Guidance Document for the Design, Siting and Operation of Earth-Lined Slurry/Effluent Stores

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1 Introduction

1.1 Introduction

This document outlines the principles and approach to the planning, assessment, design, construction and operation and maintenance of earth-lined slurry/effluent stores (ELSs) as detailed in Department of Agriculture and Food Specification S.131: Minimum Specification for Earth-Lined Slurry/Effluent Stores and Ancillary Works (S.131). It is designed to give information and guidance concerning all stages of ELS sizing, assessment, design and construction. Each section below outlines the scope and methodology of each stage and more detailed information is given in the relevant chapters. Agricultural activities and processes give rise to a range of liquid sources including animal slurries, silage effluent, dairy washings and dirty water. The safe management of these sources is an objective for all farmers. Sufficient storage capacity for animal slurries shall be provided to enable safe management of slurries during closed periods and when slurry cannot be spread due to poor weather conditions. Conventional slurry storage infrastructure requires significant investment to make up the slurry capacity shortfall. ELSs are an internationally recognised form of storage for varying types of effluents including those of industrial and agricultural origin and can be used to successfully store animal slurry. It is important however, that the objective shall always be good environmental management of the slurry and effluent production on a farm. Before evaluating the capacity requirements for any store, the client shall make every effort to make their farming operation as efficient as possible by reducing the quantities of liquids requiring storage. Diverting as much clean water as possible away from dirty water streams is an example of how the storage capacity requirement may be reduced.

1.2 What is an earth-lined slurry/effluent store?

ELSs are subsoil-based structures which are used as a method of slurry storage. They may be used to store neat, dilute or separated slurries and the storage and settlement of dirty water. ELSs are typically < 20 m wide, between 20 to 50 m in length and 2.5 to 3.75 m deep. The shape of an ELS is often governed by the location and the site characteristics. The tank is formed by excavating soil and subsoil to formation level and using the excavated or imported material to form surrounding banks and subsoil liner. A subsoil liner is installed to protect the surrounding environment. The size of the store must take into account the quantity of liquid which needs to be stored, precipitation falling on the store, evaporation from the store and the freeboard required.

1.3 ELS role in the storage of animal slurry and effluent

By increasing the available slurry storage capacity on Irish farms, the need for inappropriate landspreading is reduced, because farmers will have the capacity to await more favourable landspreading times when the risk of overland flow is reduced and the crop can gain maximum benefit from the nutrients contained in the slurry. By maximising the utilisation of slurry nutrients, the farmers will reduce their requirement for chemical fertilisers. Efficient recycling of nutrients within the environment is encouraged. An ELS allows farmers to increase their slurry storage capacities and consequently improve their farming practices.

1.4 Advantages and disadvantages of ELSs

Advantages:

- a sustainable design using local materials (where suitable)
- slurry/effluent storage capacity on farms can be greatly increased
- adaptable to the needs of the farmer
- low cost maintenance
- does not pose a significant threat to the environment when designed and constructed properly
- good landscape fit, particularly on gently sloping sites
- toxic gases are not emitted into confined spaces therefore there is a reduced risk to humans and animals

Disadvantages:

- requirement for competent site analysis and characterisation skills
- requirement for construction supervisor
- there are sites which will be unsuitable for construction of an ELS
- relatively high maintenance time
- there is an inherent risk in all slurry/effluent stores of drowning by humans and animals.

1.5 The need for a guidance document for ELSs

The main purpose of this guidance document is to provide comprehensive guidance for the design and construction of an ELS. While this document provides the design guidance, a separate specification document (S131) is available from the Department of Agriculture and Food for the construction of ELSs. Farmers are reminded that they have a duty under the Safety, Health and Welfare at Work Act, 2005 to provide a safe working environment on the farm, including farm buildings, for all people who may work or enter that farm. There is a further duty to ensure that any contractor, or person hired to do building work, provides and/or works in a safe environment during construction. The steps outlined in this guidance document, from the initial decision on the appropriateness of an ELS to the final installation process, involve a variety of choices at each stage. The choices made will reflect the particular approach of the designer for particular locations, but once the steps outlined are followed, the robustness and sustainability of the ELS is upheld. This document is targeted primarily at Local Authority planners, site assessors, construction supervisors, agricultural consultants and farm advisors. The guidance document is available on the website of the Department of Agriculture and Food (www.agriculture.gov.ie).

1.6 Overview of guidance document

Chapter 2: Site characterisation: general overview

Chapter 2 gives a general outline of the methodology which is employed when carrying out a site characterisation, which includes a risk based assessment, general site suitability requirements and some minimum design requirements.

Chapter 3: Undertaking the site assessment

This chapter gives guidance on how to carry out a specific assessment of a site being considered for an ELS by collating and analysing data pertaining to site location, farming practices, soil and subsoil type, groundwater protection requirements and general planning information.

Chapter 4: Regulatory procedure

Chapter 4 summarises relevant national legislation and planning regulations pertaining to obtaining planning permission for an ELS.

Chapter 5: Earth-lined slurry/effluent store design

This chapter details the design requirements necessary to ensure that the ELS is constructed to best meet the needs of the farmer with minimum impact on the environment. Design details include tank volume, length, width, depth of slurry, precipitation and evaporation requirements, freeboard, inner and outer bank slopes, minimum bank width, overall tank footprint and requirements for subsoil liner which is based on the recommendations of the site assessment.

Chapter 6: Earth-lined slurry/effluent store construction

Chapter 6 details the steps required for construction of an ELS. These include site preparation, excavation, embankment and subsoil liner construction, filling, agitation and emptying points, fencing, tractor access and external bank finish.

Chapter 7: Operation and maintenance

Guidance on routine maintenance checks is given including embankment inspection and maintenance of freeboard levels.

Chapter 8: Health and safety

This section gives guidance on possible health and safety issues which may arise including information on fencing, gates, access points and appropriate signage.

Appendices

Appendix 1 gives a brief introduction to the groundwater protection response matrix for ELSs and describes how it is utilised during site assessment and characterisation. Appendix 2 contains guidance on classifying a subsoil using BS 5930:1999. Appendix 3 tabulates excerpts from documents which assist the designer in calculating the required slurry storage capacity of the proposed ELS. Appendix 4 contains a full copy of the site characterisation form and Appendix 5 gives a worked example of how the assessor and designer utilise the specification and guidance document to investigate a proposed site, give recommendations on the site suitability and design an ELS. Appendix 6 contains the references used in the preparation of this document.

2 Site characterisation: general overview

2.1 Introduction

Earth-lined slurry/effluent stores (ELSs) are a specific approach to the storage of liquid animal manures and soiled water on farms. ELSs are a way of increasing the slurry storage capacity on farms that is not excessively expensive, but does not pose a significant threat to the environment. The decision to use an ELS will be made on an integrated evaluation of technological, environmental, economic, and logistical criteria, and personal preference on the part of the farmer, but the suitability or otherwise of the site will be of key importance in the decision making process. It is therefore important that a systematic and logical approach is followed to allow the suitability of the site to be assessed as early as possible in the decision process, so that time and expense is not wasted unnecessarily. Any development of an ELS will require planning permission. The Planning Authority will need to be provided with adequate information in a standard, easily understood and logical format to assess the proposed development. Chapters, 2 & 3 provide guidance on how to assess site suitability with the objective of collecting sufficient information to:

- determine if the ELS can be developed on the site
- demonstrate that the construction of an ELS will not create a negative impact on the environment
- to provide adequate data to enable the optimal design to be achieved.

The approach is termed site characterisation. Site characterisation combines various assessments including desk study, visual assessment and site tests to satisfy the objectives.

2.2 Objectives of the site assessment

There are certain advantages associated with ELSs over other systems. However, it is important that the raw materials to optimise these advantages are available on the site, and it is important therefore, that the site assessment is targeted, rigorous and comprehensive to ensure all areas are properly assessed and that high risk areas are avoided.

Objective	***Implication for Site Characterisation***
Protecting the environment	Identifying the receptors at risk, locating the ELS in suitable areas and applying adequate set back distances
Providing adequate storage	Ensuring that the nature and extent of the hazard is fully understood
Not relying solely on engineering measures to isolate the system from the environment	Ensuring that sufficient information is gathered to enable the risk to be controlled by natural protection, enhanced by engineering measures
Protection of groundwater	Assessing whether in-situ material can be used to build the ELS. Ensuring that the nature and variation of subsoil properties are fully understood

Table 2-1 Objectives and implications of site assessment

2.3 Risk based approach

When we interact with the environment, which by its nature can be variable and heterogeneous, we cannot rely on 100% protection at all times. This means we need to rely on risk minimisation. The concept of risk is therefore important in the overall concept of site assessment and design. Risk based assessment provides a framework for evaluating and managing pressures and impact on identified receptors. The ***Hazard-Pathway-Receptor*** model is the recommended approach. Risk can be defined as the likelihood or expected frequency of a specified adverse consequence. Applied to ELSs it expresses the likelihood of damage or contamination arising from the construction or operation of an ELS (hazard). A hazard presents a risk when it is likely to affect something of value such as groundwater or surface water (receptor). An impact can only occur if a linkage (pathway) is established between the hazard and the receptor. Protection, like risk, is a relative concept in the sense that there is an implied degree of protection (absolute protection is not possible). An increasing level of protection is equivalent to reducing the risk of damage to the receptor. Moreover, choosing the appropriate level of protection necessarily involves placing a relative value on the protected entity.

2.4 Key environmental receptors

In the context of an ELS the key environmental receptors include:

Receptor	***Issues***
Groundwater	Unless the store is properly constructed, there may be significant percolation to the aquifer, which will have a resource value in keeping with national groundwater protection criteria. In addition, nearby drinking water supplies need consideration and protection
Surface water	The risk of bank failure, resulting in transport of contaminated material into a watercourse water will need to be assessed
Soil/subsoil	The subsoil will form the sealing element of the ELS and will provide the protection to the underlying aquifer. The subsoil also has a role in attenuating pollutants
Flora and fauna	Care will need to be taken to ensure that protected areas are not impacted
Air	Minor odours will be associated with the ELS, but shall not significantly increase the odours over and above those already associated with the farmyard.
Cultural heritage	The desk study shall identify any known heritage sites. In general ELSs shall not be built within the curtilage of heritage sites. Care during construction must be exercised to eliminate damage to possible undiscovered sites
Human	The potential impact on the farm enterprise and neighbours needs to be assessed.

Table 2-2 Key environmental receptors and issues

2.5 Hazard characterisation

2.5.1 General

The principal contaminants, which constitute the hazard, are related to animal wastes (slurry), but may also include some farmyard dirty water, wash water (principally dairy washings) and silage effluent. Microbial pathogens, ammonia and nitrate pose the greatest threat to groundwater. In addition, phosphate may impact on surface water.

2.5.2 *Typical characteristics of effluent*

It has been noted that the volumes of effluent that are generated can be very variable. Similarly the chemical characteristics can also be variable. Typical characteristics of slurry in uncovered stores are; N: 3.9 $kg.m^{-3}$ and P: 0.6 kg/m^{-3} (DAF). Typical BOD values of slurry can be up to or over 20000 $mg.L^{-1}$. Because there will be some percolation from the store to the ground, the ground and associated groundwater body will be the receptor.

Research was conducted at Teagasc Grange Research Centre to evaluate the effectiveness of a compacted subsoil liner at protecting groundwater (Scully et al. 2004). A pilot-scale ELS was constructed to enable sampling of water directly beneath the compacted subsoil liner. The quality of the water sampled from directly beneath a 0.5 m thick compacted subsoil liner is presented in Table 2.3.

Parameter	***Concentrations ($mg.L^{-1}$)***		
	Mean	Standard deviation	Median
BOD	3.34	1.53	3.0
TON $mg.L^{-1}$	4.58	2.01	5.21
Ammonia $mg.L^{-1}$ N	0.127	0.048	0.1
Nitrate $mg.L^{-1}$ N	4.58	2.02	5.2
Phosphorus $mg.L^{-1}$	0.055	0.198	0.015
Chloride $mg.L^{-1}$	37.15	14.33	34.2
Faecal coliforms / 100 mls	none detected during sampling period		

Table 2-3 Water quality of sample collected directly beneath compacted subsoil liner at pilot-scale ELS at Teagasc Grange Research Centre (Scully, 2005)

Sealing of the pilot-scale ELS base to a permeability of 1 $x10^{-9}$ $m.s^{-1}$ was achieved. Under a typical ELS (3.0m depth of slurry over 1.5 m compacted subsoil liner when full), maximum velocity to groundwater could be expected to be 0.00026 $m^3.m^{-2}.d^{-1}$ using Darcy's Law;

$$v = ki$$

where: v= velocity ($m.s^{-1}$)
k = coefficient of permeability ($m.s^{-1}$)
i= hydraulic gradient.

Therefore for a 1000 m^2 ELS when full, the daily flow rate would be 0.26 $m^3.d^{-1}$.

2.6 Site suitability (general requirements)

There are a number of pre-requisites, which must be satisfied before embarking on an assessment of the suitability of a site for the construction of an ELS. These include:

2.6.1 Site restrictions

There are a number of restrictions, which shall be satisfied before embarking on the construction of an ELS subject to Local Authority planning requirements. A proposed ELS shall not be considered for:

- sites within 60 m of any well or spring used for potable water
- sites within either:
    - (a) the inner protection zone of public water drinking supply source (>10m^3.d^{-1} or PE >50) (groundwater) where the vulnerability rating is classified as extreme, or
    - (b) where an inner protection zone has not been identified and the vulnerability rating has been classed as extreme, within 300 m up gradient of the abstraction point
- sites where the minimum design requirements (Clause A.4 of S.131) cannot be achieved
- sites within 10 m of an open watercourse where slurry effluent can enter
- sites within 50 m of a lake
- sites within 15 m of a karst feature
- sites underlain directly by sand/gravel in vertical hydraulic continuity with the main watertable
- sites underlain by peat or other unstable material that is impracticable to remove
- sites liable to flooding
- sites where construction of the ELS will damage or destroy a site of potential natural or cultural heritage value
- sites that are steeply sloping (greater than 1:5).

2.6.2 Minimum design requirements

- all ELS's shall be underlain by at least 1.5 m of moderate or low permeability subsoil, with the upper 0.5 m having a permeability of less than 1 x 10^{-9} m.s^{-1}
- where a regionally important aquifer is present the total thickness shall be at least 1.5 m, with the upper 1.0 m having a permeability of less than 1 x 10^{-9} m.s^{-1}
- where the required permeability in the upper 0.5 m or 1.0 m has to be enhanced this shall be achieved by the construction of a compacted liner as described in Clause C.6 of the technical specification (S.131)
- in cases where the site assessment indicates that the in-situ subsoil has a clay content greater than 18%, is impervious (equivalent to a natural permeability of 1 x 10^{-9} m.s^{-1}), free from preferential flow paths (e.g. rootlets, worm burrows, or cracks) and that the required depth of subsoil (1.5 m minimum) is present, then the excavated portion of the tank will require a 150 mm layer of compacted subsoil (4 passes) and plastering with remoulded subsoil.

3 <u>*Undertaking the site assessment*</u>

3.1 Introduction

The purpose of site assessment is to determine the suitability of the site for the construction of an earth-lined slurry/effluent store (ELS). This chapter details an approach for completing the site assessment. The site assessment provides the basis for the ELS design and the data collected will be used to optimise the design and construction of the proposed ELS. A site assessment form for the collation of data is given in the technical specification for ELSs (S131). This shall be completed and will act as a check list, and aid in the decision making process. The text below follows the layout of this site assessment form, and the form (Appendix 4) should be referred to in combination with the text below.

3.2 Approach to site assessment

The following key steps must be undertaken:

- collation of background information
- visual assessment
- site tests
- decision process and preparation of recommendations.

3.3 Collation of supporting information

3.3.1 Preliminary consultation

The purpose of the preliminary consultation is to:

- establish the current slurry and dirty water management practice
- establish in general terms, what will be stored in the ELS
- provide the farmer with some general facts on the ELS
- establish the motivating factors for the project proposer/farmer wishing to build an ELS.

A good understanding of the issue can be gleaned in a telephone conversation or preliminary meeting with the farmer or his/her adviser. In return useful information can be provided to the farmer on budget project costs and other logistical items. The decision to consider building an ELS usually originates with the farmer. He/she may involve an adviser in the decision and procurement process. The farmer may have one or more reasons for considering the use of an ELS, and these may include:

- insufficient existing storage
- improved environmental performance
- relative cost/benefit advantages when compared to other alternatives.

The nature of the material that will enter the tank needs to be established in broad terms at this stage. When assessing the slurry storage capacity requirements of the farmer, a number of logical steps must be followed to ensure that volumes are accurately assessed. Information shall be sought concerning the number of animals producing slurry on the farm. Using this information, the amount of slurry produced on the farm may be calculated by referring to the most up to date information on slurry production rates (Appendix 3). Other effluent volumes (e.g. dairy washings, farm yard dirty water, silage effluent etc.) may also be assessed. By examining the existing slurry storage capacity on the farm and knowing the minimum storage period required by regulatory bodies, a good approximation of the slurry storage capacity of the proposed ELS can be made. It is important at this stage that the store be sized to take account of any shortfall in slurry storage capacity (this may be discussed with the farmer/advisor). The broad design sizing (see Chapter 5) can be discussed at this stage, to give the farmer an indication of the approximate size of the tank and to ascertain if he/she is willing to provide sufficient space to construct the tank, and if the ground and topography can lend itself to ELS construction. The name, address and contact details of the farmer shall be confirmed and some general items in the form can be filled out at this time.

