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Certified that the attached Thesis/Dissertation on Water Logging its Causes and Preventive Measures with Special Reference to Chambal Canal System in M.P.

was submitted by

Sri R.S. Varadarajan

and accepted for the award of Degree of ~~Doctor of Philosophy~~/Master of Engineering in W.R.D.

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WATER LOGGING-ITS CAUSES AND PREVENTIVE MEASURES WITH SPECIAL REFERENCE TO CHAMBAL CANAL SYSTEM IN MADHYA PRADESH

A DISSERTATION
submitted in partial fulfilment
of the requirements for the award of the Degree
of
MASTER OF ENGINEERING
in
WATER RESOURCES DEVELOPMENT

By
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WATER RESOURCES DEVELOPMENT TRAINING CENTRE
UNIVERSITY OF ROORKEE
ROORKEE (INDIA)
1973

PROF. PRAHLAD DAS
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CERTIFICATE

Certified that the dissertation entitled "WATER LOGGING ITS CAUSES AND PREVENTIVE MEASURES WITH SPECIAL REFERENCE TO CHAMBAL CANAL SYSTEM IN MADHYA PRADESH" which is being submitted by Shri R.S. Varadarajan in partial fulfilment of the requirement for the award of the Degree of Master of Engineering in Water Resources Development of the University of Roorkee, is a record of Shri Varadarajan's own work carried out by him under my guidance and supervision as internal guide. The matter embodied in this dissertation has not been submitted for the award of any other Degree or Diploma.

This is further to certify that Shri Varadarajan has worked for a period of more than Nine months for preparing the dissertation for the Master of Engineering Degree in Water Resources Development.

8.4.73

(PRAHLAD DAS)

C E R T I F I C A T E

The Dissertation on the subject "Water Logging its Causes, and preventive measures with special reference to Chambal Canal system in Madhya Pradesh" has been prepared under my guidance.

Approved by

Sd/-

(J.V.MEHTA)
CHIEF ENGINEER
BODHGHAT PRIYOJANA
RAIPUR (MADHYAPRADESH)

Dated 16.8.1971.

C E R T I F I C A T E

The portion of Dissertation pertaining to water-logging under Chambal Canal System, its causes and remedial measures proposed to be taken up in the Ist instance has been submitted by Shri R.S.Varadarajan. Detailed investigations for proposing permanent measures for control of water-logging problems in Chambal commanded areas are being carried out.

I have gone through the proposals and they appear fit for inclusion in the Thesis on Water-logging Problems, that has been prepared by the trainee.

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PART-I

SYNOPSIS

Irrigation and Drainage are inter-related and in most of the cases complementary to each other. It is well known that while considering the need for drainage much of the small portion of the total land surface on the earth that is available to man for growing crops requires artificial reconditioning before it is ready to produce cultivated crops. Among the items of such artificial reconditioning are Irrigation and Drainage.

There will always be a balance between the water that ultimately flows out of the underground reservoir to a valley and the inflow to the underground water from the land surface by way of rainfall. Any condition that creates obstruction to this natural phenomenon will lead to instability of inflow-outflow relationship, causing the underground water table to rise and make the land water-logged, warranting provision of artificial drainage. The cause for water-logging will have to be established before suggesting system of drainage to be adopted.

Types of Drainages:- Drainage may be for agriculture or non-agricultural purposes. Non-agricultural drainage may include municipal drainage, drainage to protect structures, drainage of playfields, race-tracks, air ports and for ensuring public-health.

Agricultural drainage deals with the removal of excess water from the land surface and from the soil of the root zone of plants i.e. surface as well as sub-surface or internal drainage. This is necessary to increase productivity of crops grown on the land by keeping the root zone without saturation for a long time.

Soil moisture relationship are very important in drainage. Thus the factors which are of primary importance in Irrigation are: infiltration capacity of the soil, field capacity, moisture storage between field capacity and wilting coefficient, and capillary conductivity of the soil.

Factors of particular importance in drainage are infiltration capacity of the soil, moisture holding capacity of the soil in the root zone between field capacity and saturation and the soil permeability and these factors are mainly governed by the soil texture, soil structure and organic matter present in the soil.

Water-logging:- When free water is present in the soil permanently within the last 1/3 of root zone of crops, and the soil pores are occupied by water to such an extent as to effectively cutoff normal circulation of air, and retardation of plant growth leading to water-logging of land results. The harmful effects of free water are poor aeration resulting in lack of oxygen to the plant roots, retardation of favourable bacterial activities, adverse biochemical changes, dilution of soil nutrients and their removal by seepage, development of certain plant diseases and in some cases, encouragement of growth of some insect pests. For detailed discussions refer para 2.1.0.

Drainage in Arid and Humid Regions:- In humid and wet regions, low lying lands with poor surface drainage may be naturally water-logged. Such lands are the most fertile and need to be efficiently drained in order to be fit for cultivation. Thus in arid regions, drainage follows irrigation and in humid regions it may have to precede agricultural development. In arid and semi-arid regions, the rise of ground water table, which leads to water-logging also brings up injurious salts causing excessive salt concentration in the root zone thereby rendering the soil saline and unproductive.

Water-logging in Chambal Command:- The commanded areas in Madhya Pradesh from Chambal Canals falls between arid and semi-arid zone. The Chambal Canal is a contour canal with command on left side and the water logging conditions are confined to the left side of the Main Canal only. (Ref. FIG.1) map). The water logging problems in the areas of Bhind, Morena Districts are attributed to the blocking of natural drainages, seepage from canal, existence of clayey soils on the left side of the Main Canal at top levels preventing infiltration and consequent stagnation of water on the land surface. Further, due to the existence of soils with comparatively lesser percentage of clay at right side of the canal compared to the left side recharge conditions have developed leading to high water table on left side of canal in confined state. About 1,45,401 acres of land under Chambal Canal system in Madhya Pradesh is under the influence of water table between 0 to 10 ft.

Salt concentration with white crusts of salt are also seen in small patches on the land surface. Pilot schemes like Maugral, Sabalgarh, Pemsar etc. have been taken up after preliminary investigations, for implementation of remedial measures. It consists mainly of clearing, deepening and widening of natural drainages, provision of additional drains where necessary, and lining of canals in embankment reaches to prevent seepage. Since the water logging conditions are only marginal at present, no costly proposals like sub-surface drainage are proposed to be taken up. After watching the behaviour of water table etc. on construction of surface drainage, further remedies would be propose

CHAPTER - 1

INTRODUCTION - HISTORY OF DEVELOPMENT OF IRRIGATION AND DRAINAGE

1.1.0. IRRIGATION

Irrigation practices are known to have developed since over four thousand years in the Valleys of Euphrates, the Tigris and the Nile in Egypt. Irrigation facilities provided by the major rivers in Egypt, China etc. is reported to be the cause for the development of civilization in these countries. After the first World War in 1918, the development in the field of Irrigation increased. From one hundred million acres at the beginning of the 20th century, the irrigated acreage in the world increased three-fold to about 300 million acres by 1955. It is estimated that before the year 2000, the irrigated acreage in the world would have exceeded the 500 million acres mark(17).

1.1.1. IRRIGATION IN INDIA

Irrigation in India has been practised from pre-historic times and appears to have been contemporary with Agriculture itself. Frequent references are found in the Vedas and other ancient Indian literature to wells, tanks, canals and dams, to the importance to the community of their efficient maintenance and operation and to the duties of the States in these matters(18).

1.1.2. Many major works in North and South India were completed during the 18th and 19th centuries. The period 1800-1836 has been called the period of the first great ventures during which the old Yamuna canals in the North and Cauvery

Delta system in the South were remodelled[18].

1.1.3. India has made rapid strides, since 1951 in the field of irrigation, when development started. The total cultiveable land in India is 194.61 m.ha (480.9 m.a.) About 85 to 90 million acres would be under irrigation by the end of 4th Five-year plan which is about 18% of cultiveable area. By the end of 5th Plan it is proposed to bring the irrigation potential to 23% of total culturable area.

1.2.0. DRAINAGE

The experience in India and other countries has shown that irrigation, while it contributes substantially towards the support of ever-increasing population of the world is not an unmixed-blessing. Provision of inadequate drainage facilities has lead to the problem of water logging and salanization of lands. There is always a balance between the inflow of water into the ground from rainfall etc. and the outflow and as a result a state of equilibrium will have been established by the underground water table. Any disturbance in this respect, for instance, by construction of roads, railway embankments, development of towns, extensive irrigation by canals thereby affecting the natural drainage capacity of drainages will lead to an imbalance in the natural inflow and outflow of ground water which originally existed. Consequently, the underground water table will try to readjust the equilibrium by creating a rise in water table at some portions and lowering in some other areas. If the water table comes close to the ground surface, it may affect the productivity of soil and water-logged conditions may develop. (Refer para 2.1.0). Under water-logged conditions the crop yield will be considerably affected. This state of affairs cannot be allowed to develop when there is already shortage of food in most of the countries in the world, compared to the rise in population. It is, therefore, necessary that adequate drainage of irrigated lands should be provided to check water-logging.

1.2.1. <u>PROBLEM OF WATER LOGGING IN CANAL IRRIGATED AREAS IN INDIA</u>

The problem of water logging exists in many states in India especially in Indo-Gangetic plains which have flat slopes and poor outfalls. In Deccan regions in the South where the drainage conditions are better, being a rolling terrain the problem is not much. In Uttar Pradesh the problem exists in the commanded areas of Ganga Canal System, Mira Canals in Maharashtra and Chambal Canals in Madhya Pradesh and Rajasthan. A rough assessment of areas water-logged in different States upto April 1959 is indicated in the table[24]

TABLE:1

States	Category A W.T. 0-5 deep area in acres		Category B W.T 5-10' deep area in acres.		Category C W.T. 10-15' deep	Category D Salt affected area deep W.T.	Total Salt affected area (Acres)
	Water logged area.	Salt affected area.	Water logged area	Salt affected area	Area (acres)	Area (acres)	
Punjab	1970520	1300000	3350000	450000	2283000	1250000	3000000
West Bengal	573750	Nil	191250	Nil	Nil	Nil	Nil
U.P.	Nil	Not known	96345	Not known	Nil	2300000	2300000
Bombay	10821	17900	Nil	53744	Not known	Nil	71644
A.P.	10456	Nil	Nil	Nil	Nil	Nil	Nil
J & K	4500	Nil	25000	Nil	24000	Nil	Nil
New Delhi	3200	Nil	6000	Nil	600	Nil	Nil
Total:	2573247	1317900	3668595	503744	2307600	3550000	5371644

1.2.2. ANTI WATER LOGGING MEASURES UNDERTAKEN IN INDIA

The need for drainage as anti-water logging measure was recognised in 1954 and prior to this year desired attention had not been given to provision of adequate drainage in canal irrigated tracts(18) by most of the States in India.

1.2.3. It was in Punjab even as early as between 1870 and 1880 that certain canals were realigned and natural drainages improved by the provision of adequate water ways in order to lower the W.T. in canal irrigated areas. A drainage board was set up in 1918, a water logging Board in 1928 and a Drainage Circle in 1944 to investigate into the problem(24).

1.2.4. The States are now alive to the situation and a number of anti-water logging measures have been taken up by the States. West Bengal has undertaken the Sonarpur Arapaneh drainage scheme, the execution of Etoberia and Kalaberia Khal schemes and others. A total area of 360.5 sq.miles is expected to be benefited by these schemes(24).

1.2.5. In U.P. several measures like the construction of surface drainage lines with the canal system, reducing the intensity of canal irrigation and implementing correct irrigation practices encouraging the use of wells have been taken up(24). Conjunctive use of well and canal irrigation is also practised in U.P.

1.2.6. Maharashtra has carried out experiments on various anti water logging measures such as canal lining, changing of cropping pattern according to soil suitability etc. and has now standardised the technique of land drainage(24).

1.2.7. In Madhya Pradesh 1,45,400 acres of land is affected by water logging. This area is under the influence of W.T. between 0-10'. Efforts are being made to combat the water logging by implementing such measures as removing obstruction to natural drainages, construction of surface drains, encouraging use of wells etc.

1.3. Water logging is a serious problem in this country. Extensive valuable agricultural land of the country is going out of use due to water logging caused by incorrect irrigation practices, over irrigation and inadequate drainage of the land. It may therefore be kept in view that scientific irrigation coupled with proper land drainage are essential for successful agriculture. It has to be realized that drainage measures are an essential part of the irrigation schemes and adequate provision for drainage should be included in the irrigation project itself. On the older canals there is need for concentrated measure to check ingress of water logging and to reclaim water logged areas.

1.3.1. The dissertation on the subject of water-logging has been divided into two parts for convenience. It presents the problems of water-logging of lands, its causes and remedial measures. Part I deals with the General aspects of the problem and Part II with the problem of water-logging in Chambal canal system.

CHAPTER - 2

WATER LOGGING - CAUSES AND EFFECTS

2.1.0. Water-logged soils create anerobic conditions at the roots of plants and suffocates the plant growth and thus render the land unfit for cultivation. The growth of normal crops is dependent upon an adequate supply of nitrogen in the form of nitrates. The process of nitirification is carried out by a kind of bacterial activity i.e. aerobic bacteria which require oxygen for their survival. The presence of excess water in the water logged soil results in the exclusion of air, reduces the supply of oxygen to these bacteria with the result that nitrification process does not take place and plant growth is affected. Thus the 'anerobic' conditions are felt by the plants. This anerobic bacteria produce gases which are harmful to the plants.

In average well drained soils, the pore spaces amount to be 40% of which 25% is filled with capillary water and the remaining 15% with air(17). In well drained soils the carbon-dioxide in the soil air dissolves with the water infiltrating through the soil forming carbonic acid which dissolves the mineral elements of the soil required by plants, and thus fresh air with oxygen is drawn from outside. When the soil is saturated under water logged condition the percolation of water is stopped and as carbon-dioxide is not dissolved its concentration rises. Consequently fresh air supply to the plant is stopped affecting the plant growth and consequent reduction in crop yield.

2.1.1. The depth of water table below the ground surface is the factor that makes the land water logged. The depth of water table at which it starts harming the crops depends on the height of capillary fringe and the type of crops grown. The height of capillary fringe depends on the characteristics of the soil, which is more in the case of fine grained soil than in the case of coarse grained soils. Normally the W.T. (including the capillary zone) should not be allowed to rise beyond the last 1/3 of root zone of the crop. Table below illustrate the depth of W.T. at which the crops normally suffer from conditions of water-logging[3]. Deep rooted plants suffer more from water-logging than shallow rooted crops.

Crop	Depth of water table
Wheat	3' to 4'
Cotton	5' to 6'
Rice	2'
Sugarcane	3'
Fodder crops	4'
Lucerne	7' to 8'

2.1.2. Similary the water table close to the ground surface may turn the land saline; but a saline soil need not necessarily be water logged. This aspect will be discussed separately in Chapter 3.

2.2.0. CAUSES OF WATER LOGGING

The general cause of water-logging is attributed to the imbalance in the following hydrological cycle.

INFLOW	OUTFLOW
Surface flow	Surface flow
+	+
Subsurface flow	Subsurface flow
+	+
Precipitation	Consumptive use
+	+
Imported water	Exported water
+	+
Decrease in surface storage	Increase in surface storage
+	+
Decrease in groundwater storage	Increase in groundwater storage.

The disturbances caused to the outflow by way of excess infiltration into the ground will tend to raise the water table leading to water logging of the land.

2.2.1. Water-logging may result from either natural or artificial causes or a combination of the two[21].

2.3.0. NATURAL CAUSES

(i) Excessive rainfall and poor surface drainage due to flat topography of the area

(ii) Submergence of adjoining lands by river floods.

(iii) Artesian pressures

(iv) Poor sub-surface drainage conditions caused by unfavourable geological formation such as perched water tables.

These factors have been described in detail in the following paras.

2.3.1. Continued excess rainfall over areas having poor drainage will lead to a rise in water table. Further, the topography of the land influences the rise of water table. A flat topography will not discharge the surface and subsurface waters quickly whereas a rolling terrain is better drained.

2.3.2. SUBMERGENCE OF ADJOINING LANDS BY RIVER FLOODS

Frequent flooding of land will lead to the growth of weeds and blocking of natural drainage in the water shed. The small depressions or ponds will continue to hold water even after the flood receeds. This phenomenon if continued will add to the increase of underground water table and consequent water logging of the land.

2.3.3. ARTESIAN PRESSURES

Water table in the land may be under confined condition due to impervious nature of top soil and recharge conditions at higher elevations. This makes the area marshy.

2.3.4. POOR SUB SURFACE DRAINAGE CONDITIONS CAUSED BY UNFAVOURABLE GEOLOGICAL FORMATION

Existence of impervious soils, barrier, or stratas not far below the ground surface in stratified formations and also along the general direction of the flow of underground water will impede the movement of water and creates a high water table. This is known as perched water table, and will be different from the general underground water table.

2.4.0. ARTIFICIAL CAUSES

These include -

(i) High intensity of irrigation irrespective of the soil and sub-soil characteristics.

(ii) Heavy seepage losses from canals, distributaries and water courses and from water impounded in reservoirs.

(iii) Heavy bunding or enclosing irrigated fields and chocking up of natural drainages.

(iv) Abandonment of existing percolation wells.

(v) Wrong and defective methods of irrigation and over-irrigation.

(vi) Badly aligned canals.

These have been described in the following paras.

2.4.1. High Intensity of Irrigation:- A land not receiving any irrigation water in the past is brought under extensive irrigation, the excess water infiltrating into the pound may contribute to rise of water table.

2.4.2. Heavy seepage losses from canals & reservoirs:- Depending upon the drainage arrangements provided downstream of the earth dam or the canal banks, the height of water impounded in the dam, canal and the characteristics of soil in the bed of canal and at the dam basin, there would be inflow of water into the ground rising the water table.

2.4.3. Heavy Bunding of fields and choking up of natural Drainages:-

At times the fields will be bunded up more than that required from the point of view of water requirement of crop leading to excess water storage and consequent infiltration of water into the ground raising the water table.

Another cause of water-logging is ~~due to~~ the blockage of natural drainages by construction of bunds along small nallas for Rabi Irrigation etc. and also provision of inadequate waterway for culverts, bridges etc. where the road or railway crosses the drainages obstructing flow.

2.4.4. Wrong and Defective methods of irrigation:- Owing to wrong notion of supplying more water for better crop yields among farmers, over irrigation has become a practice all over. This excess water from fields will lead to water-logging of lands.

