2.0 DRAINAGE SYSTEM

2.1 General

The drainage system can be classified into surface and sub surface drainage systems. Although the basic objective of surface and sub surface drainage is to provide a soil moisture regime conducive to better plant growth, the way this is achieved is different. Surface drainage system removes water before it has entered the soil. Provision of surface drainage results in an increase in the surface runoff by which the amount of water going into storage in the soil is reduced. Sub surface drainage system removes water after it has entered the soil. Subsurface drainage aims to increasing the rate at which water can be drained from the soil so as to lower the water table for increasing the depth of unsaturated soil above the water table.

In many areas, both surface and sub surface drainage may be required. Surface drainage is accomplished by open ditches and lateral drains. Sub surface drainage is accomplished by a system of open ditches and buried tube drains into which water seeps by gravity. Water collected in drains is conveyed to a suitable outlet. Sub surface drainage can also be accomplished by pumping from wells to lower the water table.

A thorough evaluation of topography, soils, and quality and source of water is needed for selection of the appropriate drainage system. If the topography of an area reveals that the problem area is in a closed basin, then any type of gravity drain will not serve the purpose. A basin topography often lends itself to pumping for drainage. Broad, flat fields are ideal for tiling in a grid pattern, but benches and swales call for interceptor drains.

No drainage system can be adequately designed without a knowledge of the soil profile and the drainage characteristics of the sub surface strata. Knowledge about the type of soils, thickness of various strata, continuity of strata, position of the various strata with respect to the ground surface, hydraulic conductivity and porosity of the various strata is essential for the appropriate selection of the drainage system. The sequence of permeable and impermeable soils and their ability to transmit water determines both the type of system and its design.

In a place where there exists a 3 to 4 m thick impermeable clay and silty clay underlain by water bearing coarse sands or gravel, sumps or drainage wells are preferable. For soil gradually changing to less permeable strata with depth, tube drains will have greatest effect if they are placed as shallow as possible.

Water source often governs the type of drainage to be installed. If excess water is due to precipitation the remedial measure would probably be better surface drainage; if due to canal seepage, an interception drain may be indicated; and if due to artesian pressure pumped wells may provide the most practical remedy.

2.2 Surface Drainage System

The natural development of stream systems provides surface drainage for most sloping land. Areas that need artificial surface drainage are either nearly level or depressional. Surface drainage is the orderly removal of excess water from the surface of land through improved natural channels or constructed ditches and through shaping of the land surface. Surface drainage systems, when properly planned, eliminate ponding, prevent prolonged saturation and accelerate flow to an outlet without siltation or erosion of soil.

Surplus surface water may originate from irrigation or from precipitation. The surplus water from irrigation is generally caused by outflow from the lower ends of furrows or irrigation borders. It is found, in most cases, that the quantities of irrigation return flow are small and not critical to the design of surface drainage channel. The minimum section of the drainage channel which can be conveniently excavated will generally prove to be greater than that required by the predicted rate of irrigation return flow. On the other hand the amount of surface water derived from precipitation which must be removed by a surface drainage system during the rainy season may be considerable, and therefore, critical in the design of surface drainage channel. Whenever rainfall intensity exceeds the infiltration rate of the soil, surplus water will collect on the ground surface. If the land is flat it will cause ponding. Some of the volume of ponded water will disappear without drainage after the rain stops because of continued infiltration and surface evaporation. The critical factor, therefore, is not the volume of water to be removed but the period of time which the crops can tolerate the ponding. Generally speaking, and for most crops, shallow ponding for up to 24 hours will not cause any serious damage. The tolerance limits of different field crops to ponding are as given in Table 2.1. If the fields are flooded from high water in a nearby river or from surface runoff at the foot of a nearby slope or hill, the problem is completely different and must be handled as a flooding rather than a drainage problem (Finkel, 1983). The design of diversion ditches, levees, and flood protection ditches is beyond the scope of the present manual.

Table 2.1 Recommended period of disposal for different crops based on tolerance limit of crops to ponding (IS 8835-1978)

Name of Crop	Period of Disposal
Paddy	7 to 10 days
Maize, Bajra and other similar crops	3 days
Sugarcane & Bananas	7 days
Cotton	3 days
Vegetables	1 day

Surface drainage system is comparatively simple to plan, design and construct and is usually relatively less expensive. All possible excess water from all sources should be removed before it percolates to the groundwater table to create or intensify a more expensive sub surface drainage problem. The various conditions which causes surface drainage problems are:

i) Uneven land surface with pockets or ridges which prevent or retard natural runoff. Slowly permeable soils magnify the problem.

ii) Low-capacity disposal channels within the area which remove water so slowly that the high water level in the channels causes ponding on the land for damaging period.

iii) Outlet conditions which hold the water surface above ground level such as tide water elevation or a ruling high level in river or stream in the flood season.

The traditional drainage system on heavy clay soils is surface drainage. Soils also need surface drains under any of the following situations:

i) A hard pan or tight layer exists in the upper zone.

ii) The sub soil within a depth of 100 cm remains dry even after *an extended rainy period.*

iii) In tropical and subtropical area which receives high intense rainfall and where the soil is heavy and slow permeable.

The basic surface drainage systems are:

i) the random,
ii) *the parallel, and*
iii) the cross slope or diversion system.

The system to be used will depend upon the requirement of the site. The various systems are described below.

2.2.1 The random system

Where the topography is irregular, but so flat or gently sloping as to have *wet depressions scattered over the area, a random system is used. (Fig. 2.1)* The field ditches should be so located that they will transect as many depressions as feasible along a course through the lowest part of the field towards an available outlet. The course should be selected so as to provide the least interferrence with *farming operations and a minimum of deep earth cuts. Cuts over 1 metre should* be avoided although these sometimes are necessary to reach an outlet and leave a farmable field. Ditches should extend completely through depressions to **ensure** complete drainage. Fields ditches should ordinarily not be shallower *than 15 cms or deeper than 30 cms where they are to be crossed frequently by* farming equipment. Land grading, smoothing or bedding will usually be necessary on the less permeable soils to ensure complete surface water removal.

