# Guidance for Evaluating Wastewater Lagoon Seepage Rates

State of Idaho
Department of Environmental Quality

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# Guidance for Evaluating Wastewater Lagoon Seepage Rates

**August 2016**

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# Introduction

This guidance assists wastewater lagoon owners and individuals responsible for seepage tests in complying with the seepage test requirements of the "Wastewater Rules" (Idaho Administrative Procedures Act (IDAPA) 58.01.16, subsections 493.02, 493.03, and 493.04). These subsections require owners of municipal wastewater facilities in the State of Idaho to conduct seepage tests on their lagoons prior to being put into service and at mandated intervals thereafter. Measured seepage rates must meet facility-specific operating standards corresponding to the date of construction or major modification of each lagoon. For certain industrial facilities, seepage testing may also be required by permit or prior DEQ approval requirements. This seepage testing guidance was developed to provide assistance to owners, operators and consultants of both municipal and nonmunicipal wastewater lagoons.

This guidance is intended to assist facilities in collecting, reviewing, and validating seepage test data for compliance determinations. Every seepage test procedure must be submitted to the Idaho Department of Environmental Quality (DEQ) for review and approval prior to testing. Deviations from this guidance are permissible and may be submitted to DEQ for review and approval prior to lagoon seepage testing.

The current procedure has been revised from the April 2009 *Guidance for Evaluating Wastewater Lagoon Seepage Rates* to incorporate recommendations from an external report that reviewed methods to process and evaluate seepage test data. The review results were published in the *Wastewater Lagoon Seepage Test Statistical Review* (URS 2011) at http://www.deq.idaho.gov/media/768089-lagoon-seepage-test-statistical-review-1011.pdf. The revisions include defensible methods to determine whether seepage test submittals meet the regulatory limits, revised seepage test spreadsheets that better accommodate statistical recommendations, and a multimetric approach to compliance determinations.

# 1 Authority

DEQ is charged with protecting human health and the environment in the Environmental Protection and Health Act (EPHA), Idaho Code §39-101 et seq. EPHA also specifically provides that it is the policy of the state to maintain the existing high quality of the state's ground water and to prevent ground water contamination to the maximum extent practical (Idaho Code §39-102(2) and (3)). Under the authority granted to DEQ in EPHA, and in accordance with IDAPA (Idaho Code §67-5201 et seq.), DEQ has adopted applicable rules, the "Ground Water Quality Rule" (IDAPA 58.01.11), "Water Quality Standards" (IDAPA 58.01.02), and "Wastewater Rules" (IDAPA 58.01.16). These rules have been developed to execute DEQ's mandate to protect human health and the environment and to prevent ground water contamination through subsurface discharge of wastewater. To document compliance with these rules, DEQ has generated this guidance.

# 2 Purpose

To ensure the quality of environmental data and information gathered during seepage testing, this guidance establishes a standard procedure by which new and existing wastewater lagoons can be evaluated to determine compliance status with seepage rate requirements and permits established by the State of Idaho. This document provides guidance on how to perform seepage rate tests to develop defensible methods for determining valid data, and how to prepare seepage test procedure and report submittals that meet regulatory requirements.

# 3 Background

IDAPA 58.01.16 requires that municipal wastewater lagoons in the State of Idaho meet facility-specific operating standards including the following:

- The maximum allowable seepage rate for municipal lagoons constructed after April 15, 2007, is one-eighth inch (0.125 inches) per day, which is approximately 3,400 gallons per acre per day.
- The maximum allowable seepage rate for existing municipal lagoons constructed prior to April 15, 2007, is one-quarter inch (0.25 inches) per day or less.
- A seepage test may also be required due to changes of the condition of the liner.
- A seepage test may be required after solids removal.
- The procedure used for performing a seepage test or alternative analysis must be approved by DEQ. Wastewater lagoon plans and specifications submitted to DEQ for review and approval shall contain this procedure for seepage rate testing of the constructed lagoon, or a procedure that DEQ approves specifically for a site prior to the test being started.
- All municipal wastewater lagoons must be seepage tested by an Idaho-licensed professional engineer (PE), an Idaho-licensed professional geologist (PG), or by individuals under their direct supervision.

Wastewater lagoons in the State of Idaho may need to meet a site-specific seepage rate. In the past, measurements to determine compliance with the required seepage rate have been performed using a variety of instruments and procedures. Lagoon seepage rates can be estimated from water balance measurements, and “quantifying the uncertainty surrounding the measurements is crucial if data from seepage tests are used to determine if lagoons are meeting engineering specifications and operating within regulatory guidelines” (Ham 2002). Uncertainty is the term used in this guidance to describe the sum of the sources or error. Standard test procedure development will ensure consistent seepage measurement techniques and simplify DEQ’s approval process for test procedures and reported results.

For certain industrial facilities, seepage testing may also be required by permit, and this guidance assists in reviewing and validating seepage test data for compliance determinations.

# 4 Overview of the Seepage Test Procedure and Seepage Test Report

When preparing and submitting the seepage test procedure and seepage test report, DEQ suggests the following steps below:

1. Read this guidance—After reading this guidance, consult with DEQ for site-specific issues about developing and submitting the seepage test procedure, testing the lagoon, and preparing and submitting the final seepage test report. Two documents must be submitted to DEQ: the seepage test procedure, which describes the basis for the testing, and the seepage test report, which describes the results of the testing. Appendices A and B provide checklists on what should be included in the seepage test procedure and final report submittals.
2. Develop seepage test procedure—DEQ strongly recommends that this guidance is used to develop the seepage test procedure. Section 5 describes what DEQ expects in the submitted seepage test procedure.
3. Submit seepage test procedure to DEQ for approval—Plan ahead to ensure that DEQ has adequate time to review the submitted procedure before the intended seepage testing. DEQ recommends a minimum of 45 days.
4. Receive/review DEQ approval—After receiving DEQ approval and before starting seepage testing, carefully review DEQ's approval letter as it may contain additional requirements for the seepage test procedure that must be followed. The procedure and approval letter constitute the entire approved procedure.
5. Seepage test lagoon—Seepage test the lagoon following the approved procedure. It is imperative that additional comments contained in the approval letter are incorporated into the procedure performed for the test. The test procedure and DEQ approval letter should be available on site during testing. Ideally, all personnel involved in seepage testing will have read both the test procedure and the DEQ approval letter. Consult with DEQ for site-specific issues. Deviations from the approved procedure must be approved by DEQ prior to testing.
6. Write seepage test report—Compile all data into a written seepage test report and discuss how the procedure and quality assurance project plan (QAPP) were followed. Provide an interpretation of the results and clearly state the conclusion(s) of the test. Section 8 describes what DEQ expects in the submitted seepage test report.
7. Submit seepage test report to DEQ— Seepage test data must be submitted to DEQ for review and approval. The data in the test report must be submitted in electronic form importable to MS Excel. Two DEQ seepage calculation spreadsheets (manual method and mechanical/electronic method) may be used to expedite the review (section 7). A lagoon seepage test is considered passing if the measured seepage rate is less than the established regulatory limit and the data analyses satisfy the assessment metrics in section 6.

# 5 Seepage Test Procedure

The seepage test procedure is the basis for preparing and conducting a test. Proper planning to obtain quality data for a seepage test includes, but is not limited to, the following:

- Familiarity with the project site and environmental conditions
  - Conduct a site visit
  - Take photographs of project site
  - Identify physical characteristics (e.g., proximity to surface water, exposed ground water)
- Lagoon construction and operation
  - Number of lagoons
  - Lagoon design and related piping/transfer structures
  - Stilling well design and location
  - Sludge depth at time of testing
- Understanding the test equipment needed and considering any constraints the site poses.

Many factors are considered in planning the procedure as the "lagoon seepage will be dependent on environmental conditions during the test, accuracy and precision of measurements among other factors that may be site specific during the seepage test" (Ham 2002). Lagoon seepage rates can be estimated from water balance measurements where inputs and outputs into an isolated lagoon are determined from measuring changes in lagoon water depth and evaporation (Ham 2002). "The uncertainty surrounding the calculation of lagoon seepage is dependent on the errors in measured precipitation, depth changes and evaporation" (Ham 2002). The seepage test procedure should account for the variables and uncertainties that can influence the data during testing.

## 5.1 Seepage Test Procedure to DEQ

For each lagoon to be tested, a seepage test procedure must be submitted and approved by DEQ before testing begins. The seepage test procedure should be site-specific and all relevant information should be submitted to DEQ in one document. A well-prepared seepage test procedure considers the test method and all factors needed to produce defensible data.

In the seepage test procedure submittal to DEQ, site conditions and lagoon construction and history need to be understood as each site will have site-specific variables to consider. Therefore, seepage test procedures previously approved may not be used for other lagoons or other locations without DEQ's prior written approval. Once a seepage test procedure has been approved, no deviations can be made to it without DEQ's prior written approval.

A suggested outline for the seepage test procedure is provided below. Appendix A provides a checklist of what should be considered and/or included in the seepage test procedure.

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## Title
Provide the project name (lagoon(s) and site) and owner.

## Purpose
Include the reason the lagoon is being tested.

## Applicable Seepage Rate
Identify the lagoon-specific seepage rate requirement.

## Project Description
Provide the name of the project, project owner, and project location; the wastewater characteristics; the geographic, geologic, and hydrologic setting; a history of the site; and the lagoon liner material. A picture of the current site is recommended. Provide any pertinent historical information for the lagoon or the site (e.g., this could include information about a failed liner or ground water infiltration).

## Personnel
Identify the Idaho-licensed PE or PG responsible for the test. Identify roles, responsibilities, and qualifications/training of all people who will assist with seepage test.