2.5.0. EFFECTS OF WATER LOGGING

The following are the main factors responsible for the infertility of water-logged lands:

(i) Retardation of plant growth

(ii) Difficulty in carrying out cultivation operations

(iii) Competition from the natural vegetation of water logged soils

(iv) Salinization of lands

(v) Adverse effect on community health.

These factors have been described in the following paras:

2.5.1. Retardation of plant growth:- The growth of plants will be affected badly due to water logged conditions as explained in para 2.1.0.

2.5.2. Difficulty in carrying out cultivation operation:-

Proper tillage and preparation of the field for optimum conditions of germination is not possible for most crops in a soil which is constantly wet.

2.5.3. Competition from the natural vegetation of water-logged Soils:-

There are certain plants or weeds which are adopted to growth in saturated soils. These plants take root in the water logged lands and grow in great profusion supressing the useful crops grown in the field. Protection of the crop against them would need constant toeing which makes the crop uneconomical.

2.5.4. Salinization of lands - Lands become saline under water logged conditions due to concentration of salts at the surface.

2.5.5. Adverse effect on community health- The formation of stagnant pools and the generally damp climate is very favourable to the breeding and multiplication of malarial parasite, which is extremely detrimental to the health of the community.

2.5.6. It may thus be seen that water logging presents serious problems and antiwater logging measures to combat the problem is of urgent necessity.

CHAPTER - 3

WATER LOGGING AND SALINITY

3.1. INTRODUCTION

As already pointed out salinity problems have occured in many states in India especially Rajasthan, Punjab, U.P., West Bengal and Gujarat. Rajasthan being in arid-zone the problem is more acute there and so also in U.P. and Punjab.

3.2. PROBLEMS OF SALINITY

Salt-efflorescence is worse type of damage to lands than water logging. It spreads in deep soil zones where natural contents of the salts in the sub-soil are great and they accumulate and come upto the surface of the soil by capillary action due to the rise of the sub-soil water table. After lowering the water table by drainage or by lift irrigation the salts at the surface do not disappear unless they are specially treated for.

3.3. IN HUMID CLIMATES annual depths of rainfall are sufficient to leech excess quantity of soluble salts to drainage outlets or to depths below the root zones.

3.4. In irrigated regions ample supplies of irrigation water, properly applied, may accomplish the same results provided satisfactory soil structure can be maintained and adequate sub soil drainage is available. When these problems are not ful-filled, continued irrigation causes rise in ground water levels and increasing accumulations of soluble salts in the root zone.

3.5. On an average, 50,000 acres of good fertile land is affected every year in Northern India. In U.S.A. more than

25% of irrigated farm land suffers from the salt trouble. In these days of growing food demand to feed the increasing world population the importance of reclaiming such land and of maintaining the salt balance of all land under agriculture is obvious.

3.6. FORMATION OF SALINE AND ALKALI SOILS

The processes which lead to the formation of salted soils can be summarised as follows:

(i) Salinization - This is the process of salt accumulation in soils. It occurs where neither the surface nor ground waters drain away satisfactorily. Salt is concentrated by water evaporation. Sodium salts usually predominate in early stages of salinization. Calcium carbonate and calcium sulphate are less soluble, so they accumulate more slowly and then precipitate as the process of evaporation and concentration proceed.

(ii) Alkalization- As salts concentrate in soils, there is an equilibrium established between the positively charged ions in solution and those adsorbed on the soil colloid. As sodium salts become more concentrated in the soil solution, greater quantities of Na ions are adsorbed. As the percentage of exchangeable sodium is increased, the soil becomes more alkaline in reaction, and for this reason, the process is termed alkalization.

3.7. SOIL RECLAMATION PROCESS

3.7.1. De-salinization:- This is the process of leaching away of soluble salts from soils which have had large accumulation. When the salts are largely removed, the colloids tend to disperse and decrease permeability.

3.7.2. Degradation:- If a soil undergoing desalinization does not contain gypsum or calcium carbonate, there are no bases to replace sodium after the soluble salts have been removed. Exchangeable sodium then tends to hydrolize and form sodium hydroxide with hydrogen being added to the clay. The sodium hydroxide reacts readily with the carbon dioxide from the soil air to form sodium carbonate.

$Co2 + H2o\ (H_2Co3) + 2\ NaoH = Na2Co3 + 2H2O$. with extensive leaching, the sodium carbonate is gradually removed and the hydrogen exchange for sodium is brought to near completion with a resulting drop in PH. This practice is adopted in Punjab for reclaiming land which is discussed at the end of this chapter. The PH of 'Degraded' alkali soils may be less than $\angle$ 6.0. where soils contain calcium carbonate or gypsum, large quantieis of calcium are maintained in the soil solution. Calcium is then exchanged for sodium during the leaching process and a normal soil results.

3.7.3. Regrading:- This is the procedure whereby lime or gypsum is added to an acid degraded soil and the calcium replaces the hydrogen on the soil colloids, giving a normal soil with respect to exchangeable ions.

3.8. RELATION BETWEEN CROP RESPONSE AND SOIL SALINITY AS DETERMINED BY THE SATURATION EXTRACT METHOD (12 b)

Conductivity of extract millimhos/cm at 25oC	Crop response
0-2	Salinity effects negligible for most crops.
2-4	Yield of many sensitive crops restricted.
4-8	Yields of many crops restricted.
8-16	Only tolerant crops yield satisfactorily.
Above 16	Only a few tolerant crops yield satisfactorily.

The above table gives the tolerance of some plants to salts.

3.9. WATER LOGGING NOT THE NECESSARY CAUSE OF SALINISATION AND ALKALIZATION OF LAND(22)

It has since been established that salinization/alkalization of land does not occur only due to presence of a high water table. Salinization or alkalinization of land may also be due to poor quality of water supplied for irrigation. If the water contains excess harmful salts they will be deposited in the soil pores and on the surface during the process of evaporation and makes the soil saline/alkaline.

3.10. SOIL RECLAMATION

This can be accomplished by a suitable combination of (1) leaching (2) application of amendments,(3) proper soil management,(4) growing of alkali resistant crops and (5) measures to reduce evaporation[21].

3.10.1. RECLAMATION OF SALINE SOILS

The first step in reclaiming saline soils is to instal drains for leaching soluble salts. Soil should be well drained to attempt leaching as leaching requires unrestricted passage of water through and out of the root zone. The second step in reclaiming saline soils is to leach salts by adding an excess of water to the soil so that much of it goes on through and drains away from the rooting zone. In order to be effective in removing salts at least 10% or more of the water added should be carried to the drains. The most desirable method is to make level chaks of about 1/4 acre each so that each chak can be irrigated independently from the water course. In no case should the water be allowed to pass from one chak to another. To make leaching effective the chak should be so levelled that water stands uniformly over the surface. Flooding is usually maintained for several days. The water supply is then shut off and the flooded waters allowed to percolate through the soil. After the soils become dry, flooding operations are repeated until most of the excess salts have been washed to depths below the root zone. Drying between leaching periods stimulates root growth of any vegetation that may exist, aids aggregation and permits the formation of surface cracks that facilitate infiltration during subsequent flooding. Soil samples are taken and salt content analysed after each flooding.

Cropping may also facilitate leaching where roots or incorporated residues make the soil more permeable. A crop should be chosen which is adaptable to wet conditions and tolerant to salt. Among such crops are rice, barley, sweet clover, tall wheat grass Bermud grass etc. Carbon dioxide released into the soil may also increase calcium solubility and facilitate desired base exchange reactions. When the rice or other crop is harvested, soil samples are tested again to see the effect of leaching and the depth to which the salts have been washed out.

The salts should be washed below the root zone say upto 10'[30] from the surface. For this purpose rice should be the first initial crop in any project.

On account of continuous leaching and the growth of crop (such as rice) for this purpose during reclamation, the available nitorgen in the soil is reduced considerably.

Treating the surface with liberal applications of coarse farm manure or ploughing under a good green manure crop helps not only to set right the nitrogen deficiency but also tends to keep the soil surface open and to provide channels for water entrance. Where lands are covered with encrushed salts, alternate flooding and surface drainage prior to leaching may remove appriciable quantities of soluble salts and thus facilitate subsequent leaching.

3.11. TYPES OF SALTS

The most common salts that affect the productivity of soils are carbonates, chlorides and sulphates of sodium; other salts that may be troublesome are carbonates;chlorides and sulphates of magnesium and potassium and chlorides and nitrates of calcium. Mg.K and Ca are utilized in plant growth, but cause salt troubles when present in the soils in excessive amounts.

Soils that contain excessive quantities of caustic salts such as sodium carbonate which dissolve organic matter and cause the formation of a dark coloured crust at the soil surface are called "black alkali"; soils that contain excessive quantities of neutral salts which cause the formation of a white crust at the soil surface are called"white alkali".

Black alakali is more injurious to plant growth than white alakali. However both types of salts are injurious when present in relatively small proportions and may prevent plant growth when present in only slightly greater proportions.

The limits of tolerance of plants for different alkali salts in the soil are as below[19]-

Sodium chloride - 0.5%

Sodium sulphate - 1 %

Sodium carbonate - 0.05%

Only black alkali salts cause harmful effects on the physical properties of soils. Fortunately black alkali soils are less common than white alkali soils. Both types can be reclaimed by proper corrective measures and appropriate cultural procedures, provided ample supplies of water are available.

3.11.1. The alkalinity or salinity of a soil is measured by hydrogen ion concentration which is termed PH. Any value of PH higher than 8.5 to 10 makes the soil Alkaline and a value less than 8.5 leads to salinity of land. The table given below shows the conditions for different soils[7].

TABLE - 11

Conditions for saline, saline alkali, & alkali soils

Salt condition.	Common term.	Salt index Conductivity of saturation extract Millimhos per at 25°C	Sodium index Exchangeable sodium %age	Hydrogen Ion pH index	Reclamation.
Saline	White alkali.	4	15	8.5	Leaching.
Saline alkali.		4	15	Generally about 8.5.	Leaching necessary and possible, but as salts are removed the sodium must be replaced to prevent dispersion of soil particles and reduction of permeability.
Alkali	Black Alkali	2	15	Generally between 8.5-10.0	Low permeability due to dispersion of soils by the sodium; requires replacing the sodium to improve the permeability so that leaching can proceed.

Since a pH of 7.0 is neutral, pH values less than 7.0 indicate an acid soil which is common in the non arid regions. Note that the larger the pH, the less the concentration of hydrogen ions, since pH is the logarithm of the reciprocal of the hydrogen ion concentration of calcium and magnisum. A pH value of 7.5 to 8 usually indicates the presence of carbonates and a PH of 8.5 and above usually indicate appreciable exchangable sodium.

3.12. REMEDIES FOR ALKALI:

Thus the method of reclamation of alkali soils consists of the following:-

1. Deep under drainage which lowers the water table coupled with copious applications of irrigation water enabling washing of excess salts out of the soil root zone.
2. Deep and regular tillage prevents formation of surface crusts of salts, and keeps the soil structure open for infiltration and under drainage.
3. Chemical treatment such as the use of gypsum or other soil amendments is particularly useful in the reclamation of black alkali soils.
4. Growing of alkali resistant crops, specially those which provide good cover hasten the reclamation by improving soil structure and reducing evaporation.
5. Application of manure and providing mulch cover improves soil structure, provides plant nutrition, reduces evaporation, and encourages infiltration.

3.13. SALT PROBLEMS IN SOME OF THE STATES IN INDIA AND RECLAMATION OF LANDS (16)

3.1.3.1. Punjab:

The reclamation practices in the Punjab where the soils are alluvial, consist of provisions of additional irrigation supplies (1 cusecs for 50 acres) for leaching followed by cultivation of one or two crops of paddy for moderately and highly saline soils with PH ranging from 8.5 to 9 and 9 to 9.5 respectively. The crop rotation generally advocated is rice followed by berseem or Sanji, then sugarcane followed by wheat or cotton.

3.13.2. Maharasthra:

In Maharashtra where the soils are derived from the wheathering of the traps, the practice of reclamation of saline soils consists of 3 to 4 years cycle of cultivation of salt tolerant varieties of sugar cane preceded by Sesbania aculeata as green manure. The rate of Sesbania aculeata (Jantar) was found to be more effective and enduring,than that of chemical amendments, e.g. sulphuric acid, sulphur, calcium chloride, gypsum etc. Varieties of sugar cane grown during mid-monsoon are also employed to facilitate leaching. Crop rotations indicated include sesbania, sugar cane, cotton or lucerne and paddy. For alkali soils the practice has been described as: ploughing, bunding and levelling during hot weather, intermittent flooding, cropping of winter fodder followed by 'Jantar' and subsequent application of gypsum (3 tons/acre) or cropping of lucerne or selected sugar cane varieties. A special treatment of farm yard manure with basal dose of gypsum (3 tons/acre) and a layer of dry cane leaves has also been indicated for alkali soils.

3.13.3. Gujarat:

In this state where the soils display widely varying characteristics, experiences in Maharashtra are said to be applicable. For 'Bhal' lands which are described as highly saline, with calcareous content 4 to 10% and in some areas highly sodimized, 66" of water is reported to leach chloride content of 12% to 3' depth and green manuring with sesbania after leaching followed by paddy will restore near normal productivity.

In 'Khar' or Coastal low lands reclamation is achieved in 2 to 5 years from percolating rain water which leaches out the chlorides after the lands are protected from tides and provided with a drainage system.

CHAPTER - 4

REMEDIAL MEASURES

4.1.0. GENERAL

For adequate crop production and maintenance of soil fertility, the water table must be maintained at a depth of not less than 6' below ground surface. Where the water logged conditions exist the lowering of the water table to the desired level can be achieved either if the amount of inflow into the soil can be reduced and/or the amount of outflow can be increased. In other words either the excess water should be eliminated or the drainage capacity of the area both surface and subsurface should be improved.

4.2.0. Anti water logging measures may be broadly classified into two categories:

(a) Preventive

(b) Curative.

These have been listed as below:

4.2.1. Preventive measures:

(a) Pre-Irrigation soil surveys(29)

(b) Maintenance of natural drainages in the irrigated areas.

(c) Restriction of intensity of irrigation to say 45%

(d) Refusal of canal irrigation to areas where the spring level is already high.

(e) Encouraging use of wells

(f) Devising cropping according to soil suitability and avoiding over irrigation.

(g) Conjunctive use of canal and tubewell irrigation.

4.2.2. Curative measures:- This implies artificial draining of a land already water-logged. The following measures may be considered.

(a) Improvement of natural drainage lines and construction of additional drains where necessary.

(b) Provision of artificial drainage arrangements surface or subsurface depending upon the soil and topographical characteristics.

(c) Lining of canals or distributories to prevent percolation losses.

(d) Scraping the surfave salt and leaching the lands by flooding during monsoon.

(e) Growing test crops of fodder, millet and the like according to their salt resistantecapacity and the concentration of salts in the top soil.

(f) An appropriate crop rotation including the use of green manure.

(g) Construction of seepage drains, channels parallel to the existing channels.

(h) Installation of tube wells in the commanded area and pumping water for irrigation. Local pumping from small depressions may be adopted to control W.T. (Water table)

A few of the above measures are described in the following paras:

4.2.3. Pre-Irrigation soil survey:- A survey of soil in the commanded area of irrigation canal should be carried out before irrigation is carried out in the area. This gives an idea of the properties of the soil, Salt contents and soil-moisture etc. so that future precautions may be taken up to prevent water logging.

4.2.4. Maintenance of natural drainages in the Drainage area:

Natural drainages should not be interfered. Crossing of these drainge by Railways, Roads, canals etc. should provide for adequate water wayages.

4.2.5. Restriction of Intensity of Irrigation:

Limiting the intensity of irrigation to say 45% or in the alternative to enforce non-perennial irrigation on the lands not suitable for heavy irrigation like sugar-cane crops, in view of their poor natural drainage capacity, would go a long way in preventing water logging of the area. Under Nira Canal system (Deccan Canals) in Maharashtra, to stabilize irrigation Sugar factories were established. The areas selected for the cultivation were better drained than others and the obligation to excavate drains and to maintain them was imposed on the management according to contract for water supply[22]. Also annual closure of canal at head for 10-15 days in a year helps to arrest water logging[13].

4.2.6. Refusing Irrigation to areas where the spring level is high

In portions where the underground water table is already high in a drainage area, irrigation water is not supplied to maintain the water table at low levels.

4.2.7. Use of wells:

Normally in an irrigated area percolation wells will be out of use due to the availability of irrigation waters. Encouraging the people in the area to use these wells will be of great help in maintaining the water table at lower depths.

4.2.8. Devising Cropping pattern according to soil suitability:

Depending upon the characteristics of the soil to the soil moisture relation, tolerance to salts etc. the pattern of cropping should be proposed. The crops may be grown in rotation so that a few of the lands will get less water to compenstate large volumes required by other crops.

4.2.9. Artificial Drainage arrangements:

This consists of eliminating excess water from surface and sub-surface by constructing artificial drains, wells etc. Certain special problems and their remedies are discussed in para 4.3.0. below. Where water logging is caused by floods from rivers, construction of embankments and other flood control works would be helpful in preventing flooding.

4.2.10. Lining of Canals:-

Considerable saving in water and corresponding saving in drainage requirements can be obtained if the canals in an irrigation system is lined. By doing so, it is estimated that losses that occur in seepage in canals could be reduced from 1/7 or 1/8 which contributes to the prevention of water-logging in the area.

4.2.1.. Improvement of natural drainage lines:

This implies removal and clearing of man-made obstructions on natural drainages in the water shed. Improvement of river channel capacity reduces flooding by lowering flood levels.

4.2.12. Construction of seepage drains:

Seepage or interception drains along the canal embankment, rivers, nallas, depressions etc. will reduce the W.T. (water table) in adjoining lands by intercepting seepage from those sources.

4.2.13. Scraping the surface salts and leaching the land by flooding during monsoon:

Leaching is initiating downward movement of salts in the broad sense. This has also been discussed in Chapter 3 under reclamation of saline soils. Leaching by flooding is the nature's way of reclaiming soils; where the rainfall is fairly high the soluble salts are carried away to the soil crust or into the natural drainages and rivers.

4.2.14. Conjunctive use of canal and tubewell irrigation:-

Irrigation by tube wells combined with canal irrigation goes a long way in preventing the rise of sub-soil water table and consequent water logging problems.

