

**ELECTRICAL LEAK LOCATION SURVEY
GENERAL GUIDE**



AUGUST 2017



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1.0 HANDBOOK INSTRUCTIONS

This handbook is intended for use by design engineers, regulatory agencies, construction quality assurance agencies, and any individuals seeking a basic knowledge of electrical leak location surveys. It is not a comprehensive guide for the performance of leak location surveys. It describes the most commonly used mobile liner integrity / leak location methods.

For more specific information related to your project, contact Abigail Gilson, TRI Environmental Director of Liner Integrity Services, at abeck@tri-env.com, 512-623-0511. TRI Environmental is a world-wide educational and service platform for liner integrity and leak location surveys. TRI performs electrical leak location surveys, provides leak location survey equipment, refers leak location companies world-wide, and provides technician training and certification.

2.0 EXPOSED GEOMEMBRANE SURVEYS

- References:** ASTM D6747: Standard Guide for Selection of Techniques for Electrical Detection of Leaks in Geomembranes
- ASTM D7002: Standard Practice for Leak Location on Exposed Geomembranes Using the Water Puddle System
- ASTM D7703: Standard Practice for Electrical Leak Location on Exposed Geomembranes Using the Water Lance System
- ASTM D7240: Leak Location using Geomembranes with an Insulating Layer in Intimate Contact with a Conductive Layer via Electrical Capacitance Technique (Conductive Geomembrane Spark Test)
- ASTM D7953: Standard Practice for Electrical Leak Location on Exposed Geomembranes Using the Arc Testing Method

2.1 Water Puddle Method (ASTM D7002)

The water puddle method is generally the preferred method for bare, non-conductive geomembrane due to its speed, but it requires a water source and becomes less sensitive on extreme side slopes and on sites with poor boundary conditions. When slopes are steeper than 2H:1V, the water lance method or arc testing method should be used. The method must demonstrate that it can locate a 1 mm diameter leak.

A low voltage direct current source is introduced to the water sprayed above the geomembrane and grounded to the subgrade underneath the geomembrane. An ammeter in series with the circuit converts the increase in voltage to an audible signal when the equipment passes over a leak.

The water sprayed onto the survey area to perform the test must be contained in the survey area (above the geomembrane to be tested). Conductive features such as concrete sumps and batten strips must be isolated and cannot be tested, since they will ground out the survey (give a false positive signal). Holes will not likely be detected on wrinkles unless conductive-backed geomembrane is used, or if the operator makes a successful attempt to push down the wrinkles and create intimate contact between the geomembrane and the subgrade.

2.2 Water Lance Method (ASTM D7703)

The water lance method is generally used when slopes are steeper than 2H:1V, but it can also be used on flat areas. It requires a water source and becomes less sensitive on sites with poor boundary conditions. The method must demonstrate that it can locate a 1 mm diameter leak.

A low voltage direct current source is introduced to the water sprayed above the geomembrane and grounded to the subgrade underneath the geomembrane. An ammeter in series with the circuit converts

the increase in voltage to an audible signal when the equipment passes over a leak.

The water sprayed onto the survey area to perform the test must be contained in the survey area (above the geomembrane to be tested). Conductive features such as concrete sumps and batten strips must be isolated and cannot be tested, since they will ground out the survey (give a false positive signal). Holes will not likely be detected on wrinkles unless conductive-backed geomembrane is used, or if the operator makes a successful to push down the wrinkles and create intimate contact with the subgrade.

2.3 Conductive-Backed Geomembrane Spark Testing Method (ASTM D7240)

The conductive-backed geomembrane spark testing method is generally preferred for bare conductive-backed geomembranes, since no water is required to perform the test and it is typically performed by installers. The method must demonstrate that it can locate a 1 mm diameter leak. This method requires conductive-backed geomembrane.

A high voltage pulsed power supply charges a capacitor formed by the underlying conductive layer, the non-conductive layer of the geomembrane and a coupling pad. The area is swept with a brush-like test wand to locate points where the capacitor discharges through a leak. When the system senses the discharge current, it is converted into a visible spark and an audible alarm.

The surface of the geomembrane must be clean and dry. Unless the conductive geomembrane has been installed with the conductive layer sufficiently broken in the fusion weld, this method cannot be used to test fusion-welded seams. Holes can be detected on wrinkles and other “poor contact” conditions due to the conductive backing of the geomembrane.

2.4 Arc Testing Method (ASTM D7953)

The arc testing method is sometimes preferred for bare geomembranes, since no water is required to perform the test and it can be more sensitive than the water-based methods because the leak detection does not depend on water getting through the leak. The method must demonstrate that it can locate a 1 mm diameter leak.

A high voltage power supply is applied to a test wand above the geomembrane and is grounded to the underlying conductive layer. The area is swept with a test wand and an electrical arc is formed in the presence of a leak. When the system senses the discharge current arc, it is converted into visual and audio alarms. The test wand can be custom sizes and shapes for specific applications.

This type of test requires that the geomembrane is in contact with the subgrade. If the separation distance is greater than 3 cm, such as on a wrinkle or other “poor contact” conditions, the instrument is not likely to arc. Therefore, in the presence of wrinkles, it may not be the preferred method unless the survey is being performed on conductive-backed geomembrane. The surface of the geomembrane must be clean and dry.