## Equipment
Identify the equipment that will be used during the seepage test along with the manufacturer's specifications and calibration recommendations. Include the equipment manufacturer's specification sheets for the equipment used to measure water levels for the evaporative pan and lagoon, and any specific equipment conditions that must be taken into account when performing the test (e.g., does the equipment require that it is in a vertical position?).

## Procedure
At a minimum, include the following site-specific information in the procedure:

- Details about how the lagoon will be isolated and verified that it remains isolated during testing.
  - If multiple lagoons are on site, the piping and connections between the cells should be discussed and presented in a map, sketch, or drawing.
  - If multiple lagoons are being tested, the order of testing may need to be explained, along with any bypass piping or methods for isolation during testing.
- Details about whether the lagoon will be filled to maximum design operational depth and how the actual testing depth will be measured and documented.
- Details of the lagoon stilling well, its planned location, and consideration of wind and wave attenuation based upon locations and setup.
- Details about the planned evaporative pan setup or alternative method for evaluating evaporation during testing.
- Details about the precipitation gauge setup.
- Details about how measurements will be recorded.

- Details about how the assessment metrics will be considered during testing to establish (1) data quality, (2) data sufficiency, (3) comparability, (4) consistency, (5) category, (6) completeness/validity, and (7) compliance. Include how the length of testing needed will be determined. For example, the tables in section 6 can be used to fulfill this requirement: Table 1 provides the assessment rubric, and Table 2 provides an assessment checklist that can be modified with site-specific information.

**Quality Assurance Project Plan**
Describe the testing/measurement methods and QAPP to be used. In the QAPP describe how a reasonable level of verification will occur at various data collection stages to determine data quality. The QAPP can be included as a section or an appendix in the procedure, or an internet file share or cloud storage provider (such as Dropbox or Google Drive) to the QAPP provided in the procedure is acceptable if the document is large.

**Calculations**
Provide the calculations to be used, with consideration for sample and equipment error. The DEQ calculation spreadsheets are a resource for seepage testers, and DEQ recommends that the current versions are used.

**Conclusions**
Summarize the key elements for the evaluation.

The responsible charge Idaho-licensed PE or PG’s seal shall be affixed, signed and dated, when the seepage test procedure is submitted.

## 5.2 Seepage Test Procedure Development

### 5.2.1 Project Description, Background, Lagoon Information, Performance History, and Site Characterization

A thorough understanding of the project site is essential for preparing a sound seepage test procedure. The name of the project, project owner, and project location; the wastewater characteristics; the geographic, geologic, and hydrologic setting; site history; and the lagoon liner material should be included in the seepage test procedure and final seepage test report. The following can assist with site characterization:

- Project site map
  - Site wells and other pertinent area wells
  - Impaired surface or ground water bodies that may have hydrogeological connection to lagoon seepage
- Facility drawings
- Lagoon information
  - Lagoon record drawings with location of pipes and transfer structures
  - Lagoon age and construction materials
  - Lagoon record drawings establishing ground water depth
- Pictures of pertinent features.

If previous seepage tests have been conducted, the information known about those tests should be provided. Site information (e.g., previous lagoon tests, geology, and geography) provides vital data about each site. Historical site information can help determine and evaluate changes in measurement values at the site.

### 5.2.2 Seepage Test Personnel

All lagoons covered under IDAPA 58.01.16.493 must be seepage tested by an Idaho-licensed PE or PG, or by individuals under their direct supervision. Submittals associated with the seepage test shall have the responsible charge Idaho-licensed PE or PG's seal affixed, signed and dated. Relevant information (e.g., identity, tasks, experience) about the personnel that will be involved in the seepage testing should be provided in the seepage test procedure. The responsible charge PE or PG should be knowledgeable about the procedure, the site-specific seepage test, and the conclusions drawn from the data.

### 5.2.3 Lagoon Stabilization and Design Operational Depth

Lagoons to be tested should be filled and maintained at maximum design operational depth prior to the beginning of the test period to allow for initial saturation and stabilization. Typically for earthen lagoons, this time frame is at least 2 weeks. The saturation period is not required for synthetically lined lagoons with no cover material; however, on a case-by-case basis synthetically lined lagoons may still need to stabilize before testing. The data collected before the start of the testing should provide information to determine if the lagoon has stabilized. Test data in the report submittal should include a description of how the lagoon was stabilized before the testing. If a lagoon is not properly stabilized, the seepage rates will be inconsistent and may show a failing test (Ham 2002).

Sludge levels in the lagoons should be considered when planning a seepage test. Depending upon methods used for sludge removal, lagoons may need to be seepage tested following sludge removal.

In most instances, a source of clean water will be necessary for filling both the lagoon and evaporation pan for all new lagoon construction. On a case-by-case basis, wastewater may be allowed. DEQ recommends a discussion with the DEQ regional office during procedure planning to determine the water source.

### 5.2.4 Lagoon Isolation

Generally, seepage tests are done when the lagoon is isolated with no inflow, outflow, precipitation, or runoff (Ham 2002). Inflow and outflow should be eliminated during the test (Ham 2002). Normally, the lagoon must be isolated during the test. Isolating and testing each lagoon cell will provide an understanding of seepage specific to that lagoon, and thus the influences of that lagoon on ground water. The seepage test procedure should describe how the lagoon will be isolated during testing and how the test contractor will verify isolation was maintained throughout the duration of the test.

A discussion of existing ground water conditions beneath the lagoon at the time of the test should be provided in the seepage test procedure. DEQ will not accept seepage test results if the ground water elevation is greater than the lagoon bottom. A hydraulic break must exist between the ground water and lagoon. If ground water level is near or above the bottom of the lagoon liner contact your regional DEQ office prior to developing a seepage test procedure.

If the lagoons cannot be isolated, flow-monitoring equipment may be used if approved in advance by DEQ. Flow-monitoring equipment introduces additional errors into the calculations that must be considered and discussed with DEQ. In general, if the lagoon will be tested when it is not isolated, the seepage test procedure should describe how the flow meter equipment works, its suitability for this application, limitations, and sources of error. If the lagoon cannot be isolated, the calculations using the flow monitoring data must include a discussion of sources of error. The calculations that will be used to determine flow with the proposed equipment including propagation of error calculations should be provided in the seepage test procedure. Lagoon elevation changes that would be expected during testing should also be discussed as they pertain to the equipment siting and capacity. This may require some pretesting evaluation of lagoon levels under the conditions that the test will be performed.

### 5.2.5 Weather Conditions to Consider in Planning a Seepage Test

Weather conditions to consider in planning a seepage test include freezing temperatures, winds, precipitation, and high evaporation rates.

#### *5.2.5.1 Freezing Temperatures*

Freezing temperature may cause issues of uncertainty during seepage testing. The seepage rate test period should be planned to avoid freezing temperatures and ice. Freezing temperatures may cause water in the lagoon to freeze (may have ice) and will nullify test data and therefore nullify the data collected during that 24-hour period. Freezing temperatures may cause water in the evaporation pan to freeze. If the water in the pan partially or completely freezes, the evaporation data are nullified and cannot be used in the data analysis. The temperature data submitted should validate that the pan and lagoon did not freeze during the test period. During spring and fall test periods when freezing temperatures may occur, DEQ recommends that a water temperature probe be placed in the pan and lagoon stilling well to evaluate whether temperatures reached freezing. Water temperature data collected during testing can be used to evaluate data quality and sufficiency in the assessment metrics.

#### *5.2.5.2 Wind*

Wind affects seepage testing. Higher wind speeds create errors and greater uncertainty of test results (Ham 2002). It is recommended that wind speeds are less than 9 miles per hour at the start and end of a test to minimize errors caused by wave-action (Ham 2002). It is recommended that seepage rate calculations use data collected when wind speeds were below 9 mph. Seepage test data collected during windy conditions can be biased by short-term changes in wind speed and direction, and wind drag can cause water levels to rise downwind and fall upwind in the lagoon (Ham 1999). It is strongly recommended that a wind gauge be used on site to determine wind speeds and direction during testing. Wind speed documentation can support data quality and sufficiency metrics assessments in the analysis of the seepage test conclusions. Since wind speeds affect the uncertainty of testing, the effects should be described in the seepage test report.

#### *5.2.5.3 Precipitation*

Precipitation is a variable that must be addressed, and the precision of the water balance equation is optimized when testing occurs during times with no precipitation (Ham 2002). It is recommended that data collected during periods of significant rainfall be omitted from the seepage calculation. Since precipitation and runoff from side embankments may introduce uncertainty, their effects and significance should be described in the seepage test report. During a seepage test, a precipitation gauge (rain gauge) will be set up. Point measurements of precipitation are subject to errors such as those created from winds or obstructions (Dingman 2002). The precipitation gauge chosen and the siting of the gauge should be discussed in the seepage test procedure. During testing, the amount of precipitation accounted for must be considered in the lagoon assessment metrics and discussed in the seepage test report, as precipitation is difficult to account for in the water balance (Ham 2002; Dingman 2002). Rainfall may introduce uncertainties to the evaporative pan data such as water splashing in or out of the pan or evaporation that may not correspond to the pan evaporation coefficient during rain. DEQ recommends that tests are restricted to times when rainfall is minimal. If a precipitation event occurs, seepage testers should account for additional flows into the lagoon, the affected water-level measurements, and uncertainty in the seepage calculation. If rain occurs during testing, describe the effects of precipitation on data analyses in the seepage test report. If the error or uncertainties due to precipitation become significant, then the testing duration may need to be extended to demonstrate that the data are valid. On a case-by-case basis, DEQ may accept nonconsecutive test days, eliminating the data collected during precipitation. In these instances, the entire set of data should be collected during precipitation and a justification for eliminating data included in the seepage test report.

