Design and Installation of a Drainage System

Liam F. Galvin, an Foras Taluntais, Land Reclamation Seminar Oct. 24 – 26, 1978

The installation of a drainage system has as its main objective the removal of excess water from the soil resulting in an improvement in trafficability and the development of a favourable root zone for plant growth. The excess water may occur either on the surface or within the soil and the drainage system must be designed to cope with the prevailing conditions. It should be emphasised, however, that the installation of even a very intensive system of drains is no guarantee of success. To ensure the maximum potential production is attainable, each scheme must be scientifically designed and properly installed. If either of these requirements is not fully implemented maximum returns will not be achieved on the drainage investment.

Land in need of reclamation can be compared to a farm that has not been fertilized for a number of years in the sense that anything one does in either case will result in some improvement. In the case of unfertilized land an advisor will invariably base fertilizer recommendation on the result of soil analyses. This is the only way he can be sure that the very best mix of fertilizers and trace elements is used. An experienced Advisor could probably come fairly close to the ideal mix without sampling and then top up later if deficiency symptoms appeared in the grass or the animals.

This is the major difference between fertilizer recommendations and reclamation design – it can be very difficult and expensive to "top-up" an inadequate reclamation design at a later stage. For example if a compact soil that required ripping at very close intervals (say 50cm) is subsoiled or mole drained at 1.2 metre intervals, then the whole field must be completely disrupted again, at a later date, if maximum production is to be achieved. Similarly if a soil that should have been gravel-moled is mole drained initially, it too will be subject to disruption in rectifying this error in design.

Apart altogether from the expense and difficulties associated in a second reclamation operation, there is a danger of breaking some of the piped drains. Furthermore farmers usually put a lot of effort and money into stone removal and surface grading prior to re-seeding and are naturally very anxious to avoid any subsequent subsoil disturbance. In the circumstances it is absolutely essential to be right first time with the reclamation design and to see that the scheme is installed in accordance with the specification. Otherwise one may be faced with the alternative of difficult corrective measures or of living with a sub-standard job.

Drainage Problems

A pre-requisite for any design is the accurate identification f the particular problem involved. In the case of land reclamation, the three problems most frequently encountered are:

(a) High water table
(b) Seepage and springs
(c) Impervious soils

(a) High Water table

The upper surface of free ground water is referred to as a water table. It marks the dividing line between ground water and capillary water (water under tension). In fine textured soils it may be difficult to recognise the top of the saturated zone (water table) because of the gradual change from saturated soil to moist soil. By excavating a narrow hole about a metre deep, the water table can be ascertained by allowing the free water to come to equilibrium. In the case of impermeable soils it may take hours or even day for the watertable to establish itself. In those circumstances steps should be taken to prevent inflow of surface water or rainfall into the hole. The depth of the watertable can vary substantially from ground level to 5 to 10 metres below the surface. Usually it is only when the watertable rises to within 50 – 75cm of the ground surface over an extended period that it creates a drainage problem.

The most important requirements for design are:

1. Soil permeability – if there is more than one layer, the permeability of each layer must be found.
2. The depth of each layer of soil and the depth of the impermeable layer.
3. The depth at which the watertable is to be controlled.
4. The drainage design coefficient

On the basis of this information a number of drain depth/spacing designs can be calculated and the most appropriate or least expensive design selected for installation. For grassland, the drainage co-efficients normally suggested are as set out in Table 1.

Table 1. Suggested Drainage Co-efficients for Grassland	
Normal piped drainage	10 – 12 mm per day
Mole drainage	Up to 20mm per day

The water table height is usually controlled at a depth of 30 cm below the ground surface. This figure may however have to be increased in certain situations e.g. in peaty soils where shrinkage is expected etc.