3.0 COVERED GEOMEMBRANE SURVEYS

References: ASTM D6747: Standard Guide for Selection of Techniques for Electrical Detection of Leaks in Geomembranes

ASTM D7007: Standard Practices for Electrical Methods for Locating Leaks in Geomembranes Covered with Water or Earth Materials

3.1 Dipole Method – Soil Covered Geomembrane (ASTM D7007)

The dipole method is used for geomembranes covered with earth, gravel, concrete, sand or any other conductive medium. The sensitivity of the survey depends highly on site conditions and the lining system materials. The suggested minimum sensitivity for earthen materials less than 0.6 meters thick is a 6.4 mm diameter leak, though adverse site conditions can decrease the sensitivity and excellent site conditions can enable the location of pinholes.

A high voltage is applied to the cover material with a current injector electrode. The power source is grounded to the subgrade underneath the geomembrane. Voltage measurements are taken in a grid pattern throughout the survey area using a dipole instrument. Leak locations cause a sine wave pattern in the voltage measurements as the dipole instrument travels across a hole location.

The survey area must be electrically isolated from the surrounding ground. Generally, a perimeter isolation trench surrounds the survey area, with the geomembrane exposed. Any conductive objects such as access roads, metal sump pipes, or standing water must be removed before the survey can be performed. Holes may not be detected on wrinkles unless the wrinkle is full of water, or if the hole on a wrinkle is significant enough for soil to create continuous contact between the cover soil and subgrade.

The data collected by the roving dipole instrument is recorded and downloaded into computer software for analysis. The ASTM requires the data to be recorded but does not specify how it is analyzed. Data can be analyzed graphically or by mapping the voltage contours. Graphical data analysis displays the data as voltage slices of the survey area, as graphed in software such as Excel. Voltage contour mapping data analysis shows the voltage measurements in plan view of the survey area. An example of graphical data analysis is shown in Figure 1. An example of voltage contour mapping data analysis is shown in Figure 2.

A leak detection distance test is performed before beginning the survey using either a real or an artificial leak to validate the proposed measurement grid spacing. An artificial leak is essentially a metal disk of a given diameter to mimic an actual leak. The metal disc is grounded to the conductive layer underlying the geomembrane. The distance from the artificial leak ground and the power source ground should be an adequate distance to mimic an actual leak. The leak detection distance test protocol requires that the magnitude of the sine wave signal produced by the real or artificial leak be at least three times that of the background voltage oscillations as measured when the leak is not there. This is known as the signal to noise ratio. A sample of leak detection distance test results are shown in Figure 3.

Once a leak is located by the survey, it must be excavated and the leak cleaned off and removed from the electrical circuit so that the area around the leak can be checked for leaks in the surrounding area, since large leaks can mask smaller adjacent leaks.

Figure 1: Graphical Data Analysis.

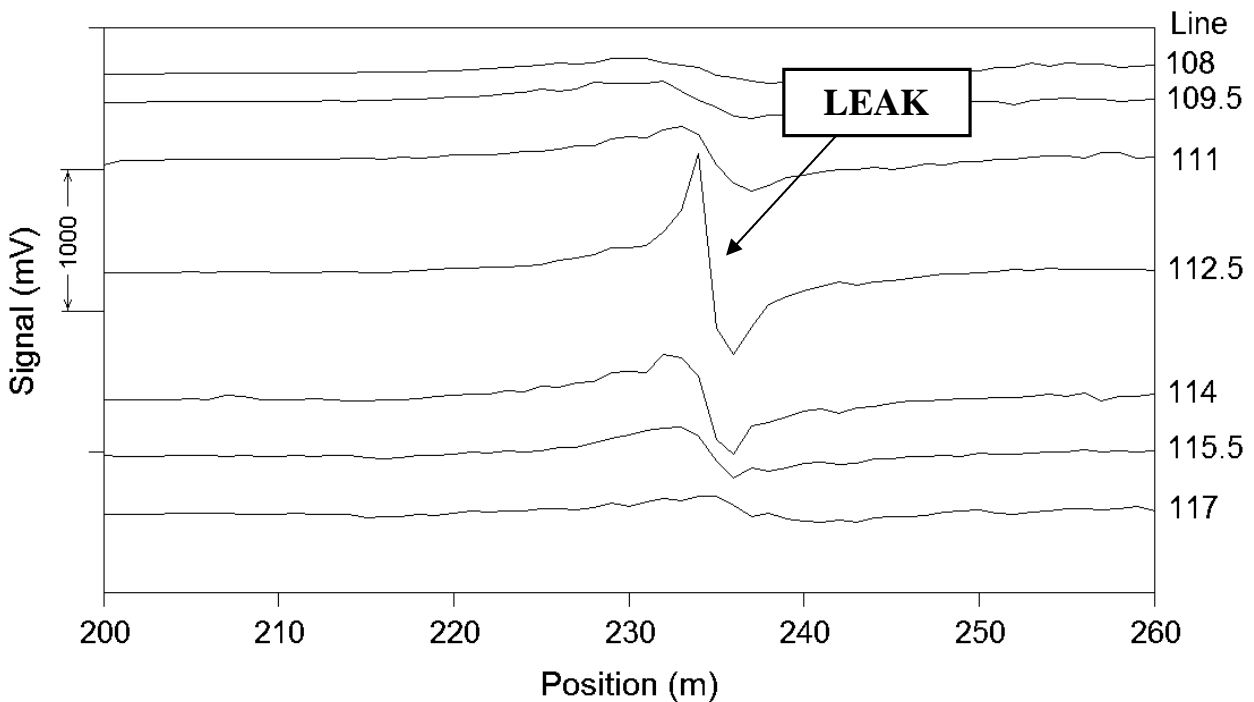


Figure 2: Voltage Contour Mapping Data Analysis.