#### *5.2.5.4 High Evaporation Rates*

Evaporation is a function of temperature, humidity, wind, and other meteorological conditions (Ham 1999). When evaporation is high, seepage test data can lead to more uncertain results (Ham 1999, 2002). It is recommended that the evaporation rates should be less than 0.2 inches per day (5 millimeters per day) during seepage testing (Ham 2002). If high rates of evaporation occur during the seepage test, the seepage test report should discuss evaporation, the data set, and quality used for evaluating the seepage rate calculation. The accuracy and magnitude of the evaporation measurements impact the seepage calculations (Ham 1999, 2002). During the day evaporation rates change in the lagoon and the pan. Continuous evaporation measurements taken over 24 hours may assist with understanding of the evaporation and understanding when evaporation rates are low may assist in designing a test that avoids high evaporation rate periods.

### 5.2.6 Equipment

To assess the metrics associated with a seepage test, the equipment information with the manufacturer’s specifications should be included in the seepage test procedure. The DEQ Quality Management Plan (QMP) states “quality data and information constitute the foundation of informed decision making” (DEQ 2012). For quality assurance, the integrity of the scientific data collected involves looking at the equipment care, calibration, calibration verification, and data collection during the seepage test.

#### *5.2.6.1 Equipment Accuracy*

Equipment used in seepage testing varies. Equipment accuracy may create shifting in the categorization and completeness metric as discussed in section 6. In certain circumstances, equipment accuracy could adversely affect categorization of seepage rates. For example, less accurate equipment used in a test may create a Category 2 classification, whereas, more accurate equipment in the same circumstances would create a Category 1 classification (URS 2011). Section 6 provides additional discussion on this point. Measurement accuracy and precision can also influence the test duration (Ham 2002). Equipment accuracy used to measure water levels will need to be evaluated by the PE or PG to assess whether the potential deviation from true value measurements can provide a clear indication of meeting the requirements. Equipment accuracy is discussed in sections 5.2.7.2 and 5.2.8.2.

Note that no universal agreement exists for defining terms used by instrument and electronic manufacturers. Therefore, equipment users are responsible for researching and confirming equipment performance and accuracy of the proposed equipment. *Electronic Instrumentation and Measurement Techniques* (Cooper 1978) and the United States Bureau of Reclamation *Water Measurement Manual* (USBR 2001) are two good references on electronic instrumentation.

#### *5.2.6.2 Equipment Calibration, Inspection, and Maintenance*

To assess the data quality, equipment calibration, inspection, and maintenance must be considered. Due to the many types of equipment (i.e., electronic pressure transducers) that can be used, this section provides general guidance on testing, inspection, and maintenance procedures for broad categories of equipment only. In most cases, equipment manufacturers include inspection and maintenance information in their operating manuals. A discussion of the equipment and equipment calibration is needed for data assurance (URS 2011).

Equipment must be calibrated for site conditions. Information should be presented showing the calibration of instruments and equipment:

- Was (or will be) performed within an acceptable time prior to generating measurement data.
- Was (or will be) performed using standards that *bracket* the range of reported measurement results and equipment operating ranges (e.g., temperature and voltage).

Both field and manufacturer’s calibrations should be considered. An instrument should be calibrated (or recalibrated) as follows:

- Upon initial installation
- After physical relocation (before further use)
- After any repairs or service that might affect its calibration (before further use)
- As indicated by manufacturer’s specifications

#### *5.2.6.3 Equipment Protection*

All equipment should be protected from animals and vandalism to ensure a valid test. Seepage testers should consider any impacts to the data collected in the equipment setup with protection barriers (e.g., a protective barrier on the evaporative pan should deter birds or other animals that may use the pan for drinking water and not create shadowing of significance on the pan).

### 5.2.7 Manual Measurement Equipment

This section provides the measurement and equipment requirements and recommendations for using manual equipment.

#### *5.2.7.1 Measurement Requirements for the Manual Method*

Measurements must be taken until a sufficient number of calculated seepage rates exist to make a valid decision for compliance determination and the metrics discussed in section 6 are achieved. Equipment should be used pursuant to manufacturer's specifications. Site conditions during the test that influence the equipment must be noted. All measurements must be collected by the same individual to ensure consistency as discussed in section 6.4, and the responsible charge PE or PG must be able to discuss the data collection process and data.

When using a hook gauge, the gauge readings shall be repeated a minimum of seven times and numerically averaged to obtain a result for the time period. The measurements should be taken at the same hour each test day. Calculations may be conducted on a 24-hour interval; however, if possible interim data should be collected and submitted for evaluation. Interim data can provide further information on the behavior of the lagoon and evaporation pan during the test period and additional details supporting the seepage test report conclusions.

- Report water surface readings in inches, to the nearest resolution decimal. The datum elevation may be assumed.
- A complete data set is needed for each testing interval. The data set includes all of the measurements used in the seepage calculations for each test interval. At a minimum, the following information should be recorded each time measurements are taken: date, time, person reading the hook gauge, air temperature, lagoon surface elevation (Es), pan surface elevation (Epan), precipitation, influent flow, and effluent flow. Wind speeds and direction are recommended, along with any other data collected for evaluation to explain the behavior of the lagoon and evaporative pan.

#### *5.2.7.2 Equipment Requirements for the Manual Method*

The following equipment is required when using the manual method. Additional details on equipment set are provided in section 5.2.10.

1. Precipitation gauge, accurate to at least 0.01 inches. Determine the optimal siting to avoid obstructions. The precipitation gauge should be in an open space and none of the surrounding objects should extend into the conical space defined by a 45-degree angle centered on the gauge (Brackensiek et al. 1979; Dingman 2002).
2. Temperature recorder capable of recording hourly air temperatures. An example would be a weatherproof deployable electronic temperature sensor or data logger (shaded or protected from direct sunlight).
3. Class A evaporation pan and pan stilling well or alternative equipment to be used when evaluating evaporation must be outlined in the seepage test procedure.
4. Hook gauge with Vernier scale, accurate to 0.001 feet (0.012 inches).

5. Hook gauge stilling well for the lagoon.

### 5.2.8 Mechanical or Electronic Measurement Equipment

This section provides the measurement and equipment requirements and recommendations when using mechanical or electronic equipment.

#### *5.2.8.1 Measurement Requirements for the Mechanical or Electronic Method*

Measurements must be taken until a sufficient number of calculated seepage rates exist to make a valid decision for compliance determination and the metrics discussed in section 6 are achieved.

Electronic equipment may be programmed to collect multiple data points around the prescribed data collection time. For example, if the data collection time is 9:00 a.m., the equipment may be programmed to collect data every second, every 15 seconds, every minute, or some other interval before and after 9:00 a.m. These measurements may be averaged to minimize the effects from wave action or other factors influencing a single-measurement point. For this measurement method, the interval around the datum used to calculate the lagoon and evaporation pan elevations should be limited to 5 minutes or less, depending on the equipment used. Every minute or fraction of minute is recommended. A limited number of data points on each side of the 24-hour measurement point can be averaged together to reduce “noise” occurring at the time of the 24-hour measurement. The sampling frequency of 1 minute or less helps provide more data points close to the 24-hour sample to reduce noise at sampling, evaluate testing consistency, track water additions to the evaporative pan, and assist in evaluating potential anomalies that may occur during the test. All data from all equipment should be measured at the same interval chosen for the lagoon water elevation measurement equipment.

Calculations should be conducted on a 24-hour interval. If possible, interim data should be collected and submitted for evaluation. Data collected during the 24-hour intervals can provide further information on the behavior of the lagoon and evaporation pan during the test period and can provide additional details supporting the seepage test report conclusions.

Equipment should be used following manufacturer’s specifications, and the site conditions during the testing that influence the equipment must be noted. One individual is responsible for taking all measurements, and the responsible charge PE or PG must be able to discuss the data collected. Interim data can provide further information on the behavior of the lagoon and evaporation pan during the test period as well as additional details supporting the seepage test report conclusions.

- Report water surface readings in inches, to the nearest resolution decimal. A complete data set is needed for each testing interval. At a minimum, the following information should be recorded each time measurements are taken: date, time, air temperature, lagoon surface elevation (Es), pan surface elevation (Epan), precipitation, influent flow, and effluent flow. Wind speeds and direction data are recommended, along with any other data collected for evaluation to explain the behavior of the lagoon and evaporative pan.

#### 5.2.8.2 Equipment Requirements for the Mechanical or Electronic Method

The equipment requirements and recommendations when using the mechanical or electronic method include the following:

1. Precipitation gauge, with accuracy to at least 0.01 inches, which can record precipitation at approximately the same interval as the electronic recorder used. Determine the optimal siting to avoid obstructions. The precipitation gauge should be in an open space, and none of the surrounding objects should extend into the conical space defined by a 45-degree angle centered on the gauge (Brackensiek et al. 1979; Dingman 2002).
2. Temperature recorder capable of recording hourly air temperatures. An example would be a weatherproof deployable electronic temperature sensor or data logger (shaded or protected from sunlight).
3. Class A evaporation pan and pan stilling well or alternative equipment to be used when evaluating evaporation must be outlined in the seepage test procedure.
4. Liquid surface measuring equipment to measure lagoon surface elevation and evaporation pan surface elevation. In most cases, the equipment to measure these two parameters must be accurate to 0.001 feet (0.012 inches) to determine compliance with IDAPA 58.01.16. Equipment includes ultrasonic equipment, pressure transducers, and float-operated equipment, each having associated electronic recorders to log the data. Effects associated with barometric pressure must be taken into account, and the barometric pressure impact to the equipment should be discussed in the seepage test procedure. Based upon the equipment used, additional information that affects equipment accuracy may be needed, such as impacts from equipment orientation, thermal gradients, or voltage variability.
5. Lagoon stilling well.

