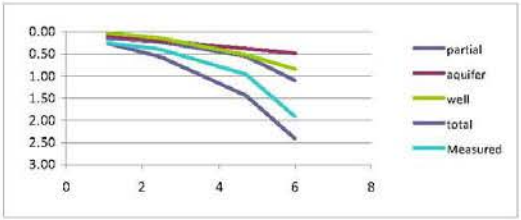
	B	C	n
Rorabaugh	0.0500	2.932E-02	1.30

	partial	aquifer	well	total	Measured
1	0.14	0.06	0.03	0.23	0.25
2	0.22	0.12	0.09	0.43	0.38
5	0.55	0.24	0.22	1.00	0.96
6	1.10	0.30	0.30	1.70	1.92
0	0.00	0.00	0.00	0.00	0.00



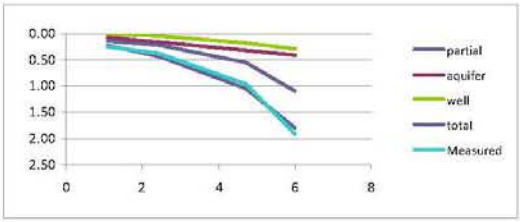
	B	C
Kasenow	0.0801	2.331E-02

	partial	aquifer	well	total	Measured
1	0.14	0.09	0.03	0.26	0.25
2	0.22	0.19	0.13	0.54	0.38
5	0.55	0.38	0.51	1.44	0.96
6	1.10	0.48	0.84	2.42	1.92
0	0.00	0.00	0.00	0.00	0.00



	B	C
Bierschenk	0.0683	8.173E-03

	partial	aquifer	well	total	Measured
1	0.14	0.08	0.01	0.23	0.25
2	0.22	0.16	0.05	0.43	0.38
5	0.55	0.32	0.18	1.05	0.96
6	1.10	0.41	0.29	1.80	1.92
0	0.00	0.00	0.00	0.00	0.00



