

Field Verification of the Performance of Release Detection Methods for Underground Storage Tank Systems

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I. INTRODUCTION

I.A. NEED FOR FIELD EVALUATION OF RELEASE DETECTION PERFORMANCE

Routine testing of underground storage tank systems (USTs) for releases can provide an early warning that material stored in the tank has escaped to the environment and is required under federal regulations [1]. The decision to rely on release detection as a critical portion of release prevention efforts was supported at the time the regulations were finalized by detailed laboratory analyses and a wealth of anecdotal evidence from tank owners, regulators and leak detection system manufacturers suggesting that the systems were effective [1-3]. Studies conducted since the regulations were issued have focused on the performance of release detection methods under relatively ideal conditions and have consistently proven that most methods are effective under such conditions [4-6]. No systematic, quantitative evaluation of the performance of release detection under realistic field conditions has been conducted in the 13 years since the regulations were finalized. More recent anecdotal evidence suggests that failures of release detection methods are more common than would be hoped [7]. Two types of errors are possible when testing an underground storage tank system: missed detections (declaring no leak when one is present) and false alarms (declaring a leak when none is present). A missed detection has potential environmental consequences as the release may continue unabated until the error is corrected, while a false alarm has economic consequences as a sound system undergoes further testing and possible closure based on the faulty test results.

I. B. GOALS OF THE STUDY

This study was designed to provide quantitative information about the performance of release detection systems operating under a large number of “routine” conditions. Specific goals were to:

- Quantify the probability of each type of leak detection failure (missed detection and false alarm) for classes of methods (e.g., tank tightness testing or automatic tank gauging) and for individual brands if sufficient data were collected, and
- Understand the sources of failures in UST systems and leak detection methods (e.g., human error by owners, operators or testers; mechanical failure; environmental variables).

II. METHODOLOGY

II. A. OVERVIEW OF STUDY DESIGN

Evaluating the performance of release detection methods requires the collection of a large number of release detection test results combined with an independent, hopefully conclusive, determination of the leak status of each UST system. Gathering such information directly by conducting a release detection test followed by a UST system “autopsy” would be very costly. A more cost-effective approach selected for this study was to collect data from systems where both pieces of information were already available or were soon to be established. Since many state and local agencies send inspectors to UST system closures to determine the system’s release status, and all systems were required by regulation to be tested routinely for releases by the time the study was initiated, such inspections offered an obvious means of collecting the required information. Consequently, it was decided to ask state agencies to collect data on past release detection activities and on the release status of the systems they inspected. Although data collected in this manner was expected to be inferior in quality and less complete than a comprehensive study conducted by a single research group, it was anticipated that the large sample size that could be accessed in this manner might compensate for these shortcomings.

II.B. RECRUITMENT OF AGENCIES

Agencies were recruited for participation in the study in several ways. The concept of the study was described at the March 1998 National UST Conference in Long Beach California and interested agency representatives were asked to sign up for possible participation. In September 1998 an invitation letter was sent to the leak prevention and remediation program contacts in all 50 states and to each of the ten US EPA regional offices. A request for participants was also printed in *LUSTLINE*. Draft survey forms based on those that had been used in a similar, previous study in California were distributed for review to 29 state and local agencies expressing interest in participating in this project [8]. Comments on

the form from the agencies were collected for three months and the form was revised based on their comments. In February 1999, the National Survey Form-Version 1.0 was distributed to the 29 agencies that had expressed interest during the peer review process.

II. C. DESIGN OF SURVEY FORM

The final survey form that emerged after review by participating agencies was a one-page, check box style, legal size questionnaire. The front of the form contained all of the questions, while the back of the form included instructions and a space for inspector's comments. Appendix B contains a reduced size version of both sides of the survey form. The form was divided into four major sections: agency and site information, system information, leak detection and release information.

Agency and Site Information

Agency information, including the name of the inspector, the name of the agency and the date of inspection, was required so that incomplete or obviously erroneous forms could be returned for correction. The reason for inspection (removal, repair, release investigation, compliance inspection, other) was listed because it provided useful information about the status of the system and site during the inspection and what portions of the system the inspector might be able to see. For example, more complete current leak detection records are typically available at a release investigation, but a more complete view of the tank and piping is available during a closure inspection. Information about the site (name, identification number, address and facility type) was required to correct incomplete information and to check for any geographic trends in the data.

UST System Information

Characteristics of the tank and piping were solicited to determine whether the system was in compliance with the major portions of release prevention regulations and to identify any trends in release detection performance between older and newer systems. The material of construction, the number of walls (single or double) and the age were sought for both tanks and piping. Other information collected

for the tank included whether the system had been cathodically protected (for steel systems), the type of product in the tank, and whether the system had been upgraded with spill prevention and overflow containment devices. Information specific to the piping included whether there was containment around the dispenser and/or turbine areas and the type of pump that was present (pressure or suction). Each of these system characteristics was deemed likely to change the probability of a release and to indicate the system's compliance with aspects of release prevention regulations other than release detection.

Leak Detection Information

The most detailed information on the survey form related to the leak detection methods employed at the facility. Each release detection method allowed under the federal UST regulations, either singly or as a combined method, was included on the form [1]. For each method that is purchased commercially, space was provided for inspectors to list the brand and model of equipment employed if it was known. The inspector could also note if a permanently installed leak detection method was non-operational or in alarm mode at the time of inspection by marking an "N" or an "A" next to the relevant method. Information on the result and date of the last tank tightness test, piping tightness test or statistical inventory reconciliation was also requested. Similar information on the most recent test results was not solicited for the other methods because it was believed that this information would be unavailable to inspectors in most instances.

Release Information

In this last segment of the survey form, the inspector indicated whether a release was present at the time of inspection based on their best professional judgment (e.g., determined by visual or olfactory evidence). If a release was thought to exist, the date the release started and/or the date it was discovered was requested. Because certain methods of leak detection are applicable only to specific types of releases (e.g., an internal tank tightness test will not detect an overflow), the source of the release was sought. Further characteristics of the release that inspectors were asked to determine included the cause of the

release, how it was identified, how old it was, how large an area was affected and whether it had impacted soil and/or groundwater resources.

