# Evaluation of the TraceTek™ TT5000 Product Sensitive Cable For use as a Leak Detection System For Buried Pipelines

Final Report

PREPARED FOR:

Tyco Thermal Controls

**November 21, 2002**

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# Evaluation of the TraceTek$^{TM}$ TT5000 Product Sensitive Cable For use as a Leak Detection System For Buried Pipelines

PREPARED FOR:

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**November 21, 2002**

## Preface

This report describes a third-party evaluation of the TraceTek TT5000 fuel sensing system when used to detect leaks in underground pipelines. The evaluation was conducted by Ken Wilcox Associates, Inc. at the Fuels Management Research Center in Grain Valley, Missouri. Work was directed by Mr. Ken McCoy of Tyco Thermal Controls and Mr. Terry Warren, Industrial Heater.

Technical questions should be addressed to Mr. McCoy at Tyco Thermal Controls, phone 650 474-7485 or Mr. Warren at Industrial heater phone 901 382-4761.

Approved:

H. Kendall Wilcox, Ph.D.
President

November 21, 2002

# Test Report for TraceTek Cable Evaluation

## Background

TraceTek cables are product sensitive and will change electrical characteristics when exposed to hydrocarbons. These cables have been used to monitor for pipeline leaks by burying alongside new or existing installations. Various regulatory agencies need independent data to assure that such systems will work as advertised. This report describes the testing that was conducted by KWA Between October 2001 and November 2002. These results demonstrate that the TraceTek cable will detect product releases from pipelines when it is installed correctly.

## Description of the TraceTek System

The TraceTek system consists of up to 124 product sensitive cables each up to one mile long, and a monitoring console that displays the alarms and the location of any release that occurs along the length of the line. The cable is installed in slotted pipe along side or above the pipeline. These can be easily installed at a new facility as well as retroactively installed on existing systems. A site suitability study is conducted at each potential site to determine that the soil and backfill conditions will be suitable for migration of the product from a leak to the cable.

## Description of Test Facility

The test procedures, including the major features of the test container, were developed by Patrick Lay, a registered geologist at EARTH-TECH in Ft. Walton Beach, Florida. These test conditions were intended to duplicate as much as possible the natural environment around a pipeline. A copy of this test plan is provided in Appendix A of this report.

The test container was constructed at the KWA test laboratory in Grain Valley, Missouri. A cross section of the test bed is shown in Figure 1. The test bed consisted of a box with nominal dimensions of 3 ft deep, 3 ft wide and 10 ft long.

For the first series of tests, approximately six inches of clean sand was added to the bottom of the test bed and compacted as much as possible. A 12-inch diameter plastic pipe was placed on top of the sand and a slotted pipe containing the Trace Tec cable was placed at the same level at approximately the 7 o'clock position of the pipe. An additional 12 inches of sand was then added to the box to the top of the pipe and a second slotted pipe and cable were placed at the 10 o'clock position. Four inches of sand were then used to cover the pipe and a third slotted pipe was placed at the 12 o'clock position. A polyethylene barrier was placed over the third slotted pipe and a final 6-inch layer of sand was added on top of the slotted plastic barrier.