4.3.0. SPECIAL DRAINAGE PROBLEMS AND THEIR REMEDIES

Some of the problems that are encountered during investigation for a project and their remedies are generally as given in the following paras:

4.3.1. Perched water table:-

The occurence of this water table is due to the disposition of the soil materials in stratified soils. Sand layers are overlain or underlain by relatively impervious strata of clays or other slowly permeable soils, which when irrigation water is applied impede the percolation of the excess water. The drainage consists in removal of water by sub-surface drains placed closed to the clay layer and lowering of the water table.

4.3.2. Artesian Pressures:-

Artesian pressures are caused due to confined condition of aquifers. The method of draining water under artesian pressures is by means of relief wells coupled with the drainage lines[27]. Relief wells will relieve the artesian pressures which may otherwise cause the tile drainage lines to blow out.

4.3.3. If the problem is only canal seepage it would call for an interception drain along the canal[28].

4.3.4. Basin type of topography lends itself well to pumping for drainage[28].

4.3.5. Disregarding other factors, flat slopes lend themselves well to tiling on a grid system[28].

4.3.6. Pockets requiring drainage are usually best drained by sumps.[28].

CHAPTER - 5

INVESTIGATIONS FOR DRAINAGE SCHEMES

5.1. NECESSITY

One of the essential requirements for planning drainage works is an intimate knowledge of the area to be drained. It has been seen from previous chapters that drainage has a marked influence upon the physical conditions of soil. The proper location and correct design for drainage works, require a knowledge of the soil and its conditions so far as water content is concerned. They require also a knowledge of topography and the source and the direction of movement of the waters to be removed.

5.2. Surface drainage is a must for drainage of irrigated lands.

5.3. The Investigations are divided into two categories:

(1) Geological investigations.

(2) Hydrological investigations.

5.3.1. Geological:

Salient features of certain important items of detailed investigations that are to be carried out in planning drainage and anti-water-logging schemes are discussed in this chapter.

Map of the area:- A survey map of the area to be drained indicating all the topographical features should be prepared. Good topographical maps are essential for a study of a drainage problem since they provide frequently the key to the essential features of the system of drainage, such as the location and type of outlet (gravity or pumped), surface slopes, existing degree of drainage etc. The accuracy of vertical control is particularly important. For preliminary studies, a vertical interval of 2' to 5' may be adequate. Detailed studies require an interval of 1' or less in flat land.

The topographic survey should clearly indicate the position, alignment and gradient of existing ditches, streams, culverts and such other physical features as roads, railway tracks, canals etc. In major projects the use of areal photographs in conjunction with a ground survey will be of assistance in locating areas of poor drainage and cultural features. In Chambal project 4" to a mile toposheet showing all the features in detail along with ground contours at an interval of 1'-0" were prepared. In areas where such a plan is not available, it has to be prepared. The preliminary idea about the condition of ground water can be had from water levels in wells. For this purpose, a village map usually 330' to an inch is obtained and a grid of wells normally covering one square mile is prepared. For a future study it is very essential to locate the available wells on a plan. A general recording of levels of ground water in wells will have to be made before the onset of monsoon, preferably in the month of April and May and also after the monsoon.

The natural drains will have to be marked clearly and their bed levels, number, condition and size recorded, Cross Sections of the nalla should be taken at suitable intervals to give an idea of the waterway available. It is very essential for the survey party to locate barriers such as dams or obstructions provided across the natural drains.

Apart from the nalla details, a detailed note of cross-drainage works along both railways and road is to be made. The field book of the survey party should be clear and should indicate all physical conditions of the country.

5.3.1.1. Sub-surface exploration:

Data relative to the character of soils and subsoils, elevation of water table subterrerean conditions are obtained by means of borings or test pits, a record or log being kept as shown in Fig.1(b&c).

5.3.1.2. Sometimes underground formations are responsible for creating water-logging conditions and therefore a trace of the sub-surface geological formation should be obtained to assess the causes of water logging. Perched water tables due to the existance of clay layer at the bottom in the case of sedimentary formations and Artesian conditions are some examples for water logging due to uneven of underground formations.

5.3.1.3. Soil Investigation:-

Soil survey of the commanded area is an important investigation in order to assess the drainage possibilities or danger of developing alkaline surface.

A thorough knowledge of the way soils absorb water and the capacity of the different soils on the field to store water is vital as this enables the application of the optimum quantity of water for the needs of crop. For a correct

Contd.

understanding of the storage characteristics of the soil and subsoil it is necessary to understand some of the more important constants dealt with in the soil. Moisture studies. These have been separately described in brief in the Chapter on sub-surface drainage.

5.3.1.4. Artesian Pressure:-

Water logging may also be due to artesian pressures in sub-soil and therefore investigation in this respect is very necessary.

5.3.1.5. Depth to Impervious layers:-

The depth to the impervious strata underground is important in locating the drains. Most of the drainage formulae for determining depth and spacing of the drains take into account this information. The term 'Impermeable' is a relative term. All soils are more or less permeable. From the drainage point of view, if the permeability of the subsoil is about 1/10th of that of the sub-surface soil it can be considered impermeable. There will be water-logging above this layer, if the rainfall rate or the rate at which the water is added to the soil exceeds the permeability of this layer. The flow pattern of the water moving towards the drain will be altered drastically by this layer of low permeability. The drains will have to be spaced closer to achieve the same effect as in a deep permeable soil.

5.3.1.6. Soil Survey:-

For carrying out soil surveys the best method is to establish a grid system for the area to be surveyd to enable the observation points to be shown in detail. It would be generally sufficient if grid lines are established at one mile intervals horizontally and vertically. Auger holes 3" to 4" size dug to depths of 10' to 15' depending on the nature of the soil may be taken at 1/2 mile interval. Sometimes, if clay or other hard strata is struck, the holes may be stopped at smaller depth. Soils at every foot depth should be examined on the field for the various characteristics and logged accurately. Representative soil samples should be analysed in a soil laboratory both for physical and chemical properties. For facilities in planning, grid lines may be drawn on close contour maps so that all important features like roads, water courses etc. may be seen in relation to the soil profiles. Figs. 1(a),(b) and (c) show the arrangement of the grid lines and how the logging of the soils may be maintained.

5.3.1.7. Soil properties:-

Detailed study of the following properties of soil in the area to be drained is one of the important aspects of drainage and they are briefly described as under.

(i) Soil texture:- Soil texture refers to the relative proportions of various size groups of individual soil grains in a soil mass. Soil texture can play an important part in the design of drainage systems since it gives an idea about the soil permeability as well. An increase in the percentage of clay makes the drainage character of the soil poor.

Silty clay loam - SiCL	Clay-C- less than 0.002 mm
Clay loam - CL	Silt-Si- 0.002 to 0.05 mm
Sandy loam - SL	Sand - S - 0.05 to 1 mm
Coarse sand - CoS	Gravel - G 7 1 mm
Fine gravel - FG.	

(ii) Soil structure:- Structure refers to the condition of the soil grains (clay,silt,sand etc.) in the way they are arranged and bounded together into aggregates with definite shape. The structure in which particles are relatively uniform in size has comparatively large pore space in between the particles, whereas those soils in which the size of grains vary greatly may become closely packed and thus the volume of space between the grains is restricted.

The usual type of soil structure are described as below:

Massive structure - m

Platy - (Leaf or flaky) - Pl

Prism like -(Columner) - Pr

Blocky - (Cube like) - bk

Granular - Gr - Very porous.

(iii) Porisity:- One of the requirements of soils is porosity. In order that plants may grow successfully in a soil, it must be in a condition that will allow roots to penetrate freely and thus obtain the necessary supply of food and moisture. Porosity is also necessary to allow water and air for transpiration. A fine grained soil mass is less porous and therefore absorbs soil water slowly but once the water is absorbed, it holds the water against gravity for a longer period compared to coarse grained soils which are more porous. The capillary action is more in the case of fine grained soils mass,than the coarse grained soils. The power of tight soils (fine grained soils) to hold water decreases the effectiveness of the drains in them and increases the time necessary to remove excess water. Porosity is defined as the ratio of voids (air and water filled space) to the total volume of soil + water and air. It is denoted by

$$n = \frac{V_v}{V}$$

n = porosity Vv = Vol.of voids

V = Total vol.of soil

(iv) Specific gravity:- This is also determined for soils under investigation since it is required in ascertaining certain soil properties. It is defined as the ratio of the weight of a given volume of dry soil to the weight of an equal volume of water.

(v) Intake:- Rate of infiltration from a furrow into the soil is refered to as Intake. This form is specially used to indicate infiltration occuring under a particular soil configuration. Each type of soil has its own rate of water intake and capacity of water retention.

Normally clayey soils have a slow rate of Intake, some being less than 0.1"/hr. with the soil management condition being equal (crop residue, cover crops, blowing depth etc.) a coarse or sandy soil can take more than 3"/hr. The rate of intake is measured by a Ring Infiltrator. Average final intake rates for different soils are given below:

Soil type	Intake rate in inches/hr.
Clay	Less than 0.1
Clay loam	0.1 to 0.2
Silt loam	0.3 to 0.7
Silt	0.8 to 1.2
Sandy loam	1.3 to 2.4
Sand	over 2.5

The rate of infiltration is one of the factors contributing for the rise of water table.

5.3.1.8. Permeability:

This is one of the important properties of the soil governing the flow of water through soil pores in a homogeneous soil. 'Permeability' of a soil is its capacity to transmit fluids. It is used as a qualitative term i.e. it is used as a term for this property of soil. The term is also modified to describe the relative case of transmission as "Rapidly permeable", or "Slowly permeable".

Hydraulic Conductivity: of a soil is a numerical value for permeability. It is the proportionality factor 'K' in Darcy's equation(1856). It is denoted by

$$V = K\,I$$

for velocity of water flowing through a porous media under saturated conditions

V = velocity of water through the pores of the soil

K = Hydraulic conductivity

I = Hydraulic gradient.

There are several methods for determining the permeability/hydraulic conductivity of soils. Both laboratory and field methods are available to ascertain the nature of the soil in respect of permeability.

Laboratory permeability: Laboratory permeability of soil gives only approximate results of 'K' as it does not represent field conditions correctly. Two methods are in vogue for determining the permeability of soils in the laboratory:

1. Constant head permeameter method
2. Variable head permeameter method

The method of determining soil permeability by constant head permeameter consists in maintaining a constant head of water percolating,through a soil sample and measuring the rate of discharge when constant outflow is obtained. The formula for this condition of flow is given by,

$$K = \frac{Q\,L}{h.A}$$

Where K = hydraulic conductivity

L = length of sample

h = head of water

A = Area of cross-section of soil sample.

In the variable head permeameter method the outflow discharges through the soil sample for variable heads are measured at suitable time intervals and an equation is evolved for the permeability.

If 'Q' is the total flow through the soil, then $\frac{dQ}{dt}$ is the rate of flow per unit time and by Darcy's law

$$\frac{dQ}{dt} = \frac{KAh}{L}$$

Where K = hydraulic conductivity

h = hydraulic head in the water column at time t. measured with respect to the upper soil surface.

A = Area of cross-section of the cylinder containing the soil sample.

L = Length of soil columns

For variable heads from h1 to h2 in time t1 to t2 the formula reduces to

$$K = 2.303 \left(\frac{aL}{A(t_1-t_2)} \right) \ \mathrm{Log}_{10}\frac{h1}{h_2}$$

Where a = Area of cross-section of the stand pipe.

Field Methods:- Field methods are adopted to determine the permeability of soils in-situ in order to have a fairly correct idea of the permeability at the point of observation of soils.

(1) Single Auger Hole method:- This is a very simple method requiring small amount of equipment. The procedure is to dig a hole in the soil beneath a water table. After allowing the water level in the hole to come into equilibrium (Fig.4) the water is pumped out of the hole and measurements are made of the rate of rise of water in the hole. Various formulae have been developed based on the data obtained from this method for determining the hydraulic conductivity and they are described in brief below:

(1) Hooghoudt's formula: Dr.S.B.Hooghoudt made substantial contribution to drainage design with his development and perfection of the auger hole method of determining hydraulic conductivity. He developed an equation by considering the above data with certain assumptions.

Assumptions (1) The soil is homogeneous

(2) Impervious layer exists below the soil surface

(3) Water flows into the auger hole horizontally from sides and vertically upwards at the bottom of the hole.

When the impervious layer is of great depth: The formula for this condition is given by

$$K = \frac{2.3aS}{(2d+a)\,t} \log_{10} \frac{yo}{y1} \quad \ldots\ldots \quad (1)$$

Where K = hydraulic conductivity

a = Radius of the hole

$S = \text{Constant} = \frac{ad}{0.19}$

Here 'S' has the dimension of length

d = depth of hole below the water table.

y_o and y_1 — [illegible] rise of water in the hole from y_o to y_1.

When the auger hole terminates on an impermeable layer the vertical flow of water through the bottom will be equal to zero and equation (1) reduces to

$$K = \left(\frac{2.3aS}{2d.\Delta t} \log_{10} \frac{y_o}{y_1} \right) \ldots\ldots\ldots\ldots (2)$$

Since $S = \frac{ad}{0.19}$ introducing this in the above equation, we get for an impermeable layer,

$$K = \frac{2.3(a)^2\ 86400\ \log_{10} \frac{y_o}{y_1}}{(2)(0.19)\qquad \Delta t}$$

$$\text{i.e. } K = \underline{523000\ (a^2.\log_{10}\ \frac{y_o/y_1}{\Delta t}} \ldots\ldots\ldots (3)$$

If a = radius of hole in meters

Δt = Time in seconds

Then K = Hydi-conductivity in meters/day.

Ernsts' Charts: Ernst made a detailed study of the flow into an auger hole and developed graphs which are easier to use than Hooghoudts' formula. Ref.(Fig.4 & 5).

Permeability of layered soils by two auger hole method

Ernst's method - When the profile consists of two layers having an appreciable difference in conductivity, Ernst proposes that the hydraulic conductivity of each layer be determined by digging two auger holes of different depths. The bottom of the Ist hole should be approximately 10 cm. above the lower layer. The second hole should extend well into the lower layer. If there is a third layer, the bottom of the second hole should stay above that layer. Since the formulas are based on (d-h) greater than 15 cm, Ernst derives the following equation,(REF: FIG:6)

$$K_1 d_1 + K_2(d_2 - d_1) = K d_2$$

Where K_1 is the conductivity as measured in the first hole,

K_2 is the conductivity for the two layers as measured by the rate of rise in the second hole. The conductivity of the lower layer, K2, is computed from the above equations. This equation gives fairly reliable results if $K2 > K1$. If $K < < K_1$ the equation may give negative results for K2. If accurate values are desired for K2 measurements in the second hole shou-d be delayed until the water table has lowered to a position below the interface of the two layers.

5.3.1.9. There are two assumptions made in deriving the equations for layered soils. The Ist one is that the stream-lines are horizontal and are independent of the way in which the permeability of the soil profile changes. The second is that the amount of water flowing out of each layer depends only on the permeability of the layer out of which it flows. Both the assumptions are questionable. However,Ernst,indicates that the resulting error is not $>$ about $\pm$ 10%.

5.3.1.10. Other Methods:-

Another method of permeability (hydraulic conductivity) that is usually adopted is as follows:

A bore hole is made in a soil especially when artesian conditions are to be expected. No free water as a rule is met with until the impervious stratum is pierced. At this point which is called the level of the First strong flow. (F.S.F) water rushes in to the bore, sometimes with a hissing noise and rises with an appreciable velocity which gradually diminishes until after some hours water remains stationary. This point is called the final water level(F.W.L). Difference between F.W.L and F.S.F. may be 1'-0" to 8'-0".

Before test is taken, initial water level is recorded and the rise in water level in 5 minutes is noted. The rise in small bore hole of 6" dia. is recorded by a galvanometer equipment and then the percentage rise is calculated. The K/A ratio is then known for a particular percentage rise. The chart given below is prepared by Maharashtra Organisation.

K = Permeability

A = Area of auger hole.

Percentage rise r/H x 100	K/A
2	0.10
3	0.16
4	0.22
5	0.27
6	0.32
7	0.38
8	0.43
9	0.48
10	0.54
11	0.60
12	0.66
13	0.72
14	0.78
15	0.84
16	0.90
17	0.96
18	1.02
19	1.08
20	1.14
21	1.26

and so on

When K/A is 71 and the percentage is greater than 18, then the stratum is quite pervious and this stratum is normally cut when surface drains are to be deepened. Bore holes of nallas are usually taken and the levels of the pervious strata is obtained which is normally the criterion for fixing bed levels.

5.3.1.11. Murum Isobar :

Main purpose of obtaining permeability is to locate the pervious strata which is essential to fix the bed levels of seepage drains, Surface drains and sub-surface drains. A contour of the pervious strata is known as murum iso-bar and is drawn in case of any scheme. This can be prepared after careful soil analysis as already discussed.

5.3.2. Hydrological investigation:

Data relative to source and amount of water supply are necessary to determine the quantity that must be removed and to furnish a basis for the capacity of drains.

5.3.3. Floods:

Information relative to storm intensity and its duration is particularly necessary to determine the capacity of drains, in the case of surface waters.

With data concerning rainfall, tributory area and a knowledge of surface and soil conditions, it is possible, by using coefficients of runoff, to form an estimate of the supply of water that may be expected under ordinary conditions. But, it may be noted, that all theoretical determinations of this kind may be subject to wide variations from actual amounts. The most reliable results relative to runoff from a given area are those based upon direct measurements of discharge. These when taken over a series of years give fairly reliable data from which to determine average discharge.

5.3.4. Data for ground water supply:

Data which may be collected relative to ground water supply are confined principally to sources of such supply, that is, where surface waters are lost into the sub soils. This may include also, seepage from natural streams where the same occur. In making investigations of this sort it is essential, in so far as possible to determine the amount of such losses and the areas over which they occur. The character of materials through which seepage waters pass and the steepness of the slopes down which they move are also important. It is sometimes possible, by means of these data and by the use of percolation coefficients to estimate with in rough limits the amount of water which may enter an area from a given source.

5.3.2.1. Record of water table levels:[2]

A record of water table levels may be kept from the observation of water levels in wells existing in the area requiring drainage. Simultaneously the water samples may be taken from wells and sent to laboratory for analysis to determine the presence of any objectionable salts, solids and other substances dissolved beyond limits set for the purpose. Ref. Fig.7.