II. D. DATA COLLECTION AND QUALITY ASSURANCE

Survey forms were collected from agencies between February 1999 and January 2000. In most cases the inspections were completed during that period as well, but in some cases detailed file records were reviewed to provide the required information. One other important data source was “retrofitted” survey forms that were originally submitted for a California State Water Resources Control Board sponsored study [8]. The survey forms designed for the national study requested a few important additional pieces of information that were not included on the California forms. It was decided to transfer the relevant information from the California forms to the national survey forms and to return these 335 forms to the agencies that had submitted them originally to obtain the additional information. Once received, every survey form was assigned an identification number that uniquely identified its record in the Microsoft® Access 1997 database designed to contain all project data. The identification number was also written on the hard copy of each form so that data entry could be checked if discrepancies were identified. The finished database contained 115 fields directly corresponding to questions on the survey form. A series of 26 forms led the data entry person through the entry of each piece of survey information into the corresponding database field. The forms contain boxes for each field in the main data table, with most responses selected from drop-down menus to ensure consistent data entry.

Continuing communication between UC Davis and the participating agencies was essential to ensure that the survey forms were completed in a consistent manner. Two products, an email list service and a World Wide Web page, were established by April 1999 to assist in communicating the project status. The email list was open to anyone and was used primarily to distribute monthly newsletters. The web page (<http://cee.engr.ucdavis.edu/faculty/young/lstudy/lstudy.htm>) contains project updates, contact information, a list of participating agencies and allows the download of survey forms and past newsletters.

Each survey form required inspectors to complete a minimum of 22 fields of information and inevitably some of these questions were answered incompletely or incorrectly on some of the submitted forms. A quality assurance program was instituted to identify and correct these errors. Blank submissions to necessary questions (e.g., those questions for which one of the listed answers *must* have been true, such as the material of tank and piping construction) were not allowed, as they would bias the statistical results. Data might have been omitted because either the inspector could not determine the answer, in which case the inspector was encouraged to indicate *Unknown* or because the inspector was not adequately trained in how to properly complete the forms. In either case, the inclusion of blank answers would introduce a non-sampling error into the results [9]. Those forms that lacked any piece of information were returned to the respective agency with a memorandum explaining the quality assurance process. The agencies were asked to fill in the missing information on the returned forms and resubmit them. Once the forms were deemed acceptable, they were entered into the database.

Another form of quality assurance practiced throughout the study was to examine the data table for errors added during data entry, such as misspellings (this was particularly a problem for inspector's names), or errors in the survey forms such as extra data or non-standard responses. The query function was utilized to find records that posed possible problems, and enabled the data entry person to directly correct the error by comparing the entered data with the original survey form. The most frequent type of corrections made during this data checking process related to the fields for pipe and tank material, leak detection method, and release identification method. Some of these problems were caused by problems in the survey form design.

The field for pipe material contained separate choices for *Galvanized Steel* and for *C.P.*; it was intended that only one of these be selected but the instructions were not clear. Some inspectors marked both choices when they encountered a cathodically protected steel piping system while others simply marked *C.P.* for such systems. All records that selected both *Galvanized Steel* and *C.P.* were corrected to indicate only *C.P.* *Galvanized Steel* was the only choice of steel provided on the survey form for tank or piping material. This choice was intended to encompass all steel systems without adequate corrosion

protection. In some instances, inspectors selected *Other* for the tank and piping material and described *Other* as bare steel, unprotected steel, asphalt tar-coated steel, or steel. All entries listing steel that was not cathodically protected were considered *Galvanized Steel*. Inspectors also occasionally indicated brand name materials in the other tank materials field. A query was designed to select such records and to complete the following substitutions:

- Plasteel → *Composite*
- ACT-100 → *Composite*
- Permatank → *Composite*
- sti-P3 → *Galvanized Steel* for Tank Material
- *Manufacturer's CP* for Tank CP/Lining

Several typical problems were related to the completion of the leak detection section of the survey form. Some records indicated the last PT, SIR, or TTT test results, however the field for the test date was left null. In some cases omitting the date was a data entry error that was corrected by referring to the original survey form. In other cases the date was not provided on the form and placing the choice *Unknown* in the *Date is Known* field indicated this. Another type of data checking involved comparing the field *Leak Detection* to choices for individual methods. Whenever the database indicated that leak detection methods were not being implemented at a particular site, yet information specific to leak detection methods was present such as *Brand Name, Model Number, or Problem* this triggered a check of the database against the original survey form. Conversely, if the database indicated for some records that leak detection methods were being implemented at a particular site, yet information specific to that leak detection method was absent such as *Brand Name, Model Number, or Problem* this also initiated a check of the original form.

In the case of a release, the inspector was asked to note how the release was discovered. Choices for this question were *Leak Detection Method(s), Closure/Removal, Property Transfer, Visual/Olfactory, Water in Tank, Other, or Unknown*. When *Leak Detection method(s)* was selected as the form of identification, some records failed to further indicate the specific leak detection method used as identification. If only one leak detection method was specified in the Leak Detection Section of the

survey form, then the record was corrected to identify that specified method as the method of identification. If more than one leak detection method was specified, then the record was corrected to read *Unknown* as the leak detection method of identification.

In some instances, the inspectors selected more than one tank product. It is assumed that this occurred either because the inspector was unaware that for varying characteristics of the UST site, they were to complete separate forms for each varying condition or because the tank system(s) being inspected actually contained two products, as in the case of a multi-compartment tank.

In either case, the first product indicated on the form was assumed to be the predominant species and therefore the record was corrected to read accordingly. In these events, a note was made in the *Comments* section of the database. This omission of data was considered acceptable since only 12 out of the 1648 records indicated multiple products.

III. RESULTS AND DISCUSSION

III. A. OVERVIEW OF DATABASE

A total of 1792 survey forms were submitted during the course of the project (Table 1). Over 35% of these forms had to be sent back to the agency for additional information, but this figure overstates the problems encountered in completing the forms since nearly half of the returned forms were those being “retrofit” from the previous California study [8]. Over 75% of the forms returned for completion were subsequently resubmitted. On only one occasion was an incomplete form returned more than once to an agency. By the end of the study 1648 valid records were submitted, almost 92% of the forms originally submitted. Because of a record keeping error, there is a discrepancy between the number of records included in the final database and the number that would be calculated by subtracting the unreturned forms from those initially submitted for six of the states (indicated with an asterisk in Table 1). The discrepancy affects 10 records out of a total of 1792 submitted (0.5%) so it is unlikely to bias the study results. Almost 75% of the records in the final database come from just four states (Kansas, California, South Carolina and Michigan). Although these states are diverse, the study’s initial goal of obtaining an approximately representative nationwide picture of leak detection performance was not met.

