Chapter 4

1.0 Factors related to drainage

For the design of agricultural land drainage systems we group all these disciplines together in three types of input factors: the agricultural objectives, the environmental parameters and the engineering

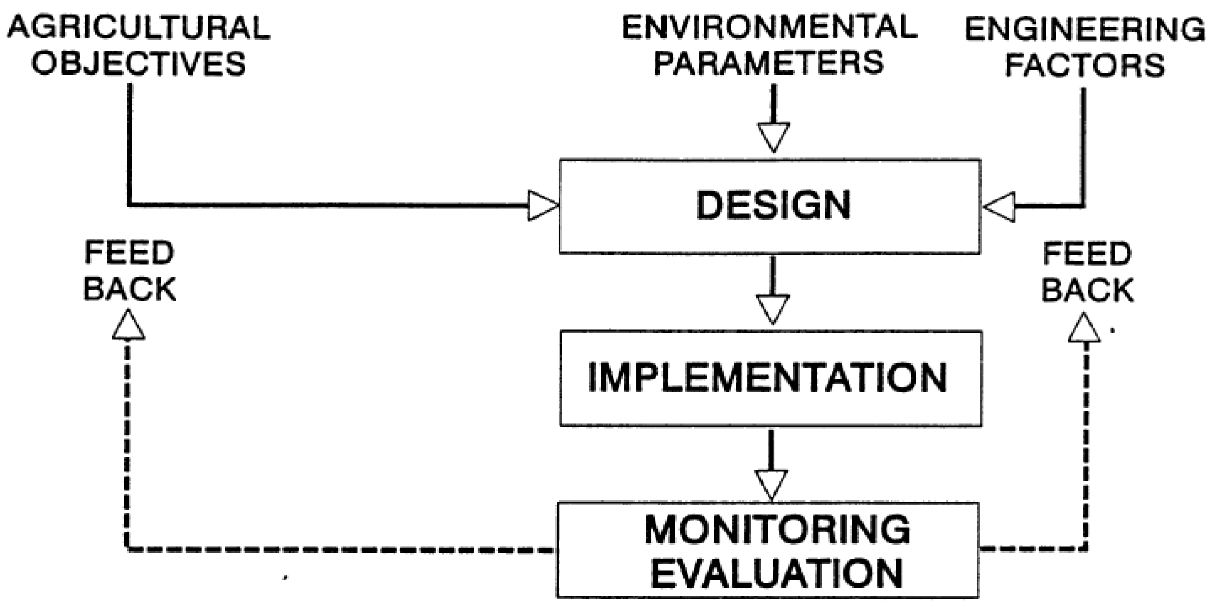


Table 1 Examples of engineering factors by type of drainage system

Type of drainage system	Enigineering factor
Surface drainage system	Length and slope of the fields, dimensions of beds, terraces and open drains
Subsurface drainage system	Depth, spacing, and dimensions of open or pipe drains
Tubewell drainage system	Depth, spacing, and dimensions of wells, pump capacity
Main drainage system	Depth, width, cross-section, and slope of drains, spacing of the network

4.1 The agriculture objective of drainage

The three main objectives of drainage are: prevention or reduction of ponded and/or waterlogged conditions, salinity control and making new land available for agriculture. The first two objectives are aimed at conserving or improving existing agricultural areas, whereas the third objective brings new areas into cultivation. These objectives are met through two direct effects and a large number of indirect effects. The direct effects of installing a drainage system land are:

- A reduction in the average amount of water stored on or in the soil, inducing drier soil conditions and reducing waterlogging;
- A discharge of water through the system.

The direct effects are mainly determined by the hydrological conditions, the hydraulic properties of the soil, and the physical characteristics of the drainage system. The direct effects trigger a series of indirect effects. These are determined by climate, soil, crop, agricultural practices, and the social, economic, and environmental conditions. Assessing the indirect effects (including the extent to which the objectives are met) is therefore much more difficult, but not less important, than assessing the

The indirect effects can be either positive or negative. Some examples are:

- Positive effects owing to the drier soil conditions: increased aeration of the soil; stabilized soil structure; higher availability of nitrogen in the soil; higher and more diversified crop production; better workability of the land; earlier planting dates; reduction of peak discharges by an increased temporary storage of water in the soil;
- Negative effects owing to the drier soil conditions: decomposition of organic matter; soil subsidence; acidification of potential acid sulphate soils; reduced irrigation efficiency; increased risk of drought; ecological damage;
- The indirect effects of drier soil conditions on weeds, pests, and plant diseases: these can be both positive and negative; the net result depends on the ecological conditions;
- Positive effects owing to the discharge: removal of salts or other harmful substances from the soil; availability of drainage water for various purposes;
- Negative effects owing to the discharge: excessive leaching of valuable nutrients from the soil; downstream environmental damage by salty or otherwise polluted drainage water; the presence of ditches, canals, and structures impeding accessibility and interfering with other infra structural elements of the land.