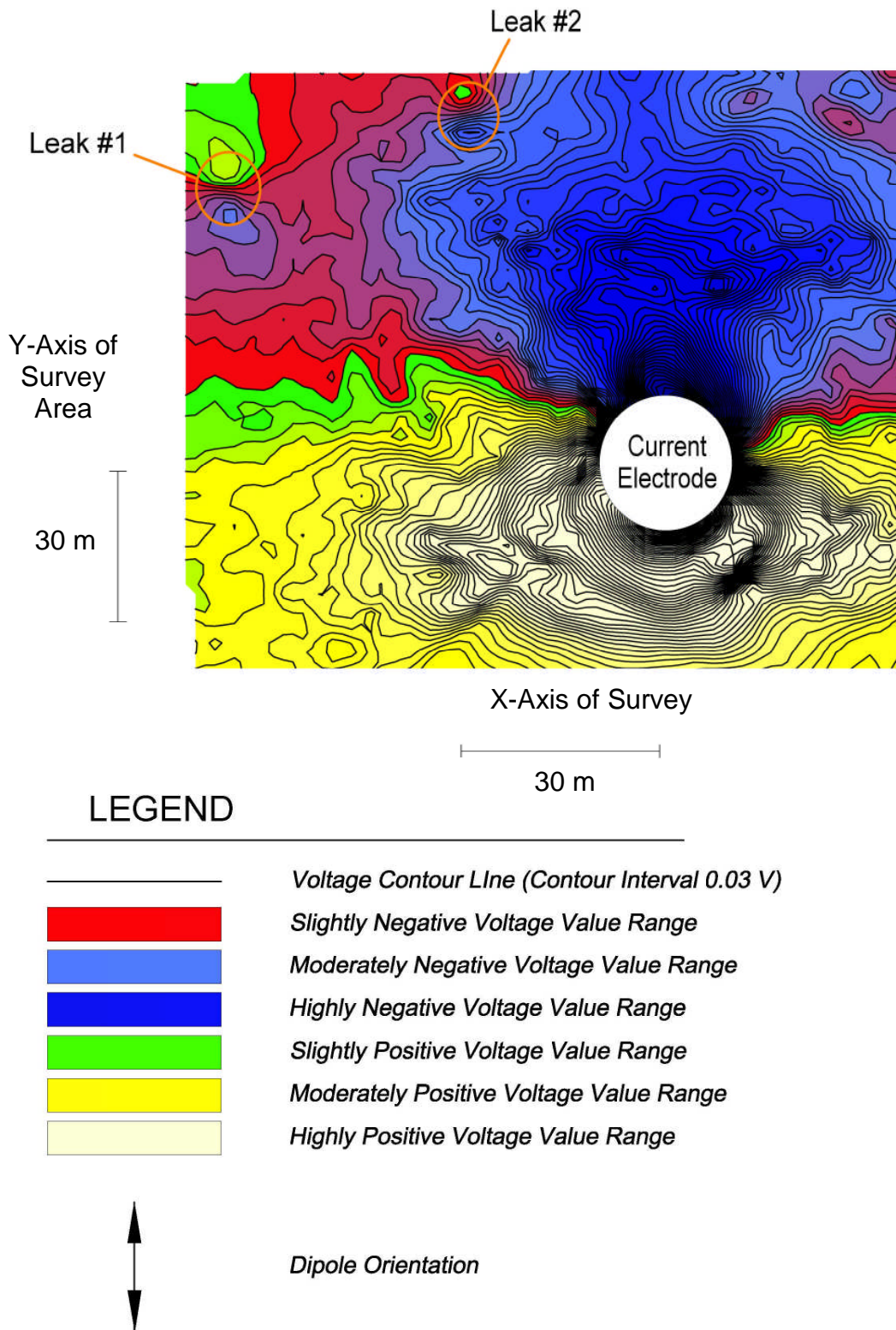
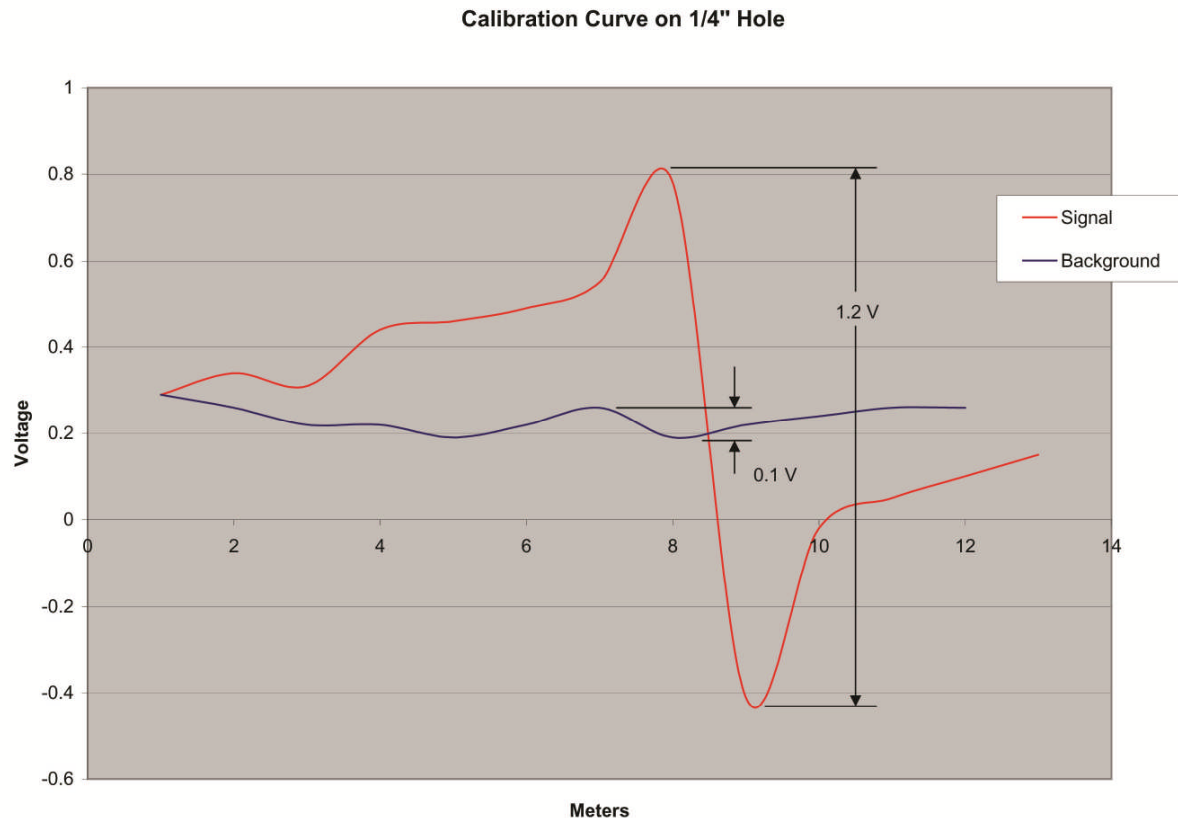


