

**REVISED Work Plan to Evaluate In-Situ Soil Flushing
of Perchlorate-Impacted Soil
Tronox, LLC
Henderson, Nevada**

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Tronox Project
Henderson, Nevada

Responsible 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.



Susan M. Crowley, CEM 1428 Exp.: 03/08/11
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1.0 INTRODUCTION

Northgate Environmental Management, Inc. (Northgate) has prepared this work plan on behalf of Tronox LLC, for the Tronox facility located in Henderson, Nevada (the Site; Figure 1). This document describes work to be performed to evaluate the technical feasibility and effectiveness of in-situ flushing to remediate perchlorate in Site soils.

Perchlorate has been detected in samples of vadose zone soil at the Site (Northgate, 2010a). These unsaturated soils may be a continuing source of perchlorate to groundwater. Reduction of perchlorate mass in these unsaturated soils may reduce an on-going source of perchlorate to groundwater.

Perchlorate is very soluble in water and is not readily adsorbed on the surface of unsaturated soils (Urbansky, 2003). In-situ flushing may be an effective remedial technology for sites with highly permeable sediments (e.g., sands and gravels) with relatively few heterogeneities (USEPA, 1991). Considering the high solubility of perchlorate and the presence of coarse-grained alluvial sediments over much of the vadose zone at the Site¹, in-situ soil flushing is a technique that has potential to reduce perchlorate mass in the soil.

In-situ soil flushing is essentially an acceleration of the natural process of precipitation and infiltration. The Site receives an average of approximately four inches of rainfall a year. A Site-specific infiltration rate has not yet been developed, though the USGS has estimated that 2 percent of this precipitation eventually reaches the groundwater in undeveloped land areas in the region (USGS, 2007).

The proposed evaluation consists of laboratory-scale column testing, as detailed below. Based on the results of the laboratory-scale testing, a pilot-scale demonstration may also be performed to further assess this technology for use at the Site.

¹ While the vadose-zone lithology at the Site consists primarily of sands and gravels, it should be noted that discontinuous caliche layers are present over much of the Site. They are most frequently encountered at depths greater than 10 feet below ground surface and usually within a few feet of the contact between alluvium (Qal) and Upper Muddy Creek formation (UMCf). They generally range from one to less than three feet in thickness. The presence of these caliche deposits may impact the feasibility and effectiveness of flushing perchlorate from soil to groundwater at the Site.



2.0 OBJECTIVES

The objective of the proposed program is to examine the feasibility of in-situ soil flushing as a remedial approach to decrease perchlorate mass in on-Site soils. Data will be generated in laboratory-scale column tests to measure percolation and leaching rates from soil samples and to help estimate the amount of perchlorate that can potentially be flushed from on-Site vadose zone soils. The specific objectives of the laboratory scale column tests are as follows:

- Simulate the percolation of 150% of annual rainfall through a laboratory soil column, for comparison with USGS estimates of groundwater recharge.
- Measure the amount of perchlorate that can be leached from soil columns as a function of flushing volume. Tests will be conducted on samples of alluvium gathered from the Site that contain a range of initial perchlorate concentrations.
- Measure the leaching rate of other materials that may be flushed out of the soil along with perchlorate.

After the column studies are completed, the data may be used to finalize the design of an on-Site pilot scale demonstration of in-situ soil flushing, as appropriate. If the column studies show that soil flushing will not be a feasible alternative, or if better remedial approaches are developed, pilot scale tests of in-situ soil flushing may be revised or postponed with the concurrence of the regulators.



3.0 DESCRIPTION OF THE EVALUATION PROJECT

The proposed evaluation project will be conducted in two stages: laboratory scale column tests, followed by a pilot scale demonstration at the Site, as appropriate. Each of these stages is described below.

3.1 Laboratory Scale Column Tests

Tests will be conducted in laboratory-scale leaching column studies using soil samples obtained from the Site. Stabilized Lake Mead water will be used for the flushing tests. A laboratory experienced in setting up and conducting treatability tests (including leaching tests) for environmental remediation will perform all column tests. A description of their qualifications and experience is included as Appendix A to this work plan.

Four separate column tests will be conducted as detailed in Table 1. Each of these tests will be run on homogenized samples of soil taken from the alluvium layer at the Site. Samples of soil run in these column tests will be collected in areas where previous sampling indicated that soil contains perchlorate in the desired range of concentrations.

The collection of soil and water required for these column tests will be coordinated with other drilling activities at the Site.

Soils to be used for testing are expected to be classified as gravely sands or sandy gravels. Approximately 800 pounds of soil will be delivered to the laboratory – 200 pounds of soil anticipated to contain less than 100 mg/kg of perchlorate, 200 pounds anticipated to contain between 100 – 1,000 mg/kg of perchlorate, and 400 pounds anticipated to contain more than 1,000 mg/kg. Soil materials of each concentration range will be homogenized, sampled, and analyzed by the laboratory prior to conducting the column studies. Table 2 lists the analytes and methods that will be used in the analysis of soil samples.