The depth of the impermeable layer below the surface is a major factor in drainage design and must always be considered. Its importance is illustrated by the following example:

Permeability, (K) = 0.9 m/day
Drainage Coefficient, (q) = 0.01 m/day
Controlled water table depth below surface = 0.4 m
Depth of piped drains = 0.9m

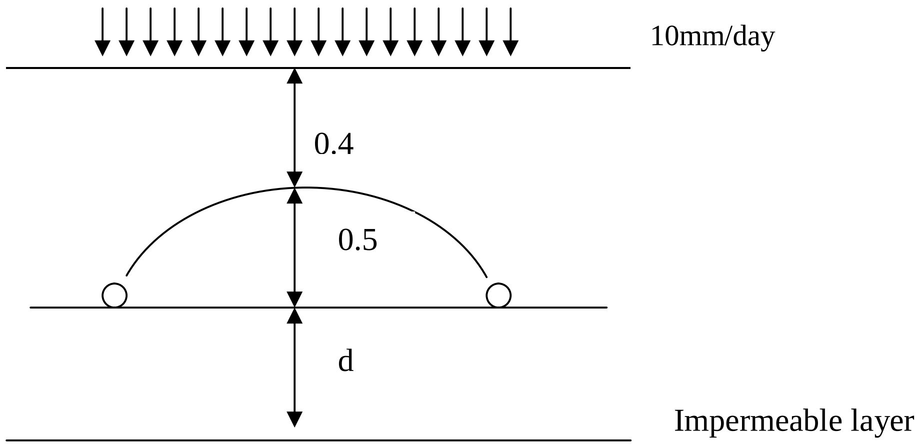

Table 2. Effect of Depth to the Impermeable Layer on Drain Spacing

Depth of Impermeable Layer below Drains (metres)	Spacing (Metres) Pipe Size 50 mm	Spacing (Metres) Pipe Size 100 mm	Spacing (Metres) Pipe Size 200 mm
0	9.5	9.5	9.5
0.5	15.5	15.9	16.2
1	18.7	19.4	20
2	22	23.4	24.8
5	22.7	26.2	29.6

These results show that while the size of drain (or drain plus porous fill) has very little effect, the depth of the impermeable layer below the drain depth has a major effect on the spacing. In fact the drain spacing can be doubled if the impermeable layer is 1 metre below the drain level and still further increased as the depth of the impermeable layer increases.

The lessons to be learned from the data in Table 2 are:

1. If the impermeable layer is at drain depth, then drains must be installed at approx. 10 metre spacing to achieve an efficient drainage system.
2. If the impermeable layer is even 0.5 metre below drain depth the spacing can be increased to 15 metres (50% increase) and where the impermeable layer is 1 metre down, the drain spacing can be doubled.

3. It is quite obvious that substantial savings can be achieved where one knows of the existence of a deep impermeable layer. In the circumstances the small expenditure involved in hiring an excavator to dig a few trial holes can pay big dividends. In any case this is a pre-requisite for a rational design.

Occasionally one comes across ponded water on an impervious layer at shallow depth. This is known as a perched water table. It is sometimes possible to overcome this problem by shattering the impermeable barrier. However if the underlying subsoil is not sufficiently permeable, a drainage system will also be required. Site investigations are again essential for the production of an effective design.

(b) Seepage and Springs

Seepage or springs occur where underground water is forced to the surface under pressure. In all such situations, the seepage water is forced upwards from a permeable stratum through less permeable strata. Energy is lost in the process and very often the effective pressure near the surface is so low that the seepage water just oozes through the surface.

In seepage situations, preliminary investigations should include the examination of the soil in deep trial holes and the installation of piezometers. Piezometers are pipes, open at the base only, which are driven vertically into the soil to various depths. Each piezometer measures the soil water pressure at the installation depth and the pressure distribution through the soil profile is thus obtained. The optimum depth and spacing of drains to achieve the required drainage effect can then be designed. In most cases the optimum design will require the installation of drains at much greater depths than normal.

(c) Impervious soil

The drainage problems that can be classified under impervious soils are many and varied. They include the whole range of heavy mineral soils and peats varying in depth from 10 cm to several metres.