Table 1: Dipole Survey Methodology Comparison

Method	Pros	Cons
Graphical Data Analysis	<ul style="list-style-type: none"> -Does not require high-precision GPS or sophisticated data recording software 	<ul style="list-style-type: none"> -Data typically requires manual manipulation -Can be difficult to relocate leak locations from data -Relies on string lines for measurement accuracy
Voltage Contour Mapping Data Analysis	<ul style="list-style-type: none"> -Faster than graphical data analysis if GPS is used to guide measurement grid rather than string lines -Measurement locations highly accurate due to GPS-guided grid lines -Leak locations highly accurate due to high-precision GPS -Provides meaningful quality control documentation (voltage map) -Does not require high level of operator skill with senior review of data 	<ul style="list-style-type: none"> -Requires high-precision GPS and sophisticated data recording software

Figure 3: A Leak Detection Distance Test. The graph shows the sine wave pattern produced by an artificial leak. In this case, the signal to noise ratio is 12.



2.5 Dipole Method – Water Covered Geomembrane (ASTM D7007)

The survey setup and methodology for water-covered geomembrane is essentially the same as the soil-covered survey method. The same data recording and analysis techniques can be used, but the ASTM does not require data recording for water-covered geomembranes, since the leak signal can be converted to a real-time audible alarm. The minimum sensitivity for water-covered geomembrane is a 1.4 mm diameter leak. Although the ASTM specified minimum sensitivity of this method is lower than that specified for the water puddle and water lance methods, this method is typically more sensitive than the aforementioned methods due to the hydraulic head over leak locations, which provides better hole contact.

Rather than taking voltage measurements at discrete points throughout the survey area, the voltage is continuously measured by an analog-based voltmeter. When the voltage increases beyond a given threshold, with either a positive or negative magnitude, an audible tone alerts the operator. The equipment is swept along the survey area in lines throughout the survey area.

The leak detection distance test consists of finding the “minimum detectable distance” that the equipment can be swept by the artificial or actual leak with the target diameter. The minimum detectable distance is the distance from the actual or artificial leak where the increase in signal is easily discernible from the background noise. This minimum detectable distance dictates the spacing of the survey lines. No signal to noise ratio calculation is required.

ATTACHMENT 1

**DESIGNING FOR LEAK LOCATION
SURVEYS**

**DESIGNING FOR ELECTRICAL LEAK LOCATION
GENERAL GUIDE**



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1.0 HANDBOOK INSTRUCTIONS

This handbook is intended for use by design engineers and earthworks and liner installer contractors. It does not contend to be comprehensive. An experienced leak location contractor should review project specific construction plans and specifications. ASTM D6747 should also be used as a reference for method selection.

2.0 BOUNDARY CONDITIONS

The four critical boundary conditions in order to conduct an electrical leak location survey are:

1. Conductive material over geomembrane (unless the geomembrane is bare)
2. Conductive material below geomembrane
3. Good contact of material above and below geomembrane through leak
4. Material above and below geomembrane are only in contact through leak locations

The following sections describe how these four conditions must be addressed during the design and construction of a facility where a leak location survey is specified.