To provide an overview of the nature of the UST systems included in the survey database, the remainder of this section summarizes some important elements of system design and the size and extent of any associated releases. As expected, the vast majority (83.4%) of the systems in the database were being inspected during closure (Table 2). This bias toward systems that were being removed from service, many in advance of or soon after the 1998 deadline for removing or upgrading substandard UST systems, was anticipated in the study design. All that was deemed necessary for determining the success of leak detection was to have systems that had previously been tested for releases with one of the federally approved release detection methods and that could subsequently be checked for releases with an independent method, such as an inspection at closure. The success of this approach is discussed in

section III.B. below. It is important to note that because of the bias toward systems being removed from service in this sample, NO conclusions should be drawn from this study regarding compliance with regulatory requirements or prevalence of releases in the average operating UST system.

Table 1. Summary of survey form submission and the quality assurance process

	<i>Forms Initially Submitted</i>	<i>Forms Sent Back</i>	<i>Sent Back forms Resubmitted</i>	<i>Forms Included in Database</i>	<i>Percent of Total Forms Included</i>
Alabama	7	3	3	6*	0.4
Arizona	18	6	6	18	1.1
California	379	335	216	263*	16.0
Colorado	13	5	4	12	0.7
Florida	108	38	27	96*	5.8
Kansas	521	0	0	521	31.6
Maine	13	2	0	12*	0.7
Maryland	109	37	33	116*	7.0
Michigan	198	101	101	198	12.0
Montana	20	10	10	20	1.2
Nebraska	32	4	4	32	1.9
New Mexico	7	0	0	7	0.4
New York	34	3	1	32	1.9
North Carolina	23	2	2	19*	1.2
South Carolina	245	57	54	242	14.7
Utah	35	24	24	36*	2.2
West Virginia	30	12	0	18	1.1
Total	1792	639	485	1648	

*The total number of forms included in the database for these states does not match the value calculated from (submitted-sent back+resubmitted) because of accounting errors.

Table 2. Reasons for inspection

	Number	Percentage
Removal/closure	1374	83.4
Compliance	114	6.9
Other	95	5.8
Release investigation	49	3.0
Repair	13	0.8
Unknown	3	0.2

The typical underground tank included in this survey was over 15 years old, was constructed of steel that was not adequately protected from corrosion, was single walled, and had not been upgraded with either a spill bucket or an overflow protection device (Table 3). These characteristics are typical of the UST population that was closed or upgraded in response to the federal regulations [1]. A total of 552 systems (33.5%) featured tanks that were corrosion protected (cathodically protected steel, fiberglass or composite).

Table 3. Summary of tank design characteristics

	Number	Percentage
<u>Tank Material</u>		
Steel	1336	81.1
Fiberglass	220	13.3
Composite	75	4.6
Other	9	0.5
Unknown	8	0.5
<u>Tank Walls</u>		
Single	1542	93.6
Double	77	4.7
Jacketed	21	1.3
Unknown	8	0.5
<u>Tank CP/Liner</u>		
None	1358	82.4
Manufacturer CP	184	11.2
Retrofit CP	73	4.4
Lined	22	1.3
Retrofit CP and Lined	11	0.7
<u>Tank Age</u>		
> 15 years	1097	66.6
11-15 years	285	17.3
6-10 years	149	9.0
0-5 years	29	1.8
Unknown	88	5.3
<u>Upgrade</u>		
None	975	59.2
Spill bucket and overflow protection	416	25.2
Spill bucket	170	10.3
Overflow protection	33	2.0
Unknown	54	3.3

Piping systems surveyed were also generally unprotected from corrosion, more than 15 years old, and single walled (Table 4). Only 352 of the piping systems (21.4%) were corrosion protected. The pumping systems associated with the piping were more diverse, with a significant representation (>20% each) of pressure, suction and safe suction designs.

Table 4. Summary of piping design characteristics

	Number	Percentage
<u>Piping Material</u>		
Unprotected steel	949	57.6
Fiberglass	298	18.1
Steel with cathodic protection	54	3.3
Flexible plastic	41	2.5
Other	111	6.7
Unknown	195	11.8
<u>Piping Walls</u>		
Single	1487	90.2
Double	89	5.4
Trench liner	7	0.4
Unknown	65	3.9
<u>Piping Age</u>		
> 15 years	1031	62.6
10-15 years	324	19.7
5-10 years	157	9.5
0-5 years	50	3.0
Unknown	86	5.2
<u>Pump type</u>		
Conventional suction	575	34.9
Pressure	534	32.4
Safe suction	375	22.8
None	59	3.6
Other	50	3.0
Unknown	55	3.3

The vast majority (84.3%) of the systems surveyed were reported to be using release detection (Table 5). However, this statistic overstates compliance with the federal release detection regulations. For example, 298 of the 1390 systems reported to be practicing release detection were only using manual inventory reconciliation, which is not allowed as an independent release detection method under the federal regulations. The regulations allow a variety of methods of release detection to be used in varying

combinations [1]. Only 191 of the systems surveyed had release detection configurations that apparently met those requirements for both tank and piping release detection. An even smaller number of systems were probably performing the tests regularly enough to satisfy the regulations. For instance tank tightness testing was required annually prior to December 1998 for systems that did not meet the design standards for upgraded systems, but only 15 of the 49 bare steel systems using tank testing for release detection had been tested in the 365 days before they were inspected. The remainder of these systems had been tested more than 4 years earlier on average. The most common methods of release detection in the study population were tank or line tightness tests. This finding is not surprising since investments in permanently installed monitoring equipment might not be warranted for systems about to close.

Table 5. Summary of Release Detection Methods Used

	Number	Percentage
<u>Release detection utilized?</u>		
Yes	1390	84.3
No	194	11.8
Unknown	64	3.9
<u>Methods of release detection</u>		
Manual inventory reconciliation	966	58.6
Manual tank gauging	192	11.7
Statistical inventory reconciliation	227	13.8
Dispenser sump detection	11	0.7
Tank tightness testing	533	32.3
Piping tightness testing	385	23.4
Automatic tank gauging	215	13.0
Interstitial monitoring	57	3.5
Groundwater monitoring	34	2.1
Vapor monitoring	73	4.4
Mechanical line leak detector	321	19.5
Electronic line leak detector	48	2.9

Releases were indicated for 943 (57.2%) of the systems in the database. The characteristics of these releases, to the extent they were known, are summarized in Table 6. Most of the releases were either considered old or had occurred at an unknown time in the past. Fewer than five percent of the releases were thought by inspectors to have occurred within the year prior to the inspection.