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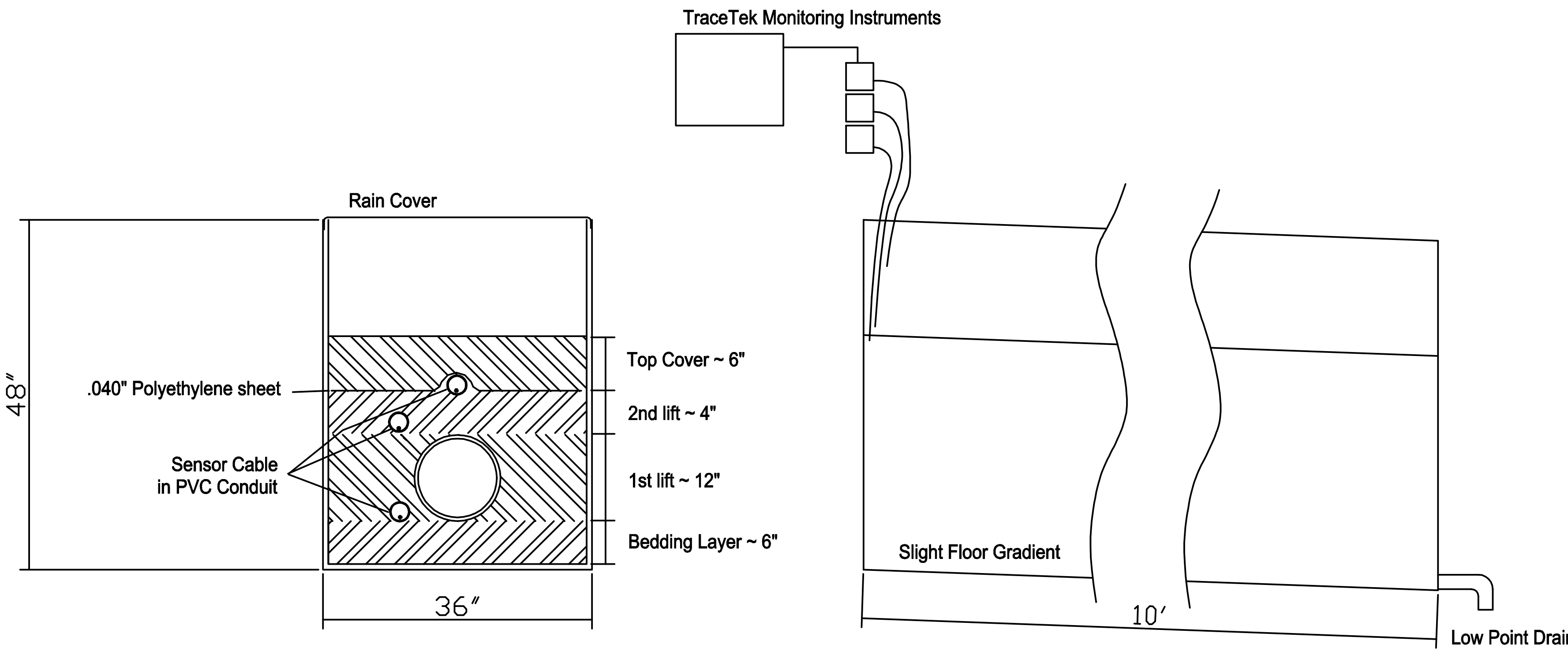


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Leads from the TraceTek cables were routed out of the container and connected to the monitoring system. Fuel was introduced into the test bed at a rate of 0.2 gallons per hour. The leak point was at the center of the test container, either at the bottom of the pipeline or at the top, depending on the test objectives.

**Description of Test Procedures**

After the test bed was set up for the testing, a leak was introduced into the backfill using a peristaltic pump. The rate of the leak was set at a nominal value of 0.2 gal/hr. Addition of fuel to the test bed continued until one or more alarms occurred or it became evident that further leaks were not likely to produce any further alarms. Fuel was removed from the test bed using a second peristaltic pump as it accumulated to prevent flooding of the test bed. When the rate of removal reached the rate of the leak the test was allowed to continue for a short time and then terminated.

Two types of test conditions were created: Testing under dry conditions; and testing with a water table present. The leak was introduced either at the top of the pipeline or underneath the pipeline at the midpoint of the test bed. For high water table conditions, the level of water was set at the top of the pipe and monitored in the slotted pipe that was used for fuel removal.

A total of six tests were conducted using this test set up: Three without a water table and three with a water table. Leaks were introduced at both the top and bottom of the pipeline. Jet A obtained from an airport was the fuel used for all tests.

**Test Results**

A detailed description of each test is provided below. The results are summarized in Table 1.

<u>Test 1</u>

Test 1 was conducted with damp sand backfill and no water table. A leak of 0.2 gal/h was introduced at the bottom of the pipe at the midpoint of the test container. Sensors were located at the 7 o'clock and 10 o'clock positions, and at the 12 o'clock position about four inches above the top of the pipe.