3.0 MATERIAL SPECIFICATIONS

3.1 Geomembranes

Geomembranes must be electrically insulative. Polyethylene, polyvinyl chloride, polypropylene, chlorosulfonated polyethylene and bituminous geomembranes are sufficiently electrically insulative. EPDM is not. Excessive leakage in terms of number or size of holes in the geomembrane will compromise the sensitivity of a leak location survey. Any locations of poor hole contact (wrinkles, subgrade depressions) will decrease the sensitivity of a survey and possibly result in undetected leaks. Material and placement methods should minimize the production of wrinkles and areas of trampolining.

If survey sensitivity is a high concern, conductive-backed geomembrane should be specified. When a material is referred to as “conductive-backed geomembrane”, it refers to an insulative geomembrane, with a conductive layer beneath the insulative layer, manufactured specifically to assist leak location surveys. The conductive backing allows leak detection on poor hole contact scenarios and also increases overall leak detection sensitivity. If a dipole method survey is to be performed, the conductive-backed geomembrane installation requires a specialty welder and special installation protocol. GSE’s Leak Location Liner fulfills these requirements.

In a double-lined impoundment, a conductive layer must be present under the primary geomembrane. In the absence of a conductive layer (i.e. geocomposite only), conductive-backed geomembrane or other sufficiently conductive products such as conductive geotextile should be specified. Alternatively, the leak detection layer can be filled with water.

3.2 Geocomposites

Geocomposites alone are not conductive, but the application of water to the geocomposite can enable a leak location survey. Water can be added to the geocomposite during construction, or after construction via rainfall or surface watering, as long as enough water is added to travel down to the geocomposite. With hole contact being an important parameter in survey sensitivity, a geocomposite may decrease method sensitivity.

A conductive geotextile can be specified as the geotextile portion of the geocomposite directly in contact with the geomembrane to be tested in order to enable leak detection.

If a non-conductive geomembrane is used as the primary geomembrane in a double-lined impoundment and a geocomposite is present in the leak detection layer, the leak detection layer must be flooded with water to perform the survey. The primary geomembrane must also be flooded and the water-covered dipole method should be used.

3.3 Geotextiles

Geotextiles alone are not conductive, but the application of water to the geotextile will enable a leak location survey. Water can be added to the geotextile during construction, or after construction via rainfall or surface watering, as long as enough water is added to travel down to the geotextile. If a geotextile is adjacent to moist soil material and covered, the moisture tends to wick through the geotextile, thus enabling a survey. Geotextiles can be left intact in perimeter isolation trenches as long as they are dry. In the case of rainfall, it is typically necessary to wait for dry weather for the geotextile to dry out before performing a survey.

A conductive geotextile can be specified to be placed underneath the primary geomembrane in a double-lined impoundment in order to enable leak detection of the primary geomembrane. The conductive geotextile/geomembrane interface may still have contact problems unless the leak location is wet or dirty.

3.4 Geosynthetic Clay Liners (GCL)

The high quality clay component of a GCL is highly conductive, however due to the discrete clay granules surrounded by geotextiles, the moisture content of a GCL must be fairly high in order to perform a leak location survey. The minimum moisture content of a GCL required to perform a leak location survey can be estimated at 8%, though this value will vary for different GCL products. A single composite liner with GCL does not require any special preparation; moisture will easily wick into the GCL from the subgrade, since the GCL is extremely hydrophilic. Encapsulated GCL, however, will tend to stay at the moisture content that it was placed at. In arid climates where GCL panels are left uncovered for some time before being covered with the primary liner, the product can desiccate within one working shift. In arid climates, it is advisable to either rehydrate the GCL before covering with the primary liner, or specify a conductive geomembrane as the primary geomembrane. Encapsulated GCLs can also have problems with electrical conductivity over the panel overlaps, especially in arid climates. If the overlaps are not conductive, it is advisable to place a bare copper wire in a network under the GCL. The concept of the layout is to run the network of wires so that each and every panel is connected to at least one wire. The wire is then made accessible to the leak location surveyor by running it out through the anchor trench. At least two discrete wires should be placed, in order for the leak location surveyor to check the conductivity through the bulk of at least one GCL panel. If the overlaps are conductive, then two separate wires should be placed under the GCL; they do not need to touch every panel.

