Prepared for Nevada Environmental Response Trust Henderson, Nevada

Project Number **21-41400C**

Prepared By Ramboll Environ US Corporation Emeryville, California

Date September 7, 2017

BARRIER WALL INTEGRITY FIELD EVALUATION WORK PLAN NEVADA ENVIRONMENTAL RESPONSE TRUST SITE HENDERSON, NEVADA

Ramboll Environ 2200 Powell Street Suite 700 Emeryville, CA 94608 USA www.ramboll-environ.com



Barrier Wall Integrity Field Evaluation Work Plan

Nevada Environmental Response Trust Site (Former Tronox LLC Site) Henderson, Nevada

Nevada Environmental Response Trust (NERT) Representative Certification

I certify that this document and all attachments submitted to the Division were prepared at the request of, or under the direction or supervision of NERT. Based on my own involvement and/or my inquiry of the person or persons who manage the system(s) or those directly responsible for gathering the information or preparing the document, or the immediate supervisor of such person(s), the information submitted and provided herein is, to the best of my knowledge and belief, true, accurate, and complete in all material respects.

Office of the Nevada Environmental Response Trust

Le Petomane XXVII, Inc., not individually, but solely in its representative capacity as the Nevada Environmental Response Trust Trustee ANDRED STEWDERL, N.P. OF THE NERT TRUST TRUSTE, ON DEHALT OF JAD STEWDERL,

____, not individually, but solely in his

Signature:

representative capacity as President of the Nevada Environmental Response Trust Trustee

Name: Jay A. Steinberg, not individually, but solely in his representative capacity as President of the Nevada Environmental Response Trust Trustee

Title: Solely as President and not individually

Company: Le Petomane XXVII, Inc., not individually, but solely in its representative capacity as the Nevada Environmental Response Trust Trustee

Date:



Barrier Wall Integrity Field Evaluation Work Plan

Nevada Environmental Response Trust Site (Former Tronox LLC Site) Henderson, Nevada

Responsible Certified Environmental Manager (CEM) for this Project

I hereby certify that I am responsible for the services described in this document and for the preparation of this document. The services described in this document have been provided in a manner consistent with the current standards of the profession and, to the best of my knowledge, comply with all applicable federal, state and local statutes, regulations and ordinances.

September 7, 2017

John M. Pekala, PG Senior Manager Date

Certified Environmental Manager Ramboll Environ US Corporation CEM Certificate Number: 2347 CEM Expiration Date: September 20, 2018

The following individuals provided input to this document:

John M. Pekala, PG Jessica E. Donovan, PG Jonathan Johnson, PhD Jinjun Wang, PhD, PE Christopher J. Ritchie, PE Ruben So



DateSeptember 7, 2017Prepared byRamboll Environ US CorporationDescriptionBarrier Wall Integrity Field Evaluation Work Plan

Project No. **21-41400C**

Ramboll Environ 2200 Powell Street Suite 700 Emeryville, CA 94608 USA

T +1 510 655 7400 F +1 510 655 9517 www.ramboll-environ.com



CONTENTS

1.	INTRODUCTION	1
2.	CONSTRUCTION AND PRIOR INVESTIGATIONS	2
3.	TECHNOLOGY DESCRIPTION	4
4.	GEOPHYSICAL SURVEYS	6
4.1	Preliminary Field Activities	6
4.2	Implementation and Design	6
5.	TRACER TESTS	8
5.1	Preliminary Activities	8
5.2	Implementation And Design	9
5.3	Tracer Test Permitting Requirements	10
6.	CPT INVESTIGATION	11
6.1	Preliminary Activities	12
6.2	Implementation And Design	12
7.	REPORTING	13
8.	SCHEDULE	14
9.	REFERENCES	15

TABLES

 Table 1
 Electromagnetic Geophysical Survey Areas

FIGURES

Figure 1	Overview of Site		
Figure 2	Interceptor Well Field and Barrier Wall		
Figure 3	Survey and Circuit Wire Layout		
Figure 4	Survey 1 Layout		
Figure 5	Survey 2 Layout		
Figure 6	Survey 3 Layout		
Figure 7	Typical Layout for Tracer Test		
Figure 8	Typical Arrangement of CPT Soundings		

APPENDICES

Appendix A	Safety Data Sheets for Dye Tracers
Appendix B	Procedures and Criteria Analysis of Fluorescent Dyes

ACRONYMS AND ABBREVIATIONS

AOC	Area of Concern		
ASTM	American Society of Testing and Materials		
СРТ	Cone Penetration Test		
FGD	Field Guidance Document		
FSP	Field Sampling Plan		
GPR	Ground Penetrating Radar		
HASP	Health and Safety Plan		
HPT	Hydraulic Profiling Tool		
IWF	Interceptor Well Field		
NDEP	Nevada Division of Environmental Protection		
OUL	Ozark Underground Laboratory		
QAPP	Quality Assurance Project Plan		
RI/FS	Remedial Investigation Feasibility Study		
SAP	Sampling and Analysis Plan		
UMCf	Upper Muddy Creek Formation		

1. INTRODUCTION

Ramboll Environ US Corporation (Ramboll Environ) has prepared this work plan for an evaluation of the integrity of the barrier wall located immediately downgradient of the Interceptor Well Field (IWF) at the Nevada Environmental Response Trust (NERT or the Trust) Site in Henderson, Nevada (the "Site"). This work is being undertaken to address questions raised by the Nevada Division of Environmental Protection (NDEP) regarding the integrity of the barrier wall in their May 20, 2015 letter commenting on the 2014 Semiannual Remedial Performance Report (NDEP 2015). This work will also provide information that will be used to assess the utility of the barrier wall as a component of the long-term remedy that is being developed as part of the Remedial Investigation and Feasibility Study (RI/FS).

The objective of this proposed barrier wall integrity evaluation is to identify locations that may be providing preferential paths for groundwater flow through, around, and underneath the barrier wall and to evaluate these locations with technologies that can better characterize the extent and magnitude of zones of preferential flow at the barrier wall. This will be accomplished by first mapping the entire wall with surface geophysics to locate the potential preferential flow zones, and then using the results of the geophysics investigation to identify specific areas for tracer testing and a Cone Penetration Test (CPT) investigation. The results of this evaluation will also be used in conjunction with additional soil and groundwater sampling results from the Phase 2 RI, currently in progress, to further understand the mechanism(s) of perchlorate migration in groundwater downgradient of the barrier wall. Together, these data collection efforts will inform the conceptual model for this area, specifically, seeking to identify the source(s) of increasing concentrations of perchlorate in groundwater.

2. CONSTRUCTION AND PRIOR INVESTIGATIONS

NDEP and Kerr-McGee entered into a Consent Agreement in 1999 to mitigate the discharge of perchlorate from a surface water seep adjacent to the Las Vegas Wash. In October 2001, NDEP issued an Administrative Order of Consent (AOC) to be executed by Kerr-McGee (NDEP 2001). The AOC outlined the work to be performed and the schedule for completing of the remedial action, which was designed to reduce the amount of perchlorate in the groundwater ultimately discharging to the Las Vegas Wash. The AOC required the construction of a perchlorate treatment system capable of processing 825 gallons per minute. This included the construction of a low-permeability barrier wall approximately 50 feet downgradient of the IWF to increase the capture of perchlorate-contaminated groundwater. The barrier wall was to serve as a source control method, restricting the transport of contaminants from source areas to downgradient groundwater and offsite receptors. The AOC stipulated that the barrier wall be completed by October 31, 2001. Figure 1 provides an overview of the site and groundwater extraction systems in the vicinity of the site. Figure 2 shows the area of the IWF and the barrier wall.

The barrier wall was constructed in 2001 using the conventional slurry trench method. Wall specifications (Kerr McGee 2001a) indicate the wall was designed to be 1,700 feet long, 60 feet deep, and three feet wide; however, documents produced after construction (Northgate 2010b) indicate that the installed wall is approximately 1,600 feet long. Specifications also indicated that the soil-bentonite slurry wall was constructed to penetrate the alluvium, which consists of silty sand and small gravel. The lower-most 25 feet of the wall were designed to tie into the Upper Muddy Creek formation (UMCf), which consists of sandy and clayey silt; however, documents produced after construction (Northgate 2010b) indicate that approximately 30 feet of the wall tied into the UMCf. The design criteria for the hydraulic conductivity of the barrier wall was 1 x 10⁻⁶ centimeters per second (cm/s) (Northgate 2010a). Correspondence from Kerr-McGee in December of 2001 indicated that groundwater extraction at the IWF more than doubled after construction, due in part to the barrier wall (Kerr McGee 2001b).

In 2010, four samples of the barrier wall were collected for permeability testing by Northgate Environmental Management (Northgate 2010a) on behalf of Kerr-McGee. The top of the wall was reportedly encountered between one and 4.9 feet below ground surface (bgs). Samples taken for permeability testing appear to have been collected within the vadose zone and not in areas where the wall is in contact with groundwater. Nevertheless, three of these samples met the design criteria, with only one sample slightly above the permeability design criteria (hydraulic conductivity of 2.3 x 10⁻⁶ cm/s). The study also analyzed water levels on either side of the wall. Overall, the study concluded that there were no significant leaks in the barrier wall in the four areas that were examined. There is no documentation of permeability testing at greater depths.

A subsequent evaluation of barrier wall performance conducted by Ramboll Environ, on behalf of the Trust, was conducted by examining historical water levels (measured from 2006 to 2016) from well pairs upgradient and downgradient of the wall (Ramboll Environ 2016). Seven well pairs were analyzed over periods of time under varying hydraulic conditions, including the time period after shutdown of the groundwater recharge trenches downgradient of the interceptor well field and barrier wall (Northgate 2010a). The data collected in this evaluation indicated the presence of significant groundwater elevation differences across the wall. Based on this analysis, the wall appeared to provide an effective barrier to groundwater flow.

Despite the results of the previous barrier wall investigations described above, there remain questions regarding the source(s) of perchlorate in areas between the barrier wall and the downgradient former recharge trenches (Figure 2), particularly given that perchlorate and hexavalent chromium concentrations have been increasing in recent periods.

3. TECHNOLOGY DESCRIPTION

Three different technologies are proposed to evaluate the integrity of the barrier wall, namely surface geophysics, tracer testing, and CPT surveys. These technologies will be utilized in a phased approach with the scope of the tracer testing and CPT surveys being dependent on the results of the surface geophysics. Therefore, this work plan describes an assumed scope for the tracer testing and CPT surveys, which may be modified pending the results of the geophysical survey. This approach allows the most efficient use of the tracer testing and the CPT surveys. Each of the technologies operates at a different scale. The geophysical survey will be used to evaluate the entire wall. The tracer test will be used to evaluate specific areas of the wall, and CPT will be used to evaluate specific points and narrow cross-sections of the wall.

Based on the documents available and reviewed to date, a number of discrepancies exist regarding the wall's configuration, methods of construction, and as-built conditions. For example, construction equipment used, length of the wall, surface grade at time of construction, and depth and location of the wall as constructed are uncertain. In addition, excavation under Tronox wastewater lines to the WC ponds, which cross the wall between IWF wells I-O and I-V, may not have taken place during the barrier wall construction, which could have left a gap where the low permeability soil slurry for the barrier wall was not placed.

Surface geophysics will be used to map, measure, and evaluate the integrity of the barrier wall. Mapping and measuring will use a combination of GPR and shallow electromagnetic (EM) methods, while the evaluation of integrity will be performed using a larger scale EM survey using Willowstick[™] methodology. The GPR methodology uses radar pulses to obtain an image of the subsurface. Shallow EM surveys use induction to measure the electrical conductivity of the subsurface without requiring ground contact. The GPR and EM survey will be used to locate, mark, and survey the wall location for future work. The larger scale Willowstick[™] EM survey will be performed by energizing the subsurface at two locations, typically two wells that are connected by a long loop of wire and then measuring the electromagnetic field between the energized points. The method has proven effective at identifying zones of preferential groundwater flow through or around low conductivity barriers such as dams. The proposed plan for the implementation of the surface geophysics is described in Section 4.

Tracer tests will be used to evaluate specific segments of the barrier wall, which will be identified based on geophysical survey results and other information about the wall. Tracer tests will be performed at select locations by injecting a fluorescent dye in close proximity to the wall. The injection will take place on the upgradient side of the wall in a newly-installed well at each tracer test location. Monitoring will be conducted at two new monitoring wells for each tracer injection, installed downgradient and in close proximity to the wall, and in existing downgradient wells along the potential path of the tracer. The proposed plan for the implementation of the tracer tests is described in Section 5.

The CPT investigation will be used to evaluate specific locations and cross-sections through the wall. These locations will be selected based on the results from the geophysics survey and tracer tests. In addition to the engineering parameters collected through the traditional CPT method, pressure dissipation testing devices will be added to the CPT sensors to evaluate in-situ hydraulic conductivity of the wall materials at select locations. Following completion, each CPT sounding will be filled with grout during withdrawal that has at least an order of magnitude lower hydraulic

conductivity than the wall design specification to preserve the wall integrity. The proposed CPT survey plan is described in Section 6.

The activities described in this work plan will be implemented in accordance with the Site Management Plan (SMP), Revision 3 (Ramboll Environ 2017). All intrusive activities conducted as part of this entire investigation including activities described in Section 5 (Tracer Tests) and Section 6 (CPT Investigation) of this work plan will be performed in concurrence with the NDEP-approved Sampling and Analysis Plan, Revision 1 (SAP) for the Site. The SAP is comprised of the Field Sampling Plan ("FSP"; ENVIRON 2014a), Health and Safety Plan ("HASP"; ENVIRON 2014b), and the Quality Assurance Project Plan ("QAPP"; ENVIRON 2014c, currently under revision). Work to be performed within the Tronox leasehold will be coordinated in advance with Tronox.

4. GEOPHYSICAL SURVEYS

Two sets of geophysical surveys will be conducted. The first set is a ground penetrating radar (GPR) and EM survey to locate the top of the wall. The purpose of this activity is to find, mark and survey the wall location for future work. The second type of survey is a large scale EM survey. The design of the field program for this survey has been prepared in conjunction with personnel from Willowstick[™] Technologies, a geophysics contractor. Willowstick[™] is known for their development of new instrumentation and improved software algorithms for electromagnetic surveying, specifically optimized to identify preferential groundwater flow paths, and is therefore, well qualified to assist with the proposed survey. While information regarding the site has been provided and discussed, the final field program would require that the geophysical team conduct a field survey of the area to identify any potential issues that may interfere with their work. Any significant deviations to the plan will be discussed with the Trust and NDEP prior to implementation.

4.1 Preliminary Field Activities

Field activities will be initiated with a site visit to the survey area to provide control points and measurements for the implementation of the geophysical surveys. The GPR survey and the EM survey will be tested over a portion of the wall in selected areas before surveying the whole wall. If one method or the other is found to be incapable or only marginally capable of providing the wall location then the superior method will be selected to complete the survey.

For each phase of the large scale EM geophysical survey, a wire will be run to connect two wells, one upgradient and one downgradient of the barrier wall, with an electrode placed in contact with groundwater in each well to be energized. The wire must be run between the two groundwater wells. However the wire must be run as a long loop (often 10,000 feet or longer) around the barrier wall, as shown in the proposed wire layout in Figure 3. The circuit wire is placed outside the study area as far away as possible due to the strong magnetic field influence around it. The site visit will allow for site access constraints to be evaluated and the specific locations for placement of the wire to be determined.

4.2 Implementation and Design

The GPR survey will be conducted first to identify the top of the wall. Ramboll Environ will provide oversight of a GPR survey contractor. Upon completion of the GPR survey, locations of the centerline of the wall will be marked and surveyed so that specific locations along the wall can be identified in the future. Electromagnetic geophysical measurements will be conducted by energizing groundwater via a pair of wells on opposite sides of the wall by placing an electrode below the water level surface in the well. These points will create a distribution of electrical current in saturated groundwater. Measurements of the electromagnetic field will then be taken at a 16-foot grid spacing in the area of the barrier wall to generate a map of the magnetic field lines. Lines found at a high density can be interpreted as related to preferential water flow paths in the subsurface.

Implementation along the entire barrier wall will require three survey areas and the use of six different wells as electrodes. Figure 3 shows the proposed layout of wire loops, wells, and survey areas for the field program. Figure 4 shows the eastern most survey area, Survey 1. For this survey electrodes will be placed in wells M-22D and M-220. The electromagnetic field in the vicinity of the wall generated by the charged electrodes will be measured on a 16-foot grid

spacing. The grid will extend beyond the wall's eastern extent and will also overlap with a portion of Survey 2 to the west for quality control. Figure 5 shows the central survey area, Survey 2. For this survey, electrodes will be placed in wells M-38 and M-216. The electromagnetic field in the vicinity of the wall generated by the charged electrodes will be measured on a 16-foot grid spacing. Some measurement points for Survey 2 will be duplicated by measurements made during Survey 1 and Survey 3 for quality control. Figure 6 shows the western most survey area, Survey 3. For this survey, electrodes will be placed in wells M-37 and M-215. The electromagnetic field in the vicinity of the wall generated by the charged electrodes will be measured on a 16-foot grid spacing. The grid will extend beyond the wall's western extent and will also overlap with a portion of Survey 2 for quality control. The surveys proposed are summarized in Table 1.

