# Subsoil Investigations for Naturally Occurring Protective Layers

**Purpose**

Provide a consistent investigative process and acceptable criteria for conducting subsoil investigations for naturally occurring protective layers

**Relevant Legislation**

*Agricultural Operation Practices Act*
- Standards and Administration Regulation
- Administrative Procedures Regulation

**Related Technical Guidelines**

| | |
|---|---|
| Agdex 096-50 | Reclamation of Groundwater Monitoring Wells |
| Agdex 096-51 | Monitoring Well Construction, Installation and Development |
| Agdex 096-60 | Subsoil Investigation Information for Applicants (Currently *under development*) |
| Agdex 096-61 | Determining Equivalent Protective Layers and Constructed Liners |
| Agdex 096-62 | Subsoil Investigations for Manure Storage Facilities and Manure Collection Areas |

## 1. Introduction

This guideline is for consultants to assess subsoil characteristics of a naturally occurring protective layer at a site for a manure storage facility or a manure collection area. “Facilities” in this guideline refers to both manure storages and manure collection areas.

For the purpose of this guideline, “subsoil investigation” is equivalent to “soils investigation” as found in the Administrative Procedures Regulation of the *Agricultural Operation Practices Act*.

Subsoil investigations must be completed by a member of the Association of Professional Engineers and Geoscientists of Alberta or the Alberta Institute of Agrologists.

Questions about the use of this guideline for specific permit applications should be discussed with an approval officer of the Natural Resources Conservation Board (NRCB).

## 2. Regulatory Requirements

The subsoil investigation will need to determine the:
- hydraulic conductivity of the subsoils,
- depth to the water table, and
- depth to the uppermost groundwater resource.

The hydraulic conductivity and depth requirements for a naturally occurring protective layer, as regulated by Section 9 of the Standards and Administration Regulation, are found in Table 1. These requirements are based on saturated hydraulic conductivity values and thus all tests and methods in this guideline are for saturated conditions.

More information on determining the depth to the water table and the uppermost groundwater resource can be found in Agdex 096-62, “Subsoil Investigations for Manure Storage Facilities and Manure Collection Areas.”

***Table 1.*** *Naturally occurring protective layer depth and hydraulic conductivity requirements*

| Facility Type | Depth (m) | Hydraulic Conductivity (cm/s) |
|---|---|---|
| Liquid manure storage | 10 | not more than 1 X $10^{-6}$ |
| Catch basin | 5 | not more than 1 X $10^{-6}$ |
| Solid manure storage | 2 | not more than 1 X $10^{-6}$ |

## 3. General Requirements

The subsoil investigation must include:

- All test holes completed to an appropriate depth to assess the naturally occurring protective layer for the proposed facility (Figure 1)
- The minimum number of test holes as described in section 4; additional test holes may be required
- Hydraulic conductivity test results of the proposed naturally occurring protective layer required for each test hole, unless section 7 is applied
- Design hydraulic conductivity, including an explanation of how it was determined and how it meets the requirements of the regulations
- Reporting, as described in section 8

## 4. Test Holes

The number, location and depth of test holes, which may include both boreholes and test pits, required to assess subsoils for a naturally occurring protective layer is dictated by subsoil characteristics, proposed facility depth, and depth to the water table. More test holes are required for larger facilities.

**During a subsoil investigation for a naturally occurring protective layer, consultants should consider collecting enough subsoil samples to complete an assessment for a compacted soil liner if it becomes necessary.**

The investigation should ensure characterization of the naturally occurring protective layer extends to a depth that includes construction excavation. Test holes must be advanced to a depth greater than one metre below the bottom of the proposed naturally occurring protective layer to ensure the uppermost groundwater resource is not present.

