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Moorepark Dairy Levy Research Update

Land Drainage - A farmer's practical guide to draining grassland in Ireland

Moorepark Animal & Grassland Research and Innovation Centre
Moorepark'13 Open Day

Wednesday 3rd July, 2013
Series 20

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Teagasc
Agriculture and Food Development Authority

Contents

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Summary

- No drainage work should be carried out before the drainage characteristics of the soil are established by a site and soil test pit investigation.
- Two types of drainage system exist: a groundwater drainage system and a shallow drainage system. The design of the system depends entirely on the drainage characteristics of the soil.
- Distinguishing between the two types of drainage systems essentially comes down to whether or not a permeable layer is present (at a workable depth) that will allow the flow of water with relative ease. If such a layer is evident, a piped drain system at that depth is likely to be effective. If no such layer is found during soil test pit investigations, it will be necessary to improve the drainage capacity of the soil. This involves a disruption technique such as moling, gravel moling or subsoiling in tandem with collector drains.
- Drains are not effective unless they are placed in a free draining soil layer or complimentary measures (mole drainage, subsoiling) are used to improve soil drainage capacity. If water is not moving through the soil in one or other of these two ways, the water table will not be lowered.
- Outfall level must not dictate the drainage system depth. If a free draining layer is present, it must be utilised.
- Drain pipes should always be used for drains longer than 30 m. If these get blocked it is a drainage stone and not a drainage pipe issue.
- Drainage stone should not be filled to the top of the field trench except for very limited conditions (the bottom of an obvious hollow). Otherwise it is an extremely expensive way of collecting little water.
- Most of the stone being used for land drainage today is too big. Clean aggregate in the 10–40 mm (0.4 to 1.5 inch approx) grading band should be used. Generally you get what you pay for.
- Subsoiling is not effective unless a shallow impermeable layer is being broken or field drains have been installed prior to the operation. Otherwise it will not have any long-term effect and may do more harm than good.
- Most land drainage systems are poorly maintained. Open drains should be clean and as deep as possible and field drains feeding into them should be regularly rodded or jetted.

Introduction

Ireland's competitive advantage in ruminant livestock production is based on low cost grass-based systems. Additionally, to achieve the targets set out in the Food Harvest 2020 report there will be a requirement to increase the productivity from these systems. Two thirds of the land area of Ireland is classified as lowland mineral soils, of which one third consists of heavy soils (or poorly drained soils). The proportion of heavy soils various greatly between counties; Cork 14, Tipperary 19, Kerry 26, Clare 37 and Limerick 42 per cent, respectively. The rate of water infiltration on heavy soils is significantly reduced compared to free draining soils, often exacerbated by higher rainfall, resulting in a significant reduction in grass production and utilization. The provision of effective drainage for these soils is essential to enable an effective grass-based system to be planned in a realistic and businesslike manner.

There are many books and internet sources that tackle a wide range of drainage issues, but this short booklet summarises the most appropriate solutions for the specific conditions encountered in Ireland (high precipitation and very difficult soils). As we all know, in some areas of the country our soils and precipitation do not always leave us with perfectly drained fields. This leads to problems in some areas where the soils ability to drain is lower than the amount of water falling onto the soil.

Benefits of improved drainage to a grassland farmer:

The foremost benefits of land drainage are:

- Increased yield and lower production costs
- An extended grazing season
- Reduced surface damage by livestock
- Improved trafficability/accessibility for machinery
- Reduced reliance on supplementary feedstuffs
- Reduced disease risk to livestock
- Better availability of N in soil

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Background

Where is the water moving on and under my farm?

It is important to be aware of the various pathways of water movement in the landscape if the causes of land drainage problems are to be understood. These are best illustrated by referring to the diagrams below and taking a look at the explanations of the different terms provided.

Soil water logging can be caused in many ways

- Where the permeability of the soil or a particular soil layer is low. Permeability is defined as the capability of soil to permit the flow of water through its pore spaces. With low permeability, not all water will easily enter the soil and it will quickly become waterlogged. This signifies a rain fed problem.
- Where the water table is close to the ground surface (either in the valley floor near a river or on a slope) the volume of soil that can store water is small. This signifies a ground water problem.
- Where upward movement of water (seepage or spring lines) saturates the soil

To achieve effective drainage the works will have to solve one or more of these problems and possibly a combination of all three.

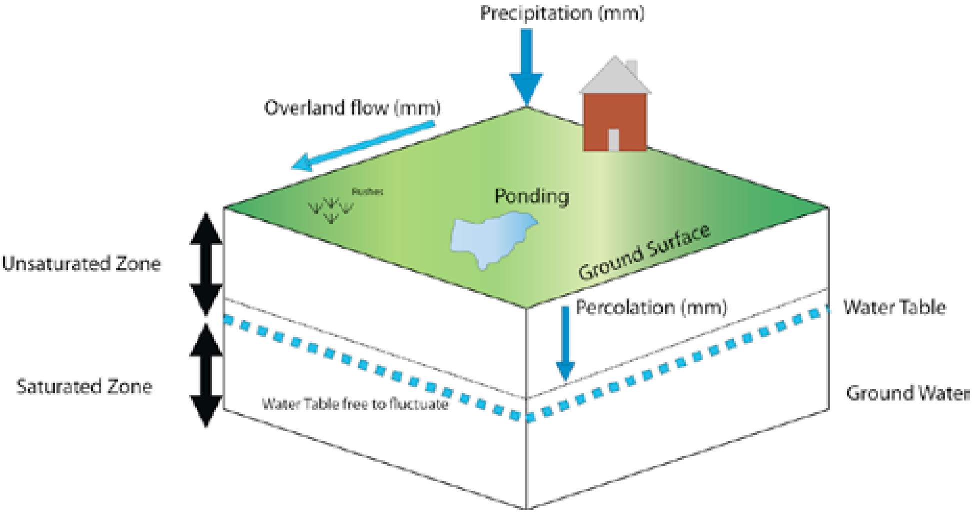


Figure 1. Illustration of the important terms that are explained below and used in the remainder of the booklet

Important terms:

Precipitation: measured in millimetres (mm) (1 inch = 25.4 mm), the amount of water that falls on your farm is an important figure. Together with your soil type, this will tell you a lot about how much water needs to be drained away. Precipitation amounts for different locations are available on the Met Éireann website e.g. daily rainfall (mm)

Overland flow: measured in mm, this is the portion of precipitation that does not contribute to water entering/infiltrating/percolating into the soil, as it literally travels over the land surface. This value changes depending on your topsoil characteristics and drainage class (well, moderate or poor), as well as the rainfall pattern and intensity and field slope. The term runoff is also used but this is where water runs off the land and flows into a river. Overland flow does not need to discharge to a river.

Percolation: measured in mm, is the amount of water that soaks through the soil and is dependent on the soil type and its capacity to drain. Percolation, or effective drainage, is the most important figure for a drainage design as a sub-surface drainage system will siphon off a percentage of this water. The difference between the total rainfall and the sum of evapotranspiration (amount of water that returns to the atmosphere through your grass cover) and overland flow results in the percolation amount. Average annual rainfall in Ireland ranges from about 750-1500 mm, increasing from east to west (excluding mountainous areas). Approximately 500 mm of this will evaporate so the amount to be drained can range from 250-1000 mm. One mm of water to be drained amounts to 10,000 litres/hectare (ha). This must be taken into account during the drainage design phase, as every drainage system has a maximum capacity.

Ground Water: when digging a deep hole in soil sometimes water flows in from the sides at a particular depth. The depth where the water gathers is the water table. Above this point is the unsaturated soil and below this point is the saturated soil. If the water table is within 0.5 m of the soil surface over an extended period, it will create surface problems. Dropping the water table will prevent waterlogging of soil and improve drainage.

A simple rule of thumb with respect to ground water flow direction is as follows: ground water generally flows in the direction of the slope of the land to a stream, spring, lake or sea. On a slope a shallow water table is called a perched water table but you should be aware that there is often another water table deeper down. In a valley floor the water table will be also shallow, as indicated in Figure 2 (red arrows). Drilling for a water supply is generally into deeper ground water and not the perched water table. When the water table is shallow the amount of water the soil can store is small.

A spring: this is where the ground surface and ground water intersect. Springs arise on slopes at the junction of permeable and impermeable layers. Typically, each seepage incident needs a site-specific drainage solution, upslope of the seepage. A spring may appear and disappear depending on the water table height at any one time (See Figure 2).

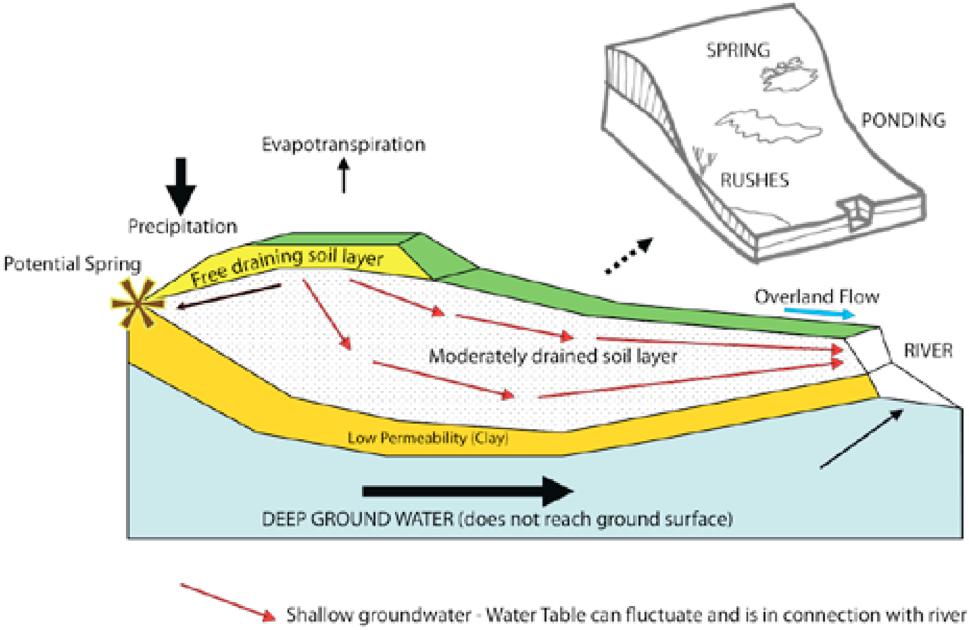


Figure 2. Illustration of how ground water interacts with surface water and the ground surface. It includes a simple sketch showing typical features on moderately to poorly drained land e.g. spring, seepage, ponding and rushes in a shallow water table area

Soil Test Pit and Site Investigation

Introduction

The land drainage problems encountered in Ireland are complex and varied, and a full understanding of the issues involved is required before commencing drainage works. The first step is a detailed investigation into the causes of moderate to poor drainage. At the back of the booklet you will find worked examples (Appendix A-C).