Using data collected from wells it will be possible to draw ground water contours. These are dashed lines and drawn at a 5'-0" vertical interval to correspond to the interval of the surface contours. Ground water contours show the configuration of water table surface in the same way that surface contours show the configuration of the land surface. The direction of ground water flow can be determined as perpendicular to the water table contour lines shown by arrows.

5.3.2.2. Depth to ground water table:

This is known as Hydro-Isobath and gives an idea about the extent of areas under the influence of water logging as shown by hatched portions in the working map. Ref. Fig.7.

5.2.2.3. Observation of Canal seepage:

Seepage from canals is one of the contributing factors for increase of water table. As much as 25% of the head discharge of canal is lost in seepage. Seepage losses are determined by installing measuring notches or weirs above or below a known length of canal in which there are no offsets. Pond infiltration tests perhaps give better results. This consists in creating ponding of water in the canal by closing the canal by means of a water tight bund and observing the rate of lowering of water level in a fixed time.

5.3.2.4. Outflow from drainage areas:

Wherever possible data should be obtained in respect of outflow from existing drainage systems. These data should then be corelated not only with the soil type but with other characteristics such as texture and permeability. By collecting data of this kind it would be possible to extrapolate. The data obtained in one area for use in other areas. This needs judgement and experience.

5.3.2.5. The draw down capacity and area of influence of pumped wells should be determined wherever data are available. The possibility of using wells should not be overlooked.

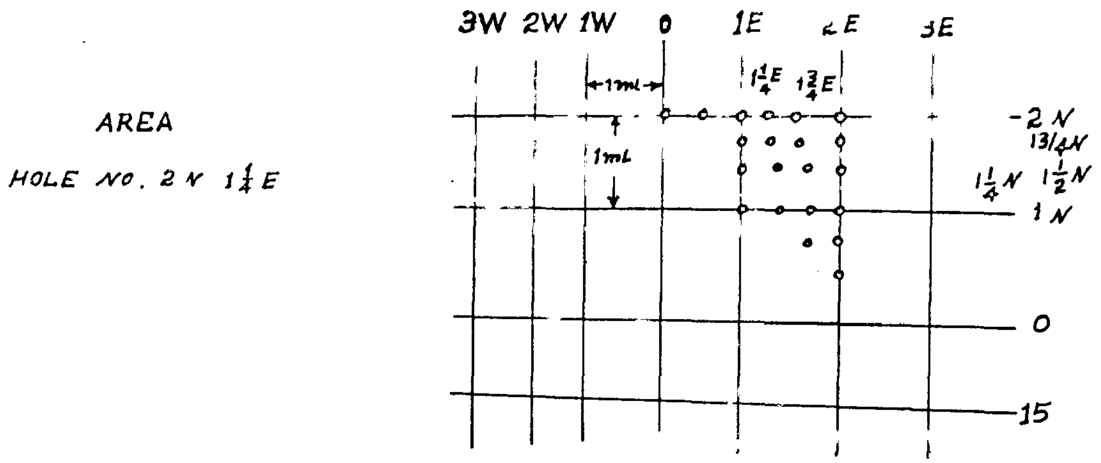


FIG 1(a) GRID SYSTEM ALLOWANCE FOR REFERENCING INTERMEDIATE BORING

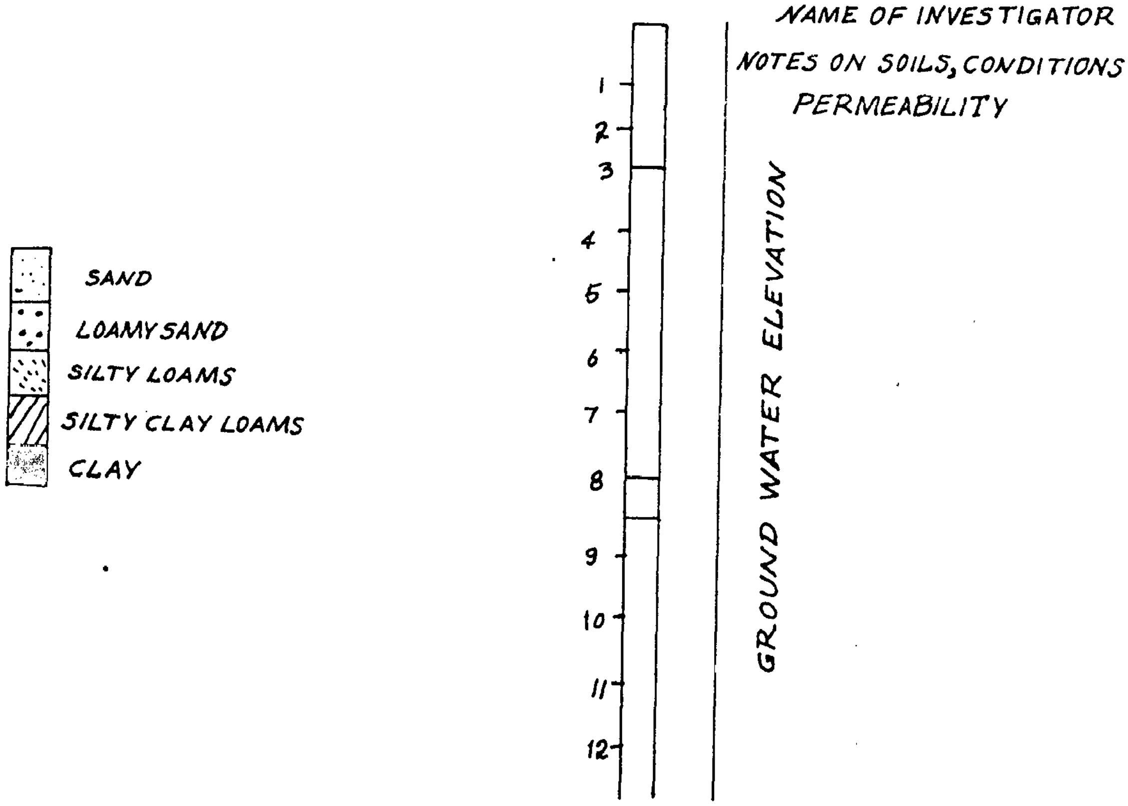


FIG. 1(b) SHOWING METHOD OF LOGGING BORE HOLES

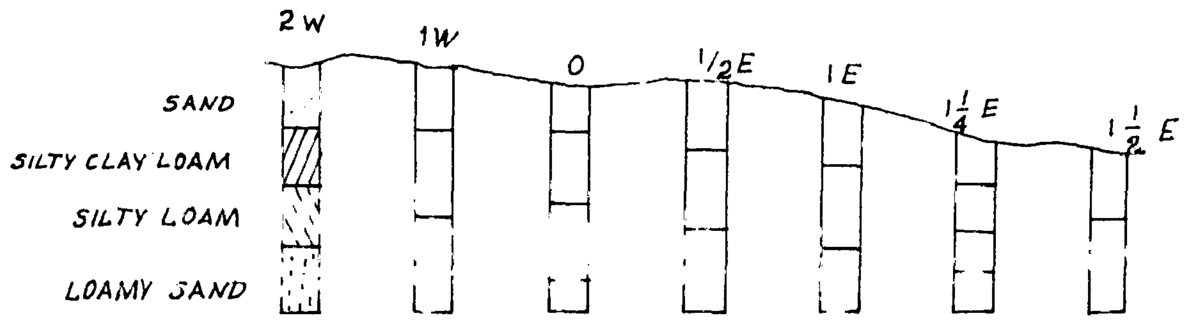


FIG 1(c) SHOWING PROFILE LINE — 2 N

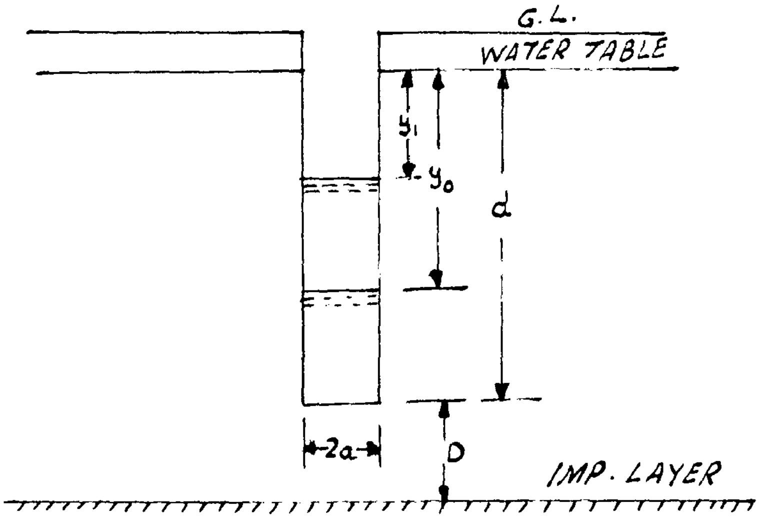


FIG: 2 SINGLE AUGER HOLE METHOD

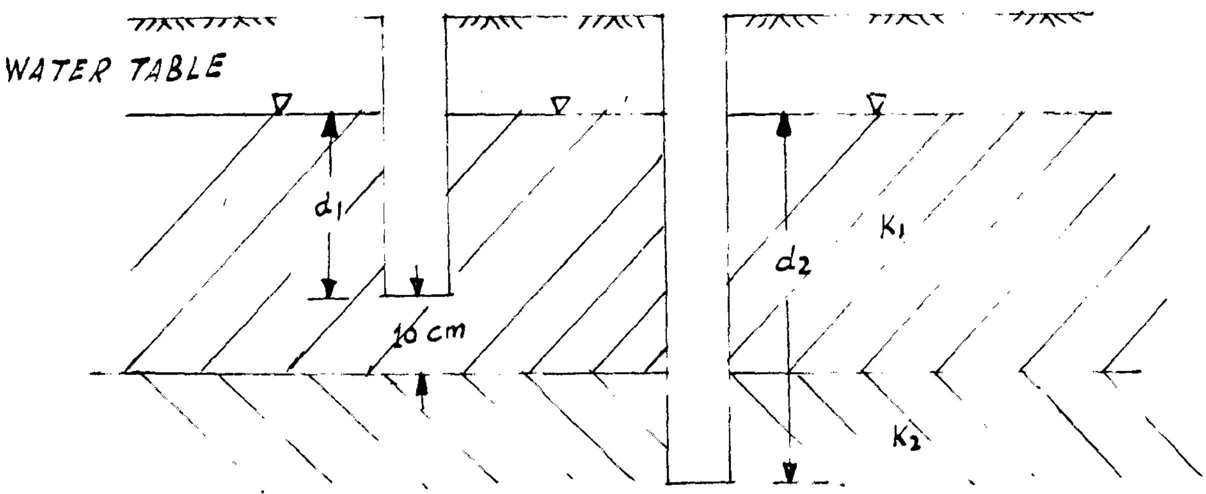


FIG: 6 DOUBLE AUGER HOLE METHOD

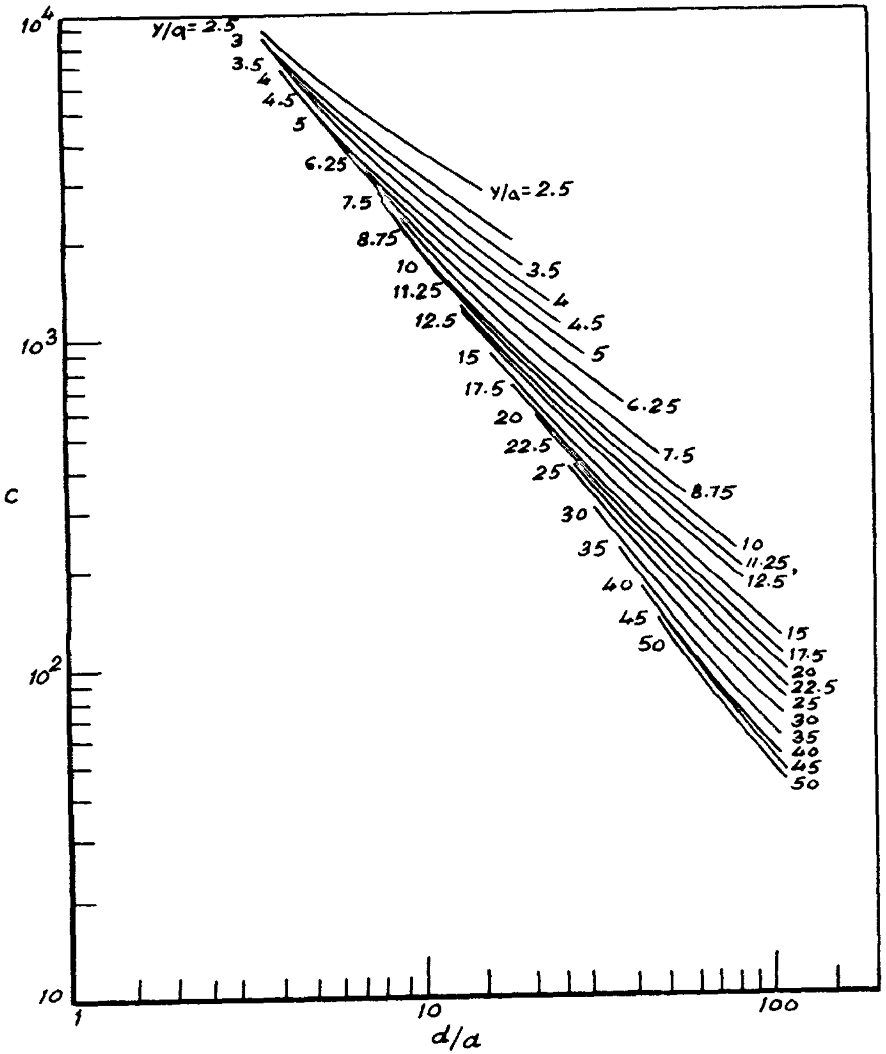


FIG. 4 - Ernst chart for impermeable layer at bottom of auger hole dy/dt in ft/sec. K is given in ft/day after Maasland & Haskew.

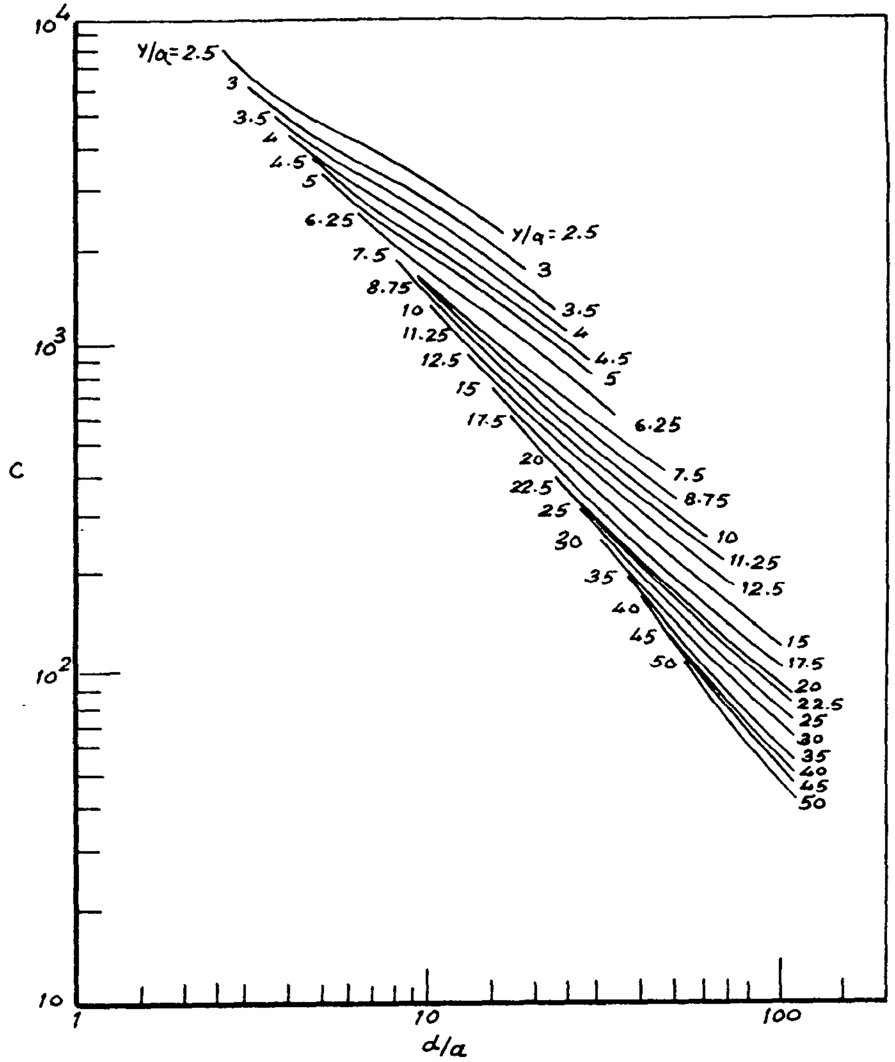


FIG. 5 - Ernst chart for impermeable layer an infinite distance below auger hole dy/dt is in ft/sec K is given in ft/day.