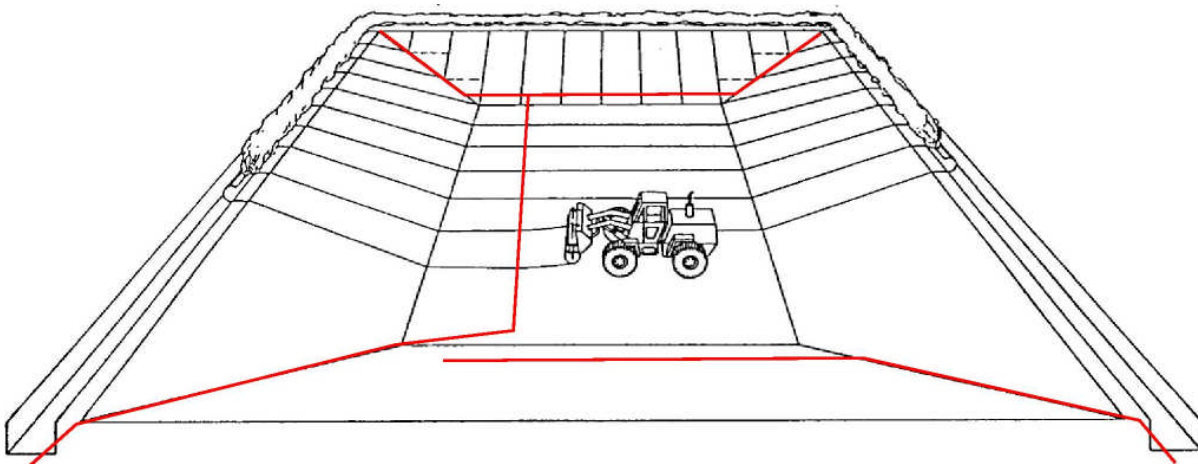


Figure 1: Hypothetical copper wire layout for encapsulated GCL. Copper wire is shown as a red line.

3.5 Cover Material

The material covering the geomembrane should always be moisture conditioned, unless the project is located in a wet climate and the material is already sufficiently moist. Highly porous material such as gravel does not require moisture conditioning, since the material will require watering during the leak survey regardless. This is only true for large gravel particles (greater than approximately 5 cm). All other materials should have moisture within the mass of the cover layer. Surficial watering directly in front of the leak location survey may be required regardless.

3.6 Subgrade Material

Subgrade conductivity will not be a problem with a compacted clay liner. However, if there is no design requirement for a compacted clay liner and onsite soils are used, there is a small chance that the material will be either too dry or contain a mineral content that is not sufficiently conductive. In that case, the subgrade material must be watered before placement of the geomembrane. Subgrade conductivity testing should be performed in the case of questionable site soils, or a conductive-backed geomembrane should be specified as the geomembrane type.

Geomembrane rub sheets should not be allowed to remain under the geomembrane to be tested.

4.0 CONSTRUCTION SEQUENCING

4.1 Dipole Method – Soil Covered Geomembrane (ASTM D7007)

An isolation trench must be specified as part of construction sequencing around the perimeter of the survey area. In climates with spells of extreme rain events, a rain flap should also be considered. Rain flaps are welded in the isolation trenches and propped up by soil so that in the case of extreme rain where the trench will fill up with water, electrical isolation will still be provided by the rain flap. The rain flap must be welded to the base geomembrane.

Access roads can typically remain in place, as long as there is a strip of geomembrane or rain flap bisecting the access road, creating electrical isolation.

4.2 Dipole Method – Water Covered Geomembrane (ASTM D7007)

Consideration for the installation of any grounded objects should be given with respect to the construction sequencing. The survey should be performed before any necessary grounded objects are installed.

If a double-lined impoundment lacks a conductive-backed geomembrane for the primary geomembrane or lacks a conductive geotextile underneath the primary geomembrane, the leak detection layer must be flooded in order to survey the primary geomembrane. There should be ballast over the primary geomembrane to avoid damage, or the impoundment should be filled with water at the same rate that the leak detection layer is filled (or before).

4.3 Water Puddle and Water Lance Methods (ASTMs D7002 and D7703)

The geomembrane must be completely installed in the area to be tested. Consideration for the direction of run-off flow should be given for bare geomembrane survey methods using water as a conductive medium. If water is allowed to flow freely out of the survey area to touch ground, an electrical short will be created. Interim rain flaps can be used where necessary to contain the water within the survey area.

4.4 Arc Testing and Spark Testing Methods (ASTM D7953 and D7240)

The geomembrane must be clean and dry. Testing can be performed directly up to but not including any grounded features.

5.0 GROUNDED OBJECTS

Objects that will provide a source of electrical grounding should be carefully designed, or the construction sequence modified to enable a leak location survey. For example, a metal pipe penetrating the liner system should have a plastic boot so that water sprayed on the geomembrane or soil covering it will not touch the metal pipe. For pond applications, concrete inlet or outlet structures, including metal batten strips, will ground out the survey. In some cases the design cannot be modified, but a rain flap can be welded as an interim measure to intercept water flowing to a grounded object.

6.0 SPECIFYING METHODS

The appropriate survey method will depend on the condition of the geomembrane during the survey; whether it is bare or covered, whether it is the primary geomembrane or the secondary geomembrane, and whether the geomembrane has a conductive backing or not. The “Electrical Leak Location Survey General Guide” covers the various methods and their general applications.

The primary geomembrane of a double-lined impoundment can be surveyed using the dipole with soil as cover if there is ballast material over the primary geomembrane. In that case, the primary geomembrane must be conductive or have a conductive geotextile underneath it, or the leak detection layer must be flooded up to the level of the top of the ballast layer. In order to survey the side slopes, or if there is no ballast material over the geomembrane, the impoundment must be completely filled with water and a dipole with water as cover method must be performed. Alternatively, conductive-backed geomembrane can be specified as the primary geomembrane and subsequently any method can be performed on it (if the conductive-backed geomembrane is installed properly).

A survey can be conducted either before or after cover material placement, or both. The minimum sensitivities of each method, as described in the “Electrical Leak Location Survey General Guide” should be considered. For geomembranes that are to be covered by earthen materials, a survey should be performed both directly after liner installation and after cover material placement. This will result in the maximum leak detection sensitivity. If small holes are not a concern and only one method can be specified due to cost constraints, then a dipole survey should be performed after placement of the cover materials, since this method will locate the major leaks caused by placement of the cover material. +

If a dipole survey is specified, the method of data analysis can be specified. The advantages and disadvantages of each method of data analysis are described in the “Electrical Leak Location Survey General Guide”.