3.3.2 Collation of relevant environmental data

(i) *General*

The purposes of this section are to:

- obtain information relevant to the site
- identify targets at risk
- establish if there are site restrictions
- allow the ranking of sites if a number of possible sites are being considered.

A desk study involves the assessment of available data pertaining to the site and adjoining area that may determine whether the site has any restrictions to the development of an ELS. The following information will need to be collated and the form completed as necessary.

(ii) *Topography*

Base maps can be purchased from the Ordnance Survey of Ireland, or from regional map shops. A set of maps suitable for planning applications, termed a planning pack is the most suitable way to buy the maps and these can be used later for the preparation of a planning application. The relevant Discovery series 1:50,000 scale map will establish the regional topographical context, showing relative slopes, surface water features and other relevant topographical features. The grid reference for the site shall be determined, and can be easily computed from the Discovery map. The best available base map information is at scales of 1:2,500 and 1:10,000. These maps provide useful information on the immediate topography and may identify potential sites of natural or cultural heritage.

(iii) *Surface water*

The location of the nearest surface waters, their distance from the proposed site and where relevant the designation (under national regulations) shall be established.

(iv) *Geological and hydrogeological*

The existing source of water on the farm shall be established, i.e. whether mains, private, or group scheme. The relevant geological and hydrogeological information for the site shall be compiled. The Geological Survey of Ireland (GSI) is the principal source of this information (www.gsi.ie*)*. This website lists available groundwater protection schemes. The GSI produces maps of groundwater resources (aquifers) and vulnerability to contamination (groundwater vulnerability). These are combined to produce a map of groundwater protection zones. In general this information is available from the website, but the relevant contact details are: The Groundwater Section, Geological Survey of Ireland, Beggars Bush, Dublin 4. A national aquifer map is available on the GSI website, and it is possible to zoom in to the area in question and print the relevant excerpt if required.

Note: If a complete groundwater vulnerability map (showing extreme, high, moderate and low vulnerability areas) has not been produced by the GSI, maps of extremely vulnerable areas, created by the Water Framework Directive River Basin District (WFD RBD) consultants, will be available on the GSI website. General soil and subsoil maps are available from Teagasc. Existing data, available from the GSI includes location of outcropping bedrock and karst features and existing depth to bedrock data from their well databases. From this, areas of shallow subsoils (rock within 1.0 m of surface) can be delineated. This can then be used in the desk study. Where information from the GSI well and karst databases is used in a desk study, the townland in which the feature is located (or more specific location if available) shall be highlighted on a map. The data, when compiled shall be compared to the groundwater protection response matrix in Appendix A to establish the preliminary groundwater protection response for the proposed development.

Flora, fauna and cultural heritage

The relevant Local Authority will have a list of designated NHA's, candidate SAC's and an inventory of protected structures, where this is relevant. If more detail is required government bodies such as the Department of Environment, Heritage and Local Government (DEHLG) and the Office of Public Works (OPW), can be contacted to discuss particular areas. If areas are identified, the extent of the restricted area shall be plotted on a map and a brief description provided in the form.

(vi) ***Drainage***

The drainage patterns of the area being examined are critical, and field drainage maps for the particular area shall be sought from the farmer or their advisor, and general information on the density of drainage in the area, can be determined from the topographical maps. Reference to topographical maps produced prior to the 1950's will indicate previously wet areas that may have since been drained.

(vii) ***Public utilities***

The Local Authority shall be consulted with regard to the location of public water supplies and water mains in the area. Locations of gas lines, electricity cables, and communications networks need to be established in consultation with the relevant utilities. The relevant contact numbers for each utility can be found in the phone book. The status of these shall be assessed at this stage, and the need for further investigation highlighted if necessary.

(viii) ***General planning***

The county development plan shall be consulted to establish if there are any restrictions to developments of this sort. This will be available for consultation at the Local Authority offices. The development plan may indicate set back distances that have been decided unilaterally by the Local Authority.

3.3.3 Interpreting the results of the background information

- having reviewed the topographical maps and identified surface water features, possible topographical constraints, and the presence of any mapped areas of heritage you will have discovered and collated any/all information relating to surface water and heritage from the relevant sources

- having collated and examined this information, potential constraints such as significant archaeological, natural heritage and/or historical features within the proposed site may be highlighted. To avoid accidental damage, a trial hole assessment shall not be undertaken in areas which are at or adjacent to significant sites (e.g. SAC's, NHA's)
- the geological information collated will have indicated the potential of encountering karst or high resource value aquifers. The subsoils information collated from subsoil maps, permeability maps, vulnerability maps and other subsoil information sources will have highlighted the possibility of encountering gravel or potentially low permeability material
- once the aquifer and vulnerability classes are established, reference to the groundwater protection matrix (Appendix 1) will allow determination of the appropriate response and the requirements associated with that response. Areas classed as having a 'low' vulnerability are likely to be underlain by low permeability subsoil. The on-site assessment will later confirm or modify such responses
- you will have established the prevailing climatic data, and established any constraints relating to land drainage, utilities, and planning constraints
- any information on satisfactory or unsatisfactory local experience with ELSs can be incorporated at this time to complete the desk study assessment.

By this stage you may be in a position to eliminate sites that present insurmountable constraints.

3.4 Visual assessment

The purpose of the visual assessment is to:

- verify desk study findings
- make an on-site assessment of the hazard
- evaluate the sensitivity of the identified receptors
- finalise the selection of the preferred location.

3.4.1 On-site hazard evaluation

Photographs shall be taken on the site, to record the general layout and structures, and various features of interest. It is important that the farmer is present during this process to discuss the various changes in farm activities that occur through the year.

3.4.2 Visual assessment of receptors

(i) *Topography and landscape fit*

A survey which will incorporate relevant site levels, minimum distances etc. shall be undertaken to survey the proposed ELS site. The survey information will be used principally in the design process, to make optimum use of topography and minimise earth works cost. The topographical survey will also allow the production of sections through the site, which will aid construction planning and costing.

The landscape position reflects the location of the site in the landscape (e.g. crest of hill, valley, slope of hill) and ideally the site shall be down slope of the farmyard area to allow gravity flow of slurry to the ELS. If it is not it will be necessary to pump or haul the slurry/soiled waters to the store. A general overview of landuse, density of dwellings, surface water ponding, waterbodies, drainage, vegetation, and condition of the ground shall be made, and the relative distances of potential receptors from the ELS established.

(ii) ***Cultural heritage***

Using the information from the desk study, a visual assessment of the site shall be undertaken and the potential risk assessed. If the desk study had identified any protected sites nearby, then the assessment will need to be more thorough. Photographs shall be taken for reference.

(iii) ***Human***

Location of dwellings or other places of collection such as nearby schools, churches, hospitals, etc. shall be established and their distance from the ELS determined. Overhead wires, poles and any other utilities shall be marked on drawings.

(iv) ***Flora and fauna***

Using the information from the desk study, a visual assessment of the site shall be undertaken and the potential risk assessed. The vegetation indicators shall be described and photographed. Trees that may potentially be close to the ELS shall be marked on drawings.

(v) ***Surface water***

The density of surface water features shall be noted as this will give an indication of the relative permeability of the ground. The characteristics of the nearest watercourse shall be described. Other surface water features such as ponding, lakes, beaches, natural wetlands, streams and drainage ditches shall be identified.

(vi) ***Drainage systems***

Sites that may once have been wet will require special attention, because of the possibility that existing drainage pipes may be in place, which could result in short-circuiting of the system. This shall be evaluated as part of the site assessment.

(vii) ***Groundwater***

Existing domestic and farm wells within 100 m and public water supplies within 300 m of the proposed site shall be identified and their distance and location in terms of groundwater flow direction estimated. Water table levels may possibly be determined as part of the trial hole programme. Baseline groundwater quality data shall be collected at this time if considered appropriate.

(viii) ***Climate***

The prevailing wind direction across the proposed ELS shall be identified, and the sensitivity of any receptors downwind identified. Any localised rainfall conditions shall be particularly noted.

(ix) ***Soil and subsoils***

Any areas of outcropping rock shall be identified and examined. Road cuttings and any open excavations in the vicinity of the site shall be examined, to provide information on the subsoil profile. Similarly, the shape and nature of banks in watercourses can provide useful insights to the ground conditions.

3.4.3 Interpreting the results of the visual assessment

The minimum set back distances that shall be referenced in the visual assessment are set out in Section 2.6.1. If any of the requirements cannot be met then the ELS cannot be developed on the site. The nature of the hazard should be fully understood at this stage. A reasonable understanding of the geological and hydrogeological setting, will have been established, and will be verified as part of the trial hole. Any constraints imposed by the presence of natural or cultural heritage features will be understood, and the potential of encountering drainage systems will have been evaluated. The influence of slopes on the stability of banks, and surface water run-off shall be considered.

3.5 Trial holes

3.5.1 General

The purpose of the trial hole is to determine:

- the soil and subsoil characteristics.
- the depth of the water table
- the depth to bedrock

If the examination of the trial holes can be arranged to coincide with the visual assessment it may save time and expense.

3.5.2 Conducting and logging the trial hole

The trial holes shall be dug to at least 2 m below the proposed base level of the ELS. This could potentially mean holes up to 5 m deep, so a machine capable of excavating to this depth shall be engaged (excavation shall take account of all health and safety requirements for deep excavations). A minimum of two holes shall be dug. These shall be at either end of the store under the footprint of each bank and not under the inner floor footprint of the proposed store. On sloping sites they shall be located in line with the up-hill side of the bottom where the proposed store excavation will be at its deepest. Further trial holes shall be dug on sites where the ground conditions are considered to be variable. The holes shall be left open for 48 hours to establish the depth to the water table (if present) and shall be securely fenced in line with all health and safety requirements during this period. Groundwater conditions shall be described, and if necessary the holes shall be left open or fitted with a standpipe to enable groundwater levels to be established. The thickness of the topsoil shall be recorded. An accurate description of all subsoils encountered is required to enable design and re-use to be considered. The subsoils shall be recorded in a professional manner with reference to the BS 5930 standard description method. This method is outlined in Appendix 2. Subsoils suitable for use in embankment construction (dense, plastic subsoils) shall be recorded in each trial hole and the appropriate horizons identified. The most appropriate horizon for use as liner material shall be identified in each trial hole. The following criteria shall be visually assessed in the trial hole for the chosen horizon:

- that the percentage of material greater than 20 mm is less than 30%
- that the percentage of material greater than 60 mm is less than 20%.

Representative samples shall be taken from this horizon in each trial hole for laboratory testing at an approved laboratory and the following tests on the samples shall be undertaken to BS 1377; Particle Size Distribution Analysis and Atterberg limits. The results of these tests shall be entered into the site assessment form.

3.5.3 Interpreting the findings from the trial hole investigation

The results of testing shall meet the following requirements (see Table 3.1).

Liner type	***Minimum acceptable criteria***	***Subsoil thickness required below invert level of store***
Compacted liner	the percentage of material greater than 60 mm is less than 20%.	Minimum 1.5 m required in all cases
	the percentage of material greater than 20 mm is less than 30%	
	10% clay or greater	
	Plasticity index 10% to 60%	
	Liquid limit 20% to 90%	
In-situ liner	18% clay or greater	Minimum 1.5 m required in all cases

Table 3-1 Minimum subsoil requirements

When assessing the clay fraction of the subsoil being tested, the methodology used shall be that recommended in BS5930:1999 Code of practice for site investigations. The clay fraction value used in the subsoil assessment shall be the percentage of clay present in the fraction of the subsoil sample whose particle size is < 20 mm.

3.6 Decision process and preparation of recommendations

Information collected	***Relevance***	***Implications***
Topography	Slopes	Not allowed if greater than 1:5
Surface water	Receptor sensitivity Receiving water	Set back distance
Hydrogeological setting	Receptor sensitivity Pathway assessment	Design Set back distance Monitoring
Cultural heritage	Receptor sensitivity	Set back distance
Natural heritage	Receptor sensitivity	Set back distance
Climate	Receptor sensitivity (odours)	Set back distance Design (rainfall)
Housing	Receptor sensitivity	Set back distance
Farm inventory survey	Hazard assessment	Design
Depth to rock	Pathway assessment	Design Construction
Subsoil type	Pathway assessment Liner suitability	Site suitability
BS5930 soil/subsoil description	Pathway assessment Liner suitability	Site suitability
Depth to water table (if present)	Pathway assessment	Water table lowering system may be required
Percentage of clay	Pathway assessment Liner suitability	Minimum acceptable criteria
Liquid limit	Pathway assessment Liner suitability	Minimum acceptable criteria
Plasticity limit	Pathway assessment Liner suitability	Minimum acceptable criteria

Table 3-2 Desk study information and site assessment phases

Table 3.2 summarises the information collected from the desk study and site assessment phases. The information is used to make recommendations as to whether an ELS can be constructed on the site. In situations where the results of the laboratory tests and the analysis of the trial hole data do not appear to complement each other, then a more conservative design or further investigations may be required.

Recommendations shall be outlined in relation to any site specific requirements necessary for the ELS design. With regard to the installation of a water table lowering system, the assessor will have examined the depth of the water table and the nature of the subsoils. This will enable them to make a judgement on whether such a system is required (e.g. may not be necessary if the soils are naturally impervious as perched water tables can be encountered).

4 Regulatory procedure

4.1 Introduction

The construction of earth-lined slurry/effluent stores (ELS) will require obtaining full planning permission. Relevant governing legislation, the planning process and required documentation is described in this chapter.

4.2 Relevant legislation

The primary piece of legislation governing the requirement and process of planning permission is the Local Government (Planning and Development) Act of 2000 and any subsequent regulations (Planning and Development Regulations, 2001).

4.3 Planning pre-consultation

Like any proposed development requiring planning permission, it is always wise to have prior consultation with the local Planning Authority, in order to ascertain their likely requirements, including any fees or charges, and possible response, and to ensure as smooth a path through the planning process as possible. Once the applicant has some idea of the approximate details of the ELS planning proposal, with approximate sizing, location and site information, they should enter into discussion with the local planning officer to ensure the proposal will meet with all the local planning authority's requirements. It will be necessary at this stage to confirm the full extent of the planning category and the fee and the required ancillary documentation to accompany the basic planning application. All planning authorities now have websites, on which most planning material can be easily accessed.

4.4 Planning permission/documentation

Local Authority planning application forms and guidance documents are normally available directly from the planning office of each local authority, or can be downloaded from the local authority website. In addition, at least two weeks before submission of the planning application, a notice must be placed in an approved newspaper, and a site notice erected in accordance with Local Authority requirements. In general, the basic documentation required with any farm planning application includes the following:

- completed planning application form, including farm operation details
- copy of advertisement from local/national papers detailing planning application
- copy of necessary site notice, required to be displayed prominently at site during application period.
- payment of planning application fee
- map showing location(s) of site notice
- proposed construction layout, cross section, and design.
- site characterisation report detailing trial hole and subsoil analysis results.

Ensure that all documents are fully completed as errors/omissions could result in a delay to your planning application being processed.

5 Earth-lined slurry/effluent store design

5.1 Introduction

This chapter gives guidance on the design aspects of an earth-lined slurry/effluent store (ELS). The design approach recognises that each site will have its own special characteristics and requirements and each design will therefore be tailored to meet the needs of the farmer based on the his/her slurry storage requirements utilising the information and recommendations of the site assessment. The design process is concerned with ensuring that the required volume of liquid is stored in an environmentally safe manner. Careful design will ensure that the ELS is robust and environmentally safe.

5.2 Preparation for the design

In approaching the design for an ELS, familiarity with the available background information, in particular the requirements of the farm, the site assessment results and the site layout is essential. The designer shall be fully familiar with the proposed site, through actually visiting the site and also speaking with the farmer/client. This ensures that the client's requirements will be fully understood and that the designer can consider the incorporation of particular existing landscape features into the proposed design. The designer must be able to visualise the finished product, and its impact on the surrounding environment. An understanding of current slurry management procedures is of particular importance as this will allow the designer to incorporate the ELS into the existing storage system in the most appropriate way. The requirements of the site shall be fully incorporated into the design. If necessary, this may require the installation of a water table lowering system or the location and rerouting of land drains which may have been encountered during the trial hole investigations. Any such requirements will comprise part of the site assessor's recommendations.

5.3 Volume requirements

5.3.1 Slurry and other liquid volumes requiring storage

When calculating the required slurry/effluent storage volume for an ELS, the assessor will have gathered information on the number of animals on the farm and the existing slurry storage capacity already available to the client. Therefore the designer may calculate the shortfall in slurry storage capacity and incorporate this into the design calculation. If the storage of other effluents is required (dairy washings, farm yard runoff etc.) the assessor will have discussed this with the client and assessed the volumes requiring storage and the designer will be able to tailor the design accordingly. Appendix 3 gives guidance on how to calculate slurry volumes and other liquid volumes requiring storage.

5.3.2 Precipitation and evaporation volume

The net rainfall capacity of the ELS is based on the period during which the ELS will be in operation and the likely precipitation on the store during that period. Current recommendations are tabulated in Appendix 3 and a worked example is given to assist the designer in assessing the net rainfall volume in the store.