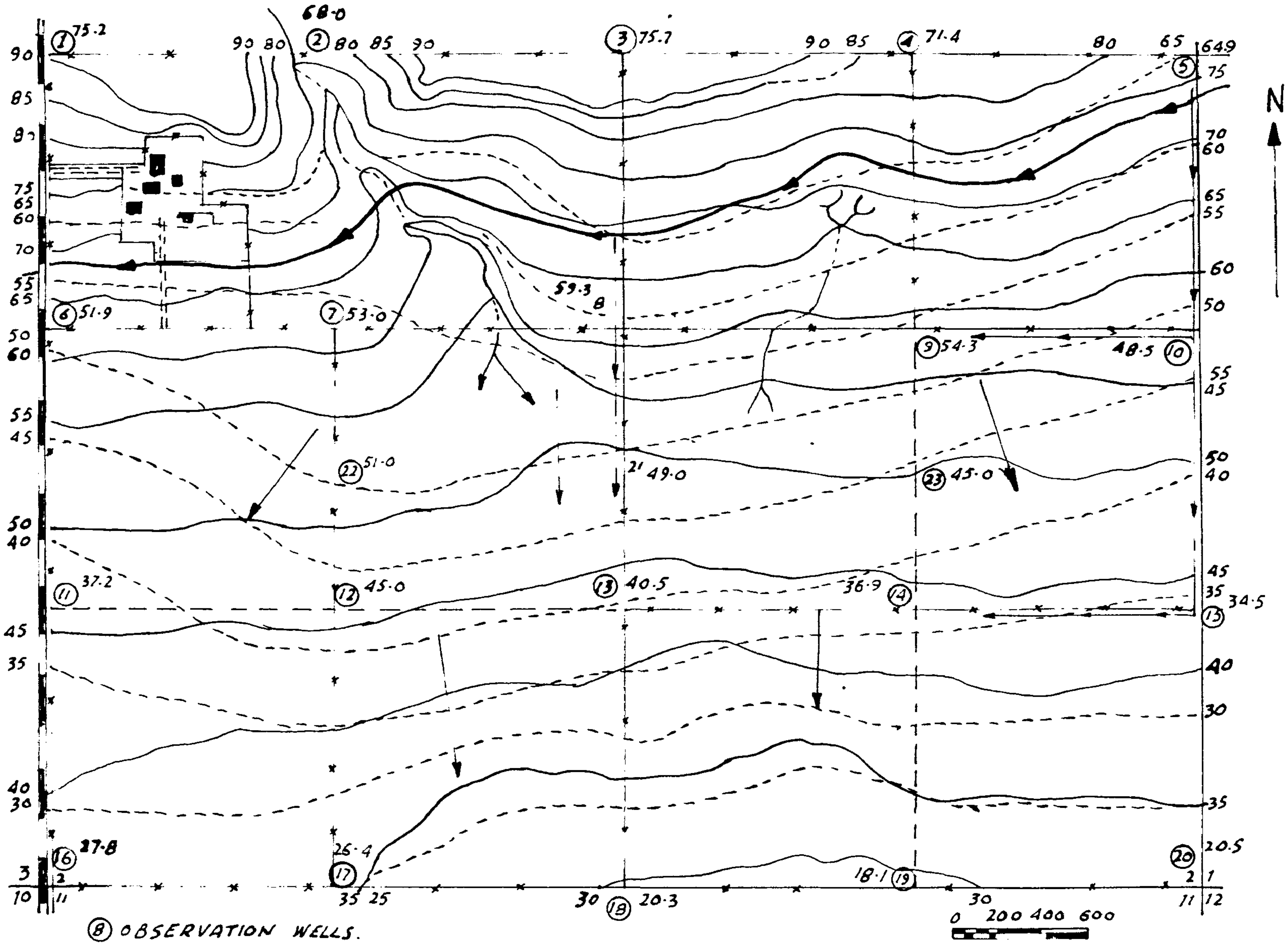


FIG. 7 WORKING MAP (TOPOGRAPHY AND GROUND-WATER CONTOURS)

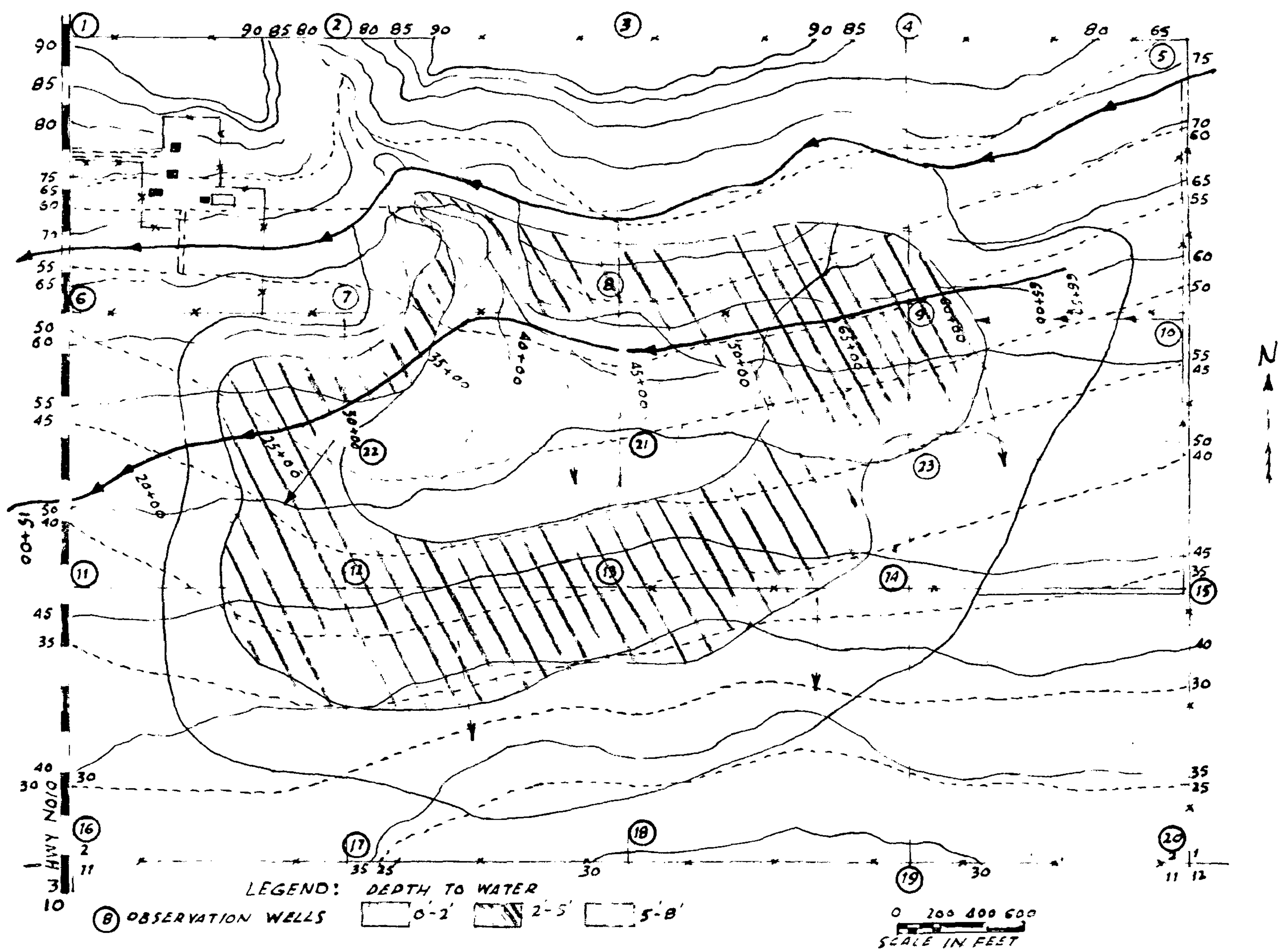


FIG. 8 WORKING MAP (COMPLETED)

CHAPTER-6

PRINCIPLES OF DRAINAGE OF LAND

6.1.0. Definition of Drainage:

In its broadest sense, land drainage in the humid regions, is the removal of the free water, both from the land surface and from the soil of the root zone of plants. In modern farming it is also understood as control of ground water table. In the arid regions, drainage is only one of the agencies for such control.

6.1.1. Purpose of Drainage:

The purpose of drainage is to remove all free water from the surface of cropped fields and from the soil of the root zone as quickly as practicable after it accumulates so as to prevent interference of this water with the root functions and plant growth.

6.1.2. More than a century ago (1835) the first tile drains were laid in U.S.A. Those were hand made tiles and were installed on the farm of "the father of tile drainage"(9).

6.2.0. Design of Drainage systems:

The main principles involved in the design of a drainage system are :-

a) Rate of water removal or drainage requirement

b) Site investigations

c) Design criteria to be followed

Experience gained on working of similar works implemented in other places will have to be considered for designing an economic and successful drainage project.

6.3.0. Methods of Drainage:

The drainage methods are broadly classified into three categories:-

a) Surface drainage

b) Sub-surface drainage

c) Combination of the two systems (a) & (b).

6.3.1. Surface drainage problems, involve only the rapid removal of that part of storm water from the surface and which has not entered the ground.

6.3.2. The removal of water that has already entered the soil profile is sub surface drainage. Sub-surface drainage is also needed for release of artesian pressures, interception of seepage along sloping land and removal of alkali from the root zone.

6.3.3. Combination of the two systems are normally adopted so that sub-surface drains discharge into lateral open drains and both surface and underground water are drained.

6.3.4. Adoption of any of the above methods, however, depends upon the topography of land requiring drainage and its subterranean geological conditions, and characteristics of soil.

6.4. Differences in Drainage in Humid and Arid Areas:

Drainage in humid areas has to do largely with excess water resulting from precipitation. In arid and semi-arid areas the need for drainage arises principally from irrigation.

Surface drainage systems may be required in either humid or in irrigated areas. Surface drainage is usually an integral part of irrigation systems on slowly permeable soils or in areas of high precipitation rates.

6.4.1. The purpose of sub-surface drainage is to lower the water table to a point where it will not inferfere with plant growth and development. The minimum depth at which the water level should be maintained varies according to both crop requirement and the soil. But one of the principle factors in the height of the water table in arid areas is control of salinity and alkalinity in the soil and ground water. This is a major reason for the difference in the sub-surface drainage of humid and of arid climates.

6.4.2. The depth of drains in humid climates is generally 3 to 5'. Water is relatively pure, there usually is a natural excess of water over plant requirements, and there is a net downward movement of ground water.

6.4.3. Soils in semi-arid or arid climates requires sub surface drains at least 5 to 7' deep. Most of the water needed by crop is added by irrigation, usually ground water is somewhat saline because of salts in the soil, the irrigation water, or both. A water table as high as 24-30 inches below the surface, suitable in many humid areas, would create a harmful salt concentration in the root zone in arid areas.

6.5. <u>Design of Surface Drainage System</u>:

6.5.1. <u>Principles of Surface drainage</u>:

Surface drainage is accomplished in two general ways:

1. Water is removed from the ground surface within the area affected or

2. by means of certain construction outside the area, the water is diverted away from the area to be protected.

In either case the system is conveniently divided into three functional parts. For details refer para 6.11

(1) Collection system:

Bedding, surface field ditches, row ditches or diversion ditches are part of the system that first picks up water from the land.

(2) Disposal system:

This is part of the system that receives water from the collection system and conveys it usually in open channel to the outlet.

(3) Outlet:

This is the end point of drainage system under consideration.

Fundamentally, surface drainage uses the potential energy that exists due to elevation to provide a hydraulic gradient. The surface drainage system creates a free water surface slope to move water from the land to an outlet at a lower elevation.

The water surface profile is the starting point in the design of the disposal system channels. The design of the disposal system involves, the computation of a water surface profile through the control points for known or trial channel sections. The control points are, outlet, land elevation at critical low areas, and restriction in the channel such as culverts, bridges and weirs.

Bernoulli's theorem is adopted to compute the hydraulic grade line for steady flow conditions. Losses of head etc. are calculated by an open channel formula usually Manning's. Head losses at entry to bridges, culverts etc. are computed from formula using appropriate loss coefficients.

6.5.2. Merits and Demerits of the system:

Demerits (1) Difficulty in farming operations.

(2) The system requires constant maintenance at high cost, Such as removal or control of vegetative growth, removal of fallen trees, drift bars and other debris that accumulate in the ditches.

(3) Cost of land removed from cultivation.

(4) Require construction of bridges across them for animals and vehicles.

Merits:(i) Low initial cost of construction compared to sub-surface drainage system. Easy of construction.

(ii) Ability to carry large quantities of water.

6.5.3. General design factors:

Water is conveyed to distant outlet points by open drains. Water may flow from ground surface as well as from collecting tile drains in many cases. Selection of drain outfall is an important factor in the design. The bed level and water surface level of the drain depends on the elevation of the outlet.

(1) Bed slope depends upon the velocity to be permitted for the soil under consideration and is in confirmity with surface slope.

(2) Side slopes of the drain depends upon the soil type. Range is ½ to 1 in. stiff clay to 3 to 1 in. in loose open sandy formation. In the case of farming operations by machinery flatter side slopes may be provided.

(3) Depth range from 5' to 8'. Laterals should be provided at suitable internals depending upon the soil permeability and rate of drainage desired.

(4) The bottom of the drain must be low enough to drain the land which it serves.

(5) The ditch/drain must have sufficient capacity with in its banks at all points to carry the water brought into it.

(6) The side slopes must be such that the banks will remain stable.

(7) The velocity of flow must be such that neither serious scouring nor silting will occur. Manning's formula is used with the value of n =0.035 to 0.04 to take into effect probable weed growth.

(8) It may usually be adequate to provide the drain capacity such as to drain the surface water and the root zone of excess water resulting from a severe storm rainfall with in a period of about 72 hours. However, for sensitive crops larger capacity may be required.

(9) A storm frequency of 5 to 10 years is usually considered adequate. A drain capacity for 10 years recurance intermal may be suitable for areas larger than 5 acres. For areas less than 5 acres, 5 years recurance interval may be adopted. It may usually be found adequate to provide drain capacity equal to 50% of the peak discharge. This will, of course, cause some flooding of the area for a few days which should normally be found within the tolerance limits of Crops indicated in para 3.10.1.

6.6. <u>Factors affecting rate of water removal from a Drainage Area:</u>

The rate of removal of excess water by an open drain is influenced by :

(1) Rainfall

(2) Size of drainage area

(3) Run-off characteristics including slope of land, soil and vegetation and crop tolerance to standing water.

(4) Degree of protection required.

6.6.1. <u>Methods of determining rate of water removal from a drainage area:</u>

6.6.2. <u>Drainage coefficient:</u>

The required rate of drainage is the key factor in establishing the required capacity of drains and their spacing. This rate expressed as the depth in inches of water that is drained off from a given area in 24 hours is the 'Drainage Coefficient' or ' Drainage Modulus'.

The method of ascertaining the drainage coefficient differs depending upon whether the area under study is arid or humid. In the case of areas requiring drainage under arid zones, the drainage coefficient is assesed from the percolation losses from the quantity of irrigation water diverted to the area and the effect of precipitation is normally neglected, being small. Whereas in Humid regions, the drainage coefficient is fixed by adding the run-off ascertained from a designed storm for draining the surface area as indicated in paras 6.5.8. and 6.5.9. to the quantity of excess water infiltrating into the ground from irrigation in the area.

6.6.3. Drainage coefficient for arid zones:

A method which has gained considerable recognition for the assessment of drainage coefficient is as detailed below. Make an estimate of percent loss to deep percolation from irrigation, the percent canal or ditch loss from other known sources and apply these percentages to the amount of irrigation water diverted assuming no precipitation.

As an illustration the following example is considered. Area to be drained - 200 acres.

(1) From consumptive use studies it has been found that deep percolation loss from irrigation is 20%.

(2) From ditch flow measurements ithas been determined that field ditch loss is 8% of water applied.

(3) The cultivator for maximum yield applies 4" irrigation every two weeks and no precipitation occurs during this period.

(4) The area is isolated from any other adjacent area in so far as ground water inflow is concerned and that there is no accretion from deep artesian wells.

(5) There is no significant sub-soil drainage from the area.

Therefore, total loss through percolation is

20 + 8 = 28%

i.e. $4" \times \frac{28"}{100} = 1.12"$ lost through percolation in each irrigation.

This works out to 0.67 cfs from 200 acres.

This is accretion to ground water from field irrigation loss through deep percolation. Sometimes an additional allowance must be made for seepage from main canal which contributes a significant portion towards deep percolation loss.

Method 2:

U.S. Salinity Laboratory has suggested two types of estimate of drainage water quantities based on the assumption that all drainage water comes from irrigation water applied to the same field or area being drained.

(a) $$Ddw = \frac{Eciw}{(ECdw - ECiw)} \times DCw$$

where Ddw = quantity of drainage water to be removed in cm.

DCw = consumptive use of water (evapo transpiration) in cm.

ECdw+ECiw = Electrical conductivity of drainage and Irrigation water respectively, or salt tolerance of crop to be grown.

(b) Another estimate of depth of drainage water is based on Irrigation efficiency:-

$$Ddw = Diw\ (1-E)$$

Where E = Irrigation efficiency

Diw = Ddw + DCw = quantity of irrigation water in cm. applied to the field.

Since irrigation efficiency is low, the portion of irrigation water that must be removed is high ranging commonly between 20% to 70%, total amount of water to be removed/drained can be found by addition to this the portion of rainfall to be drained. However, the effect of rainfall is may be neglected for arid regions.

6.6.4. Drainage in Humid Regions:

In humid area the drainage coefficient takes into account both the effect of rainfall and irrigation water, and it may be determined as indicated in para 6.6.1.

(a) U.S.D.A. soil conservation service gives an 'Emperical formula for determining the rate of water removal.

$$Q = KM^{x}$$

Where,

Q = Run-off in cft/sec

K = a constant

M = water shed area in sq. miles.

x = an exponent

The correctness of water quantity from this formula depends upon the accuracy of constants K & X. Values of K & x are found to vary from 24 to 150 and 0.85 to 0.6 respectively.

Similar figures should be obtained on the basis of experiments to suit local conditions in India as well.

(b) Curves are also established by U.S.D.A. for determining drainage coefficients. Some such curves are given in fig. 19(a) and (b). Similar curves should be establised for areas under study in India.

6.7. Capacity of Drain:

Capacity of drain is computed by applying the applicable drainage coefficient to the area served as discussed in the previous paras.

6.7.1. Open type sub-surface drains may be used as dual purpose drains to collect and dispose off both surface water and ground water. The open drain section may be a Cunnete section so that the top section will be available for carrying flood waters and the bottom section for carrying the normal design discharge.

6.8. Section of Drain:

For maximum economy of excavation trapezoidal sections are adopted in practice for easy construction even though a semi-circle has the smallest wetted perimeter. Construction equipment to be used, soil characteristics are also to be considered in the design of section.

6.8.1. Depth:

This should be sufficient to drain the area adequately and is also governed by the topography of the area and the relative elevation of outfall points. Where tile line outlet into ditch a minimum depth of 4' to 6' may be required. Allowance is also made in some cases for accumulation of silt.

6.8.2. Width:

This depends upon the nature of the soil and the type of section to be adopted, to dispose off the excess water.

6.9.0 Spacing of Drains:

The spacing of drains depend upon the topography of the area to be drained and the soil characteristics. If the topography is unduloting the location is more or less dictated. If the surface is uniform then depending on the soil type the spacing is determined. For impervious soils close spacing is adopted than previous soils.

A formula used for ascertaining the spacing of drains has been given by Donnan. This formula assumes an impervious soil layer at a reasonable depth overlaid by a pervious soil strata:

$$S = \frac{4K}{q} \left[H^2 - h_o^2 \right]$$

S = spacing between drains

K = permeability of soil in ft/year.

q = discharge entering the drain in cfs.