The leak was continued for 7 days and 19 hours. The total volume of fuel introduced during the test was 37.4 gallons, which is an average rate of 0.20 gal/h. Fuel was removed from the test container during the test so that there was no accumulation of fuel at the container bottom. A check at the end of the test indicated that the amount of fuel being removed from the bottom of the container was approximately the same as the amount being introduced. This indicated that no further fuel was being absorbed into the backfill and the test was terminated at that point.

No alarms were observed during these tests. A possible explanation is that the sand backfill was so course that the fuel flowed directly from the injection point to the container bottom without spreading by capillary action to the sensors.

Test 2.

Test 2 was conducted with the same type of sand with the water table at a depth of 24 inches from the container bottom or near the top of the pipe. A leak of 0.2 gal/h was introduced at the top of the pipe at the midpoint of the test container. Sensors were located at the 7 o'clock and 10 o'clock positions, and at the 12 o'clock position about four inches above the top of the pipe.

The leak was continued for 1 day and 22.5 hours. The total volume of fuel introduced during the test was 7.9 gallons, which is an average rate of 0.17 gal/h. No fuel was removed from the container during this test resulting in a volume of fuel per square foot of 0.25 gal.

Alarms were observed on the two upper sensors. The cable in the 10 o'clock position alarmed after 5h 39m and the cable at the 12 o'clock position alarmed after 6h 27 min. The location for the 12 o'clock alarm was at 4 ft and at 6 ft for the 10 o'clock position. The cable located at the 7 o'clock position was completely under water and was not expected to alarm.

Test 3

Test three was conducted without a water table with wet sand as the backfill. A leak of 0.2 gal/h was introduced at the top of the pipe at the midpoint of the test container. Sensors were again located at the 7 o'clock and 10 o'clock positions, and at the 12 o'clock position about four inches above the top of the pipe.

The leak was continued for 9 days and 20 hours. The total volume of fuel introduced during the test was 42.9 gallons, which is an average rate of 0.18 gal/h. Fuel was removed from the bottom of the container continuously during this test. A check at the end of the test indicated that the amount of fuel being removed from the bottom of the container was approximately the same as the amount being introduced. This indicated that no further fuel was being absorbed into the backfill and the test was terminated.

The sensor in the 7 o'clock position alarmed after 6 hours at a distance of 5 ft. Neither of the other two sensors detected the presence of the leak during the entire 9 day period.

Test 4

Test 4 was conducted similar to Test 3 except that the leak was located at the bottom of the pipe. The soil was damp, but there was no water table in the container during the test. A leak of 0.2 gal/h of Jet A was introduced at the midpoint of the pipe. Fuel was again removed from the bottom of the container during the test. Sensors were again located at the 7 o'clock and 10 o'clock positions, and at the 12 o'clock position about four inches above the top of the pipe.

The leak was continued for 21 days and 6 hours. The total volume of fuel introduced during the test was 63 gallons, which is an average rate of 0.12 gal/h. Fuel was removed from the bottom of the container continuously during this test. A check at the end of the test indicated that the amount of fuel being removed from the bottom of the container was approximately the same as the amount being introduced. This indicated that no further fuel was being absorbed into the backfill and the test was terminated.

The sensor in the 7 o'clock position alarmed after 10 days and 4.5 hours at a distance of 5 feet. Neither of the other two sensors detected the presence of the leak during the entire 21 day period.

Test 5

Test 5 was conducted with the water table located at the bottom of the pipeline. The leak was also located at the bottom of the pipe. A leak of 0.2 gal/h of Jet A was introduced at the midpoint of the pipe. The fuel was only allowed to accumulate to a depth of approximately 6 inches above the water table level. Sensors were again located at the 7 o'clock and 10 o'clock positions, and at the 12 o'clock position about four inches above the top of the pipe.