5.4 Configuration of an ELS

The basic configuration of an ELS has been defined in the specification (S131). Table 5.1 below tabulates the essential requirements of ELS configuration and Figure 5.1 the general layout.

Maximum liquid depth	m	3.0
Minimum freeboard depth	m	0.75
Minimum ground level to top of banks	m	0.6
Maximum inner bank slope	deg	33
Maximum outer bank slope	deg	33
Minimum width of top of bank	m	3.0

Table 5-1 Minimum requirements for configuration of an ELS

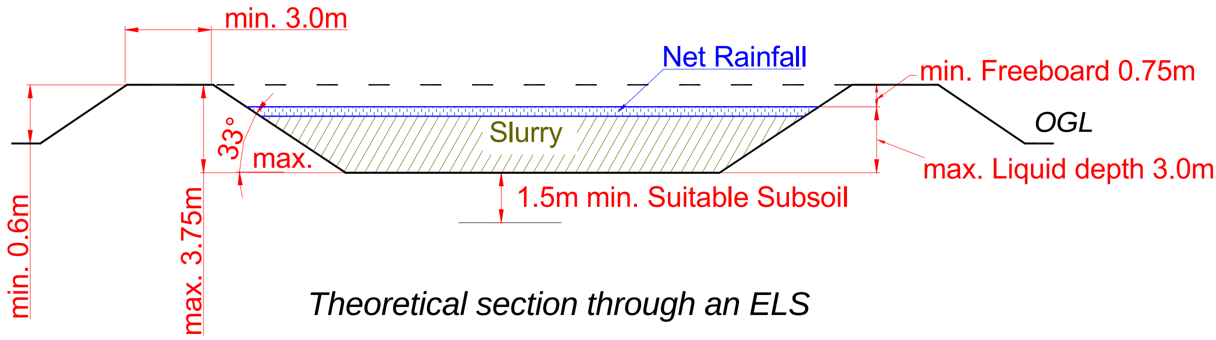


Figure 5-1 Basic configuration of an ELS (H.Scully)

5.5 Embankment design

Embankment construction shall be in accordance with S131 (Clause C.5 of S.131). The embankment height is dictated by the slurry storage requirement, the design depth of the store, settlement requirements and the portion of the store being constructed beneath the original ground level. When the embankments are constructed of dense plastic subsoil a settlement allowance of approximately 5 % must be included in the design. The embankments shall be constructed using the same machinery specified for the construction of a compacted subsoil liner (Section 6.5). The banks of the store shall not be less than 600 mm high above ground level on all sides of the store. This applies particularly on the upper side of a store built on a slope so that uncontrolled ingress of surface water, in the most extreme rainstorms, shall not be possible. The embankments shall be constructed so that at all times the inner bank slope shall be less than 33 degrees from horizontal (1 in 1.5). The core of the embankments shall be well-compacted. The design top width of the embankments is determined by the necessity for access to the store. To facilitate this, top widths of the embankments shall not be less than 3.0 m and preferably 4.0 m which has a very large factor of safety when compared to minimum widths based on engineering design.

5.6 Subsoil liner design

The subsoil liner component of an ELS is designed by utilising the information in the site assessment form to select the most appropriate of three possible design scenarios. The requirements and design layout of each of three scenarios is detailed below.

Note: In all scenarios, the value of the clay percentage used is that percentage of clay obtained when the particle size distribution is adjusted by excluding materials larger than 20 mm.

5.6.1 Scenario A

Scenario A		
		Properties
Minimum requirements:	1.5 m subsoil depth beneath store invert	Low to moderate permeability
	Compacted subsoil liner component	<20% comprised of particles >60mm
		<30% comprised of particles >20mm
		>10% clay
		Plasticity index 10% to 60%
		Liquid limit 20% to 90%

If the minimum requirements listed above are met, then the compacted subsoil liner shall be designed as follows:

- the upper 0.5 m of the subsoil underlying the ELS shall be reworked to form the compacted subsoil liner component of the ELS. This liner shall underlie both the base and inner bank faces of the ELS. The liner shall be constructed by building up the minimum thickness of 0.5 m in layers. Each layer shall be constructed by placing 150 mm of subsoil in position and making four passes (two each in cross directions) with a hydraulic excavator (capable of exerting a ground pressure of 40 kPa) or equivalent compaction plant over the entire layer. Once 0.5 m of compacted subsoil liner has been constructed the surface of the liner shall be finished by plastering with remoulded subsoil.

5.6.2 Scenario B

Scenario B		
		Properties
Minimum requirements:	1.5 m subsoil depth beneath store invert	Low to moderate permeability
	Aquifer category	Underlain by a regionally important aquifer
	Compacted subsoil liner component	<20% comprised of particles >60mm
		<30% comprised of particles >20mm
		>10% clay
		Plasticity index 10% to 60%
		Liquid limit 20% to 90%

Scenario B is identical to scenario A except that the site is underlain by a regionally important aquifer. The recommended design methodology is similar to that of scenario A with the following exceptions:

- the compacted subsoil liner component shall be at least 1.0 m thick
- six passes shall be made over each layer.

5.6.3 Scenario C

Scenario C		
		Properties
Minimum requirements:	1.5 m subsoil depth beneath store invert	Clay content >18 %
		Impervious and free of preferential flow paths

If the site assessment shows that all of the above conditions are met, then the subsoil liner component of the ELS is designed as follows:

The subsoil liner shall comprise 1.5 m of subsoil underlying the invert of the ELS. Approximately 200 mm of the 1.5 m subsoil depth shall be excavated at the base of the store and recompacted in the following manner:

- the excavated subsoil shall be reworked to a compacted thickness of 150 mm. This shall be achieved by passing the tracks of a hydraulic excavator capable of exerting a ground pressure of at least 40 kPa (or equivalent using suitable compaction plant) over the subsoil at least four times (two each in cross directions). Once this has been completed the base of the store shall be plastered with remoulded subsoil.
- the inner banks of the ELS shall also incorporate a compacted subsoil liner. This liner shall be constructed as per the design appropriate to scenario A.

The basic requirements of each of the three design scenarios is summarised in Figure 5.2 below.

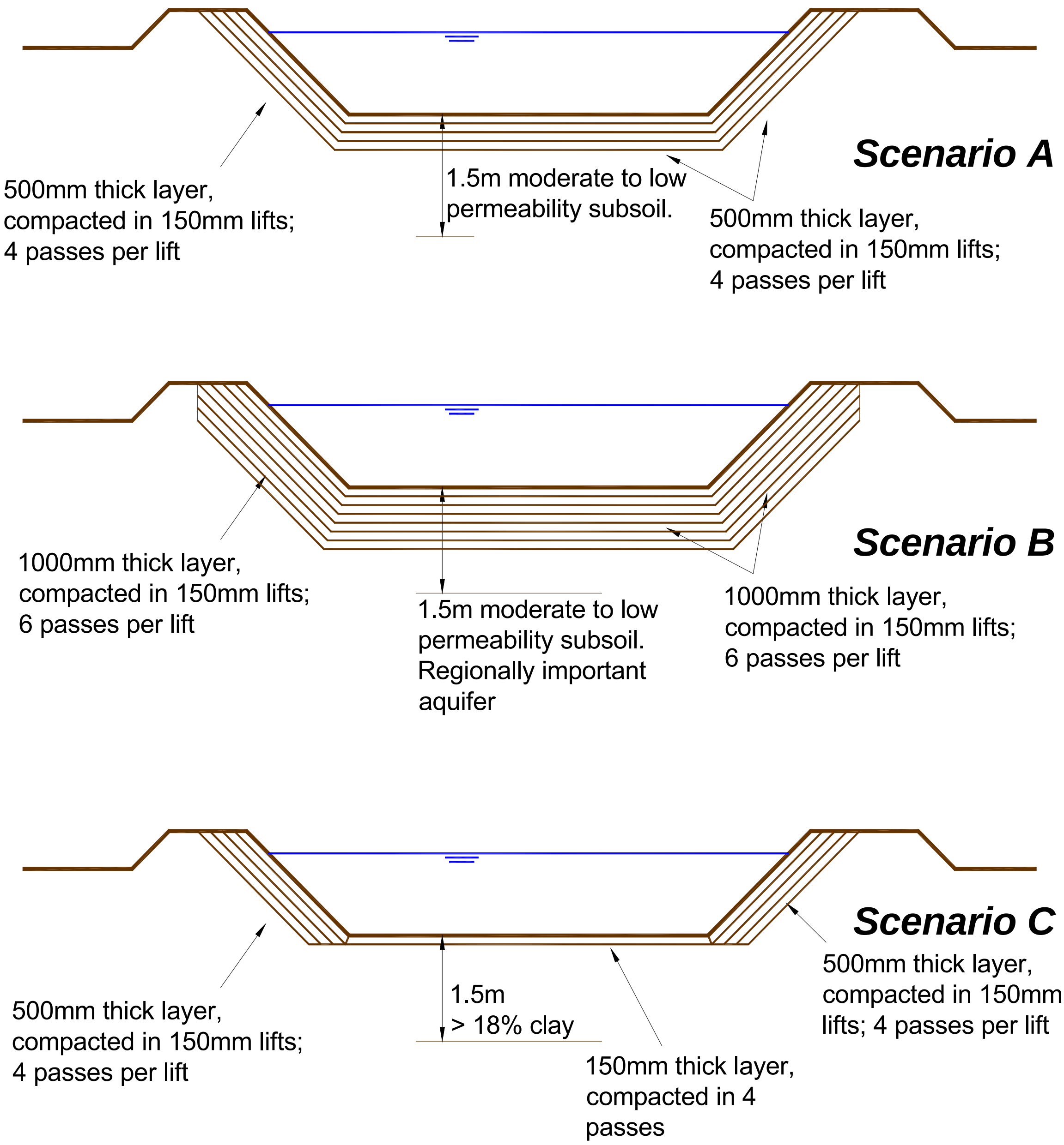


Figure 5-2 Scenario A, B and C options for design of compacted subsoil liner in an ELS (H.Scully)

Examination of the site assessment information will enable the designer to select the required design. It must be borne in mind at all times that the basic design requirement is that all ELSs shall be underlain by at least 1.5 m of moderate or low permeability subsoil, with the upper 0.5 m or 1.0 m having a permeability of less than 1 x 10^{-9} $m.s^{-1}$ and that this permeability be achieved by construction of a compacted liner.

6 Earth-lined slurry/effluent store construction

6.1 Introduction

The method of construction of an earth-lined slurry/effluent store (ELS) is site-specific and shall always be in accordance with Department of Agriculture and Food specification S.131: minimum specification for earth-lined slurry/effluent stores and ancillary works (S.131) and necessary health and safety requirements. Where ideal site criteria are not encountered works must be undertaken to ensure that all requirements are met or alternative storage structures shall be constructed. Costs at some sites, for example where rock is close to the surface, may make safe construction of an ELS uneconomic.

6.2 Working conditions

Where possible, the works must be planned so that they shall be carried out in dry weather conditions (Clause C.1 of S.131). During construction, care must be taken to ensure that excavated subsoil being used in the construction of the subsoil liner is not allowed to dry out excessively as this could reduce the subsoils compactibility. In Ireland, with the main types of compaction plant the optimum moisture contents of many subsoils are fairly close to their natural moisture contents and in such cases compaction can be carried out successfully. Irish subsoils are generally within ± five percent of optimum moisture content and therefore are suitable for compaction without normally requiring moisture content amendment. However, if subsoils being utilised in the compacted subsoil liner become excessively wet or dry, construction of the compacted subsoil liner shall not take place until the subsoil has returned to at or near its in-situ moisture content. This shall be assessed by the construction supervisor.

6.3 Site preparation

6.3.1 Clearing the site

The construction site must be cleared of trees (a tree removal order may be required), scrub, roots and all other vegetation (Clause C.2 of S.131). Trees near to a proposed site can pose particular problems since their root systems can affect ground moisture levels for a distance of approximately 1.5 times the tree height. On all sites, the topsoil within the store footprint shall be stripped. Any other unsuitable subsoil layers as indicated by the designer based on the site assessment shall also be removed.

6.3.2 Installation of water table lowering system

Where deemed necessary by the site assessor, a groundwater control drainage system shall be installed (Clause C.4 of S.131). This shall consist of deep cut-off drains 7.0 m outside the toe of the banks and extending 600 ~ 750 mm below the floor of the store. These drains can be used for a monitoring system for the store if feasible. Drainage shall not be provided underneath the floor of the store.

6.3.3 Drainage system

All old drainage or percolation systems encountered shall be completely removed from and rerouted around the ELS footprint to a distance of at least 7.0 m and the exposed vacant channels thoroughly filled and compacted with cohesive subsoil. Failure to remove old drainage systems properly constitutes the single biggest risk to surface water contamination from earth-lined slurry/effluent stores. Farms, even in naturally dry soils can have generations of land-drain pipelines beneath the surface.

6.4 Embankment construction

The embankments shall be not less than 600 mm high above ground level and be well-compacted. The embankments shall be constructed of suitable excavated material (dense plastic subsoil) identified during the site assessment. However, some clean mineral aggregate not suitable for lining (such as stones, gravel, sand, and coarse subsoil material) may be used in the outer 1.0 m of the toe of the banks only. Under no circumstances, shall this material be utilised in any other part of the embankment. Uncontrolled ingress of surface water, in the most extreme rainstorms, shall not be possible. The embankments shall be constructed by placing the appropriate subsoil in layers no thicker than 250 mm and using a minimum 20 tonne hydraulic excavator to effect compaction (2/3 passes per layer). This will ensure that the embankment is stable and well-compacted. Subsoil liner compaction is more stringent and is detailed in section 6.5 of the guidance document (Clause C.6 of S.131). Soil embankments generally experience 5% settlement. By constructing the embankments in the described manner, the robustness of the embankments is assured.

6.5 Subsoil liner construction

It is imperative that the liner subsoil in the floor and inner bank surfaces of the store and the core of the banks are thoroughly compacted. If the subsoil liner is stony or has a relatively high gravel content, the proportion of these materials present shall be such that they are embedded in the dense matrix of the subsoil liner itself and do not create any air-filled porosity by bridging or result in the liner subsoil losing any of its overall plasticity. A 20+ tonne (at minimum) tracked excavator shall be used to construct the store and effect optimum compaction. Floors and banks shall be built in layers/lifts of 150 mm and compacted until the desired density and sealing has been achieved (Clause C.6 of S.131). A minimum of four runs (two each in cross directions) per lift should give adequate compaction in normal conditions. On sites susceptible to groundwater pollution a minimum of six runs or its equivalent with compacting machinery shall be used. Alternative compaction plant may be used if it can be clearly demonstrated that **at least** equivalent compaction will be achieved.

6.5.1 Compaction of subsoils

The design and construction of compacted subsoil liners is governed by the strength and degree of compaction required to ensure low permeability. The geotechnical component of a subsoil liner is determined by the nature of the subsoil being utilised. The base and inner slopes of the ELS shall consist of a mineral layer which satisfies permeability and thickness requirements with a combined effect in terms of protection of soil, groundwater and surface water at least equivalent to a permeability of 1×10^{-9} $m.s^{-1}$ over a thickness of between 0.5 and 1.0 m depending on the underlying aquifer classification. The site assessment will have determined the presence of the required thickness of subsoil and the designer will have utilised this in his/her design. Achieving the required permeability may require compaction of a minimum thickness of subsoil, resulting in a compacted subsoil liner.

6.5.2 Compactive energy

Compactive energy is a function of the weight of the machine used to effect compaction, the thickness of the lift and the number of passes of the machine over each lift. Additional passes cannot be used to compensate for machines which are too light for the construction of the liner. Machine size is usually specified in terms of contact pressure exerted by the machine. For a hydraulic excavator, the contact pressure is determined based on the operating weight of the machine and the contact area of the machine on the ground. (e.g. hydraulic excavator 20000 kg operating weight, track width 600 mm, tumbler length 2.5 m. Therefore the contact pressure = (20000/(2.5 x 2 x 0.6)) = 65.4 kPa). Weight is important to ensure that penetration of the specified loose lift is attained. A lift thickness of 150 mm is suitable for most compaction procedures and coupled with a 20000 kg hydraulic excavator capable of exerting a ground pressure greater than 40 kPa and a minimum of four passes per lift, effective compaction should be achieved. Compactive effort may be through vibration, kneading, impact or pressure. These four different types of effort may be found in two principle types of compaction force; static or vibratory. The difference between the two is summarised below:

Static force: This is simply the deadweight of the machine, applying downward force on the soil surface, compressing the soil particles. The only way to change the effective compaction force is to add to or subtract from the weight of the machine. Static compaction is effective over relatively shallow depths (<300 mm approximately). Kneading and pressure are two examples of static compaction.

Vibratory force: This uses a mechanism, usually engine-driven, to create a downward force in addition to the machine's static weight. The vibrating mechanism is usually a rotating eccentric weight or piston/spring combination (in rammers). The compactors deliver a rapid sequence of blows (impacts) to the surface, thereby affecting the shallow layers as well as the deeper layers. Vibration moves through the material, setting particles in motion and moving them closer together to achieve the highest density possible.