2.2.2 The Parallel System

Where topography is flat and regular, and a random system is impractical or inadequate, field ditches should be established in parallel (Fig.,2.2) but not *necessarily at equidistance. Orientation of field ditches will depend upon direction* of land slope; location of diversions, cross-slope ditches and mains and laterals of the disposal system. Usually, field ditches should run parallel field ditches depends upon size of the lands that can be tilled and harvested economically, on *water tolerance of crops and on the amount and cost of the necessary land* forming. Where sub surface drainage may be used in **conjunction** with field ditches for protection of crops highly sensitive to water, such as tobacco, field-

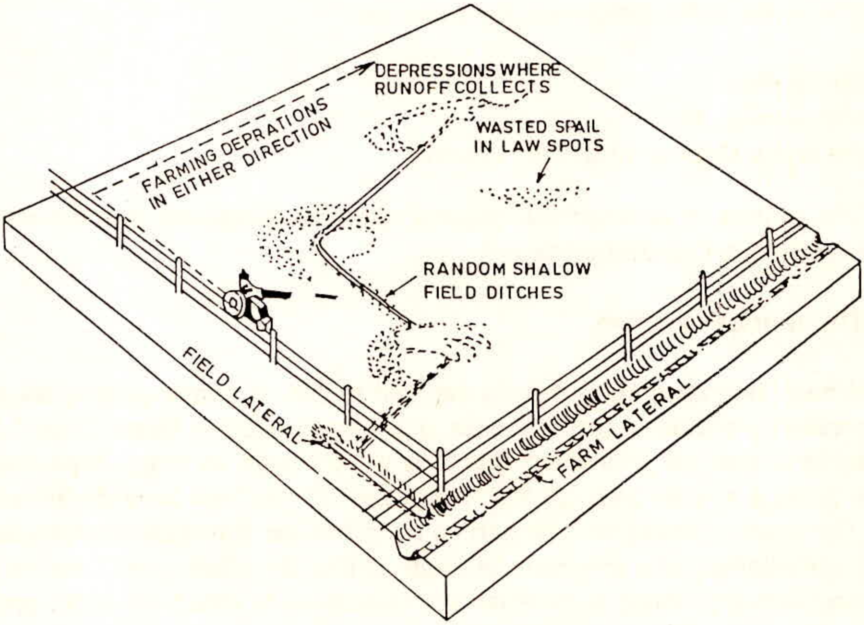

Fig.2.1 Random System

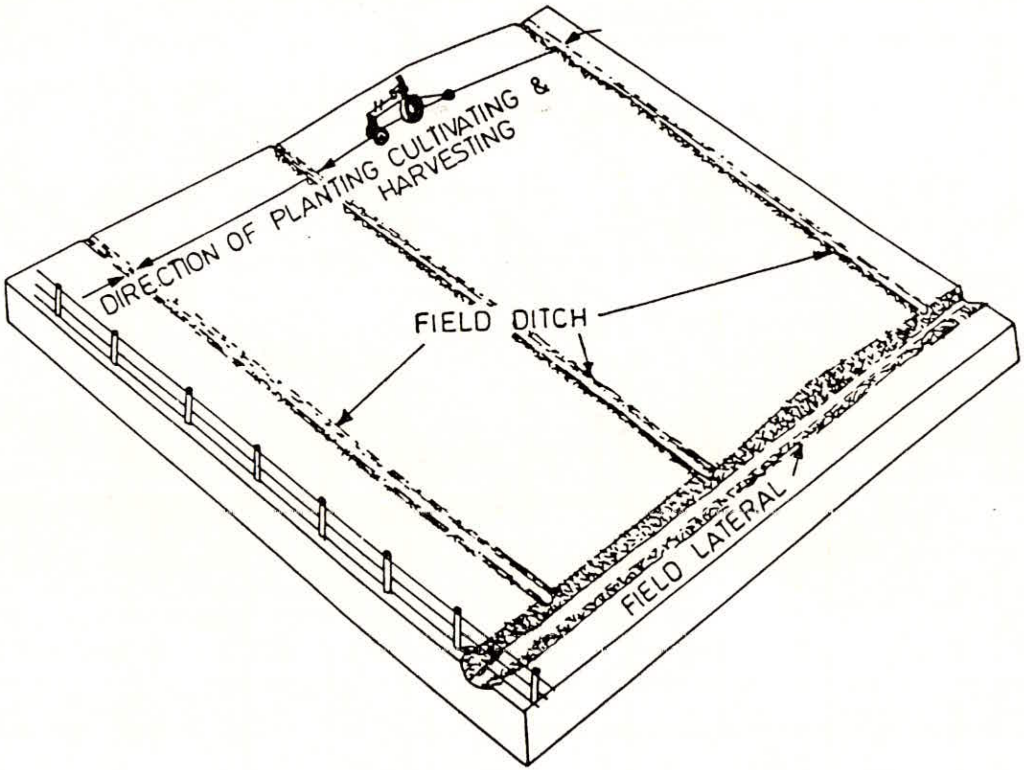

Fig.2.2(a) Parallel system depicting field layout suited to growing a variety of row crops, including cotton, corn, soyabeans, sugarcane, grain sorghum (Drainage of Agricultural Land, SCS, USDA, 1972)