4.2 Environmental aspects of drainage

When we introduce a drainage system into an area, we are manipulating the environment. In this section we briefly discuss the environmental impacts of the two direct effects of drainage (e.g. a lower watertable and an increase in discharge), they are categorized as impacts in the project area itself and outside the project area.

Side-effects inside the Project Area

Loss of Wetland

Wetlands are lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface. When wetlands are reclaimed, they lose their original function as lands harbouring particular plant and animal communities.

Change of the Habitat

Improving the drainage in land that is already used for crop production or grazing may appear environmentally less damaging than converting wetlands into crop land. But, in both humid and arid regions, improved drainage can still lead to a drastic change in habitat conditions. Consequently, plant and animal life can be considerably affected

Subsidence

A well-known effect of drainage is the subsidence of the land surface. Subsidence is the downward movement of the ground surface and is caused by the consolidation of clay soils due to lowering the watertable, the irreversible subsidence of peat soils as a result of oxidation and the compression of deep layers as a result of the extraction of water for irrigation. Subsidence not only affect the land use, it also affects the elevation of the reclaimed area. Consequently, it will affect the water levels in the drainage system, the possibility of drainage by gravity, and the lift and capacity of pumping stations

Soil Salinity

In irrigated agriculture, irrigation itself is the main source of salts. About one-third of the gross area of irrigated land (270 million ha) is to some extent affected by salinity. Even if the irrigation water is of good quality, it still brings in large amounts of salts. In arid and semi-arid regions, irrigation can also cause secondary salinisation through the capillary rise of saline groundwater. To prevent salinisation, all these salts have to be removed by the drainage water. So drainage is the price one has to pay for sustainable agriculture in irrigated lands.

Soil Sodicity

Salty soils usually contain several types of salts, one of these is sodium. At places, where the concentration of sodium is relatively high, a sodic soil may develop. Sodic soils are characterized by a poor soil structure: they have a low infiltration rate and a low hydraulic conductivity, they are poorly aerated and difficult to cultivate. Thus, sodic soils adversely affect plant's growth. For efficient crop production, sodic soils need improvement by reducing the amount of sodium present in the root zone. This is done in two stages: firstly, chemicals rich in calcium, such as gypsum, are mixed with the soil. The calcium will replace the sodium. Secondly, the replaced sodium is leached from the root zone.

Erosion

Drainage can either increase or decrease erosion. A lower watertable will result in a drier top soil, which, under certain conditions, can increase wind erosion (e.g. of peat soils). On the other hand, a subsurface drainage system can reduce surface runoff and subsequently decrease erosion. In sloping areas (slopes > 2%), surface drainage is closely related to erosion control.

Side-effects outside the Project Area

Disposal of Drainage Effluent

Drainage water has to be disposed of, either by gravity flow or by pumping, via a canal or directly into a river leading to the sea, or, more rarely, into an inland lake without an outlet. On the way to its destination, the drainage water can influence its surroundings in various ways. On a small scale, this can happen when one farmer drains his land and evacuates his drainage water to the land of his downstream neighbour. On a larger scale excessive drainage water can increase peak river flows causing inundations in the downstream parts of river catchments.

4.3 Soil and hydrological conditions

In Chapter 2, it was shown that when irrigation is introduced into an area, the natural conditions are changed and may need a drainage system. To predict the effects of these changes, the soil and hydrological factors under which the drainage system will have to function need to be known. Some of the most important factors are briefly discussed.