6.5.3 Some compaction specification guidance

Track length on ground	***Track width***	***Machine weight***	***Ground pressure***		
(m)	(m)	(kg)	(kg.m^{-2})	(kPa)	(psi)
3.00	0.6	13950	3875.0	38.0	5.5
3.27	0.6	19700	5028.1	49.3	7.2
3.28	0.6	20575	5235.4	51.3	7.4
3.37	0.6	18070	4468.3	43.8	6.4
3.37	0.6	19300	4772.5	46.8	6.8
3.37	0.6	20095	4969.1	48.7	7.1
3.37	0.6	19021	4703.5	46.1	6.7
3.45	0.6	19650	4746.4	46.5	6.8
3.66	0.6	23069	5252.5	51.5	7.5
3.66	0.6	21340	4858.8	47.6	6.9
3.83	0.6	24200	5265.4	51.6	7.5

Table 6-1 Ground pressure values for a sample of hydraulic excavators

Table 6.1 gives calculated ground pressure values for common hydraulic excavators used in Ireland. Ground pressure is calculated as follows:

$$GP = \frac{\text{operating weight of machine}}{\text{track area in contact with ground}} = \frac{\text{operating weight (kg)}}{\text{track length on ground (m) x track width (m)}}$$

where:

GP = ground pressure (kg.m^{-2})

When specifying compaction using compaction plant such as static or vibratory rollers, reference is usually made to the Table 6/4 of the Earthworks Specification for Road Works (NRA 2005). The table below is adapted from this specification and gives guidance on the required construction requirements for different types of compaction plant to ensure an impermeable compacted subsoil liner.

Type of compaction plant	*Category*	*Max. depth of compacted layer*	*Minimum number of passes*
		(mm)	(No.)
Smooth wheeled roller (mass per metre width of roll):	over 2100 kg to 2700 kg over 2700 kg to 5400 kg over 5400 kg	125 125 150	8 6 4
Grid roller (mass per metre width of roll):	over 2700 kg to 5400 kg over 5400 kg to 8000 kg over 8000 kg	150 150 150	10 8 4
Tamping roller (mass per metre width of roll):	over 4000 kg	225	4
Vibratory roller (mass per metre width of a vibratory roll):	less than 700 kg over 700 kg to 1300 kg over 1300 kg to 1800 kg over 1800 kg to 2300 kg over 2300 kg to 2900 kg over 2900 kg to 3600 kg over 3600 kg to 4300 kg over 4300 kg to 5000 kg over 5000 kg	100 125 150 175 200 225 250 275	Unsuitable 12 8 4 4 4 4 4 4

Table 6-2 Compaction guidance using different compaction plant (Table in NRA 2005)

6.6 Final surfaces

The inside floor and bank slopes shall be smoothed off and plastered with remoulded sub-soil. Plastering with remoulded subsoil seals any minor cracks or pores. Outer surfaces and the top of the bank can be covered with up to 300 mm of topsoil. Excess topsoil can be placed against the outer toe of the banks. The banks shall be sown as detailed in Clause C.12 of S.131. The banks shall be maintained with a short grass mat thus minimising soil erosion potential and maximising bank stability (Clause C.13 of S.131). Non pasture species such as bushes or scrub shall not be allowed to develop on the banks nor shall trees be planted within 10.0 m of the toe of the banks.

6.7 Filling/emptying and agitation points

The proposed method of agitation shall be carefully selected prior to construction, in consultation with the client and the ELS designer (Clause C.7 of S.131). The use of a vertical pump, with jetter is not permitted. The number of agitation points required will vary depending on the depth, size and shape of the slurry/effluent store in question. The number of chosen points shall be kept to the minimum necessary for complete agitation. During construction, all requirements of the selected system shall be incorporated in the structure. Agitation point(s) shall consist of a) a tractor access point; b) a secure footing for the tractor and agitator. Similar arrangements shall be made for slurry store

emptying or umbilical cord emptying procedures. Guidance on ELS shape and agitation is given below:
Circular or square pits facilitate mixing and are usually more economical to construct. Rectangular pits may be used; length to width rations of 3:1 or less are recommended (Fulhage et al., Missouri University 2000). Agitation should be carried out every 30 m approximately. Therefore if an ELS is 50 m long and 30 m wide, two agitation points would be sufficient (see Figure 6.1).

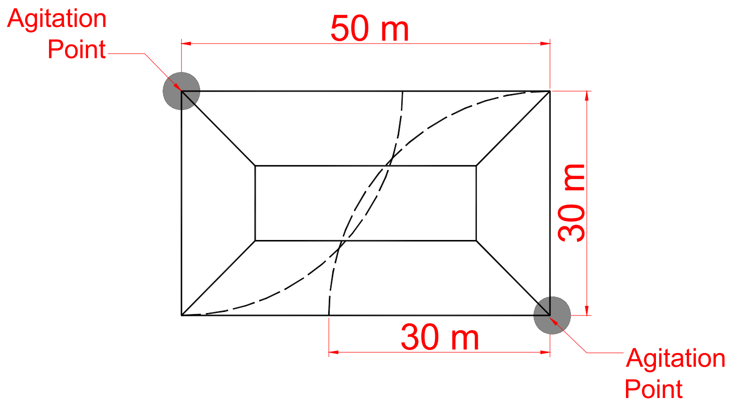


Figure 6-1 Example of how the required minimum no. of agitation points for an ELS may be assessed

<u>Pipe connections/ inlet channels</u>: It is essential that all inlet channels and pipe connections are themselves properly designed and constructed. They must not leak and they must not cause erosion of the subsoil liner or any part of the banks.
Clause C.8 of S.131 and Clause C.9 of S.131 give detailed information on the construction requirements for filling/emptying and agitation points.

6.8 Access to ELS

6.8.1 Tractor access

Tractor access for agitation, filling or emptying procedures (if required) shall be through a gated opening in the surrounding fence, at least 1.8 m high and normally 3.6 m wide. The gate shall be covered with the secure fence on battens. The access point for the tractor stand shall either be level or close to the pit edge. There shall be a raised kerb or buffer (wheel stop), at least 300mm high and 600 mm wide, across the whole access point [A gap, maximum 1.0 m wide, may be positioned in the centre of the wheel stop to facilitate the use of agitation equipment] (see Clause C.10 of S.131).

6.8.2 Other access points

Access shall be kept to an absolute minimum around the ELS for health and safety purposes. However, if emergency access is required then facilities shall be provided which will permit emergency access or escape (see Clause C.11 of S.131).

6.9 Fencing

The requirements of the fencing and gating component of the ELS are given in detail in S.131. Any fencing and access points (gates) shall be constructed in accordance with the requirements of S.131 (Clause A.2.5 of S.131).

7 <u>*Operation and maintenance*</u>

7.1 Introduction

General guidance on operation and maintenance of earth-lined slurry/effluent stores (ELSs) is given in this chapter.

7.2 Operation of the ELS

The operational requirements of an ELS are dependant on the farming system being utilised by the farmer. Basic precautions shall be taken to ensure the safety of personnel (Chapter 8). During periods of slurry agitation, no one shall be within the environs of the store alone. No one shall access the ELS unless there is no alternative and only when another person is present. During operational periods, gated openings must be kept closed and children shall not be allowed within the operational area. When the ELS is being filled by means of a slurry tanker, care must be taken to ensure that filling channels or pipes are free of debris and are structurally sound. The slurry tanker shall not pass the tractor access point. If the store is filled by means of gravity flow or by pumping, the same precautions shall be taken. Care shall be taken to ensure that at no time is the integrity of the subsoil liner compromised during ELS operation.

7.3 Maintenance of the ELS

- Earth-lined slurry/effluent stores (ELSs) must be inspected regularly (See 7.3.2) for signs of deterioration, particularly after very heavy rain and prior to filling. In order to allow proper inspection, embankments must be free from tree and shrub growth and the grass cover shall be kept short.

7.3.1 What needs to be inspected?

- the inner and outer faces of the earth embankments comprising the ELS
- the grass mat cover on the exposed surfaces of the ELS
- the liquid level in the ELS
- access points
- filling and emptying points
- equipment used in the operation of the ELS
- fence and gates surrounding the ELS.

7.3.2 How often shall it be inspected?

Recommended inspection schedule	
Liquid level in store	Weekly
Grass mat cover	
Access points	
Fencing and gates	
Inner faces of embankments	Monthly when ELS is empty
Access/filling/emptying points	Prior to filling or emptying
Gated openings	
Equipment	Prior to use and during annual service

Table 7-1 Recommended inspection schedule for ELS

7.3.3 Why shall it be inspected?

(i) ***Liquid level in the ELS***

The store liquid level shall be observed to ensure that the minimum freeboard of 0.75 m (S.131) is maintained at all times during operation of the ELS. Overtopping of the embankments of an ELS is very dangerous as the embankments will quickly erode and the contents of the store will be free to flow over the land. At no time shall the ELS freeboard be compromised. Prior to an ELS being used, the liquid level in the store must be assessed to ensure that sufficient capacity is available for slurry storage.

Figure 7-1 Example of embankment breach caused by overtopping of embankment.

(ii) ***Grass mat cover***

The grass mat cover is important as it reduces the chance of any embankment erosion. No trees, shrubs or deep rooting plants shall be located within the store footprint. Deep rooting may cause embankment instability.

Figure 7-2 Trees located within an ELS footprint (not permitted)

Frequent mowing will also discourage the establishment of trees or shrubs within the footprint of the ELS. It will also discourage potential animal burrowing.

(iii) ***Access/filling/emptying points***

Access points must be checked regularly as even small openings may allow persons or animals to access the store. The integrity of the subsoil liner must be carefully inspected around these points as careless agitation could cause damage to the surrounding liner.

(iv) ***Fencing and gates***

All fencing and gating must be examined to ensure that no damage has occurred which could allow unauthorised access to the store. Any rips/tears, openings, unlocked gates etc. shall be looked for during inspection.

(v) ***Embankment examination***

Inner embankments must be checked for signs of liner deterioration or erosion. Inner and outer embankment examination will also highlight any occurrence of leakage from the ELS. The outer toe of the embankment must be examined in this regard with particular regards for anywhere that the embankment joins another form of construction (e.g. pipework passing through the embankment). The outer face of the embankment shall be inspected when the ELS is full and also when it is empty.

Figure 7-3 Erosion on the inner embankment face of an ELS caused by careless filling of store

(vi) ***Equipment***

Regular inspection and servicing of machinery will prolong the use of the equipment and ensure safety standards are maintained. Any pipework which is installed to facilitate filling or emptying of the ELS must be maintained to prevent leakage, blockage or frost damage.

7.3.4 What is the recommended course of action if damage is observed?

(i) ***Store liquid level***

If the liquid level in the ELS rises to a point where the minimum freeboard of 750 mm is compromised, sufficient liquid must be removed from the store to ensure that at no time is the freeboard reduced. The risk of liquid levels resulting in overtopping of embankments must be minimised.

(ii) ***Grass mat***

Lack of regular mowing may encourage rooting of shrubs and trees or burrowing animals. Any shrubs or trees which take root must be removed from the embankment area immediately and the embankments examined for evidence of deep rooting. Grass must be cut regularly to maintain a short mat which will enable visual inspection of the embankments. If there are signs of burrowing animals, netting should be placed around this location and regular monitoring of the embankments must be undertaken.

(iii) ***Access/filling/emptying points***

Any damage to these points must be rectified immediately. Care must be taken to ensure that all barriers, ramps and wheel stops are maintained. If there is any sign of embankment erosion around these points, filling/emptying or agitation practices must be re-examined. If the damage is severe, the store may need to be emptied immediately. If the damage is not considered to be severe, repair should take place when the tank is next emptied.

(iv) ***Fencing and gates***

Any gaps in the fencing or gate must be dealt with immediately upon observation. At no time will access be available to animals or people through openings in the fencing system. If necessary, the store shall be emptied until repairs are made or access to the environs of the store shall be precluded.

(v) ***Embankments and subsoil liner***

If localised leakage is noted but no visible flow is observed, then remedial repairs shall take place once the store is emptied. The leakage site shall be constantly checked and if the problem is seen to accelerate, the store shall be emptied at the first available opportunity. If more general leakage is observed, filling of the store must cease immediately and the store emptied at the first available opportunity. Once the store has been emptied, the liner shall be inspected and any repairs necessary shall be undertaken. If significant leakage is observed, the store shall be emptied immediately and assistance sought. Repairs may be localised to the problem site or major repair may be required if significant damage is observed at numerous locations. Repairs may include:

Localised subsoil liner repair	Expose the affected area and allow to dry. Scarify approximately 0.25 m of the compacted subsoil liner. The scarified layer shall then be reworked in accordance with compaction guidance in sections 6.5 and 6.6.
Generalised subsoil liner repair	The store shall be emptied and allowed to dry. The upper 0.25 m of the compacted subsoil liner shall be scarified. The subsoil shall be recompacted as per section 6.5 and finished as per section 6.6. Extra subsoil may be used to further increase the subsoil liner thickness if it is deemed appropriate.
Localised embankment repair	When repairing any damage to an earthen embankment it is extremely important how the vertical cuts are made as they are very difficult to reinstate. Cuts should be made in a broad V shape so any new fill will bond with existing soil as it is replaced and compacted. If the damage is at the top of the embankment the affected area shall be removed, subsoil shall be replaced in accordance with section 6.5. Final surfaces shall be in accordance with section 6.6 and topsoil shall be replaced and the embankment area reseeded where appropriate.
Generalised embankment repair	The store shall be emptied and allowed to dry. Depending on the severity of the damage, repairs may be carried out in the same manner as localised embankment repair. Severe embankment damage may necessitate reconstruction of the affected area. Topsoil shall be stripped from the embankment. Compacted subsoil liner and subsoil forming the embankment core shall be removed. Coarse subsoils which may have been used in the outer 1.0 m toe shall also be removed. The embankment section shall be re-constructed in accordance with section 6.4. If the damage was on the outer face of the embankment, it is recommended that coarse subsoil shall not be re-used in the outer toe. Dense plastic subsoil shall be used to form the entire embankment. A constructed subsoil liner shall be replaced on the inner face of the embankment in accordance with section 6.5. The top and outer face of the embankment shall be covered with topsoil and reseeded in accordance with section 6.6.

Table 7-2 Embankment and subsoil liner remediation guidance

8 Health and safety

8.1 Introduction

The overriding document covering all health and safety issues is the Safety, Health and Welfare at Work Act 2005 which must be adhered to before, during and post construction of the earth-lined slurry/effluent store (Clause A.2 of S.131). One of the most obvious risks is drowning or being injured because of a fall into the store. Simple precautions can greatly reduce the risk of injury. A list of health and safety references which may be referred to is given at the end of this chapter. Farmers are required by law to identify the hazards and assess the risks on their farm and to draw up a written safety statement setting out the arrangements and resources provided to safeguard the safety and health of persons on the farm. Therefore, this task can be made much easier for the farmer if the correct health and safety precautions are taken at an early stage in the store construction and operation. Section 8.4 of this chapter gives some general guidance on the possible health and safety issues for children and young persons with ELSs.

8.2 Health and safety issues for slurry/effluent stores

Gases are produced when slurry decomposes. These can include methane, hydrogen sulphide, carbon dioxide and ammonia. The properties of these gases make them hazardous to human health. A particular risk is that they have the ability to displace air and cause suffocation. Hydrogen sulphide is a clear gas but may be detected by its “rotten egg” smell. However, this can lead to complacency, as very high levels of H_2S may have no discernible smell. In confined conditions, agitation of slurry can lead to very high levels of slurry gases being produced. Particular care must therefore be taken during periods of slurry agitation or when silage effluent is added. Gas release is greatest when the crust is broken. The best approach to minimizing the hazards of drowning in waste storage stores is to include features in the design to exclude both animals and people. This can be accomplished with fences and warning signs.

- gates shall be locked to limit access except to those who need to enter the store area. Provision may be provided for emergency exit in case someone accidentally enters these areas. Prominent signs indicating the hazard shall be displayed.
- slurry agitation should never be carried out alone. At least two people should always be present.
- children shall not be allowed near the agitation area.
- open slurry stores must be completely surrounded by a childproof fence at least 1800 mm in height.
- access gates must be constructed to at least the same safety standard as the fence and securely locked.
- any scrape holes and gravity entry points must be adequately protected.
- entrance to a slurry store shall not be attempted unless absolutely necessary and then only if you have a safety harness and attached rope with at least two people standing by. This is more usually applied to a confined store.
- attempt to rescue humans or livestock that have fallen into the store without assistance shall not be made.

8.3 Health and safety concerns for ELSs

Specification 131 (S.131) gives detailed information on the health and safety requirements which shall be met for an earth-lined slurry/effluent store. Clause A.2 of S.131 details the requirements for responsibility, safety during construction, safety notices, toxic gases hazard during agitation and safety fencing. Additionally Section C (Construction) gives further requirements for emergency and routine access to the ELS (Clauses C.7, C.8, C.9, C.10 and C.11 of S.131).

8.4 Children and young persons

Every year children are killed during agricultural work activities. Some simple precautions and supervision can drastically reduce the risk of injury to children. Children are naturally curious and will invariably gain entry to seemingly inaccessible places. ELSs must be fenced and gated in a fashion to deter children from entering. Crust formation is a particular hazard and can give the impression of being capable of supporting a child's weight. The consequence of falling through the crust is similar to falling through ice, namely that there is no escape. Children who have access to farm areas shall be properly supervised and instructed in proper safety measures. Any dedicated children's play area set aside for recreation shall be at a safe distance from the ELS.