6.1 Specifying Leakage Rates

It is impossible to construct a “leak free” lining system, since even in the absence of breaches through the geomembrane, vapor diffusion occurs through a geomembrane and condensation also occurs between geomembranes. Setting an allowable leakage rate should be informed by the existing available technologies and the maximum leakage that would cause impairment to groundwater. Setting an allowable leakage rate too low to achieve with existing technologies is simply a recipe for failure.

Several studies have shown that the Giroud equation is probably not applicable to typical geomembrane construction outside of Germany. Rather, the Rowe equation should be used, assuming that the contact

between the geomembrane and the underlying subgrade will likely contain wrinkling. The assumed undetected leak frequency can be used to inform the number of leaks contributing to leakage.

In order to stay under a leakage rate of 20 gallons per acre per day, it is recommended to perform both a bare geomembrane survey method and the dipole method after placement of any cover material. In order to stay under a leakage rate of 5 gallons per acre per day, it is recommended to specify either white or conductive-backed geomembrane and perform both a bare geomembrane survey method and the dipole method after placement of any cover material.

With currently available technologies, the lowest level of potential leakage can be achieved by specifying specialty conductive-backed geomembrane installed per GSE's Leak Location Liner installation procedures, performing a bare geomembrane survey directly after geomembrane installation, and then performing the dipole method after the installation of cover material, if applicable. It is technically possible to install a geomembrane without breaches with this prescription since, if installed and surveyed correctly, it eliminates the known sources of limitations in the leak location survey technologies. However, room should always be granted for human error to avoid a specification that cannot be met.

6.2 Quality Control of Surveys

Effective oversight of electrical leak location surveys is probably more effective than prescribing minimum experience qualifications. The main intent of the survey oversight should be the conformance to the applicable ASTM Standard Practice. The leak detection distance and/or sensitivity testing procedures of the applicable Standard Practice should be reviewed and understood by the entity providing oversight. The survey should be performed with the same parameters as were employed during the leak detection distance and/or sensitivity test. In addition, the oversight entity should verify that the method was comprehensively applied to the entire survey area.

If the entity in charge of survey oversight suspects that the sensitivity test performed by the survey contractor does not represent site conditions, then the option to create a "blind actual leak" should be considered. If a blind leak is installed, it should be in accordance with the Standard Guide for Placement of Blind Actual Leaks during Electrical Leak Location Surveys of Geomembranes (ASTM D7909). Per the ASTM Standard Guide, a blind actual leak is "a circular hole in the geomembrane intentionally placed by the owner or owner's representative to ensure that the site conditions are suitable for an electrical leak location survey and that a valid electrical leak location survey is performed." It should be noted that the intentional placement of a leak in an installed geomembrane is not a good geomembrane quality control practice and that additional cost may be incurred by the project for such a practice.

For soil and/or water covered survey areas, the best quality control method is to specify that a voltage map be created for the site and provided as part of the final report.

6.3 Minimum Experience Qualifications

The various methods vary significantly in how much skill is required to perform them. It is therefore reasonable to set the minimum experience qualifications according to which method is used.

Spark testing has been historically performed by liner installers. Very little training is required and no minimum experience in terms of square footage of the method completed is usually required. Once an operator learns to use the spark tester, very little can go wrong in terms of site conditions and instrument set up.

The arc tester evolved from spark testing technology, but is even easier to use. In less than one hour, an operator can be competent at performing the arc testing method.

The water-based bare liner testing is a little more complicated in terms of setting up the survey, adjusting the equipment sensitivity and controlling the site conditions so that they do not adversely impact the sensitivity of the survey. It is therefore advisable to set some minimum number of projects and square footage where this method has been performed. A reasonable minimum for the water puddle and water lance methods would be 1-2 projects and a minimum area of 10 hectares.

The dipole method is more closely related to advanced geophysical methods, which require a thorough understanding of the method, the equipment, and the site conditions. Many site conditions can adversely impact the sensitivity of a survey. It is therefore advisable that the highest level of minimum experience qualifications be applied to a dipole survey. A reasonable minimum for the dipole method would be 4-5 projects and a minimum area of 50 hectares. The minimum qualifications should apply to the lead operator onsite directing the survey.

ELL Operator certification is available, which can be substituted for the required minimum experience level. The operator certification program requires that an individual performing ELL methods be evaluated for competency and method adherence by a third party.

ATTACHMENT 2

**ELECTRICAL LEAK LOCATION SURVEY
OPERATOR CERTIFICATION**

**ELECTRICAL LEAK LOCATION SURVEY
OPERATOR CERTIFICATION**



AUGUST 2014



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1.0 OPERATOR CERTIFICATION BACKGROUND

The operator certification program intent is to uphold industry standards and provide a way of ensuring that operators are performing the electrical leak location survey (ELL) methods correctly and per ASTM standard methodology. As the world-wide demand for ELL grows, the certification program provides a tool for emerging ELL consultants to gain proficiency and credentials. It also provides a tool for site owners and project engineers and managers to evaluate the capabilities of ELL providers and establish minimum criteria for the demonstration of competency in the applied ELL methods.