STEP 1 – Look for signs of trouble

Collecting all the information at hand and noting it down will ensure you do not forget important points when considering a drainage design

- Where does the water gather or pond? Where does overland flow occur (if any)? Where does the water flow to? Where are the poorest underfoot conditions? Where are the poorest areas of grass growth? Are there other vegetated areas e.g. water loving plants such as weeds, rushes, thistles?

STEP 2 -Identify your drainage problem with soil test pits

The depth and type of drain to be installed depends entirely on your interpretation of the soil test pit(s). Remember there is no "one size fits all" solution. This information will be valuable when costing and talking with advisors, consultants or potential contractors. The design will no doubt evolve after breaking ground on the day of installation. See back of the booklet for a few examples using annotated photographs (Appendix A).

Locating your soil test pit

- Ideally you should dig a few soil test pits around your site to capture any differences in your soil profile. You are looking for a representative soil profile that best describes your drainage problem. Consider digging a soil test pit in a wet and dry area of the field/farm for comparison sake.

Digging your soil test pit:

- Dig your soil test pits down to approx 2.5 m. It is important to dig your soil test pit in two stages. First dig down to 1 m and wait for a while. This allows shallow seepage to occur if present. Second continue digging to the full depth. If you dig the entire soil test pit in one go, shallow layers could be sealed by the action of the digger. Soil test pits are very dangerous and prone to collapse; you should not enter the soil test pit but instead observe from a safe distance and inspect materials as it comes up in the digger bucket. From the digger bucket take soil samples and use the photographs and Table 3 in Appendix C as a guide to their texture. Take photographs.

The following are things to note after you have dug your test pit:

- Note the depth and thickness of the layers.
- Permeable layers will be indicated by seepage of water into the soil test pit and collapsing layers. All other layers will be less permeable.
- For each layer, consider the soil texture – sand/silt/clay per cent (see Appendix C).
- The presence of visible cracking in the soil profile.
- Depth of rooting, shallow root systems indicate poor drainage.
- Colour of different depths – rich dark brown indicates loam, pale grey indicates gley or water logged soil, black indicates a high organic matter content, orange and grey indicates water movement (washing out and rise and fall of water table). Gley soils occur in all counties and are identifiable by their pale grey colours. A problem here is that some soils are naturally certain colours. Again colours are only indicative and not a definite diagnosis i.e. if you are on shale bedrock the soil may naturally be grey in colour.

It may also help to:

- Walk open drains and inspect the soil profile to look for consistency with your soil test pits. Note any changes to the depths of certain layers e.g. the depth of rock. Remember the different layers are not uniform with perfectly parallel boundaries – these boundaries are mostly wavy in nature.
- Consult soil and bedrock maps of the area available online (Geological Survey Ireland or Teagasc). Remember these maps will be at a much bigger scale than individual fields, and therefore can only provide general information.
- Make yourself aware of previous drainage works on similar soils in the local area. How successful are they? Could they be better? Is there a more efficient way of discharging water from the soil? For example, are permeable layers present? In this way you can learn from the mistakes of others

STEP 3 – Site layout and features

It helps to have more than one person for this step. Sketching and marking out your site is your communication tool with the contractor and therefore you should give this time. (See example in Appendix B)

- Draw a sketch of your problem area (refer to any farm maps that you have to hand) and measure the sides of the field with a measuring tape. Mark these lengths on your sketch. Mark in with arrows the slope of the land noting any large breaks in slope, dips or hollows.
- Mark in any existing field and open drains and the fall direction of the water in them
- Note and sketch any surface water features in the area e.g. tapped springs, streams, rivers, lakes and sea. The site may be tidal.

Drainage Systems

Introduction

All types of agricultural drainage systems are composed of:

- A main drainage system, which receives water from the field drainage system and transports it to an outfall. Typically open drains.
- A field drainage system, which siphons off unwanted water in waterlogged soils and lowers the water level in the field.

There are two main types of field drainage system (see Figure 3):

- *Ground Water drainage system:* a network of piped drains exploiting permeable layers.
- *Shallow drainage system:* where the permeability of the soil is low at all depths and needs to be improved.

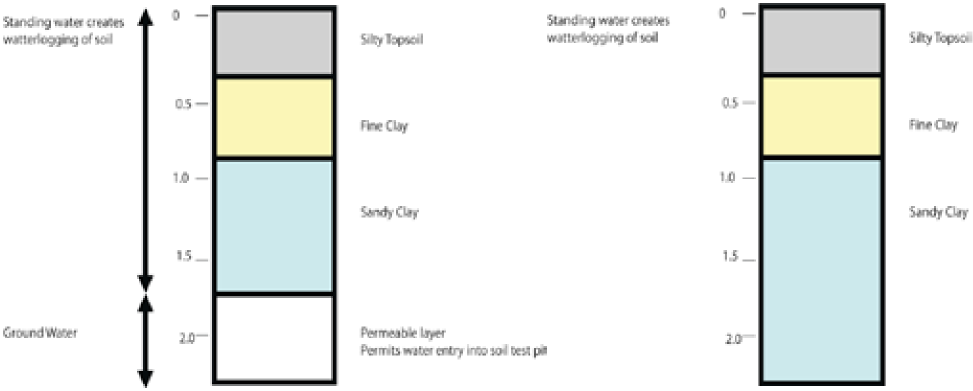


Figure 3. A typical heavy soil profile. (Left-3a) Rule of thumb: if a free draining layer is present (called "permeable layer" here) at any depth then groundwater drainage is the most appropriate solution, if not then shallow drainage (Right-3b) required

A Ground Water Drainage System

Introduction

In soil test pits where there is strong inflow of water or seepages from the faces of the pit walls, this indicates that layers of high permeability are present (See Figure 3). Under these circumstances, the use of a piped drainage system is advised.

Piped drains

The installation of a piped drain at the depth of inflow will facilitate the removal of ground water assuming a suitable outfall is available. This is the most ideal scenario for land drainage. A permeable layer at a workable depth is an opportunity not to be wasted. This type of scenario (Figure 3a) is relatively common throughout the country. As our soils were formed by deposits from melting glacial ice, the heavier coarser particles (sands and gravels) tended to be dropped first followed by the light fine particles (silts and clays). As a result the poorest subsoil can be close to the surface while more permeable layers can be found underneath. If this is evident on parts of your farm, it would be best to focus on these areas first as the potential for improvement is usually very high.

Conventional piped drains at depths of 0.8-1.5 m below ground level (bgl) have been successful where they encounter layers of high permeability. However, where layers with high permeability are deeper than this, deep drains are required. Deep piped drains are usually installed at a depth of 1.5-2.5 m and at spacings of 15-50 m, depending on the slope of the land and the permeability and thickness of the drainage layer. Piped drains should always be installed across the slope to intercept as much ground water as possible, with open drains and main piped drains running in the direction of maximum slope. If you are restricted by outfall depth, the permeable layer should still be targeted with field drains; its potential to discharge water is too great for it to be ignored. Figure 4 shows how the permeable layer can be targeted by digging the field drain to the depth required, backfilling with stone, and placing the pipe at the outfall level. In this arrangement there is still movement of water to the pipe from the permeable layer. Figure 5 shows the arrangement of a pumped outfall. The open drain is dug to the depth of the permeable layer. This acts as a sump for water flowing from the field drains at this level. A small submersible pump activated by a float switch is then used to discharge water from this open drain to the local outfall level. Such pumps are currently retailing at approximately €150 and can be run very cheaply from mains electricity. Their widespread use will depend on the availability of cheap solar power, the technology for which is advancing rapidly. In Figure 5 the level of the base of the trench is lower than the base of the river.

Deep drain installation

Due to the risk of drain collapse, deep drains can be difficult to install. As a means of preventing the drain from collapsing it should be excavated in two stages:

- Initially use a moulding bucket (shape promotes a stable bank) to open the drain to approximately two thirds of the planned final depth. This will allow excess water to soak away.
- When weather conditions allow, the drain should be further deepened by the contractor to the final depth. This can be done using a narrow tile drainage bucket.

While these drains are more difficult to install, they are very cost effective as so few are required due to the large spacing facilitated.