Table 6. Characteristics of the 943 identified releases

	Number	Percentage
Release age		
Old (> 1 year)	521	55.2
Recent (< 1 year)	44	4.7
Recent and old	3	0.3
Unknown	375	39.8
Release Source		
Tank	281	29.8
Spill/overflow	180	19.1
Piping	157	16.6
Dispenser	150	15.9
Unknown	355	37.6
Release extent		
Large (beyond excavation)	258	27.4
Localized tank	346	36.7
Localized piping	85	9.0
Localized dispenser	90	9.5
Off-site	18	1.9
Unknown	216	22.9
Release date known		
Unknown	836	88.7
Known	105	11.1
Other	2	0.2
Release cause		
Unknown	583	61.8
Known	342	36.3
Other	18	1.9
Identification method		
Known	924	98.0
Unknown	19	2.0

Release date	Number	Percentage
before 1985	4	3.8
1985-1989	12	11.4
1990-1994	11	10.5
1995-1996	4	3.8
1997-1998	13	12.4
1999-2000	24	22.9
Ongoing	37	35.2

Release cause	Number	Percentage
Physical damage	57	16.7
Corrosion	118	34.5
Mechanical failure	23	6.7
Spill/overflow	171	50.0
Faulty installation	29	8.5

Release identification	Number	Percentage
Closure	756	81.8
Visual/olfactory	178	19.3
Other	39	4.2
Leak detection	36	3.9
Property transfer	26	2.8
Water in tank	14	1.5

Many of these releases (47.8%) impacted only areas within the excavation zone near the tank, piping or dispenser. The most prevalent causes of release were spills and overfills followed closely by corrosion-related failures. Over 80% of the releases were identified during the closure of the UST systems. Fewer than 4% of the releases were identified by release detection methods, but this is not surprising given the relatively poor compliance with the release detection regulations among the sample population. The release detection methods that successfully discovered releases in the survey included tank tightness testing (11), piping tightness testing (7), manual inventory reconciliation (4), statistical inventory

reconciliation (4), automatic tank gauging systems (2) and vapor monitoring systems (1). Manual or electronic line leak detectors, manual tank gauging, interstitial monitors and sump dispensers detected no releases.

Overall, compliance with the federal release prevention regulations relating to corrosion protection, spill and overflow prevention and routine monitoring for releases was not common among the systems included in the survey. Only 79 of the 1648 systems (4.8%) had all of the elements required. Actual compliance may be less than this figure because the operability of the required system components was not verified during most of the inspections. Among these apparently compliant systems, releases were somewhat less likely than in the general survey population, with 35 of the 79 systems (44%) showing evidence of a release. Only three of the releases appeared to be recent, and all of these were associated with piping (2) or pump (1) systems.

III. B. WEAKNESSES OF DATA AND STUDY DESIGN

A number of limitations of the study design were known from the outset and related primarily to the decision to use existing inspections and test results rather than conducting dedicated ones, a decision that allowed the project to be completed within a reasonable budget. Other limitations came to light during and after the study and related to the design of the survey form and the nature of the data collected. Collectively these problems reduce the ability to make conclusive statements about the performance of release detection methods and, therefore, these limitations are discussed in detail before presenting the performance estimates in section III. C.

Failure to distinguish between facilities and systems

The first line on the survey form provided a place to indicate that more than one survey form was being submitted for a particular site. It was intended that a separate form be completed for every individual UST system at a facility so that each record in the database corresponded to a single UST system. However, the directions on the survey form indicate that multiple forms should be completed

only if there are *different* configurations among the multiple systems at the site. An inspector following these directions carefully would have submitted one form for a facility with three tanks of identical construction and release detection approach but would have submitted three forms if different release detection methods had been applied to each tank or if their construction was different (e.g., fiberglass vs. steel). This confusion between facilities and systems is significant because if one tank at a three tank facility were leaking and all three tanks passed their most recent tank tightness test, a single form might indicate that the most recent test result was a pass and that the facility had a release. That data would be interpreted as showing that tank testing was correct in 0% of the cases. If three forms had been completed for the same facility, it would have seemed that tank testing was correct in 66% of the tests since two of the passed tests occurred on non-leaking tanks. A total of 697 records (42.3%) in the database come from facilities where more than one form was completed. Since 52.0% of the facilities inspected were retail gasoline stations and since most of these have more than one tank system, it is clear that a potentially significant number of “single” forms were prepared for facilities with multiple UST systems. This fact compromises the ability to draw useful conclusions from the database about the “correctness” of release detection results.

Lack of information on release and test timing

The most important pieces of information in the survey for determining release detection performance are whether and when the system passed its last release detection test and whether and when the system had a release. However, the database contains very few records with both the date of the last test and the date of a release. The date of a release is almost never known in practice unless a catastrophic failure occurs. The situation is even more complex if more than one release has occurred over the life of the facility, as is often the case at a retail gasoline station that has been in business for many years. In the survey population, a release date was provided for only 11.1% of the systems with releases. Although test dates are more commonly known than release dates, they still were unavailable in some cases (e.g., 8.4% of tank tests) presumably because the required records were not on site at the time of inspection.

Determining that a release detection method indicated the correct leak status for a UST system requires that the test precede the release discovery by a short period, creating a strong suspicion (but not proof) that the release was also present during the test. Consequently, only database records with both test and release dates available can reasonably be used to assess release detection performance. The paucity of this type of information in the database greatly reduces the number of records available for analysis and correspondingly reduces the statistical power of the associated results.