8.5 General health and safety references for agriculture

- Health & Safety Authority: Guidelines on the preparation of a safety statement for a farm
- Health & Safety Authority: Play safe, stay safe on the farm
- Health & Safety Authority: Farm safety plan
- National Authority for Occupational Safety and Health: Code of practice on preventing accidents to children and young persons in agriculture
- Health & Safety Executive (UK), Agriculture Information Sheet No 9 (rev): Preventing access to effluent storage and similar areas on farms
- Department of Agriculture, Food and Rural Development: Good farming practice, 2001
- Teagasc: Safe slurry handling
- Teagasc: Fertilisers and animal manure, code of good practice
- Teagasc: Farm safety statement
- Teagasc, Health and Safety Authority: Farm safety handbook
- DEFRA (UK): Code of good agricultural practice for the protection of water
- BS 5502 Buildings and structures for agriculture Part 50: Code of practice for the design, construction and use of reception pits and storage tanks for slurry.

9 Appendix 1 Groundwater response matrix for ELSs

9.1 Introduction

The role of the groundwater response matrix is to provide an initial evaluation of the general suitability of a site for an earth-lined slurry/effluent store (ELS), from a hydrogeological perspective, as part of the desk study. It can also be used to indicate the measures that may be required to meet the required specification. An explanation of the role of groundwater protection responses in a groundwater protection scheme is given in *Groundwater Protection Schemes* (DoELG/EPA/GSI, 1999). The geological and hydrogeological data that place a site within a response category is general to an area, and not specific to a site. It is therefore incumbent on the developer to demonstrate that the site conditions of a specific site are determined, before a decision is taken on the suitability or otherwise of a site. Examples of uncertainty on available data can include depth to rock values (and hence vulnerability ratings) and the presence of sand/gravel. A risk assessment approach is taken in the development of this response matrix.

9.2 Vulnerability rating and aquifer classification

Table 9.1 summarises how a vulnerability rating is assigned. Once the rating has been assigned the classification of the aquifer underlying the site being investigated is assessed. The aquifer is classed as regionally important, locally important or poor. These classes are then subdivided as shown in Table 9.2.

Vulnerability Rating	Hydrogeological Conditions				
	Subsoil Permeability (Type) and Thickness			Unsaturated Zone	Karst Features
	High permeability (sand/gravel)	Moderate permeability (e.g. Sandy subsoil)	Low permeability (e.g. Clayey subsoil, clay, peat)	(Sand/gravel aquifers only)	(<30 m radius)
Extreme (E)	0 - 3.0m	0 - 3.0m	0 - 3.0m	0 - 3.0m	-
High (H)	>3.0m	3.0 - 10.0m	3.0 - 5.0m	>3.0m	N/A
Moderate (M)	N/A	>10.0m	5.0 - 10.0m	N/A	N/A
Low (L)	N/A	N/A	>10.0m	N/A	N/A

Notes: (1) N/A = not applicable.
(2) Precise permeability values cannot be given at present.
(3) Release point of contaminants is assumed to be 1-2 m below ground surface.

Table 9-1 Vulnerability rating (DELG/EPA/GSI, 1999)

Aquifer classification					
Regionally important aquifers (R)		***Locally important aquifers (L)***		***Poor aquifers (P)***	
Karstified aquifers	Rk	Sand/gravel	Lg	Bedrock which is generally unproductive except for local zones	Pl
Fissured bedrock aquifers	Rf	Bedrock which is generally moderately productive	Lm	Bedrock which is generally unproductive	Pu
Extensive sand/gravel aquifers	Rg	Bedrock which is moderately productive only in local zones	Ll		

Table 9-2 Aquifer classification (adapted from DELG/EPA/GSI,1999)

The source protection areas are delineated for public, group and industrial supplies. These areas provide additional protection by placing tighter controls on activities within the vicinity of the source. The matrix in Table 9.3 below gives the result of integrating the two regional elements of land surface zoning (vulnerability categories and resource protection areas). In practice this is achieved by superimposing the vulnerability map on the aquifer map. Each zone is represented by a code e.g. **Rf/M**, which represents areas of regionally important fissured aquifers where the groundwater is moderately vulnerable to contamination. All of the hydrogeological settings represented by the zones may not be present in each local authority area.

Vulnerability Rating	***Source Protection Area***		***RESOURCE PROTECTION AREA Aquifer Category***							
	Inner (SI)	***Outer (SO)***	***Regionally Important Aquifer***			***Locally Important Aquifer***		***Poor Aquifer***		
			Rk	***Rf***	***Rg***	***Lg***	***Ll/Lm***	***Pl***	***Pu***	
Extreme	SI/E	SO/E	Rk/E	Rf/E	Rg/E	Lg/E	Ll/E	Pl/E	Pu/E	↓
High	SI/H	SO/H	Rk/H	Rf/H	Rg/H	Lg/H	Ll/H	Pl/H	Pu/H	
Moderate	SI/M	SO/M	Rk/M	Rf/M	Rg/M	Lg/M	Ll/M	Pl/M	Pu/M	↓
Low	SI/L	SO/L	Rk/L	Rf/L	Rg/L	Lg/L	Ll/L	Pl/L	Pu/L	
	→	→	→		→		→	→		→

↓→ directions of decreasing risk to groundwater

Table 9-3 Matrix of groundwater protection zones (DELG/EPA/GSI, 2005)

The appropriate response to the risk of groundwater contamination from an ELS in the different hydrogeological settings in Ireland (see Table 9.3**)** is given by the assigned response category (**R**) appropriate to each protection zone – see Table 9.4.

9.3 Groundwater response matrix for ELSs

Vulnerability Rating	***Source Protection Area***		***RESOURCE PROTECTION AREA Aquifer Category***						
	Inner (SI)	***Outer (SO)***	***Regionally Important Aquifer***			***Locally Important Aquifer***		***Poor Aquifer***	
			Rk*	***Rf***	***Rg***	***Lg***	***Ll/Lm***	***Pl***	***Pu***
Extreme	R4	$R3^{4}$	$R3^{3}$	$R3^{2}$	R4	R4	$R3^{1}$	$R3^{1}$	$R3^{1}$
High	$R2^{4}$	$R2^{3}$	$R2^{2}$	$R2^{1}$	R4	R4	R1	R1	R1
Moderate	$R2^{3}$	$R2^{3}$	$R2^{2}$	R1	R1	R1	R1	R1	R1
Low	$R2^{3}$	$R2^{3}$	$R2^{2}$	R1	R1	R1	R1	R1	R1

**A small proportion of the country (~0.6%) is underlain by locally important karstic aquifers (Lk); in these areas, the groundwater protection responses for the Rk groundwater protection zone shall apply.*

Table 9-4 Response matrix for earth-lined slurry/effluent stores (ELSs)

The responses are given below:

R1 Acceptable, subject to normal good practice (i.e. investigation, construction, operation and maintenance in accordance with DAF Minimum Specification S131) as set out in the following requirements:

1. The ELS shall be underlain by at least 1.5 m of cohesive subsoil.

2. An upper portion of the subsoil, which will vary in thickness depending on the level of risk posed by the ELS, shall have a permeability of less than $1x10^{-9}$ $m.s^{-1}$.
   - Where this is present in situ, (i.e. the subsoil is classed as CLAY (using BS5930) and has a clay content of >18% (where the particle size distribution is adjusted by excluding materials larger than 20 mm), and is free from preferential flowpaths), the surface of the excavated portion of the store will require plastering with remoulded subsoil.
   - Where the subsoil is considered to have a permeability of greater than $1x10^{-9}$ $m.s^{-1}$, the subsoil must be enhanced by compaction to achieve the required permeability standard.
3. The upper 0.5m shall have a permeability of less than $1x10^{-9}$ $m.s^{-1}$.
4. Where the subsoil is sand/gravel in vertical hydraulic continuity with the main water table, an ELS is not acceptable.
5. The ELS shall be at least 60 m from any well or spring used for potable water.

R2[1] Acceptable, subject to normal good practice, meeting requirements 1, 2, 4 and 5 above, and the following additional requirement:

6. The minimum thickness of subsoil with a permeability of less than $1x10^{-9}m.s^{-1}$ shall be 1.0 m.

R2[2] Acceptable, subject to normal good practice, meeting design requirements 1, 2, 4, 5 and 6 above, and the following additional requirement:

7. The ELS shall be at least 15 m from karst features that indicate enhanced zones of high bedrock permeability (e.g. swallow holes and dolines (collapse features)).

R2[3] Acceptable, subject to normal good practice, meeting requirements 1, 2, 4, 5, 6 and 7 (in karst areas).

R2[4] Acceptable, subject to normal good practice, meeting requirements 1, 2, 4, 5, 6 and 7 (in karst areas) above, and the following additional requirement:

8. Where microbial pathogens and/or high nitrate concentrations are known to be present in the water supply source, more detailed site investigation and/or restrictive design requirements may be necessary.

R3[1] Not generally acceptable, unless requirements 1, 2, 3, 4 and 5 can be met (see Note 1).

R3[2] Not generally acceptable, unless requirements 1, 2, 4, 5 and 6 can be met (see Note 1).

R3[3] Not generally acceptable, unless requirements 1, 2, 4, 5, 6, and 7 can be met (see Note 1).

R3[4] Not generally acceptable, unless requirements 1, 2, 4, 5, 6, and 7 (in karst areas) can be met (see Note 1).

R4 Not acceptable.

Note 1: Achieving the required minimum subsoil thickness beneath the stores (ELSs) is unlikely.
Note 2: Where a source protection area has not been delineated by the Local Authority and the proposed ELS site lies within 300m upgradient of a public supply abstraction point, the ground water protection response as per source protection area of Table 9-3 applies.

The requirements for each groundwater response have been tabulated below to assist users. It should be noted that R3 and R4 responses generally indicate that the site is potentially unsuitable for an ELS. However if the site assessment can clearly demonstrate that the site is suitable for ELS construction, then the site may be acceptable.
e.g. If the desk study indicates that the response is $R3^1$ but the overall site assessment clearly demonstrates that requirements 1, 2, 3, 4 and 5 are met, then site may be considered suitable.

	Requirements		R1	$R2^1$	$R2^2$	$R2^3$	$R2^4$	$R3^1$	$R3^2$	$R3^3$	$R3^4$	R4
1	The ELS shall be underlain by at least 1.5 m of cohesive subsoil.											
2	An upper portion of the subsoil, which will vary in thickness depending on the level of risk posed by the ELS, shall have a permeability of less than $1x10^{-9}$ $m.s^{-1}$).	Where this is present in situ, (i.e. the subsoil is classed as CLAY (using BS5930) and has a clay content of >18% (where the particle size distribution is adjusted by excluding materials larger than 20 mm), and is free from preferential flowpaths), the surface of the excavated portion of the store will require plastering with remoulded subsoil.										
		Where the subsoil is considered to have a permeability of greater than $1x10^{-9}$ $m.s^{-1}$, the subsoil must be enhanced by compaction to achieve the required permeability standard.										not acceptable
3	The upper 0.5m shall have a permeability of less than $1x10^{-9}$ $m.s^{-1}$.											
4	Where the subsoil is sand/gravel in vertical hydraulic continuity with the main water table, an ELS is not acceptable.											
5	The ELS shall be at least 60 m away from any well or spring used for potable water.											
6	The minimum thickness of subsoil with a permeability of less than $1x10^{-9}$ $m.s^{-1}$ shall be 1.0 m.											
7	The minimum distance of the ELS shall be 15m from karst features that indicate enhanced zones of high bedrock permeability (e.g. swallow holes and dolines (collapse features)).											
8	Where microbial pathogens and/or high nitrate concentrations are known to be present in the water supply source, more detailed site investigation and/or restrictive design requirements may be necessary.											

Table 9-5 General groundwater response requirements for ELSs

10 Appendix 2 Classifying a subsoil

10.1 Introduction

Subsoils may be classified by the site assessor using the methodology outlined in BS5930:1999 Code of practice for site investigations. This methodology coupled with the laboratory test results for particle size distribution (PSD) and Atterberg limits will enable the subsoil to be accurately characterised and its appropriateness for use in the construction of an earth-lined slurry/effluent store assessed. A brief description of the laboratory test methodology is given below. The standard followed is BS1377-Part 2:1990 Methods of test for Soils for civil engineering purposes: Classification tests.

10.2 Atterberg limits

Largely through the work of A. Atterberg and A. Casagrande, the Atterberg limits and related indices have become useful characteristics of assemblages of soil particles. The limits are based on the concept that a fine-grained soil can exist in any of four states depending on its water content. A soil is solid when dry, and upon the addition of water proceeds through the semisolid, plastic and finally liquid states, as shown in Figure 10.1. The water content at the boundaries between the adjacent states are termed shrinkage limit (w_s), plastic limit (w_p) and liquid limit (w_L). The plasticity index (I_p) is defined by the following relationship: $I_p = w_L - w_p$.

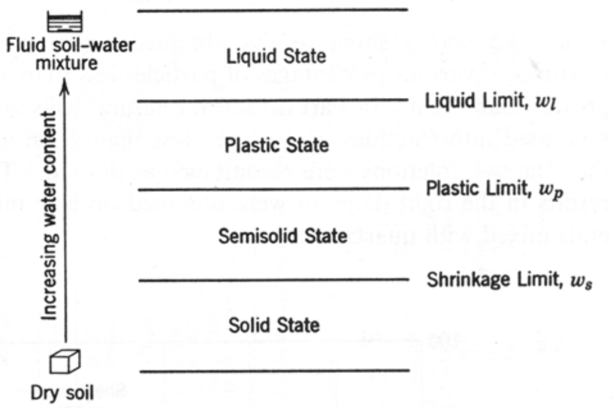


Figure 10-1 Atterberg limits and related indices (Scully 2005)

The liquid limit is determined by measuring the water content and the number of blows required to close a specific width groove for a specified length in a standard liquid limit device. The plastic limit is determined by measuring the water content of the soil when threads of the soil 3 mm in diameter begin to crumble. For an ELS requiring a compacted liner, the subsoil being used to form the liner must have a plasticity index between 10 % and 60 % and a liquid limit between 20 % and 90 %.

10.3 Particle size distribution (PSD) test

Particle size distribution tests are conducted to quantify the fraction of gravel, sand, silt and clay present in a subsoil sample. A combination of wet and dry sieving is used to determine the grading of the subsoil down to the fines (silt and clay) fraction. The relative percentages of silt and clay present is determined by sedimentation using wither the hydrometer or pipette method as outlined in BS 1377-Part 2:1990. Once the test on the subsoil has been completed, the percentages of each fraction present in the sample will be known. A particle size distribution (PSD) curve may then be drawn which allows the designer to quickly assess the grading and uniformity of the subsoil. When assessing subsoil for use in the construction of an ELS, an insitu-liner must have a minimum clay content of 18 %. A compacted subsoil liner must have at least 10 % clay present. The clay content is based on the percentage of clay present in the fraction of the whole subsoil sample passing the 20 mm sieve.

10.4 Utilising the PSD curve and Atterberg limits

The purpose of the two test methods outlined in 10.2 and 10.3 are to enable the designer to classify the subsoil using BS 5930:1999 and consequently to make a judgement on the subsoil suitability for use in the construction of an ELS. Firstly, the soil is classified as either Coarse or Fine.

COARSE SOILS: <35 % of the material is finer than 0.063 mm (passes 63 μm sieve).

FINE SOILS: >35% of the material is finer than 0.063 mm

A coarse soil may be further subdivided by sieving into Gravels or Sands.

GRAVEL: > 50 % of the coarse fraction is > 2 mm in size.

SAND: > 50 % of the coarse fraction is < 2 mm in size.

Further classification is possible by examining the percentage of fines the subsoil contains and looking at the grading curve of the sample. A fine soil may be sub-classified by examining the percentage of fines in the sample and may then be further subdivided by looking at its grading and liquid limits. A final classification stage is made possible by plotting points from the subsoil sample on a Casagrande A-line chart.

10.5 Subsoil field assessment tests

In the field, experience and sound judgement may be used to classify subsoil. The tests described below shall be used in conjunction with Table 10.2 and Figure 10.2 below for the naming of subsoils. This section is adapted from BS 5930:1999.

10.5.1 Field assessment of grading

Coarse and fine soils may be distinguished from each other simply as coarse soils do not stick together when wet whereas fine soils do. It may be necessary to adjust the water content of the sample to correctly assess this. Gravels and sands are simple to classify as sand particles are less than 2 mm in size and gravel greater than 2 mm. The boundary between fine sand and coarse silt can be assessed by eye, as coarse silt particles cannot be seen with the naked eye.

10.5.2 Field assessment of plasticity

(i) *Cohesion and plasticity of fine fraction of coarse soils*

The sample shall first be loosened and then moulded and a handful pressed in the hands. It may be necessary to add water and remove the larger gravel pieces. A soil shows cohesion when, at a certain moisture content, its particles stick together to give a relatively firm mass. If the soil can be deformed without rupture, i.e. without losing cohesion, then it exhibits plasticity. Cohesive, plastic soils included clays, silts and some peats. Sands are neither cohesive nor plastic although they do sometimes cohere when wet.