The leak was continued for 9 days and 22 hours. The total volume of fuel introduced during the test was 39 gallons, which is an average rate of 0.17 gal/h. Fuel was removed when it reached a depth of 2 in above the water table. A check at the end of the test indicated that the amount of fuel being removed from the bottom of the container was approximately the same as the amount being introduced. This indicated that no further fuel was being absorbed into the backfill and the test was terminated.

The sensor in the 7 o'clock position alarmed after 2 hours at a distance of 5 ft and at the10 o'clock position after 3days and 21 hours at a distance of 6 ft. The sensor above the pipe did not detect the leak during the almost 10 day leak period.

Test 6

Test 6 was conducted differently than the previous tests. A smaller pipe with a diameter of six inches was used in place of the larger 12 in diameter pipe. The water table was approximately 3 inches above the top of the pipe. A single sensor cable was placed in the 12 o'clock position 15 inches above the pipe. The leak was introduced at the bottom of the pipe at the midpoint of the container.

The leak was conducted over a period of 35 hr and 45 min before the leak was detected at a distance of 8 ft. This distance is approximately the center of the container when the lead length of the sensor cable is considered. A total of 6.7 gal of fuel were added to the test container, which is an average leak rate of 0.19 gal/h.

The first three tests were conducted using locally obtained sand as the fill material. This sand was relatively coarse and was designated as concrete sand by the sand company. The remaining four tests were conducted using a much finer sandy soil obtained from the Florida Panhandle.

The results of the tests conducted for this interim report are summarized in Table 1.

| **Table 1. Summary of TraceTek Results** | | | | | |
|---|---|---|---|---|---|
| **Test No.** | **Soil Type and Condition** | **Water Table** | **Leak Position** | **Time to Alarm** | **Location of Sensor Alarms** |
| 1 | Course, damp sand | None | Bottom of pipe @ center of test bed | No alarms after 7d 12h | --- |
| 2 | Course, damp sand | Above pipe | Above pipe @ center of test bed | 5h 39m<br>6h 27m | 10 o'clock@ 4 ft<br>12 o'clock@ 6 ft |
| 3 | Course, damp sand | None | Bottom of pipe@ center of test bed | 6 h<br>No additional alarms during the 9 day leak | 7 o'clock@5 ft |
| 4* | Fine, dry sandy soil | None | Bottom of pipe@ center of test bed | 8 days<br>No additional alarms during the 21 day leak | 7 o'clock@ 7 ft. |
| 5* | Fine Wet Soil | At bottom of pipe | Bottom of pipe@center of test bed | 2 h<br>3d 21 h | 7 o'clock@ 5 ft.<br>10 o'clock@ 6 ft. |
| 6* | Fine, wet sandy soil | Above pipe | Bottom of pipe@ center of test bed | 1 d 12 h | 12 o'clock@ 8 ft. (approx. center of tank) |

*Finer soil from Florida used on this test.

## Data Analysis

The data analysis was straightforward for these tests. The time to alarm for each cable and the location of the leak were recorded. Data was also recorded each day for the amount of fuel leaked into the soil and the amount recovered.

## Conclusions

It appears that the sand used in the first three tests was generally too course so that under low water table conditions the fuel went straight to the bottom of the test bed with very little spread due to capillary action. A damper soil might have prevented the fuel from dropping so rapidly, allowing it to wick further from the source of the leak. It is unlikely that this type of soil condition would be encountered in a natural environment.

It also evident that the presence of a water table can enhance the detection of leaks when the sensor is located at or near the surface of the water table. The fuel can spread rapidly across the water surface as well as accumulate sufficiently to produce an alarm in the cable directly above the pipe.

The soil used for Test 4 was relatively dry and it appears that very little wicking occurred for this test. An alarm did occur at the cable nearest the leak after 8 days, but no further alarms occurred after three weeks of leaking. A damper soil more typical of that found in high water table areas might have resulted in better leak detection, but no data is available to relate migration of fuel though damp soil as opposed to dry soil.