Uncertainty in release identification and extent

Knowing when a release began is only a part of the difficult judgment that inspectors were asked to make. They were asked to estimate, in their best professional judgment, whether a release had occurred and, if so, how big it had been. These determinations were typically made in the field using visual and olfactory evidence within the excavation zone as an UST system was being closed. Although this method is somewhat reliable, it can provide misleading results for a number of different reasons. Some geologic formations transmit released material away from the release point very efficiently (e.g., sands, gravels and karst terrain) while others retain the material and stain noticeably. Therefore, two sites with the same leak histories might appear very different during an inspection. Similarly, in some cases a petroleum release might be quickly biodegraded, while in another bioremediation may be retarded because of limited availability of nutrients or oxygen. Although regulatory agencies often require laboratory testing of soil and/or groundwater samples before a facility is closed, these results are often unavailable for several months. Waiting for these results would have delayed the study and greatly reduced the number of forms submitted. The strength of a large sample size was deemed preferable to more precise information about whether, and to what extent, a release had occurred. The extent of a release is important for assessing release detection performance because release detection methods are expected to more accurately discover releases that are larger, while missing releases that are smaller. This is expressed in the regulatory requirements for methods like tank testing that must detect releases of 0.1 gallons/hour at least 95% of the time [1]. A leak detection method that misses a leak below its detection

threshold has not made a “mistake” according to the requirements for that method but this could not be accounted for in analyzing the data for this study. The effect of this is to understate the effectiveness of release detection methods in discovering the type of release that they were designed to detect.

Inability to distinguish between leaks and releases

Regulated substances such as gasoline can get into the environment at a UST facility via a variety of routes including leaks in UST system components or spillage during product delivery or dispensing. Leak detection devices that operate inside the tank and piping system such as tank tightness tests or automatic tank gauges can detect leaks but not spills or overfills. If a release is discovered after a system passes a tank tightness test the test would be judged correct if the release was due to a spill event but would be incorrect if the release came from the tank. Inspectors were asked to indicate the source of releases they identified and were able to do so in 62.3% of the cases. The determination of release source from evidence left behind, possibly long after a release has ceased, demands some difficult professional judgment and different inspectors might come to different conclusions faced with the same evidence. Therefore, these determinations must be viewed cautiously.

III. C. LEAK DETECTION PERFORMANCE ESTIMATES

Despite the important limitations noted above regarding the survey methodology and the data collected, it is still possible to draw some useful conclusions about release detection performance from the data. This section examines each of the major release detection methods allowed under federal regulations and, to the extent possible, develops performance estimates.

Tank tightness testing

Tank tightness testing is the best represented release detection method in the survey data and therefore the most can be said about its performance. The method was used for release detection by 533 (32.3%) of the systems. Tank tightness test results are included in the database for 843 (51.1%) of the records. The additional systems presumably used the tank test as a release confirmation tool, or it may

represent an error in the database field that tracks tank test utilization. Of the systems performing a tank tightness test, 543 (64.4%) had a release while the remaining 300 (35.6%) did not. Most (98.3%) of the systems without a release had passed their most recent tank tightness test, while an additional 1.0% had an inconclusive result. Only two systems without a release had failed their most recent test. One of these tests was nearly six years (2155 days) before the inspection so it is possible that there was a release at that time but that it was no longer observable during the inspection. The other failed test occurred just 51 days before the inspection that indicated that no release had occurred. This one test may have been a false alarm, equal to a false alarm rate of about 0.3%. For the 543 systems with a release, 7 of them had failed the most recent tank test. All seven of these systems had the tank as an indicated source of the release. In four of these cases the release was discovered by the tank test, while for the other three the tests were performed between 15 and 279 days before the inspection. All 7 of the failed tank test results are therefore likely to have correctly indicated the presence of a leaking tank. Of the 536 systems that passed their tank test and subsequently were discovered to have a release, only 148 had the tank as a release source. Only 8 of these 148 systems were judged to have a “recent” release that might have been detectable by a recent tank test. Only two of these tests had been conducted in the one year prior to being inspected. These two systems might have had an ongoing release at the time the tank test was conducted. Therefore, of the nine systems that apparently had a tank leak during the time a tank test was conducted, seven of them were correctly determined by the test to have been leaking. A crude estimate of the probability of detection for tank tightness testing is therefore between 78-100%.

Statistical Inventory Reconciliation

Statistical inventory reconciliation (SIR) was used as a release detection method by 227 systems in the sample. A release was subsequently discovered at 149 of these systems while the remaining 78 had no release. Of the 149 systems with releases, 34 of them passed their most recent SIR, 7 failed and 2 had inconclusive results. No test result was reported for 106 of the systems, despite the fact that they were supposed to be using this method of release detection. The information may be missing because it was

not available at the site when the inspector visited, although it is unclear why this problem would afflict SIR to a greater degree than tank tightness testing, which did not exhibit this problem. Of the 34 passed tests, 21 of them were from systems with a tank, piping or dispenser release source, which SIR would be expected to find. Only two of these 21 cases were “recent” releases that a recent SIR might have reasonably been expected to find. For one of these two cases there is no information in the database regarding either the test or the release date, making it difficult to determine if SIR missed the leak or if it arose sometime after the testing was completed. The other case appears to be an SIR error because the test was passed just 16 days before a piping release was discovered. Among the seven failed SIR tests on systems with releases, five of them had release sources that might have been caught by SIR. Four of the five tests had been conducted in the year prior to the inspection and the last was conducted an unknown amount of time prior to the inspection. Therefore, it appears that SIR correctly indicated a release in four cases and missed one resulting in an estimated probability of detection of 80%. For the 78 systems that did not have a release there were 15 passed tests, 1 failure and 62 unreported results. The failure occurred just 49 days before the inspection that indicated no release had occurred, suggesting that this test result was in error. The resulting probability of false alarm for SIR is about 6%.

Piping tightness testing

A total of 385 records indicated that hydrostatic line tests had been conducted to determine the integrity of the piping system. Releases were discovered at 206 of these systems for which the test results were 191 pass, 0 fail, and 15 unreported. Only 35 of the systems with a release indicated the piping as a release source, and only five of these had known dates of testing and release. In two of these cases the test occurred after the inspection, possibly following a repair of a release discovered in another manner. The other three systems with known test and release dates were tested more than 1728 days prior to the onset of the release. Thus, in all five of these passed tests it is possible that the piping test reached the proper conclusion about the leak status of the line when it was tested. There is not enough information to reach even an imprecise estimate of the probability of detection for piping tightness tests. At least one

correct detection is required to establish this probability and the database does not include any detections. For the 179 systems without a release, 172 of them passed their most recent piping test while 7 had unknown results. The lack of any failed test results within the sample suggests that the probability of false alarm for line tightness tests is 0%.