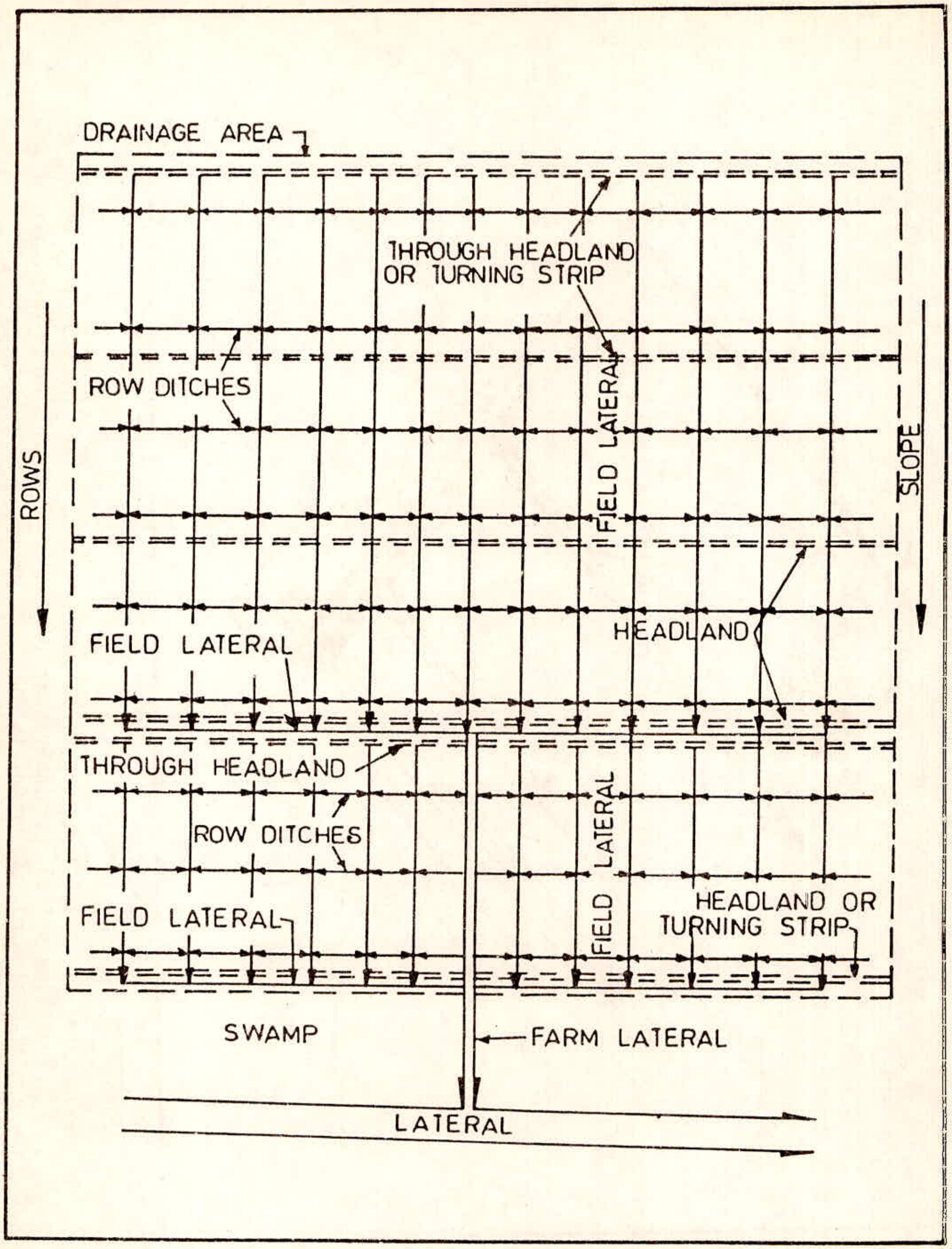

Fig.2.2(b) Parallel system, depicting field layout suited to sugarcane (Drainage of Agricultural Land, SCS, USDA, 1972)

ditch spacing may need to be adjusted to be compatible with spacing requirements of the sub surface drains.

2.2.3 The Cross-Slope System

The cross-slope system is used to drain sloping land, and to prevent accumulation of water from higher land. The system consists of one or more diversions, and field ditches built across the slope (Fig. 2.3). Whether to use diversions or field ditches, depends on the steepness of the slope, the permeability of the soil, and the possiblity of water flowing from higher land onto the field being drained. Field ditches are best on slopes under two percent. Diversions apply to steeper land. A surface-drainage system is composed of field drains which collect the excess water from land surface and conduct it to lateral ditches in which water flows to a main ditch and then to the drainage out let, usually a natural waterway (Fig. 2.4)

Field Drains:

These are shallow ditches with flat side slopes, which farm machinery can cross. A field drain is normally 23 to 31 cm (sometimes 46 cm) deep with side slope 6:1 or flatter. Horizontal spacing of field drains depends on the soil, the topography and the amount of drainage expected. Where the drains are parallel they are usually not more than 200m apart on sandy soils, 60m apart on organic soils and about 90m apart on other soils. (OGROSKY and MOCKUS, vide CHOW, 1964).

Lateral Ditches:

These are deeper than field drains, usually with a depth of a 30 cm or more and often with flat side slopes that farm machinery can cross.

Main Ditch:

The main ditch is normally constructed with a drag line and requires most of the planning and design in a drainage project. Main ditches generally run along property lines or roads, although sometimes a small natural channel may be used after enlargement in its original location.

2.3 Sub surface Drainage System

Any drain or well which is installed to control or lower the high water table in an area is considered to be an element of sub surface drainage system. The high water table may be caused due to percolation from precipitation, seepage from canals and surface water bodies located at higher elevation, irrigation water, leaching water and leakage from artesian aquifer. In arid and semi arid areas a