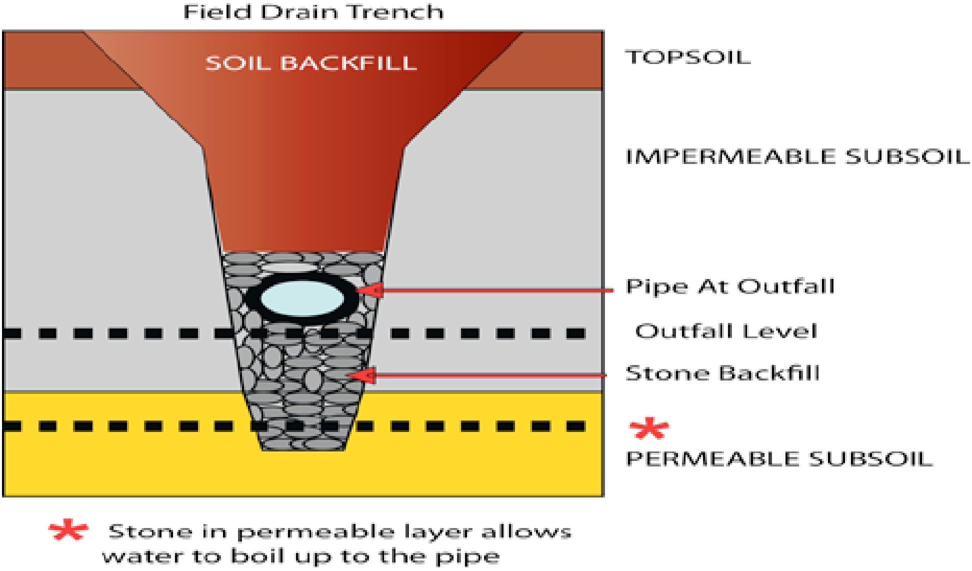


Figure 4. Targeting the permeable layer

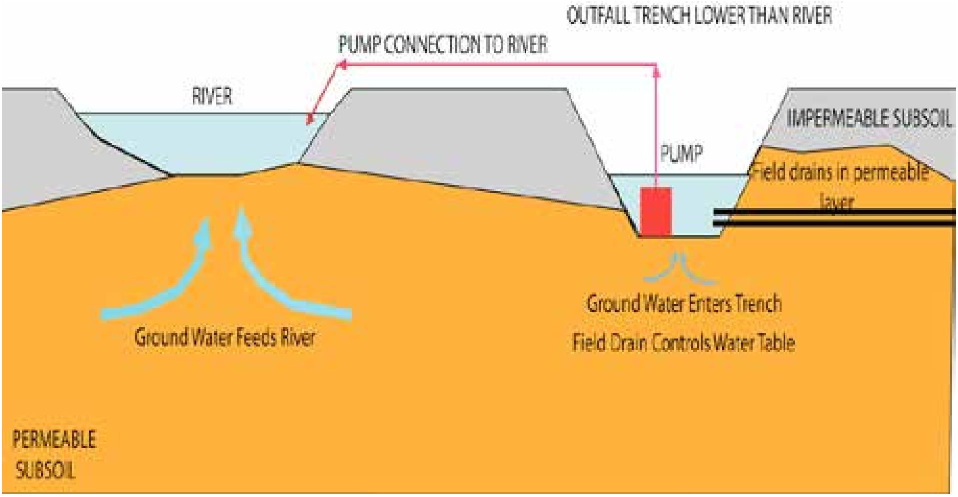


Figure 5. An example of a pumped outfall

Clean aggregate should to be used to surround the land-drain pipe in ground water drains. The gravel should be filled to a minimum depth of 300 mm from the bottom of the drain to cover the pipe. The stone should provide maximum connectivity to a layer of high permeability. It is not necessary or advisable to fill the trench with stone;

water entering the drain does so through the permeable layer, any stone filled above the top of this layer is wasteful. It is a very expensive way of collecting very little water (see section on Drainage Systems Materials for more details). Once piped and adequately stoned, the trench should be backfilled with soil. The soil cover also offers a natural protective layer minimising nutrient loss through the drainage system.

Having tapped into the permeable layer, the drain will be discharging water throughout the year, even in dry summer conditions. This will lower the water table and will allow for natural (cracking, root penetration and biological activity, etc.) or artificial (sub-soiling/ripping, etc.) improvements in permeability in the shallower layers over time, thereby facilitating surface drainage.

Groundwater seepage and springs

The drainage of seepage and springs will require an interceptor type of ground water drainage. Again, the key is getting deep enough to intercept the flow where it is moving through permeable layers above the point where it is boiling out to the surface and saturating a large area. Pipe drains are most effective in or on the layer transmitting ground water flow (characterised by high water breakthrough in the soil test pit). This issue is very site specific.

A Shallow Drainage System

Introduction

Where a soil test pit shows little ingress of water at any depth a shallow drainage system is required. These soils that have no obvious permeable layer and very low permeability throughout are more difficult to drain. Shallow drainage systems are those that aim to improve the capacity of the soil to transmit water, these include mole drainage, gravel mole drainage and sub-soiling. The aim of these drainage techniques is to improve permeability by fracturing and cracking the soil and to form a network of closely spaced channels.

Mole Drainage

Mole drainage is suited to soils with high clay content, which form stable channels. Mole drains are formed with a mole plough comprised of a torpedo-like cylindrical foot attached to a narrow leg, followed by a slightly larger diameter cylindrical expander. The foot and trailing expander form the mole channel while the leg creates a narrow slot that extends from the soil surface down to the mole channel depth. A typical mole plough has a 7-8 cm diameter foot, an 8-10 cm expander and a leg adjustable to depths of up to 60 cm (24 inches).

The success of mole drainage depends on the formation of cracks in the soil that radiate from the tip of the mole plough at shallow depths as the soil is displaced forwards, sideways and upwards. Below a critical depth, dependent on soil mechanical strength and mole plough geometry, the soil flows forwards and sideways, bringing about compaction at the foot of the plough. Thus the action of the mole plough creates both a zone of increased permeability adjacent to the mole leg (shallower depths) and a channel for water conveyance and outflow at moling depth. The mole drains should be spaced 1.0 to 2.0 m apart.

Figure 6: Mole plough showing foot and expander

Gravel-Mole Drains

Gravel filled moles employ the same principles as ordinary mole drains but are required where an ordinary mole will not remain open for a sufficiently long period to be economical. This is the case in unstable soils having lower clay content. The mole channel is formed in a similar manner but the channel is then filled with gravel which supports the channel walls. The gravel mole plough carries a hopper that has a hydraulically operated shutter to control the flow of gravel; the gravel chute also has an adjustable door that regulates the height of gravel in the mole channel. During the operation, the hopper is filled using a loading shovel or alternatively a belt conveyor from an adjacent gravel cart.

A typical gravel mole plough has 8 cm diameter leading foot and can install channels to depths of up to 50 cm (18 inches). Gravel mole drainage channels are spaced slightly wider apart at 1.5 to 2.0 m. Gravel moles require a very specific size range of gravel aggregate to ensure that they function properly. Washed aggregate within a 10-20 mm size range should be used.

Figure 7. Gravel mole plough showing hopper

Collector Drains

A well laid piped collector system is essential as an outlet for mole and gravel mole channels. The collector drains are installed across the slope of the field before mole ploughing. They should be 0.75-1.0 m deep and spaced at 15-40 m for mole drains and 20-60 m for gravel mole drains depending on soil type and slope. Stone backfill should be filled to within 25 cm (10 inches) of the surface to ensure interconnection with the mole channels. It must be a clean aggregate and which may be any size within a 10-40 mm grading band approx, greater detail is available in section Drainage System Materials. The nature of mole and gravel mole channels is such that they will breakdown over time (5-20 years) and the implementation of a robust collector drain network will allow for the operation to be repeated.

Sub-soiling

Sub-soiling and pan busting are very closely related. Pan-busting can refer to the breaking of a distinct iron pan (or other cemented layer) while sub-soiling usually refers to a more general loosening of the soil body. They provide another alternative method of improving permeability. The implement used is less refined than the mole plough and execution can be less precise. No attempt is made to form a stable channel and shattering the soil is the principle objective.

These methods are more successful where impermeable soil does not extend to depth in the profile but instead exist as layers, within reach of the surface. In this case a general loosening or breaking of an iron or plough pan may be sufficient to relief excess water. Like the mole drainage techniques, effectiveness may decrease progressively over time. Soil compaction can return to previous levels and pans can reform. Nevertheless this is a low cost technique that needs to be repeated over time. Sub-soiling can also be used in tandem with mole or gravel mole drainage in very hard and compacted soils. If carried out pre-moling, it can help bring about the desired cracking, which may not be possible using only the mole plough. In the case of gravel moling in particular, sub-soiling at 1 m spacing can facilitate gravel moles at 2 m, thereby reducing cost.

Figure 8. Single leg Sub-soiler

Successful installation

In areas of particularly high rainfall, the shallow drainage systems will have to cater for large water volumes. Capacity is improved by increasing the density of disturbance (reducing the spacing or incorporating a supplementary measure such as sub-soiling pre-moling), reducing the spacing of collector drains, isolating the site with open drains to reduce runoff from adjacent areas and maintenance of collectors and outfalls.

The effectiveness of the techniques described above depends on the extent of fissures and cracks formed during installation. The development of sufficient cracking is highly dependent on soil moisture content. The ideal time for carrying out shallow drainage is during dry summer conditions, as this will cause maximum cracking in the upper soil layers as well as improving traction and minimising wheel-spin on the soil surface. Care should be taken not to work soils under wet conditions as this can be counter-productive. The desired shattering of the soil will be replaced by smearing, which has the effect of reducing drainage capacity.

Opening and deepening of existing open drains, maintenance of existing field drains and the installation of collector drains will aid the drying process and facilitate shallow drainage installation when the opportunity arises.

Miscellaneous Drainage Issues

Land Forming

In all soil types, the removal of surface water should not be inhibited. This will occur both by overland flow and horizontal flow in the uppermost soil layers. All small differences in elevation should be eliminated to ensure a continual slope from all points of the field to an open drain. Land forming will be particularly useful in the drainage of heavy soils in high rainfall situations as overland flow will be more pronounced. Where large quantities of soil need to be moved, it is best to strip topsoil from the affected area and grade the subsoil before reinstatement of topsoil. Remember to adequately spread soil from upgraded open drains; often soil left adjacent to open drains will cause the greatest problem. Poorly planned passageways are also a common culprit in ponding surface water.

Peat drainage

The drainage of peat is not dealt with specifically in this booklet. There are two reasons for this:

1) The drainage of peaty ground will depend on what underlies the peaty layer, a lot of peat soils are reasonably drainable employing the same techniques described elsewhere in this booklet.
2) The drainage of deep peat is generally a more long term project and will need to employ a more long term approach.

While acknowledging this, it is accepted that some peats are worth draining, while others will never meet the trafficability requirements of agricultural purposes. Where peat has been successfully drained, the nature of the peat itself has been changed by the removal of water to a point where it will not “wet up” to the same extent again. If the peat is shallow, then the techniques above can be used to bring about improvements in the subsoil, thereby dropping the water table, this may involve a ground water system, mole drainage or the breaking of an iron pan. Deep peat must be reclaimed in a staged manner. Land forming and shallow open drains will discharge some excess water; when this has happened, a network of closely spaced (4-5 m) piped drains supplemented by gravel mole channels may be needed. This intensity of drainage will be expensive and will need to be carefully planned. Practical issues will also present problems due to the low bearing capacity of the peat, these include, sinking of the drains and inability to support the traffic required for the drainage operation. Polythene strips have been used in the bottom of peat field drains as a method of supporting the pipe and drainage stone, while tracked machinery is probably the only option where trafficability is extremely limited.

Drainage System Materials

Introduction

The quality of the drainage system will be largely dependent on the quality of the materials used. There are a diverse range of options available in terms of both drain pipe and the accompanying stone, and indeed some options which go without a pipe or without stone entirely. The following sections aim to highlight the importance of these materials and why careful consideration must be given to choosing the right materials for the job in question.