Approximately 100 liters of stabilized Lake Mead water will be provided to the laboratory along with the soil samples. Samples of Lake Mead water to be used in the column tests will be analyzed by the laboratory prior to conducting the column studies. Table 3 lists the analytes and methods that will be used in the analysis of water samples. Results of these analyses will be reviewed by Northgate prior to conducting the column tests.

Four soil columns will be prepared by the laboratory for testing. The test columns will be approximately 6 feet long by 6 inches in diameter. Soil with varying perchlorate concentrations



will be loaded in the test columns, and will be compacted to approximate the wet bulk density (1.856 g/cc) and moisture content (15.4 % by volume) of on-Site alluvium soils. A schematic of the laboratory scale column test apparatus is presented in Figure 2.

In the first test column, approximately 150% of the average annual rainfall at the Site will be applied to the top of the column and allowed to percolate into the soil column. A total of 2.8 liters² of water will be introduced to the top of the column, under atmospheric pressure, at a flow rate of approximately 2 ml/minute using a peristaltic pump or other suitable device. The water will be allowed to percolate through the soil column by gravity. The advancement of the percolation front will be measured as a function of time until the water drains through the bottom of the column or stops migrating downward. If sufficient water drains through the column, it will be collected and sampled for the parameters specified in Table 3.

In test columns 2, 3, and 4, water will be continuously applied to the top of the columns as described above, until a total volume of 26.1 liters (approximately 2 pore volumes of water) has been introduced. At an addition rate of 2 mL/min, this will be approximately 9 days of continuous flushing. Water samples will be collected from the bottom of the column each day and analyzed for the parameters specified in Table 3.

Upon completion of the column tests, soil from the test columns will be re-homogenized, sampled, and analyzed for the parameters specified in Table 2, and the laboratory will prepare a final report of test conditions, observations, and analytical results.

Data from these column studies will be evaluated by Northgate. The first test column will provide data about the rate of percolation through the soil and the retention capacity of the soil. Data generated is anticipated to be limited to the depth of the wetted soil within the column as a function of time. This will aid in establishing the leachate monitoring depths and sampling schedule of the pilot scale demonstration and will also be used to consider the USGS estimation of recharge rate. If the percolation front advances through the soil column and a sufficient volume of water drains to the bottom of this test column, a sample will be collected and analyzed for the parameters listed in Table 2. If available, this analysis will be compared with the analysis of initial leachate samples collected from the continuously-flushed soil columns to provide a comparison between batch and continuous flushing operations.

Data from the analysis of water samples from test columns 2, 3, and 4 will be used to prepare plots of the concentration of perchlorate in the leachate as a function of the volume of water infiltrated

² This volume represents approximately 6 inches of rainfall (i.e., 150% of the annual average rainfall for the Site).



through the column. The mass of each analyte removed from the soil column will be estimated based on the mass recovered in the leachate, and this will be compared to the “before” and “after” soil mass of that analyte derived through analysis of soil samples.

A technical memorandum covering the column test results and, as appropriate, a final pilot scale design may be prepared and reviewed with Tronox and NDEP. The following section describes the basic approach to this field test, which may be modified based on results from the column tests and exploratory borings that will be advanced in the area of the selected pilot test area.

3.2 Conceptual Pilot Scale Field Test

Following the review of the laboratory column test results, a pilot scale field demonstration of perchlorate soil flushing may be conducted at the Site. The size, duration, and flushing volumes of the pilot scale demonstration will be established based on the results of the laboratory scale column tests.

The proposed pilot study demonstration area is shown in Figure 3. This area was selected because: (1) it is near the interceptor well field, and therefore hydraulic control of the demonstration area will be maintained to the degree afforded by the Interceptor Well Field; (2) nearby soil sampling results suggest that the vadose zone in this area contains perchlorate concentrations above 100 mg/kg; (3) this area is outside the boundaries currently identified for shallow soil excavation, and therefore the excavation program and the soil flushing pilot test can be conducted in parallel if necessary; and (4) use of this area for pilot testing will not interfere with ongoing facility operations or subsurface improvements.

The final selection of the pilot study area will require additional borings and soil sampling to confirm that soil in this area contains perchlorate concentrations within the desired range and over the depth intervals needed for the pilot test and to assess the presence of caliche within the proposed test area. Four exploratory borings will be advanced to groundwater within the proposed pilot study area. Soil samples will be taken at three depth intervals from each of these boring locations and analyzed to confirm that vadose zone soils in this area contain perchlorate concentrations appropriate for the pilot scale demonstration.

Flushing water will be applied either through a percolation pond or through a drip irrigation system installed at the pilot test area.

Selection of the method of water application will be made following assessment of column study test results.



Monitoring points to be used during the pilot study demonstration will be installed. Four new leachate collection well clusters will be installed in and around the percolation area, as shown in Figure 4. Each leachate collection well cluster will provide the ability to collect water samples from three discrete depth intervals.