Automatic tank gauging

The results of the most recent release detection test were not requested on the survey form for automatic tank gauges (or for the other permanently installed methods), primarily because it was believed that this information would not be available to the inspectors during the inspection. Therefore, only qualitative estimates of performance can be provided for these methods. Of the 215 systems employing automatic tank gauges, 115 had a release and 100 did not. The tank was identified as the source of 19 of the releases and three of these were judged to be recent. It is expected that an ATG could have detected recent tank releases in these three cases so they may represent missed detections.

Manual tank gauging

Manual tank gauging is allowed as a stand alone release detection method only for smaller tanks that can be taken out of service for testing for more than one day at a time. Of the 192 systems using this method of release detection, releases were discovered in 98 cases. The tank was the source of the release in just 22 of these cases and of these only two of the releases were “recent.” These two cases may represent missed detections by manual tank gauging.

Interstitial monitoring

The proportion of releases is far lower among systems with interstitial monitors (and secondary containment) than for the other types of release detection. Just 16 of the 57 systems using interstitial monitors were found to have a release. Of these 16 cases, four were discovered to have both single walled tank and piping indicating that an error was probably made when the interstitial monitoring field was filled out. Seven of the records had both double walled pipe and tank and two recent releases were discovered among this group. One of the releases was caused by a leaking pipe and the other by a spill

and/or overflow. For the five systems that had releases and used interstitial monitoring only for the tank (because they had single walled piping), none of the releases occurred from the tank. Therefore only one of the systems using interstitial monitoring may have experienced a missed detection.

Groundwater monitoring

Groundwater monitoring was used as a release detection method for just 34 systems, the least prevalent of the major release detection methods in the database. Groundwater monitoring was the leak detection method with the greatest likelihood of being used to actually discover a release, being listed as the means of discovery 7 times, although only one of these detection events was for a system using this method for routine release monitoring. The other systems were probably conducting groundwater monitoring to investigate a release initially identified by other means. Of the 34 systems using the method routinely, 19 had a release and 15 did not. Just two of the 19 releases were estimated to be recent and both were caused by spill and/or overflow events. Both were ultimately discovered by visual/olfactory means. In one of these cases the groundwater monitor was reported to be non-operational at the time of inspection, so there is the possibility of one missed detection for this method when it is operational.

Vapor monitoring

Vapor monitoring was employed as a release detection method for 73 systems in the database. A release was discovered at 51 of these systems. Only one of these releases was considered to be recent, with the remainder being either old (37) or unknown (13). The release was localized to the area around the piping and was discovered by visual/olfactory means. Vapor monitoring should probably have discovered such a release and therefore this may represent a missed detection. No evidence of a release was found at 22 systems using vapor monitoring.

Mechanical line leak detectors

Mechanical line leak detectors are a prevalent form of nearly continuous release detection for pressurized piping systems. A total of 321 systems were reported to be using this method. Three of these systems had a pump type listed as suction, a type of piping on which mechanical line leak detectors will

not operate so these records are somehow in error. A release was identified at 194 of the systems using this method and piping was a source of release in 35 of these cases. Two of these releases were identified as recent while the remaining releases were more than one year old or of unknown age. One of the recent releases had a date of release listed that was more than 10 years before the inspection, calling this record into question. The other recent release was correctly indicated by the mechanical line leak detector, which triggered a release investigation inspection four days later. Therefore, it appears that there is one correct detection and no missed detections for mechanical line leak detectors in the database. A total of 127 systems using mechanical line leak detectors had no release discovered during the inspection.

Electronic line leak detectors

Electronic line leak detectors are more costly and less common than the mechanical variety, being used by only 48 systems in the database. Releases were discovered at 28 of these systems, but piping was the source of only three of these releases. One of the releases was judged to be recent and this release appears to have been discovered by the electronic line leak detector. The system in question had a Veeder-Root TLS 350 automatic tank gauge and a Veeder-Root PLLD line leak detector and the inspector indicated that the ATG discovered this piping release. Since the same console is used for both systems, it is likely that the electronic line leak detector and not the tank gauge discovered this piping release. In any event, the release was successfully discovered by the integrated system so should not count as a missed detection. Therefore, it appears that electronic line leak detectors had a successful detection and no missed detections in the database.

IV. CONCLUSIONS

1. The study suffered from serious limitations caused by insufficient attention to survey design and the collection of incomplete data by inspectors, typically because the data were unavailable. Most of these problems are inherent in the selected approach of relying on existing information, but some could be remedied by more careful survey design.
2. The goal of estimating the probabilities of detection and false alarm for release detection methods operated under realistic field conditions was generally not achieved. Although a large enough total sample of UST systems was surveyed (1648), most of these records lacked information required to generate a performance estimate, especially the date of release onset. The sample of systems with a recent release and a recent test result is small enough for most methods that strong conclusions about performance cannot be drawn.
3. Most methods of release detection had one or more cases in which a missed detection appeared likely, although estimating the probability of detection from these events was often not possible because of incomplete information.
4. Imprecise estimates of the performance of a few methods were developed from *very* small samples. Tank tightness testing had an estimated probability of detection between 78-100% (N=9) and a false alarm rate of about 0.3% (N=300). Statistical inventory reconciliation was estimated to have a probability of detection of 80% (N=5) and a false alarm rate of about 6% (N=16). The small sample sizes involved and the limitations noted above make these estimates subject to substantial uncertainty.

V. REFERENCES

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- [9] Lessler, Judith T. and William D. Kalsbeek. Nonsampling Error in Surveys. New York: John Wiley & Sons, Inc, 1992.