Drain Pipe

The purpose of a drain pipe is to facilitate a path of least resistance for water flow. In long drain lengths (greater than 30 m) a drain pipe is vital to allow as high a flow-rate as possible from the drain, stone backfill alone is unlikely to have sufficient flow capacity to cater for the water volume collected. Only short drain lengths (less than 30 m, or the upstream 30 m of any drain) are capable of operating at full efficiency without a pipe.

The number one reason people give when asked why they went without a pipe is that they have had countless experiences of pipe blockages. Unfortunately the process which has blocked the pipe in the past will also block the stone only drain now, except in a much shorter time. Blockages are an occupational hazard in land drainage, they can be minimised by choosing a smaller stone type to act as a better filter (next section), or removed by consistent maintenance (see section on Maintenance of the Drainage System). Going without a pipe is not a solution.

The type of pipe used has progressed over the years from clay tiles to the plastic piping that dominates today, various incarnations of each can be found on most farms. The driving factors in the evolution of the pipe have been cost, labour efficiency and fitness for purpose. Under these headings the low cost, lightweight and durability provided by the standard corrugated perforated PVC pipe will always win out. This pipe comes in a range of diameters suitable for most field drainage scenarios and performs strongly when installed correctly.

Pipe size depends on the amount of flow to the pipe which is determined by the expected rainfall, the land area serviced by the drain, the fall in the pipe, pipe material and soil permeability. Table 1 gives an indication of the area drained by a range of pipe sizes. The area you drain with one pipe is calculated as the pipe length multiplied by the drain spacing. The pipe can be sized to drain the area required using Table 1.

The following assumptions are made;

- Corrugated plastic pipe
- Pipe slope of 1 in 200
- To drain 10 mm day-1
- A 25 per cent loss in capacity due to sedimentation is allowed for

Table 1. Land area drained by varying pipe sizes

Pipe size (mm)	Pipe size (inch)	Area drained (acre)	Area drained (hectare)
50	2	0.6	0.24
65	2.6	1.2	0.49
70	2.8	1.6	0.65
80	3.1	2.3	0.93
100	3.9	3.3	1.34
110	4.3	5.6	2.27

A new type of pipe has emerged in recent times. These pipes are supplied with a pre-installed filter wrap material and are designed to be used without stone. These pipes are manufactured to a similar standard as those already discussed. A drainage pipe without stone is limited however as the water must follow a more arduous path to the pipe and the effective size of the drain is reduced, the filter material is also prone to clogging. The filter wrap is a poor replacement for good drainage stone (described next). The use of such pipes is limited to especially peaty ground which cannot support traffic carrying stone backfill, as a first step in long-term program of peat reclamation

Drainage stone

Good quality drainage stone is a vital part of any drainage system. The drainage stone has many functions:

- It acts as a connector, connecting the drain pipe to permeable layers in the subsoil, mole channels, sub-soiling cracks, spring lines or existing drains as the case may be.
- It acts as a hydraulic medium, permitting easier inflow of water to the pipe
- It acts as a filter, preventing the entry of fine particles into the pipe
- It acts as bedding, supporting the pipe and preventing damage or collapse

When deciding on the size of stone to be used it is important to consider these aspects. If the stone is too small it will have insufficient permeability to provide for an adequate connection or water movement. If it is too large it loses its filtering capabilities and presents handling problems and may damage the pipe when installed. The material needs to be robust and must not deteriorate after installation. Given these considerations the size of stone generally specified for land drainage is in the 10-40 mm (0.4-1.5 inch approx) grading band, and must be clean and free from waste material. Gravel moles require clean pea gravel in the 10-20 mm (0.4-0.8 inch approx.) grading band. Get to know the grade and quality of what is available at local quarries. The quarry owner is always keen to supply the material he has the most of at a given time, but this may not always be suitable for land drainage. Shop around and remember you generally get what you pay for.

Backfill

When considering backfilling options it is worth remembering the main function of the drainage stone used: a connection from the permeable layer (ground water drainage) or mole drains/sub-soiling cracks (shallow drainage) or spring lines. Therefore, any drainage stone filled above the point where the connection has been made is a waste of stone. It should be filled to a point where these connections have been made and no more (see Figure 9a and b). In ground water systems, the gravel should be filled to a minimum depth of 300 mm from the bottom of the drain to cover the pipe. Stone backfill for mole channel collectors should be filled to within 250 mm of the surface to ensure interconnection with the mole channels.

Any stone filled above this point is very costly and will collect very little water in normal conditions. Drainage stone filled to the surface is excusable in some scenarios where distinct surface ponds are being tapped to an outfall, but even then they should not be filled with stone along their whole length. In this case a blind inlet (Figure 9c) is used to allow surface water to flow directly to a drain pipe. The rest of the pipe can be wrapped in stone but not filled to the surface.

Remember drainage stone accounts for the bulk of the cost in most drainage schemes, it is important therefore to use the stone as efficiently as possible and to avoid waste. The width of the drainage bucket used will be a major factor in the total amount of stone required.

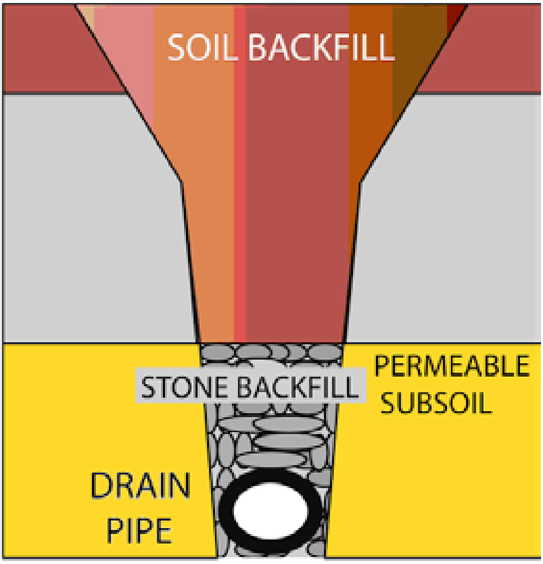


Figure 9a. Connection with permeable layer

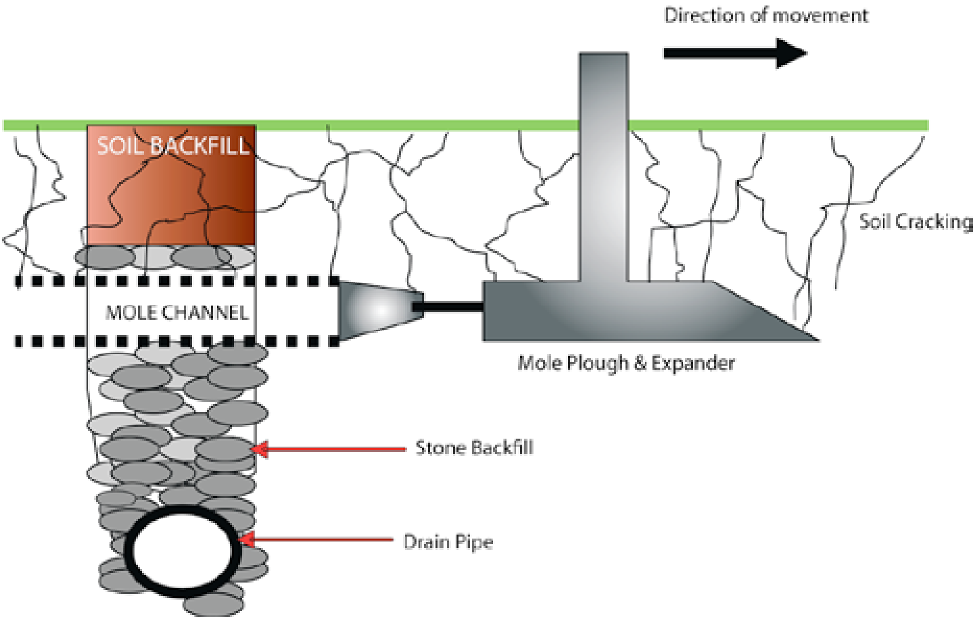


Figure 9b. Connection with mole channel

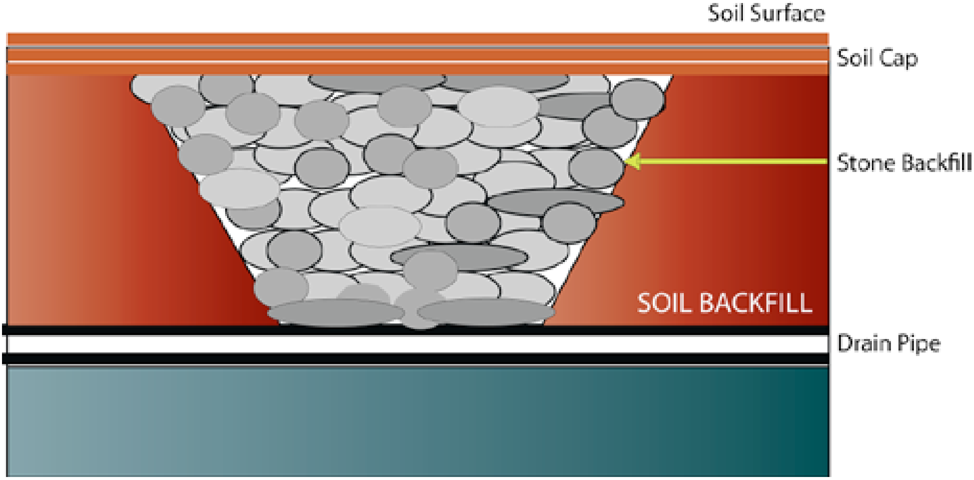


Figure 9c. Example of a blind inlet with thin soil cap

The soil removed from field drains can be spread over adjoining land, filling depressions if of suitable quality. Otherwise it may be buried by stripping back topsoil and filling before reinstating topsoil or removed to waste-ground. In any case, flow of surface water must not be impeded.

Drainage Plan & Installation Checklist

Introduction

Once the site conditions and suitable drainage system have been decided upon it is important to record as much detail as possible. On the template provided (see Appendix B) fill in all your details. Include proposed spacings, depth, pipe and stone size required as well shallow drainage type, spacings and depths as needed.