An ELL Steering Committee was assembled to advise the contents of the operator certification. The ELL Steering Committee consists of professionals who have worked closely with ELL methods in different roles, especially in method application. Members of the ELL Steering Committee who specialize in the application of the ELL methods are qualified to oversee the field portion of the Level 2 certification exam.

2.0 THREE-TIERED STRUCTURE

The operator certification program is broken down into three tiers of certification. The intent of the three tiers is to distinguish between the levels of education and practice required in order to illustrate different levels of competency. The certification encompasses both bare and covered ELL methods.

2.1 Level 1 Certification

The first tier of certification illustrates that an individual:

1. Is qualified to specify ELL for projects
2. Understands how boundary conditions affect ELL
3. Understands how the ELL methods are applied
4. Is qualified to review ELL for conformance to ASTM standards

2.2 Level 2 Certification

The second tier of certification illustrates that an individual:

1. Has passed a written exam on the application of ELL methods
2. Has passed a field exam on the application of ELL methods
3. Can competently perform ELL methods per current ASTM standards

2.3 Level 3 Certification

The third tier of certification illustrates that an individual:

1. Has satisfied the Level 1 and 2 certification criteria
2. Has a proven track record of ELL method performance
3. Maintains certification through a minimum level of annual field experience

3.0 LEVEL 1 CRITERIA

The first tier is an educational component. An individual shall receive at least six (6) hours of classroom education (or equivalent) in the following subject areas:

1. ELL terminology, history, background
2. Electrical Basics

3. Bare and covered ELL methodology
4. Criteria for specifying ELL
5. Current ASTM methods for ELL
6. Boundary conditions affecting ELL performance
7. Site safety

An individual shall receive at least four (4) hours of hands-on training in the following subject areas:

1. Operating equipment for bare and covered ELL methods
2. Performing a sensitivity test for bare and covered ELL methods
3. Locating leaks in bare and covered geomembranes
4. Setting up a ELL circuit for bare and covered ELL methods

4.0 LEVEL 2 CRITERIA

The second tier is a demonstration that the Level 1 education and field training can be applied by an individual. The Field Exam can be conducted to a production survey by an individual.

4.1 Written Exam

The written exam, which is administered through a third-party, shall test an individual's ability to:

1. Interpret plans and specifications for ELL
2. Understand electrical measurements
3. Perform methods per ASTM standards
4. Troubleshoot field difficulties
5. Effectively collect and interpret data
6. Identify poor boundary conditions
7. Understand method limitations

4.2 Field Exam

The field exam shall be proctored by a qualified member of the ELL Steering Committee. The proctor shall observe an individual in the field as the individual performs an ELL method and without interfering shall document:

1. Which method is being performed
2. Where electrodes are placed
3. Where artificial leak is placed and grounded, if applicable
4. What voltage is used for the method
5. Survey set up procedures
6. Equipment set up and calibration procedures
7. Sensitivity test procedures
8. Procedures for locating leaks
9. Procedures for recording and analyzing data, if applicable
10. Any ASTM procedures lacking during field observation

The field exam is method-specific. The documentation of the field exam shall be provided to the ELL Steering Committee. The ELL Steering Committee shall deliberate on whether the individual has demonstrated the ability to locate actual leaks in the field using the applied methodology. If an individual demonstrates the ability to locate actual leaks, but some aspect of the ASTM procedure is lacking, the ELL Steering Committee shall evaluate whether that lacking procedure was crucial for locating leaks and performing a thorough survey. The actual location of leaks shall weigh more heavily on the Committee's pass/fail decision than the following of the ASTM standard.

The results of the field exam, including critiques and comments from the ELL Steering Committee, shall be submitted to the examinee(s) along with a Level 2 certificate if applicable.

The ELL Steering Committee shall maintain a list of all individuals who have passed the written and field examinations and keep on file a copy of the actual examination documentation.

5.0 LEVEL 3 CRITERIA

The third tier is a demonstration that the individual can competently perform the ELL method(s) and has a proven track record of doing so. Although not necessary to show that an operator can successfully perform the methods, an owner or design engineer might opt for this level of experience to reduce project liability. The minimum level of experience is method-specific. The experience for a given method would be called out for a specific project employing that method.

For Level 3 certification, the individual must maintain a minimum level of ELL method performance on an average annual basis as follows:

1. Bare geomembrane arc testing method: 1 project and 0.4 hectares (1 acre)
2. Bare geomembrane spark testing method: 1 project and 0.4 hectares (1 acre)
3. Bare geomembrane water puddle method: 1 project and 2 hectares (5 acres)
4. Bare geomembrane water lance method: 1 project and 2 hectares (5 acres)
5. Water-covered geomembrane dipole method: 2 projects and 4 hectares (10 acres)
6. Soil-covered geomembrane dipole method: 2 projects and 20 hectares (50 acres)

An excess of survey experience one year can carry into the next year, but no longer than three years past the date of the qualifying experience.

In order to receive level 3 certification, an individual must submit documentation of the aforementioned experience requirements to the ELL Steering Committee. The documentation required shall consist of:

1. The name of the project
2. The method applied
3. Sensitivity test set up and results
4. Number and size of located leaks

The ELL Steering Committee shall maintain an actively updated list of all individuals who maintain current level 3 certification, and which method the certification applies to.