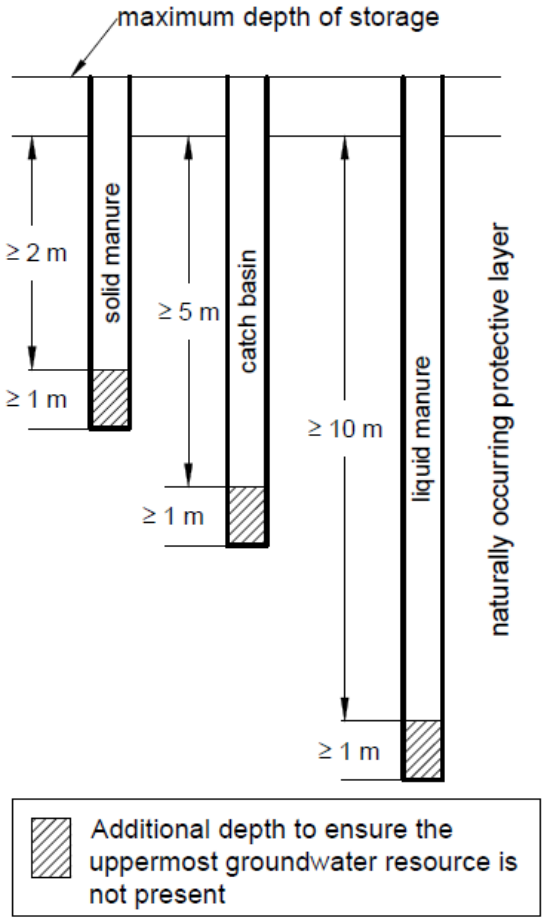


***Figure 1.*** *Minimum test hole depth for naturally occurring protective layers.*

Figures 2 to 5 show minimum test hole placements for various facility types and sizes. Contact the NRCB to discuss whether a variation in the number or location of test holes is warranted when:

- The investigation includes adjacent facility footprints (sharing of test hole results)
- There are changes in topography and/or geologic conditions within the facility footprint
- Existing facilities and infrastructure do not allow for the test hole locations in the figures

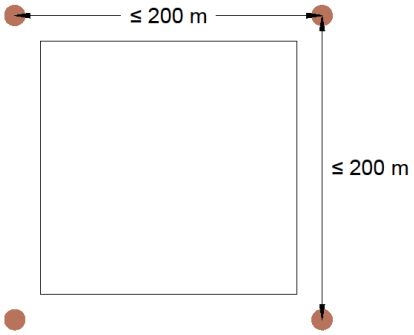


***Figure 2.*** *Suggested test hole locations for* ***small solid*** *manure storages and feedlots (≤ 200 metres in length and width).*

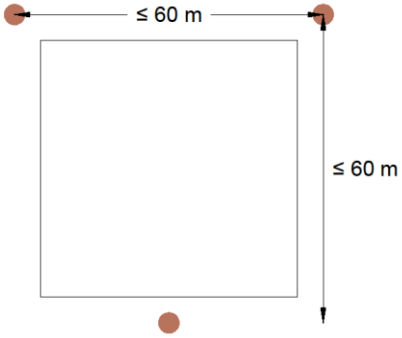


***Figure 3.*** *Suggested test hole locations for* ***small liquid*** *manure storages and catch basins (≤ 60 metres in length and width).*

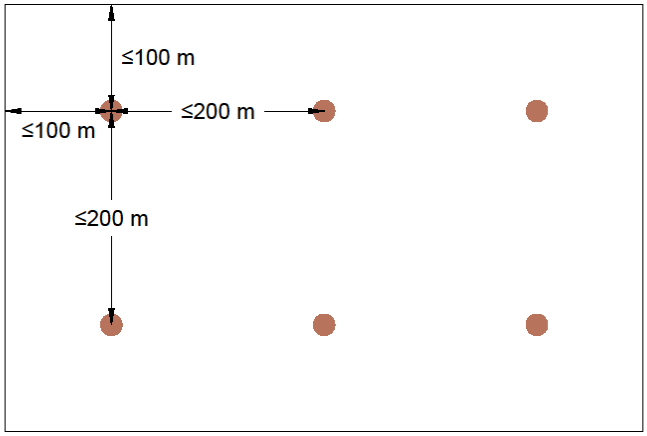


***Figure 4.*** *Suggested test hole locations for* ***large solid*** *manure storages and feedlots (> 200 metres in length or width).*

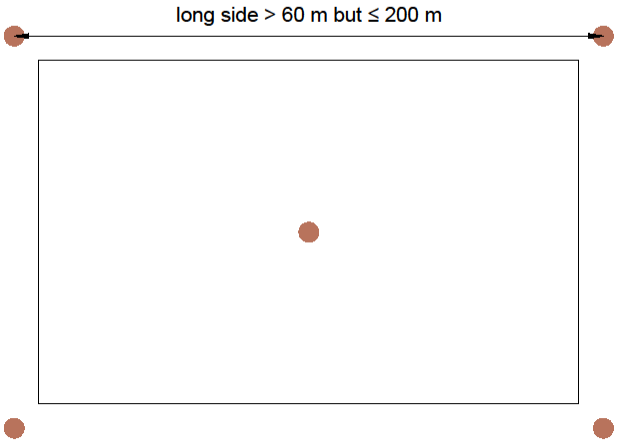


***Figure 5.*** *Suggested test hole locations for* ***large liquid*** *manure storages and catch basins (> 60 metres in length or width).*