Three groundwater monitoring wells, also shown in Figure 4, will also be utilized as monitoring and sampling locations. Existing groundwater monitoring wells will be utilized for this purpose if possible, though the final selection of the pilot study location may necessitate adding new monitoring wells.

The bermed percolation pond or drip system will be supplied with stabilized Lake Mead water obtained from a metered connection located near the old Building D-1. Five days a week, water will be introduced to the percolation area. An inert and distinctive tracer material, such as sodium bromide, may be added to this water to provide a direct indication of subsurface flow. Water will be allowed to percolate into the ground, and the rate of infiltration will be observed by monitoring a flow totalizer on the water connection. The evaporation rate will be estimated by monitoring the water level in an evaporation pan located near the pilot test area. This procedure will continue for up to six weeks.

Water levels will be measured and samples of the leachate/groundwater at all pilot study monitoring points will be collected on a bi-weekly basis. This monitoring program will continue throughout the active period of flushing (weeks 1-6) and for four weeks after the flushing of water has concluded. Water samples collected will be analyzed in accordance with Table 3.

At the conclusion of the pilot test, all analytical data collected during the demonstration will be evaluated. The amount of water flushed through the soil will be documented, and estimates of the mass of perchlorate flushed from the soil will be made. Estimates of flushing requirements for specific areas of the Site will be generated, and the conclusions of this pilot scale demonstration will be documented. Boring logs from the Site will be reviewed and lithologic cross-sections to show where caliche deposits have been observed will be prepared. A report on the test conditions and results will be prepared and submitted to NDEP.

After completion of the field work and evaluation of the data, the percolation area will be graded, and all monitoring points installed specifically to conduct this test will be properly abandoned.



3.3 Sampling Procedures

3.3.1 Soil Sampling Procedures

Soil samples will be collected using the sonic drill rig employed during the capture zone evaluation drilling activities (Northgate, 2010b). Soil borings will be logged in the field using the procedures described in SOP-14 – Field Documentation (BRC, 2009d) and SOP-17 – Soil Logging (BRC, 2009e). Soil samples for laboratory analysis will be collected with a split-spoon sampler fitted with brass liners using the procedures described in BRC SOP-23 – Split Spoon Sampling (BRC, 2009h).

Equipment cleaning or decontamination procedures will be per the procedures described in SOP-31 – Drilling Equipment Decontamination (BRC, 2009i).

Sample containers will be sealed, labeled, and placed inside an ice chest under chain-of-custody protocol using the procedures described in SOP-06 – Sample Management and Shipping (BRC, 2009b).

Each sampling borehole will be abandoned once the target depth has been reached and the necessary samples are obtained. The boreholes will be abandoned by backfilling with a bentonite/neat cement grout using the procedures described in SOP-19 – Borehole Abandonment (BRC, 2009f). Soil cuttings (including unused soil cores) will be temporarily stored in U.S. Department of Transportation (DOT)-approved steel 55-gallon drums or debris boxes while awaiting receipt of the final laboratory results. Containers will be managed according to the procedures described in SOP-34 – Investigative Derived Waste (IDW) Management (BRC, 2009j). At the end of each day, equipment decontamination water will be temporarily stored in DOT-approved 55-gallon drums. Each drum will be marked with water-proof labels and water-proof markers. Each drum will receive a unique identification number and will be catalogued for waste capture documentation purposes. Following characterization, each drum of material will be disposed of as appropriate per federal, state, and local requirements.

3.3.2 Water Sampling Procedures

Water samples will be collected in the field from monitoring wells and from temporary leachate collection wells. All water samples will be collected using the procedures described in SOP-05 – Water Sampling (BRC, 2009a). Field data will be recorded using the procedures described in SOP-14 – Field Documentation (BRC, 2009d).



Sample containers will be sealed, labeled, and placed on ice inside an ice chest provided to the laboratory under chain-of-custody protocol using the procedures described in SOP-06 – Sample Management and Shipping (BRC, 2009b).

Temporary leachate collection wells will be abandoned after completion of the pilot scale demonstration. The temporary wells will be abandoned using the procedures described in SOP-21 – MW Destruction (BRC, 2009g). Soil cuttings (including unused soil cores) will be temporarily stored in U.S. Department of Transportation (DOT)-approved steel 55-gallon drums while awaiting receipt of the final laboratory results.

Purge water and other materials associated with the installation, sampling, and abandonment of groundwater and leachate monitoring points will be managed according to the procedures described in SOP-34 – Investigative Derived Waste (IDW) Management (BRC, 2009j).



4.0 PROPOSED SOIL FLUSHING EVALUATION SCHEDULE

The proposed schedule for the work described in this work plan is presented in Figure 5.



5.0 REFERENCES

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FIGURES



TABLES



APPENDIX A

**QUALIFICATIONS AND EXPERIENCE OF
LABORATORY SELECTED TO CONDUCT COLUMN STUDIES**