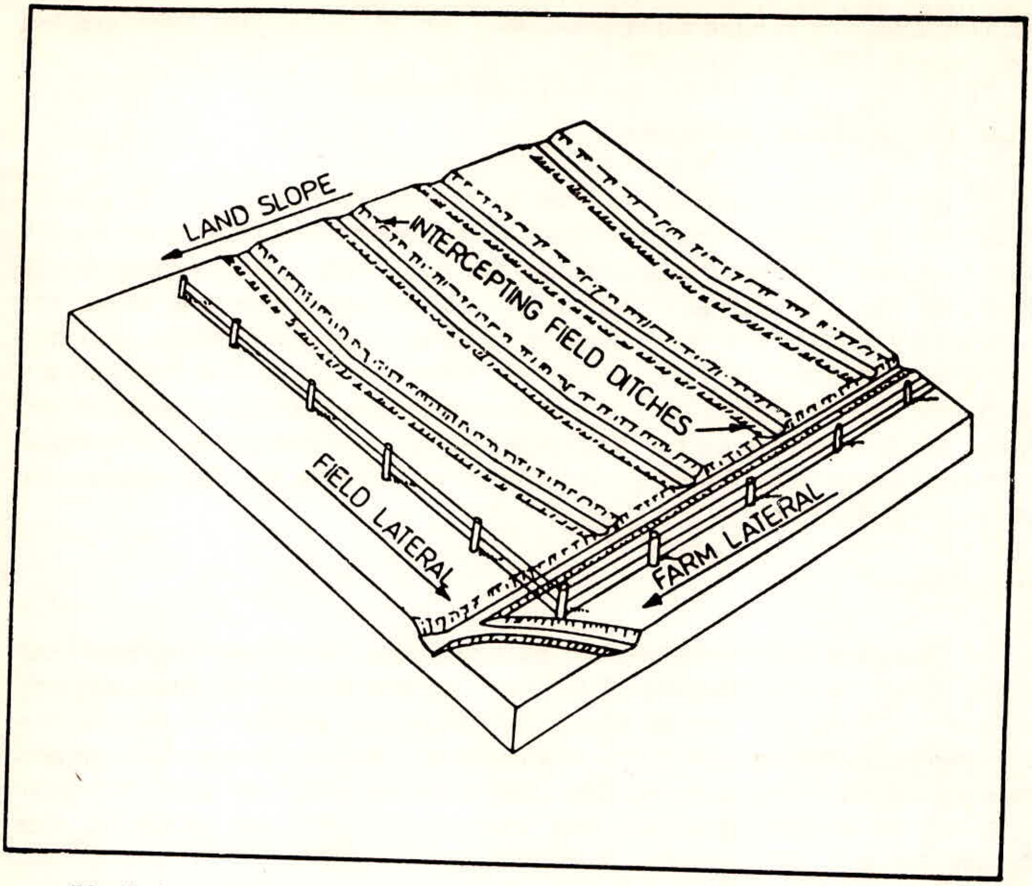

Fig.2.3 Cross-slope system on slight to moderate slopes
(Drainage of Agricultural Land, SCS, USDA,1972)

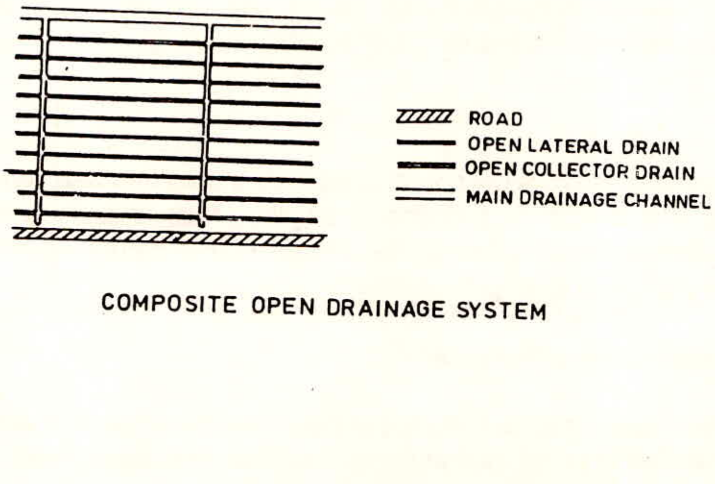

Fig.2.4 Lay out of a surface drainage system showing lateral drain, collectoral drain and main drainage channel

minor portion of excess water comes form precipitation. The major source of excess water is precipitation. The major sources of excess water in irrigated areas are percolation losses from the irrigation and leaching water applied and seepage losses from irrigation canals. In humid, arid and semi arid areas, the sources of excess water may be ground water moving through shallow aquifers and emerging as springs or ground water under artesian pressure. When the total quantity of water introduced into the sub surface in an area from the vaious sources exceeds the total quantity disposed of through natural drainage processes the water table will rise. It is then necessary to install artificial drains to remove the surplus water to maintain the water table at some predetermined level which is not harmful to crops.

2.3.1 Classification of Sub surface Drainage

From a functional point of view, sub surface drainage falls into two classes: relief and interception drainage. Relief drainage is used to lower a high water table which is generally flat or of very low gradient. Interception drainage is to intercept, reduce the flow and lower the flow line of the water in the problem area. An isometric profile indicating relief and interception drains is shown in Fig. 2.5. In planning a sub surface drainage system, the site conditions should be evaluated to decide whether to use relief or interception drainage.

2.3.1.1 Relief Drainage

In a relief drainage systm one can distinguish three categories of drains: field laterals, collectors and main drains. The field lateral, collectors and main drain can be either bureid pipes or open ditches or a combination of both. Ditches used for sub surface drainage may carry both surface and sub surface water. Ditches are best adapted to large flat fields where lack of grade, soil characteristics or economic conditions do not favour buried drains. The advantages in using ditches include the following:

i) They usually have lower initial cost than drains.
ii) Inspection of ditches is easier than inspection of drains.
iii) They are applicable in some organic soils where drains are not suitable due to subsidence.
iv) Ditches may be used on a very flat gradient where the permissible depth of the outlet is not adequate to permit the installation of drains having the minimum required grade. The gradient required for water transport is approximately 0.01% in ditches and 0.1% in pipe drains.

The disadvantages in using ditches are as follows:

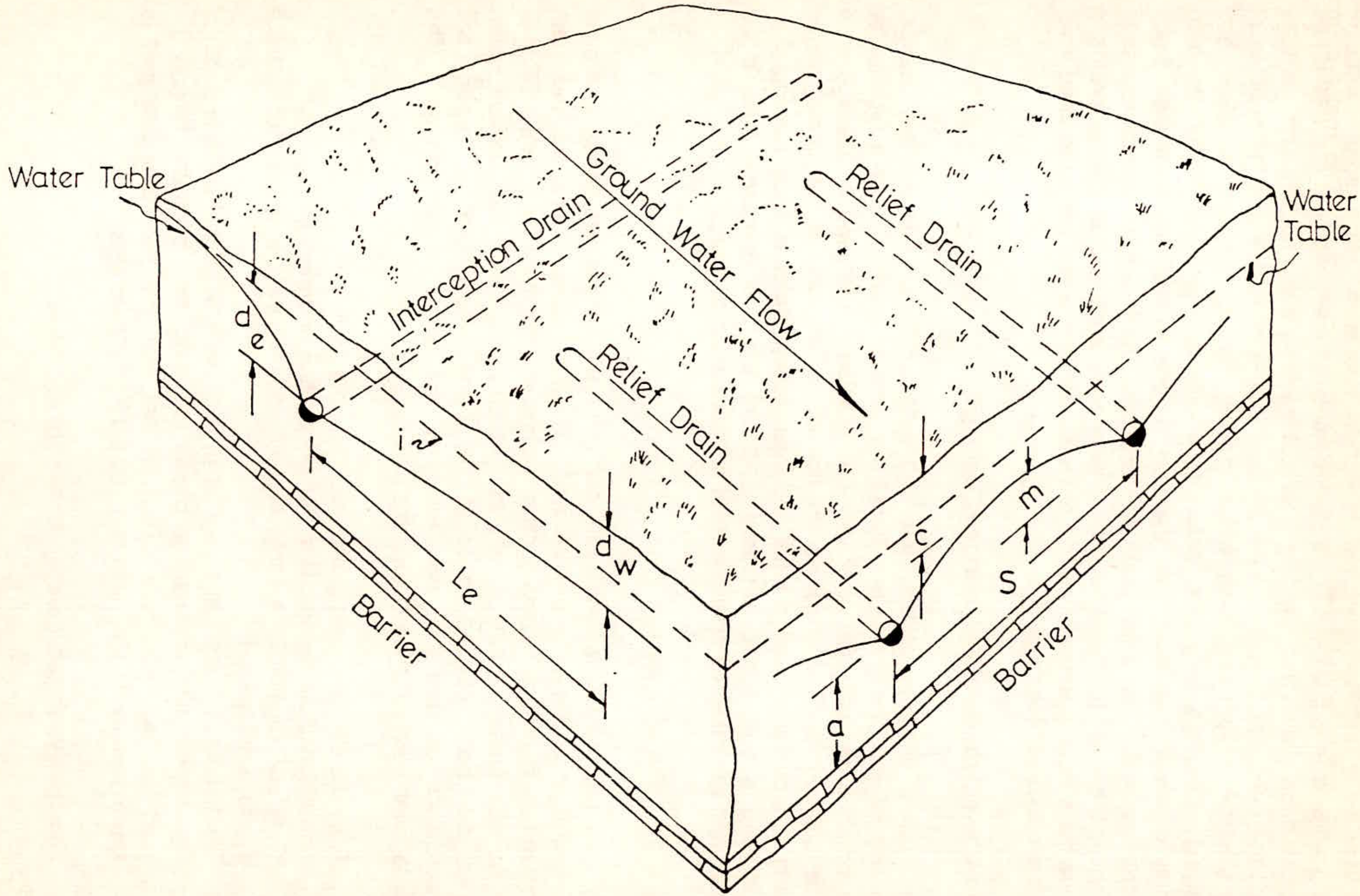

Fig.2.5 An isometric view of relief and interception drains

i) Ditches require considerable right of way which reduce the area of land available for cropping. This is particularly true in unstable soils where flat side slopes are required.

ii) Ditches usually require more frequent and costly maintenance than drains because of weed growth and erosion.

Buried Drains

Buried rains refer to any type of buried conduit with open joints or perforations which collect and or convey drainage water. Drains may be fabricated from clay, concrete, bitumenised fibre, metal, palstic or other material of suitable quality. Drains, if properly installed, require little maintenance. They are usually preferred by land owners as they are buried and no land is removed from cultivation and maintenance is considerably less than for ditches. Relief drainage systems are classified into four general types:

i) Parallel
ii) Herringbone
iii) Double main, and
iv) Random

The four systems are shown in Fig.2.6.

2.3.1.2 Interception Drainage

The first step towards solving an agricultural drainage problem is to identify the cause. Sometimes what appears to be a major drainage problem can be solved by a simple remedy once the cause is recognized. An example of this is water logging which is caused by water coming in from outside the wet area. This problem can be abated by a single drain which intercepts the flow. On sloping land it is worth trying the effect of an interception drain before putting in a relief drainage system. A few examples are mentioned here for which interception drainage is appropriate. Under natural conditions, a sub surface barrier causes reduction in the deph of aquifer which leads the water table surface to rise up to or near the ground surface (Fig.2.7). This causes a wet or seep area near the barrier. This situation is often found in alluvial flood plains where ancient channel changes have built up barriers of fine grained sediments, some times referred to as slack-water deposits (SCS U.S.D.A. 1973). This conditions is difficult to detect and usually requires extensive subsoil exploration. The presence of unexplainable wet areas surrounded by dry areas suggests such a nonuniformity in subsoil material. The corrective measure may be construction of a parallel drain just up slope from the barrier. If a permeable layer, sandwiched between layers of less permeable material outcrops causing a seep that may affect a considerable area below the out crop, the remedial measure would be installation