(ii) *Toughness of fine soils*

Toughness refers to the character of a thread of moist soil rolled on the palm of the hand, moulded together, and rolled again until it has dried sufficiently to break at a diameter of approximately 3 mm. In this condition:

Subsoil type	***Toughness characteristics***
Inorganic clays of high plasticity	Fairly stiff and tough
Inorganic clays of low plasticity	Softer and more crumbly
Inorganic silts	Weak and often soft thread that breaks up, crumbles readily, and may be difficult to form
Organic soils and peat	Very weak, spongy or fibrous thread, which may be difficult to form at all, and whose lumps crumble readily

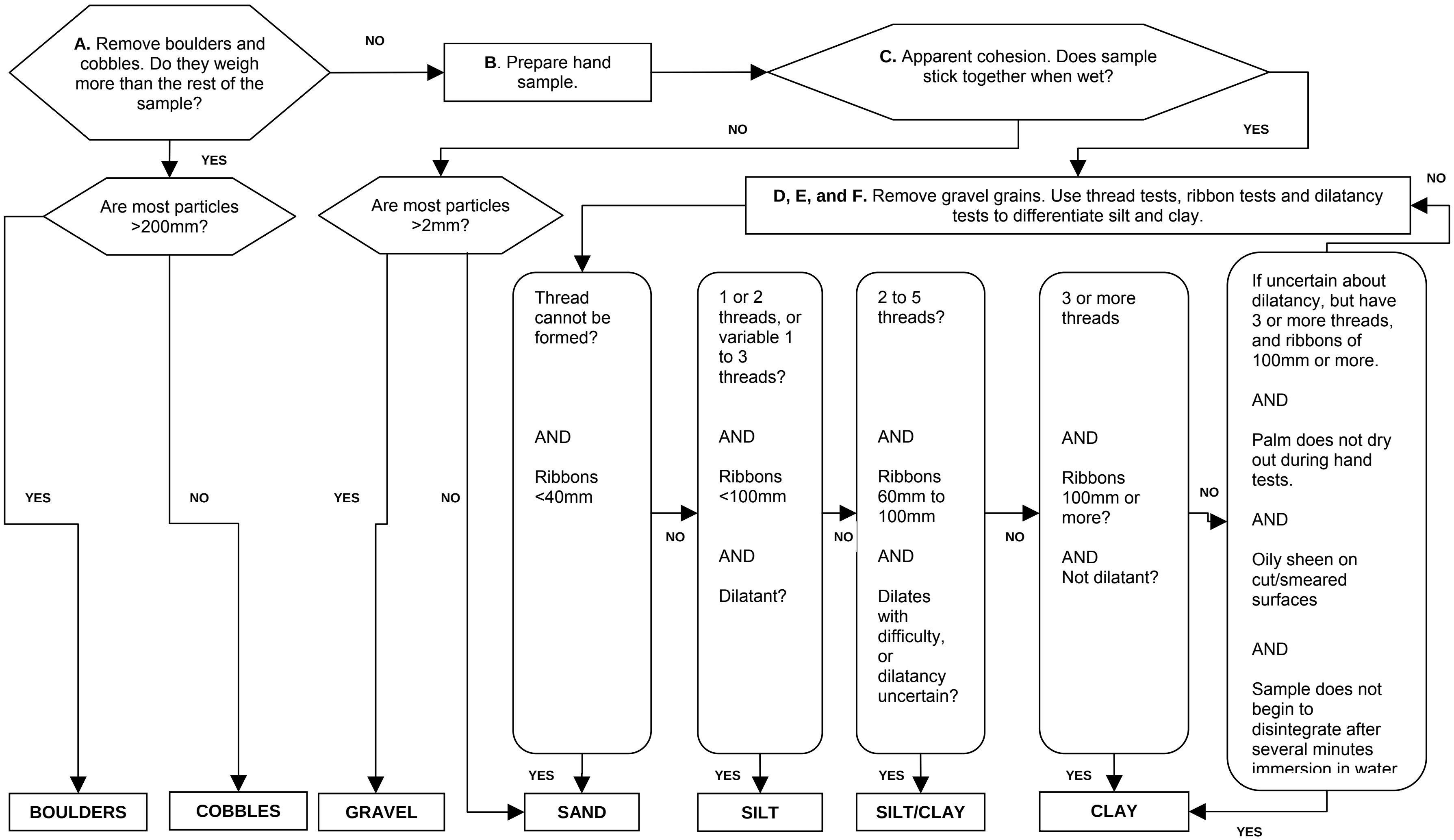
Table 10-1 Toughness characteristics for characterising the toughness of fine soils (BS5930:1999)

(iii) *Dilatancy test*

A pat of subsoil sample moistened to be soft, but not sticky, is held on the open horizontal palm of the hand. The side of the hand is then jarred against the other hand several times. Dilatancy is shown by the appearance of a shiny film of water on the surface of the pat. When the pat is squeezed or pressed with the fingers, the surface dulls as the pat stiffens and finally crumbles. These reactions are marked only for predominantly silt-size material and fine sand, and normally indicate the presence of these materials.

10.6 Using results to classify subsoil

The table and flow chart below assist the assessor is classifying the subsoil being characterised. The results of the field classification tests shall be used in conjunction with the laboratory analysis to ensure that the subsoil has been correctly classified.


A. Remove boulders and cobbles. Do they weigh more than the rest of the sample?
NO
B. Prepare hand sample.
C. Apparent cohesion. Does sample stick together when wet?
NO
YES
YES
Are most particles >200mm?
Are most particles >2mm?
D, E, and F. Remove gravel grains. Use thread tests, ribbon tests and dilatancy tests to differentiate silt and clay.
NO
Thread cannot be formed? AND Ribbons <40mm
1 or 2 threads, or variable 1 to 3 threads? AND Ribbons <100mm AND Dilatant?
2 to 5 threads? AND Ribbons 60mm to 100mm AND Dilates with difficulty, or dilatancy uncertain?
3 or more threads AND Ribbons 100mm or more? AND Not dilatant?
If uncertain about dilatancy, but have 3 or more threads, and ribbons of 100mm or more. AND Palm does not dry out during hand tests. AND Oily sheen on cut/smeared surfaces AND Sample does not begin to disintegrate after several minutes immersion in water
YES
NO
YES
NO
NO
NO
NO
NO
YES
YES
YES
YES
YES
BOULDERS
COBBLES
GRAVEL
SAND
SILT
SILT/CLAY
CLAY

Particle sizes as defined in BS5930:1999		
Boulder	>200 mm	Larger than a soccer ball
Cobble	60 ~ 200 mm	Smaller than a soccer ball, but larger than a tennis ball
Gravel	2 ~ 60 mm	Smaller than a tennis ball, but larger than match heads
Sand	0.06 ~ 2mm	Smaller than match head, but larger than flour
Silt	0.002 ~ 0.06 mm	Smaller than flour (not visible to the naked eye)
Clay	< 0.002 mm (2μm)	Not visible to the naked eye

A: Examine Boulders and Cobbles (test adapted from BS5930:1999)	**B and C: Preparation of Sample and Apparent Cohesion Test** (tests taken from BS5930:1999)
• using a hammer, trowel or pick, clean off a portion of trial pit wall. • examine whether the quantity of boulders/cobbles is dominant over finer material. This will usually be easily done by eye. If unsure, separate boulders/cobbles from finer material in two sample bags and compare weights by hand.	• collect a hand-sized representative sample from the cleaned-off portion of the trial pit wall. • remove particles larger than 2 mm, as far as possible. • crush clumps of subsoil and break down the structure of the sample/ • slowly add water (preferably as a fine spray), mixing and moulding the sample until it is the consistency of putty; it shall be pliable but not sticky and shouldn't leave a film of material on your hands. Can the sample be made pliable at the appropriate moisture content? • if it can, squeeze the sample in your fist ~ does it stick together?
D: Thread Test (test adapted from combination of BS5930:1999 and ASTM(1984))	**E: Ribbon Test** (test adapted from the USDA (NRCS/SCS Soil Survey Handbook)
• ensure the sample is of the consistency of putty. This is very important! Add extra water or sample to moisten or dry the sample. • check that no particles greater than 1 or 2 mm occur in the prepared sample. • gently roll a thread 3 mm in diameter across the width of the palm of your hand. Remove excess material. • if a thread can be rolled, break it and try to re-roll without adding additional water. • repeat until the thread can no longer be rolled without breaking. • record the total number of threads that were rolled and re-rolled. • repeat the test at least twice per sample. Water can be added between east test repetition, to return the sample to the consistency of putty.	• ensure the sample if of the consistency of putty. This is very important! Add extra water or sample to moisten or dry the sample. • check that no particles greater than 1 or 2 mm occur. • form your moist sample into a large roll in your hand, approximately the width of your thumb. • hold your hand and arm parallel with the ground. Using your thumb, press the sample over your index finger to form a uniform ribbon about thumb-width and 0.5 cm thick. Let this ribbon hang over your index finger and continue to extrude the ribbon between thumb and index finger until it breaks. Be careful not to press your thumb through the ribbon. • measure the total length of the formed ribbon when it breaks (i.e. from tip of thumb to end of ribbon). • repeat this test at least three times per sample to obtain an average ribbon value. Water can be added between each repetition, to return the sample to the consistency of putty.
F: Dilatancy Test (test taken from BS5930:1999)	
• wet the sample such that it is slightly more wet (and softer) than for a thread test, but not so wet that free water is visible at the surface.	

- spread the sample in the palm of one hand, such that no free water is visible at the surface.
- using the other hand, jar the sample 5 times by slapping the heel of your hand or the ball of your thumb. Take note of whether water rises to the surface or not, and how quickly it does so.
- squeeze the sample, again noting if the water disappears or not, and how quickly.
- dilatant samples will show clear and rapid emergence of a sheen of water at the surface during shaking, and clear and rapid disappearance from the surface during squeezing. Non dilatant samples will show no discernible sheen.
- decide whether your sample has Dilatancy. Beginners often find it quite difficult to determine the presence of a sheen, unless it is very obvious. It will become easier once samples with clear Dilatancy are observed.

Criteria for describing density /compactness (fine subsoils) (BS5930:1999)		**Criteria for describing discontinuities** (BS5930:1999)	
Term	**Field Test**	**Term**	**Mean spacing (mm)**
Uncompact	Easily moulded or crushed in fingers	Very widely	>2000
Compact	Can be moulded or crushed by strong finger pressure	Widely	2000 ~ 600
Very soft	Finger easily pushed up to 25 mm	Medium	600 ~ 200
Soft	Finger pushed up to 10 mm	Closely	200 ~ 60
Firm	Thumb makes impression easily	Very closely	60 ~ 20
Stiff	Can be indented slightly by thumb	Extremely closely	<20
Very stiff	Can be indented by thumbnail	Fissured	Breaks into blocks along unpolished discontinuities
Hard	Can be scratched by thumbnail	Sheared	Breaks into blocks along polished discontinuities

Figure 10-2 Flow chart to aid in classification of subsoils in Ireland

(adapted from GSI, 2001)

Table 10-2 Field tests for classification of subsoils (GSI, 2001)

11 Appendix 3 ELS capacity calculations

The required liquid capacity of an earth-lined slurry/effluent store may be calculated using the following methodology.

- the amount of slurry produced is calculated based on the number of cattle on the farm.
- the existing slurry storage capacity is calculated.
- the required slurry storage capacity on the farm is calculated based on the most up-to-date regulations (e.g. European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2005) (GAPPW).
- the shortfall in slurry storage and any other effluent suitable for storage is calculated
- the net rainfall capacity is calculated and the ELS sized accordingly.

11.1Slurry production

The European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2005, has produced data which enables the estimation of neat excreta quantities produced by different classes of livestock. Table 11.1 below is adapted from this data and is used to assist in the calculation of slurry production on a farm.

Livestock category	*Sub-category*	*Neat excreta (urine & faeces) ($m^3.wk^{-1}$)*
Cattle	Dairy cows	0.33
	Suckler cow	0.29
	Beef cattle (> 2 years)	0.26
	Cattle (1 to 2 years)	0.15
	Cattle (< 1 year)	0.08

Table 11-1 Estimated quantities of neat excreta produced by different classes of livestock (av. weight animals) (adapted from Table 2, Schedule 2, GAPPW, 2005)

11.2Regulatory slurry capacity requirement

Once the weekly slurry production from the farm has been established, the next stage is to ascertain the required storage period (usually in weeks). This period is determined by referring to the most current regulatory guidelines including Local Authority Agricultural Bye-Laws and the European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2005. The most current guidance is given below (Table 11.2) but it must be noted that this guidance may change and that at all times the designer must apply the most up-to date guidance available.

Zonal configuration	
Zone A	16 weeks slurry storage capacity
Zone B	18 weeks slurry storage capacity
Zone C	20/22 weeks slurry storage capacity

Table 11-2 Proposed zonal configuration under European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2005 (adapted from GAPPW, 2005)

Zonal Configuration			
Counties in Zone A	Counties in Zone B	Counties in Zone C	
		C1	C2
Carlow	Clare	Cavan	Donegal
Cork	Galway	Monaghan	Leitrim
Dublin	Kerry		
Kildare	Limerick		
Kilkenny	Longford		
Laois	Louth		
Offaly	Mayo		
Tipperary	Meath		
Waterford	Roscommon		
Wexford	Sligo		
Wicklow	Westmeath		

C_2 Recognising the high water quality in counties Leitrim and Donegal and the lesser agricultural pressures in comparison with counties Cavan and Monaghan, two weeks lesser storage is required in Counties Donegal and Leitrim.

Table 11-3 Proposed zonal configuration under European Communities Good Agricultural Practice for Protection of Waters, 2005 (adapted from GAPPW, 2005)

Figure 11.1 illustrates the proposed zonal configuration.

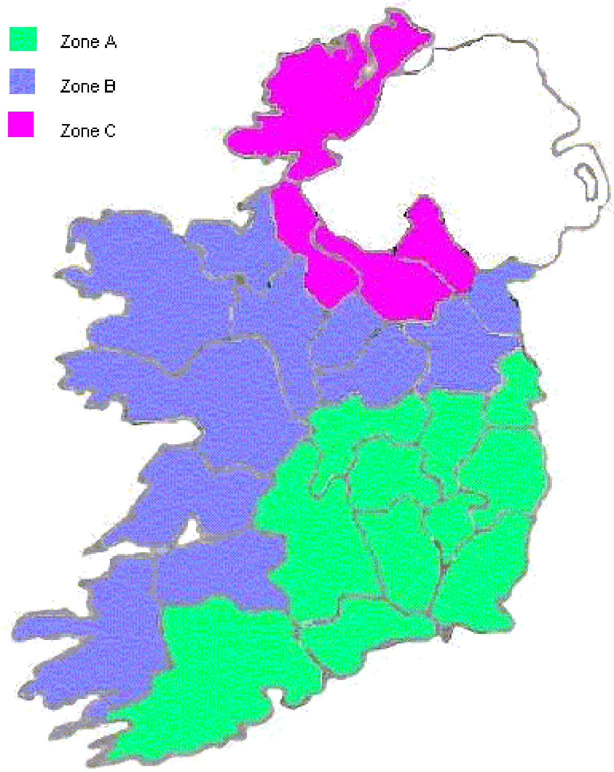


Figure 11-1 Proposed zonal configuration under European Communities Good Agricultural Practice for Protection of Waters, 2005 (adapted from GAPPW, 2005))

11.3 ELS storage capacity

By following the steps in this appendix, you will have calculated how much slurry storage the farmer requires. The final step is to assess the existing slurry capacity on the farm and to design the ELS based on the shortfall. However, at this stage it is important to take into account any other potentially useful liquids which may require storage and subsequent recycling. An ELS may offer an opportunity to store farmyard runoff.

11.4 Net rainfall capacity calculation

Current guidance on net rainfall calculations are as follows:

- a net rainfall ($mm.wk^{-1}$) is given for each county.

Current guidance may be obtained from the European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2005 (Schedule 2, Table 4). This table is given below:

County	***$mm.wk^{-1}$***
Carlow	24
Cavan	27
Clare	32
Cork	37
Donegal	38
Dublin	17
Galway	34
Kerry	45
Kildare	18
Kilkenny	23
Laois	22
Leitrim	33
Limerick	26
Longford	23
Louth	20
Mayo	40
Meath	19
Monaghan	23
Offaly	20
Roscommon	26
Sligo	32
Tipperary	27
Waterford	31
Westmeath	21
Wexford	25
Wicklow	33

Table 11-4 Average net rainfall during the specified storage period (GAPPW, 2005)

Using this value and multiplying it by the required storage period will enable the designer to calculate the required net rainfall falling on the ELS. An estimate of the net rainfall volume may be made at this point but will be further refined during the ELS sizing process.