DRAINAGE REQUIREMENT

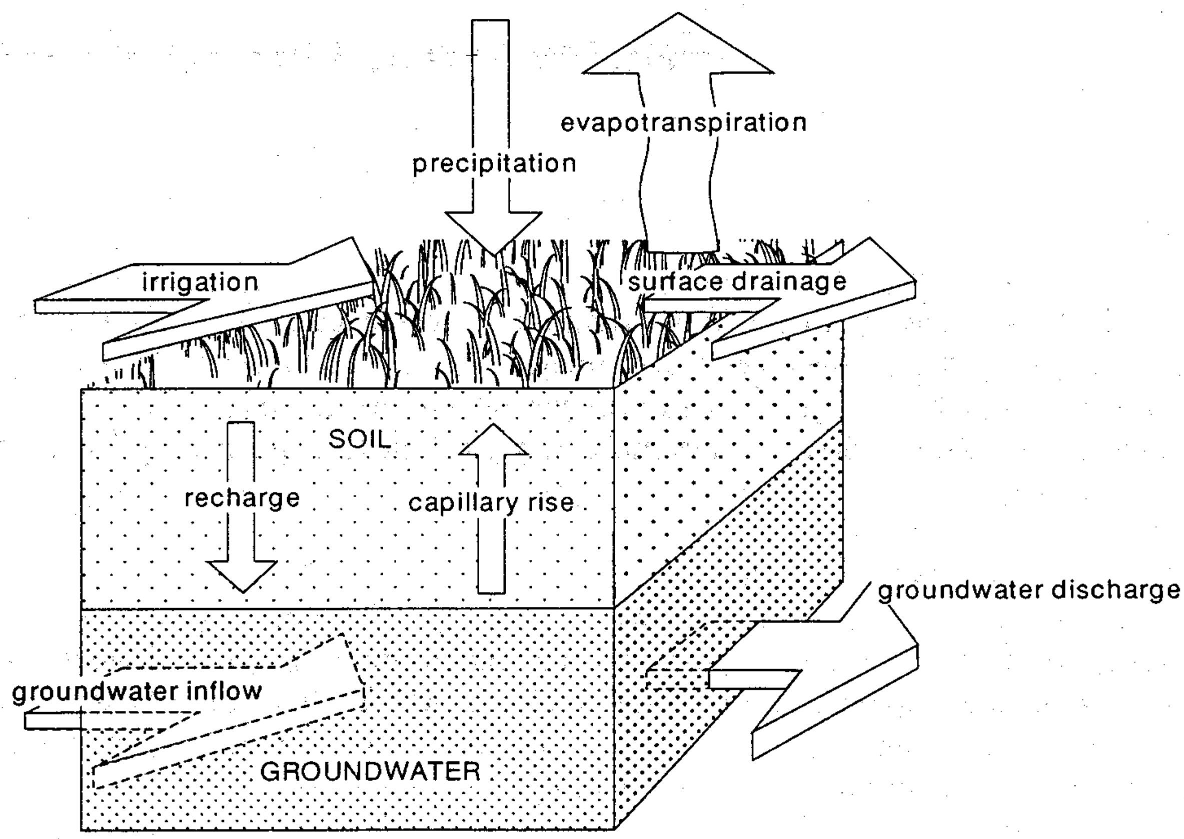
For the design of a drainage system, the drainage requirement or the drainable surplus has to be known. This is the amount of water that must be removed from an area within a certain period so as to avoid an unacceptable rise in the levels of the groundwater or surface water.

The **drainage requirement** is the amount of water that must be removed from an area within a certain period so as to avoid an unacceptable rise in the levels of the groundwater or surface water. Calculating the drainage requirement is a major problem in many irrigated areas. The natural conditions in these areas are diverse, and different water resources may be involved in the calculations. Therefore field work has to be carried out to find out what the general features of the groundwater regime are, and the water and salt regimes and their balances have to be studied. A proper understanding of these regimes allows the drainage engineer to predict how they will be affected by drainage. The rate of water removal often referred to Drainage Coefficient.

To calculate the drainage requirement, an analysis has to be made of the overall water balance of the study area (Figure 4.1). Water balances are often assessed for an average year.
Waterlogging and salinity problems, however, are not of the same duration or frequency every year. Therefore there is often a need to assess water balances, not only for an average year, but also for specific years (e.g. a very dry year or a year with extreme rainfall), or eve for specific periods (e.g. the growing season or the irrigation season).

Therefore, the drainage requirement is based on:

1. The maximum duration and frequency of surface ponding
2. Maximum height of the water table
3. The minimum rate at which water table is lowered.



THE WATER TABLE

The water table is the upper boundary of the groundwater. It is defined as the locus of points at which the pressure in the groundwater is equal to atmospheric pressure.

Below the water table, all the soil pores are filled with water. This is known as the saturated zone (Figure 23). Most of the flow of groundwater towards the drains takes place in the saturated zone. Above the water table, there is a zone where the soil pores are filled partly with water and partly with air. This is the unsaturated zone. Water in the unsaturated zone originates from rain or irrigation water that has infiltrated into the soil, and from the capillary rise of groundwater. The unsaturated zone is very important for plant growth. This is the zone where roots take up water.

