Principles of Land Drainage

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Summary

- Almost half of agricultural land in Ireland would benefit from reclamation and drainage
- Impeded drainage has three main causes; low *hydraulic conductivity*, high water- table and seepage and springs.
- There is a need for a better understanding of the underlying causes of drainage problems and of the design and implementation of appropriate drainage systems
- The first step of any drainage works is a detailed investigation into the causes of poor drainage using test pits
- Two main 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.
- The decision between the two main systems essentially comes down to whether or not a 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 is likely to be effective, at this depth. If no such layer is found during investigations, it is necessary to improve the water carrying capacity of the soil. This involves a disruption technique such as moling, gravel moling or subsoiling in tandem with collector drains.
- The best way to maintain a drainage system is to maintain its outlets and outfalls.

Causes of impeded drainage

Drainage problems in Ireland are largely due to our complex geological and glacial history. Glacial processes led to the formation of rolling and undulating landscapes, made up of haphazardly sorted rock and soil materials. Layers of varying texture and composition have the effect of irregularly distributing groundwater flow, with fine textured soils acting as a barrier to movement, impeding drainage, and layers of gravels and sands promoting water flow, transmitting groundwater over large areas with resulting seepages and springs on lower ground.

The rate at which water moves through a soil, *hydraulic conductivity*, varies enormously depending on the soil type and management. Open gravelly soils have a capacity for water flow that is hundreds of thousands of times that of compacted heavy clay. In free draining soils the rate at which water flows downwards through the soil is always greater than then that being supplied by rainfall. In poorly drained soils the rate of infiltration at the soil surface is regularly exceeded by the rainfall rate due to:

- Low *hydraulic conductivity* in the subsoil (or a layer of the subsoil)
- High watertable due to low lying position and poor/poorly-maintained outfall
- Upward movement of water from seepage and springs

Objectives of land drainage

To achieve effective drainage the works will have to solve one or more of these problems and possibly a combination of all three. The objective of any form of land drainage is to lower the water-table providing suitable conditions for grass growth and utilisation. A controlled water table promotes deeper rooting which improves sward productivity. It also improves load-bearing capacity of the soil and lessens the damage caused by grazing and machinery. When planning any drainage programme, the potential of the land to be drained needs to be first assessed to determine if the costs incurred will result in an economic return through additional yield and utilisation of the grass or other crops grown. Some thought is needed in deciding the most appropriate part of the farm to drain. From a management point of view it is better to drain that land which is nearer to the farmyard and work outwards. However it may be more beneficial to decide where to commence works once the drainage potential has been established by site investigation. This ensures a better return on the investment.

Drainage investigations

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 poor drainage.

Knowledge of previous drainage schemes in the area, and their effectiveness will often provide a useful insight. A number of test pits (at least 2.5 m deep) should be excavated within the area to be drained. The test pits should be dug in areas that are representative of area as a whole. As the test pits are dug, the faces of the pits are observed, soil type should be established and the rate and depth of water seepage into the test pit (if any) recorded. Visible cracking, areas of looser soil and rooting depth should be noted as these can convey important information regarding the drainage status of the different layers. The depth and type of the drain to be installed will depend on the interpretation of the characteristics revealed by the test pits.

Types of drainage system

Two principle types of drainage system are distinguished:

- Groundwater drainage system: A network of piped drains establishing a deep drainage base in the soil
- Shallow drainage system: These are used where the soil is clayey (heavy) and infiltration of water is impeded at all depths.

Groundwater Drainage System

Strong inflow of water or seepages from the walls of the test pits, indicates that layers of high *hydraulic conductivity* are present. Under these circumstances the use of a piped drainage system is advised. The installation of a piped drain at the depth of inflow will facilitate the removal of groundwater assuming a suitable outfall is available. Conventional piped drains at depths of 0.8 to 1.5 m below ground level (BGL) have been successful where they encounter layers of high *hydraulic conductivity*. However, where layers with high *hydraulic conductivity* 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 *hydraulic conductivity* and thickness of the

drainage layer. Piped drains should always be installed across the slope to intercept as much groundwater as possible, with open drains and main piped drains running in the direction of maximum slope.
Due to the risk of drain collapse, deep drains are normally excavated with a tracked digger with a special deep-drain trapezoidal bucket with a bottom width of about 200 mm. For small jobs a 300mm or similar sized bucket may be used but the side walls must be well battered (sloped) to avoid cave-ins. While these drains are more difficult to install, they are very cost effective as so few are required. Where groundwater seepage and springs are identified, deep drains, 2 to 3 m BGL can be used to intercept flow. Pipe drains are most effective in or on the aquifer (layer transmitting groundwater flow characterised by high water breakthrough). This issue is very site specific.

Clean aggregate should to be used to surround the land-drain pipe in conventional and deep 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 *hydraulic conductivity*. The purpose of a drain pipe is to facilitate a path of least resistance for water flow. In long drain lengths (greater than 30m) a drain pipe is vital to allow a 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 30m of any drain) are capable of operating at full efficiency without a pipe.