The major difficulties associated with an impervious are its high water holding capacity (after drainage) and its poor drainage characteristics. The total porosity of most soils varies from 40% to 60% (by volume) and in a good soil half the total spore space will be made up of drainable pores. A good soil therefore has about 25% drainable pore space and 25% capillary pores. In a poor soil however the drainage pore space can be as low as 5% - 10% with a corresponding capillary pore space of 40% - 45%. Such soils obviously release very little water, when drained, and are said to have high water holding capacity. Another difficulty associated with these soils is that the permeability is correspondingly low due to the unfavourable pore size distribution. The overall result is that these heavy or tight soils give up very little water to a conventional system of piped drains and consequently remain wet, weak, and easily damaged even after drainage.

The objective in the reclamation of an impervious soil is to reduce the total quantity of infiltrating rainfall to a minimum and to improve the drainage characteristics as much as possible. A sizable reduction in infiltration can often be achieved by grading the soil surface to a smooth slope – this will be dealt with in more detail under the heading of "surface drainage".

An improvement in the drainage characteristics of an impervious soil can only be achieved by disrupting the soil so that its pore is changed and its permeability increased. The degree of disruption required and the best method of achieving it are dealt with more fully in another paper, but the likelihood is that mole drains, gravel moles, ripping, sub-soiling or deep ploughing will be required.

The effectiveness of the disruption will depend on the system used and on the quality of the workmanship. Soil type is also a major factor as some soils will maintain the disrupted state more or less permanently whilst others may settle back with a consequent reduction in permeability, after a short time. All these factors must be considered in designing the intensity of the drainage installation.

Surface Drainage

The need for surface drainage on many Irish soils should never be overlooked. This can be accommodated in many cases by judicious dozing and by selective surface levelling during the cultivation process. In this way, surface flow is increased and the depression storage (i.e. the amount of water held in the surface hollows and depression) is reduced to a minimum. As a result, the percentage surface run-off is increased and the amount that finds its way to the water table is correspondingly reduced. This results in a lower internal drainage demand and a drier soil, which is stronger and less liable to damage. The reduced depression storage is also a major advantage in drying the soil because a greater proportion of the available evaporating energy is applied directly to reducing the water held in capillary pores and is not dissipated in evaporating water ponded on the soil surface.

Particular attention should therefore be paid to grading on all reclamation schemes. Spoil from open water courses should be graded out properly and should never be allowed to form a barrier to water flow in the vicinity of the water course. Likewise, surface hollows should be graded off and the field surface should be well graded before re-seeding.

Design and Installation

The first essential in the preparation of a drainage design is a proper site investigation. This should include the following:

(a) Check the adequacy of the existing outfall. If it is inadequate, can it be improved? If not can a new outfall be provided at reasonable cost?
(b) Verify the site levels. These are necessary to establish the major and minor field gradients which determine the drainage layout and the capacity of the drains.
(c) Investigate the drainage problem. Where a high water table or seepage occurs, deep trial holes are necessary to verify the soil conditions at depth. For water table design the depth of the impermeable layer must be established. For seepage investigations, piezometers should be installed.

(d) Where an impervious soil occurs, trial holes are needed to examine the soil variations through the profile and the soil water conditions. Physical tests may also be required to determine the most suitable reclamation technique for that particular soil.
(e) Measure the permeability of the subsoil.
(f) Verify the nature of the topsoil and whether it could be improved by mixing with the subsoil.

On the basis of the above a drainage plan can be formulated. Particular attention should be paid to the pipe size design. This is a function of the area being drained and of the pipe gradient. Ensure that the required pipe size is accurately specified. A 50 mm smooth wall plastic pipe has a drainage capacity 50% greater than the equivalent corrugated pipe. Where the design shows that 50 mm smooth wall pipes are just adequate, it is not sufficient to specify 50 mm plastic pipes.

Subsequently the installation should be well supervised. Apart from verifying that the drains are correctly installed it is also essential to check on the quality and sufficiency of the sub surface disruption where it is specified. Gravel moles should be installed at the design depth and spacing. Sub-soiling or ripping should be done at the correct depth and the effectiveness examined by excavating slit trenches across the ripping tracks.

In all cases, the newly reclaimed land must be carefully managed, especially in the first year. At that stage the surface is still soft and more liable to poaching than it will be after the initial settlement has taken place and properly compacted topsoil has been established.