In conclusion it must be noted that proper installation and positioning of the sensor, taking into account the local site conditions, is critical to reliable detection of leaks. A suitability study should be conducted at each potential site to determine that the sensor is positioned correctly to take advantage of soil, water and backfill conditions and to insure that a leak from the pipeline will migrate toward the sensor. In dry fill, low water table conditions, the sensor should be placed on the pipeline bedding layer near by, but not beneath the bottom of pipeline. Placing the sensor cable above the pipeline in dry backfill conditions will not be effective for the early detection of leaks. In wet fill, high water table conditions, the sensor cable should be positioned above the pipeline and a polyethylene sheet should be placed along the trench to cover the sensor cable and conduit. Sensor cable that is positioned below the pipeline in high ground water conditions will not be effective for the early detection of leaks. In extreme cases where seasonal fluctuation in the level of the water table cause alternate wet or dry conditions, two cables (one at the bedding layer and one above the pipeline) should be considered.

# Appendix A

## Test plan from EARTH-TECH

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June 14, 2002

Mr. Ken McCoy
Tyco Thermal Controls
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Redwood City, CA 94063

Subject: Proposed Leak Detection Testing Procedures, Revision 1
TraceTek Independent Testing
Project number 55572, Task Order No. 01

Dear Mr. McCoy:

Tyco Thermal Controls (a division of Tyco International LTD.) has retained Earth Tech, Inc. (Earth Tech) to develop and document Proposed Leak Detection Testing Procedures for TraceTek independent testing activities. The main objective of this document is to develop an approach to further evaluate leak detection performance for a top-positioned sensor with a bottom-positioned simulated leak.

## BACKGROUND

In order to propose additional leak detection testing, Earth Tech requested information pertaining to current leak detection testing procedures. Based on the provided information, descriptions of the equipment utilized and current leak detection testing procedures are provided below.

*Test Vessel Description*

A vessel, constructed of metal, approximately 10 feet long, 3 feet wide and 3 feet high, is utilized as a closed-system test vessel to evaluate leak detection sensor performance. In order for the vessel to be mobile, the vessel sits on casters that elevates the vessel approximately 4 inches.

*Test Vessel Preparation - Soil Placement and Compaction*

The vessel is filled with approximately 6 to 8 inches of soil. The soil is compacted by tamping with a 4x4 post from the top. A bottom sensor, with associated conduit, is placed into the vessel. The bottom sensor is covered with sand to about 6 to 8 inches and again compacted as much as possible using the post. Two side-positioned sensors and a representative fuel pipeline are placed into the vessel. Fuel supply tubing is place along the pipeline with the opening located in the various positions of leak simulation (top, bottom, or sides). Approximately 4 to 6 inches of sand is added and compacted as much as possible using the post. A top sensor, with associated conduit, is placed into the vessel and is covered with plastic sheeting. Sand is added to within 6 inches of the top of the vessel and again compacted as much as possible using the post. In addition, the vessel is equipped with tubing; one end located approximately 6 inches from the bottom of the vessel and the other end connected to a peristaltic pump. The pump allows fuel to be removed during testing or upon completion of testing.

*Description of Current Testing Procedures*

Once the vessel is prepared, as noted above, the testing personnel allows the fuel supply tubing to fill with aviation gas to initiate or simulate a fuel leak. Fuel leaks are simulated at various positions (top, bottom, sides) around the piping at a rate of 0.2 gallon per hour. Once the leak is initiated and the fuel begins to accumulate in the bottom of the vessel, a peristaltic pump is used to remove excess fuel during testing or upon completion of testing. The removal rate of the fuel does not exceed the simulated leak rate of 0.2 gallon per hour. The performance of each leak detection sensor is evaluated based on the response time of detecting the leak for the various leak positions

**PROPOSED PROCEDURES**

The proposed procedures, provided below, are recommended based on the following objectives.

The main objective of these proposed procedures is to further evaluate leak detection performance for a top-positioned sensor with a bottom-positioned simulated leak. The purpose of modifications in the preparation of the testing vessel is to mimic natural subsurface conditions in the field for fuel pipeline and leak detection installation. Significant conditions necessary for the installation of a pipeline and leak detection system include the excavation into undisturbed or native soils to accommodate piping trench, the installation of the piping and leak detection system, and the restoration to pre-excavation condition. The objective of modifications in the leak detection testing methods is to maintain soil moisture content and enabling the principles of ‘fluid dynamics’ to occur upon initiation of the simulated leak.