Managing the contractor

Before installation

- Get references from other people about previous work
- Get quotes where possible using your drainage plan.
- Sit down with your contractor and go over the drainage plan.
- Check drain plan and ensure it is properly marked out in the field. Matching stakes at the start and end of a drain should be colour co-ordinated and marked on a sketch.
- Walk the site with the contractor and explain the marking system of drains that is in place
- Check all materials and equipment (e.g. grade of pipe, gravel diameter, digger buckets, shallow drainage implements etc.)

During installation

- Open main drains should be installed/up-graded first, then in-field drains and finally cross cutting field drains e.g. mole drains.
- Start the operation from the downstream end of the site and work upwards to the upstream part. This will also discharge water away from the drainage works.
- Check materials to ensure no damage to pipes has occurred.
- Constantly check levels. In some cases gravel infill may help correct final levels.
- For mole drains, gravel mole drains or sub-soiling, ensure suitable depth is being achieved and spacing is as planned.
- Consider using a sediment trap at the point of water exit from your site, this sediment can be slacked back onto the field afterwards. Sediment lost from the drainage system as it settles will prevent full efficiency in your open drains.

After installation

- For pipe drains inspect the entire installation (pipes, gravel, joints and levels) before backfilling of trench.

After backfilling

- Ensure that the soil backfill is not compacted afterwards to prevent local drainage problems. Instead let the backfill settle naturally.
- Over time, inspect the drain discharge points to ensure water exits the system.

Maintenance of the Drainage System

Introduction

Every drainage scheme is only as good as its outfall. Cleaning and upgrading of open drains acting as outfalls from land drains is an important step in any drainage scheme. Before commencing land drainage the proposed outfall should be assessed and where necessary upgraded. Open drains, running in the direction of maximum slope, should be established to a great a depth as possible. This will maximise the potential for land drainage, with associated benefits. Soil from such works, where suitable, can be spread over the adjoining land filling depressions and should not impede surface runoff (overland flow directly to a watercourse). Unsuitable soil should be buried and covered with topsoil or removed to waste ground. Sediment traps are advisable during installation to prevent sediment build up which decreases the efficiency of your drain. When installing drainage systems, their future maintenance should be a consideration. In this regard piping of existing open drains, over elaborate networks and use of junctions should be avoided where possible.

Figure 10. Examples of old and blocked pipes

Drain outlets should be regularly cleaned and maintained especially if open drains are cleaned/upgraded as this may result in blockages at the drain outlet. The use of a concrete or un-perforated plastic pipe over the end of the drain pipe, minimum 1 m in length, will protect the outlet from damage and will make locating and maintaining it easier.

Pipes are easily cleaned using drain jetters (Figure 11) where available. These are specially designed high pressure hoses which are fed up the drain pipe from the outlet. The water pressure removes any dirt, sediment or iron deposits from the pipe and its perforations. The technique is very simple and very effective in rejuvenating underperforming drainage systems. The equipment is becoming more popular and most parts of the country are now serviced by suitably equipped contractors (this is another advantage of a piped system; pipeless drains do not facilitate such maintenance). In the absence of such equipment, simple rodding may relieve minor blockages, often found close to the pipe outlet.

Figure 11. Drain jetter and blockage due to iron ochre

Indicative Costs

Introduction

The cost of drainage works will vary depending on such factors as soil type, site access, extent of open drains, availability/cost of backfill stone, and experience with drainage works among other factors. As such, costs are quite variable and will be specific to a particular job. Table 2 provides guidelines only. Cost for the provision of open drains is not included.

Table 2 covers as far as possible the general arrangements available. Where a shallow drainage system is considered, the price will depend largely on the collector drains required. If an existing drainage system of closely spaced piped drains is already in place at the appropriate depth, it may be possible to pull mole drains through this existing network or from an existing open drains. In this case, the cost of mole drainage can be very cost effective. Where a collector system needs to be installed the total cost will be higher.

It is of utmost importance that the selection of a drainage system for a particular site is not decided on the basis of cost. An effective drainage system should be designed and costed and then a decision made as to whether or not to proceed. It is important to remember that the closer the drain spacing the higher the cost.

Table 2. Approximate costs of drainage systems

Drainage System	Drain Spacing (m)	Depth (m)	Cost/m (€)	Cost/ Acre (€)	Cost/ hectare (€)
Piped drainage system					
Conventional system – (costly and ineffective)	8	0.8 - 1.5	5-7	2500-3500	6200-8600
Ground water drainage	15 - 50	1.0 - 2.5	8-11	1500-2500	3700-6200
Shallow drainage system					
Mole drainage	1 - 1.5	0.45 - 0.6	-	50	125
Gravel mole drainage	1 - 1.5	0.35 - 0.5	-	600	1480
Collector drains	20	0.75 - 1.0	5-7	1000-1400	2500-3500
Collector drains	40	0.75 - 1.0	5-7	500-700	1200-1700
Collector drains	60	0.75 - 1.0	5-7	350-450	800-1150

Other Considerations

Introduction

Drainage work must comply with the Environmental Impact Assessment legislation as outlined below.

Compliance with Environmental Impact Assessment (EIA) Legislation

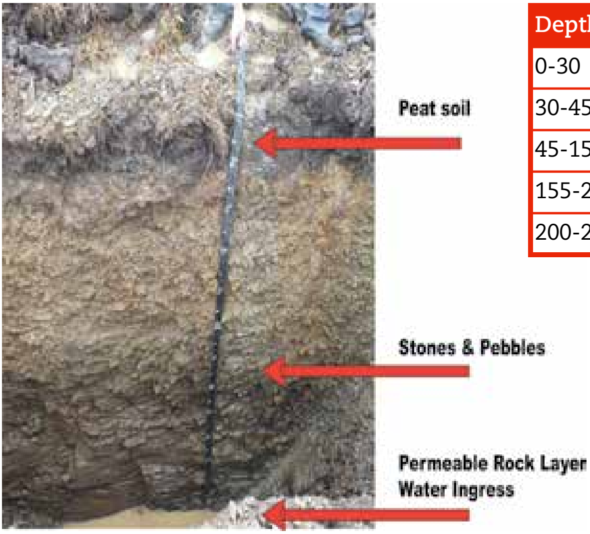
Land drainage works on lands used for agriculture is covered by the EIA Regulations and is controlled by Department of Agriculture Food & Marine (DAFM). Such drainage works include the following:

- Installing open drains.
- Installing field drains (not open) such as those using plastic pipe with drainage stone or field drains with drainage stone only or mole drains (no pipe or drainage stone) or gravel filled mole drains (no pipe but filled with gravel)
- Opening of a short distance of watercourse.
- For the purposes of the Regulations the area will be considered to be the area of works (drains plus immediate vicinity) rather than the area of the field.
- Screening by DAFM is required where drainage work exceeds 15 ha.
- The thresholds will be the areas of works undertaken in any one year or the sum of such areas over a five year period, beginning on the 8th September 2011.
- Further details at: http://www.agriculture.gov.ie

Appendix A
EXAMPLES OF SOIL TEST PIT PROFILES

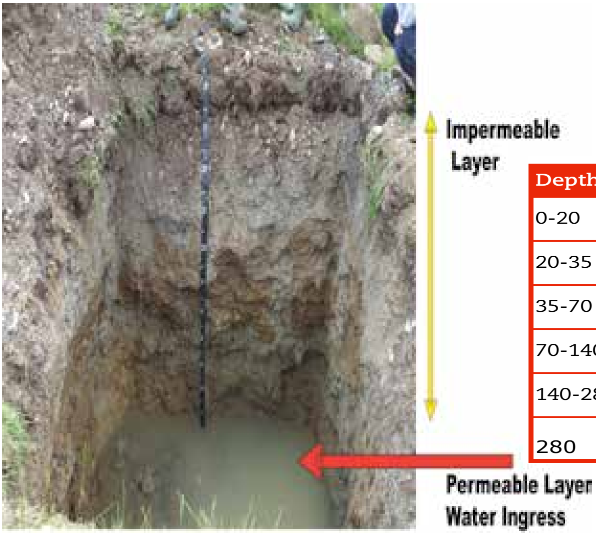
Photo examples of permeable layer with water Ingress:

Peat soil with shallow bedrock and water ingress evident in soil test pit



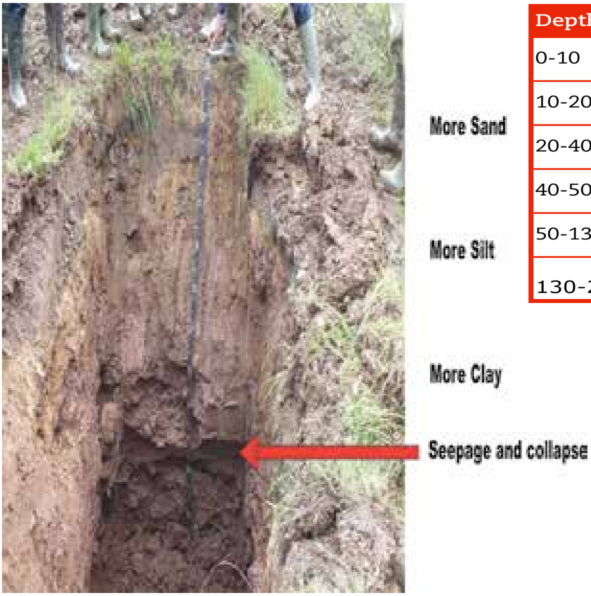
Depth (cm)	Description
0-30	Peaty topsoil
30-45	Yellowish Layer
45-155	Lots of stones & pebbles
155-200	Permeable shale rock
200-250	Less permeable shale rock

Impermeable layer overlying a permeable layer with obvious water ingress



Depth (cm)	Description
0-20	Top soil layer (silt and clay)
20-35	Gravel & stones
35-70	Heavy layer
70-140	Heavy layer with orange and grey colours
140-280	Seepage of water
280	Rock

Increasing clay content with depth increasing underlain by a permeable layer that is obvious due to soil test pit collapse.