### 5.2.9 Evaporation Measurement Equipment

As uncertainty in evaporation is a significant factor (Ham 2002) in the seepage rate calculation, options, such as an evaporation pan or other methods for evaluating evaporation, are discussed below and may be proposed in the seepage test procedure.

#### 5.2.9.1 Evaporation Pan

An evaporative pan can be used to assess evaporation during testing. The evaporative pan in an evaporation station should be located on a level area as close to the lagoon as possible. The pan must be leveled and supported 6 inches above existing ground. If necessary, shims should be used to level the pan. A typical evaporation setup, which includes a Class A evaporation pan, is found at http://www.crh.noaa.gov/gid/Local_Information/coop/evapStations/ or http://www.nwstc.noaa.gov/DATAACQ/d.EVAP/evappan.html.

The objective is to duplicate lagoon exposure as closely as possible (e.g., sun, wind, rain). The equipment site should be fairly level, sodded if applicable, and free from obstructions. The equipment site should represent the principal natural agricultural soils and area conditions. Often the area has packed dirt on the berms surrounding the lagoon. Under no circumstances should the pan or instrument shelter be placed on a concrete slab or pedestal, over asphalt, or on crushed rock. The area surrounding wastewater lagoons are usually vegetation free and dirt (without asphalt or concrete). In these circumstances, locating the equipment over bare dirt may be acceptable. Obstructions such as trees or buildings should not be closer than two (preferably four) times the height of the object above the pan. The exposure should be free from obstructions that may cast shadows over the pan during any part of the day. Pan fencing to keep out animals should be thin wire, which is less likely to affect wind current and shading on the pan. Stainless steel pans or galvanized pans annually painted with aluminum are required for use with this method (NOAA 2010).

Generally, clean water should be used in the evaporation pan for lagoon tests as the pan coefficients were derived using clean water. Wastewater may be allowed for existing lagoons or evaporation pans on a case-by-case basis with DEQ approval.

Water levels in the pan are important as they influence evaporation and consistency with the pan coefficients. Initial water level in the pan should be about 2 inches below the lip and monitored to keep the level between 2 and 3 inches below the lip of the pan. Replace the water in the pan at the end of test intervals as needed, so that the level is maintained. When water is added to the pan, the water levels must be recorded before and after. Air temperature, *not water temperature*, must be monitored to obtain the median air temperature during the test period, which in turn establishes the appropriate pan coefficient. The median air temperature is needed for each testing interval. The measured pan evaporation is multiplied by the pan coefficient (section 7.3, Table 4) to obtain the lagoon evaporation. It is recommended that water temperature is also monitored for data evaluation as discussed in section 5.2.5.1.

The pan stilling well should be anchored in the pan and not moved after the beginning of the test period.

#### *5.2.9.2 Alternative Methods for Measuring Evaporation*

Lagoon evaporation may be calculated using meteorological data (i.e., wind speed, direction, air temperature, and relative humidity), and pond liquid surface temperatures. An example of measuring evaporation is described in Ham (1999) using a bulk transfer equation. Alternative methods for measuring evaporation will be evaluated on a case-by-case basis.

### 5.2.10 Lagoon Stilling Well

The purpose of a stilling well is to reduce or prevent movement of the water surface in the well. The stilling well should reduce wind and wave effects. The lagoon stilling well should be protected from animals and vandalism during the testing.

#### *5.2.10.1 Lagoon and Evaporative Stilling Well Setup*

The lagoon stilling well should be rigid, not prone to movement during testing, and accessible. Generally, an appropriate length of 6-inch diameter polyvinyl chloride (PVC) pipe (Class 150 PVC) is needed for adequate stability, with a suitable anchor support base for use as a lagoon stilling well. If an alternative location is planned, such as a transfer structure, appropriate materials and equipment for a stilling well are needed in that location. Details (drawings, sketches, or pictures) of the stilling well must be provided, showing that movement of the stilling well (vertical or horizontal) will not occur during testing. Provide a discussion that supports the diagram.

#### *5.2.10.2 Lagoon Stilling Well Location*

The location for the lagoon stilling well must be approved by DEQ prior to testing. Wind speed and direction have significant impact on water level due to fetch and wave action (Ham 2002), and installing the lagoon stilling well as near to the center of the lagoon as possible is usually recommended. However, mounting the stilling well in the center of the lagoon may be difficult considering access and personnel safety; therefore, the stilling well may be placed at another location in the lagoon. This placement may be a transfer structure, fixed stilling well built into the lagoon, or a mounted stilling well on the side of the lagoon. It may be practical to install a permanent stilling well before filling the lagoon, rather than using a temporary setup.

DEQ recommends placing the lagoon stilling well somewhere along a line through the middle of the lagoon that is perpendicular to the prevailing wind direction (Figure 1), since the amount of fetch in the lagoon should increase across the lagoon in the direction of prevailing winds.

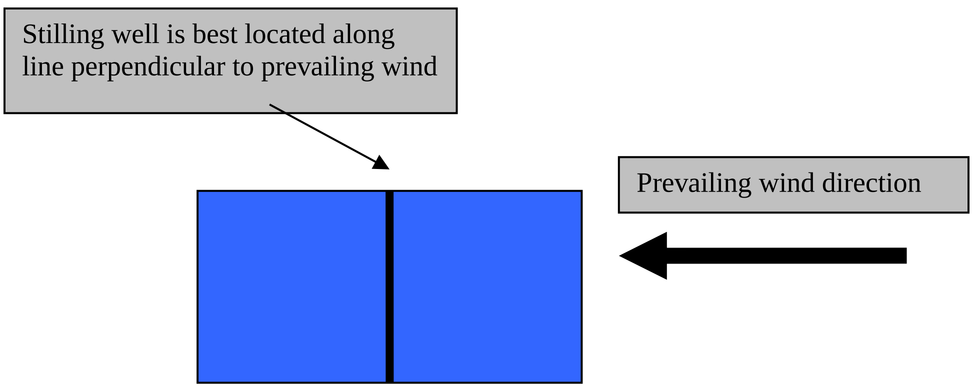


**Figure 1. Lagoon stilling well siting.**

The lagoon stilling well should be installed at 90 degrees to the water surface for accurate measurements. Mark a spot on top of the stilling well to be used as a test measurement reference point for the water surface measurements. A picture can be taken for data quality assurance each time the stilling well is checked against movement and a marked spot. All measurements must be taken with the measuring device in the same position. Measurements should continue to be taken until all of the seepage test assessment metrics discussed in section 6 have been achieved.

Wind and wave action will affect measurements during testing (Ham 2002). In the seepage test procedure, discuss wind and its potential effects on the testing and stilling well setup. The official start and stop of a seepage test should coincide with periods of low wind speed to minimize errors caused by wave action. In the seepage test report, discuss wind speeds and their effects on the data collected.

### 5.2.11 Photographs

Pictures from a photo reference point that show the following items should be provided in the seepage test report:

- The lagoon before, during, and after the test.

- The lagoon stilling well setup before, during, and after the test. Include pictures of the desiccant tube for barometrically compensated equipment.
- The evaporative pan setup, before and during the test, showing equipment protective measures against animals and other interferences.
- Gates, valves, piping, connections, or other items used to isolate the lagoon.
- Any tangible obstructions or issues that occur during the seepage test.

## 5.3 Quality Assurance Project Plan

In support of the agency mission, DEQ is dedicated to using and providing objective, correct, reliable, and understandable information. Decisions made by DEQ are subject to public review and, often, rigorous scrutiny. Therefore, DEQ's goal is to ensure that all decisions are based on data of known and acceptable quality. To ensure that data and results are of the appropriate quality, a quality assurance project plan (QAPP) must be included in the submitted seepage test procedure and must include quality assurance and quality control (QA/QC) activities for the scope of work for the site-specific seepage test. The QAPP integrates the appropriate technical and quality aspects of the seepage test. The purpose of the QAPP is to document results and data collection activities and to provide a project-specific *blueprint* for obtaining the type, quantity, and quality of data needed to determine compliance with allowable seepage rates. The QAPP documents how QA/QC is applied to the task or project, or some aspect of a project, to ensure that the results obtained are of the type, quantity, and quality needed and expected.

QC is the overall system of activities that measures the attributes and performance of a process, item, or service against defined standards to verify that they meet the stated requirements established by the customer (ANSI 2004). The QC goal is to provide a reasonable level of verification at various data collection stages that data quality is maintained. QC must be included with the testing, especially specified procedures for seepage testing QC that include processes for data collection, data management, and data review, verification, and validation. Measurement uncertainties are the errors associated with data management, equipment, and sampling activities. At each measurement phase, errors can occur that, in most cases, are additive. One goal of a quality management system is to control measurement uncertainty to keep it to an acceptable level.

QAPPs should be developed in accordance with the requirements of United States Environmental Protection Agency's (EPA's) *EPA Requirements for Quality Assurance Project Plans* (EPA 2001) using the additional guidance contained in *Guidance for Quality Assurance Project Plans* (EPA 2002). The requirements and guidance documents can be downloaded or printed from [www.epa.gov/quality/qa_docs.html](www.epa.gov/quality/qa_docs.html).

The QAPP can be a section or appendix in the submitted test procedure. If the QAPP document is large, then the project owner/operator/consultant may provide a web link to the document via an Internet file share or cloud storage provider (e.g., Dropbox or Google Drive). The PE or PG responsible for the seepage test shall maintain current records providing factual evidence that required QC activities and/or tests have been performed. These records shall include the work of subcontractors and suppliers and shall be maintained in an acceptable form to DEQ.