Appendix D

Mass of Rhodamine WT Removed During Test 1B

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	Average Pumping Rate (gpm)			Average Dye Conc (ppb)			Mass Removed (µg)			Accumulative Mass Removed (µg)			Recovered
Date	Well 0449	Well 0450		Well 0449	Well 0450		Well 0449	Well 0450		Well 0449	Well 0450	Total	%
8/30/2010	17.87	17.41		0.0916	0.1390		8913.15	13171.11				0.00	0.000
8/31/2010	17.86	17.41		0.9110	0.1396		88567.42	13231.06		88567.42		88567.42	0.043
9/1/2010	17.85	17.39		2.5821	0.1730		250878.11	16378.99		339445.53		339445.53	0.163
9/2/2010	17.84	17.38		2.9144	0.7239		283008.68	68480.61		622454.20	68480.61	690934.82	0.332
9/3/2010	17.85	17.39		2.5954	3.0012		252168.19	284080.86		874622.40	352561.48	1227183.87	0.590
9/4/2010	17.86	17.4		2.1797	7.0182		211896.82	664702.45		1086519.22	1017263.92	2103783.14	1.011
9/5/2010	17.87	17.41		1.8370	11.3048		178689.69	1071311.81		1265208.91	2088575.73	3353784.64	1.612
9/6/2010	17.85	17.39		1.5857	10.9750		154068.52	1038867.90		1419277.43	3127443.63	4546721.06	2.186
9/7/2010	17.83	17.38		1.3804	12.1738		133974.57	1151673.00		1553252.00	4279116.63	5832368.64	2.804
9/8/2010	17.82	17.4		1.2102	13.8355		117390.94	1310386.74		1670642.95	5589503.37	7260146.32	3.490
9/9/2010	17.82	17.41		1.0584	14.3393		102662.09	1358879.58		1773305.04	6948382.95	8721687.99	4.193
9/10/2010	17.81	17.41		0.9534	14.4783		92422.06	1372056.67		1865727.10	8320439.62	10186166.72	4.897
9/11/2010	17.8	17.4		0.8555	14.3433		82888.51	1358475.28		1948615.60	9678914.90	11627530.50	5.590
9/12/2010	17.8	17.4		0.7740	14.5025		74992.73	1373554.82		2023608.33	11052469.72	13076078.06	6.287
9/13/2010	17.8	17.4		0.7104	13.0077		68833.55	1231981.91		2092441.88	12284451.63	14376893.52	6.912
9/14/2010	17.81	17.41		0.6609	11.4919		64068.81	1089039.66		2156510.69	13373491.29	15530001.98	7.466
9/15/2010	17.79	17.35		0.6369	10.7633		61672.16	1016484.03		2218182.86	14389975.32	16608158.18	7.985
9/16/2010	17.78	17.29		0.6018	10.4130		58246.16	979997.27		2276429.02	15369972.59	17646401.60	8.484
9/17/2010	17.79	17.26		0.5662	10.2939		54832.55	967105.12		2331261.57	16337077.70	18668339.27	8.975
9/18/2010	17.78	17.26		0.5328	10.1795		51564.30	956357.02		2382825.87	17293434.72	19676260.59	9.460
9/19/2010	17.77	17.26		0.4981	9.9273		48176.10	932666.05		2431001.97	18226100.77	20657102.74	9.931
9/20/2010	17.78	17.29		0.4677	9.3784		45264.19	882630.91		2476266.15	19108731.68	21584997.83	10.377
9/21/2010	17.78	17.3		0.4428	8.8230		42854.09	830843.19		2519120.24	19939574.87	22458695.12	10.797
9/22/2010	17.79	17.31		0.4240	8.4269		41057.17	794000.50		2560177.41	20733575.37	23293752.78	11.199
9/23/2010	17.78	17.14		0.4043	8.0292		39132.09	749095.61		2599309.50	21482670.98	24081980.48	11.578
9/24/2010	17.78	17.02		0.3848	7.7031		37240.85	713639.34		2636550.35	22196310.32	24832860.67	11.939
9/25/2010	17.81	17.03		0.3637	7.4997		35257.77	695202.44		2671808.12	22891512.75	25563320.88	12.290
9/26/2010	17.82	17.05		0.3456	7.3743		33522.85	684386.64		2705330.97	23575899.40	26281230.37	12.635
9/27/2010	17.83	17.06		0.3263	7.3194		31670.04	679683.15		2737001.01	24255582.54	26992583.55	12.977
9/28/2010	17.84	17.08		0.3061	7.2713		29726.78	676012.65		2766727.80	24931595.19	27698322.99	13.317
9/29/2010	17.83	17.07		0.2984	7.0984		28959.31	659550.28		2795687.11	25591145.47	28386832.58	13.648
9/30/2010	17.83	17.06		0.2933	6.9507		28461.25	645452.71		2824148.36	26236598.17	29060746.53	13.972
10/1/2010	17.83	17.07		0.2891	6.5486		28054.84	608467.48		2852203.20	26845065.65	29697268.85	14.278
10/2/2010	17.85	17.08		0.2840	6.3883		27589.03	593917.09		2879792.24	27438982.74	30318774.97	14.576
10/3/2010	17.88	17.08		0.2753	6.1902		26794.63	575497.74		2906586.86	28014480.48	30921067.34	14.866