Table 1: Electromagnetic Geophysical Survey Areas			
Name	South Well	North Well	
Survey 1	M-22D	M-220	
Survey 2	M-38	M-216	
Survey 3	M-37	M-215	

Ramboll Environ will provide oversight of the electromagnetic geophysical contractor while they are on site. The electromagnetic geophysical contractor will conduct the survey and prepare a report containing maps, graphs, images and tables. The report will also contain the contractor's interpretation of the wall with respect to preferential groundwater flow paths. Ramboll Environ will conduct an internal review of the geophysical results from the contractor to verify the interpretations. The results of the geophysics investigation will be evaluated together with available construction documents in consultation with the Trust to develop final locations for the tracer test. Geophysics data will also be used to determine potential areas for the CPT investigation.

5. TRACER TESTS

Building on the information obtained during the surface geophysical survey, tracer tests will be used to evaluate specific segments of the barrier wall. To implement this study, fluorescent dye tracers will be injected on the upgradient side of the barrier wall via newly-installed wells at each tracer test location in close proximity to the wall. Also at each tracer test location, monitoring for the artificial tracers will take place on the downgradient side of the wall in two new wells to be installed in close proximity to the wall, and in existing monitoring wells reasonably expected to be within a potential flow path of the tracer. In addition, influent from the IWF would be sampled for tracer at either the East or the West manifold feed line, or both, depending on the selected location of the tracer test. The IWF monitoring will be used to identify uptake of tracers via the extraction wells.

The specific locations of tracer tests will be dependent on the results of the geophysical survey discussed in Section 4, and will be selected after the geophysical survey is completed. Finalization of the tracer test implementation plan (including the number of and specific locations of tracer tests) will be conducted once the final locations are selected. In this section, a generalized tracer test plan is discussed. The final components of the tracer test implementation plan, selection of wells, schedule, and tracers to be injected, will be determined in consultation with the Trust prior to implementation. For illustrative purposes, a test at only one location is presented in the following sections. Other locations would be conducted in the same manner, or as otherwise modified by the Trust.

5.1 Preliminary Activities

For tracer tests at each selected location, a network of three wells will be installed in a line perpendicular to and crossing the wall. One injection well will be installed upgradient and within approximately five feet of the wall. Two additional wells will be installed downgradient of the wall with one well within approximately five feet of the wall and another approximately 10 feet further downgradient. Additional wells in the vicinity of and downgradient of the injection well will be monitored for tracer breakthrough. Before actual implementation of the tracer tests, all wells selected for monitoring will be sampled and tested two times to determine background fluorescence. Sampling for background fluorescence will be conducted using the same methods as monitoring for tracer breakthrough, described in Section 5.2.

All of the new wells will be installed by a licensed contractor using sonic drilling methods and constructed as four-inch PVC with a screened interval straddling the water table and reaching to within approximately 10 feet of the bottom of the wall. Ramboll Environ will provide oversight during the drilling.

Aboveground and underground utilities that could potentially be affected by the drilling of the wells will be identified prior to initiating any intrusive activities. Activities associated with subsurface clearance will follow procedures outlined in Field Guidance Document (FGD) 003 (ENVIRON 2014a).

A sonic drilling rig will be utilized to advance all boreholes to approximately 50 feet bgs. All wells will be constructed of four-inch diameter Schedule 40 PVC casing. Well drilling and completion will follow procedures outlined in FGD 003 and FGD 007 (ENVIRON 2014a). Wastes derived from the drilling process will be handled in accordance with FGD 001 (ENVIRON 2014a).

Following well installation and construction, the new monitoring wells will be developed following FGD 008 (ENVIRON 2014a). Water quality parameters, flow rate, and water level information will be recorded during development.

As specified in FGD 007 (ENVIRON 2014a), well locations and elevations will be surveyed by a Nevada-licensed surveyor and tied to an established state or county benchmark. Horizontal coordinates will be surveyed to a horizontal accuracy of at least 0.1 foot and referenced to the Nevada Coordinate System of 1983 (NAD83). The vertical elevations survey will be accurate to 0.01 foot relative to mean sea level datum (NAVD88).

5.2 Implementation And Design

Tracers will be injected at the proposed injection wells which will be constructed about five feet upgradient of the wall. Locating the injection points in close proximity to the wall is intended to maximize the contact of the tracer with the wall and minimize the amount of injected tracer that would be captured by the interceptor wells. Figure 7 shows a proposed layout for a tracer test with proposed injection and monitoring in the vicinity of the IWF. The specific location of each injection/monitoring well configuration will be determined based on the results of the geophysical surveys. Monitoring would be conducted at the two new monitoring wells and at monitoring wells M-179 and M-73, thereby providing a well network of four monitoring wells for each tracer test. In addition to sampling at these four monitoring wells, it is also proposed that the IWF be monitored at either the west manifold or the east manifold or both on the same schedule as wells M-179, M-73 and the newly installed monitoring wells.

Injections will consist of some combination of three fluorescent dyes to allow identification of the source at the downgradient monitoring well. For instance, two injections in close proximity will be conducted using a different tracer in each injection well so that origin of the dye can be distinguished in the monitoring conducted at the wells downgradient.

The fluorescent dyes proposed to be used as tracers are fluorescein, rhodamine WT, and eoscein. Each of these has been used extensively in groundwater and surface water applications. They are safe, non-toxic, and can be measured over a concentration range spanning up to six orders of magnitude, so that detection of a very small fraction of the injected concentration is possible. Safety data sheets for these dyes are included in Appendix A. Further, all of these tracers are measured by a single analytical method, so that analytical costs are minimized.

The amount of tracer injected in any well will consist of five pounds of fluorescein and/or ten pounds of rhodamine WT and/or eight pounds of eoscein. The total mass of tracer injected in a well could range from 5 to 23 pounds depending on which tracers are injected in each well. However, most typically, one or two of these tracers will be injected at any single location. Injection of each tracer will occur in liquid form and be followed by five well volumes of stabilized Lake Mead water. Fluorescent tracers will be purchased from Ozark Underground Laboratory (OUL).

Monitoring will be conducted by collecting grab samples of ground water and by analyzing activated carbon samplers. The carbon samplers absorb tracer continuously and accumulate tracer over time. Therefore, they are the best indication of timing of dye arrival at a sampling station. Grab samples provide a measure of dye concentrations at fixed times. Activated carbon samplers will be placed in each downgradient monitoring well at approximately the same time as

the tracer injections in upgradient wells. On a weekly basis throughout an anticipated 17-week monitoring period, the activated carbon sampler will be removed from the well, a grab groundwater sample will be collected, and a new carbon sampler will be placed in the well. Both the carbon samplers and the grab samples will be delivered to OUL for analysis. The procedures and analysis for the carbon samplers are described in Appendix B. Grab samples will be analyzed if dye tracer is detected during the analysis of the associated carbon sampler. If the dye tracer is not detected in the carbon sampler, then the grab sample will not be analyzed, unless there is another valid reason to analyze the grab sample, such as damage or loss of the associated carbon sampler.

5.3 Tracer Test Permitting Requirements

The tracer test will require an Underground Injection Control (UIC) permit since it involves injection of a chemical tracer into the subsurface via injection wells. NDEP administers the Nevada UIC program and regulates injection wells under the authority of the Nevada Revised Statutes (NRS) 445A.300 - 445A.730 and the Nevada Administrative Code (NAC) NAC 445A.810 - 445A.925, inclusive. Typically, for short term field tests for purposes of remediation (less than six months), a Class V General Short-Term Remediation UIC permit is required. The UIC short-term general permit falls under NAC 445A.891 and is valid for a period of six months. However, the injection of tracer is not intended for remediation purposes. Based on communication with NDEP Bureau of Water pollution Control, approval for the injection of tracer can be sought through the existing UIC permit (UIC Permit UNEV94218), which provides for the operation of two on-site recharge trenches downgradient of the barrier wall (currently idle), by submitting UIC Form U240: UIC Requests for Chemical Use and an accompanying letter with supplemental information (purpose of injection, locations, description of monitoring, etc.).

The tracer test will also require a NAC 534.441 Monitor Well Drilling Waiver and a NAC 534.320 Notice of Intent Card to install injection wells and monitoring wells. As required, the injection and monitoring wells will be drilled by a licensed well driller pursuant to Nevada Revised Statutes 534.160 and will be constructed pursuant to NAC Chapter 534 – Underground Water and Wells.

6. CPT INVESTIGATION

Following the surface geophysical survey and tracer tests, a CPT survey will be completed to evaluate the in-situ engineering and hydraulic properties of the barrier wall. CPT soundings have been used extensively in subsurface media characterizations and have been shown to be an effective method of subsurface characterization, especially in media with discrete stratigraphic horizons and discontinuous lenses. Since ASTM adopted the CPT procedure as test D-3441 in 1974, CPT technologies have evolved and become more accurate. CPT sensors produce a computerized log of tip and sleeve resistance, induced pore pressure just behind the cone tip, pore pressure ratio, and continuous lithological interpretations. The sleeve friction measures the average skin friction as the probe is advanced through the soil. The friction ratio is used to classify the soil, by its behavior or reaction to the cone being forced through the soil. Friction ratio is used to classify soil types, where high ratios generally indicate clayey materials while lower ratios are typical of sandy materials.

The barrier wall was manufactured by mixing a significant amount of clay with native soil as a slurry before placing the slurry into the excavated trench. The friction ratio associated with the slurry of the barrier wall should have a different value from the surrounding unconsolidated materials, allowing the slurry wall to be mapped. In addition, a Hydraulic Profiling Tool (HPT) can be added to the CPT, which uses a sensitive, down-hole transducer to monitor the matrix back-pressure response to water injection. This tool will be used in a new hole and adjacent to an interval that is suspected of being compromised, to approximate the hydraulic conductivity in-situ. Due to the likely long duration (multiple days) of a full HPT hydraulic test, limited and focused use of the HPT will be performed, with the primary goal to determine if high hydraulic conductivity zones are present, rather than to characterize the complete hydraulic conductivity profile throughout the low conductivity barrier wall.

Technical challenges exist to successful implementation of CPT at the NERT Site. First, the presence of caliche and cobbles in the subsurface across the NERT Site typically limit the penetration depth and therefore the utility of CPT for investigation. However, the caliche and cobbles were removed during excavation of the trench for the barrier wall. Therefore, the area directly over the barrier wall and down to the full depth of the wall is expected to be free of caliche and cobbles and will not constrain the depth of the CPT investigation. As necessary, CPT soundings will be re-attempted at adjacent locations if shallow refusal is encountered.

Second, backfill has been placed over the wall obscuring the wall location, and a surveyed location of the wall location is not available. This makes it a challenge to find the location of the wall centerline to begin the CPT investigation. To address this concern, as described in Section 4, a GPR survey is proposed to locate the top of the wall. The results of the GPR survey will be available prior to the CPT investigation.

Third, the construction of the wall may not have been vertically plumb. If the barrier wall was not constructed vertically plumb, then a single CPT sounding is not guaranteed to stay within the same vertical plane as the wall, which may limit the vertical extent of wall that is tested. Ramboll Environ has reviewed limited documentation regarding wall specifications, but has not yet obtained drawings, reports, or notes that should have been generated during construction that would describe the as-built conditions of the wall. To best address this constraint, it is proposed that this investigation be performed using transects consisting of several CPT soundings perpendicular to the wall. Figure 8 shows a typical layout of CPT transects that will be used to

identify potential preferential flow areas within the barrier wall. The CPT investigation will be conducted at approximately three areas with up to 20 points each forming several cross-sections within the same area. A CPT transect will intersect a non-plumb vertical barrier wall in multiple locations. These locations can be combined to reconstruct the wall properties over a greater vertical extent than a single CPT sounding.

Finalization of the CPT implementation plan will be conducted once the final locations are selected. The final components of the CPT implementation plan, selection of locations, and schedule, will be determined in consultation with the Trust prior to implementation. A test at only one location along a single cross-section is presented in the sections below; however, multiple cross-sections would typically be constructed in one area.

6.1 Preliminary Activities

The specific locations for the CPT investigation will be dependent on the results of the geophysical survey, discussed in Section 4 and will be decided and designed after the geophysical survey and tracer tests are completed. The geophysics will result in non-destructive testing of the wall, and a map that will provide guidance to the other tests. The tracer test will result in direct evidence showing whether or not there is preferential flow through the wall at specific locations. The CPT investigation will show whether or not there are physical differences within the wall that might be related to preferential flow paths through the barrier wall. The CPT investigation will require locations selected to be reviewed on the ground to determine access constraints for the CPT rig. Locations of the selected CPT cross sections will be identified with a field deployable GPS unit with sub-meter scale accuracy. Locations of the proposed transects will be marked out in advance for the CPT rig.

6.2 Implementation And Design

Layout of a typical CPT investigation section is shown in Figure 8. The wall width is expected to be three feet. CPT soundings will be performed starting from the centerline and pushing through the backfill down into the soil slurry of the barrier wall and then to the bottom of the soil slurry media comprising the barrier wall. Each hole will be grouted to the surface with a grout material that is below the hydraulic conductivity design criteria for the barrier wall (1 x 10^{-6} cm/s) by two orders of magnitude, and the next direct push point will be offset from the prior hole. The process will be continued until the entire width of the barrier wall has been explored at that location. At any particular location, several parallel cross-sections may be explored in the same area to provide additional information. It is anticipated that three to four locations will be discussed with the Trust after the geophysical survey has been completed and while CPT investigation areas are being selected.

7. **REPORTING**

Informal field updates between the Trust, the contractor, and Ramboll Environ staff are planned during the geophysical investigation.

The duration of the tracer tests has a degree of uncertainty. At this time it is proposed that the tracer tests be monitored for 17 weeks from the time of tracer injection. Results of the monthly monitoring will be provided to the Trust every other month via email updates. At the end of the proposed monitoring period, a teleconference will be held with the Trust to review the results of the tracer tests and discuss proposed locations along the barrier wall for the CPT investigation. Areas where preferential flow or compromised integrity is suspected will be further investigated using the proposed CPT surveys.

A final report combining the results of the geophysics survey, the tracer tests, and the CPT investigation will be integrated into the Remedial Investigation Report for Operable Unit 1. This will be a comprehensive report describing the data and field work from all three investigations and will provide conclusions regarding the integrity of the barrier wall in the regions investigated.

8. SCHEDULE

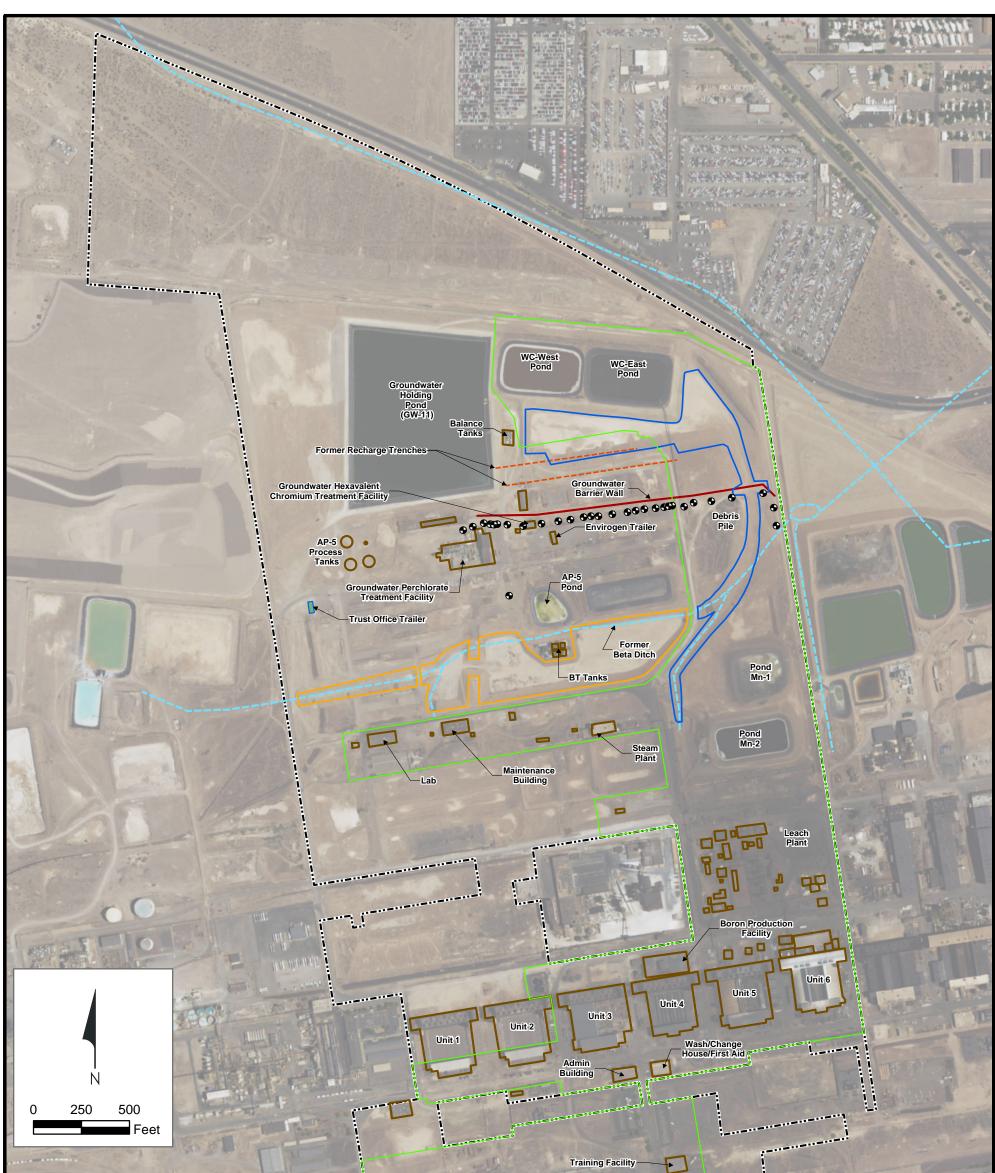
This Project schedule is divided into 5 distinct tasks: a document review, a geophysical survey, a tracer test, a CPT investigation, and analysis and reporting. These are scheduled to run sequentially. Upon receiving NDEP approval of this Work Plan, it is anticipated that the work will be performed along the timeline proposed in the schedule below:

Task Description	Time Required
Task 1. Document Review	3 to 5 weeks
Task 2. Geophysical Survey	12 to 15 weeks
Task 3. Tracer Testing	27 to 30 weeks
Task 2. CPT Investigation	5 to 7 weeks
Task 3. Data Analysis and Reporting.	5 to 7 weeks

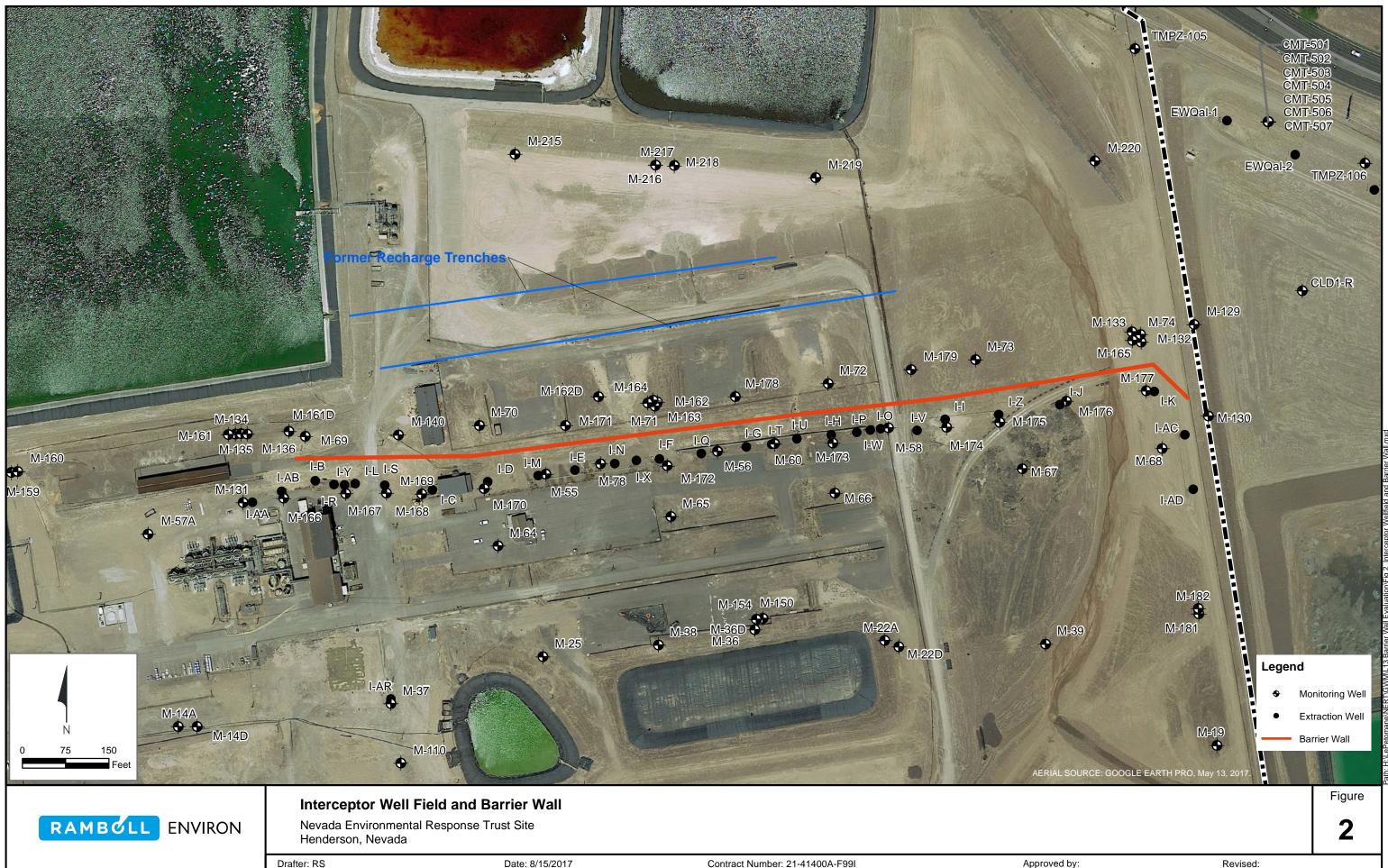
9. REFERENCES

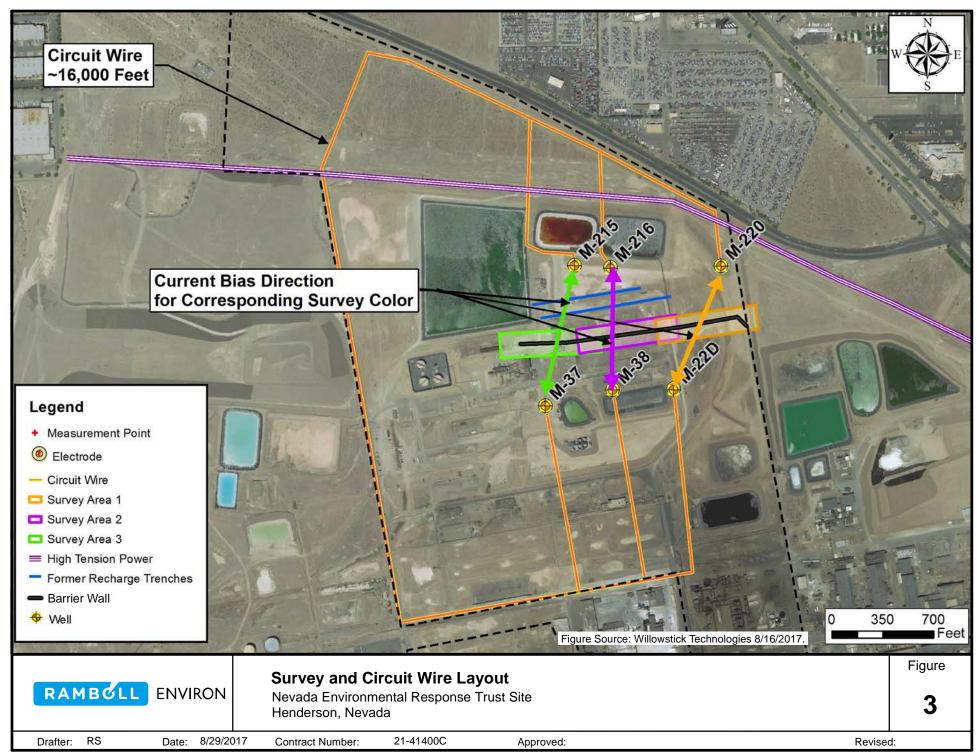
- Nevada Division of Environmental Protection (NDEP), 2001. Administrative Order on Consent. October.
- Nevada Division of Environmental Protection (NDEP), 2015. Response to: Semi-Annual Remedial Performance Report for Chromium and Perchlorate, Nevada Environmental Response Trust Site; Henderson, Nevada. May 20.
- Northgate Environmental Management, Inc., 2010a. Memorandum. Results of Barrier Wall Permeability Testing, Tronox Facility, Henderson, Nevada. September 29.
- Northgate Environmental Management, Inc., 2010b. Capture Zone Evaluation Report; Tronox Facility, Henderson, Nevada. December 3.
- ENVIRON, 2014a. Field Sampling Plan, Revision 1; Nevada Environmental Response Trust Site; Henderson, Nevada. July 18. NDEP approved August 1, 2014.
- ENVIRON, 2014b. Health and Safety Plan for Remedial Investigation and General Site Activities, Revision 1; Nevada Environmental Response Trust Site; Henderson, Nevada. July 18. NDEP approved August 1, 2014.
- ENVIRON, 2014c. Quality Assurance Project Plan, Revision 1; Nevada Environmental Response Trust Site; Henderson, Nevada. July 18. NDEP approved August 1, 2014.
- Ramboll Environ, 2016. Annual Remedial Performance Report for Chromium and Perchlorate, Nevada Environmental Response Trust Site; Henderson, Nevada. October 31.
- Ramboll Environ, 2017. Site Management Plan, Revision 3; Nevada Environmental Response Trust Site; Henderson, Nevada, February 13.
- Kerr McGee Corporation, 2001a. Soil-Bentonite Slurry Cutoff Wall Specifications
- Kerr McGee Corporation, 2001b. Perchlorate Remediation Monthly Progress Report, Letter to NDEP Todd Croft, December 5.

FIGURES

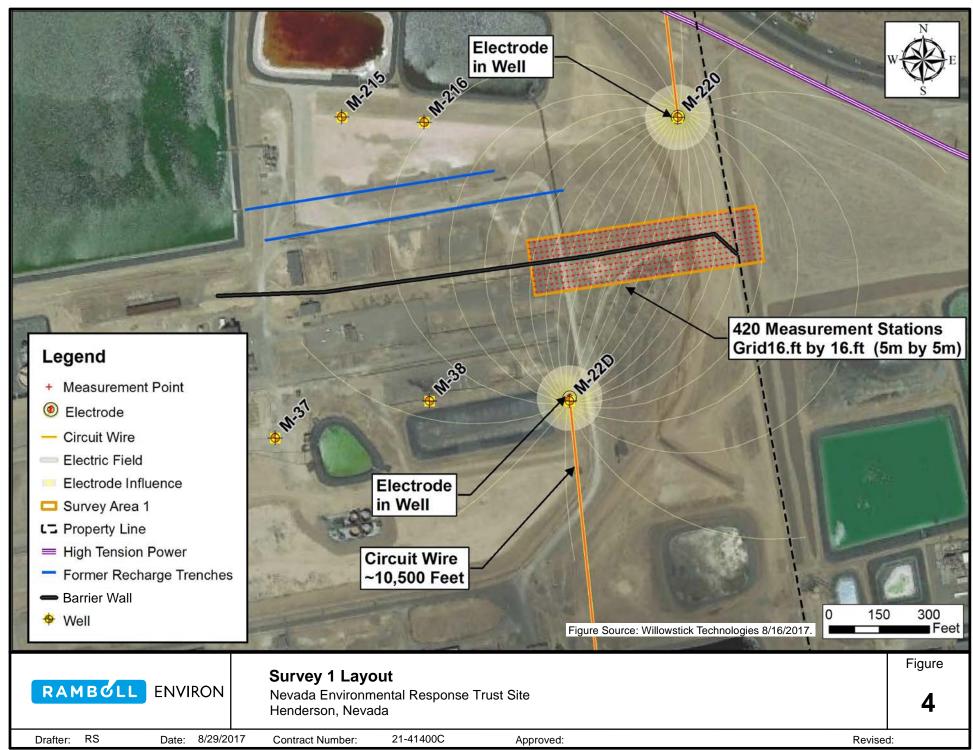


11-	Warehouse	
Legend		60 3 1 1 - S
Extraction Well NERT Site Boundary Tronox Leasehold Central Retention Basin		
Northern Retention Basin Facility Area Features (Buildings and Tanks)		Al and a second
Groundwater Barrier Wall Former Ditches	Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swissto Community	ipo, and the GIS User
RAMBOLL ENVIRON	Overview of Site Nevada Environmental Response Trust Site, Henderson, Nevada	Figure 1
2200 Powell St., Suite 700, Emeryville, CA 94608	Drafter: RS Date: 9/1/2017 Contract Number: 21-41400C Approved by:	Revised:

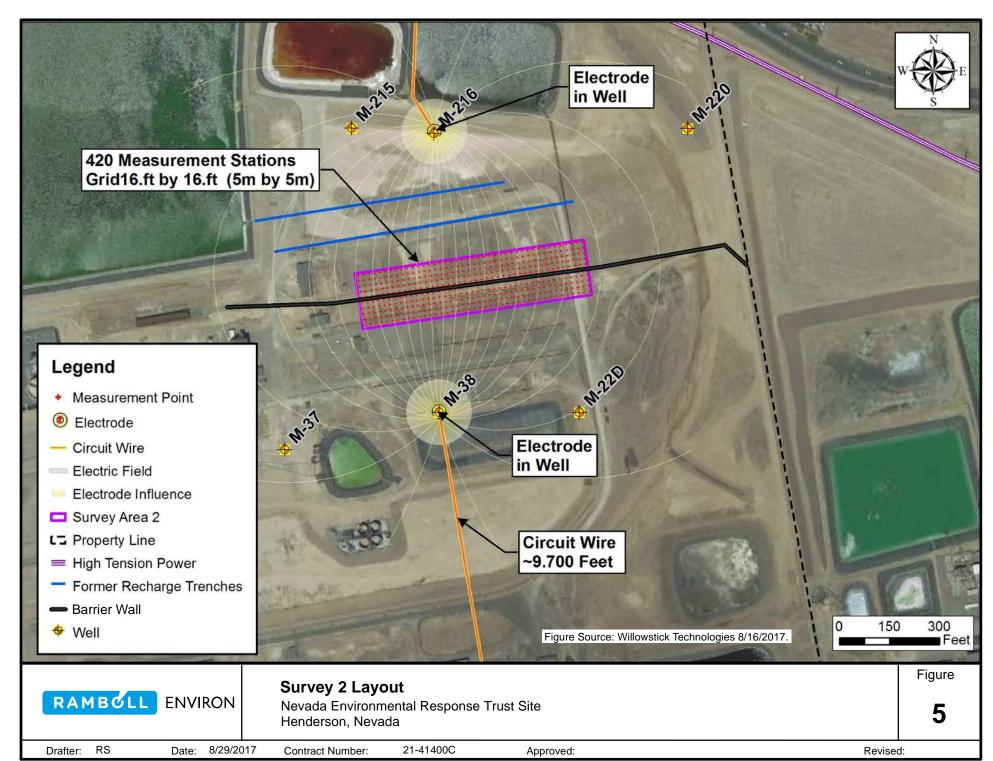




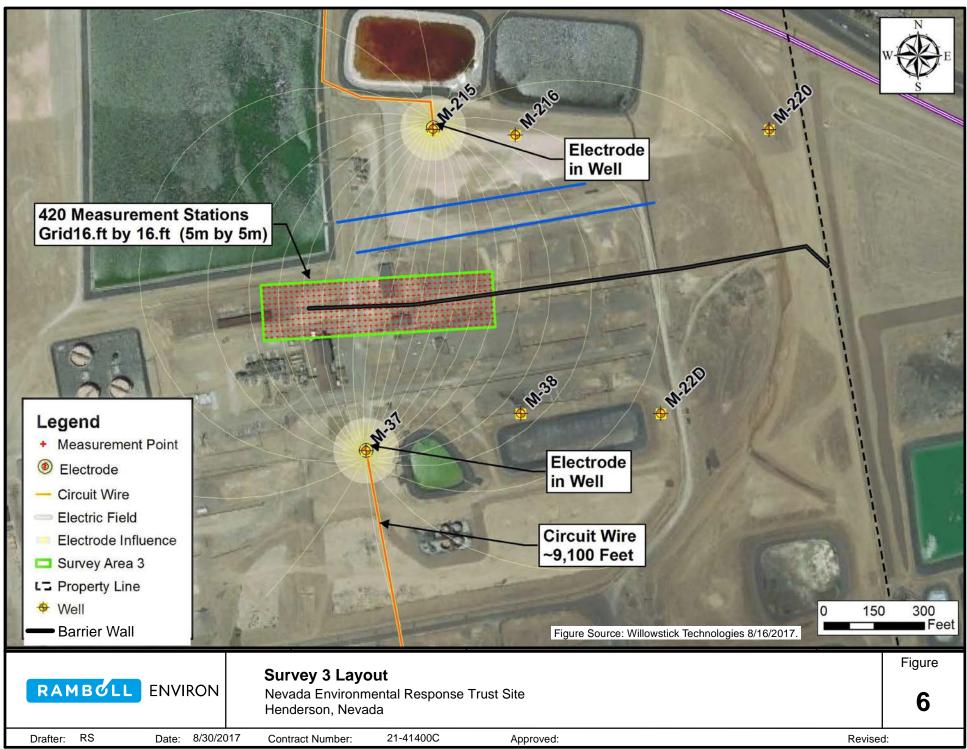
Path: H:\LePetomane\NERT\GWM\L13 Barrier Wall Evaluation\Fig 3_Survey Layout.mxd