DEPTH TO THE WATER TABLE

The depth to the water table is measured in observation wells (Figure 25). An observation well is a small-diameter plastic pipe (>Ø 12 mm), placed in the soil. The pipe is perforated over a length that the water table is expected to fluctuate. Sometimes a gravel filter is placed around the pipe to ease the flow of water and to prevent the perforations from becoming clogged by fine particles like clay and silt. In stable soils (e.g. heavy clay soils), simply an auger hole can be made in the ground and no pipe is needed (Figure 25A).

Water levels can be measured in various ways (Figure 26)

The wetted tape method (Figure 26A): A steel tape (calibrated in millimetres), with a weight attached to it, is lowered into the pipe or auger hole to below the water level. The lowered length of tape from the reference point (e.g. the top of the pipe) is noted. The tape is then pulled up and the length of its wetted part is measured. (This is easier to see if the lower part of the tape is chalked.) The depth to the water level from the reference point is obtained by subtracting the wetted length from the total lowered length.

With a mechanical sounder (Figure 26B): This consists of a small steel or copper tube (10 to 20 mm in diameter and 50 to 70 mm long), which is closed at its upper end, open at its bottom end, and connected to a calibrated steel tape. When lowered into the pipe, it produces a characteristic plopping sound upon hitting the water. The depth to the water level can be read directly from the steel tape.

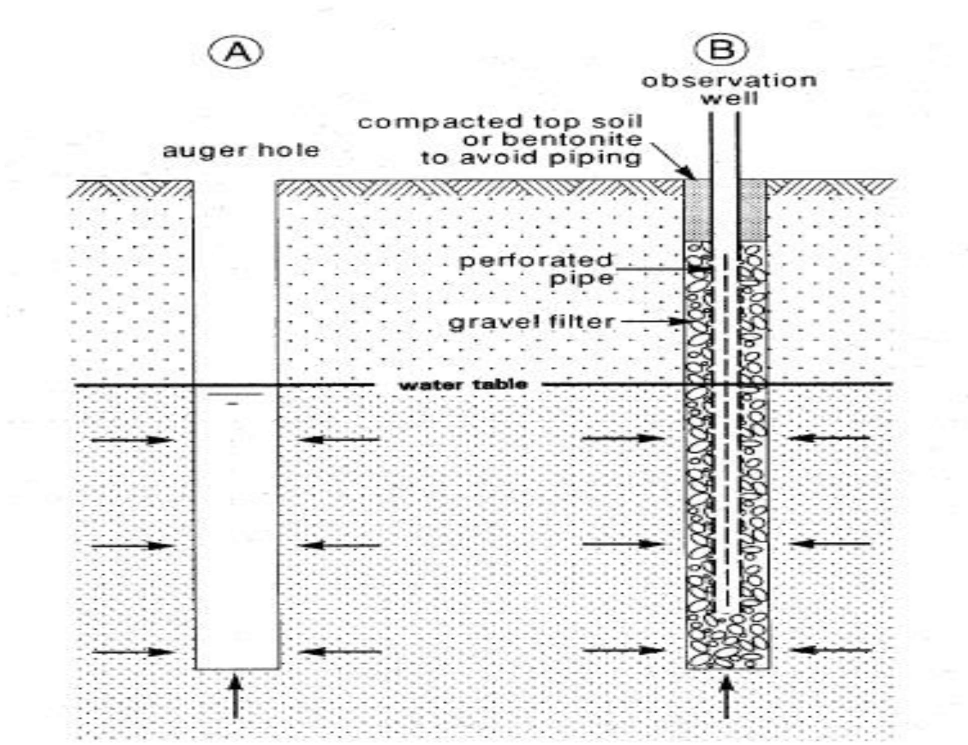
With an electric water-level indicator (Figure 26C): This consists of a double electric wire with electrodes at their lower ends. The upper ends of the wire are connected to a battery and an indicator device (lamp, amp meter, and sounder). When the wire is lowered into the pipe and the electrodes touch the water, the electrical circuit closes, which is shown by the indicator. If the wire is attached to a calibrated steel tape, the depth to the water level can be read directly.