APPENDIX A

PARTICIPATING INSPECTORS AND AGENCIES

Name	State Agency ¹	Name	State Agency ¹	
R.	Acierno	Colorado DLE	Howard Debauche	Kansas DHE
Ron	Adams	Kansas DHE	Raul Diaz	California SWRCB
Barry	Addertion	North Carolina DENR	Doug Doubek	Kansas DHE
Roy	Alexander	California SWRCB	Chris DuFex	Colorado DLE
	Allinder	California SWRCB	E. Elkin	Florida DEP
Ross	Arbelius	Florida DEP	Pejman Eshraghi	Arizona DEQ
Bruce	Ard	Kansas DHE	Tim Fillmore	California SWRCB
Robert	Aronne	Arizona DEQ	John Fishler	Arizona DEQ
	Ballen	California SWRCB	Luis Flores	California SWRCB
Phyllis	Barnett	Florida DEP	David Flowers	Florida DEP
A.	Bates	Nebraska SFM	Kasey Foley	California SWRCB
Gene	Belcastro	California SWRCB		Michigan DEQ
G. A.	Black	Michigan DEQ	Sergio Garcia	California SWRCB
Theresa	Blazicevich	Montana DEQ	Leonard Gill	Michigan DEQ
D.	Booth	California SWRCB	Jesse Goodley	Colorado DLE
Lois	Bouletle	Michigan DEQ	Dan Graham	North Carolina DENR
S.	Brezinski	Maine DEP	Tom Gray	New Mexico ED
Letitia	Briggs	California SWRCB	Leroy Griffin	California SWRCB
A.	Brooks	Montana DEQ	Bruce Hall	Utah DERR
R.	Bryant	California SWRCB	Paul Harding	Utah DERR
Susan	Bull	Maryland DE	Carolyn Hawkins	California SWRCB
M.	Buren	California SWRCB	Bill Heimann	Kansas DHE
D.	Burns	California SWRCB	James Henderson	South Carolina DHEC
John	Burton	Florida DEP	Carol Herington	New York DEC
Tom	Buttrick	Michigan DEQ	Robert Hill	Maryland DE
Blasé	Campbell	Florida DEP	Craig Hodes	Alabama DEM
Robert	Caper	Florida DEP	Richard Holcomb	Colorado DLE
	Carrier	New York DEC		California SWRCB
	Carver	California SWRCB	John Hooks	North Carolina DWM
Laura	Chaddock	California SWRCB	Phil Hudecek	California SWRCB
	Charbonneau	Michigan DEQ	Meer Husain	Kansas DHE
Neil	Checketts	Utah DERR	Don Jackson	West Virginia DEP
Eugene	Cherno	Florida DEP	George Johanson	Utah DERR
Mary	Coll	Maine DEP	Linda Johnson	Florida DEP
R.	Cooper	Florida DEP	John Kara	California SWRCB
Bruc	Costa	Utah DERR	David Karlau	Montana DEQ
Chris	Costello	New York DEC	Dan Kellerman	Kansas DHE
Mark	Cramer	California SWRCB		Florida DEP
Guy	Dansie	Utah DERR	Lynn Konzer	Michigan DEQ
Matt	Dareangelo	New York DEC	T. Lane	New York DEC
Warren	Davis	Michigan DEQ	Scott Lang	Kansas DHE
			B. Lehmaun	California SWRCB

	Name	State Agency ¹
Jerry	Lemos	California SWRCB
	Lockman	Colorado DLE
J.	Long	Alabama DEM
	Lucantonio	New York DEC
Greg	Lyon	California SWRCB
B.	MacGregor	California SWRCB
Stan	Marcotte	Kansas DHE
Deborah	Mayo	North Carolina DENR
Robert	McClellan	California SWRCB
	McGee	Michigan DEQ
	McKinley	Michigan DEQ
Steve	Miettinen	Michigan DEQ
	Moldenhauer	Florida DEP
B.	Nelson	California SWRCB
Al	Netto	California SWRCB
	Netto	New York DEC
Brad	Newton	North Carolina DENR
Brad	Nicolet	California SWRCB
	Ortega	California SWRCB
J.	Ortiz	California SWRCB
M.	Padila	Arizona DEQ
Kyle	Parker	Kansas DHE
Rick	Pawley	Michigan DEQ
Leslie	Pedigo	Florida DEP
Lorenzo	Perez	California SWRCB
L.A.	Perreault	California SWRCB
Drew	Pinkorsky	Florida DEP
Chuck	Pippen	North Carolina DENR
Carl	R.	California SWRCB
R.	Rapista	California SWRCB
Greg	Rasmussen	Nebraska SFM
Jim	Ray	California SWRCB
M.	Rees	California SWRCB
	Reid	California SWRCB
John	Rigter	California SWRCB
Larry	Rineleant	Nebraska SFM
R. R.	Roberts	Michigan DEQ
Brown	Roe	Maryland DE
	Rose	California SWRCB
Jeff	Rosert	California SWRCB
Laura	Ross	Arizona DEQ
Scott	Ross	Florida DEP
William	Ross	Florida DEP
Clinton	Rossmann	Nebraska SFM
M.	Rost	California SWRCB

	Name	State Agency ¹
Meredith	Roth	Kansas DHE
Jeff	Rusert	California SWRCB
Ted	Ryan	California SWRCB
Jim	Sappington	California SWRCB
	Sasson	California SWRCB
Ted	Scharf	Maine DEP
Bernd	Schleicher	California SWRCB
Charlie	Schwartz	North Carolina DENR
R.	Self	California SWRCB
Mike	Sheffield	Florida DEP
Don	Shelrock	California SWRCB
Rolland	Shrewsbury	Florida DEP
Linda	Shurlow	California SWRCB
Steve	Singer	Florida DEP
J.	Smith	California SWRCB
G.	Smool	California SWRCB
Greg	Soonhein	California SWRCB
Lea	Spann	California SWRCB
J. S.	Stevenson	Florida DEP
Angie	Sweeney	Florida DEP
Carries	Szot-Ferguson	North Carolina DENR
Jeff	Taber	California SWRCB
Joseph	Thayer	Florida DEP
William	Thornton	Kansas DHE
Susan	Tiffany	Maryland DE
Kevin	Tinsley	California SWRCB
Sandy	Tosch	California SWRCB
Eric	Trevena	California SWRCB
	Tsumara	California SWRCB
Loretta	Tucker	California SWRCB
David	Van Dyne	California SWRCB
Sande	Wages	California SWRCB
Ken	Wall	Florida DEP
Glen	Wall	Maine DEP
Thomas	Webb	Michigan DEQ
Dan	Wells	Kansas DHE
Frank	Wezner	Maine DEP
J.	White	California SWRCB
Charles	Wicke	Florida DEP
Paul	Wilkinson	Alabama DEM
E.	Wilson	Arizona DEQ
David	Wilson	Utah DERR
Gladys	Wong	California SWRCB

APPENDIX B

SURVEY FORM

This survey should be completed for any UST site for which some independent evidence of leak status is available (typically an open excavation). The form should be filled out *even if there is no evidence* of a current or past release. Please exercise your best professional judgement when evaluating the tank systems, their components and any possible release. Try to fill in at least one box on every line (except as noted below).