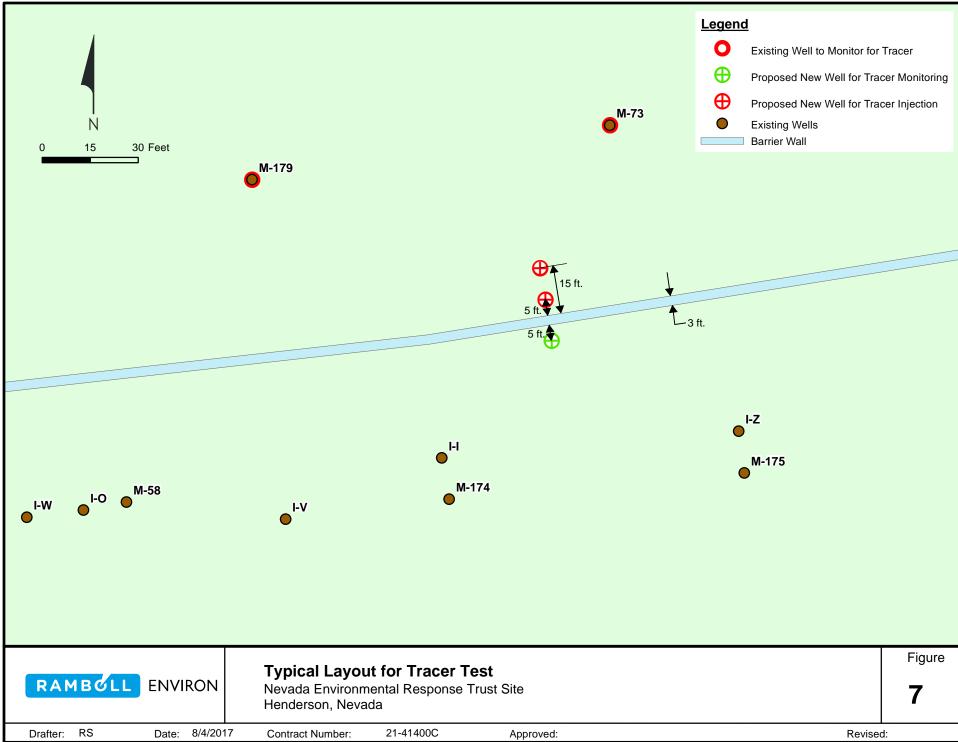
Path: H:\LePetomane\NERT\GWM\L13 Barrier Wall Evaluation\Fig 4_Survey 1 Layout.mxd



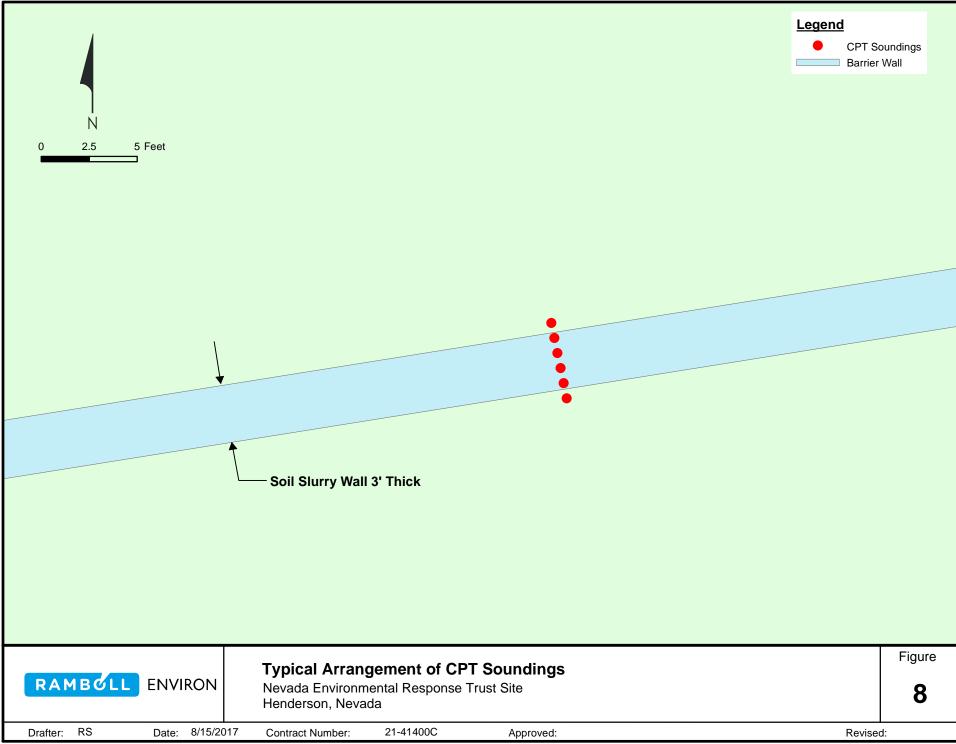
Path: H:\LePetomane\NERT\GWM\L13 Barrier Wall Evaluation\Fig 5_Survey 2 Layout.mxd



Path: H:\LePetomane\NERT\GWM\L13 Barrier Wall Evaluation\Fig 6_Survey 3 Layout.mxd



Path: H:\LePetomane\NERT\GWM\L13 Barrier Wall Evaluation\Fig 7_Typical Layout for Tracer Test.mxd



Path: H:\LePetomane\NERT\GWM\L13 Barrier Wall Evaluation\Fig 8_Typical Arrangement of CPT Borings.mxd

APPENDIX A SAFETY DATA SHEETS FOR DYE TRACERS



SAFETY DATA SHEET (SDS) REVISION DATE: 03/03/2016

Color your everything, may your Hue come true

SECTION I. IDENTIFICATION OF THE SUBSTANCE/MIXTURE AND OF THE COMPANY/UNDERTAKING

PRODUCT IDENTIFIER:

PRODUCT NAME	HUE EOSINE EX CONC
PRODUCT NUMBER	1-C6-087-XPC
COLOR INDEX NAME	ACID RED 087
COLOR INDEX NO	45380
C. A. S. #	17372-87-1
CHEMICAL FAMILY	XANTHENE DYE

INTENDED USE OF THE PRODUCT:

FELT TIP, MARKER INKS, WATER BASED COATINGS AND SPECIALTY INKS, PRINTING ON NYLON, SILK AND WOOL.

NAME, ADDRESS AND TELEPHONE OF RESPONSIBLE PARTY:

HUE CORPORATION	TELEPHONE	714-389-3130
P.O. BOX 509	FAX	714-389-9731
TUSTIN, CA 92781	EMAIL	SUPPORT@HUECORPORATION.COM

EMERGENCY TELEPHONE NUMBER:

CHEMTREC (USA)	1-800-424-9300
CHEMTREC (OUTSIDE USA)	1-703-527-3887

SECTION 2. HAZARD(S) IDENTIFICATION

CLASSIFICATION OF THE SUBSTANCE OR MIXTURE:

GHS-US

ACUTE TOX. - INHALATION (CATEGORY 5) EYE DAM./IRRITATION (CATEGORY 2B) SKIN CORR./IRRITATION (CATEGORY 3)

GHS LABELING:

HAZARD PICTOGRAMS (GHS-US): NO SYMBOL

SIGNAL WORD WARNING

HAZARD STATEMENT(S)	H333 - MAY BE HARMFUL IF INHALED
	H320 - CAUSES EYE IRRITATION
	H316 - CAUSES MILD SKIN IRRITATION

PRECAUTIONARY STATEMENTS P305 + 351 + P338 - IF IN EYES: RINSE CAUTIOUSLY WITH WATER FOR

		SEVERAL MINUTES. REMOVE CONTACT LENSES IF PRESENT AND EASY TO DO. CONTINUE RINSING. P337 + P313 - IF EYE IRRITATION OCCURS/PERSISTS: GET MEDICAL ADVICE AND ATTENTION. P261 - AVOID BREATHING DUST/FUMES/GAS/MIST/VAPORS/SPRAY P264 - WASH FACE THOROUGHLY AFTER HANDLING. P322 + P313 - IF SKIN IRRITATION OCCURS: GET MEDICAL ADVICE/ ATTENTION. P304 + 312 - IF INHALED: CALL A POISON CENTER/DOCTOR/PHYSICIAN IF YOU FEEL UNWELL P501 - DISPOSE OF CONTENTS/ CONTAINER IN ACCORDANCE WITH LOCAL/ REGIONAL/ NATIONAL INTERNATIONAL REGULATIONS.			
OTHER HAZARDS UNKNOWN ACUT	OTHER HAZARDS NO DATA AVAILABLE UNKNOWN ACUTE TOXICITY NO DATA AVAILABLE				
SECTION 3. COMI DESCRIPTION OF			N INGREDIENTS XTURE OF DYES.		
SUBSTANCE:					
NAME		C.A.S.#	WEIGHT 100%	GHS-US CLASSIFICATION	
ACID RED 087		17372-87-1	100%	ACUTE TOX INHALATION (CATEGORY 5) EYE DAM./IRRITATION (CATEGORY 2B) SKIN CORR./IRRITATION (CATEGORY 3)	
SECTION 4. FIRS	T AID MEASUR	ES			
FIRST AID MEASU					
INHALATION:	REMOVE TO FRESH AIR. IF BREATHING IS DIFFICULT, GIVE OXYGEN AND GET IMMEDIATE MEDICAL ATTENTION.				
SKIN:	WASH WITH MILD SOAP AND WATER. IF IRRITATION OCCURS GET MEDICAL ATTENTION. IF CLOTHING IS CONTAMINATED, RE-MOVE AND WASH BEFORE REUSE.				
EYES:	FLUSH EYES WITH WATER FOR AT LEAST 15 MINUTES, HOLDING EYELIDS APART FOR THOROUGH IRRIGATION. GET IMMEDIATE MEDICAL ATTENTION.				
INGESTION: INDUCE VOMITING - SEEK IMMEDIATE MEDICAL ATTENTION.					
MOST IMPORTANT SYMPTOMS AND EFFECTS, ACUTE AND DELAYED:					
THIS PRODUCT IS NOT HAZARDOUS AS DEFINED BY HAZARDOUS COMMUNICATION STANDARD. HOWEVER, AS WITH ALL CHEMICAL; HANDLE WITH CARE, AVOID EYE AND SKIN CONTACT, AVOID INHALATION OF DUSTS OR VAPORS. WASH THOROUGHLY AFTER HANDLING. KEEP CONTAINERS CLOSED.					

SECTION 5. FIRE-FIGHTING MEASURES

EXTINGUISHING MEDIA:

WATER, DRY CHEMICAL, CARBON DIOXIDE, FOAM.

SPECIAL HAZARDS ARISING FROM SUBSTANCE OR MEDIA:

FIREFIGHTERS SHOULD BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS TO GUARD AGAINST POTENTIALLY TOXIC AND IRRITATING FUMES. AVOID DUSTING. DUST CAN FORM EXPLOSIVE MIXTURES WITH AIR.

PROTECTION/ADVICE FOR FIREFIGHTER(S):

BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS AND PROTECTIVE CLOTHING.

SECTION 6. ACCIDENTAL RELEASE MEASURES

PERSONAL PRECAUTIONS:

REMOVE PERSONS FROM DANGER AREA.

ENVIROMENTAL PRECAUTIONS:

AVOID ANY UNCONTROLLED RELEASE OF MATERIAL. DO NOT EMPTY INTO DRAINS OR THE AQUATIC ENVIRONMENT.

EMERGENCY PROCEDURES:

NO ADDITIONAL INFORMATION

METHODS AND MATERIALS FOR CONTAMINENT AND CLEANING UP:

WHERE SPILLS ARE POSSIBLE, A COMPREHENSIVE SPILL RESPONSE PLAN SHOULD BE DEVELOPED AND IMPLEMENTED. AVOID ANY UNCONTROLLED RELEASE OF MATERIAL.

UTILIZE RECOMMENDED PROTECTIVE CLOTHING AND EQUIPMENT (SEE SECTION 8). SPILLS SHOULD BE SWEPT UP USING AN ABSORBENT DUST CONTROL PRODUCT AND PLACED IN CONTAINERS. SPILL AREA CAN BE WASHED WITH WATER. COLLECT WATER FOR APPROVED DISPOSAL. IN THE EVENT OF UNCONTROLLED RELEASE OF THIS MATERIAL, THE USER SHOULD DETERMINE IF THE RELEASE IS REPORTABLE UNDER APPLICABLE LAWS AND REGULATIONS.

SECTION 7. HANDLING AND STORAGE

PRECAUTIONS FOR SAFE HANDLING:

HANDLE WITH CARE. AVOID OVER EXPOSURE. USE NIOSH/OSHA APPROVED RESPIRATOR, WORK GLOVES, AND CLOTHING. WASH AFTER HANDLING. SENSITIVE INDIVIDUALS MAY EXPERIENCE RESPIRATORY ALLERGIES. MAY CAUSE SKIN IRRITATION. USE WITH LOCAL VENTILATION.

CONDITIONS FOR SAFE STORAGE, INCLUDING ANY INCOMPATIBILITIES:

USE PROCESS ENCLOSURES, LOCAL EXHAUST VENTILATION OR OTHER ENGINEERING CONTROLS TO KEEP AIRBORNE LEVELS BELOW RECOMMENDED EXPOSURE LIMITS.

KEEP AWAY FROM HEAT. KEEP AWAY FROM SOURCES OF IGNITION.

KEEP AWAY FROM STRONG OXIDIZING AND REDUSING AGENTS.

SPECIFIC END USES:

FELT TIP, MARKER INKS, WATER BASED COATINGS AND SPECIALTY INKS, PRINTING ON NYLON, SILK AND WOOL.

SECTION 8. EXPOSURE CONTROLS / PERSONAL PROTECTION

CONTROL PARAMETERS:

INGREDIENTS WITH LIMIT VALUES THAT REQUIRE MONITORING AT THE WORKPLACE - NOT REQUIRED

EXPOSURE CONTROLS:

APPROPRIATE ENGINEERING CONTROLS - THE USUAL PRECAUTIONARY MEASURES ARE TO BE ADHERED TO WHEN HANDLING CHEMICALS.

PERSONAL PROTECTIVE EQUIPMENT:



HAND PROTECTION	WEAR IMPERMEABLE RUBBER OR PLASTIC GLOVES
EYE PROTECTION	TIGHTLY SEALED SAFETY GOGGLES OR FULL FACE SIDE SHIELDS.
SKIN AND BODY	APRON, COVERALLS AND NON-LEATHER SOLED WORK SHOES.
	WASH DYE CONTAMINATED CLOTHES AND SKIN WITH MILD SOAP AND
	DETERGENTS.
RESPIRATORY	WEAR OSHA/NIOSH APPROVED DUST MASK/RESPIRATOR
HYGIENE MEASURES	HANDLE IN ACCORDANCE WITH GOOD INDUSTRIAL HYGIENE AND SAFETY
	PRACTICES. WASH HANDS AFTER HANDLING MATERIAL.
OTHER PROTECTION	DELUGE SAFETY SHOWER AND EYE WASH STATION SHOULD BE LOCATED
	NEAR WORK AREA.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

INFORMATION ON BASIC PHYSICAL AND CHEMICAL PROPERTIES :

APPEARANCE, COLOR, ODOR	POWDER, NO ODOR
рН	7.0 - 8.5
MELTING POINT/FREEZING POINT	ND
INITIAL BOILING POINT/BOILING RANGE	0.00
FLASHPOINT	NOT APPLICABLE
EVAPORATION RATE	NO DATA
FLAMMABILITY (SOLID,GAS)	NORMALLY STABLE, NOT COMBUSTIBLE NOR FLAMMABLE
UPPER EXPLOSIVE LIMITS	NA
LOWER EXPLOSIVE LIMITS	NA
VAPOR PRESSURE	NA
VAPOR DENSITY	NA
RELATIVE DENSITY	NA

SOLUBILITY IN WATER SOLUBLE PARTITION COEFFICIENT N-OCTANOL/WATER NO DATA AUTO-IGNITION TEMPERATURE NO DATA DECOMPOSITION TEMPERATURE NO DATA VISCOSITY, DYNAMIC NO DATA VISCOSITY, CINEMATIC NO DATA **EXPLOSIVE PROPERTIES** N/A OXIDIZING PROPERTIES NA OTHER INFORMATION NA

SECTION 10. STABILITY AND REACTIVITY

CHEMICAL STABILITYSTABLE UNDER NORMAL STORAGE AND HANDLING CONDITIONS.CONDITIONS TO AVOIDOXIDIZING & REDUCING AGENTS MAY DESTROY COLOR.INCOMPATIBLE MATERIALSOXIDIZING & REDUCING AGENTS MAY DESTROY COLOR.HAZARDOUS DECOMPOSITION PRODUCTS - CO, CO2, OXIDES OF NITROGEN AND OTHER POTENTIALLY
TOXIC FUMES.