Fig. 1a .Test pit excavation

Fig 1b. Drainage trench excavation

Shallow Drainage Systems

Where a 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 hydraulic conductivity 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 and gravel mole drainage. The aim of these drainage techniques is to improve hydraulic conductivity by fracturing and cracking the soil and to form a network of closely spaced channels.

Mole drainage is suited to soils with a 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. 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 hydraulic conductivity adjacent to the mole leg (shallower depths) and a channel for water conveyance and outflow at moling depth.

The effectiveness of mole drains depends on the extent of suitable cracking during installation. As such the ideal time for carrying out mole drainage is during dry summer conditions. This will cause maximum cracking in the upper soil layers as well as facilitating adequate traction preventing wheel-spin on the surface.

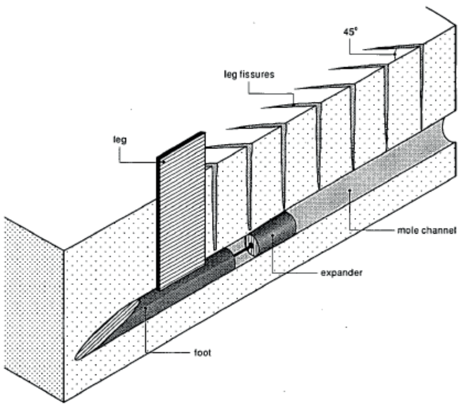

Fig. 2a .Mole plough showing cylindrical foot and expander, 2b. Cracking and channel formation

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 render its application 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 which has a hydraulically operated shutter to control the flow of gravel; the gravel chute also has an adjustable door which 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. 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.

Subsoiling is used effectively where an iron pan or cemented layer impedes drainage. The effect is to break the layer and crack the soil. A stable outlet channel will not be formed.


Fig. 3a. Gravel Mole plough showing hopper, 3b. Operation and filling of gravel mole plough

Collector drains, which are installed across the slope at 0.75 m BGL, are required for all mole drains. Depending on the topography and slope the collector drains will be at a spacing of 10–60 m. A larger spacing reduces costs but results in a higher chance of failure. The mole drains themselves are drawn at right angles to the collectors (up-slope) at spacings of 1.0-1.5 m and a depth of approximately 0.4-0.5 m. Stone backfill for collectors should be filled to within 250 mm of the surface to ensure interconnection with the mole channels.

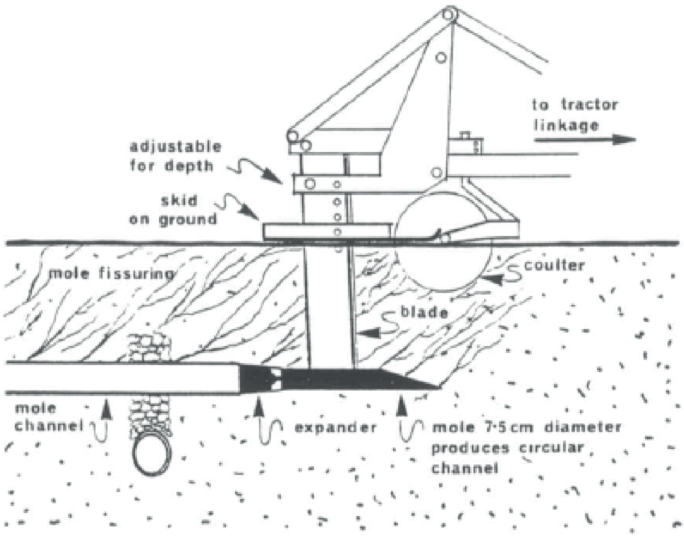

Fig. 4. Mole ploughing showing intersection with a piped collector drain

Outfalls/Maintenance

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 as great a depth as possible. This will maximise the potential for land drainage, with associated benefits. Spoil from such works, where suitable, can be spread over the adjoining land filling depressions and should not impede surface runoff to the watercourse. Unsuitable spoil should be buried and covered with topsoil or removed to waste ground.

When a drainage scheme has been completed, the layout should be drawn and noted on a farm map. This map can then be used as a guide when maintaining the works, as well as a record of the works. Land 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.

Approximate Costs

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. The table below provides guidelines only. Cost for the provision of open drains is not included.

The table 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 BGL, it may be possible to pull mole drains through this existing network or from 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 the 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.

Table 1: Approximate costs of land drainage

Drainage System	Drain Spacing (m)	Depth (m)	Cost/m (€)	Cost/Ac (€)	Cost/Ha (€)
Groundwater Drainage systems					
Conventional System	8	0.8 - 1.5	5-7	2500-3500	6200-8600
Deep Drainage	15 - 50	1.5 - 2.5	9-11	1500-2500	3700-6200
Shallow Drainage systems					
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	5-7	1000-1400	2500-3500
Collector Drains	40	0.75	5-7	500-700	1200-1700
Collector Drains	60	0.75	5-7	350-450	800-1150

Conclusions

Approximately half the land area in Ireland is in need of reclamation and drainage. There is enormous potential for developing our land resources through effective land drainage. The drainage problems in Ireland are as a result of two major factors; high excess rainfall and a complex geological and glacial history. There is a need for a better understanding of the underlying causes of drainage problems and of the design and implementation of appropriate drainage systems.