# 6 Seepage Test Results Assessment and Metrics

Methods to demonstrate compliance with IDAPA 58.01.16, a permit, or both must be submitted to DEQ for review and approval prior to conducting a required seepage test. “The precision and resolution of the technique must be quantified so stakeholders can assess the utility of the results” (Ham 2002). DEQ will employ assessment metrics (URS 2011) to quantify uncertainty and evaluate seepage test data submitted for compliance determinations (DEQ 2012).

“A multi-metric approach to compliance determination will be used in evaluating the seepage test. The metrics are (1) Data Quality; (2) Data Sufficiency; (3) Comparability; (4) Consistency; (5) Category; (6) Completeness/Validity; and (7) Compliance” (URS 2011). Table 1 summarizes these components and their functions. It is recommended that seepage testers become familiar with the metrics that will be used in seepage test reviews prior to submitting a seepage test procedure or seepage test report for DEQ review. The seepage test procedure should note the seven metrics as used in the data assessment (e.g., incorporating Table 1 into the procedure and referencing this guidance is adequate). The seepage test report submittal should provide information to demonstrate conformance with these metrics as applicable. It is recommended that during a seepage test, the seepage rate calculations and analysis are done on a routine basis during the test period using the metrics described in the following sections.

**Table 1. Seepage test assessment rubric.**

| Parameter | Description and Objectives |
|---|---|
| Data quality | Determine whether data were collected at the proper times/intervals and whether appropriate procedures were employed. |
| Data sufficiency | Determine if the minimum number of data/measurements (electronic equipment) or sufficient measurements (hook gauge) was obtained during testing. |
| Comparability | Evaluate the degree to which levels in the lagoon and evaporation pan compare. Include any precipitation or other significant weather/events in this comparison. |
| Consistency | Determine if most of the seepage rates conform to the +/- 20% standard. |
| Category | Evaluate the impact of the errors/uncertainties and make a determination of whether the lagoon status is Category 1, 2, 3, or 4. |
| Completeness | Evaluate whether a sufficient number of calculated seepage rates exist to make a valid decision for compliance determination. |
| Compliance | Assess whether the anticipated average seepage rate exceeds the regulatory limit. |

*Source*: URS 2011

## 6.1 Data Quality

The seepage test report should provide discussion demonstrating data quality (URS 2011). Data of sufficient quality are required for compliance determination of a seepage test (URS 2011; DEQ 2012). The data quality assessment considers whether data were collected at the proper times or intervals and whether appropriate procedures were used. The assessment includes, but is not limited to, ensuring the QAPP was followed, reviewing equipment calibration, assessing calculations performed outside the DEQ spreadsheet, evaluating equipment setup, and reviewing other considerations, which appear in this guidance (URS 2011). QC for data quality is discussed in section 5.3.

## 6.2 Data Sufficiency

The seepage test report should provide information to demonstrate that the data are sufficient. The data collected and analyzed must be sufficient for evaluating the seepage test as multiple types of data support calculation of the seepage rate for each time period, as well as for determining the equipment and sampling errors (URS 2011). As an aid to seepage testers, Table 2 and Table 3 provide checklists for data sufficiency that should be followed in the test procedure and included with the test report. Section 5 suggests what information is needed for background, during data collection, and on the equipment so a data sufficiency checklist can be developed for the site-specific seepage test procedure. Additional equipment and site-specific circumstances may require changes/additions to the checklist.

**Table 2. Example data sufficiency checklist for manual method tests.**

| Manual Test | Status | Example Equipment | Minimum Required Frequency | Example Comments |
|---|---|---|---|---|
| Lagoon surface elevation | Required | Hook gauge | Daily | Identify person taking readings. All readings taken must be provided. |
| Evaporative pan elevation | Required | Hook gauge | Daily | Water level in pan will be kept to between 2 and 3 inches below the lip of the pan. Take photos each visit. |
| Lagoon stilling well | Required | Variable | Daily | Evaluate/confirm that stilling well has not moved. Take photos each visit. |
| Evaporative pan protective barrier | Required | Variable | Daily | Take photos each visit (e.g., chicken wire over top of pan can protect from birds and other animals). |
| Precipitation | Required | Precipitation gauge | Daily | Taken at approximately the same time as lagoon and pan measurements |
| Effluent/influent flow into lagoon | Required | Variable | Seepage test specific | Test with flows will only be allowed on a limited case-by-case basis. |
| Wind speed | Recommended | Variable | Daily | Each time increment that the hook gauge is read. |
| Ambient air temperature | Required | Weatherproof electronic temperature sensor | Hourly | This is required for ambient air. |
| Water temperature | Recommended | Temperature sensor | Hourly | This information can provide test data validation. |

*Source*: Adapted from URS 2011

**Table 3. Example data sufficiency checklist for mechanical or electronic method tests.**

| Mechanical/ Electronic Test | Status | Example Equipment | Minimum Required Frequency | Example Comments |
|---|---|---|---|---|
| Lagoon surface elevation | Required | Variable | Daily | Electronic submittal of all data collected. |
| Evaporative pan elevation | Required | Variable | Daily | Water level in pan will be kept to between 2 and 3 inches below the lip of the pan. Take photos each visit. |
| Lagoon stilling well | Required | Variable | Daily | Evaluate/confirm that stilling well has not moved. Take photos each visit. |
| Evaporative pan protective barrier | Required | Variable | Daily | Take photos each visit (e.g., chicken wire over top of pan can protect from birds and other animals). |
| Precipitation | Required | Precipitation gauge | Daily | Taken at approximately the same time as lagoon and pan measurements |
| Effluent/influent flow into lagoon | Required | Variable | Seepage test specific | Test with flows will only be allowed on a limited case-by-case basis. |
| Wind speed | Recommended | Variable | Daily | Each time the lagoon and evaporative pan level elevations are recorded |
| Ambient air temperature | Required | Weatherproof electronic temperature sensor | Hourly | This is required for ambient air. |
| Water temperature | Recommended | Temperature sensor | Hourly | This information can provide test data validation. |

*Source*: Adapted from URS 2011

## 6.3 Comparability

The seepage test report should provide information to demonstrate appropriate comparability of the data collected (URS 2011). The water in the evaporation pan and in the lagoon should be exposed to the same weather conditions, and theory predicts that they should rise and decrease in a synchronized manner. A time series graph of the amount of evaporation in the lagoon overlain on the amount of evaporation in the evaporation pan overlain with precipitation should be generated. This evaporation graph is expected to be synchronized with increases and decreases coinciding. In practice, variations may occur and the specific site test factors that contribute to deviations and an unsynchronized graph should be discussed in the seepage test report to determine how the influences affect the seepage results.

## 6.4 Consistency

The seepage test report should provide information to demonstrate consistency of seepage rate measurements when comparing the 24-hour intervals (URS 2011). Measurements taken should show that a *consistent pattern* is evident.

A *consistent pattern* is defined as follows: the calculated seepage for each 24-hour interval test period (using the average of the readings for each test period) shall be within 20% of the calculated seepage for the previous test periods.

If an inconsistency is noted, testing should continue until a consistent pattern as defined herein is achieved. Consistency compares the last calculated seepage rate to an interval around the average seepage rate of the preceding period. The interval is equal to +/- 20% of the average value. If the last calculated seepage rate for a time period falls within the +/- 20% interval, consistency is considered to be proved.

## 6.5 Category Determination

The seepage test report should include a discussion that evaluates the impact of the errors/uncertainties and determines whether the lagoon status is a Category 1, 2, 3, or 4 classification. Category 1, 2, 3, and 4 classification examples are shown in Figure 2, which is a conceptual model of the category determination approach and uses the seepage rate of 0.25 inches per day as the example regulatory limit. The small, square boxes on the diagram represent valid average seepage rates (i.e., averages conforming to the completeness requirement that have been validated by the discomfort curve analysis discussed in section 6.6). The equal-length vertical error bars above and below the boxes represent the amount of error or uncertainty contributed by the equipment and sampling errors calculated in the DEQ spreadsheet.