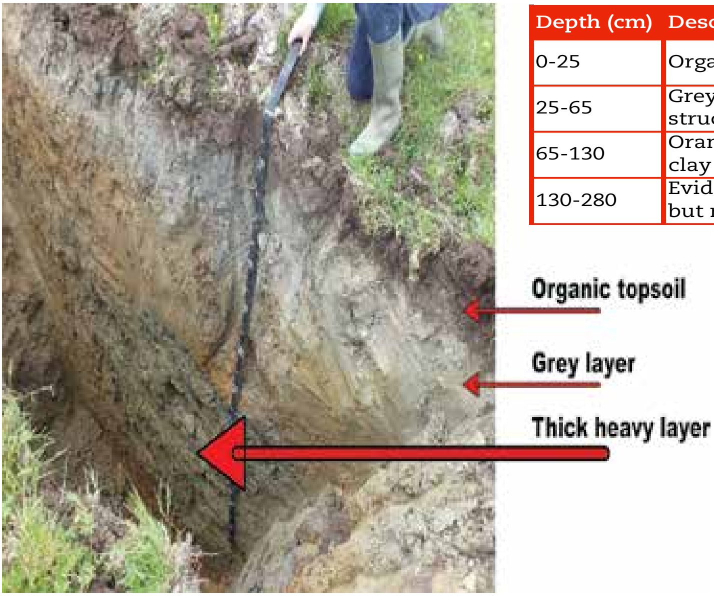


Depth (cm)	Description
0-10	Dark organic rich topsoil
10-20	Orange and grey colours. Sandy clay loam
20-40	Grey, root cracking, stone free. Silty clay loam
40-50	Orange
50-130	Still roots at 130 cm. Clay loam
130-240	Sandy clay loam –seepage occurs causing collapse

No Water Ingress example:

Heavy soil throughout profile and no water gathering in soil test pit

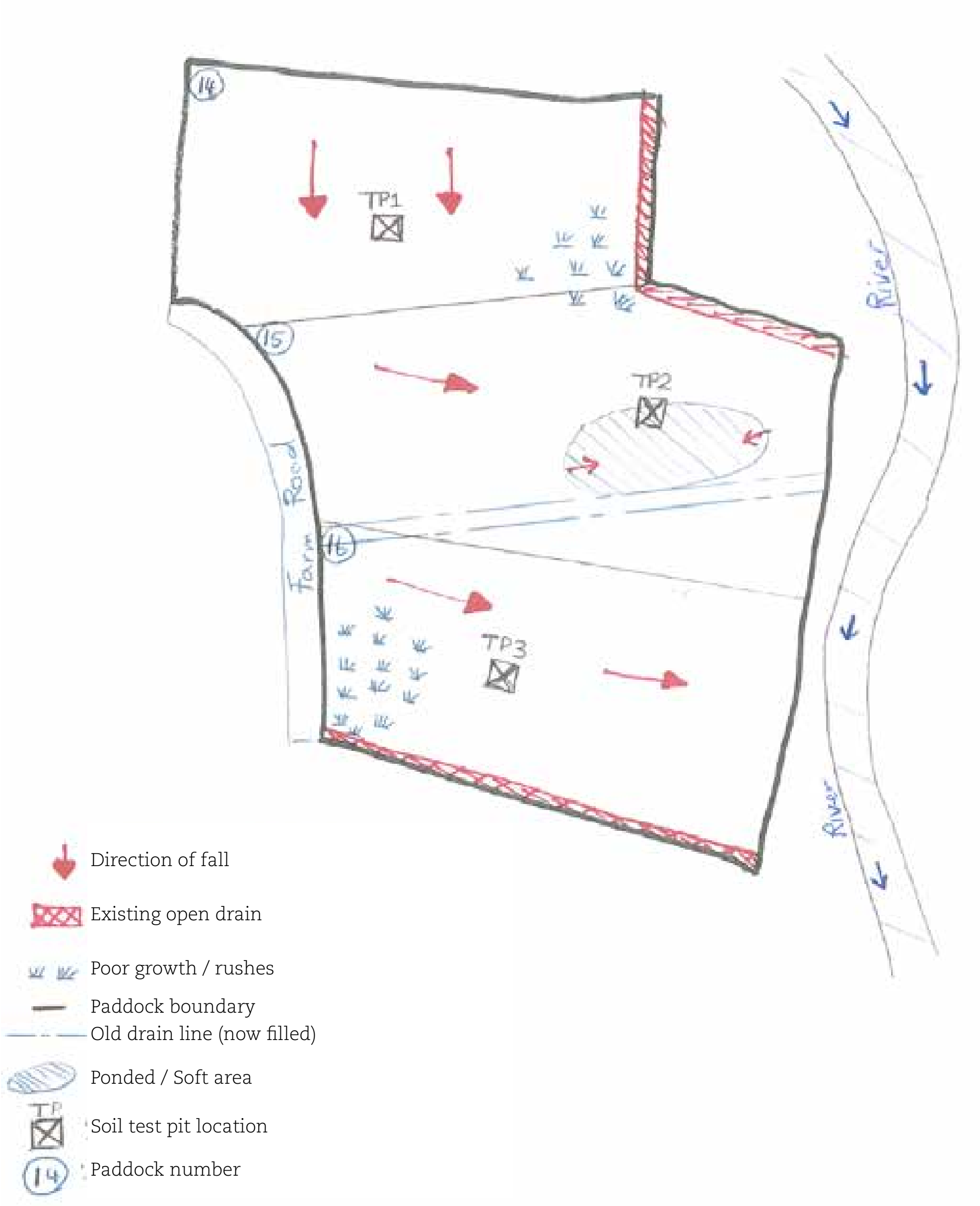
Depth (cm)	Description
0-25	Organic topsoil
25-65	Grey layer with no structure, silty clay loam
65-130	Orange & Grey layer, silty clay loam
130-280	Evidence of some stones but no water ingress