Multiple Forms:

Whenever a site contains multiple tank or piping configurations, multiple products or varied release detection methods, the inspector should complete one form for each different configuration and check the box indicating that more than one form has been completed for the site. Indicate the total number of forms to be filed for the site.

Site Information:

Provide information about the site as requested. If your agency assigns each site a unique identifying number, please include that number in the Facility ID# space, otherwise leave it blank.

System Information:

Tank Material: Note the material of tank construction. Composite means fiberglass bonded to steel.

C.P./lining: Note whether the tank(s) have manufacturer installed or retrofit cathodic protection and/or internal lining. Check all boxes that apply (e.g., retrofit C.P. and lined)

Tank Walls: Note whether the tank(s) are single walled, double walled, or jacketed with an interstitial space.

Product: Note the last known contents of the tank(s).

Tank Age: Note the age of the tank(s).

Upgrade: Note whether the tank(s) have spill and overflow devices in place at the time of inspection.

Piping Material: Note the material of the piping in contact with liquid product (not vent lines).

Piping Walls: Note whether the pipes are single walled, double walled or single walled contained in a trench liner.

Piping Age: Note the age of the piping. If the site has piping of different ages, please note that.

Containment: This section refers to the presence of containment sumps under the dispenser or around the pump turbine. Check the appropriate box(es) if these sump(s) are present.

Pump type: Note the type of pumping system. Safe suction (European Suction) refers to suction lines with only one check valve located as close as possible to the tank. Conventional suction is any other suction system.

Leak Detection

Note the type of leak detection equipment at the site, and whether it was operational at the time of the inspection.

Last TTT: Note the date and result of the last tank tightness test, if any.

Last PT: Note the date and result of the last piping tightness test (hydrostatic line test), if any.

Last SIR: Note the date and result of the last statistical inventory reconciliation, if any.

Release Information

Indicate if there appears to have been no release at the site, a release to the environment, or a release that was contained by the secondary containment system. Provide an estimate of the date the release began and/or the date the release was discovered, if known. If the release was discovered during your inspection, please use the date of the inspection.

Source: Identify the portion of the system that leaked or indicate that the release came from a spill or overflow. A tank leak is any failure of a tank surface that is not directly a part of any piping connection. A piping leak is a failure of any portion of the piping (except as defined as a dispenser leak) up to and including connections to the tank. Dispenser leaks are releases from those portions of the piping which, if the piping is double walled, would be on the dispenser side of the terminus of the double walled condition, or if single walled, those portions of the piping that are above grade under a dispenser.

Cause: Indicate the reason for the release. Mark as many boxes as apply.

How identified: Specify how the system owner/operator became aware of the presence of a release (if they had).

Estimated Age: Estimate the age of the newest portion of a release. If multiple releases have occurred, note that.

Estimated Extent: Estimate the extent of the release, based upon any and all information available to you at the time of the inspection and your best professional judgement.

Medium Affected: Indicate which environmental compartments have been affected by the release.

Key to abbreviations

C.P.	Cathodic Protection	TTT	Tank Tightness Test (precision test)
LD	Leak Detection	PT	Piping Test (hydrostatic line test)
Galv.	Galvanized	ATG	Automatic Tank Gauging System
SIR	Statistical Inventory Reconciliation	Vapor	Vapor Monitoring System
GW	Groundwater Monitoring System	LLD	Line Leak Detector

Check here if you are filling out more than one form for this site (see instructions) Number of forms for this site _____

Agency Information Inspector _____ Agency: _____ Date: _____

Reason for inspection: Removal Repair Release investigation Compliance inspection Other _____

Site Information Site name _____ Facility ID # _____

Address _____
Street Address _____ City _____ County _____

Facility type Retail Gasoline Outlet Other _____

System Information

Tank Material Galv. Steel Fiberglass Composite Other _____

C.P./lining Manufacturer's C.P. Retrofit C.P. Lined

Walls Single wall Double wall (same material) Double wall (jacketed) Unknown

Product Gasoline Diesel Used oil Haz. Substance Heating oil Other

Age 0-5yr 6-10yr 11-15yr >15yr Unknown

Upgrade Spill bucket Overfill protection None Unknown

Piping Material Galv. steel C.P. Rigid fiberglass Flexible plastic Other _____

Walls Single wall Double wall (rigid) Double wall (trench liner)

Age 0-5yr 5-10yr 10-15yr >15yr Unknown

Containment Dispenser sump Turbine sump None Unknown

Pump type Pressure Safe suction Conv. suction None Other _____

Leak Detection

Check all method(s) used at time of inspection or release identification

- | | |
|---|--|
| <input type="checkbox"/> Manual Inventory Reconciliation | <input type="checkbox"/> Manual Tank Gauging |
| <input type="checkbox"/> SIR (Brand/Model _____) | <input type="checkbox"/> Dispenser sump LD |
| <input type="checkbox"/> TTT (Brand/Model _____) | <input type="checkbox"/> Hydrostatic line test (Brand/Model _____) |
| <input type="checkbox"/> ATG (Brand/Model _____) | <input type="checkbox"/> Interstitial (Brand/Model _____) |
| <input type="checkbox"/> GW (Brand/Model _____) | <input type="checkbox"/> Vapor (Brand/Model _____) |
| <input type="checkbox"/> Mechanical LLD (Brand/Model _____) | <input type="checkbox"/> Electronic LLD (Brand/Model _____) |
| <input type="checkbox"/> No leak detection was used | <input type="checkbox"/> Unknown |

Note: Mark an "N" next to any type of leak detection that was installed but non-operational at the time of inspection.
Mark an "A" next to any type of leak detection that was in alarm mode at the time of inspection.

Last TTT? Pass Fail Inconclusive Date _____

Last PT? Pass Fail Inconclusive Date _____

Last SIR? Pass Fail Inconclusive Date _____

Release Information

No release (skip remainder of section) Release to environment (suspected) Release to secondary containment

Date release discovered _____ Estimated date of initial release _____

Source Tank Piping Dispenser Spill/Overfill Unknown

Cause Physical damage Corrosion Mechanical failure Spill/Overfill

Faulty installation Unknown Other _____

How identified? LD method(s) specify _____ Closure/Removal Property transfer

Visual/olfactory Water in tank Unknown Other _____

Estimated age Recent (< 1yr) Old (>1yr) Unknown

Estimated extent Localized tank Localized piping Localized Dispenser Large (beyond excavated area) Off-site

Medium affected Soil Perched groundwater Regional groundwater