SECTION 11. TOXICOLOGICAL INFORMATION

TOXICOLOGICAL EFFECTS :

EFFECTS TO EYES (ANIMAL)NO DATA AVAILABLESKIN IRRITATION (ANIMAL)NO DATA AVAILABLE	
SKIN CORROSION/IRRITATION NOT CLASSIFIED	
SERIOUS EYE DAMAGE/IRRITATION CAUSES SERIOUS EYE IRRITATION	
RESPIRATORY OR SKIN SENSITIZATION NOT CLASSIFIED	
GERM CELL MUTAGENICITY NOT CLASSIFIED	
CARCINOGENICITY NOT CLASSIFIED	
REPRODUCTIVE TOXICITY NOT CLASSIFIED	
SPECIFIC TARGET ORGAN TOXICITY (SINGLE EXPOSURE) MAY CAUSE DROWSINESS OR DIZZINESS.	
ASPIRATION HAZARD NOT CLASSIFIED	
INHALATION MAY CAUSE DROWSINESS OR DIZZINESS.	
EYE CONTACT CAUSES SERIOUS EYE IRRITATION.	
INGESTION INGESTION MAY CAUSE NAUSEA, VOMITING AND DIARRHEA	

SECTION 12. ECOLOGICAL INFORMATION

TOXICITY	NA
PERSISTENCE AND DEGRADABI	LITY
BIOACCUMULATIVE POTENTIAL	NA
MOBILITY IN SOIL	NA
OTHER ADVERSE EFFECTS	NA

NA

SECTION 13. DISPOSAL CONSIDERATION

WASTE DISPOSAL RECOMMENDATION :

EMPTY BAGS THOROUGHLY. CARRY OUT THE PROPER RECYLING, REUSAGE OR DISPOSAL. PLEASE REFER TO THE RELEVANT EU REGULATIONS, IN PARTICULAR THE GUIDELINES/DECISIONS OF THE COUNCIL REGARDING HANDLING OF WASTES (E.G. 75/442/EEC, 91/689/EEC, 94/67/EC, 94/904/EC) AS IMPLEMENTED IN NATIONAL REGULATIONS.

REGIONAL RECOMMENDATION :

BURY OR INCINERATE ACCORDANCE WITH FEDERAL, STATE AND LOCAL REGULATIONS.

CONTAINERS SHOULD NOT BE REUSED WITHOUT PROFESSIONAL CLEANING AND RECONDITIONING. OBSERVE ALL LABELED SAFEGUARDS UNTIL CLEANED, RECONDITIONED OR DESTROYED.

PLEASE REFER TO SECTION 8 (EXPOSURE CONTROLS / PERSONAL PROTECTION) OF THIS SDS.

SECTION 14. TRANSPORTATION INFORMATION		
UN NUMBER UN PROPER SHIPPING NAME	NONE NONE	
DEPARTMENT OF TRANSPORTATIO	ON (DOT) : NOT HAZARDOUS FOR TRANSPORTATION	
TRANSPORT HAZARD CLASS(ES)		
HAZARD LABLES (DOT) :		
PACKING GROUP (DOT) DOT SPECIAL PROVISIONS	NA NA	
ADDITIONAL INFORMATION:		
OVERLAND TRANSPORT TRANSPORT BY SEA AIR TRANSPORT DOT QUANTITY LIMITATIONS PASS DOT QUANTITY LIMITATIONS CARG	GO AIRCRAFT NA	
SECTION 15. REGULATORY INFOR	RMATION	
US FEDERAL REGULATIONS:		
THIS SUBSTANCE IS LISTED ON U	NITED STATES TSCA (TOXIC SUBSTANCE CONTROL ACT) INVENTORY.	
US STATE REGULATIONS:		
NONE		
CHEMICAL IDENTITY:		
17372-87-1 TSCA DSL X -	NDSL EINECS ELINCS ENCS CHINA KECL PICCS AICS	

TSCA STATUS IN COMPLIANCE E C CLASSIFICATION (67/548/EEC - 88/379/EEC) N/A EINECS NUMBER REACH CLASSIFICATION **R PHRASES** ADDITIONAL REGULATORY INFORMATION CONTAINS: <11PPM BENZENE, (CAS#71-43-2) <11PPM TOLUENE, (CAS#108-88-3) <11PPM XYLENES, (CAS#1330-20-7) SECTION 16. OTHER INFORMATION _____ **INDICATION OF CHANGES:** NA **OTHER INFORMATION:** NA GHS FULL TEXT PHRASES: MAY BE HARMFUL IF INHALED H333 CAUSES EYE IRRITATION H320 CASUES MILD SKIN IRRITATION H316 HEALTH FLAMMABILITY REACTIVITY PERSONAL PROT H. M. I. S. CLASSIFICATION: 0 0 D 1 HMIS CODE: 4 - SEVERE HAZARD, 3 - SERIOUS HAZARD, 2 - MODERATE HAZARD, 1 - SLIGHT HAZARD, 0 - MINIMAL HAZARD SAFETY DATA SHEET (SDS) **REVISION DATE: 03/03/2016**

ALL INFORMATION AND DATA APPEARING ON THIS SDS ARE BELIEVED TO BE RELIABLE AND ACCURATE. HOWEVER, IT IS THE USER'S RESPONSIBILITY TO DETERMINE THE SAFETY, TOXICITY, AND SUITABILITY FOR USE OF THE PRODUCT DESCRIBED. SINCE THE ACTUAL USE BY OTHERS IS BEYOND OUR CONTROL, NO GUARANTEE, EXPRESSED OR IMPLIED, IS MADE BY HUE CORPORATION. USER ASSUMES ALL RISK AND RESPONSIBILITY.



SAFETY DATA SHEET (SDS) REVISION DATE: 03/03/2016

Color your everything, may your Hue come true

SECTION I. IDENTIFICATION OF THE SUBSTANCE/MIXTURE AND OF THE COMPANY/UNDERTAKING

PRODUCT IDENTIFIER:

PRODUCT NAME	HUE URANINE CONC	(Also known as Fluorescein)
PRODUCT NUMBER		
COLOR INDEX NAME	ACID YELLOW 073	
COLOR INDEX NO	45350	
C. A. S. #	518-47-8	
CHEMICAL FAMILY	XANTHENE	

INTENDED USE OF THE PRODUCT:

FELT TIP, MARKER INKS, WATER BASED COATINGS AND LEAK DETECTION

NAME, ADDRESS AND TELEPHONE OF RESPONSIBLE PARTY:

HUE CORPORATION	TELEPHONE	714-389-3130
P.O. BOX 509	FAX	714-389-9731
TUSTIN, CA 92781	EMAIL	SUPPORT@HUECORPORATION.COM

EMERGENCY TELEPHONE NUMBER:

CHEMTREC (USA)	1-800-424-9300
CHEMTREC (OUTSIDE USA)	1-703-527-3887

SECTION 2. HAZARD(S) IDENTIFICATION

CLASSIFICATION OF THE SUBSTANCE OR MIXTURE:

GHS-US ACUTE TOX. - INHALATION (CATEGORY 5) EYE DAM./IRRITATION (CATEGORY 2B) SKIN CORR./IRRITATION (CATEGORY 3)

GHS LABELING:

HAZARD PICTOGRAMS (GHS-US): NO SYMBOL

SIGNAL WORD WARNING

HAZARD STATEMENT(S) H333 - MAY BE HARMFUL IF INHALED H320 - CAUSES EYE IRRITATION H316 - CAUSES MILD SKIN IRRITATION

PRECAUTIONARY STATEMENTS P305 + 351 + P338 - IF IN EYES: RINSE CAUTIOUSLY WITH WATER FOR SEVERAL MINUTES. REMOVE CONTACT LENSES IF PRESENT AND EASY

	-	GET MEDICAL ADVIO P261 - AVOID BREAT P264 - WASH FACE P322 + P313 - IF SKII ATTENTION. P304 + 312 - IF INHA IF YOU FEEL UNWEI NO DATA AVAILABLE	E IRRITATION OCCURS/PERSISTS: CE AND ATTENTION. THING DUST/FUMES/GAS/MIST/VAPORS/SPRAY THOROUGHLY AFTER HANDLING. N IRRITATION OCCURS: GET MEDICAL ADVICE/ LED: CALL A POISON CENTER/DOCTOR/PHYSICIAN LL
UNKNOWN ACUT	ETOXICITY	NO DATA AVAILABLE	<u>-</u>
SECTION 3. COM	POSITION / INFO	RMATION ON INGREDI	
DESCRIPTION O	MIXTURE: PROF	PRIETARY MIXTURE OF	DYES.
SUBSTANCE:			
NAME	C.A.S.#	WEIGHT 100%	GHS-US CLASSIFICATION
ACID YELLOW 073	518-47-8	100%	ACUTE TOX INHALATION (CATEGORY 5) EYE DAM./IRRITATION (CATEGORY 2B) SKIN CORR./IRRITATION (CATEGORY 3)
SECTION 4. FIRS	ST AID MEASURES	6	
FIRST AID MEAS			
INHALATION:	REMOVE TO FR		G IS DIFFICULT, GIVE OXYGEN AND GET IMMEDIATE
SKIN:	-		IF IRRITATION OCCURS GET MEDICAL ATTENTION. MOVE AND WASH BEFORE REUSE.
EYES:			AST 15 MINUTES, HOLDING EYELIDS APART IMEDIATE MEDICAL ATTENTION.
INGESTION:	INDUCE VOMIT	ING - SEEK IMMEDIATE	MEDICAL ATTENTION.
MOST IMPORTANT SYMPTOMS AND EFFECTS, ACUTE AND DELAYED:			
THIS PRODUCT IS NOT HAZARDOUS AS DEFINED BY HAZARDOUS COMMUNICATION STANDARD. HOWEVER, AS WITH ALL CHEMICAL; HANDLE WITH CARE, AVOID EYE AND SKIN CONTACT, AVOID INHALATION OF DUSTS OR VAPORS. WASH THOROUGHLY AFTER HANDLING. KEEP CONTAINERS CLOSED.			
SECTION 5. FIRE	-FIGHTING MEAS	SURES	

EXTINGUISHING MEDIA:

WATER, DRY CHEMICAL, CARBON DIOXIDE, FOAM.

SPECIAL HAZARDS ARISING FROM SUBSTANCE OR MEDIA:

FIREFIGHTERS SHOULD BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS TO GUARD AGAINST POTENTIALLY TOXIC AND IRRITATING FUMES. AVOID DUSTING. DUST CAN FORM EXPLOSIVE MIXTURES WITH AIR.

PROTECTION/ADVICE FOR FIREFIGHTER(S):

BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS AND PROTECTIVE CLOTHING.

SECTION 6. ACCIDENTAL RELEASE MEASURES

PERSONAL PRECAUTIONS:

REMOVE PERSONS FROM DANGER AREA.

ENVIROMENTAL PRECAUTIONS:

AVOID ANY UNCONTROLLED RELEASE OF MATERIAL. DO NOT EMPTY INTO DRAINS OR THE AQUATIC ENVIRONMENT.

EMERGENCY PROCEDURES:

NO ADDITIONAL INFORMATION

METHODS AND MATERIALS FOR CONTAMINENT AND CLEANING UP:

WHERE SPILLS ARE POSSIBLE, A COMPREHENSIVE SPILL RESPONSE PLAN SHOULD BE DEVELOPED AND IMPLEMENTED. AVOID ANY UNCONTROLLED RELEASE OF MATERIAL.

UTILIZE RECOMMENDED PROTECTIVE CLOTHING AND EQUIPMENT (SEE SECTION 8). SPILLS SHOULD BE SWEPT UP USING AN ABSORBENT DUST CONTROL PRODUCT AND PLACED IN CONTAINERS. SPILL AREA CAN BE WASHED WITH WATER. COLLECT WATER FOR APPROVED DISPOSAL. IN THE EVENT OF UNCONTROLLED RELEASE OF THIS MATERIAL, THE USER SHOULD DETERMINE IF THE RELEASE IS REPORTABLE UNDER APPLICABLE LAWS AND REGULATIONS.

SECTION 7. HANDLING AND STORAGE

PRECAUTIONS FOR SAFE HANDLING:

HANDLE WITH CARE. AVOID OVER EXPOSURE. USE NIOSH/OSHA APPROVED RESPIRATOR, WORK GLOVES, AND CLOTHING. WASH AFTER HANDLING. SENSITIVE INDIVIDUALS MAY EXPERIENCE RESPIRATORY ALLERGIES. MAY CAUSE SKIN IRRITATION. USE WITH LOCAL VENTILATION.

CONDITIONS FOR SAFE STORAGE, INCLUDING ANY INCOMPATIBILITIES:

USE PROCESS ENCLOSURES, LOCAL EXHAUST VENTILATION OR OTHER ENGINEERING CONTROLS TO KEEP AIRBORNE LEVELS BELOW RECOMMENDED EXPOSURE LIMITS.

KEEP AWAY FROM HEAT. KEEP AWAY FROM SOURCES OF IGNITION.

KEEP AWAY FROM STRONG OXIDIZING AND REDUSING AGENTS.

4

SPECIFIC END USES:

FELT TIP, MARKER INKS, WATER BASED COATINGS AND LEAK DETECTION

SECTION 8. EXPOSURE CONTROLS / PERSONAL PROTECTION

CONTROL PARAMETERS:

INGREDIENTS WITH LIMIT VALUES THAT REQUIRE MONITORING AT THE WORKPLACE - NOT REQUIRED

EXPOSURE CONTROLS:

APPROPRIATE ENGINEERING CONTROLS - THE USUAL PRECAUTIONARY MEASURES ARE TO BE ADHERED TO WHEN HANDLING CHEMICALS.

PERSONAL PROTECTIVE EQUIPMENT:



HAND PROTECTION EYE PROTECTION SKIN AND BODY	WEAR IMPERMEABLE RUBBER OR PLASTIC GLOVES TIGHTLY SEALED SAFETY GOGGLES OR FULL FACE SIDE SHIELDS. APRON, COVERALLS AND NON-LEATHER SOLED WORK SHOES. WASH DYE CONTAMINATED CLOTHES AND SKIN WITH MILD SOAP AND DETERGENTS.
RESPIRATORY HYGIENE MEASURES OTHER PROTECTION	WEAR OSHA/NIOSH APPROVED DUST MASK/RESPIRATOR HANDLE IN ACCORDANCE WITH GOOD INDUSTRIAL HYGIENE AND SAFETY PRACTICES. WASH HANDS AFTER HANDLING MATERIAL. DELUGE SAFETY SHOWER AND EYE WASH STATION SHOULD BE LOCATED NEAR WORK AREA.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

INFORMATION ON BASIC PHYSICAL AND CHEMICAL PROPERTIES :

APPEARANCE, COLOR, ODOR	YELLOW POWDER, NO ODOR
pH	8.0 - 9.0
MELTING POINT/FREEZING POINT	ND
INITIAL BOILING POINT/BOILING RANGE	0.00
FLASHPOINT	NORMALLY STABLE, NOT COMBUSTIBLE NOR FLAMMABLE
EVAPORATION RATE	NO DATA
FLAMMABILITY (SOLID,GAS)	NORMALLY STABLE, NOT COMBUSTIBLE NOR FLAMMABLE
UPPER EXPLOSIVE LIMITS	NA
LOWER EXPLOSIVE LIMITS	NA
VAPOR PRESSURE	NA
VAPOR DENSITY	NA
RELATIVE DENSITY	NA
SOLUBILITY IN WATER	SOLUBLE
PARTITION COEFFICIENT N-OCTANOL/WATER	NO DATA

AUTO-IGNITION TEMPERATURE	NO DATA
DECOMPOSITION TEMPERATURE	NO DATA
VISCOSITY, DYNAMIC	NO DATA
VISCOSITY, CINEMATIC	NO DATA
EXPLOSIVE PROPERTIES	N/A
OXIDIZING PROPERTIES	NA
OTHER INFORMATION	NA

SECTION 10. STABILITY AND REACTIVITY CHEMICAL STABILITY STABLE UNDER NORMAL STORAGE AND HANDLING CONDITIONS. CONDITIONS TO AVOID **OXIDIZING & REDUCING AGENTS MAY DESTROY COLOR.** INCOMPATIBLE MATERIALS **OXIDIZING & REDUCING AGENTS MAY DESTROY COLOR.** HAZARDOUS DECOMPOSITION PRODUCTS - CO, CO2, OXIDES OF NITROGEN AND OTHER POTENTIALLY TOXIC FUMES. SECTION 11. TOXICOLOGICAL INFORMATION TOXICOLOGICAL EFFECTS : **ORAL (ANIMAL** GREATER THAN 7,000 MG/KG - RAT DERMAL (ANIMAL) NA EFFECTS TO EYES (ANIMAL) EYES - RABBIT, NOT IRRITATING SKIN - RABBIT, SLIGHT IRRITANT SKIN IRRITATION (ANIMAL) SKIN CORROSION/IRRITATION NOT CLASSIFIED SERIOUS EYE DAMAGE/IRRITATION CAUSES EYE IRRITATION RESPIRATORY OR SKIN SENSITIZATION NOT CLASSIFIED GERM CELL MUTAGENICITY NOT CLASSIFIED CARCINOGENICITY NOT CLASSIFIED REPRODUCTIVE TOXICITY NOT CLASSIFIED SPECIFIC TARGET ORGAN TOXICITY (SINGLE EXPOSURE) MAY CAUSE DROWSINESS OR DIZZINESS. ASPIRATION HAZARD NOT CLASSIFIED INHALATION MAY CAUSE DROWSINESS OR DIZZINESS. EYE CONTACT CAUSES SERIOUS EYE IRRITATION. INGESTION INGESTION MAY CAUSE NAUSEA, VOMITING AND DIARRHEA

 SECTION 12. ECOLOGICAL INFORMATION

 TOXICITY
 NA

 PERSISTENCE AND DEGRADABILITY
 NA

 BIOACCUMULATIVE POTENTIAL
 NA

 MOBILITY IN SOIL
 LC-50 (LETHAL CONCENTRATION) UG = MICROGRAMS/LITER CHANNEL

 CATFISH - 2,267,000 UG/LITER
 RAINBOW TROUT - 1,372,000 UG/LITER

 BLUEGILL - 3,433,000 UG/LITER
 OTHER ADVERSE EFFECTS

 NA
 NA

SECTION 13. DISPOSAL CONSIDERATION

WASTE DISPOSAL RECOMMENDATION :

EMPTY BAGS THOROUGHLY. CARRY OUT THE PROPER RECYLING, REUSAGE OR DISPOSAL. PLEASE REFER TO THE RELEVANT EU REGULATIONS, IN PARTICULAR THE GUIDELINES/DECISIONS OF THE COUNCIL REGARDING HANDLING OF WASTES (E.G. 75/442/EEC, 91/689/EEC, 94/67/EC, 94/904/EC) AS IMPLEMENTED IN NATIONAL REGULATIONS.