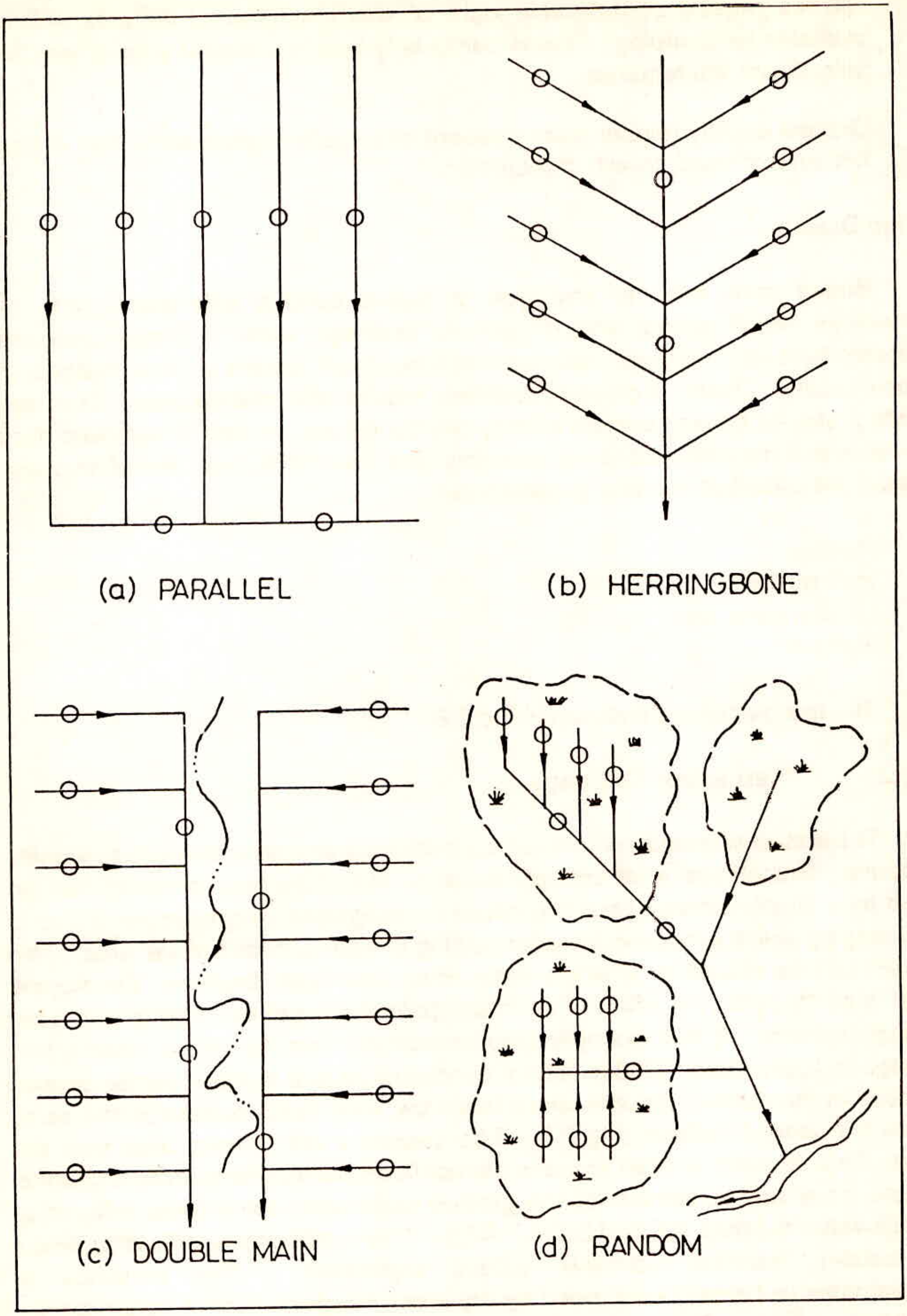

Fig.2.6 Types of subsurface drainage systems

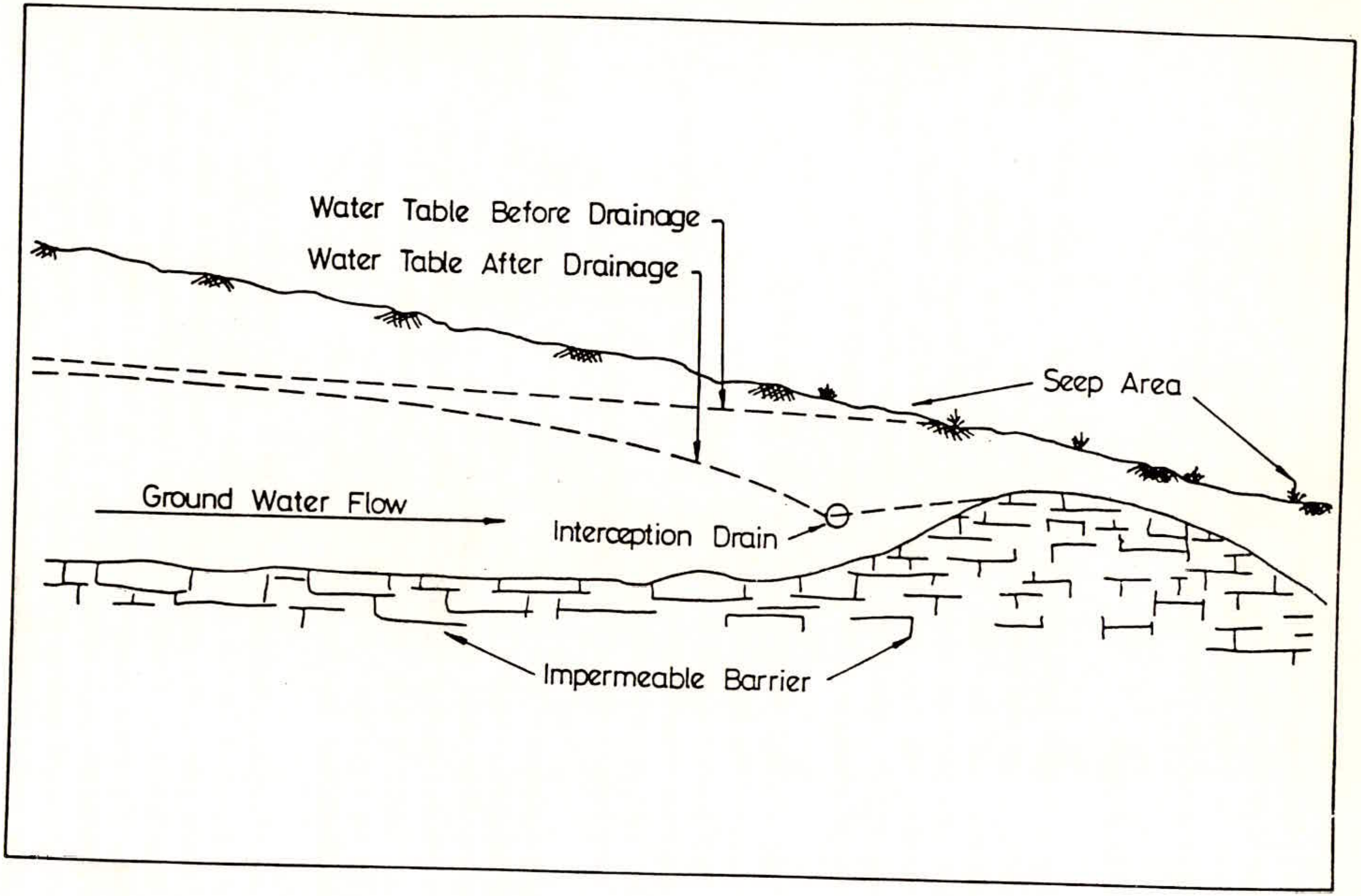

Fig.2.7 Rise in watertable due to presence of subsurface barrier and effective position of the interception drain for reducing seep area

of intercepting drains. The interception drain should be located as shown in Fig. 2.8 at the base of the impermeable layer to collect the flow from the aquifer, and prevent seepage at the ground surface. An intercepting drain may also be on open ditch dug down to the impervious layer as shown in Fig. 2.9. In such case the intercepting drain would intercept surface flow besides the sub surface flow.