H = Maximum depth of water table above the impervious strata.

h_o = Depth of water in the drain above the impervious strata.

(Ref. fig.10).

6.10. Spoil Banks:

Spoil banks are generally avoided as far as possible as they obstruct farming operations. However, where they are to be used, openings should be left in the spoil bank where a natural drainage channel intersects the ditch and at least every 500' along the ditch.

6.11. Type of layout of drainage system(Surface drains):

Various pattern of lay out are used individually or in combination of two or more systems depending upon the topography and other features encountered on the field for the removal of excess water. They are as indicated below. Flatter side slopes for ditches may be adopted to facilitate farming by machinery since machines are common in modern agriculture.

6.11.1 Bedding System:

This is a method of surface drainage consisting of narrow width plow lands in which the dead furrows run parallel to the prevailing land slope. The area between two adjacent dead furrows is known as bed. Bedding is most practicable on flat slopes of less than 1.5%, where the soils are slowly permeable and the tile drainage is not possible.

Design and layout of this system involves the proper spacing of dead furrows, depth of bed and grade in the channel. The width of bed depends upon the land slope, drainage characteristics of the soil and the cropping pattern. Ref. Fig. 11.

Bed width recommended for the upper Mississippi region-

W = 23 to 30' for very slow internal drainage

= 44 to 51' for slow internal drainage

= 58 to 93' for fair internal drainage

Depth: d = 0.5' to 1.5' allowing ½ height for dead furrow. The depth actually depends on soil characteristics and tillage practices.

Bed grade will be more or less equal to the general ground slope because of flat land.

Length of bed may vary between 300' to 1000 ft. If the length is more then additional collection ditches can be proposed.

In the bedded area the direction of farming may be parallel or normal to the dead furrows.

6.11.3. Natural or Random ditch system:

This system is used for areas having staggered pods or pot holes that are too deep or too large to be filled by land levelling.

The surface drainage ditches may meander from one low spot to another, collecting the water and carrying it to an outlet ditch.

Drainage in these areas is improved if the entire field is smoothed or graded to remove minor depressions and allow the surface water to flow to the ditches.

Ref. fig.12.

6.11.4. Intercepting system:

This is applicable to broad flat areas which are wet because of the seepage from adjoining high lands. In the case of sub-surface drainage where internal drainage is good a line of tile properly located at the foot of the slope will intercept the flow and relieve the wet condition of the low areas. Where the area consists of many shallow depressions and water collects in them without infiltrating through them because of the impermeable nature of soil and sub-surface drainage not possible, open ditches constructed across the sloping land will relieve the surface water. Ref. Fig.10(a).

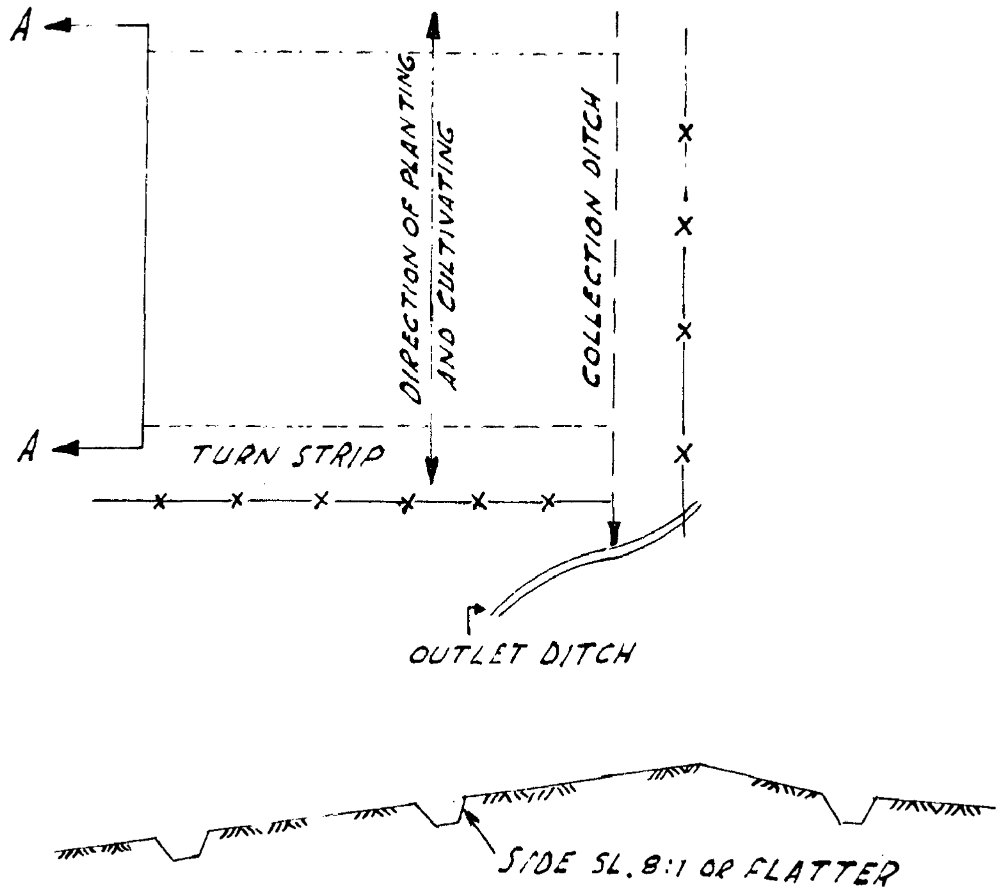
The success of this drainage system depends upon the elemination of depressions between the ditches.

6.11.5. Parallel or diversion ditch system:

On flat lands of poorly drained soils that have numerous shallow depressions the parallel ditch system is suitable. In general, the parallel ditches are spaced 600 to 1200 ft. apart and the land between the ditches is sloped and smoothed to eliminate any minor depression or obstructions to the over land flow of the water. (Ref. Fig.13).

6.11.6. Land Smoothing:

Most of the soil that require surface drainage have many depressions in surface which may vary in size and shape. All high points and shallow depressions should be smoothed and filled up respectively, Where as large depressions should be connected to a ditch so as to improve the over land flow of water.



SECTION ON AA

FIG. 13: PARALLEL FIELD DITCH SYSTEM OF SURFACE DRAINAGE.

CHAPTER - 7

SUB-SURFACE DRAINAGE

7.1. A subsurface drain is one that is beneath the surface of the soil. It may be a tile drain or Mole drain used to collect water that flows out of the soil and carry it to a conveyance channel or outlet structure.

7.2. SUB SURFACE DRAINAGE PRINCIPLES

The flow of water in saturated zone below the ground surface is based on Darcy's law,

$$Q = AKi$$

K = Permeability of soil

i = Hydraulic gradient ; A = Area of Soil

This is the fundamental equation on which the quantity of flow in simple drainage problems are assessed.

The quantity of water reaching a tile pipe placed under ground below water table is estimated by drawing a flownet. (Ref. Fig. 14.5 and Fig.15.)

7.3. HYDRAULIC DESIGN OF SUB SURFACE DRAINS

The subsurface drains may be designed considering the following points:

1) Drainage coefficient of the area to be drained.
2) The hydraulic characteristics of the materials used for carrying the water.
3) The size and spacing of the drain should be adequate to carry the water at a designed slope.
4) The pipes should not run under pressure.

7.3.1. Flow of water into a tile drain:- The general laws for the flow of water in open channels also hold good for tile drains provided the water does not run under pressure.

7.3.2. Drainage Coefficient:

(a) For Arid regions the drainage coefficient is fixed as discussed in para 6.5.2.

(b) For Humid areas the coefficient will have to be ascertained by judgement and experience considering the rainfall its frequency and duration, porosity and permeability of soils; crops to be grown.

The U.S. Department of Agriculture has recommended drainage coefficients for different cases, as below.

Two cases are considered:

(1) No surface water admitted to the tile and complete surface drainage provided.

(2) Surface water admitted to the tile through surface inlets.

For case (1) Drainage coefficient recommended by U.S.D.A.

Soil	Field crops	Truck crops.
Mineral	10-13 mm	13-19 mm
Organic	13-19 mm	19-28 mm

For case (2) Drainage coefficient

	Bhind Inlet		Open Inlets	
Soil	Field crops.	Truck crops.	Field crops.	Truck crops.
Mineral	13-19 mm	19-25 mm	13-38 mm	25-38 mm
Organic	19-25 mm	38-51 mm	25-38 mm	51-102 mm

Similar figures of drainage coefficient should be established for local conditions with the guidance of above tables.

7.4. SIZE OF TILE DRAINS

The size of a tile drain is fixed after establishing the drainage coefficient for the area under study as discussed in para 7.3.2 and the grade of the line and the velocity.

The smallest size of tile generally recommended is 12 cm size. It is based on the need to provide good agriculture drainage for a long period and cost of main-tenance, construction methods etc. A larger tile minimises the possibilities of clogging with sediment, roots or other material.

Velocity of water flowing in the drain may be calculated using either Kutter or Maning's formulae, for a given grade of tile line and the area of tile determined.

There are many Emperical formulas given by different authors for determining the velocity in a tile drainage. But, out of them a formula recommended by the U.S.D.A. appears to give better results than the others. This formula also takes into account the unevenness of the joints between the individual pipes.

The velocity obtained by U.S.D.A. formula should however be reduced by 10% for sub-mains and 15% for laterals, Since the formula gives higher velocities too large for mains and submains.

The formula is given by

$$V = 138\, r^{2/3}\, s^{1/2}$$

This applies to both clay and concrete tile and for all sizes from 4" to 12".

7.5. <u>DEPTH OF DRAINS AND SPACING</u>

The depth at which the drains are to be fixed below ground level depends on the soil permeability, crops type and outlet positions. It also depends upon the position of an impervious strata available at reasonable depth below ground level as inflow into the tile is governed by these factors.

The inflow into the pipe increases linearly with the depth of pipe below ground level.

Certain Engineers have recommended the drain depth and spacing based on their experience which are given below. This is only a guide for selection of depth of pipe and its actual depth is fixed, according to the factors that should be considered as discussed above, for local conditions.

(1) C.G.Elliot: - Depth 2' to 2½' in dense heavy soils; 4' in light open sandy soils.

Spacing - 30' to 40' in dense soils largely clay; 60 ft in mixed clays with fine sand. 70 to 80' in alluvium, glacial drift and sandy loams. 150' to 200' in sandy lands or those containing much vegetable matter having sandy or gravelly sub-soil.

(2) A.G.Smith: Depth - General average of 3½ ft.

Spacing: In eastern farming about 32 ft. to 70 ft. on pervious soils.

On sandy loam soils with clay sub-soil it is 100 ft.

(3) W.J.Schlick: Depth: 3½ to 4' usually the latter using closer spacings, rather than shallower depths to expedite action of drains.

Spacing: Maximum 100' used for crops in average soil condition.

For truck crops - 50 to 75 ft.

In taro cases with sand or gravelly sub-soil a maximum of 200' spacing is recommended.

7.6. DETERMINATION OF SPACING OF DRAINS

A number of formulae are available for determination of the spacing of drains. In short, the procedure adopted in theso formulae to arrive at the spacing of drain is to assume a suitable drainage rate, determine suitable characteristics of the soil and selecting a suitable depth for the drain compute the spacing.

The formulae are derived based on two conditions

(1) Steady state flow in homogeneous, Isotropic media

(2) Non-steady state flow consideration.

7.6.1. Steady State Condition:

The main assumptions made in respect of derivation of formulae under steady state are :-

(1) The soil is homogenoous and of hydraulic conductivity 'K'

(2) The drains are evenly spaced a distance S apart.

(3) The hydraulic gradient at any point is equal to the slope of the water table above the point.

(4) Darcy's law is valid for flow of water through soils.

(5) An impermeable layer underlies the drain at a depth d.

(6) Rain is falling or irrigation water is applied at a uniform rate, v.

(7) The origion of co-ordinates is taken on the impermeable layer below the centre of one of the drains.

The formulae are given below:-

(1) Hooghoudt's formula:

Hooghoudt gives the following formula for drain spacing and the diagram representing his problem is shown in Fig. 15 This is for homogeneous soil.

$$S^2 = 8(K/v)dHo + 4(K/v)Ho^2 \quad \ldots\ldots\ldots\ldots\ldots (1)$$

This is the equation of ellipse. Nomographs have been established for finding out the spacing. Ref. Figs. 17&18.

Where d = Depth of impervious layer below the tile line

Ho = Height of water table midway between the tile lines above the line connecting the centres of the tile line.

K = Coefficient of permeability of the soil

v = Rate of discharge/unit area of land surface drained.

<u>For layered soils</u>:- having different permeabilities above and below the tile line, the above equation is modified as -

$$S^2 = \frac{4}{v}(Ka\, Ho^2) + \frac{8}{v}(Kb.d.Ho) \quad \ldots\ldots (2)$$

where Ka = Hydraulic conductivity of soil above the drain line

Kb = Hydraulic conductivity of soil below the drain line

Where $Ka = \frac{K_1 l_1 + K_2 l_2 + \ldots}{l_1 + l_2 + l_3}$

Similarly Kb is determined for different thickness of soil layers and the drain spacing be calculated for a given set of conditions.

(2) <u>Donnan's Formula</u>:- This formula assumes that the entry of flow into the drain as horizontal which is not the case the flow being radial.

$$S = \frac{4K}{Q}(H^2 - ho^2)$$

where H = Maximum height of water table midway between the tile lines above the impervious layer.

ho = depth of impervious layer below the cable of tile

This formula gives only approximate results.

(3) Kirkham's formula: - This formula given by him is supposed to give better results than Hooghoudt's. It is as below:

$$H_o = \left(\frac{Sv}{K}\right) F\left(\frac{2r}{S}, H/S\right)$$

Where all the symbols are defined as per equation(1)

and

$$F(r2/S, H/S) = \frac{1}{\pi}\left\{\left(\log_e \frac{S}{\pi r} + \sum_{m=1}^{\infty}\left[\frac{1}{m}\left(\cos\frac{2m\pi r}{S} \cos m\pi\right)\left(\cos\frac{2m\pi}{S}H - 1\right)\right]\right\}$$

For convenience of calculations, graphs are prepared for this formula to obtain drain spacing see Ref.Fig.19.

7.6.2. For Unsteady State conditions:

The flow phenomenon involved in sub-surface drainage is one of the transient or unsteady state where the conditions of equilibrium between the water table and the rainfall and/or irrigation does not always exist. Based on the studies for transient drainage problems, U.S.Bureau of Reclamation have evolved the following formula for spacing of drains

$$S = \pi \sqrt{\frac{KDt}{f \log_e\left(\frac{4}{\pi}\cdot\frac{y_0}{y}\right)}} - D\log_e(D/4r)$$

y = Ht of water table before drainage.
y_0 = Ht of water table after drainage.

(REF FIG:15) where $D = (d + y_0/2)$

For easy calculations, charts have been prepared from which the spacing can be determined.

The drain spacing from both steady and unsteady conditions may be ascertained from the above formulae and the coinciding figure may be adopted as the required spacing of drains.

7.7. GRADE OF PIPE

Sub-surface drains can be laid at a variety of slopes.

However to keep the line self cleansing it is necessary to have a grade that will develop sufficient velocity to carry the sediments away. The slope recommended for a 4" tile should not be less than about 0.2% to develop a velocity of about 1 ft/sec, when flowing full to avoid sediment deposition. It reduces for 12" line and above to 0.05%.

7.8. MOLE DRAINS

Mole drains are formed by pulling a plug/ball through the sub-soil having a good structural stability. The soil should be cohesive having sufficient moisture content. The lay out of drains is similar to tile drains. Mole drains may empty into open ditches, tile lines or other mole channels. If the moles empty into open ditches, a short length of metal tubing may be useful in protecting the outlet.

Where closer spacing is required mole drains may be adopted, if other conditions permit. Normally a spacing of 10 to 30 ft. are adopted depending upon depth and degree of drainage required.

7.9. ENVELOPE MATERIALS

In order to prevent entry of fine sand, silt etc. entering the drains filter materials like, gravel, coarse sand are placed around the pipe.

This also helps in maintaining stability of the soil round the pipe after its installation. About 2" thickness of gravel round the pipe may be adopted.

7.10. ENTRY OF WATER INTO A SUBSURFACE DRAIN

The water enters into the drains through the holes or cracks between the successive pipes. In unstable soils the crack width be as small as possible to prevent possible entry of soil particles.

7.11. OUTLETS FOR DRAINAGE

There are two types of outlets

(1) Gravity outlets

(2) Pump outlets

Gravity Outlets:- Include natural channels, tile drains and open drains. The outlet should have sufficient capacity to carry additional discharge where the drainage system is connected to other tile drains. Where the pipe outlet into an open drain the end of the outlet pipe should be sufficiently above the normal water level in the drain.

Pump Outlets: are used where gravity outlets are not available. The essential parts of a pumping outlet are a pump, and a sump or storage basin. Pumps are operated for certain number of hours in a day depending upon the discharge to be handled. The pump should be installed in such a way as to provide minimum lift and the pump house is not flooded.

7.12. LOAD ON DRAIN PIPES

The drain tile should be installed so that the load over the pipe due to fill material over it does not exceed the required average minimum crushing strength of the tile material.

Different formula are available for calculating the loads on pipes depending upon the width of the trenches in which the drains are placed. One such formula which is commonly used is given by

$$W_c = C_d W Bd^2$$

Where W_c = total load on the conduit

W = Unit weight of fill material

Cd = load coefficient for ditch conduits

Bd = width of ditch at top of conduit.

7.13. <u>LAYOUT OF SUBSURFACE DRAINAGE SYSTEM</u>

The topography of the land, source of water to be removed and various other field conditions determine the right location of the tile lines and the proper type of drainage system.

The system of sub-surface drainage consists of main drain, sub-mains and the laterals, A main drain is the one into which several lines of tile lines empty their water. The main usually have outfalls into open drains. A sub main is a short main which collects water from a number of tile lines and discharges into the main. A lateral is a tile line collecting water from the soil and discharges into the sub-main or main.

Tile systems can be classified by three general types

(1) Parallel system

(2) Random system

(3) Intercepting system.

7.13.1. <u>The parallel system</u>: The parallel line system is used in poorly drained soils having little slope and approximately uniform texture. Variations are the grid-iron and parallel systems, the Herringbone system, the double main system and the grouping system, Fig. 16(a)

7.13.2. In the grid Iron and parallel system , One main or submain serves as many laterals as possible. Thus the length and number of outlets are kept to a minimum. The laterals enter the mains from one side only. This is the most economical arrangement as the land on only one side of the submain or main is double drained, that is, a narrow strip of land along the main is drained by both the sub main and the lateral. The system can be used on land that is uniformly wet if it slopes generally towards the main or sub-main. Fig. 16(b).