REGIONAL RECOMMENDATION :

BURY OR INCINERATE ACCORDANCE WITH FEDERAL, STATE AND LOCAL REGULATIONS.

CONTAINERS SHOULD NOT BE REUSED WITHOUT PROFESSIONAL CLEANING AND RECONDITIONING. OBSERVE ALL LABELED SAFEGUARDS UNTIL CLEANED, RECONDITIONED OR DESTROYED.

PLEASE REFER TO SECTION 8 (EXPOSURE CONTROLS / PERSONAL PROTECTION) OF THIS SDS.

SECTION 14. TRANSPORTATION INFORMATION		
UN NUMBER NON UN PROPER SHIPPING NAME NON	—	
DEPARTMENT OF TRANSPORTATION (DC	DT): NOT HAZARDOUS FOR TRANSPORTATION	
TRANSPORT HAZARD CLASS(ES)		
HAZARD LABLES (DOT) :		
PACKING GROUP (DOT) NA DOT SPECIAL PROVISIONS NA		
ADDITIONAL INFORMATION:		
OVERLAND TRANSPORTNONTRANSPORT BY SEANONAIR TRANSPORTNONDOT QUANTITY LIMITATIONS PASSENGEDOT QUANTITY LIMITATIONS CARGO AIR	E E R AIRCRAFT NA	
SECTION 15. REGULATORY INFORMATIC	DN	
US FEDERAL REGULATIONS: THE SUBSTANCES IS LISTED ON UNITED STATES TSCA (TOXIC SUBSTANCE CONTROL ACT) INVENTORY.		
US STATE REGULATIONS:		
NONE		
CHEMICAL IDENTITY:		
518-47-8 TSCA DSL NDSL EINE X	CS ELINCS ENCS CHINA KECL PICCS AICS	

TSCA STATUS IN COMPLIANCE E C CLASSIFICATION (67/548/EEC - 88/379/EEC) N/A EINECS NUMBER REACH CLASSIFICATION R PHRASES ADDITIONAL REGULATORY INFORMATION

SECTION 16. OTHER INFORMATION

INDICATION OF CHANGES:

NA

OTHER INFORMATION:

NA

GHS FULL TEXT PHRASES:

MAY BE HARMFUL IF INHALEDH333CAUSES EYE IRRITATIONH320CASUES MILD SKIN IRRITATIONH316

 HEALTH
 FLAMMABILITY
 REACTIVITY
 PERSONAL PROT

 H. M. I. S. CLASSIFICATION:
 1
 0
 0
 D

 HMIS CODE:
 4 - SEVERE HAZARD, 3 - SERIOUS HAZARD, 2 - MODERATE HAZARD, 1 - SLIGHT HAZARD, 0 - MINIMAL HAZARD
 D

SAFETY DATA SHEET (SDS) REVISION DATE: 03/03/2016

ALL INFORMATION AND DATA APPEARING ON THIS SDS ARE BELIEVED TO BE RELIABLE AND ACCURATE. HOWEVER, IT IS THE USER'S RESPONSIBILITY TO DETERMINE THE SAFETY, TOXICITY, AND SUITABILITY FOR USE OF THE PRODUCT DESCRIBED. SINCE THE ACTUAL USE BY OTHERS IS BEYOND OUR CONTROL, NO GUARANTEE, EXPRESSED OR IMPLIED, IS MADE BY HUE CORPORATION. USER ASSUMES ALL RISK AND RESPONSIBILITY.



Safety Data Sheet INTRACID RHODAMINE WT LIQUID

Safety Data Sheet dated: 5/13/2015 - version 1 Date of first edition: 5/13/2015

1. IDENTIFICATION

Product identifier

Mixture identification:

Trade name: INTRACID RHODAMINE WT LIQUID

Other means of identification:

Trade code: A45171566

Recommended use of the chemical and restrictions on use

Recommended use: Industrial color additive

Restrictions on use: Not Determined

Name, address, and telephone number of the chemical manufacturer, importer, or other responsible party

Sensient Colors LLC 2515 N. Jefferson 63106 St. Louis, MO (USA) Phone: 1 800-325-8110 Emergency Number(CHEMTREC): 1-800-424-9300

2. HAZARD(S) IDENTIFICATION

The identity of the individual components of this product is proprietary information and is considered a trade secret pursuant to 29 CFR 1910.1200

Hazardous components as defined in the OSHA Hazard Communication Standard: components with a HEALTH hazard (carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, etc..) and/or a PHYSICAL hazard (a combustible liquid, a compressed gas, explosive, flammable, an organic peroxide, an oxidizer, pyrophoric, unstable (reactive) or water-reactive, etc.)



Classification of the chemical

Eye Irrit. 2B Causes eye irritation

Label elements

Symbols:

() Warning

Code	Description
H315	Causes skin irritation.
H320	Causes eye irritation
Code	Description
P264	Wash Thoroughly after handling.
P280	Wear protective gloves/protective clothing/eye protection/face protection.
P302+P352	IF ON SKIN: Wash with plenty of water/
P305+P351+P33 8 P321	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Specific treatment (see On this label).
P332+P313	If skin irritation occurs: Get medical advice/attention.
P337+P313	If eye irritation persists: Get medical advice/attention.

P362+P364 Take off contaminated clothing and wash it before reuse.

Ingredient(s) with unknown acute toxicity:

None

Hazards not otherwise classified identified during the classification process:

None

3. COMPOSITION/INFORMATION ON INGREDIENTS

Substances

Not Determined

Mixtures

Hazardous components within the meaning of 29 CFR 1910.1200 and related classification:

1.1.4	- 6	
LISU	01	components

Qty	Name	Ident. Numb.	Classification	Registration Number
10-12.5 %	RHODAMINE LIQUID	CAS:65392-81-6 EC:265-730-6	Skin Irrit. 2, H315; Eye Irrit. 2B, H320	
10-12.5 %	RHODAMINE LIQUID	CAS: 75701-30-3 EC: 278-292-6	Skin Irrit. 2, H315; Eye Irrit. 2B, H320	
1-3 %	TRIMELLITIC ACID	CAS: 528-44-9 EC: 208-432-3	Skin Irrit. 2, H315; Eye Irrit. 2A, H319; STOT SE 3, H335	

4. FIRST AID MEASURES

Description of first aid measures

In case of skin contact:

Immediately take off all contaminated clothing and shoes.

Immediately remove any contaminated clothing, shoes or stockings.

After contact with skin, wash immediately with soap and plenty of water.

In case of eye contact:

Wash immediately and thoroughly with running water, keeping eyelids regularly raised, for at least 15 minutes. Cold water may be used. Check for and remove any contact lenses at once. OBTAIN A MEDICAL EXAMINATION.

Protect the eyes with a sterile gauze or a clean, dry handkerchief.

In case of ingestion:

Do not induce vomiting, get medical attention showing the MSDS and label hazardous.

In case of inhalation:

Remove casualty to fresh air and keep warm and at rest.

Most important symptoms/effects, acute and delayed

Eye irritation

Eye damages

Skin Irritation

Erythema

Indication of any immediate medical attention and special treatment needed

In case of accident or unwellness, seek medical advice immediately (show directions for use or safety data sheet if possible).

5. FIRE-FIGHTING MEASURES

Extinguishing media

Suitable extinguishing media:

Water, CO2, foam, chemical powders, according to the materials involved in the fire.

In case of fire, use foam, dry chemical, CO2.

Unsuitable extinguishing media:

None in particular.

Specific hazards arising from the chemical

Do not inhale explosion and combustion gases.

Burning produces heavy smoke.

Hazardous combustion products: Not Determined

Explosive properties: Not Determined

Oxidising properties: Not Determined

Special protective equipment and precautions for fire-fighters

Use suitable breathing apparatus .

Collect contaminated fire extinguishing water separately. This must not be discharged into drains. Move undamaged containers from immediate hazard area if it can be done safely.

6. ACCIDENTAL RELEASE MEASURES

Personal precautions, protective equipment and emergency procedures

Wear personal protection equipment.

Remove persons to safety.

See protective measures under point 7 and 8.

Methods and material for containment and cleaning up

Suitable material for taking up: dry and inert absorbing material (e.g. vermiculite, sand, earth).

Wash with plenty of water.

7. HANDLING AND STORAGE

Precautions for safe handling

Avoid contact with skin and eyes, inhalation of vapours and mists.

Don't use empty container before they have been cleaned.

Before making transfer operations, assure that there aren't any incompatible material residuals in the containers.

Contamined clothing should be changed before entering eating areas.

Do not eat or drink while working.

See also section 8 for recommended protective equipment.

Conditions for safe storage, including any incompatibilities

Storage temperature: Not Determined

Incompatible materials:

None in particular.

Instructions as regards storage premises:

Adequately ventilated premises.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Control parameters

No Data Available

Appropriate engineering controls: Not Determined

Individual protection measures

Eye/face protection:

Use close fitting safety goggles, don't use eye lens.

Skin protection:

Use clothing that provides comprehensive protection to the skin, e.g. cotton, rubber, PVC or viton.

Hand protection:

Use protective gloves that provide comprehensive protection, e.g. P.V.C., neoprene or rubber.

Respiratory protection:

Not Determined

9. PHYSICAL AND CHEMICAL PROPERTIES

Information on basic physical and chemical properties

Physical State Liquid Appearance: Liquid, Odour: Not Determined Odour threshold: Not Determined pH: 10.50 Melting point/ range: Not Determined Boiling point/ range: Not Determined Flash point: > 100°C / 212°F Evaporation rate: Not Determined Upper/lower flammability or explosive limits: Not Determined Vapour density: Not Determined Vapour pressure: Not Determined Density: Not Determined Water solubility: Not Determined Lipid solubility: Not Determined Partition coefficient (n-octanol/water): Not Determined Auto-ignition temperature: Not Determined Decomposition temperature: Not Determined Viscosity: Not Determined Explosive properties: Not Determined Oxidising properties: Not Determined Flammability (Solid, Gas): Not Determined

Other information

Substance group relevant properties: Not Determined Miscibility: Not Determined Fat Solubility: Not Determined Conductivity: Not Determined

10. STABILITY AND REACTIVITY

Reactivity

Stable under normal conditions.

Chemical stability

Data not Available.

Possibility of hazardous reactions

Burning produces carbon monoxide and/or carbon dioxide.

Conditions to avoid

Stable under normal conditions of temperature and pressure.

Incompatible materials

Avoid strong oxidizing agents, peroxides, acids, alkali metals.

Hazardous decomposition products

Burning produces carbon monoxide and/or carbon dioxide.

11. TOXICOLOGICAL INFORMATION

Information on toxicological effects

Toxicological information of the product: No Data Available

Substance(s) listed on the IARC Monographs:

None

Substance(s) listed as OSHA Carcinogen(s):

None

Substance(s) listed as NIOSH Carcinogen(s):

None

Substance(s) listed on the NTP report on Carcinogens:

None

12. ECOLOGICAL INFORMATION

Toxicity

Adopt good working practices, so that the product is not released into the environment.

Eco-toxicity:

List of Eco-Toxicological properties of the product

No Data Available

Persistence and degradability

Not Determined

Bioaccumulative potential

Not Determined

Mobility in soil

Not Determined

Other adverse effects

Not Determined

13. DISPOSAL CONSIDERATIONS

Waste treatment methods

Recover if possible. In so doing, comply with the local and national regulations currently in force.

14. TRANSPORT INFORMATION

UN number

ADR-UN number: N/A DOT-UN Number: N/A IATA-Un number: N/A IMDG-Un number: N/A

UN proper ship	oping name
	ADR-Shipping Name: N/A
	DOT Proper Shipping Name: N/A
	IATA-Technical name: N/A
	IMDG-Technical name: N/A
Transport haza	ard class(es)
-	ADR-Class: N/A
	DOT Hazard Class: N/A
	IATA-Class: N/A
	IMDG-Class: N/A
Packing group	
	ADR-Packing Group: N/A
	Exempted for ADR: N/A
	IATA-Packing group: N/A
	IMDG-Packing group: N/A
Environmental	
	Marine pollutant: No
	Environmental Pollutant: Not Determined
Transport in b	ulk according to Annex II of MARPOL73/78 and the IBC Code
	Not Determined
Special precau	
	Transportation (DOT):
	DOT-Special Provision(s): N/A
	DOT Label(s): N/A
	DOT Symbol: N/A
	DOT Cargo Aircraft: N/A
	DOT Passenger Aircraft: N/A
	DOT/TDG Bulk: N/A
	DOT Non-Bulk: N/A
Road and Rail (A	ADR-RID):
	ADR-Label: N/A
	ADR-Upper number: N/A
	ADR Tunnel Restriction Code: N/A
Air (IATA):	
、	IATA-Passenger Aircraft: N/A
	IATA-Cargo Aircraft: N/A
	IATA-Label: N/A
	IATA-Sub Risk: N/A
	IATA-Erg: N/A
	IATA-Special Provisioning: N/A
Sea (IMDG):	·····
	IMDG-Stowage Code: N/A
	IMDG-Stowage Note: N/A
	IMDG-Sub Risk: N/A
	IMDG-Special Provisioning: N/A
	IMDG-Page: N/A
	IMDG-Label: N/A
	IMDG-EMS: N/A
	IMDG-MFAG: N/A
15. REGULAT	ORY INFORMATION

USA - Federal regulations

TSCA - Toxic Substances Control Act

TSCA inventory:

All the components are listed on the TSCA inventory

TSCA listed substances:

RHODAMINE LIQUID	
RHODAMINE LIQUID	
TRIMELLITIC ACID	

is listed in TSCA Section 8b is listed in TSCA Section 8b is listed in TSCA Section 8b, Section 5

Section 302 - Extremely Hazardous Substances:

no substances listed

Section 304 - Hazardous substances:

no substances listed

Section 313 - Toxic chemical list:

no substances listed

CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act

Substance(s) listed under CERCLA:

no substances listed

CAA - Clean Air Act

CAA listed substances:

no substances listed

CWA - Clean Water Act

CWA listed substances:

no substances listed

USA - State specific regulations

California Proposition 65

Substance(s) listed under California Proposition 65:

no substances listed

Massachusetts Right to know

Substance(s) listed under Massachusetts Right to know:

no substances listed

Pennsylvania Right to know

Substance(s) listed under Pennsylvania Right to know:

no substances listed

New Jersey Right to know

Substance(s) listed under New Jersey Right to know:

no substances listed

16. OTHER INFORMATION

- Code Description
- H315 Causes skin irritation.
- H319 Causes serious eye irritation.
- H320 Causes eye irritation
- H335 May cause respiratory irritation.

Safety Data Sheet dated: 5/13/2015 - version 1

The information contained herein is based on our state of knowledge at the above-specified date. It refers solely to the product indicated and constitutes no guarantee of particular quality. The information relates only to the specific material and may not be valid for such material used in combination with any other material or in any process.

This document was prepared by a competent person who has received appropriate training.

It is the duty of the user to ensure that this information is appropriate and complete with respect to the specific use intended.

This MSDS cancels and replaces any preceding release.

Legend to abbreviations and acronyms used in the safety data sheet:

ADR: European Agreement concerning the International Carriage of Dangerous Goods by Road.

RID: Regulation Concerning the International Transport of Dangerous Goods by Rail

IMDG: International Maritime Code for Dangerous Goods

IATA: International Air Transport Association

IATA-DGR: Dangerous Goods Regulation by the "International Air Transport Association" (IATA)

ICAO: International Civil Aviation Organization

ICAO-TI: Technical Instructions by the "International Civil Aviation Organization" (ICAO)

GHS: Globally Harmonized System of Classification and Labeling of Chemicals

CLP: Classification, Labeling, Packaging

EINECS: European Inventory of Existing Commercial Chemical Substances

INCI: International Nomenclature of Cosmetic Ingredients

CAS: Chemical Abstracts Service (division of the American Chemical Society)

GefStoffVO: Ordnance on Hazardous Substances, Germany

LC50: Lethal concentration, for 50 percent of test population

LD50: Lethal dose, for 50 percent of test population

DNEL: Derived No Effect Level

PNEC: Predicted No Effect Concentration

TLV: Threshold Limiting Value

TWATLV: Threshold Limiting Value for the Time Weighted Average 8 hour day. (ACGIH Standard)

STEL: Short Term Exposure limit

STOT: Specific Target Organ Toxicity

WGK: German Water Hazard Class

KSt: Explosion coefficient

y for the damage.