2.3.2 Vertical Drainage

Rise of groundwater table can be prevented and groundwater table can be lowered by pumping groundwater through tube wells. The tube well with a pumping equipment comprises the vertical drainage system. Power should be available at a reasonable cost for operating a vertical drainage system. Recently eucalyptus plantation has been made use of for lowering the water table. The eucalyptus trees act like vertical drainage system for which no power supply is required. Tube well drainage systems are suitable under the following conditions:

i) in flat land with high water table position in a large area,
ii) groundwater under artesian condition,
iii) absence of adequate gravity drainage outlet,
iv) if ground water lowering beyond 2.5m. is required and an impervious layer does not exist at a shallow depth, and
v) the ground water is saline & it rises at an alarming rate.

Before installation of tube well drainage system it is necessary to ascertain the hydraulic interconnection of the pumped aquifer and the shallow water table aquifer. If saline water table exists at shallow depth, a vertical drainage system can not skim the thin layer of good quality water overlying the saline water. For skimming the good quality water a horizontal drainage system is more appropriate. A vertical drainage system can arrest the rise of saline water table which can not be affected by a horizontal drainage system.

The use of vertical drainage is much more restricted by the geohydrological conditions of the area and it can not be regarded merely as a substitute of gravity drainage. Unlike gravity drainage which has been practiced in various forms since long, the technique of well drainage is comparatively recent development and the number of projects where well drainage is being applied is still small. The design of a vertical drainage system should suggest the locations of wells, their number and pumping schedule and should also suggest utilization of the pumped water if it is good or disposal of the same it is of poor quality.

Conjunctive use of canal and tubewell water as practised in many areas needs to be mentioned.