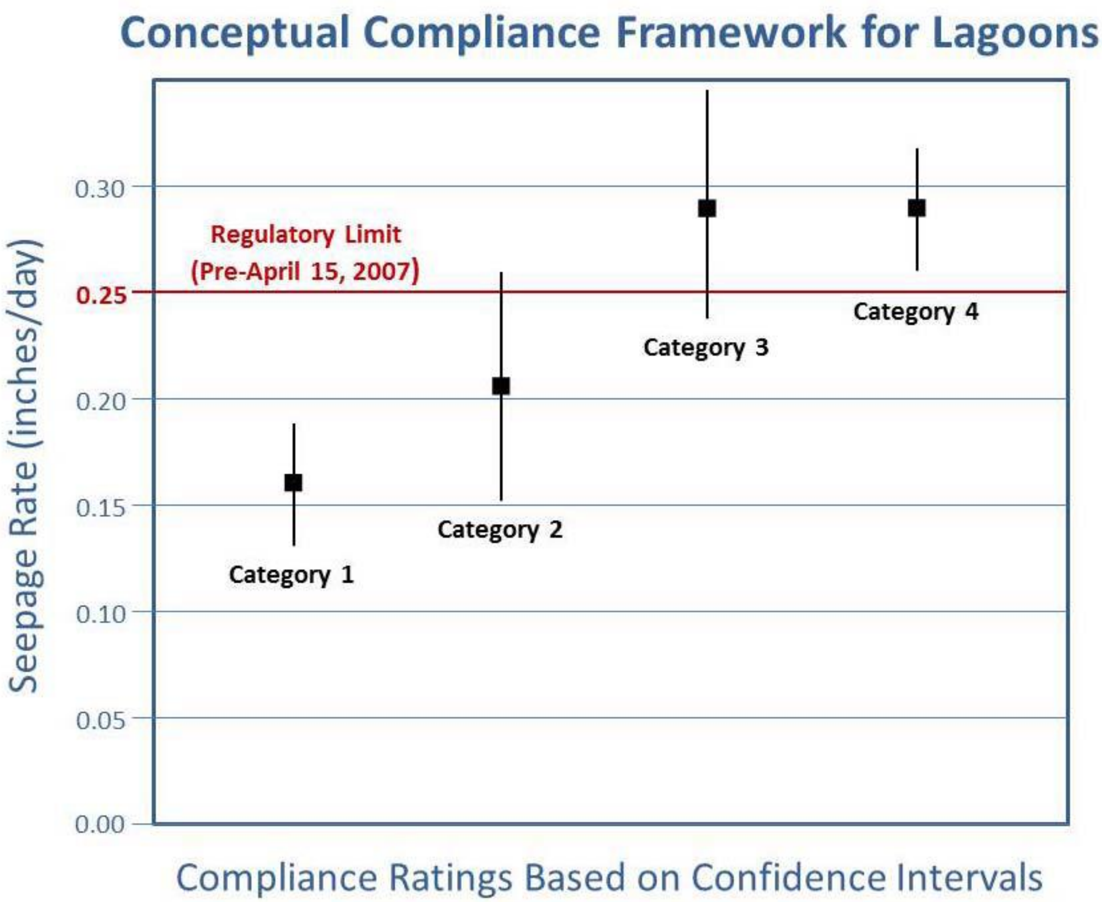


**Figure 2. Conceptual model for categorization in compliance assessment for lagoons constructed prior to April 15, 2007 (URS 2011).**

To be classified as Category 1, the average must be below the regulatory limit, and the highest point on the upper error bar must fall below the regulatory limit. Category 1 is the most stringent but also the most desirable classification category. Category 2 also has a valid average that falls below the regulatory limit, but the error bar extends above the regulatory limit. Thus, the uncertainty associated with equipment and sampling invokes a caveat for decision-making (i.e., the lagoon is possibly noncompliant). Testing procedure details such as accuracy of equipment create the possibility of shifting from a Category 1 status to a Category 2 classification (URS 2011). Using less accurate equipment has the potential to create larger vertical error bars (Category 2 or 3) which may lead to an inconclusive test.

## 6.6 Completeness

The seepage test report should evaluate whether a sufficient number of calculated seepage rates exist to make a valid decision for compliance determination and shows data completeness through a statistical means to create a defensible and objective number of seepage dates needed for complete data (URS 2011). Typically, the duration of seepage testing is 5 to 15 days. Occasionally ideal conditions may support a test that is less than 5 days, however, as lagoons are dynamic systems it is expected that seepage tests are never less than 3 days in duration to also support the comparability metric in section 6.3. Test duration depends upon the site-specific procedure used, environmental variables, and the assessment metric evaluation. During testing it is recommended that seepage testers use the Visual Sample Plan (VSP) software for completeness analysis. VSP is public domain software developed by Pacific Northwest National Laboratory, which that can be downloaded without charge at http://vsp.pnnl.gov (URS 2011). DEQ strongly recommends using the VSP tool to determine when sufficient data have been collected to validate calculated seepage rates for each lagoon. The VSP should calculate the number of seepage testing days needed for each test based upon the data that are being collected. DEQ recommends that data be entered into the VSP during seepage testing by the responsible charge PE or PG to evaluate the testing duration needed for the completeness metric.

## 6.7 Compliance

The seepage test report results should provide the seepage rates for each 24-hour interval. The seepage rates calculated for each 24-hour interval are to be averaged using the calculations in the DEQ spreadsheet (section 7) to obtain an expected daily seepage rate. This rate will be compared to the appropriate regulatory limit for a compliant or noncompliant determination. Demonstrating that the compliance metric is met is conditioned upon satisfying the six other metrics as listed in Table 1.

# 7 Seepage Rate Calculations

The basic water balance equation considers changes in lagoon depth, evaporation, and precipitation to calculate a seepage rate. With the information recorded each time measurements are taken (required measurements are listed in sections 5.2.7.1 and 5.2.8.1), the overall seepage rate for the testing period can be calculated using Equation 1, Equation 2, and Equation 4 in section 7.2.

## 7.1 DEQ Seepage Calculation Spreadsheets

The DEQ seepage calculation spreadsheets are a resource to assist seepage testers with seepage test data and seepage test metric assessment. DEQ recommends using these seepage test spreadsheets and submitting them with the seepage test report to DEQ as the calculations are known to DEQ and include calculation principles outlined in the *Wastewater Lagoon Seepage Test Statistical Review* (URS 2011). Two versions are available for evaluating lagoon seepage data: (1) manual equipment method used for a hook gauge and (2) mechanical or electronic equipment method. These spreadsheets automatically include both sampling and equipment errors and calculate seepage values from the input values of precipitation, pan evaporation, and lagoon surface elevation changes over the course of the test. The DEQ seepage calculation spreadsheets were developed to reduce the time and effort required for seepage testing analysis and to provide a level of consistency with review. The basic seepage rate calculations are found in section 7.2. Additional details, such as inflow from liner contribution during rain events, are factored into the DEQ seepage calculation spreadsheets.

If the DEQ seepage calculation spreadsheets are not used, then DEQ must evaluate the alternative calculations used and how sampling and equipment errors are factored into the calculations. Allow for additional review time and discussion in the seepage test procedure for alternatives to the DEQ seepage calculation spreadsheet. If alternative calculations are proposed, they should be conservative with respect to adverse ground water impact (i.e., *worst-case* scenarios must be taken into account).

## 7.2 Equations

The equations shown below are used in the DEQ seepage calculation spreadsheets, which are discussed in section 7.1. The DEQ seepage calculation spreadsheets provide an example of how the calculations are used.

$$\mathbf{S_{r1}} = \frac{\textbf{Precipitation }(\boldsymbol{inches})+\textbf{ES}(\boldsymbol{inches})-\mathbf{I_L}(\boldsymbol{inches})-\mathbf{Q}(\boldsymbol{inches})}{\boldsymbol{n}\,(\boldsymbol{day})} = \frac{\boldsymbol{inches}}{\boldsymbol{day}}$$

**Equation 1. Seepage rate in inches per day.**

where:

$S_{r1}$ = Seepage rate in inches per day.

Precipitation = Precipitation gauge measurements collected during seepage testing (inches).

ES = Lagoon surface elevation change in inches ($E_{s0}$ - $E_{sn}$). Positive if the n-day surface is lower than day 0; negative if the n-day surface is higher than day 0.

$$ES = E_{s0}(inches) - E_{sn}(inches) = inches \quad \text{(Equation 1a)}$$

$E_{s0}$ = Lagoon surface elevation, day 0 in inches. Note that $E_{s0}$ represents the start of a unique test interval and could mean day zero or the start of a new test interval.

$E_{sn}$ = Lagoon surface elevation, day n in inches.

$I_L$ = Net lagoon evaporation, which is calculated from the net corrected pan evaporation in inches (may be a positive or negative number).

$$I_L = P\left[Precipitation\ (inches) + E_{pan0}(inches) - E_{pan\,n}(inches)\right] = inches \quad \text{(Equation 1b)}$$

P = Evaporation pan coefficient, from Table 4 (unitless).

Evap Pan = Epan 0 - Epan n = inches

Evap Pan = Evaporation pan elevation change in inches.

$E_{pan0}$ = Evaporation pan surface elevation, day 0 in inches. Note that $E_{pan0}$ represents the start of a unique test interval and could mean day zero or the start of a new test interval.

$E_{pan\,n}$ = Evaporation pan surface elevation, day n in inches.

Q = Net change in water levels from flow into and out of the lagoon over the lagoon area in inches. May be positive (effluent flow > influent flow) or negative (effluent flow < influent flow). Value is zero if lagoon is completely isolated with no inflow or outflow.

$$Q = \frac{(\text{effluent flow} - \text{influent flow in gallons})}{(\text{lagoon surface area ft}^2)} \bullet \frac{(\text{ft}^3)}{(7.48\text{gals})} \bullet \frac{(12\text{in})}{(\text{ft})} = \text{inches (Equation 1c)}$$

n = Time in days.

$$S_{r2} = [S_{r1}] \bullet \left[\frac{(1\,ft)}{(12\,in.).}\right] \bullet \left[\frac{43{,}560\,ft^2}{(1\,acre)}\right] \bullet \left[\frac{(7.48\,gal)}{(ft^3)}\right] = \frac{gallons}{acre/day}$$

**Equation 2. Seepage rate in gallons per acre per day.**

where:

$S_{r2}$ = Seepage rate in gallons per acre per day.

$S_{r1}$ = Seepage rate in inches per day from Equation 1.

$$S_{r1}\ \text{Error} = \sqrt{a_1^2 + a_2^2 \ldots + a_n^2}$$

**Equation 3. $S_{r1}$ error propagation.**

where:

$S_{r1}$ Error = Error associated with the data used to calculate $S_{r1.}$ Error calculations are based on the propagation of uncertainty. Each measurement taken will have uncertainties due to measurement limitations of the equipment, therefore in the calculation of $S_{r1,}$ it is important to understand how the error propagates.

$a_x$ = Error associated with ES, $I_{L,}$ and Q (from Equation 1).

$$\text{ES Error} = \sqrt{b_1^2 + b_2^2 \ldots + b_n^2}$$

**Equation 4. ES error propagation.**

where:

ES Error = Error associated with the data used to calculate ES (Equation 1a). Error calculations are based on the propagation of uncertainty. Each measurement taken will have uncertainties due to measurement limitations of the equipment; therefore, in the calculation of ES, it is important to understand how the error propagates.