Appendix B

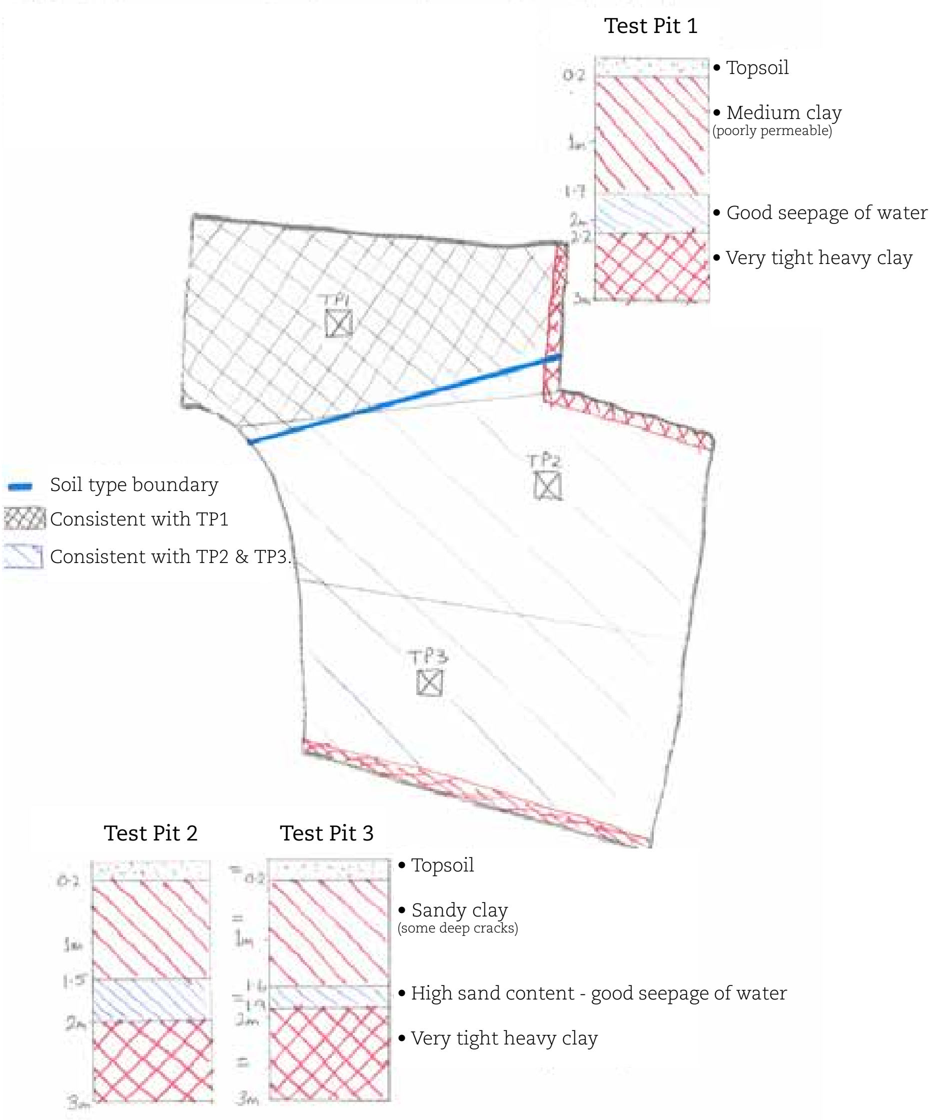
Drainage Design Example

Rough Sketch

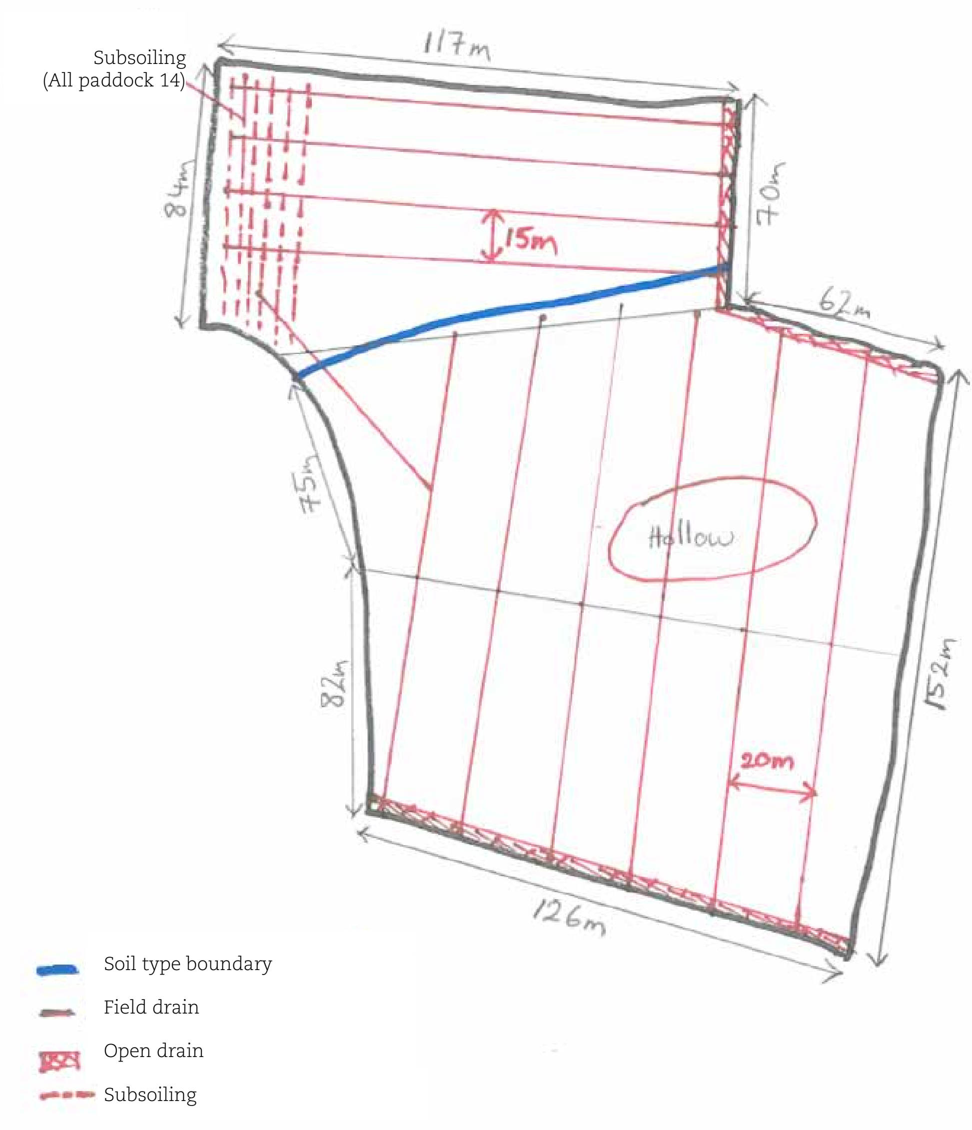


Establishing soil type

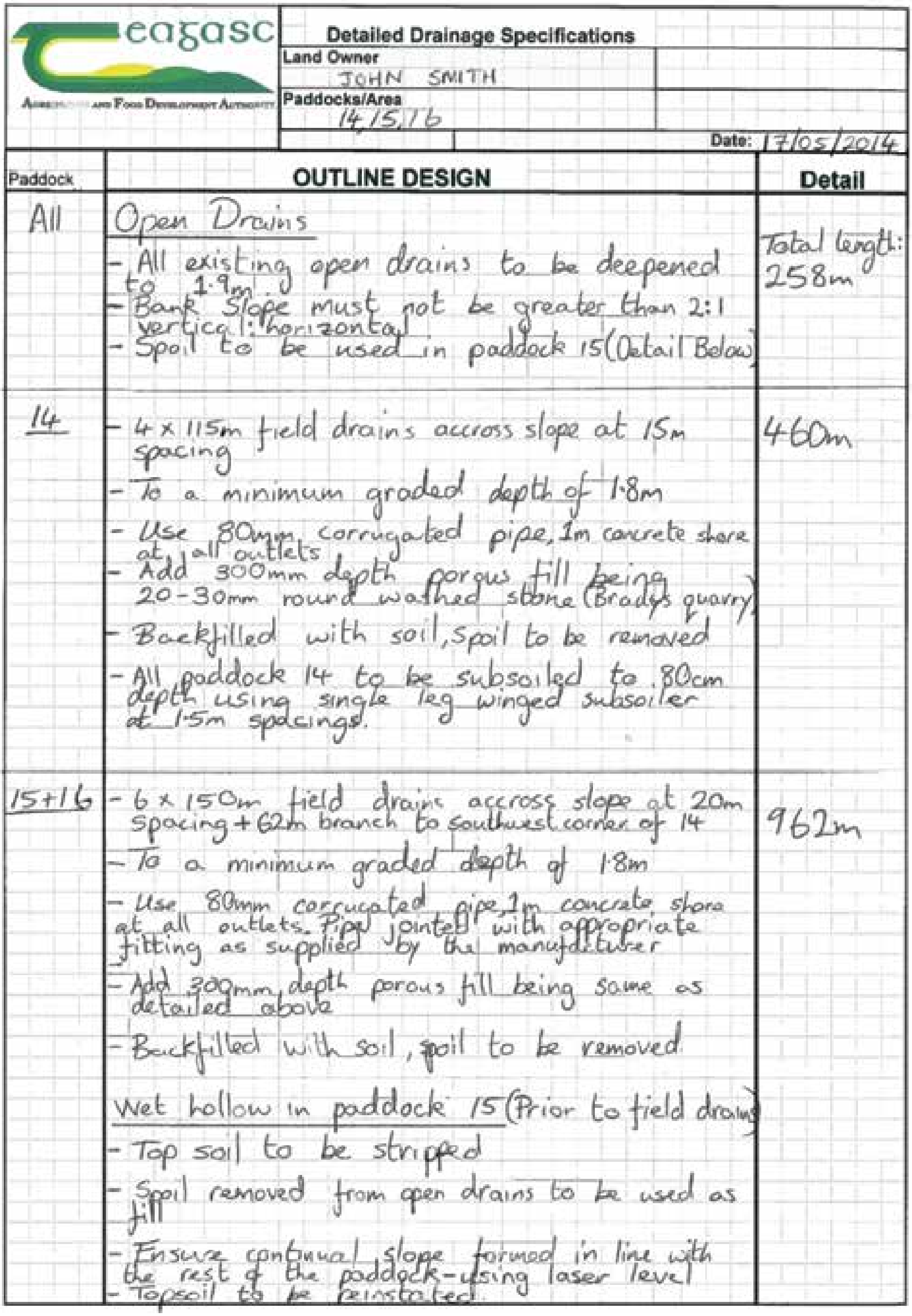
- Existing open drains are cleaned
- Soil test pits are dug
- Soil type is established
- Refer to Appendix C for soil textures



Drain layout sketch



Drainage specifications (to be kept as a record, with layout sketch)



Detailed Drainage Specifications

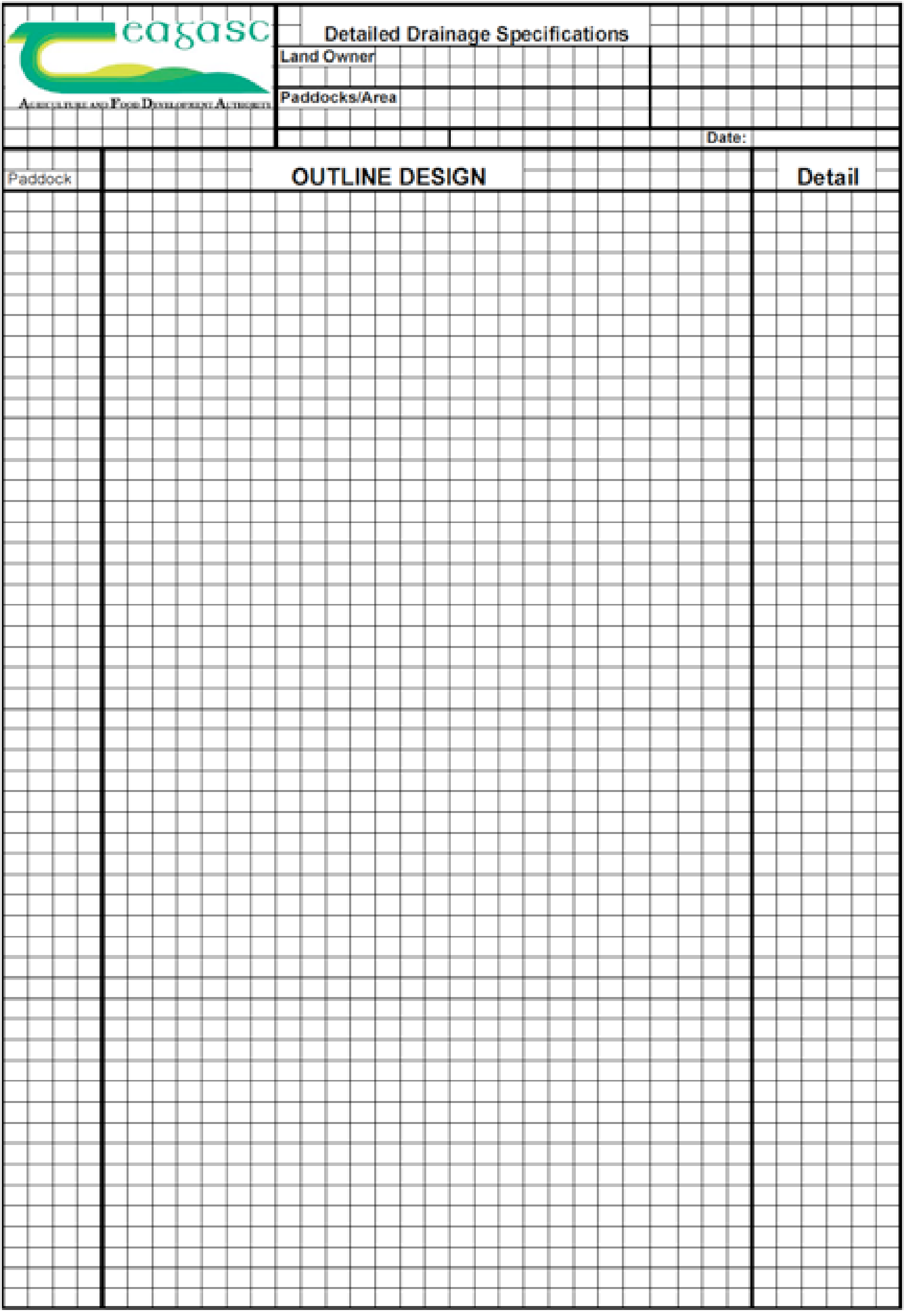
Land Owner JOHN SMITH

Paddocks/Area 14,15,16

Date: 17/05/2014

Paddock	**OUTLINE DESIGN**	**Detail**
All	Open Drains - All existing open drains to be deepened to 1.9m - Bank Slope must not be greater than 2:1 vertical: horizontal - Spoil to be used in paddock 15 (Detail Below)	Total length: 258m
14	- 4 x 115m field drains accross slope at 15m spacing - To a minimum graded depth of 1.8m - Use 80mm corrugated pipe, 1m concrete shore at all outlets - Add 300mm depth porous fill being 20-30mm round washed stone (Bradys quarry) - Backfilled with soil, spoil to be removed - All paddock 14 to be subsoiled to 80cm depth using single leg winged subsoiler at 1.5m spacings.	460m
15+16	- 6 x 150m field drains accross slope at 20m spacing + 62m branch to southwest corner of 14 - To a minimum graded depth of 1.8m - Use 80mm corrugated pipe, 1m concrete shore at all outlets. Pipe jointed with appropriate fitting as supplied by the manufacturer - Add 300mm depth porous fill being same as detailed above - Backfilled with soil, spoil to be removed Wet hollow in paddock 15 (Prior to field drains) - Top soil to be stripped - Spoil removed from open drains to be used as fill - Ensure continual slope formed in line with the rest of the paddock - using laser level - Topsoil to be reinstated.	962m