Barrier Wall Integrity Field Evaluation Work Plan Nevada Environmental Response Trust Site Henderson, Nevada

APPENDIX B PROCEDURES AND CRITERIA ANALYSIS OF FLUORESCENT DYES



PROCEDURES AND CRITERIA ANALYSIS OF FLUORESCENT DYES IN WATER AND CHARCOAL SAMPLERS:

FLUORESCEIN, EOSINE, RHODAMINE WT, AND SULFORHODAMINE B DYES

Revision Date: March 3, 2015

Thomas Aley, PHG, PG President and Shiloh L. Beeman, PG Sr. Hydrogeologist

Ozark Underground Laboratory, Inc. 1572 Aley Lane Protem, Missouri 65733 417-785-4289 contact@ozarkundergroundlab.com

INTRODUCTION

This document describes standard procedures and criteria currently in use at the Ozark Underground Laboratory (OUL) as of the date shown on the title page. Some samples may be subjected to different procedures and criteria because of unique conditions; such non-standard procedures and criteria are identified in reports for those samples. Standard procedures and criteria change as knowledge and experience increases and as equipment is improved or upgraded. The OUL maintains a summary of changes in standard procedures and criteria.

TRACER DYES AND SAMPLE TYPES

Dye Nomenclature

Dye manufacturers and retailers use a myriad of names for the dyes. This causes confusion among dye users and report readers. The primary dyes used at the OUL and described in this document are included in Table 1 below.

OUL Common Name	Color Index Number	Color Index Name	Other Names
Fluorescein	45350	Acid Yellow 73	uranine, uranine C, sodium fluorescein, fluorescein LT and fluorescent yellow/green
Eosine	45380 Acid Red 87 eosin, eosine		eosin, eosine OJ, and D&C Red 22
Rhodamine WT	e WT None Acid Red 388 fluorescent red (but n assigned rhodamine B)		fluorescent red (but not the same as rhodamine B)
Sulforhodamine B	45100	Acid Red 52	pontacyl brilliant pink B, lissamine red 4B, and fluoro brilliant pink

Table 1.	Primary	OUL Dye	Nomenclature.
----------	---------	---------	---------------

The OUL routinely provides dye for tracing projects. Dyes purchased for groundwater tracing are always mixtures that contain both dye and an associated diluent. Diluents enable the manufacturer to standardize the dye mixture so that there are minimal differences among batches. Additionally, diluents are often designed to make it easier to dissolve the dye mixture in water, or to produce a product which meets a particular market need (groundwater tracing is only a tiny fraction of the dye market). The percent of dye in "as-sold" dye mixtures often varies dramatically among manufacturers and retailers, and retailers are sometimes incorrect about the percent of dye in their products. The OUL subjects all of its dyes to strict quality control (QC) testing. Table 2 summarizes the as-sold dye mixtures used by the OUL.

OUL Common Name	Form	Dye Equivalent		
Fluorescein Powder		75% dye equivalent, 25% diluent		
Eosine	Powder	75% dye equivalent, 25% diluent		
Rhodamine WT	Liquid	20% dye equivalent, 80% diluent		
Sulforhodamine B	Powder	75% dye equivalent, 25% diluent		

Table 2. As-Sold Dye Mixtures at the OUL.

Analytical results are based on the as-sold weights of the dyes provided by the OUL. The use of dyes from other sources is discouraged due to the wide variability of dye equivalents within the market. However, if alternate source dyes are used, a sample should be provided to the OUL for quality control and to determine if a correction factor is necessary for the analytical results.

Types of Samples

Typical samples that are collected for fluorescent tracer dye analysis include charcoal samplers (also called activated carbon or charcoal packets) and water samples.

The charcoal samplers are packets of fiberglass screening partially filled with 4.25 grams of activated coconut charcoal. The charcoal used by the OUL is Calgon 207C coconut shell carbon, 6 to 12 mesh, or equivalent. The most commonly used charcoal samplers are about 4 inches long by 2 inches wide. A cigar-shaped sampler is made for use in very small diameter wells (such as 1-inch diameter piezometers); this is a special order item and should be specifically requested in advance when needed. All of the samplers are closed by heat sealing.

In specialized projects, soil samples have been collected from soil cores and analyzed for fluorescent tracer dyes. Project-specific procedures have been developed for projects such as these. For additional information, please contact the OUL.

FIELD PROCEDURES

Field procedures included in this section are intended as guidance, and not firm requirements. Placement of samplers and other field procedures require adjustment to field conditions. Personnel at the OUL are available to provide additional assistance for implementation of field procedures specific to specialized field conditions.

Placement of Samplers

Charcoal samplers are placed so as to be exposed to as much water as possible. Water should flow through the packet. In springs and streams they are typically attached to a rock or other anchor in a riffle area. Attachment of the packets often uses plastic tie wires. In swifter water galvanized wire (such as electric fence wire) is often used. Other types of anchoring wire can be used. Electrical wire with plastic insulation is also good. Packets are attached so that they extend outward from the anchor rather than laying flat against it. Two or more separately anchored packets are typically used for sampling springs and streams. The placement of multiple packets is recommended in order to minimize the chance of loss during the sampling period. The use of fewer packets is discouraged except when the spring or stream is so small that there is not appropriate space for placing multiple packets.

When pumping wells are being sampled, the samplers are typically placed in sample holders made of plastic pipe fittings. Brass hose fittings can be at the end of the sample holders so that the sample holders can be installed on outside hose bibs and water which has run through the samplers can be directed to waste through a connected garden hose. The samplers can be unscrewed in the middle so that charcoal packets can be changed. The middle portions of the samplers consist of 1.5 inch diameter pipe and pipe fitting.

Charcoal packets can be lowered into monitoring wells for sampling purposes. In general, if the well is screened, samplers should be placed approximately in the middle of the screened interval. Due to the typically lower volume of water that flows through a well, only one charcoal sampler should be used per well. However, multiple packets can be placed in a single well at depths to test different depth horizons when desirable. A weight should be added near the charcoal packet to ensure that it will not float. The weight should be of such a nature that it will not affect water quality. One common approach is to anchor the packets with a white or uncolored plastic cable tie to the top of a dedicated weighted disposable bailer. We typically run nylon cord from the top of the well to the charcoal packet and its weight. *Do not use colored cord* since some of them are colored with fluorescent dyes. Nylon fishing line should not be used since it can be readily cut by a sharp projection in the well.

In some cases, especially with small diameter wells and appreciable well depths, the weighted disposable bailers sink very slowly or may even fail to sink because of friction and floating of the anchoring cord. In such cases a weight may be added to the top of the disposable bailer. Stainless steel weights are ideal, but are not needed in all cases. All weights should be cleaned prior to use; the cleaning approach should comply with decontamination procedures in use at the project site.

Optional Preparation of Charcoal Samplers

Charcoal packets routinely contain some fine powder that washes off rapidly when they are placed in water. While not usually necessary, the following optional preparation step is suggested if the fine charcoal powder is problematic.

Charcoal packets can be triple rinsed with distilled, demineralized, or reagent water known to be free of tracer dyes. This rinsing is typically done by soaking. With this approach,

approximately 25 packets are placed in one gallon of water and soaked for at least 10 minutes. The packets are then removed from the water and excess water is shaken off the packets. The packets are then placed in a second gallon of water and again soaked for at least 10 minutes. After this soaking they are removed from the water and excess water is shaken off the packets. The packets are then placed in a third gallon of water and the procedure is again repeated. Rinsed packets are placed in plastic bags and are placed at sampling stations within three days. Packets can also be rinsed in jets of water for about one minute; this requires more water and is typically difficult to do in the field with water known to be free of tracer dyes.

Collection and Replacement of Samplers

Samplers are routinely collected and replaced at each of the sampling stations. The frequency of sampler collection and replacement is determined by the nature of the study. Collections at one week intervals are common, but shorter or longer collection frequencies are acceptable and sometimes more appropriate. Shorter sampling frequencies are often used in the early phases of a study to better characterize time of travel. As an illustration, we often collect and change charcoal packets 1, 2, 4, and 7 days after dye injection. Subsequent sampling is then weekly.

The sampling interval in wells at hazardous wastes sites should generally be no longer than about a week. Contaminants in the water can sometimes use up sorption sites on the charcoal that would otherwise adsorb the dye. This is especially important if the dye might pass in a relatively short duration pulse.

Where convenient, the collected samplers should be briefly rinsed in the water being sampled to remove dirt and accumulated organic material. This is not necessary with well samples. The packets are shaken to remove excess water. Next, the packet (or packets) are placed in a plastic bag (Whirl-Pak® bags are ideal). The bag is labeled on the outside with a black permanent type felt marker pen, such as a Sharpie®. *Use only pens that have black ink*; colored inks may contain fluorescent dyes. The notations include station name or number and the date and time of collection. Labels must not be inserted inside the sample bags.

Collected samplers are kept in the dark to minimize algal growth on the charcoal prior to analysis work. New charcoal samplers are routinely placed when used charcoal packets are collected. The last set of samplers placed at a stream or spring is commonly not collected.

Water Samples

Water samples are often collected. They should be collected in either glass or plastic; the OUL routinely uses 50 milliliter (mL) research-grade polypropylene copolymer Perfector Scientific vials (Catalog Number 2650) for such water samples. No more than 30 mL of water is required for analysis. The sides of the vials should be labeled with the project name, sample ID, sample date and time with a black permanent felt tip pen. *Do not label the lid only*. The vials should be placed in the dark and refrigerated immediately after collection, and maintained under refrigeration until shipment. The OUL supplies vials for the collection of water samples.

Sample Shipment

When water or charcoal samplers are collected for shipment to the OUL they should be shipped promptly. We prefer (and in some studies require) that samples be refrigerated with frozen re-usable ice packs upon collection and that they be shipped refrigerated with frozen ice packs by overnight express. *Do not ship samplers packed in wet ice* since this can create a potential for cross contamination when the ice melts. Our experience indicates that it is not essential for samplers to be maintained under refrigeration; yet maintaining them under refrigeration clearly minimizes some potential problems. A product known as "green ice" should not be used for maintaining the samples in a refrigerated condition since this product contains a dye which could contaminate samples if the "green ice" container were to break or leak.

We receive good overnight and second day air service from both UPS and FedEx. The U.S. Postal Service does not typically provide next day service to us. DHL does not provide overnight service to us. FedEx is recommended for international shipments. The OUL does not receive Saturday delivery.

Each shipment of charcoal samplers or water samples *must be accompanied by a sample custody document*. The OUL provides a sheet (which bears the title "Samples for Fluorescence Analysis") that can be used if desired. These sheets can be augmented by a client's chain-of-custody forms or any other relevant documentation. OUL's custody document works well for charcoal samplers because it allows for both the placement date and time as well as the collection date and time. Many other standard chain-of-custody documents do not allow for these types of samples. Attachment 1 includes a copy of OUL's Sample Collection Data Sheet.

Please write legibly on the custody documents and *use black ink*. Check the accuracy of the sample sheet against the samples prior to shipment to identify and correct errors that may delay the analysis of your samples following receipt at the laboratory.

Supplies Provided by the OUL

The OUL provides supplies for the collection of fluorescent tracer dyes. Supplies provided upon request are charcoal packets, Whirl-Pak® bags (to contain the charcoal packets after collection for shipment to the laboratory), and water vials. These supplies are subjected to strict QA/QC procedures to ensure the materials are free of any potential tracer dye contaminants. The charge for these materials is included in the cost of sample analysis. Upon request, coolers and re-freezable ice packs are also provided for return shipment of samples.

The OUL also has tracer dyes available for purchase. These dyes are subject to strict QA/QC testing. All analytical work is based upon the OUL as-sold weight of the dyes.

LABORATORY PROCEDURES

The following procedures are followed upon receipt of samples at the laboratory.

Receipt of Samples

Samplers shipped to the OUL are logged in and refrigerated upon receipt. Prior to cleaning and analysis, samplers are assigned a laboratory identification number.

It sometimes occurs that there are discrepancies between the sample collection data sheet and the actual samples received. When this occurs, a "Discrepancy Sheet" form is completed and sent to the shipper of the sample for resolution. The purpose of the form is to help resolve discrepancies, even when they may be minor. Many discrepancies arise from illegible custody documents. *Please write legibly* on the custody documents and *use black ink*. Check the accuracy of the sample sheet against the samples prior to shipment to identify and correct errors that may delay the analysis of your samples following receipt at the laboratory.

Cleaning of Charcoal Samplers

Samplers are cleaned by spraying them with jets of clean water from a laboratory well in a carbonate aquifer. OUL uses non-chlorinated water for the cleansing to minimize dye deterioration. We do not wash samplers in public water supplies. Effective cleansing cannot generally be accomplished simply by washing in a conventional laboratory sink even if the sink is equipped with a spray unit.

The duration of packet washing depends upon the condition of the sampler. Very clean samplers may require less than a minute of washing; dirtier samplers may require several minutes of washing.

Elution of the Charcoal

There are various eluting solutions that can be used for the recovery of tracer dyes. The solutions typically include an alcohol, water, and a strong basic solution such as aqueous ammonia and /or potassium hydroxide.

The standard elution solution used at the OUL is a mixture of 5% aqua ammonia and 95% isopropyl alcohol solution and sufficient potassium hydroxide pellets to saturate the solution. The isopropyl alcohol solution is 70% alcohol and 30% water. The aqua ammonia solution is 29% ammonia. The potassium hydroxide is added until a super-saturated layer is visible in the bottom of the container. This super-saturated layer is not used for elution. Preparation of eluting solutions uses dedicated glassware which is never used in contact with dyes or dye solutions.

The eluting solution will elute fluorescein, eosine, rhodamine WT, and sulforhodamine B dyes. It is also suitable for separating fluorescein peaks from peaks of some naturally present materials found in may be found in samplers.

Fifteen mL of the eluting solution is poured over the washed charcoal in a disposable sample beaker. The sample beaker is capped. The sample is allowed to stand for 60 minutes. After this time, the liquid is carefully poured off the charcoal into a new disposable beaker which has been appropriately labeled with the laboratory identification number. A few grains of charcoal may inadvertently pass into the second beaker; no attempt is made to remove these from the second sample beaker. After the pouring, a small amount of the elutant will remain in the initial sample beaker. After the transfer of the elutant to the second sample beaker, the contents of the first sample beaker (the eluted charcoal) are discarded. Samples are kept refrigerated until analyzed.

pH Adjustment of Water Samples

The fluorescence intensity of several of the commonly used fluorescent tracer dyes is pH dependent. The pH of samples analyzed for fluorescein, eosine, and pyranine dyes are adjust to a target pH of greater than 9.5 in order to obtain maximum fluorescence intensities.

Adjustment of pH is achieved by placing samples in a high ammonia atmosphere for at least two hours in order to increase the pH of the sample. Reagent water standards are placed in the same atmosphere as the samples. If dye concentrations in a sample are off-scale and require dilution for quantification of the dye concentration, the diluting water used is OUL reagent water that has been pH adjusted in a high ammonia atmosphere. Samples that are only analyzed for rhodamine WT or sulforhodamine B are not required to be pH adjusted.

Analysis on the Shimadzu RF-5301

The OUL uses a Shimadzu spectrofluorophotometer model RF-5301. This instrument is capable of synchronous scanning. The OUL also owns a Shimadzu RF-540 spectrofluorometers that is occasionally used for special purposes.

A sample of the elutant or water is withdrawn from the sample container using a disposable polyethylene pipette. Approximately 3 mL of the sample is then placed in disposable rectangular polystyrene cuvette. The cuvette has a maximum capacity of 3.5 mL. The cuvette is designed for fluorometric analysis; all four sides and the bottom are clear. The acceptable spectral range of these cuvettes is 340 to 800 nm. The pipettes and cuvettes are discarded after one use.

The cuvette is then placed in the RF-5301. This instrument is controlled by a programmable computer and operated by proprietary software developed for dye tracing applications.

Our instruments are operated and maintained in accordance with the manufacturer's recommendations. On-site installation of our first instrument and a training session on its use was provided by the instrument supplier. Repairs are made by a Shimadzu-authorized repairman.

Our typical analysis of an elutant sample where fluorescein, eosine, rhodamine WT, or sulforhodamine B dyes may be present includes synchronous scanning of excitation and emission spectra with a 17 nm separation between excitation and emission wavelengths. For these dyes,

the excitation scan is from 443 to 613 nm; the emission scan is from 460 to 630 nm. The emission fluorescence from the scan is plotted on a graph. The typical scan speed setting is "fast" on the RF-5301. The typical sensitivity setting used is "high."