	Average Pumping Rate (gpm)			Average Dye Conc (ppb)			Mass Removed (µg)			Accumulative Mass Removed (µg)			Recovered
Date	Well 0449	Well 0450		Well 0449	Well 0450		Well 0449	Well 0450		Well 0449	Well 0450	Total	%
10/4/2010	17.9	17.08		0.2679	5.9673		26099.26	554777.07		2932686.13	28569257.55	31501943.68	15.145
10/5/2010	17.93	17.08		0.2624	5.8407		25613.68	543004.73		2958299.81	29112262.29	32070562.09	15.419
10/6/2010	17.94	17.06		0.2556	5.7049		24955.26	529759.71		2983255.06	29642021.99	32625277.06	15.685
10/7/2010	17.95	17.04		0.2486	5.7049		24292.69	529145.73		3007547.76	30171167.72	33178715.48	15.951
10/8/2010	17.96	17.04		0.2428	5.6599		23736.64	524963.51		3031284.40	30696131.23	33727415.63	16.215
10/9/2010	17.98	17.02		0.2365	5.5991		23145.28	518722.45		3054429.67	31214853.68	34269283.35	16.476
10/10/2010	18.01	17.03		0.2302	5.5373		22564.39	513296.58		3076994.06	31728150.26	34805144.32	16.733
10/11/2010	18.04	17.03		0.2229	5.4455		21890.06	504785.66		3098884.12	32232935.92	35331820.04	16.986
10/12/2010	18.06	17.12		0.2183	5.2736		21456.26	491432.49		3120340.37	32724368.41	35844708.78	17.233
10/13/2010	18.1	17.14		0.2151	5.0090		21196.58	467321.26		3141536.95	33191689.67	36333226.62	17.468
10/14/2010	18.13	17.14		0.2112	4.8367		20841.77	451248.36		3162378.72	33642938.02	36805316.75	17.695
10/15/2010	18.17	17.14		0.2100	4.6856		20771.68	437152.82		3183150.40	34080090.84	37263241.24	17.915
10/16/2010	18.19	17.14		0.2058	4.5720		20373.05	426555.25		3203523.46	34506646.09	37710169.55	18.130
10/17/2010	18.21	17.13		0.2017	3.6669		19990.71	341910.05		3223514.17	34848556.14	38072070.31	18.304
10/18/2010	18.26	17.15		0.1973	3.4115		19613.52	318466.53		3243127.69	35167022.67	38410150.36	18.466
10/19/2010	18.29	17.14		0.1930	2.9308		19212.26	273435.04		3262339.95	35440457.72	38702797.66	18.607
10/20/2010	18.33	17.16		0.1905	2.6548		19005.53	247971.00		3281345.48	35688428.71	38969774.19	18.735
10/21/2010	18.32	17.15		0.2034	2.6336		20285.98	245851.21		3301631.46	35934279.92	39235911.38	18.863
10/22/2010	18.32	17.13		0.2034	2.5421		20284.05	237031.88		3321915.51	36171311.80	39493227.31	18.987
10/23/2010	18.31	17.12		0.1919	2.2967		19123.69	214023.15		3341039.20	36385334.95	39726374.15	19.099
10/24/2010	18.28	17.11		0.1956	2.2608		19462.95	210558.53		3360502.14	36595893.49	39956395.63	19.210
10/25/2010	18.29	17.11		0.1934	2.4087		19254.43	224328.01		3379756.57	36820221.50	40199978.08	19.327
10/26/2010	18.3	17.14		0.1905	2.4685		18980.73	230306.63		3398737.30	37050528.13	40449265.43	19.447
10/27/2010	18.28	17.13		0.1896	2.4053		18867.32	224274.24		3417604.62	37274802.37	40692407.00	19.564
10/28/2010	18.28	17.14		0.1901	2.5756		18915.69	240292.78		3436520.31	37515095.15	40951615.46	19.688
10/29/2010	18.29	17.14		0.1894	2.8546		18851.37	266327.02		3455371.68	37781422.17	41236793.85	19.825
10/30/2010	18.28	17.16		0.1863	2.7990		18532.88	261436.93		3473904.56	38042859.10	41516763.66	19.960
10/31/2010	18.22	17.13		0.1827	2.6232		18115.99	244595.82		3492020.54	38287454.92	41779475.47	20.086
11/1/2010	18.21	17.15		0.1808	2.1787		17916.75	203381.75		3509937.29	38490836.67	42000773.96	20.193
11/2/2010	11.37	17.2		3.2304	2.5881		199926.56	242306.18		3709863.86	38733142.85	42443006.71	20.405
11/3/2010	1.03	17.25		6.0222	2.8754		33763.29	269983.26		3743627.15	39003126.11	42746753.26	20.551
11/4/2010	8.91	14.95		2.8158	3.0120		136565.19	245105.84		3880192.34	39248231.95	43128424.29	20.735
11/5/2010	18.61	17.12		0.3667	2.1236		37143.99	197891.60		3917336.33	39446123.55	43363459.88	20.848
11/6/2010	18.54	17.13		0.3178	2.0725		32067.76	193240.19		3949404.08	39639363.74	43588767.82	20.956
11/7/2010	18.53	17.12		0.3028	1.9693		30543.83	183512.89		3979947.91	39822876.63	43802824.54	21.059
11/8/2010	18.51	17.11		0.2908	1.8824		29295.52	175316.69		4009243.43	39998193.32	44007436.74	21.157