Blank template



teagasc

Agriculture and Food Development Authority

Detailed Drainage Specifications

Land Owner

Paddocks/Area

Date:

Paddock

OUTLINE DESIGN

Detail

Notes on drainage design example:

These sketches and specification document are presented as a guide to the simple steps taken to establish and document the most suitable drainage design for a particular site. Initial observations are noted on the site sketch. Land slope, historic features, areas of poor growth, water loving vegetation or poor underfoot conditions are noted as well as any surface water features. This information would be used to pick the most suitable areas for a more detailed investigation by means of a soil test pit. Remember the test pits should be dug in areas that represent the range of soils to be found on the site. In this case the soil test pits are spread throughout the site; soil test pit (TP) 1 and soil TP 3 look at conditions in central areas on two of the paddocks, while soil TP2 looks at conditions in a waterlogged low lying area. This will determine if any soil problem is evident in this area or if the waterlogging is just a result of a depression in the field at this point.

After digging the test pits and inspecting the cleaned open drains it was seen that the whole site is underlain by a consistent layer of free draining permeable material, first encountered at depths of 1.5-1.7 m below the surface. It was discovered that most of the area of paddock 14 has a more impermeable subsoil (consistent with TP 1) than that of paddock 15 and 16 (consistent with TP 2 and 3).

The first step in improving the site would be to removing the depression from paddock 15. Here the topsoil would be stripped and the soil material from the deepening of the open drains would be used as fill. This would be levelled in line with the rest of the field, after which time the topsoil would be reinstated. This would be carried out prior to the drainage work.

The proposed approach taken to drain the site would be a series of ground water drains to 1.8-1.9 m depth, backfilled with 300 mm of clean, 20-30 mm round stone, thereafter backfilled with soil. All drains would be pulled across the field slope, that is east-west in paddock 14 and north south in paddock 15 and 16. One drain would be branched to account for the irregular field shape. In paddocks 15 and 16 drains would be spaced at 20 m apart. There was evidence in the subsoil (higher sand content and cracking) that the lowering of the water table in this area would facilitate the natural improvement of this layer over time.

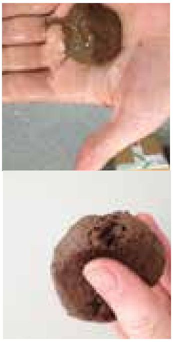
In paddock 14, drain spacings would be 15 m, reflecting the heavier nature of the subsoil there. It was also slightly thicker, so water would not move as quickly from the surface layers to the drains. To deal with this, more drains per unit area would need to be provided. In dry summer conditions it would be proposed that all of paddock 14 be sub-soiled to a depth of 80 cm. This would improve the level of cracking in the heavy subsoil, allowing surface water to move through the profile more easily. As described above, the nature of the subsoil in paddock 15 and 16 would allow this process to happen naturally. Subsoiling to this depth requires a lot of pulling power and surface traction. For this reason a single-leg sub-soiler would be advised, to be pulled at 1.5 m spacings. Multiple legs would increase the power required.

Appendix C

Hand Assessment Of Soil Texture

Introduction

Soil texture describes the sand, silt and clay per cent content of your soil sample. Texture is broken up into several categories. The texture indirectly tells you about how fast the water will travel through a soil. This is important for drainage, as it identifies the permeable or impermeable layers. Typically a sample is sent away for analysis and the exact sand silt clay per cent is determined. This is expensive and time consuming. In the field there are a few simple ways of estimating textural classes. The following photographs and techniques are used in different parts of the world. Simply take some soil out of the digger bucket which represents a particular layer that you have noticed. Remove any plant (organic) or stone material. Pour a little bit of water on your sample and in the palm of your hand work the water into the sample. Now start to roll the sample into a ball. While you are rolling the sample into a ball you should note any feeling of grittiness as this denotes sand content. Also do this near to your ear and listen for this grittiness. Next, as in picture below push the ball between your thumb and first finger and keep going until it breaks, or else roll the ball into a ribbon. The hand technique summaries in Table 3 is a modified version of a technique widely around the world. A good idea would be to take photographs of your ribbons during the soil test pit excavation work.

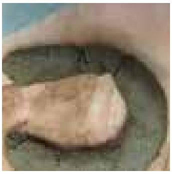


Sandy loam

- Can form a ball but only with a lot of care.
- Ball collapses when you try to push it between thumb and finger.
- Feels gritty

Silty clay loam

- Still a feel of sand
- Cannot join ribbon ends together without breaking
- Doughy feel



If you can form a ring end to end without breaking the ribbon it may fall into the following categories. (First, reform a ball shape)

Clay loam

- Polish the surface with your thumb, it feels smooth with few irregularities

Clay or Silty clay

- Very polished looking (only experience will help you here).

Sandy clay

- Very polished but a few gritty particles are still evident.

If you can form an end to end ribbon but cannot mould the ribbon around the side of your hand without breaking it could be:

- **A Silt loam** if its feels silky or
- **A Loam** if there is a slight gritty feel.

The analysis of soil texture allows for the classification of soils into these different groups. The soil texture chart below (Figure C.1-available at soils.usda.gov) is used to differentiate between the groups on the basis of their relative contents of sand, silt and clay.

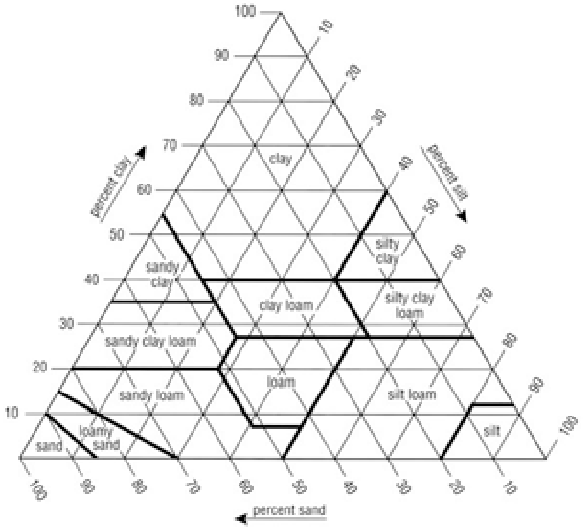


Figure C.1. -Texture Triangle – all textural classes assessed on sand/silt/clay per cent in the soil sample. Equivalent to hand assessment outlined in Table 3. *Source: USDA*

This chart can be used to define certain characteristics of the groups. For example in Figure C.2 the chart is divided into 3 sections. The green section identifies the soil types that have a suitable texture for producing stable mole drains, (this includes the very heavy clays and silty clays), the orange section identifies soil types that may be suitable for mole drainage (this includes the remainder of the clays as wells as the parts of the silty clay, clay loam and silty clay loam groups) while the uncoloured section identifies soil types which are unsuitable, due to poor stablility.

🟩 Soils that are very suitable for mole drainage

🟧 Soils that may be suitable for mole drainage

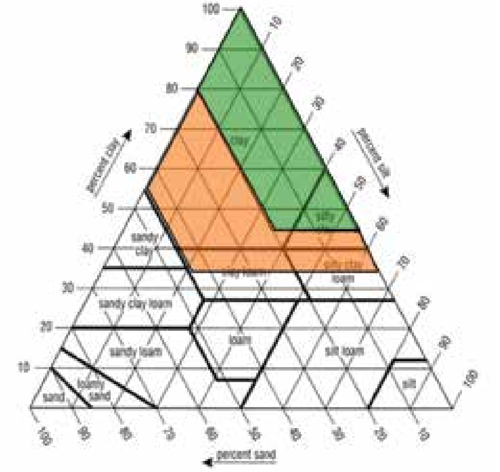


Figure C.2 -Texture Triangle – showing the suitability of soil types for mole drainage.

Table 3. More detailed analyses of the hand technique. Classes in bold text are poorly permeable, with associated drainage issues

Texture Name	Behaviour of moist bolus	Approx clay %
Clay Loam	Ribbon of 40 - 50 mm.	30-35
Clay Loam, Sandy	Medium size sand grains visible in finer matrix; will form ribbon of 40 -50 mm.	30-35
Silty Clay Loam	Fine sand can be felt and gritty sound when held up to ear during ribboning; will form ribbon of 40 - 50 mm.	30-35 & silt >25
Sandy Clay	Fine to medium sand can be seen, felt or heard in clayey matrix; will form ribbon of 50 - 75 mm.	35-40
Silty Clay	Smooth and silky to manipulate; ribbon 50 - 75 mm.	35-40 & silt >25
Light Clay	Smooth to touch; slight resistance to ribbon shearing between thumb and forefinger; will form ribbon of 50 - 75 mm.	35-40
Light Medium Clay	Smooth to touch; slight to moderate resistance to ribboning (greater than for light clay); will form ribbon of about 75 mm.	40-45
Medium Clay	Like plasticine; can be moulded into a necklace without fracture; has moderate resistance to ribboning shear; will form ribbon of 75 mm or more.	45-55
Medium Heavy Clay	Handles like plasticine; can be moulded into a necklace without fracture; has moderate to firm resistance to ribboning shear; will form ribbon of 75 mm or more.	>50
Heavy Clay	Handles like stiff plasticine; can be moulded into a necklace without fracture; has firm resistance to ribboning shear; will form ribbon of 75 mm or more.	>50

Available free at:
http://vro.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/soilhealth_texture_pdf/$FILE/QRG_Texture.pdf

Notes

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