## 5. In-Situ Hydraulic Conductivity Testing

Single well response tests, or slug tests, are acceptable methods for determining in-situ hydraulic conductivity for naturally occurring protective layers. Tests must be conducted in properly constructed, installed and developed monitoring wells. For more information see Agdex 096-51, "Monitoring Well Construction, Installation and Development."

In-situ hydraulic conductivity tests must be conducted throughout the proposed naturally occurring protective layer (i.e., the effective well screen length should extend across the entire thickness of the proposed naturally occurring protective layer). A naturally occurring protective layer does not need to be the entire thickness of the subsoil unit.

Groundwater level measurements should be recorded frequently at the beginning of the test and can decrease in frequency over time. Measurements should continue until the well recovers at least 90 per cent, or up to a week, whichever is shorter.

Rising or falling head hydraulic conductivity tests must be performed under fully saturated conditions and test choice should be based on the following:

- Details of well construction
- Resting depth to groundwater
- Elevation and depth of the subsoil material to be tested

Most in-situ hydraulic conductivity test methods will provide horizontal hydraulic conductivity values. The potential effects of significant clay content on vertical and horizontal hydraulic conductivity characteristics should be considered when determining in-situ hydraulic conductivity.

In-situ hydraulic conductivity test results can be compared directly to the regulatory requirements (see Table 1) for naturally occurring protective layers.

**Section 5.2 lists the in-situ hydraulic conductivity tests for determining groundwater resources referenced in section 6.2 of Agdex 096-62, "Subsoil Investigations for Manure Storage Facilities and Manure Collection Areas."**

### 5.1 Unsaturated subsoil conditions

If some or all of the subsoil material to be tested is unsaturated, saturation is required prior to in-situ hydraulic conductivity testing. If required, adding clean, potable water to monitoring wells must occur under the consultant's direction. Water additions should continue for as many days as required to obtain a water level with a consistent high and low point for multiple days. This ensures saturation of the formation to the point that slug test results will be representative of the naturally occurring material. Following saturation, a falling head slug test can be conducted.

***Use of a rising head test after saturation is not appropriate and will not be accepted.***

### 5.2 Hydraulic conductivity test methods

The following in-situ test methods are suitable for measuring the hydraulic conductivity of naturally occurring protective layers. The calculation used to determine hydraulic conductivity must match the hydrogeological conditions present within the facility footprint, which will be either unconfined or confined.

Suitable in-situ test methods for **unconfined** conditions are:

- Bouwer, H. and R.C. Rice, 1976. A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells, Water Resources Research, vol. 12, no. 3, pp. 423-428.
- Hvorslev, M.J., 1951. Time Lag and Soil Permeability in Ground-Water Observations, Bull. No. 36, Waterways Exper. Sta. Corps of Engrs., U.S. Army, Vicksburg, Mississippi, 50 pages.
- ASTM D6391-99, "Standard Test Method for Field Measurement of Hydraulic Conductivity Limits of Porous Materials using Two Stages of Infiltration from a Borehole (Stage 1 – Vertical Hydraulic Conductivity)."

Suitable in-situ test methods for **confined** conditions are:

- Hvorslev, M.J., 1951. Time Lag Soil Permeability in Ground-Water Observations, Bull. No. 36, Waterways Exper. Sta. Corps of Engrs., U.S. Army, Vicksburg, Mississippi, 50 pages.
- Cooper, H.H., J.D. Bredehoeft, and I.S. Popodopalas, 1967. Response of a Finite-Diameter Well to an Instantaneous Charge of Water, Water Resources Research, vol. 3, pp. 236 – 269.

## 6. Laboratory Hydraulic Conductivity Testing

The following laboratory test method is acceptable for determining the hydraulic conductivity of naturally occurring protective layers on undisturbed soil samples (e.g., Shelby tubes):

- ASTM D5084, "Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter"

Laboratory test methods and results on disturbed soil samples are not acceptable for estimating hydraulic conductivity of naturally occurring protective layers.