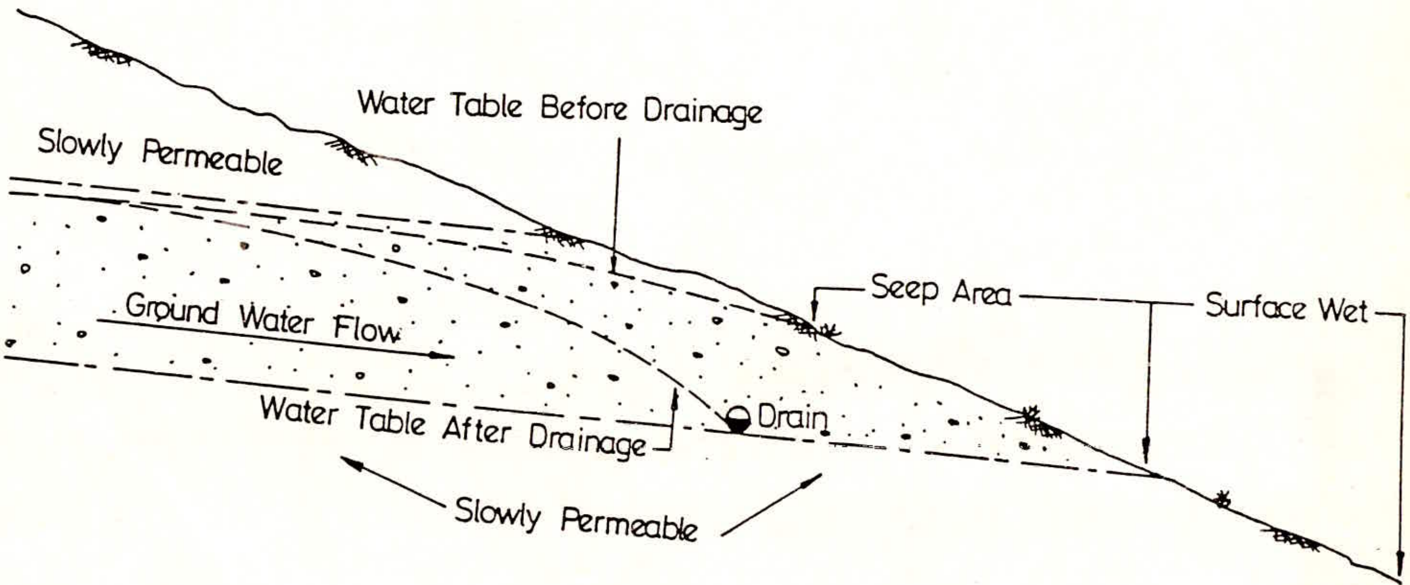

Fig.2.8(a) Intercepting drain at out crop of aquifer

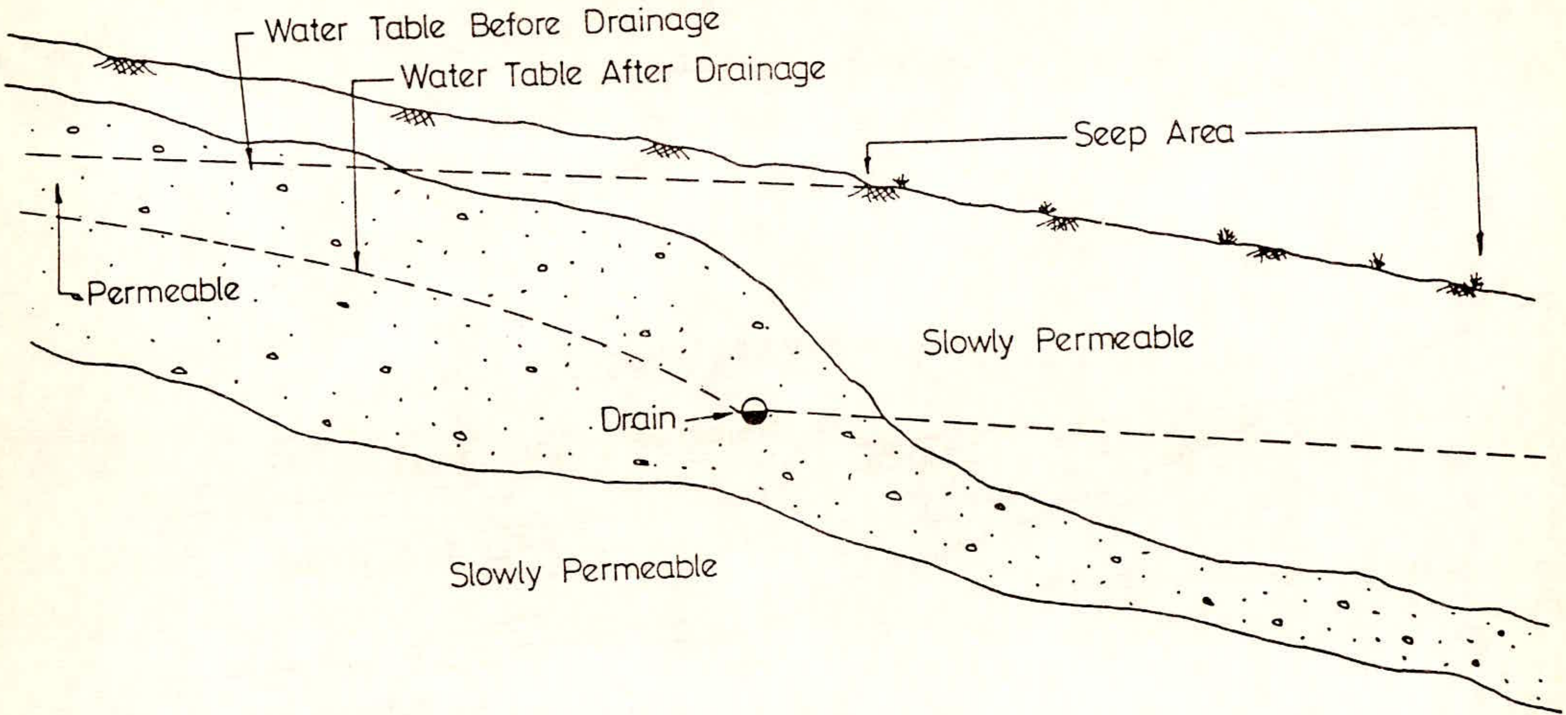

Fig.2.8(b) Interception drain in a constricted aquifer

2.3.3 Mole Drainage

Mole drainage are unlined, unprotected round channels formed by a mole plough without digging a trench, by pulling a smooth bullet shaped object through the subsoil at a depth of about 0.7 meter. The mole usually consists of a sharp pointed cylindrical steel core, about 30 to 65 cm long and 5 and 8 cm in diameter. The mole is attached to a horizontal beam by means of of a sharply wedged steel blade as shown in Fig. 2.10. A short cylindrical metal core or sphare is attached to the rear of the mole by means of a short chain. The expander serves to clear the channel and gives a smooth finish. Mole drainage is particularly appropriate in dense, poorly pervious clay soils which have a certain general slope. The primary aim by this method is not to control the ground water table, but to remove excess water from the field surface from topsoil. The water reaches the mole channel mainly through the fissures and cracks that are formed when the moles are being drawn as shown in Fig.2.11. Mole drains normally discharges into an, open drain at a lower elevation. The main risk in mole drainage is the collapse of the drains due to lack of stability of the soil. Mole drain depth and spacing are usually not calculated. In some countries in Eastern Europe, the spacing is related to soil texture but for the most part it becomes a judgement factor based on experience. The distance between the drains usually varies between 2 to 5m. The depth is limited by the available power needed to construct the drains and by the fact that they should always be well above the water level in the respective collector ditches. Suitable depths are found to be 45 to 55 cm (New Zealand) and 70 to 90 cm (Eastern Europe). The mole channels should have a regular gradient to avoid water remain standing in lower section because this might eventually cause their collapse. To prevent standing water and silting up, the slope of the channel should not be too flat, preferably not less than 1%. A gradient of more than 3% should be avoided as it results in too high flow velocity which will cause scouring of the drains. The lengths of the drains is limited to 100 meters for slope between 1 to 1.5% but length up to 600 meter have also been applied. The suitability of the soil for mole drainage has been associated mainly with a minimum clay content (26 to 50%). The effective life of the mole drains may be between 3 to 15 years depending upon the type of soil and its stability.

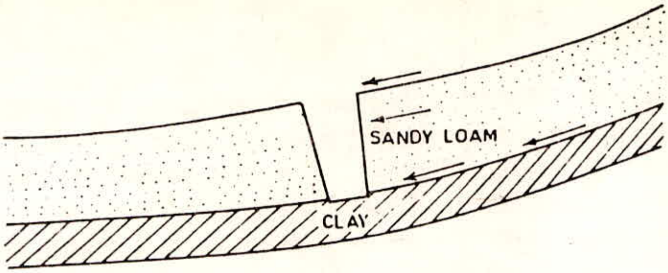

Fig.2.9 An open ditch intercepting drain

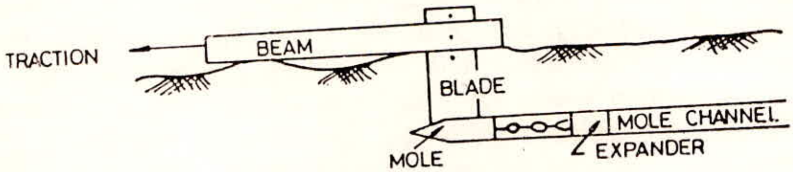

Fig.2.10 Mole Plough

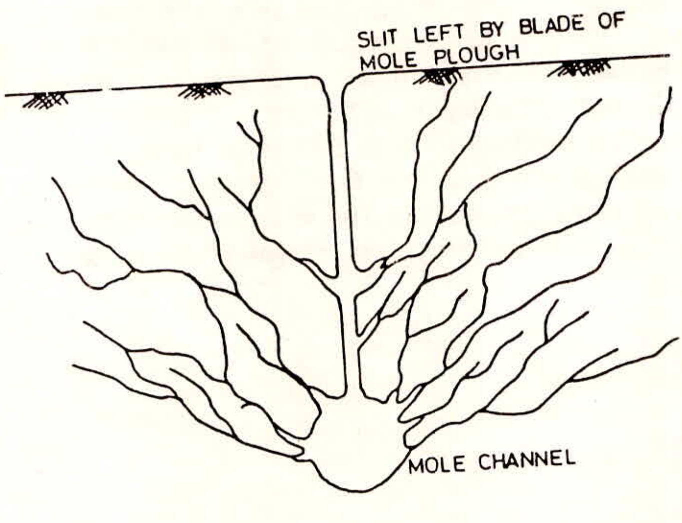

Figure 2.11 Cracking and fissuring of heavy soil as a result of mole drainage