11.5 ELS liquid volume calculation (worked example)

Slurry/effluent production on farm				
A	Animal type		(Table 11.1)	Beef cattle (> 2 years)
B	No. of animals	no.	Site assessment report	150
C	Slurry production per animal	$m^3.animal^{-1}.wk^{-1}$	(Table 11.1)	0.26
D	Slurry production on farm	$m^3.wk^{-1}$	B x C	39
Slurry capacity				
E	Existing slurry storage capacity on farm	m^3	Site assessment report	300
F	Location of farm	county	Site assessment report	Meath
G	Farm zoning designation		Table 11.3	B
H	Minimum closed period	wk	Table 11.2	18
I	Extra slurry capacity	wk	Requirements of client	4
J	Minimum slurry storage requirement for farm	m^3	D x H	702
K	Minimum ELS slurry capacity	m^3	J - E	402
L	ELS slurry capacity based on clients requirements	m^3	((H + I) x D) - E	558
Net rainfall				
M	Net rainfall	$mm.wk^{-1}$	Table 11.4	19
N	Estimated liquid surface area of ELS	m^2	(L ÷ 2)	240
O	Estimated net rainfall capacity for ELS	m^3	N x (M ÷ 1000) x (H + I) x 1.1	110.4
P	Net rainfall capacity requirement if extra storage capacity not included	m^3	(K ÷ 2) x (M ÷ 1000) x H x 1.1	75.62
Farmyard runoff [note 1]				
Q	Area of farmyard	m^2	Site assessment report	1000
R	Required storage period for farmyard runoff	wk	Requirements of client	20
S	Volume of runoff produced over closed period	m^3	Q x R x (M ÷ 1000)	380
SUMMARY				
T	Minimum ELS liquid capacity	m^3	K + P	477.62
U	ELS liquid capacity for 20 weeks slurry storage	m^3	L + O	668.4
V	ELS liquid capacity for 20 weeks slurry and farmyard runoff storage	m^3	L + S + ((((L + S) ÷ 2)) x R x (M ÷ 1000) x 1.1)	1134

Note 1: If farmyard runoff is stored with slurry then it must also be treated as slurry. If storage is required for this liquid stream, then storage in an alternative location such as a dedicated ELS may be advantageous in terms of permitted landspreading times.

Table 11-5 Worked example illustrating how the liquid capacity of an ELS may be calculated (H. Scully, 2005)

12 Appendix 4 Site assessment form

12.1General details

Name and address of applicant:	
Telephone number:	
Fax number:	
Email address:	
PPS number:	
Herd number:	
Name and address of consultant:	
Telephone number:	
Fax number:	
Email address:	
Site location and townland:	
Grid reference:	
Proposed dimensions of ELS:	

12.2Background information

Topographical maps as per planning pack to accompany this application:				YES/NO
Local experience of ELSs (if available):				
Surface water~ Description of surface water features in proximity of the site including designation:				
Geology and Hydrogeology				
Water supply (tick as appropriate):	Mains	Private well/borehole	Group well/borehole	
Soil (name and type):				
Subsoil:				
Bedrock geology:				
Aquifer category (tick as appropriate):	Regionally important	Locally important	Poor	
Groundwater vulnerability (tick as appropriate where available):	Extreme	High	Moderate	Low
Is there a groundwater protection scheme (Yes/No):		***Groundwater protection response for ELS:***		
Presence of significant sites (including reference):	Archaeological:			
	Natural:			
Utilities (locations):		***Safe***	***Needs further investigation***	
Power lines:	Above ground:			
	Below ground:			
Gas mains:				
Sewerage:				
Water mains:				
County development plan:				
No. and type of animals on farm producing slurry:				
Existing slurry storage capacity on farm (slurry storage volume allowing for freeboard, m^3):				
Comments: (integrate the information above in order to comment on the potential suitability of the site, potential targets at risk and/or any potential site restrictions)				

12.3Visual assessment

Slope:	
Density of dwellings, places of gathering within 500m of site (give distance to nearest feature):	
Property boundaries (distance to nearest):	
Roads (distance to):	
Existing land use:	
Outcrops (rock and/or subsoil): Note if any and describe	
Surface water ponding:	
Beaches/shellfish areas/wetlands:	
Karst features:	
Lakes/watercourse/stream*:	
Drainage Systems*:	Open – Piped -
Wells*:	
Springs*:	
Type of vegetation (note any areas of wetland vegetation):	
Cultural heritage assessment (comment on potential risk):	
Natural heritage assessment (comment on potential risk):	
Comments: (integrate the information above in order to comment on the potential suitability of the site, potential targets at risk, the suitability of the site to construct an ELS and the location of the proposed system within the site).	

Note Water Level

12.4 Trial hole

The minimum depth of the trial holes shall be 2.0 m below the lowest level of the proposed ELS.

<table>
<tr><td colspan="2">Trial hole number:</td><td></td><td colspan="2">Date and time of excavation:</td><td></td></tr>
<tr><td colspan="2">Depth of trial hole (m):</td><td></td><td colspan="2">Date and time of examination:</td><td></td></tr>
<tr><td colspan="5">Depth from ground surface to bedrock (m) if present:</td><td></td></tr>
<tr><td colspan="5">Depth from ground surface to water table (m) if present:</td><td></td></tr>
<tr><td>Depth from ground surface (m)</td><td colspan="2">Soil/subsoil texture and classification (note plasticity and dilatancy results)</td><td>Density/ compactness</td><td>Colour</td><td>Preferential flowpaths</td></tr>
<tr><td>0.2</td><td colspan="2" rowspan="25"></td><td rowspan="25"></td><td rowspan="25"></td><td rowspan="25"></td></tr>
<tr><td>0.4</td></tr>
<tr><td>0.6</td></tr>
<tr><td>0.6</td></tr>
<tr><td>1.0</td></tr>
<tr><td>1.2</td></tr>
<tr><td>1.4</td></tr>
<tr><td>1.6</td></tr>
<tr><td>1.8</td></tr>
<tr><td>2.0</td></tr>
<tr><td>2.2</td></tr>
<tr><td>2.4</td></tr>
<tr><td>2.6</td></tr>
<tr><td>2.8</td></tr>
<tr><td>3.0</td></tr>
<tr><td>3.2</td></tr>
<tr><td>3.4</td></tr>
<tr><td>3.6</td></tr>
<tr><td>3.8</td></tr>
<tr><td>4.0</td></tr>
<tr><td>4.2</td></tr>
<tr><td>4.4</td></tr>
<tr><td>4.6</td></tr>
<tr><td>4.8</td></tr>
<tr><td>5.0</td></tr>
<tr><td colspan="6">Other information (where relevant)</td></tr>
<tr><td colspan="3">Depth of water ingress (m):</td><td></td><td rowspan="2">Rock type (if present):</td><td rowspan="2"></td></tr>
<tr><td colspan="3">Sample depth (m):</td><td></td></tr>
<tr><td colspan="3">Compaction test result (visual description):</td><td colspan="3"></td></tr>
<tr><td colspan="6">Evaluation:</td></tr>
</table>

12.5 Laboratory soil test results

Trial Hole	*% Clay*	*Liquid limit*	*Plasticity index*

12.6 Sketch of site

Sketch of site showing measurement to trial hole locations, wells and direction of groundwater flow (if known), proposed store (including distances from boundaries), adjacent structures, watercourses, significant sites and other relevant features. North point shall always be included. (A copy of the site layout drawing shall be used if available)

(Certificate to be typed on Site Assessor's headed paper)

Certificate of completion of site assessment for earth-lined slurry/effluent store

Name of Owner: ______________________________

Address of Owner: ______________________________
____

Address of site: ______________________________
____

Is the site suitable to construct an ELS: YES NO

Depth to bedrock: __________ m

Thickness of liner required: __________ m

Depth to suitable layer for liner: __________ m

Thickness of suitable layer for liner: __________ m

Type of liner (insitu or compacted liner): ______________________

Depth to suitable layers for embankment construction: __________ m

Special Conditions (if any)______________________________
____
____
____

Name of Site Assessor: ______________________________

Address of Site Assessor: ______________________________
____

Site Assessor's signature: ______________________________

Date: ______________
Phone:______________
Fax: ______________

Company Stamp:

(Certificate to be typed on Construction Supervisor's headed paper)

Certificate of completion of earth-lined slurry/effluent store

Name of Owner: ____

PPS No. of Owner: ____

Herd No. of Owner: ____

Address of Owner: ____
____

Address of site: ____
____

Name of contractor: ____

Address of contractor:____
____

I certify that the subsoil-lined slurry/effluent store has been constructed in strict compliance with Department of Agriculture and Food Specification S. 131 and that all requirements of the site assessment report and all planning conditions have been fully adhered to. Furthermore, I certify that I oversaw the construction of the subsoil liner, and certify that the banks of the store are in compliance with BS5502 part 50 and that the store is of suitable construction to remain in a leak tight nature for a minimum of 20 years.

Planning Ref: ____________________________

Name of Construction Supervisor:____

Address of Construction Supervisor:____
____

Professional Body Membership No. (if applicable):______________

Construction Supervisor's signature: ______________________

Date: ____________________

Phone: ____________________

Fax: ____________________

Company Stamp:

13 Appendix 5 Worked example

Note: This example concerns an ELS which was constructed in November 2000 in Teagasc Grange Research Centre for the purposes of research (Scully et al., 2004). Intensive monitoring of the ELS in terms of its environmental sustainability and operation have been conducted and research into the efficacy of constructed subsoil liners were evaluated. Therefore the construction of the store differs slightly from the Department of Agriculture and Food Specification (S131). The store at Grange is operating successfully and the results of the research programme utilised in the formulation of the Specification. ELSs shall be designed and constructed according to S131.

13.1General details

Name and address of applicant:	
Telephone number:	
Fax number:	
Email address:	
PPS number:	
Herd number:	
Name and address of consultant:	
Telephone number:	
Fax number:	
Email address:	
Site location and townland:	
Grid reference:	(Irish Grid) 288795.23, 252221.69
Proposed dimensions of ELS:	(detailed in design below)

13.2Background information

<table>
<tr><td colspan="5">Topographical maps as per planning pack to accompany this application:</td><td>YES</td></tr>
<tr><td colspan="4">Local experience of ELSs (if available):</td><td colspan="2">Design and construction of a number of ELS systems</td></tr>
<tr><td colspan="4">Surface water~ Description of surface water features in proximity of the site including designation:</td><td colspan="2">Small stream ~ 200 m uphill of site</td></tr>
<tr><td colspan="6">Geology and Hydrogeology</td></tr>
<tr><td rowspan="2">Water supply (tick as appropriate):</td><td>Mains</td><td colspan="2">Private well/borehole</td><td colspan="2">Group well/borehole</td></tr>
<tr><td></td><td colspan="2">Private well</td><td colspan="2"></td></tr>
<tr><td>Soil (name and type):</td><td colspan="5">Ashbourne Series (Soil Survey), Gley</td></tr>
<tr><td>Subsoil:</td><td colspan="5">Glacial till</td></tr>
<tr><td>Bedrock geology:</td><td colspan="5">Lucan formation limestone (Calp)
Dinantian Upper Impure Limestones (DUIL)</td></tr>
<tr><td rowspan="2">Aquifer category (tick as appropriate):</td><td>Regionally important</td><td colspan="2">Locally important</td><td colspan="2">Poor</td></tr>
<tr><td></td><td colspan="2">Lm</td><td colspan="2"></td></tr>
<tr><td rowspan="2">Groundwater vulnerability (tick as appropriate where available):</td><td>Extreme</td><td>High</td><td colspan="2">Moderate</td><td>Low</td></tr>
<tr><td></td><td></td><td colspan="2"></td><td>Low</td></tr>
<tr><td>Is there a groundwater protection scheme (Yes/No):</td><td>Yes</td><td colspan="3">Groundwater protection response for ELS:</td><td>R1</td></tr>
<tr><td rowspan="2">Presence of significant sites (including reference:</td><td>Archaeological:</td><td colspan="4">None within the site area or within any significant proximity</td></tr>
<tr><td>Natural:</td><td colspan="4">None within the site area or within any significant proximity (Rathmoylan esker is approx. 2km distant)</td></tr>
<tr><td colspan="2">Utilities (locations):</td><td colspan="2">Safe</td><td colspan="2">Needs further investigation</td></tr>
<tr><td rowspan="2">Power lines:</td><td>Above ground:</td><td colspan="2">Safe</td><td colspan="2"></td></tr>
<tr><td>Below ground:</td><td colspan="2">Safe</td><td colspan="2"></td></tr>
<tr><td colspan="2">Gas mains:</td><td colspan="2">Safe</td><td colspan="2"></td></tr>
<tr><td colspan="2">Sewerage:</td><td colspan="2">Safe</td><td colspan="2"></td></tr>
<tr><td colspan="2">Water mains:</td><td colspan="2">Safe</td><td colspan="2"></td></tr>
<tr><td colspan="2">County development plan:</td><td colspan="4">Have consulted county council</td></tr>
<tr><td colspan="6">Comments: (integrate the information above in order to comment the potential suitability of the site, potential targets at risk and/or any potential site restrictions)
The presence of both gley soil and low vulnerability suggest that the site is underlain by thick low permeability material. Therefore groundwater is likely to be well protected and the subsoil is likely to be suitable for an ELS.
After conducting a detailed desk study, it is the opinion of the assessor that the site is potentially suitable for construction of an ELS. Visual assessment is recommended.</td></tr>
</table>

13.3Visual assessment

Slope:	Low surface slope
Density of dwellings, places of gathering within 500m of site (give distance to nearest feature):	None
Property boundaries (distance to nearest):	500 m approximately from nearest boundary
Roads (distance to):	>500 m to public roads, site alongside private farm roadway
Existing land use:	Grassland
Outcrops (rock and/or subsoil): Note if any and describe	No outcrops
Surface water ponding:	None observed
Beaches/shellfish areas/wetlands:	None
Karst features:	None
Lakes/watercourse/stream*:	River approx. 500 m from site, small stream approximately 200m uphill of site
Drainage Systems*:	Open - Some at distance from site (usually dry) Piped - Some existing land drains which will be identified and rerouted/blocked
Wells*:	Yes (farm is served by private well but at distance > 1km from site)
Springs*:	None
Type of vegetation (note any areas of wetland vegetation):	Grassland
Cultural heritage assessment (comment on potential risk):	Very low
Natural heritage assessment (comment on potential risk):	Very low. The Rathmoylan Esker is approximately 2 km from the proposed site.
Comments: (integrate the information above in order to comment on the potential suitability of the site, potential targets at risk, the suitability of the site to construct an ELS and the location of the proposed system within the site). The site appears suitable for construction of an ELS. However, particular care must be taken to locate and block /reroute any land drains within the site footprint as per the requirements of S131. Trial hole investigation is recommended.	

**Note Water Level*

Information required to complete Sections 13.2 and 13.3 was collated from site visits, discussion with the client regarding their requirements and a desk study. As part of the desk study, the website of the Geological Survey of Ireland was consulted (www.gsi.ie) to gather information pertaining to the bedrock geology, presence of karst features, aquifer type and vulnerability, presence of source protection areas and groundwater protection schemes (if any). This information has been tabulated below and a map taken from the GSI online web mapping system showing the proposed site location is illustrated in Figure 13.1.

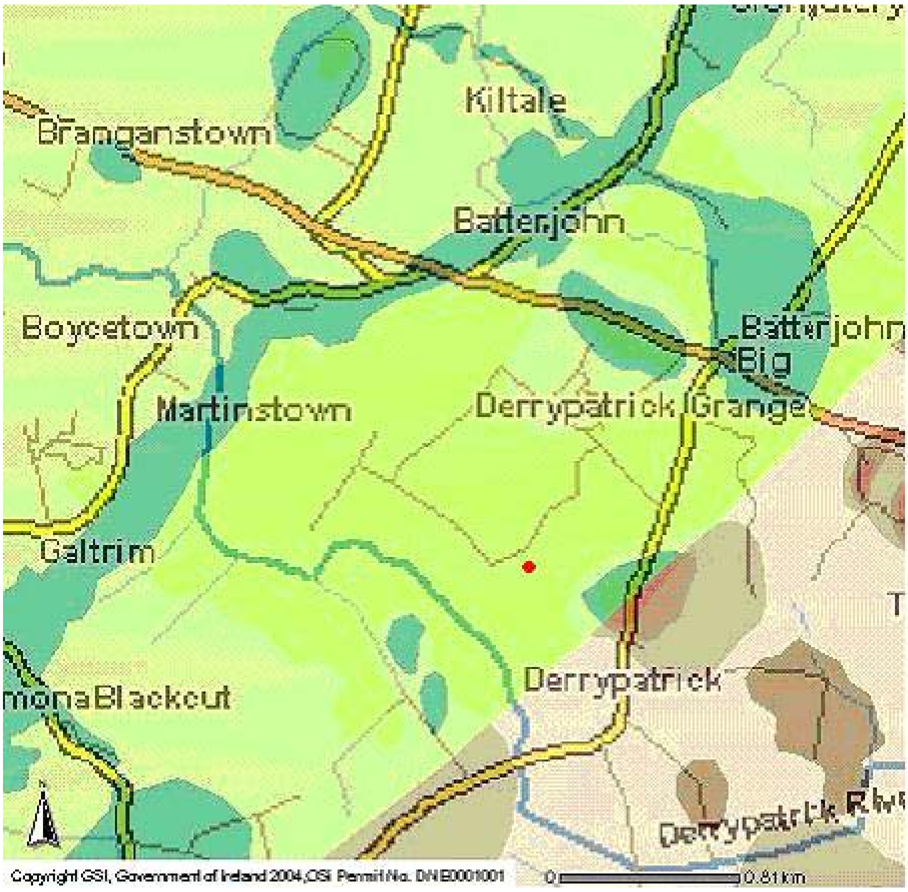


Figure 13-1 Proposed ELS location (adapted from www.gsi.ie)

Bedrock	DUIL	Dinantian upper impure limestones
Aquifer	Lm	Locally Important Aquifer~ Bedrock which is generally moderately productive
Vulnerability	L	
Source Protection Area		
Groundwater Protection Zone	Lm/L	

Table 13-1 Groundwater and bedrock information obtained for proposed ELS site from the Geological Survey of Ireland (www.gsi.ie)

Nearest Borehole Record (from www.gsi.ie)	
Record and ID	1 4509
Borehole Number	GSI-98-124
X	289420
Y	251460
County	Meath
Comp-Bhole	GSI BH-1
Year Month Day	1998 6 17
Angle Azimuth	-1 -1
Length	8.2
OD-metres	-1
Rockhead	Not met
Lith-base Lith-top	Clay Sand

Table 13-2 Details of nearest online borehole record to proposed ELS

(adapted from www.gsi.ie)

The information gathered during this desk study allows the site assessor to characterise a potential site to a very good degree prior to excavation of a trial hole. However, in terms of vulnerability, subsoil type, depth to water table etc. the groundwater information is general and the final arbiter of the suitability of a site for an ELS in respect of these parameters is the information gathered from the trial hole excavation.