### 6.1 Modifying laboratory hydraulic conductivity values for field application

Hydraulic conductivity values determined by laboratory methods must be increased by an order of magnitude to estimate field hydraulic conductivity. This accounts for the fact that the laboratory sample only represents a small section of the total depth of a naturally occurring protective layer.

For example, a laboratory hydraulic conductivity value of 1 x $10^{-8}$ cm/s would correspond to an assumed field hydraulic conductivity of 1 x $10^{-7}$ cm/s.

### 6.2 Number of samples tested for hydraulic conductivity

Table 2 shows the minimum number of samples required to assess a naturally occurring protective layer based on the facility type. When more than one sample is required, the sample locations should be evenly distributed throughout the proposed naturally occurring protective layer thickness, see Figure 6.

***Table 2.*** *Number of samples tested for laboratory hydraulic conductivity*

| Facility Type | Minimum number of samples for laboratory hydraulic conductivity |
|---|---|
| Solid storage | 1 sample per test hole |
| Catch basin | 2 samples in a single test hole |
| Liquid storage | 3 samples in a single test hole |

Additionally, the number of required samples for laboratory tests may be varied if an equivalent layer is proposed (Agdex 096-61, "Determining Equivalent Protective Layers and Constructed Liners"). Contact the NRCB to discuss whether a variation in the number of samples for laboratory tests is warranted.

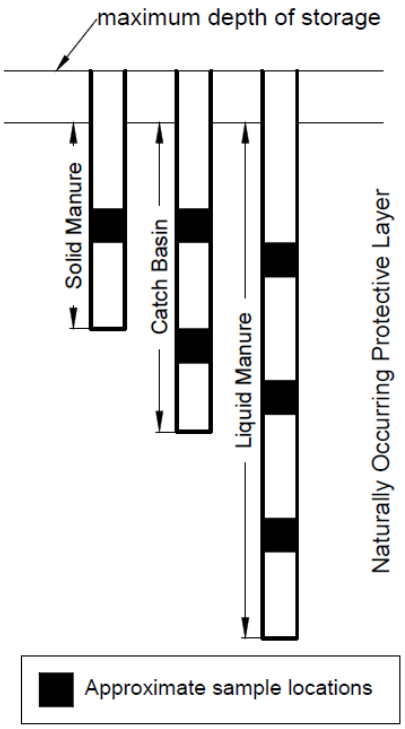


***Figure 6.*** *Sample locations should be evenly distributed throughout the proposed naturally occurring protective layer thickness.*

## 7. Subsoil Consistency Testing (Optional)

Section 7 can be used to reduce the number of hydraulic conductivity tests completed as part of a subsoil investigation. If Section 7 is not applied, the tests described in Section 3 are required for each borehole.

Particle size analysis and hydraulic conductivity on the same subsoil unit provides a relationship between those two results for that test hole.

Testing subsoil consistency across a facility footprint (or part of a facility footprint) requires that at least one test hole is tested for hydraulic conductivity (in-situ or laboratory). Samples taken for particle size analysis must be collected from the same subsoil used for hydraulic conductivity testing. For determining consistency, samples for particle size analysis and hydraulic conductivity should be taken as close together as possible (Figures 7 to 9).

Subsoils from different test holes with particle size analysis results that meet the consistency test can generally be considered to have a similar hydraulic conductivity without further hydraulic conductivity testing.

To be considered consistent with a subsoil sample tested for hydraulic conductivity, other subsoil samples must:

- Be taken from a similar subsoil unit
- Be at a similar depth
- Have a clay content ≥ 20%
- Fall within the same texture class (figure 10) as the sample tested for hydraulic conductivity

Alternatively, subsoil samples that fall within an adjacent texture class (Figure 10) must:

- Be taken from a similar subsoil unit
- Be at a similar depth
- Have a clay content ≥ 20%
- Have a clay content within ±3% of the clay content in the hydraulic conductivity subsoil sample

***If the naturally occurring protective layer consists of bedrock, particle size analysis cannot be used to determine subsoil consistency.***