Table 3. Excitation	and emission slit	width settings	routinely used	for dye analysis.
---------------------	-------------------	----------------	----------------	-------------------

Parameter	Excitation Slit (nm)	Emission Slit (nm)
ES, FL, RWT, and SRB in elutant	3	1.5
ES, FL, RWT, and SRB in water	5	3

Note: ES = Eosine. FL = Fluorescein. RWT = Rhodamine WT. SRB = Sulforhodamine B.

The instrument produces a plot of the synchronous scan for each sample; the plot shows emission fluorescence only. The synchronous scans are subjected to computer peak picks using proprietary software; peaks are picked to the nearest 0.1 nm. Instrument operators have the ability to manually adjust peaks as necessary based upon computer-picked peaks and experience. All samples run on the RF-5301 are stored electronically with sample information. All samples analyzed are recorded in a bound journal.

Quantification

We calculate the magnitude of fluorescence peaks for fluorescein, eosine, rhodamine WT, and sulforhodamine B dyes in both elutant and water samples. Dye quantities are expressed in microgram per liter (parts per billion; ppb). The dye concentrations are calculated by separating fluorescence peaks due to dyes from background fluorescence on the charts, and then calculating the area within the fluorescence peak. This area is proportional to areas obtained from standard solutions.

We run dye concentration standards each day the RF-5301 is used. Six standards are used; the standard or standards appropriate for the analysis work being conducted are selected. All standards are based upon the as-sold weights of the dyes. The standards are as follows:

- 1) 10 ppb fluorescein and 100 ppb rhodamine WT in well water from the Jefferson City-Cotter Formation
- 2) 10 ppb eosine in well water from the Jefferson City-Cotter Formation
- 3) 100 ppb sulforhodamine B in well water from the Jefferson City-Cotter Formation.
- 4) 10 ppb fluorescein and 100 ppb rhodamine WT in elutant.
- 5) 10 ppb eosine in elutant.
- 6) 100 ppb sulforhodamine B in elutant.

Preparation of Standards

Dye standards are prepared as follows:

<u>Step 1.</u> A small sample of the as-sold dye is placed in a pre-weighed sample vial and the vial is again weighed to determine the weight of the dye. We attempt to use a sample weighing between 1 and 5 grams. This sample is then diluted with well water to make a 1% dye solution by weight (based upon the as-sold weight of the dye). The resulting dye solution is allowed to sit for at least four hours to ensure that all dye is fully dissolved.

<u>Step 2.</u> One part of each dye solution from Step 1 is placed in a mixing container with 99 parts of well water. Separate mixtures are made for fluorescein, rhodamine WT, eosine, and sulforhodamine B. The resulting solutions contain 100 mg/L dye (100 parts per million dye mixture). The typical prepared volume of this mixture is appropriate for the sample bottles being used; we commonly prepare about 50 mL of the Step 2 solutions. The dye solution from Step 1 that is used in making the Step 2 solution is withdrawn with a digital Finnpipette which is capable of measuring volumes between 0.200 and 1.000 mL at intervals of 0.005 mL. The calibration certificate with this instrument indicates that the accuracy (in percent) is as follows:

At 0.200 mL, 0.90%

At 0.300 mL, 0.28%

At 1.000 mL, 0.30%

The Step 2 solution is called the long term standard. OUL experience indicates that Step 2 solutions, if kept refrigerated, will not deteriorate appreciably over periods of less than a year. Furthermore, these Step 2 solutions may last substantially longer than one year.

<u>Step 3.</u> A series of intermediate-term dye solutions are made. Approximately 45 mL. of each intermediate-term dye solution is made. All volume measurements of less than 5 mL are made with a digital Finnpipette. (see description in Step 2). All other volume measurements are made with Rheinland Kohn Geprufte Sicherheit 50 mL capacity pump dispenser which will pump within plus or minus 1% of the set value. The following solutions are made; all concentrations are based on the as-sold weight of the dyes:

1) 1 ppm fluorescein dye and 10 ppm rhodamine WT dye.

2) 1 ppm eosine.

3) 10 ppm sulforhodamine B dye.

<u>Step 4.</u> A series of six short-term dye standards are made from solutions in Step 3. These standards were identified earlier in this section. In the experience of the OUL these standards have a useful shelf life in excess of one week. However, in practice, Step 4 elutant standards are made weekly, and Step 4 water standards are made daily.

Dilution of Samples

Samples with peaks that have arbitrary fluorescence unit values of 500 or more are diluted a hundred fold to ensure accurate quantification.

Some water samples have high turbidity or color which interferes with accurate detection and measurement of dye concentrations. It is often possible to dilute these samples and then measure the dye concentration in the diluted sample.

The typical dilutions are either 10 fold (1:10) or 100 fold (1:100). A 1:10 dilution involves combining one part of the test sample with 9 parts of water (if the sample is water) or elutant (if the sample is elutant). A 1:100 dilution involves combining one part of the test sample is combined with 99 parts of water or elutant, based upon the sample media. Typically, 0.300 mL of the test solution is combined with 29.700 mL of water (or elutant as appropriate) to yield a new test solution.

All volume measurements of less than 5 mL are made with a digital Finnpipette. All other volume measurements are made with Rheinland Kohn Geprufte Sicherheit 50 mL capacity pump dispenser which will pump within plus or minus 1% of the set value.

The water used for dilution is from a carbonate aquifer. All dilution water is pH adjusted to greater than pH 9.5 by holding it in open containers in a high ammonia concentration chamber. This adjustment takes a minimum of two hours.

Quality Control

Laboratory blanks are run for every sample where the last two digits of the laboratory numbers are 00, 20, 40, 60, or 80. A charcoal packet is placed in a pumping well sampler and at least 25 gallons of unchlorinated water is passed through the sampler at a rate of about 2.5 gallons per minute. The sampler is then subjected to the same analytical protocol as all other samplers.

System functioning tests of the analytical instruments are conducted in accordance with the manufacturer's recommendations. Spiked samples are also analyzed when appropriate for quality control purposes.

All materials used in sampling and analysis work are routinely analyzed for the presence of any compounds that might create fluorescence peaks in or near the acceptable wavelength ranges for any of the tracer dyes. This testing includes approximately 1% of materials used.

Project specific QA/QC samples may include sample replicates and sample duplicates. A replicate sample is when a single sample is analyzed twice. A sample duplicate is where two samples are collected in a single location and both are analyzed. Sample replicates and duplicates are run for QA/QC purposes upon request of the client. These results are reported in the Certificate of Analysis.

Reports

Sample analysis results are typically reported in a Certificate of Analysis. However, specialized reports are provided in accordance with the needs of the client. Certificates of Analysis typically provide a listing of station number, sample ID, and dye concentrations if detected. Standard data format includes deliverables in MS Excel and Adobe Acrobat (.pdf)

format. Hard copy of the data package, and copies of the analytical charts are available upon request.

Work at the OUL is directed by Mr. Thomas Aley. Mr. Aley has 45 years of professional experience in hydrology and hydrogeology. He is certified as a Professional Hydrogeologist (Certificate #179) by the American Institute of Hydrology and licenced as a Professional Geologist in Missouri, Arkansas, Kentucky, and Alabama. Additional details regarding laboratory qualifications are available upon request.

Waste Disposal

All laboratory wastes are disposed of according to applicable state and federal regulations. Waste elutant and water samples are collected in 15 gallon poly drums and disposed with a certified waste disposal facilityas non-hazardous waste.

In special cases, wastes for a particular project may be segregated and returned to the client upon completion of the project. These projects may have samples that contain contaminants that the client must account for all materials generated and disposed. These situations are managed on a case-by-case basis.

CRITERIA FOR DETERMINATION OF POSITIVE DYE RECOVERIES

Normal Emission Ranges and Detection Limits

The OUL has established normal emission fluorescence wavelength ranges for each of the four dyes described in this document. The normal acceptable range equals mean values plus and minus two standard deviations. These values are derived from actual groundwater tracing studies conducted by the OUL.

The detection limits are based upon concentrations of dye necessary to produce emission fluorescence peaks where the signal to noise ratio is 3. The detection limits are realistic for most field studies since they are based upon results from actual field samples rather than being based upon values from spiked samples in a matrix of reagent water or the elutants from unused activated carbon samplers. In some cases detection limits may be smaller than reported if the water being sampled has very little fluorescent material in it. In some cases detection limits may be greater than reported; this most commonly occurs if the sample is turbid due to suspended material or a coloring agent such as tannic compounds. Turbid samples are typically allowed to settle, centrifuged, or, if these steps are not effective, diluted prior to analysis.

Table 4 provides normal emission wavelength ranges and detection limits for the four dyes when analyzed on the OUL's RF-5301 for samples analyzed as of March 3, 2015.

Table 4. RF-5301 Spectrofluorophotometer. Normal emission wavelength ranges and detection
limits for fluorescein, eosine, rhodamine WT, and sulforhodamine B dyes in water and elutant
samples.

Fluorescent Dye	t Dye Normal Acceptable Emission Wavelength Range (nm)		Detection Limit (ppb)		
	Elutant	Water	Elutant	Water	
Eosine	539.3 to 545.1	532.5 to 537.0	0.050	0.015	
Fluorescein	514.1 to 519.2	505.9 to 509.7	0.025	0.002	
Rhodamine WT	564.6 to 571.2	571.9 to 577.2	0.170	0.015	
Sulforhodamine B	575.2 to 582.0	580.1 to 583.7	0.080	0.008	

Note: Detection limits are based upon the as-sold weight of the dye mixtures normally used by the OUL. Fluorescein and eosine detection limits in water are based on samples pH adjusted to greater than 9.5.

It is important to note that the normal acceptable emission wavelength ranges are subject to change based on instrument maintenance, a change in instrumentation, or slight changes in dye formulation. Significant changes in normal acceptable emission wavelength ranges will be updated in this document as they occur.

Fluorescence Background

Due to the nature of fluorescence analysis, it is important to identify and characterize any potential background fluorescence at dye introduction and monitoring locations prior to the introduction of any tracer dyes.

There is generally little or no detectable fluorescence background in or near the general range of eosine, rhodamine WT, and sulforhodamine B dyes encountered in most groundwater tracing studies. There is often some fluorescence background in or near the range of fluorescein dye present at some of the stations used in groundwater tracing studies.

Criteria for Determining Dye Recoveries

The following sections identify normal criteria used by the OUL for determining dye recoveries. The primary instrument in use is a Shimadzu RF-5301.

EOSINE

Normal Criteria Used by the OUL for Determining <u>Eosine</u> Dye Recoveries <u>in Elutants</u> from Charcoal Samplers

Criterion 1. There must be at least one fluorescence peak in the range of 540.0 to 545.8 nm in the sample.

Criterion 2. The dye concentration associated with the fluorescence peak must be at least 3 times the detection limit. The eosine detection limit in elutant samples is 0.050 ppb, thus this dye concentration limit equals 0.150 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of eosine. Much background fluorescence yields low, broad, and asymmetrical fluorescence peaks rather than the more narrow and symmetrical fluorescence peaks typical of eosine. In addition, there must be no other factors which suggest that the fluorescence peak may not be eosine dye from our groundwater tracing work.

Normal Criteria Used by the OUL for Determining <u>Eosine</u> Dye Recoveries <u>in Water</u> Samples

Criterion 1. In most cases, the associated charcoal samplers for the station should also contain eosine dye in accordance with the criteria listed above. This criterion may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be eosine dye from our groundwater tracing work. The fluorescence peak should generally be in the range of 532.8 to 537.3 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. Our eosine detection limit in water samples is 0.015 ppb, thus this dye concentration limit equals 0.045 ppb.

FLUORESCEIN

Normal Criteria Used by the OUL for Determining <u>Fluorescein</u> Dye Recoveries <u>in Elutants</u> from Charcoal Samplers

Criterion 1. There must be at least one fluorescence peak in the range of 514.5 to 519.6 nm in the sample.

Criterion 2. The dye concentration associated with the fluorescence peak must be at least 3 times the detection limit. The fluorescein detection limit in elutant samples is 0.025 ppb, thus this dye concentration limit equals 0.075 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of fluorescein. Much background fluorescence yields low, broad, and asymmetrical fluorescence peaks rather than the more narrow and symmetrical fluorescence peaks typical of fluorescein. In addition, there must be no other factors which suggest that the fluorescence peak may not be fluorescein dye from our groundwater tracing work.

Normal Criteria Used by the OUL for Determining <u>Fluorescein</u> Dye Recoveries <u>in Water</u> Samples

Criterion 1. In most cases, the associated charcoal samplers for the station should also contain fluorescein dye in accordance with the criteria listed above. This criterion may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be fluorescein dye from our groundwater tracing work. The fluorescence peak should generally be in the range of 506.8 to 510.6 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. Our fluorescein detection limit in water samples is 0.002 ppb, thus this dye concentration limit equals 0.006 ppb.

RHODAMINE WT

Normal Criteria Used by the OUL for Determining <u>Rhodamine WT</u> Dye Recoveries <u>in Elutants</u> from Charcoal Samplers

Criterion 1. There must be at least one fluorescence peak in the sample in the range of 565.2 to 571.8 nm.

Criterion 2. The dye concentration associated with the rhodamine WT peak must be at least 3 times the detection limit. The detection limit in elutant samples is 0.170 ppb, thus this dye concentration limit equals 0.510 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of rhodamine WT. In addition, there must be no other factors which suggest that the fluorescence peak may not be dye from the groundwater tracing work under investigation.

Normal Criteria Used by the OUL for Determining <u>Rhodamine WT</u> Dye Recoveries <u>in Water</u> Samples

Criterion 1. In most cases, the associated charcoal samplers for the station should also contain rhodamine WT dye in accordance with the criteria listed above. These criteria may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be rhodamine WT dye from the tracing work under investigation. The fluorescence peak should generally be in the range of 572.4 to 577.7 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. Our rhodamine WT detection limit in water samples is 0.015 ppb, thus this dye concentration limit is 0.045 ppb.

SULFORHODAMINE B

Normal Criteria Used by the OUL for Determining <u>Sulforhodamine B</u> Dye Recoveries <u>in Elutants</u> from Charcoal Samplers

Criterion 1. There must be at least one fluorescence peak in the sample in the range of 576.4 to 583.2 nm.

Criterion 2. The dye concentration associated with the sulforhodamine B peak must be at least 3 times the detection limit. The detection limit in elutant samples is 0.080 ppb, thus this dye concentration limit equals 0.240 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of sulforhodamine B. In addition, there must be no other factors which suggest that the fluorescence peak may not be dye from the groundwater tracing work under investigation.

Normal Criteria Used by the OUL for Determining <u>Sulforhodamine B</u> dye Recoveries <u>in Water</u> Samples

Criterion 1. In most cases, the associated charcoal samplers for the station should also contain sulforhodamine B dye in accordance with the criteria listed earlier. This criterion may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be sulforhodamine B dye from the tracing work under investigation. The fluorescence peak should generally be in the range of 580.8 to 584.4 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. The detection limit in water is 0.008 ppb, thus this dye concentration limit equals 0.024 ppb.

Standard Footnotes

Sometimes not all the criteria are met for a straight forward determination of tracer dye in a sample. For these reasons, the emission graph is scrutinized carefully by the analytical technician and again during the QA/QC process. Sometimes the emission graphs require interpretation as to whether or not a fluorescence peak represents the tracer dye or not. Background samples from each of the sampling stations aid in the interpretation of the emission fluorescence graphs. When the results do not meet all the criteria for a positive dye detection, often the fluorescence peak is quantified and flagged with a footnote to the result as not meeting all the criteria for a positive dye detection. Standard footnotes are as follows:

Single asterisk (*): A fluorescence peak is present that does not meet all the criteria for a positive dye recovery. However, it has been calculated as though it were the tracer dye.

Double asterisk (**): A fluorescence peak is present that does not meet all the criteria for this dye. However, it has been calculated as a positive dye recovery.

Other footnotes specific to the fluorescence signature are sometimes also used. These footnotes are often developed for a specific project.

The quantification of fluorescence peaks that do not meet all the criteria for a positive dye detection can be important for interpretation of the dataset as a whole.

ATTACHMENT 1 Sample Collection Data Sheet

OZARK UNDERGROUND LABORATORY, INC. 1572 Aley Lane Protem, MO 65733 (417) 785-4289 fax (417) 785-4290 email: contact@ozarkundergroundlab.com SAMPLE COLLECTION DATA SHEET for FLUORESCENCE ANALYSIS

Project				We	ek No:Sa	amples Colle	cted By:		<u>.</u>				
Samples	Shipped By	y:				_Samples Re	ceived By:						
				Date Samples Received:									No 🗌
Bill to:				Send Results to:			ts to:	to:					
Analyze	for: 🗌 Flu	uorescein [Eosine	Rhodamine	WT 🗌 Othe	er	Shi	p cooler to:					OUL
	OUL se only	Please indicate stations where dye was visible in the								<u>field</u>			
	-		-		5 5		ı use - use bi	ack ink only			-		use only
# CHAR REC'D	LAB NUMBER	STATION NUMBER							PLACED		COLLECTED		# WATER
		1-4 Numbers							DATE	TIME	DATE	TIME	REC'D
COMM	ENTS	-	•						-	-	•	-	-

This sheet filled out by OUL staff? Yes 🗌 No 🗌 Charts for samples on this page proofed by OUL: _Analyzed By:_____

OUL Project No._____ Date Analyzed:_____

Page ____ of ____