*Recommended Vessel Preparation - Soil Placement and Compaction*

It is recommended that the vessel be equipped with a 1-inch diameter, slotted pipe, positioned horizontally and connected to a 1-inch diameter vertical pipe to allow for the removal of excess water, as described below. It is also recommended that the vessel be equipped with a 1-inch diameter, slotted pipe, positioned vertically, to allow for the removal of excess fuel, as also described below. The vessel should be filled with approximately 32 to 34-inches of soil at increments of 6 to 8-inch lifts. The soil should be compacted by tamping with a 4x4 post from the top (as currently performed) at every 6 to 8-inch lift. Upon completion of the final lift and compaction, the soil in the vessel should be evenly saturated with approximately 25 gallons of potable water. This estimated quantity of water is less than one-forth of the anticipated pore space capacity of the soil-filled vessel (based on an estimated 25 percent porosity with 34-inches of soil).

While allowing for the water to percolate (approximately 30 minutes), the top of the soil in the vessel should be compacted again using the 4x4 post. The water level in the vessel should reach an equilibrated condition at approximately 8 to 10 inches from the bottom of the vessel. Removal of excess water using a peristaltic pump may be required.

*Recommended Vessel Preparation – Trenching and Piping Installation*

Upon completion of the vessel preparation, as noted above, a trench should be constructed of the approximate dimension 10 feet long, 1.5 feet wide and 1.25 feet deep. The soil in the bottom of the trench should be compacted using the 4x4 post. The representative fuel pipeline should be placed in the bottom of the trench (with fuel supply tubing) and the addition of approximately 6 inches of soil is added to the trench. The soil should be compacted using the 4x4 post. A top sensor, with associated conduit, should be placed into the trench and covered with approximately 3 inches of sand. The soil should be compacted using the 4x4 post.

Upon completion of this compaction, the soil in the vessel should be evenly saturated again with approximately 25 gallons of potable water. The placement of additional sand may be required if settling occurs. After allowing for the water to percolate (approximately 30 minutes), the top of the soil in the vessel should be compacted again using the 4x4 post. Plastic sheeting should be utilized to cover the 1.5-feet wide trench area, and an approximate 4 to 6 inches of soil should be added. While the water level in the vessel reaches an equilibrated condition, within 20 inches of the bottom of the vessel, insert the evacuation tubing into the vertical standpipe. The water should be removed using a peristaltic pump. After the removal of the water the vessel should reach an equilibrated condition, with the water level at approximately 10 inches from the bottom of the vessel and 24 inches from the top of soil.

*Description of Proposed Leak Detection Testing Procedures*

Once the vessel is prepared, as noted above, the testing personnel allows the fuel supply tubing to fill with aviation gas to initiate or simulate a fuel leak. The simulated leak rate of 0.2 gallon per hour is recommended. Once the leak is initiated, it is anticipated that the fuel will accumulate on the top of the water (10 inches from the bottom of the vessel). Tubing should be placed inside the vertical 1-inch slotted pipe, with the end located approximately 18 inches from the bottom of the vessel. The peristaltic pump should also be utilized to remove fuel from the 1-inch, slotted, vertical pipe during testing or upon completion of testing. The removal rate of the fuel should not exceed the simulated leak rate of 0.2 gallon per hour. In addition, the persistence of 6-inches of fuel (on top of the 10 inches of water) should be maintained through testing.

The performance of the top-positioned leak detection sensor should be evaluated based on the response time of detecting the leak for the bottom leak position.

Earth Tech, Inc. appreciates the opportunity to provide services to Tyco Thermal Controls and TraceTek. If you have any questions or require further information, please call me at (850) 862-5191.

Sincerely,

Earth Tech, Inc.

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LICENSE
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STATE OF
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PROFESSIONAL GEOLOGIST

Patrick H. Lay, P.G.
Project Manager

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