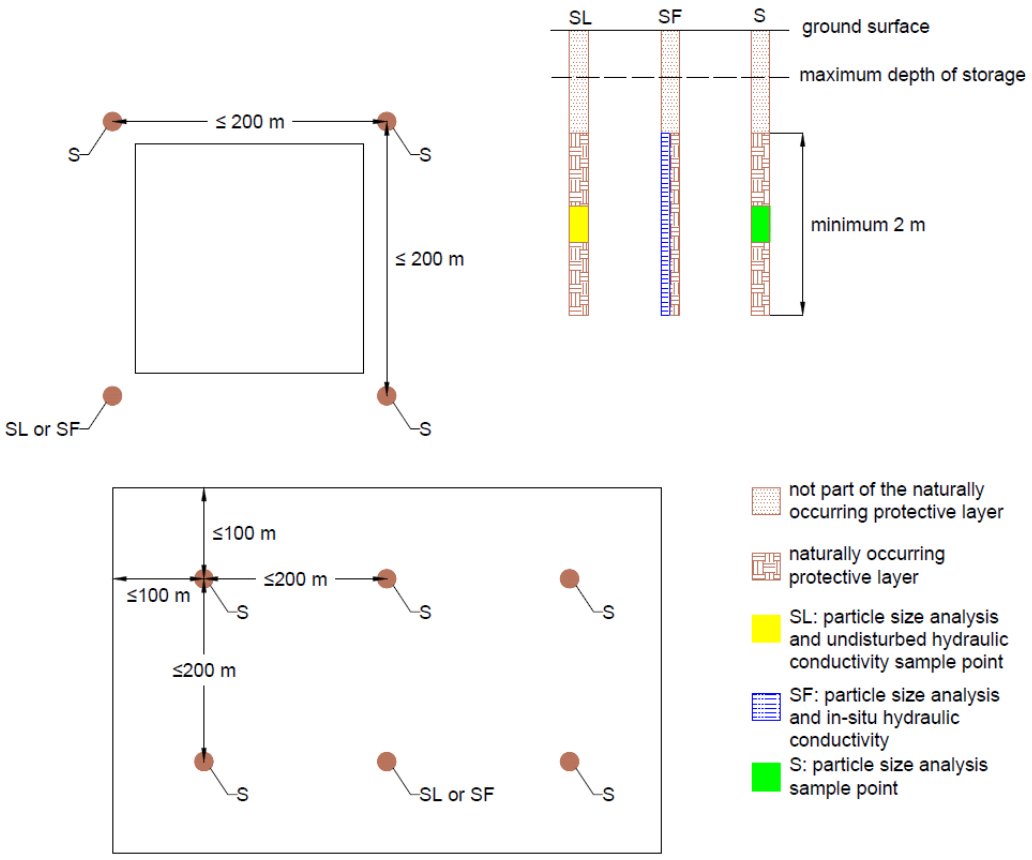


***Figure 7.*** *Solid manure storage facility approximate sample locations and sample details.*

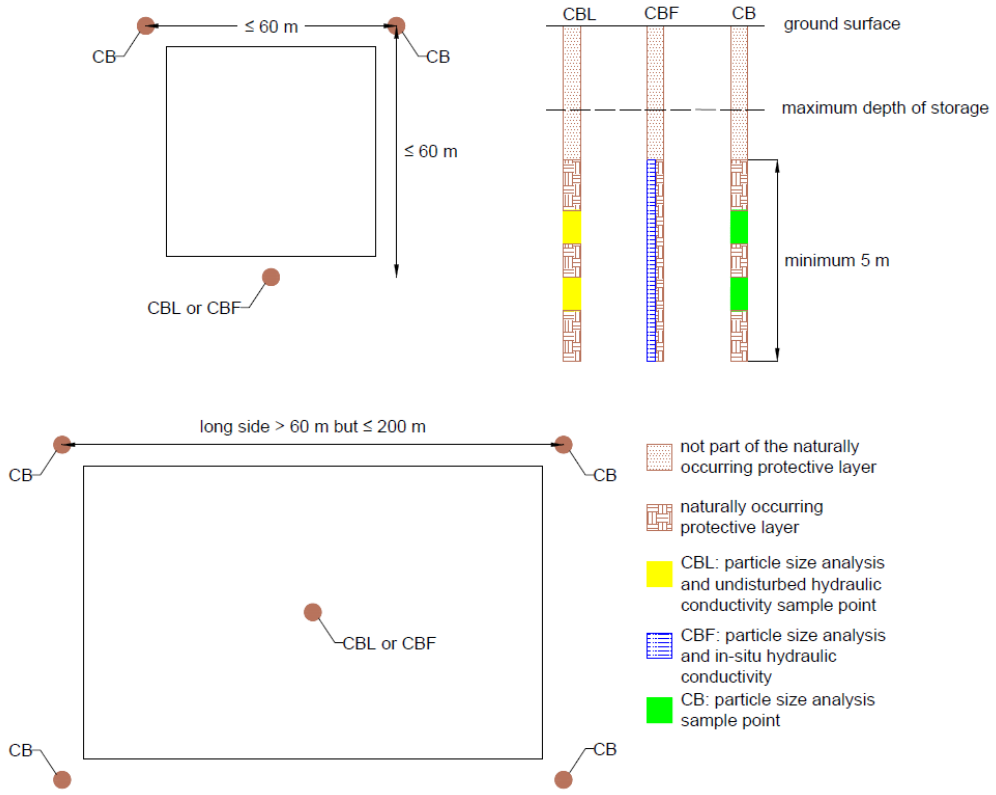


***Figure 8.*** *Catch basin approximate sample locations and sample details.*

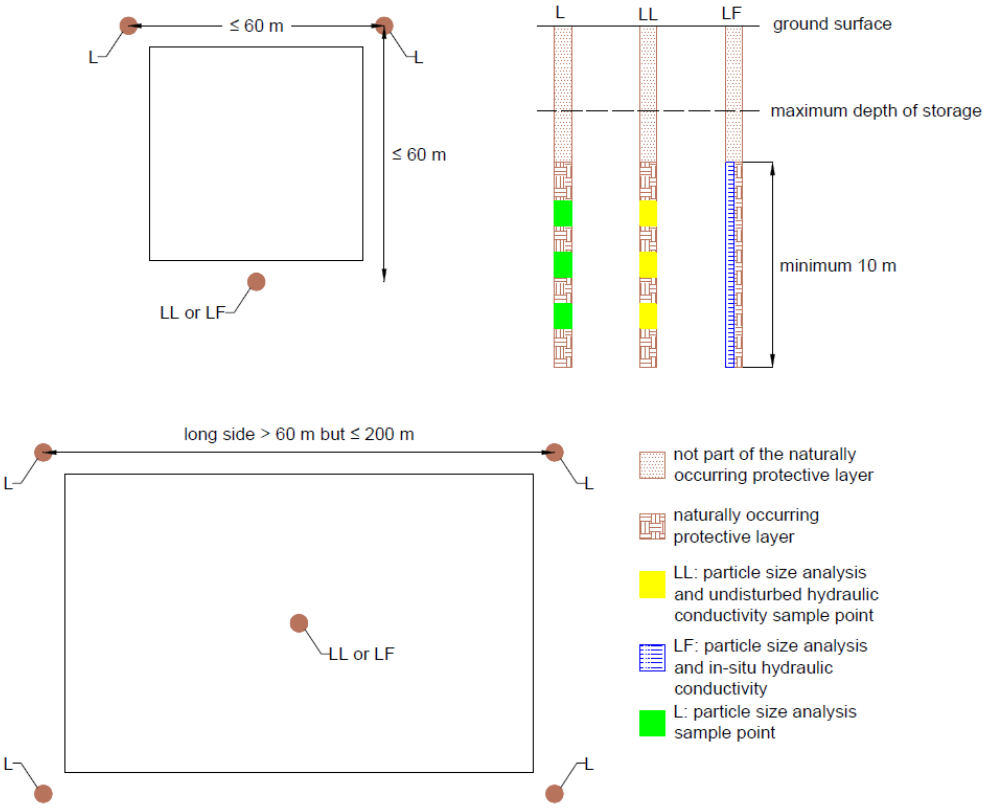


***Figure 9.*** *Liquid manure storage facility approximate sample locations and sample details.*

## 8. Reporting

The subsoil investigation report should include all relevant information used to determine the water table and the uppermost groundwater resource. More information on this reporting requirement can be found in Agdex 096-62, "Subsoil Investigations for Manure Storage Facilities and Manure Collection Areas."