$b_x$ = The manufacturer's stated accuracy of each device used to measure $E_{s0}$ and $E_{sn}$ (from Equation 1a).

$$I_L\ \text{Error} = \sqrt{(P \bullet c_1^2) + (P \bullet c_2^2) \ldots + (P \bullet c_n^2)}$$

**Equation 5. $I_L$ error propagation.**

where:

$I_L$ Error = Equipment error associated with the data used to calculate $I_L$ (from Equation 1b). Error calculations are based on the propagation of uncertainty. Each measurement taken will have uncertainties due to measurement limitations of the equipment, therefore in the calculation of $I_{L,}$ it is important to understand how the error propagates.

P = Evaporation pan coefficient from Table 4 (unitless).

$c_x$ = Error associated with the equipment for each of the calculations needed for the $S_{r1}$ equation. At minimum this should include Epan Error, and equipment accuracy (from Equation 1b).

$$\text{Effluent/Influent Error} = \sqrt{(P \bullet \mathrm{d}_1^2) + (\mathrm{P} \bullet \mathrm{d}_2^2) \ldots + (\mathrm{P} \bullet \mathrm{d}_\mathrm{n}^2)}$$

**Equation 6. Effluent/influent error propagation.**

where:

Effluent/Influent Error = Equipment error associated with the pan elevation and precipitation measurements (from Equation 1c). Each measurement taken will have uncertainties due to measurement limitations of the equipment and error propagates in the $I_L$ calculation. The error calculations are based on the Propagation of Uncertainty.

P = Evaporation pan coefficient, from Table 4 (unitless).

$d_x$ = Error associated with the equipment for each of the calculations needed for Q (from Equation 1c).

$$\text{Epan Error} = \sqrt{e_1^2 + \mathrm{e}_2^2 \ldots + \mathrm{e}_\mathrm{n}^2}$$

**Equation 7. Epan error propagation.**

where:

Epan Error = Error associated with the data used to calculate ES (from Equation 1b). Error calculations are based on the propagation of uncertainty. Each measurement taken will have uncertainties due to measurement limitations of the equipment; therefore, in the calculation of ES, it is important to understand how the error propagates.

$e_x$ = The manufacturer’s stated accuracy of each device used (from Equation 1b).

## 7.3 Evaporation Pan Coefficients

Evaporation pan coefficients (P) presented in Table 4 apply to galvanized pans annually painted with aluminum and to stainless steel pans. This type of pan painting or use of stainless steel pans is required for use with the equation for $I_L$ (net lagoon evaporation) in Equation 1.

**Table 4. Evaporation pan coefficient, P.**

| Median Air Temperature (°F) | Pan Coefficient (P) | Median Air Temperature (°F) | Pan Coefficient (P) |
|---|---|---|---|
| 30 | 1.0000 | 60 | 0.7210 |
| 31 | 0.9906 | 61 | 0.7116 |
| 32 | 0.9812 | 62 | 0.7022 |
| 33 | 0.9718 | 63 | 0.6928 |
| 34 | 0.9624 | 64 | 0.6834 |
| 35 | 0.9530 | 65 | 0.6740 |
| 36 | 0.9438 | 66 | 0.6648 |
| 37 | 0.9346 | 67 | 0.6556 |
| 38 | 0.9254 | 68 | 0.6464 |
| 39 | 0.9162 | 69 | 0.6372 |
| 40 | 0.9070 | 70 | 0.6280 |
| 41 | 0.8976 | 71 | 0.6186 |
| 42 | 0.8882 | 72 | 0.6092 |
| 43 | 0.8788 | 73 | 0.5998 |
| 44 | 0.8694 | 74 | 0.5904 |
| 45 | 0.8600 | 75 | 0.5810 |
| 46 | 0.8508 | 76 | 0.5720 |
| 47 | 0.8416 | 77 | 0.5630 |
| 48 | 0.8324 | 78 | 0.5540 |
| 49 | 0.8232 | 79 | 0.5450 |
| 50 | 0.8140 | 80 | 0.5360 |
| 51 | 0.8046 | 81 | 0.5264 |
| 52 | 0.7952 | 82 | 0.5168 |
| 53 | 0.7858 | 83 | 0.5072 |
| 54 | 0.7764 | 84 | 0.4976 |
| 55 | 0.7670 | 85 | 0.4880 |
| 56 | 0.7578 | | |
| 57 | 0.7486 | | |
| 58 | 0.7394 | | |
| 59 | 0.7302 | | |

# 8 Seepage Test Report to DEQ

After testing the lagoon, a seepage test report must be submitted to DEQ. The report must include the responsible charge Idaho-licensed PE or PG's seal affixed, signed and dated, and an interpretation and certification of the test results. All interpretations need to be well supported by the data. A checklist on what the seepage test submittal to DEQ should consider and/or include is found in Appendix B. A suggested outline for a seepage test report follows:

**Cover Page**

**Table of Contents**

**Title**
Provide the project name (lagoon(s) and site) and owner.

**Purpose**
Include the reason the lagoon was tested.

**Applicable Seepage Rate**
Identify the lagoon-specific seepage rate requirement.

**Personnel**
Identify the Idaho-licensed PE or PG responsible for the test. Identify roles, responsibilities, and qualifications/training of all people who assisted with the test.

**Equipment**
Identify the equipment used, manufacturer's specifications, and calibration information for this test.

- Equipment calibration details. This may include information about the manufacturer's recommendations for equipment calibration, if it was calibrated accordingly, and if there were additional calibrations needed for site conditions.
- Any specific equipment conditions that must be taken into account when evaluating the data (e.g., are thermal errors and corrections needed and how were those applied; did the equipment account for barometric pressure if needed; did power supply and voltage fluctuation need to be addressed?).

**Photographs**
Include pictures taken before, during and after the seepage test as described in section 5.2.11. These pictures should include at a minimum: lagoon water levels, evaporation pan setup, fencing, stilling well setups, equipment connections, desiccant quality, and lagoon isolation verification (e.g., valves, piping).

**Site Conditions**
Include a description of site conditions during testing. Was the lagoon at maximum design operational depth during the testing?

**Lagoon Isolation**
Include a description of the methods used to ensure that the lagoon was isolated during testing; provide evidence that ground water was not above the bottom of the lagoon. If the lagoon was

not isolated during the test, discuss the testing uncertainties involved and how the flows were accounted for in the water balance equation.

**Procedure**

Provide a description of the actual methods and quality assurance process used during the test. The discussion should include confirmation that the conditions in DEQ's procedure approval letter were met. Include any deviations from the approved procedure and information to support why a deviation from the DEQ-approved procedure was necessary. The approved procedure should be referenced along with DEQ's approval letter.

**Data**

Document and provide to DEQ all the data collected. Review the data, apply the seepage test assessment metrics, and explain the results in a narrative form. Review the QAPP, then document and discuss the testing methods and any deviations from the QAPP. Use this information to interpret the data and identify patterns, relationships, and/or potential anomalies.

- Include all of the raw data collected during the course of the test, and any data reduction performed. All raw data collected must be included in an appendix to the written report.
- All data used in the seepage rate calculation must be provided in the seepage test report. The data used in these decisions will contain some level of uncertainty. Equipment and sampling error are two sources of error and must be applied to the data and calculations.
- All data submitted to DEQ when using electronic equipment shall be provided in electronic form in an MS Excel spreadsheet or a version that can be transferred to an MS Excel spreadsheet. The data may be input on the electronic DEQ seepage calculation spreadsheet or the spreadsheet described in the approved procedure.

**Calculations**

Provide all calculations used. If the DEQ seepage calculation spreadsheet is used, the calculations are known, and the consideration for sample and equipment error is already included. When presenting the results, the calculations should be supplemented with a description of what has been calculated and considered in the analysis as it applies to the seepage test metrics (Table 1). The seepage test report should include a discussion relating the data and calculations as they were influenced by external factors (e.g., temperature, wind, or stilling well design).

**Conclusions**

Summarize the key elements of the evaluation. Evaluate whether the underlying assumptions hold, or whether departures are acceptable, given the actual data and other information about the seepage test. The data evaluation must consider uncertainties for equipment measurement accuracy and sampling so that it clearly demonstrates that lagoon water loss is within the allowable range established by state rules. Include a discussion in which the responsible charge PE or PG certifies that (1) the data adequately support the recommendations, and (2) interpretations based on the data are accurate and represent sound, unbiased professional judgment.

An affirmative statement from the responsible charge PE or PG must be provided indicating whether the lagoon meets or does not meet the allowable seepage rate determined by the test.

**Recommendations**

The Idaho-licensed PE or PG should recommend to DEQ the action needed based upon the test results which may be as follows:

- Accept the results of the seepage test as meeting the allowable seepage rate.
- The results from the seepage test are inconclusive, and the lagoon needs to be tested further or an alternative to another seepage test may be recommended.
- The results of the seepage test indicate a lagoon that is leaking at a rate higher than allowed. This recommendation may include the further action that should be taken.

The responsible charge Idaho-licensed PE or PG's seal shall be affixed, signed and dated, to the conclusions and recommendations.