7.13.3. The Herringbone System is applicable in places where the main or sub main lies in a narrow depression and the laterals must enter from both sides. It is less economical, since considerable double drainage occurs where the laterals and main join. If the depression over the sub main is unusually wet, however, this system will provide better drainage at that point. Fig. 16(c)

7.13.4. Double system - The double system is a modification of the grid iron system. It may be used where thesub-main is in a broad, flat depression, which may be a natural water course and sometimes may be wet because of small amounts of seepage water from nearby slopes. A submain on each side of the depression serves the double purpose of intercepting seepage water and providing sub mains for the laterals. Fig. 16(d)

7.13.5. Grouping systems: A combination of individual systems; are useful when topography and wetness on the field vary and the pattern of drainage must be changed to fit different conditions.

7.13.6. The Random System: It is used in rolling areas that have scattered wet areas somewhat isolated from each other. Tile lines are laid more or less at random to drain the wet places. It is better to locate the main so as to follow the natural drainage ways rather than to make deep cuts through ridges to make straight tile lines. Sub-mains and laterals should be extended from the main to the individual wet areas. Fig. 16(e)

7.13. 7. The Intercepting system: This system is used to intercept the seepage water from the sloping land, when the land is wet upto the valley. Fig. 16(f)

FIG-14

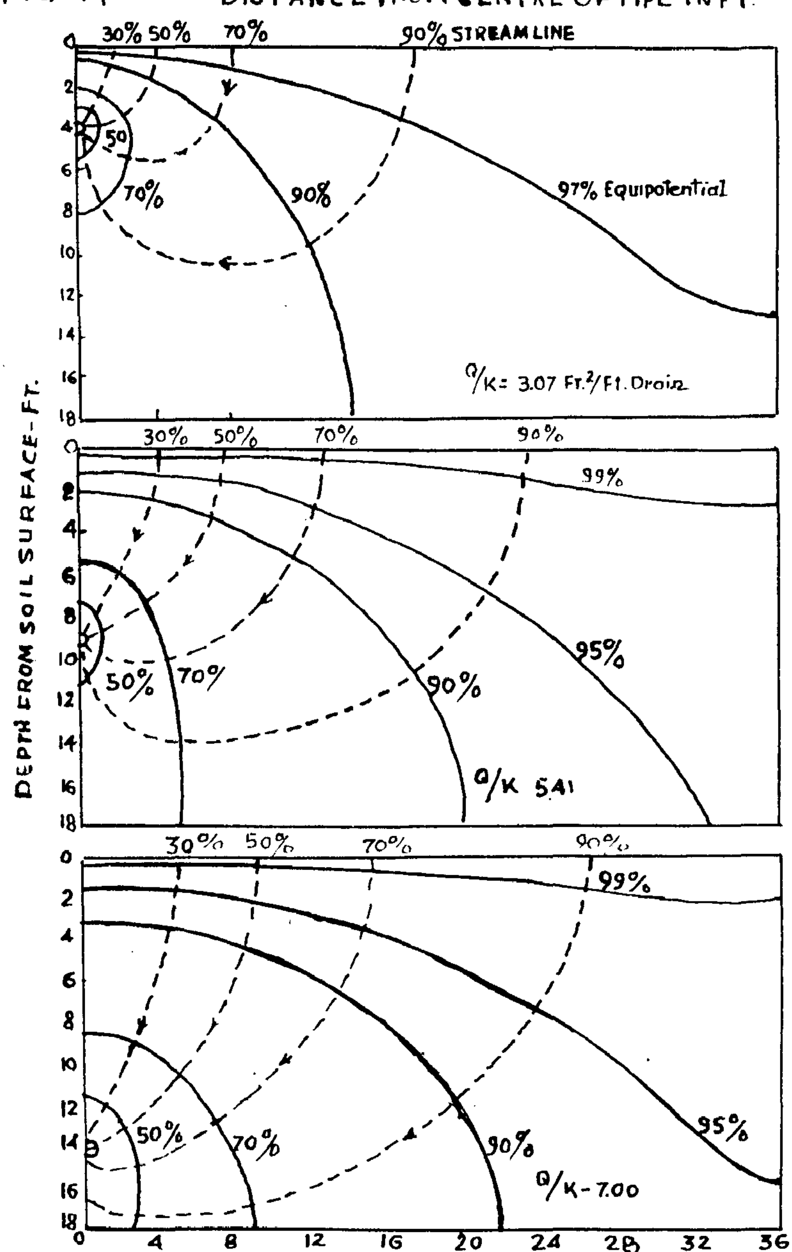


FIG 14: FLOW NET

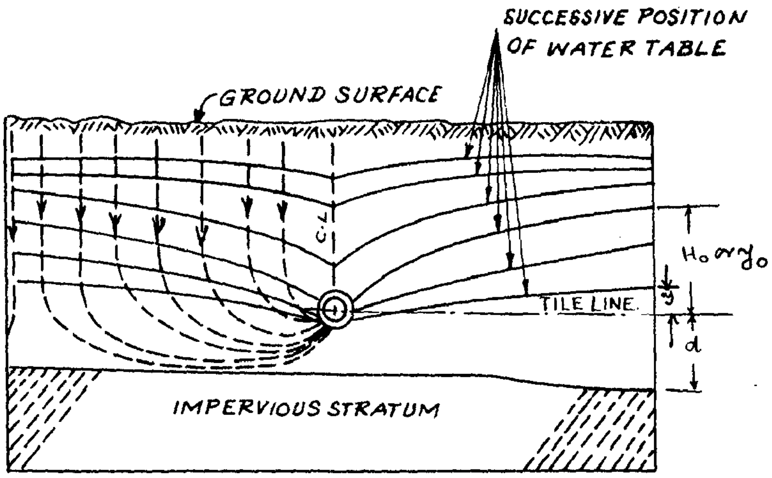


FIG.15 _Movement of water in reaching a drain pipe.

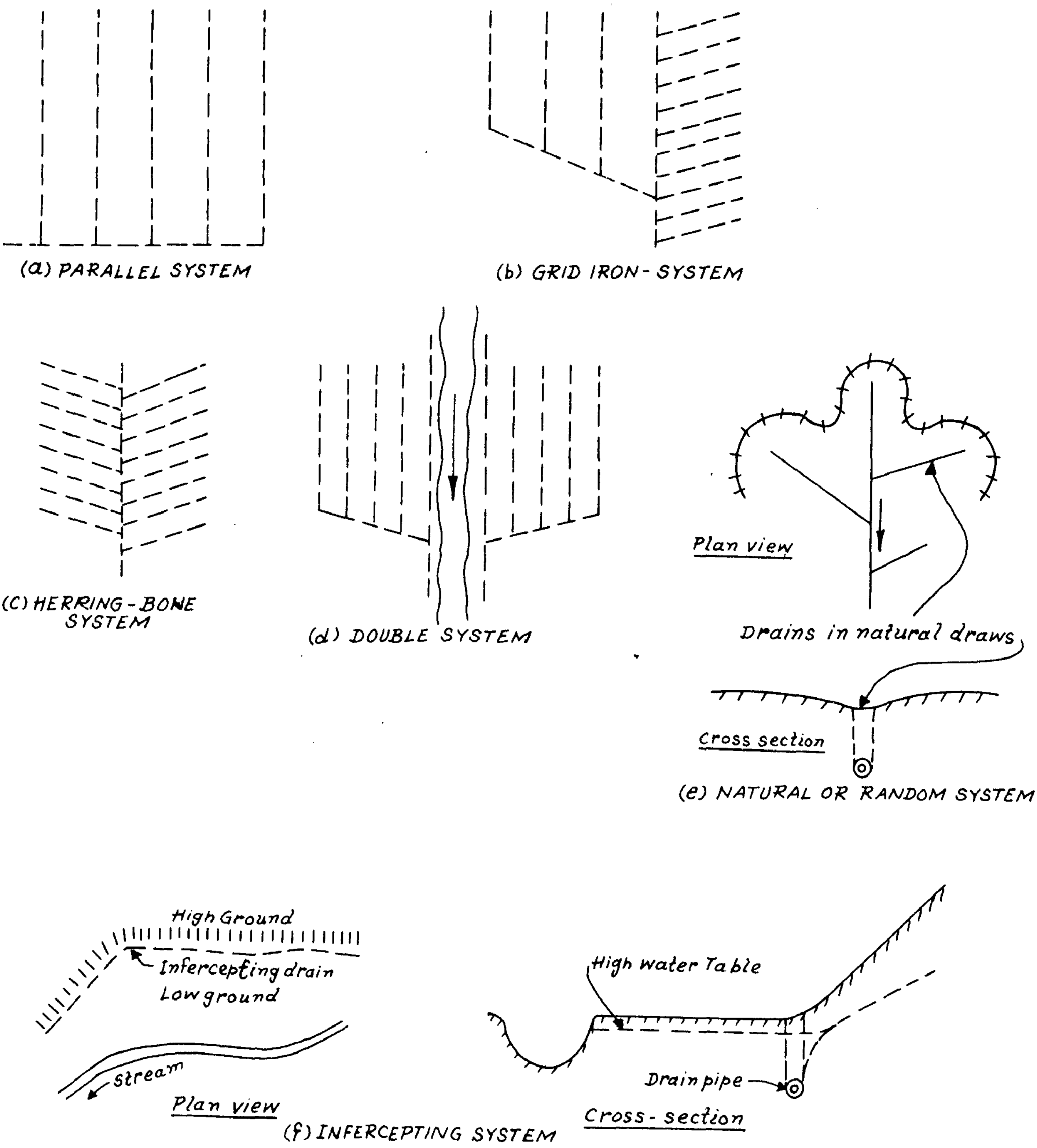


FIG.16 - Types of Sub Drainage system.

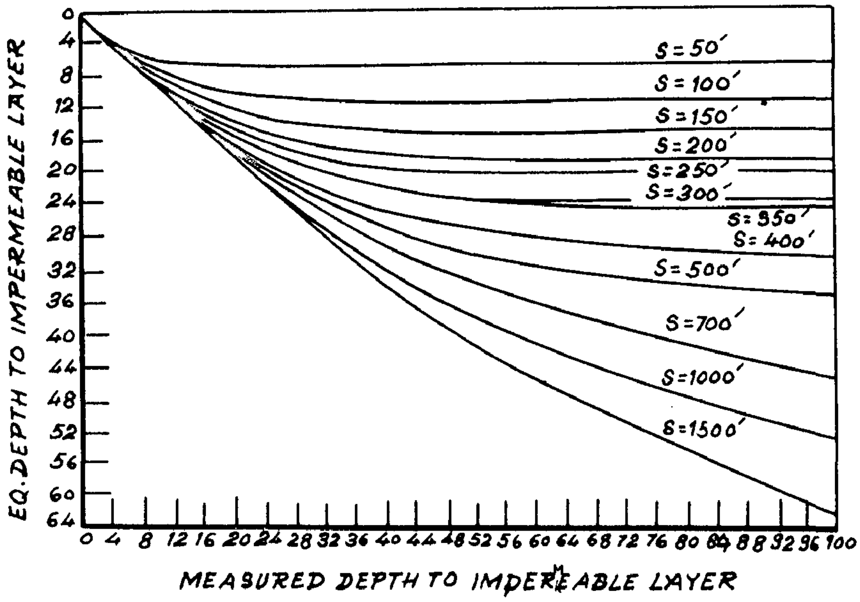


FIG.17 - Relationship between d and d' where r = 0.8' and s is the spacing. between the drains.

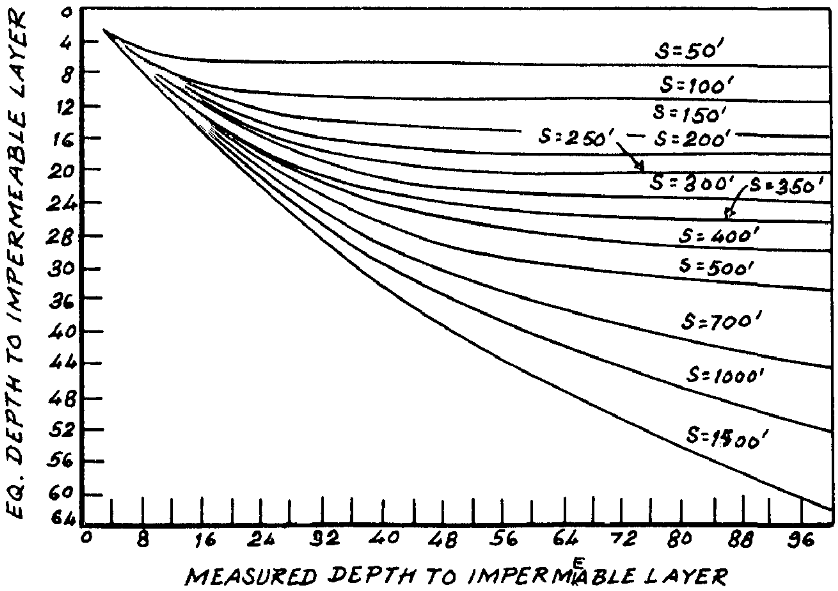


FIG.18 - Relationship between d and d' where r = 0.7' and s is the spacing between the drains.

CHAPTER - 8

PLANNING FOR A DRAINAGE SCHEME

8.1.0. GENERAL

The choice of a system of drainage to be adopted for a particular area depends primarily upon the following factors:

(1) Economy in cost

(2) Topography of the area

(3) Rainfall

(4) Drainage requirement

(5) Characteristics of the soil in the land requiring drainage.

(6) Geology of the area.

(7) Type of crops grown and their relation to Drainage.

After investigation of the area with regard to the above points, depending upon the results obtained the excess water from the area to be drained can be disposed off in the following ways:

(1) Surface drains

(2) Sub-surface drains

8.1.1. Surface Drains

These are open drains to dispose off the surface runoff from storms and irrigation as quickly as possible, depending upon the requirement relating to soil characteristics and tolerance of the crops to ponding. These drains are also used to remove excess water from the sub-soil where tile drains cannot be used due to economic and other reasons such as inadequate outfall, stratified soils, fibrous organic soils etc. The common use of open drains is as collector drains

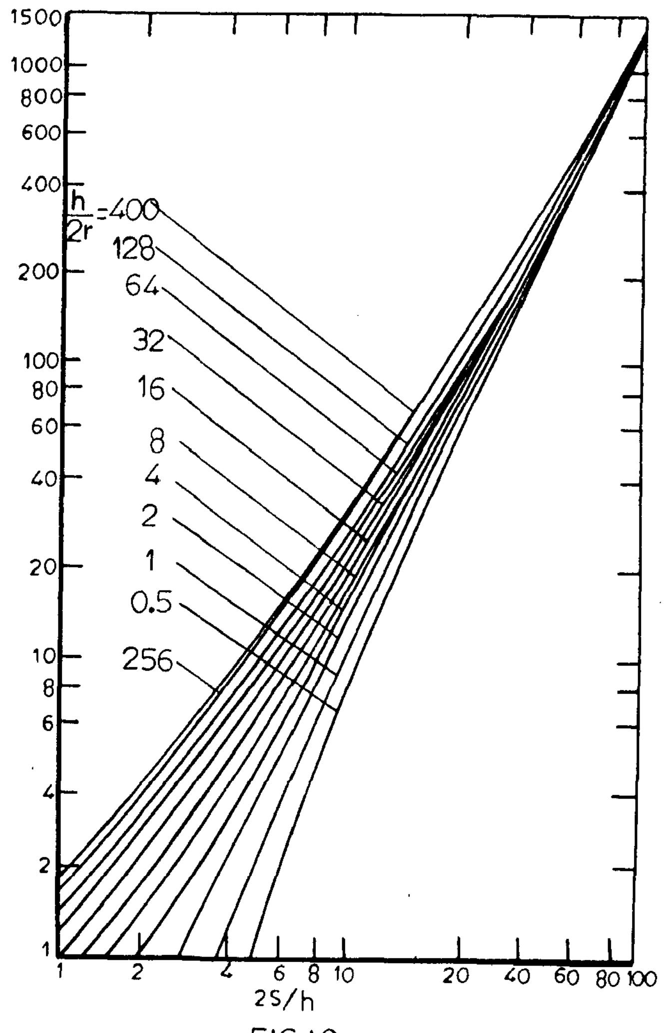

1500
1000
800
600
400
200
100
80
60
40
20
10
8
6
4
2
1
h/2r = 400
128
64
32
16
8
4
2
1
0.5
256
1
2
4
6
8
10
20
40
60
80
100
2S/h

FIG.19

CHAPTER - 8

PLANNING FOR A DRAINAGE SCHEME

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(3) Rainfall

(4) Drainage requirement

(5) Characteristics of the soil in the land requiring drainage.

(6) Geology of the area.

(7) Type of crops grown and their relation to Drainage.

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8.1.2. An important advantage of open drains for surface and sub-surface drainage is their low initial cost and ease of operation.

The merits and demerits of the system as discussed in para 6.5.2. should be kept in view before finalising the system of drainage to be adopted for a particular area.

8.2.0. SUB-SURFACE DRAINS

The following are the types of sub-surface drains for effecting control of water table:

(1) Open drains

(2) Tile drains

(3) Mole drains

(4) Drainage wells.

8.2.1. Open Drains

Open drains being cheaper are used for sub-surface drainage where feasible. The spacing is usually close and the length of the lands between them must be sufficient to carry on farm operations. The drains are normally placed in the direction of the prevailing slope.

Open drains are generally used as dual purpose drains to collect and dispose off surface water and ground water. The capacity of the drain will therefore be designed for surface run-off and the ground water discharge as illustrated in para 6.6.2. Where high value of the land prohibits the use of open drains, tile or mole drains may be a solution.

8.2.2. Tile Drains

Tile drains, though expensive, are most suited for sub-surface drainage since they can be laid at closer spacing without interferring with farming operations and do not call for aquisition of land. Tile drains can be used in all soils, but in the case of fibrous organic and fine textured mineral soils, there would be chances of differential subsidence, and therefore the tiles will have to be placed at greater depths which increases the cost of installation. The minimum depth recommended for organic soils like peat and muck is 4 ft. Deeper drains at wider spacings are economical but the economy decreases with depths greater than 4 ft. due to increase in installation costs.