13.4Trial hole

Trial hole investigations were conducted at the site in November 2000. Three holes were excavated and the profile assessed. Horizons suitable for compacted subsoil liner construction were identified and subsoil samples taken for laboratory analysis. In general, the trial holes indicated the following underlying environment (depths are approximate):

- 0.2 m to 0.5 m was a clay loam to gravelly clay loam. The soil was slightly plastic and moist. The structure was weak and classified as subangular blocky. The colour was predominantly grey. This soil would not be considered suitable for subsoil liner construction but was considered suitable for embankment construction.
- 0.5 m to 1.0 m was a gravelly CLAY to slightly gravelly CLAY. The subsoil was plastic and moist and could be classified as a glacial till. The structure was massive and very dense. This subsoil would be considered suitable for use as a compacted subsoil liner and subsoil samples were taken for analysis.
- 1.0 m to 2.2 m was a slightly gravelly CLAY. The subsoil was moist, plastic and could also be classified as a glacial till. Indeed, some site assessments would not distinguish between this horizon and the one immediately overlying it. The horizon was considered suitable for use in a compacted subsoil liner and samples were taken for laboratory analysis.
- From 2.2 m to approximately 4.2 m (horizon thickness varied over the three trial holes), a sand/gravel layer was identified forming a confined aquifer (slightly clayey sandy GRAVEL). Under normal circumstances, if such a layer was not overlain by sufficient overburden of suitable subsoil to enable ELS construction in accordance with S131, the site would be considered unsuitable. However, in this particular instance the intensive monitoring of the site was required (for research purposes), so the sand/gravel layer offered an opportunity for environmental monitoring.
- Beneath the sand/gravel horizon, shaley Namurian bedrock was encountered. The rock was finely fractured at this depth but was massive beneath. The trial hole maximum depth was reached at this point.

13.5Laboratory subsoil test results

Trial Hole	***% Clay***	***Liquid limit***	***Plasticity index***
BH-1	19	32	15

Supplementary laboratory results (detailed analysis conducted on Grange subsoil for research purposes)

Natural moisture content:		14%
Grading:	Percentage Clay	17%
	Percentage Silt	12%
	Percentage Sand	40%
	Percent Gravel	28%
Atterberg limits:	Plastic limit	17%
Coefficient of permeability:		2.74×10^{-9} m.s^{-1}
Bulk density:		2.23 Mg.m^{-3}

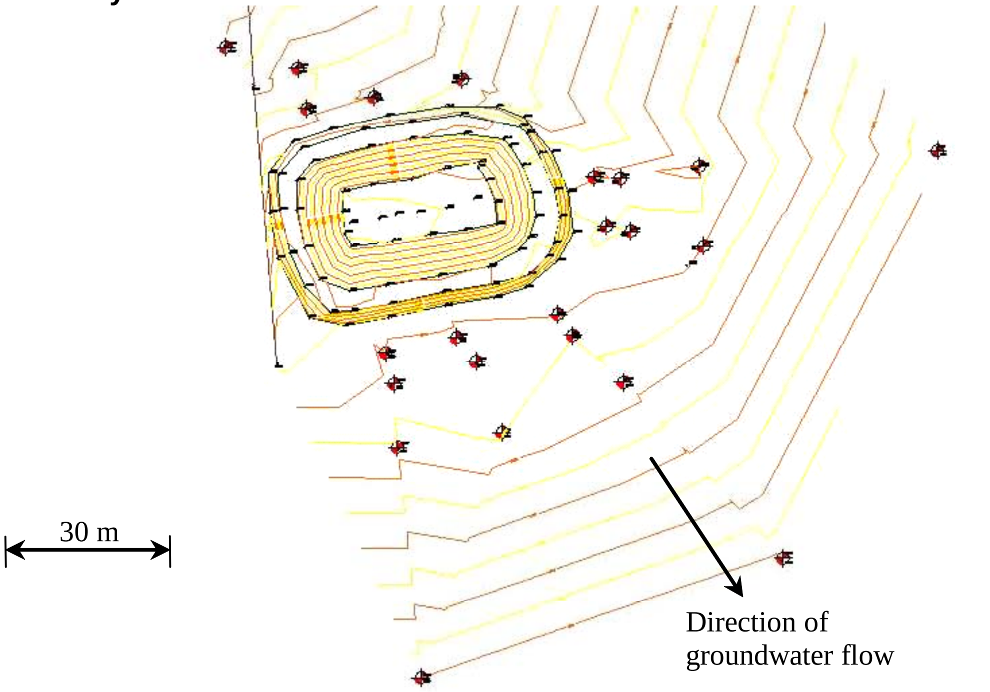
The grading information listed above is taken from a PSD test conducted on the whole subsoil sample. However, 90% of this material passed the 20 mm sieve and therefore the clay percentage is adjusted accordingly (see below).

$$\text{Revised clay \%age} = \text{Original clay \%age x} \frac{100}{\text{\%age of subsoil passing 20 mm sieve}}$$

$$\Rightarrow \text{Revised clay \%age} = 17 \text{ x } \frac{100}{90} = 18.89 \approx 19\%$$

13.6 Sketch of site

A survey of the site of the ELS was undertaken and is shown below:



Note: This survey was carried out after construction to show the topography, store dimensions, piezometer locations and also to enable the store volume to be ascertained.

13.7 Sizing the Grange ELS

13.7.1 Slurry capacity requirement

Because the ELS in Teagasc Grange was constructed for research purposes in November 2000, the method of sizing the ELS was not clearly defined. When the store was constructed a detailed survey of the store site was conducted and the exact store volume determined. The survey showed that the ELS volume was 1950 m^3 in total. This figure included provision for freeboard, slurry storage and rainfall-evaporation volumes. For the purposes of this example, the requirements of the Department of Agriculture and Food Specification (S131) are used to calculate the equivalent slurry storage capacity of the Teagasc ELS.

13.7.2 Precipitation capacity requirement

The ELS is an open store, therefore provision must be made for precipitation onto the surface of the store during periods when the ELS is being used. County Meath is located in Zone B as specified in the latest version of the Good Agricultural Practice for the Protection of Water Regulations (www.environ.ie, 2005). This means that 18 weeks minimum storage is required and that the closed period for livestock manure is from 15 October to 15 January. Current guidance for net rainfall for County Meath is 19 $mm.wk^{-1}$. Therefore the design net rainfall on the ELS is 0.019 x 18 = 0.342 m. This value is used when assessing the design volume of the ELS.

13.7.3 Overall ELS volume

By establishing the slurry, precipitation and evaporation volumes and by factoring in the freeboard requirement, the ELS volume can be calculated. We have already determined the net rainfall depth on store during the closed period to be 342 mm. Referring to specification S131 the following minimum parameters must be adhered to:

Maximum store depth	m	3.75
Minimum freeboard depth	m	0.75
Minimum ground level to top of banks	m	0.6
Maximum inner bank slope	deg	33
Maximum outer bank slope	deg	33
Minimum width of top of bank	m	3.0

Table 13-3 Minimum requirements for ELS (S131, DAF, 2005)

The Teagasc ELS has an overall store depth of 3.0 m so the maximum slurry depth is equal to store depth minus freeboard minus net rainfall = 1.908 m. Because we know the overall store volume is 1950 m^3, it is possible to calculate the slurry capacity of the constructed ELS and equate this to a number of animals by utilising the zoning designation for the site. The values below are a combination of measurements taken at the store site and the minimum requirements of the specification.

Store depth	m	3.0
Net rainfall depth	m	0.342
Inner bank slope	deg	33
Freeboard	m	0.75
Allowable slurry depth	m	1.908
Store base width	m	13.0
Store base length	m	32.0

Table 13-4 Teagasc Grange ELS dimensions

By carrying out simple geometric calculations, the volume of slurry storage available in the constructed ELS can be established and is found to be 1061m^3. The geometric calculation is illustrated in Figure 13.2.

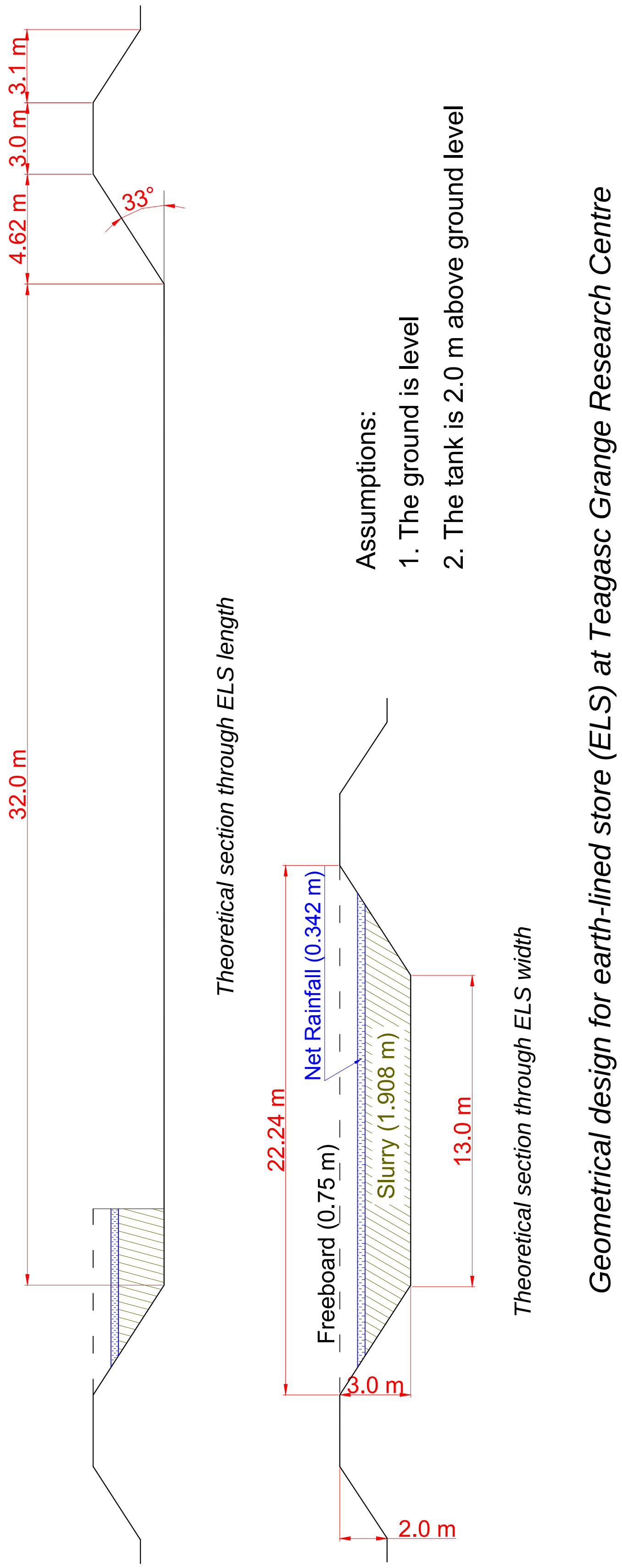


Figure 13-2 Geometrical design for earth-lined slurry/effluent store (ELS) at Teagasc Grange Research Centre (H.Scully)

Figure 13.2 assumes that the original ground is level. This is an acceptable assumption when sizing an ELS but for final design and as-built drawings, the true original ground level (OGL) must be clearly shown. The calculated slurry capacity of the ELS is then used to establish the number of animals equivalent to this storage volume within a specific zoning designation. Teagasc Grange lies within Zone B (County Meath) and the animals producing the slurry requiring storage are beef cattle. Therefore for a storage period of 18 weeks with an animal producing 0.26 $m^3.wk^{-1}$ of slurry (Table 11.1), 1061 m^3 is equivalent to 226 cattle. A summary of the design dimensions and volumes for Teagasc Grange ELS is given below.

Store base width (m)	13.0
Store base length (m)	32.0
Slurry volume achieved (m^3)	1061
Net rainfall volume required (m^3)	255
Total liquid volume required (m^3)	1361
Freeboard volume required (m^3)	634
Top of store width (m)	22.2
Top of store length (m)	41.2
Overall store volume (m^3)	1950
Overall footprint of works (incl. fencing) (m^2)	2016

Table 13-5 Store design calculations for Teagasc Grange ELS

This methodology lends itself very well to earth-lined slurry/effluent store design as liquid and freeboard volumes as well as the likely works footprint can be calculated. By assuming that the store fencing is located at a distance of 1.0 m from the outside of the embankments (as per the S131), an estimate of the fencing requirements can also be made (see Table 13.6 below).

Overall ELS footprint length (excl. fencing) (m)	53.4
Overall ELS footprint width (excl. fencing) (m)	34.4
Distance between embankment outer toe and fence (m)	1.0
Gate diameter (m)	3.5
No. of gates (no)	1
Fencing required (m)	180.1

Table 13-6 Fencing requirements for Teagasc Grange ELS using S131

13.8Subsoil liner design

At this point in the design process the ELS has been sized to suit the needs of the client and the design has progressed to the stage where the dimensions of the ELS have been selected. The next stage in the design is to specify the subsoil liner element of the store.

Underlying aquifer: Not regionally important (Lm)
Vulnerability: Low (L)
GW Response: R1
Clay content: 18.89 %

Design: The trial hole and laboratory analysis shows that there is a minimum depth of 1.5 m low permeability subsoil present at the proposed site location. However, downhill of the proposed site, slightly elevated water table levels were observed. This corresponded to a thin sand/gravel lens logged at a depth of approximately 1.0 m below the proposed store invert. In this situation, the normal design would be to remove the sand/gravel layer during store excavation (if feasible depending on the thickness of the layer) and to ensure that the minimum depth of 1.5 m low permeability subsoil would underlie the store. If necessary, the water table would be lowered by means of a shallow drainage system (Clause C.4, of S.131). The subsoil overlying the sand/gravel lens is impervious and free of preferential flow paths and the clay content is greater than 18%. The subsoil liner design would then proceed in accordance with scenario C (see Figure 13.3 below).

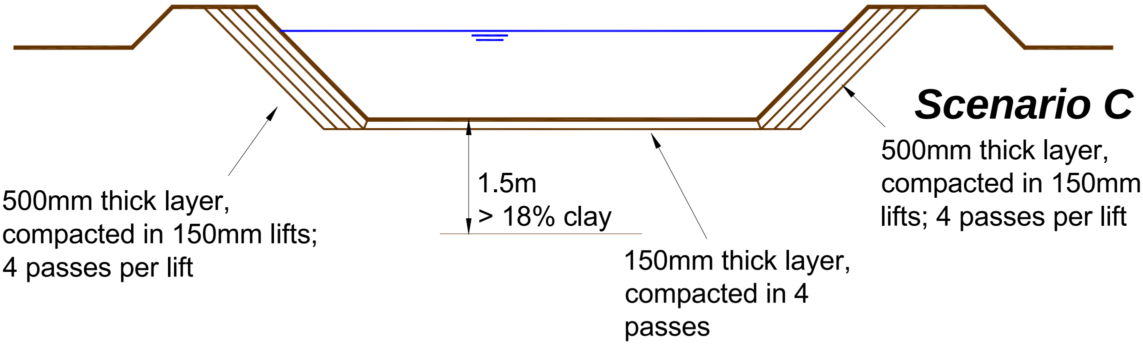


Figure 13-3 Scenario C ELS subsoil liner design (H.Scully)

However, because the ELS at Teagasc Grange was constructed for research purposes, an alternative design scenario was used. As part of the research programme, it was desirable that the groundwater beneath and surrounding the ELS could be monitored. The shallow sand/lens offered such an opportunity. Therefore, the ELS was excavated down to the sand/gravel lens and the overlying subsoil was recompacted using a hydraulic excavator as per Clause C.6 of S.131. The resulting ELS incorporated a compacted subsoil liner component, did not overlie a regionally important aquifer and facilitated the installation of piezometers to monitor and sample groundwater from around and beneath the ELS. Because the area has a history of land drainage, the design also included locating and blocking/rerouting all land drains around the proposed ELS footprint. A picture of the completed store construction is shown in Figure 13.4 below.

Figure 13-4 Teagasc Grange ELS

14 Appendix 6 References

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