# 9 References

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# Appendix A. Seepage Test Procedure

Generally the lagoon seepage test procedure should consider and/or include information on the following:

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| ☐ | **Purpose and applicable seepage rate**<br>☐ Why is the lagoon being tested?<br>☐ What is the applicable seepage rate for the lagoon (e.g., 0.125 or 0.25 inches/day)? |
| ☐ | **Project description**<br>☐ Name of project, project owner, project location.<br>☐ Site setting, history, site conditions. (Are there any unusual site conditions?)<br>☐ Lagoon age and type of construction (native materials, engineered materials, above or below ground, etc.).<br>☐ Purpose and use of the lagoon.<br>☐ Maximum operating level versus maximum design level.<br>☐ Has the lagoon passed or failed previous seepage tests? Provide known details.<br>☐ What is the lagoon liner material?<br>☐ Provide lagoon specifications, lagoon record drawings with location of pipes, transfer structures, and any other structure that may be needed for lagoon and site assessment. |
| ☐ | **Personnel**<br>☐ Identify the Idaho-licensed professional engineer (PE) or professional geologist (PG) responsible for the test.<br>☐ Ensure that the procedure has the responsible charge Idaho-licensed PE or PG's seal affixed, signed and dated.<br>☐ Identify roles, responsibilities, and qualifications/training of all people who will assist with seepage test. |
| ☐ | **Equipment**<br>☐ List all equipment used.<br>☐ For all equipment, are the manufacturer's specifications included?<br>☐ For all equipment, when was the equipment last calibrated? What are the manufacturer's recommendations for equipment calibration? Will equipment be calibrated according to manufacturer's specifications prior to testing? Will the power supply used during testing be within the manufacturer's recommendation, so that it meets the manufacturer's specification for accuracy? Are the effects of supply voltage variation considered?<br>☐ What equipment will be used for taking water-level measurements?<br>☐ What specific equipment conditions must be taken into account? Does the equipment require any special mounting in the stilling well such as vertical position or being submerged to a certain depth?<br>☐ What is the equipment accuracy?<br>☐ Will thermal errors and corrections be needed when using this equipment? How will that be accomplished? |

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| ☐ | **Procedure**<br>☐ How will the lagoon be isolated? Provide details on lagoon isolation.<br>☐ Is there potential for ground water inflow into the lagoon at this site?<br>☐ Is there a hydraulic break between the lagoon and ground water?<br>☐ How will the lagoon isolation be validated during testing?<br>☐ If more than one lagoon is tested at the site, in what order will they be tested?<br>☐ Will the lagoon be filled to its maximum design operational depth? For how long prior to testing?<br>☐ What is the designed test depth?<br>☐ When is the test planned for? Review the expected seasonal weather for the testing period. Are freezing conditions expected during that time frame? |
| ☐ | **Procedure and lagoon stilling well**<br>Review the lagoon stilling well and its placement. Where will the equipment be placed?<br>☐ Is the stilling well in the center of the lagoon?<br>☐ <u>If an alternative location is proposed:</u><br>▪ If the well is off-center, how will wind affect the well? Is the well perpendicular or parallel to prevailing wind direction?<br>▪ Where will the stilling well be placed?<br>▪ Will the manufacturer's recommendations for the equipment used be followed?<br>▪ How will equipment be placed/secured in the stilling well? |
| ☐ | **Procedure and mechanical equipment**<br>How will mechanical equipment account for barometric pressure?<br>☐ Does the equipment have barometric pressure compensation?<br>☐ Is the transducer/electronic equipment vented or nonvented?<br>☐ If vented, how will the equipment or the desiccant be protected from weather or other types of fouling? How will the vents be mounted to protect from kinking or other blockages? |
| ☐ | **Procedure and evaporation**<br>☐ How will evaporation be account for? Provide details of alternative methods if not using an evaporative pan.<br>☐ Is the evaporative pan setup explained? A typical Class A pan equipment setup is found at http://www.crh.noaa.gov/gid/Local_Information/coop/evapStations/<br>☐ Where is the evaporative pan located?<br>☐ Is the stilling well in the pan secured to prevent movement?<br>☐ What equipment will be used for taking measurements in the pan?<br>☐ What unauthorized entry protection (i.e., animal protection) will be in place for the pan?<br>☐ Is there any shading on the pan?<br>☐ Will pictures of pan setup be submitted? |

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| ☐ | **Procedure and weather conditions**<br>☐ Will a precipitation gauge be on site? Is it free from obstructions?<br>☐ How will precipitation measurements be recorded?<br>☐ Will precipitation measurements be taken in the same time interval as the other measurements?<br>☐ In the event of precipitation, how will precipitation contribution to water levels in the lagoon be accounted for?<br>☐ In the event of precipitation, how will precipitation liner contribution to water levels in the lagoon be accounted for?<br>☐ Will a temperature recorder, such as a weatherproof deployable electronic temperature sensor or data logger, be on site?<br>☐ Where will the temperature recorder be located?<br>☐ Does the temperature recorder need to be shaded or protected from direct sunlight (e.g., in a radiation shield or mounted on the north side of a post)?<br>☐ How will wind speed be measured and recorded? |
| ☐ | **Procedure and data collection**<br>☐ Is there a quality assurance project plan for the testing and measurement methods?<br>☐ How will the tester determine the data quality, sufficiency, and completeness of the data to determine when enough calculated seepage rates exist to make a valid decision for compliance?<br>☐ Does the procedure include a site checklist for the seepage tester?<br>☐ How will measurements be recorded?<br>☐ Will the seepage tester take pictures to verify site conditions? What pictures are planned?<br>☐ How will site conditions during the test be verified?<br>☐ How will lagoon seepage testing metrics be assessed? |
| ☐ | **Will the DEQ seepage calculation spreadsheet be used?**<br>☐ If the DEQ spreadsheet will not be used, are all calculations and a copy of the spreadsheet used provided in electronic format? (Note that additional review time is needed if the DEQ spreadsheet is not used.) |

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# Appendix B. Seepage Test Report

Generally the lagoon seepage test submittal should consider and/or include information on the following:

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| ☐ | **Purpose and applicable seepage rate**<br>☐ Why was the lagoon tested?<br>☐ What is the applicable seepage rate for the lagoon (e.g., 0.125 or 0.25 inches/day)? |
| ☐ | **Seepage test procedure**<br>☐ Was the procedure submitted and approved by DEQ prior to testing the lagoon?<br>☐ Is the procedure and DEQ approval letter attached or referenced with the seepage test submittal?<br>☐ Were all the conditions as required in the seepage test procedures approval letter discussed and met?<br>☐ Were there deviations from the approved procedure? Please discuss.<br>☐ Were all deviations preapproved in writing by DEQ? |
| ☐ | **Personnel**<br>☐ Identify the Idaho-licensed professional engineer (PE) or professional geologist (PG) responsible for the test.<br>☐ Ensure that the submittal has the responsible charge Idaho-licensed PE or PG's seal affixed, signed and dated.<br>☐ Identify roles, responsibilities, and qualifications/training of all people who assisted with the seepage testing. |
| ☐ | **Seepage testing and equipment**<br>☐ Are equipment manufacturer's specifications provided?<br>☐ What is the equipment accuracy?<br>☐ When was the equipment last calibrated?<br>☐ What are the manufacturer's recommendations for equipment calibration? Was it calibrated according to manufacturer's specifications prior to testing? Were there calibrations needed for site conditions?<br>☐ How did equipment account for barometric pressure?<br>☐ Are thermal errors considered? Thermal errors are separate from other errors affecting total transducer accuracy. Provide all calculations used for thermal correction. How was the temperature error determined? Every pressure transducer not only has a sensor-specific output signal but also a temperature error that is typical for the particular sensor type.<br>☐ What was the power supply used during pressure transducer operation? For example, if the pressure-measuring converter is calibrated at the factory with a power supply of 24 volts direct current (VDC), no change of accuracy should occur if the converter is actually operated with just 12 VDC. The effects of supply voltage variation should not exceed 0.1% per 10 V.<br>☐ Provide all data and calculations used with the data.<br>☐ Was the equipment placed and used according to manufacturer's recommendations? Review the stilling well and its placement. Was the equipment secured in the stilling well? |

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| ☐ | **Photographs**<br>☐ Are there pictures of the lagoon site before and after the test?<br>☐ Are there pictures of the lagoon and pan stilling well?<br>☐ Are there pictures to show that the pressure transducer desiccant was dry?<br>☐ Is there a picture of the evaporative pan setup?<br>o What is the evaporative pan setup? A typical Class A pan equipment setup is found at http://www.crh.noaa.gov/gid/Local_Information/coop/evapStations/.<br>o Where is the evaporative pan located?<br>o Does the picture show that the evaporative pan and its equipment are protected from animals and vandalism?<br>o Are there pictures from the testing that show the water levels in the pan were kept between 2 and 3 inches below the lip of the pan during the testing period?<br>☐ Are there pictures of the gates, valves, piping, connections or other items used to isolate the lagoon? |
| ☐ | **Seepage testing and site conditions**<br>☐ Was the lagoon filled to its maximum design operational depth prior to testing? For how long?<br>☐ Was a temperature recorder located on site? Describe location.<br>☐ Were temperatures during the course of testing provided to show that no freezing occurred?<br>☐ Were hourly air temperatures recorded?<br>☐ Were wind effects evaluated?<br>☐ Did it freeze during testing? |
| ☐ | **Seepage testing and lagoon isolation**<br>☐ Was each lagoon isolated? How?<br>☐ Did it rain during testing? How was precipitation recorded? Amount? Were precipitation measurements taken in the same time interval as the lagoon elevation changes and evaporative pan measurements?<br>☐ If the liner was exposed, was the liner contribution during the rain event considered? The data need to account for liner contribution during rain events. |
| ☐ | **Seepage testing data**<br>☐ Was there a complete data set of information for each test interval?<br>☐ Were all collected data provided to DEQ in the seepage test report and/or via electronic submission?<br>☐ What was the length of testing? How many days were the seepage testing data collected?<br>☐ Does the data meet the seepage testing metrics as discussed in the procedure? |
| ☐ | **Calculations**<br>☐ Was the DEQ seepage calculation spreadsheet used to calculate seepage?<br>☐ Did the lagoon seepage test results meet the allowable seepage rate based on the inputs used in the DEQ spreadsheet?<br>☐ If the DEQ spreadsheet was not used, were all calculations and a copy of the spreadsheet provided in electronic format? Was the alternative spreadsheet presented and approved prior to testing in the DEQ approved procedure? |