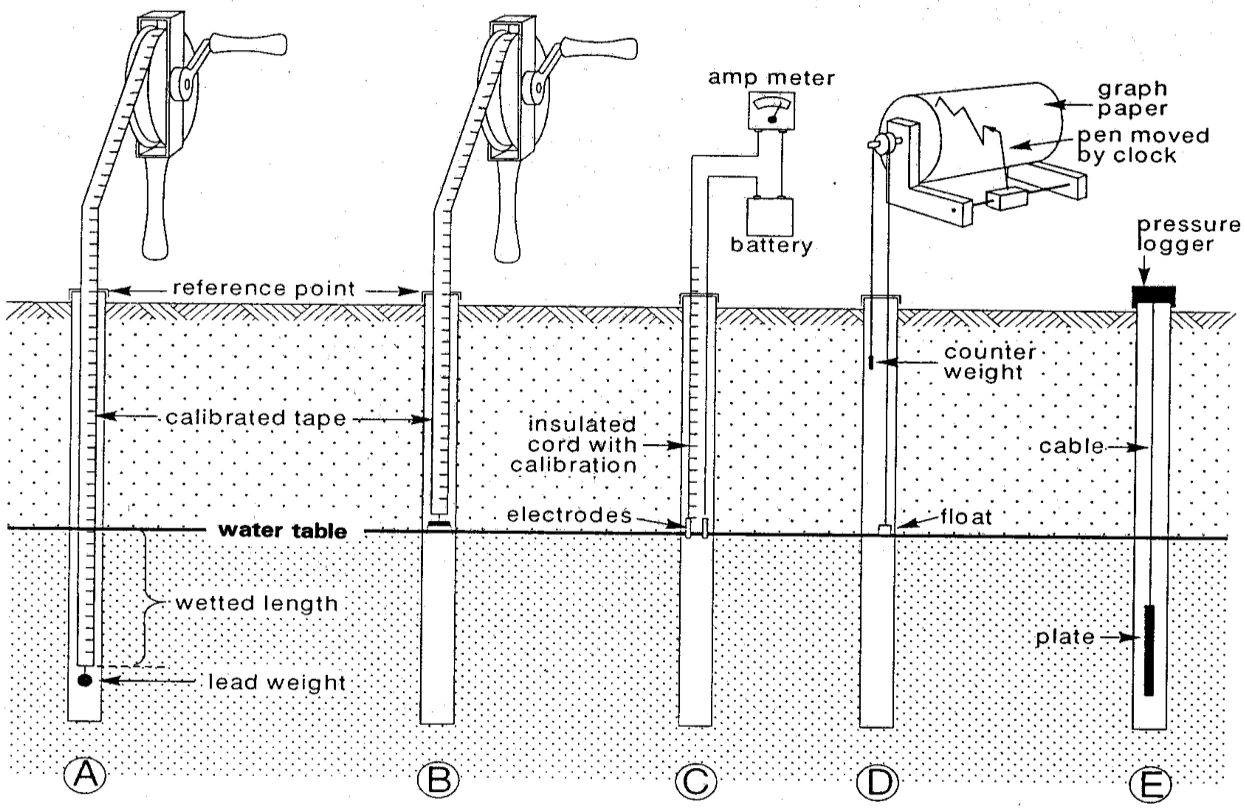
With a floating level indicator or recorder (Figure 26D): This consists of a float (60 to 150 mm in diameter) and a counterweight attached to an indicator or recorder. Recorders can generally be set for different lengths of observation period. They require relatively large pipes. The water levels are either drawn on a rotating drum or punched into a paper tape.

With a pressure logger or electronic water-level logger (Figure 26E): This measures and records the water pressure at one-hour intervals over a year. The pressure recordings are controlled by a microcomputer and stored in an internal, removable memory block. At the end of the observation period or when the memory block has reached capacity, it is removed and replaced. The recorded data are read by a personal computer. Depending on the additional software chosen, the results can be presented raw or in a calculated form. Pressure loggers have a small diameter (20 to 30 mm) and are thus well suited for measurements in small-diameter pipes.

The water levels of open water surfaces are usually read from a staff gauge (Figure 27) or a water-level indicator installed at the edge of the water surface. A pressure logger is most convenient for this purpose, because no special structures are required; the cylinder only needs to be anchored in the river bed.

The water table reacts to the various recharge and discharge components that form a groundwater system, and is therefore constantly changing. Important in any drainage investigation are the (mean) highest and the (mean) lowest water table positions, as well as the mean water table depth in a hydrological year. For this reason, water-level measurements have to be taken at frequent intervals for at least a year. The interval between readings should not exceed one month, but a fortnight may be better. All measurements in the project area should, as far as possible, be made over the shortest time span possible so that a complete picture of the water table in that time span can be obtained




amp meter
graph paper
pen moved by clock
battery
pressure logger
reference point
counter weight
calibrated tape
insulated cord with calibration
cable
electrodes
float
water table
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