The subsoil investigation report should also include the naturally occurring protective layer design for the proposed manure facility containing the following:

- Design hydraulic conductivity
- All hydraulic conductivity results:
  - In-situ hydraulic conductivity results for the naturally occurring protective layer, including:
    - methodology
    - Water level measurements over time
    - Formulas used
    - Sample or example calculations
    - Any graph and tables produced
  - Laboratory hydraulic conductivity results
- Subsoil consistency test results (e.g., particle size analysis), if any
- Recommendations
- Conclusions

## 9. Documentation

Reporting and documentation requirements are specified within the permit conditions. Approval officers use their discretion to determine these requirements for each individual file.

The NRCB may require documentation that the:

- boreholes drilled, within the footprint of a liquid manure storage facility or catch basin, be properly reclaimed as outlined in Agdex 096-50, "Reclamation of Groundwater Monitoring Wells."
- test pits, which are completed within the footprint of a liquid manure storage facility or a catch basin, be backfilled to similar pre-test conditions.

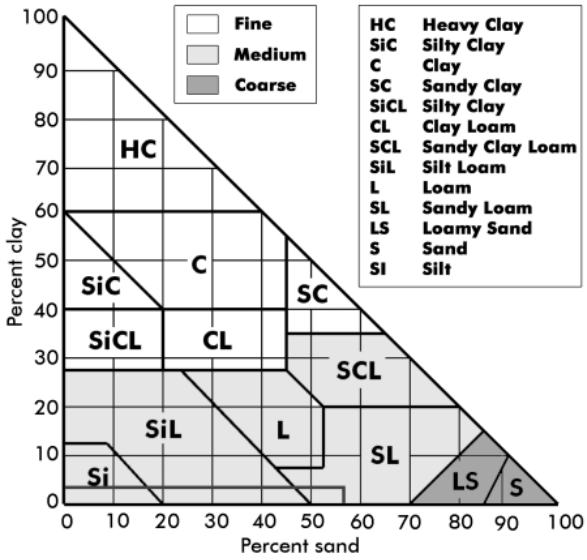


***Figure 10.*** *Canadian soil textural triangle.*[1]

## 10. Construction and Other Considerations

Construction should be completed according to the plan approved by the NRCB.

Subsoil conditions encountered during construction may unexpectedly be different than the naturally occurring protective layer that was assessed by the consultant. Suggested follow up (and supporting rationale) for unexpected subsoil situations are shown in Table 3.

Consider the following items when constructing a facility with a naturally occurring protective layer:

- Surface packing or proof rolling of formed and sloped excavation reduces fissures created by construction equipment and provides a protective "top" to the naturally occurring protective layer.
- Monitoring wells used as part of the investigation, but no longer needed, must be properly reclaimed as outlined in Agdex 096-50, "Reclamation of Groundwater Monitoring Wells."

[1]Watson, K. and D. Pennock 2016. Section 3. Soil Profile Description. From: D. Pennock, K. Watson, and P. Sanborn. 2016. Field Handbook for the Soils of Western Canada. Pedology Subcommittee, Canadian Society of Soil Science.

***Table 3.*** *Unexpected subsoil situations and suggested follow up*

| Unexpected subsoil | Rationale | Suggested follow up |
|---|---|---|
| **Small area*** of permeable material | Discovery of this small area during the facility investigation **would not** significantly change the location or design of the facility submitted by the consultant. This can commonly occur in subsoils associated with glacial till. | Remove the unexpected subsoil, replace with subsoil similar in texture to that tested and approved to be the naturally occurring protective layer, and pack similar to the surrounding subsoil unit. Report mitigative actions undertaken during construction on small permeable areas to the NRCB after construction is complete. |
| **Large area*** of permeable material | Discovery of this large area during the facility investigation **would** have significantly changed the location or design of the proposed facility had that information been discovered by the consultant. | Stop construction and notify the consultant and the NRCB. |

*If not sure whether an area is small or large, contact the NRCB.

## For more information

Contact your nearest NRCB field office or Alberta government staff (dial 310-0000 to be connected toll-free)

**Government of Alberta**
**alberta.ca/manure-management-guidelines-and-legislation**
Phone 310-FARM (3276)
Publications 780-427-0391 or open.alberta.ca
Email 310FARM@gov.ab.ca

**Natural Resources Conservation Board**
**nrcb.ca**
Morinville 780-939-1212
Red Deer 403-340-5241
Lethbridge 403-381-5166
Email info@nrcb.ca

This guideline was developed by the Technical Advisory Group, a partnership among the Government of Alberta, the Natural Resources Conservation Board (NRCB) and the agriculture industry.