	Average Pumping Rate (gpm)			Average Dye Conc (ppb)			Mass Removed (µg)			Accumulative Mass Removed (µg)			Recovered
Date	Well 0449	Well 0450		Well 0449	Well 0450		Well 0449	Well 0450		Well 0449	Well 0450	Total	%
11/9/2010	18.81	17.11		0.2889	1.8237		29575.50	169849.65		4038818.93	40168042.96	44206861.89	21.253
11/10/2010	18.9	17.1		0.2832	1.7601		29129.76	163826.95		4067948.69	40331869.91	44399818.61	21.346
11/11/2010	18.87	17.09		0.2855	1.6850		29328.89	156742.70		4097277.59	40488612.61	44585890.20	21.436
11/12/2010	18.87	17.1		0.2827	1.6486		29037.87	153453.20		4126315.46	40642065.81	44768381.27	21.523
11/13/2010	18.86	17.1		0.2822	1.6169		28971.87	150497.95		4155287.33	40792563.75	44947851.08	21.610
11/14/2010	18.84	17.08		0.2810	1.6304		28815.81	151581.54		4184103.13	40944145.29	45128248.43	21.696
11/15/2010	18.86	17.11		0.2802	1.6191		28760.85	150791.63		4212863.98	41094936.92	45307800.90	21.783
11/16/2010	18.85	17.1		0.2738	1.6670		28088.65	155157.70		4240952.63	41250094.62	45491047.25	21.871
11/17/2010	18.85	17.1		0.2598	1.7744		26655.75	165157.85		4267608.37	41415252.47	45682860.84	21.963
11/18/2010	18.86	17.1		0.2597	1.7359		26662.05	161574.32		4294270.42	41576826.79	45871097.21	22.053
11/19/2010	18.88	17.1		0.2600	1.7445		26720.29	162379.06		4320990.71	41739205.85	46060196.56	22.144
11/20/2010	18.87	17.09		0.2587	1.7196		26575.61	159960.43		4347566.32	41899166.28	46246732.60	22.234
11/21/2010	18.85	17.07		0.2514	1.7040		25796.44	158328.53		4373362.76	42057494.80	46430857.56	22.323
11/22/2010	18.82	17.07		0.2599	1.7054		26622.57	158458.87		4399985.33	42215953.67	46615939.00	22.412
11/23/2010	18.83	17.09		0.2570	1.6976		26342.76	157922.29		4426328.09	42373875.97	46800204.05	22.500
11/24/2010	18.85	17.11		0.2469	1.6205		25330.44	150921.63		4451658.53	42524797.59	46976456.12	22.585
11/25/2010	18.84	17.1		0.2355	1.5579		24150.50	145011.47		4475809.03	42669809.07	47145618.09	22.666
11/26/2010	18.87	17.12		0.2302	1.5229		23644.72	141919.51		4499453.75	42811728.58	47311182.33	22.746
11/27/2010	18.88	17.13		0.2290	1.3540		23530.93	126250.98		4522984.67	42937979.57	47460964.24	22.818
11/28/2010	18.89	17.14		0.2299	1.3199		23639.07	123139.00		4546623.75	43061118.57	47607742.32	22.888
11/29/2010	18.88	17.13		0.2275	1.2685		23383.91	118274.91		4570007.66	43179393.47	47749401.14	22.956
11/30/2010	18.87	17.13		0.2209	1.5630		22687.49	145735.98		4592695.15	43325129.45	47917824.60	23.037
12/1/2010	18.93	17.16		0.2217	1.7206		22846.92	160716.16		4615542.08	43485845.61	48101387.69	23.126
12/2/2010	18.94	17.16		0.2150	1.5986		22170.27	149321.36		4637712.34	43635166.98	48272879.32	23.208

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