The drains have to be laid at closer spacing in tight soils and at wider spacing in pervious soils. Where there is danger of choking of the drains, the open joints are surrounded with filter material. In silty soils, use of perforated pipes surrounded by filter material is helpful. Formulae for the determination of depth and spacing of drains for different soil conditions have been given and illustrated in para 7.6.0.

Correct depth and spacing which gives an economical solution for the drainage of the area should be selected keeping in view of the points discussed above.

8.2.3. Mole Drains

Mole drains are suitable in the case of fine textured plastic mineral soils where the inherent stability of the soil itself is depended upon for maintenance of the drainage channel.

The spacing and depth of mole drains is generally less than that of a tile drain; since they are laid in heavy soils, a spacing of 10 to 30' are generally suitable.

8.2.4. Drainage Wells

In underground drainage system where outfall is inadequate, shallow well pumping can be resorted to. The pumped water where possible is used for irrigation or for feeding into closeby canal or reservoir.

Deep well pumping through gravel shrouded wells can be successfully used for lowering high water table where gravity methods are not successful or are found uneconomical e.g. in tight soils, artesian pressure conditions etc. The water so pumped is used for irrigation purposes.

PART - II

CHAPTER-9

WATER LOGGING PROBLEMS OF CHAMBAL CANAL SYSTEM

9.1.0. Introduction:

Chambal Valley Development:-

The Chambal Valley development scheme is a joint venture of the States of Rajasthan and Madhya Pradesh. This project is one of the Multi-purpose river valley schemes taken up for execution just after the Independence. The River Chambal is an important tributary of Yamuna and drains about 55000 sq. miles of area in the States of Rajasthan, Madhya Pradesh and Uttar Pradesh.

9.1.1. After detailed investigations and studies it was decided to develop the irrigation and power potential of the river in three stages. The work in the Ist stage consisted of a storage dam namely, Gandhi Sagar Dam in Madhya Pradesh State, a power station at the toe of the dam with the necessary transmission system and a barrage near Kota City along with canal system on the Right as well as left bank to irrigate about 1100,000 acres of area in the two participating stages.

9.1.2. Under stage IInd another dam, Rana Pratap Sagar of 177' high and power station has been constructed at a site midway between Gandhi Sagar dam and Kota Barrage. The irrigation potential of the scheme after completion of the Stage II willincrease to 1400,000 acres.

9.1.3. The Stage III of the scheme is purely meant for power generation, and a 117' high Pick up Dam, Jawahar Sagar will be constructed approximately mid-way between the Rana Pratap Sagar Dam and Kota Barrage.

9.1.4. The three power stations of the scheme will jointly have a power potential of 2,30,000 K.W. at 60% load factor. The total installed capacity at these power stations will be 3,26,000 K.W. The topography of the area near Gandhi Sagar Dam was such that no irrigation channels would be taken off directly from the main Dam. The Chambal Valley opens out near Kota City about 60 miles downstream. and it was necessary to construct a barrage from where two Main canals one on each bank could take off to irrigate the fertile lands down below. (REF: FIG: 21)

9.2. Physiography:

The Chambal command lies in the districts of Bhind and Morena in M.P. The River Chambal forms the boundary between M.P. and Rajasthan. The main drainages of this area are Rivers Chambal, Parvati, Kunu, Kunwari, Sank and Asan which are perennial. The area under canal command has arid and semi-arid climatic conditions. The summer season is very hot with temperature exceeding 45°C. In winter the temperature goes down to 4°C.

9.2.1. The vegitation of this area consists of Kikar, Bori, Jandi, Khar Julan and Grass etc. The land is mostly single cropped. In Kharif, juwar, Bajra are sourn mixed with Arhar. Til and paddy are also grown in low lying areas. The main crop in Rabi is wheat.

9.3.0. Topography:

The command is very uneven in topography with surface slopes varying from 0.001% to 0.4%. The area is covered by deep ravines near the fringe of the River Chambal.

9.3.1. Water logged area is surrounded by the main canal, the Gudah Nala and the Ambah branch canal. The Gudah nala has a catchment area of 52 sq. miles and has hardly any capacity for carrying flood discharge (being ploughed by cultivators). Down below the nalla, small bunds are constructed for tank bed cultivation. The Ambah branch canal which crosses the Gudah nala is syphoned.

9.4.0. Soil Characteristics:

Soils in the command area of Chambal canal in M.P. contain mostly silt, clay and sand with varying percentages of clay. In water-logged areas the top soil contains more percentage of clay than the soils at the bottom with harmful salts. It is also seen that the top soil in certain areas have as low a permeability as 0.004"/hr. and the underlying soils below clay 0.26" to 0.86"/hr.

9.4.1. Pre-Irrigation soil surveys:

During the period 1953-1957, the Agricultural Research Institute, Gwalior conducted a Pre-irrigation soil survey of commanded areas under proposed Chambal canals and classified the areas according to their suitability for irrigation. Profiles were dug on the basis of 6 miles grid of the Thasils in the commanded area upto 10' depth.

9.4.2 Samples were taken first at 4"-9" and next 9"-18" and then for every foot of depth. The soil analysis was carried out for the following four factors only:-

(i) Clay percentage

(ii) PH (soil reaction)

(iii) Total soluble salts

(iv) Calcium carbonate percentage.

9.4.3. The suggested permissible limits are 20% clay, PH up to 8.5 and total soluble salts 0.20% for soils best suited for irrigated agriculture.

According to the irrigation suitability classes, the Research Institute made the classification of the area as given in the next page. (TABLE- III)

Soils of class I cover mainly the Tahasils of Bhind and Ambah and to a smaller extent Jora, Sabalgarh and Bijaipur.

Major portions in the Tahsils of Bhind, Ambah, Morena and Sheapur have soils of Class IIA. Soils of class-B are found in Tahsils of Sabalgarh, Jora, Morena, Ambah and Sheapur. Soils of class III occur in Gohad Tahsil and soils of class IV in Sheapur Tahsil and in a small area of Jora Tahsil.

Soils of class V are found in Tahsils of Gohad and Mohgaon. (REF. FIG: 20)

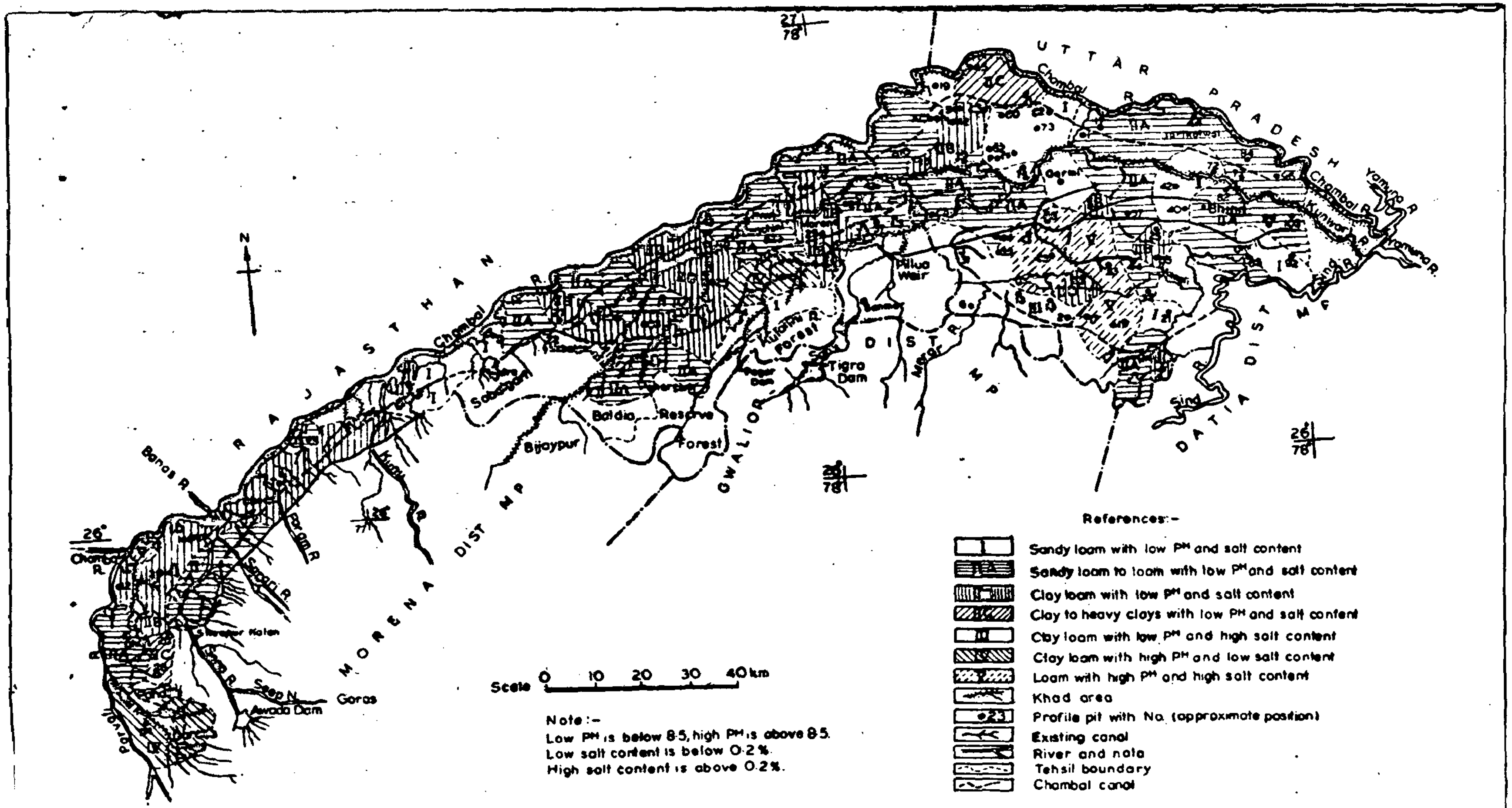

FIGURE 2a Soil Map of Chambal Commanded Area in Madhya Pradesh showing Irrigation Suitability Classes.

Class	Description of Soil	%age representation of area commanded	Clay contents	Total soluble salts	PH	Carbonate
I	Sandy loam with low PH and low salt contents	15.1%	Less than 20%	Less than 0.2%	Below 8.5	Less than 1% to 2% at top 10 to 20% below 6½ft.
IIA	Sandy loam to loam with low PH and low salt content	44.8%	20-30% 25-35% 15-22%	-do-	-do-	Less than 4% upto 4½ ft. 10% to 20% below
IIB	Clay loam with low PH and low salt content	20.9%	Sandy loam 30-40% 20-30%	0.03 to 0.1%	7 to 8	-do-
IIC	Clay to Heavy clay with low PH and low salt contents	4.7%	44-55% 45-60% 40%	0.03 to 0.15%	7 to 8.5	-do-
III	Clay loam low with PH and high salt contents	3.5%	30-40%	0.1 to 1.1%	7 to 8 & 8 to 8.5	
IV	Clay loam with high PH and low salt content	3.5%	30-40% 35-50% 25-40	0.02 to 0.19	8-8.5 8.5 to 9.5	
V	Clay loam with high PH and high salt content	7.5%	20-30% 15 to 25%	1 to 1.19	8 to 9 and 8.5 to 10	

9.5. Geology:

From the geological report of the area given by G.S.I. the following is the main geological formation in the area forming the stratigraphic sequence.

Age	Formation	Rock Type
(1) Recent	Alluvium	Silt and clay Kankar, gravel boulders, pebbles and sand.
(2) Cambrian	Upper Vindhyans	Lime stone, shale and slate, sand stone quartzite.

CHAPTER-10

PROBLEMS OF WATER LOGGING AND ITS CAUSES IN CANAL COMMANDED AREAS

10.1.0 After the introduction of canal irrigation for 7 lakh areas in M.P. in the commanded areas of Chambal project in the year 1962 the water table increased considerably in certain areas being mostly along the main canal. The water logged area is confined to the left side of canal, being a contour canal with irrigation on the left side. The areas declared water logged are indicated in Fig.22

10.1.1. In order to know the ground water conditions in the water logged area, 390 wells are observed monthly and 523 wells seasonally and 700 piezometers. The observed spring level data is given below:

Depth of W.T. below G.L. during October 1969 in ft.	Area in acres	Remarks
0'-5'	49466	Damaged
5-10	95935	-do-
10-15	33253	Protected
More than 15 ft.	39806	Safe
Total	2,18,460 acres	

10.1.2. On this basis the whole area under command has been divided into small schemes for the purpose of introduction of Drainage in these areas. As can be seen about 1,45,401 acres area is having water table between 0-16 ft. from ground surface which is quite alarming.

10.2.0 Investigations:

Detailed investigations of those areas have been taken up for suggesting anti water-logging measures. The following investigations are in hand.

(a) Survey of existing drainages, and for alignment of seepage drains along canal.

(b) Bore holes of 4" dia for determination of hydro-Isobars and Murum Iso-bars.

(c) Collection of soil samples from auger-holes in a grid of 2000' apart for mechanical analysis for ascertaining. (i) PH value (ii) Clay percentage (iii) Total soluble salts (iv) field permeability tests to determine the position of pervious strata.

10.3. Rainfall:

The area has an average annual rainfall of 30" and the season is from July to September. Normal storms do not last for more than 24 hours with a maximum of 6". The area falls under semi-arid zone.

10.4. Causes of water logging have been ascertained and proposals for remedial measures are in hand for the areas prone to be water logged as indicated in Table No.3 and Fig. No.22. The causes and remedial measures proposed to be taken up in respect of 'Mangrol Drainage Scheme' are described in the following chapters.

10.5. Water logging in Mangrol Drainage Scheme:

The area requiring drainage is confined to the left side of the Main Canal, the Ambah branch and a portion to the left of Guda nala. Fig. No.26. The total area affected is assesed as 668 ha.

10.5.1. Study of water table fluctuations:

(1) Well observations have been made since 1967 and onwards and hydrographs have been drawn. On these hydrographs the extent of rainfall and the canal operation conditions have been indicated. This shows steady rise in water table from year to year and the water table rises more towards monsoon.

(2) To find out the effect of contribution of the canal in raising the water table, piezometers were installed adjacent to the canal. The canal was completely closed in the month of May 1970 and the readings were taken. This was compared with the piezometric levels when the canal was running in full. The levels were plotted and they are indicated in fig. 23.

It may be seen that there is significant contribution of canal in rising the water table.

(3) An observation hole made in the field about 30 m away from the canal indicated that the ground water exists under a pressure of 187.5 lbs/sq. foot indicating confined conditions.

(4) Statement of seasonal variations and declines indicate the fast rising tendency of water table. Ref. Table No.V. Table No.VI indicates that the water table is rising with monsoon rainfall.

10.6. Causes of Water logging:

Studies of the affected area were made by observation of water levels in wells, piezometers and bore hole results. The causes of water logging are summarised as below:-

(1) Study of cross-section from main canal to Chambal river marked for the months of June 1970 to October 1971 indicates that the water table is high to a certain distance from the canal and falls fast, thereafter bringing the water level from about 2' below ground level to 180' below G.L. Geologically the reasons ascribed for such behaviour are -(FIG.25)

(a) It may be due to faulting and downward displacement of the aquifer zone towards Chmabal river.

(b) The deep water table on the banks of river Chambal may be a separate aquifer.

(c) The faster draining of ground water near the river helping drainage.

(d) Ground water bodies may be different due to the uneven topography of the bottom made up of impervious strata.

(e) Water level could also drop because of the deterioration of confining conditions of the aquifer towards river chambal.

However, detailed investigations are being carried out to establish the likely possibilities.

(2) Study of soil characteristics along a section from Right to Left side of the main canal (Fig. 27) indicates that the percentage of clay is significantly much less at the right side of thecanal than along the left side. Also the canal is cutting through

pervious strata. The top soils at the left side area of the canal contains more percentage of clay than their bottom layers. From this it may be said that the right portions of the Main Canal including the canal itself may be a recharge zone for the areas water-logged on the left side. Theconfining conditions observed at the left side of the canal as discussed in para 10.5.1. (3) confirms it.

In addition to the above causes several other causes as given below may be contributing to the rising of water table..

(a) Provision of inadequate water way for drainages where the Road and Railways cross them at the right side of canal. This leads to the obstruction of free flow of water and contributes to the excess infiltration of water to the ground.

(b) Natural drains choked up due to inadequate capacity and slope. This will not permit quick disposal of surface water and the result is charging of the aquifers.

CHAPTER-11

REMEDIAL MEASURES

11.1.0. Measures to check water logging in the Chambal Canal commanded area are in hand and the following proposals have been framed on an experimental basis for the present as the problem is only marginal to study ~~and watch~~ the variation in water table levels after implementing the proposals. Based on the results, further permanent measures will be taken up after detailed investigations, if called for.

(a) Lining the canal in embanked reaches and in cutting reaches where pervious strata has been punctured.

(b) Deeping and widening of existing drains and proposal of additional drains where necessary.

(c) Construction of seepage drains parallel to canal to drain away the canal seepage. The seepage drain outfall into sub-drains and the sub-drains into main drains which are the natural drainage in the area (Ref. Fig. 26.)

(d) Restricted supply of irrigation water

(e) Selection of suitable crops after study of soil profiles.

(f) Scientific method of irrigation like border strip method and applying water as when required.

(g) Combined use of tube-well and canal irrigation.

11.2. Salt Balance:

Consequent upon rising of water table close to the ground surface, white patches of salt are observed. This is predominant near the main canal at the left side to a distance of about 500 ft. So far only the total soluble salt content has been assessed and not the composition and percentage of various salts. The conductivity (total soluble salt content) of the soil solution varies from 0.1 to 6.6 milli mhos/cm. indicating varied percentage of salt content. The conductivity and other characteristics of the soil should be brought down to the designed limits as suggested in para 9.4.3. by the process of leaching.

11.3. Design of Drainage System:

It is proposed to clear the natural drainages and to improve them by giving proper section and slope for carrying the surface run-off and also to construct additional drains where necessary. The details are shown in Fig. 26. The design of drainage channels are discussed below.

11.3.1. Drain Section:

The most important factor in the design of drains is the drainage coefficient. This is fixed up as below :-

A study of the rain fall from the year 1942 to 1970 reveals that, if a cycle of 5 years is taken as representative rainfall, the area has an average maximum rainfall intensity of 12.5 cm(5") in 24 hours. It is also seen from the data that mostly the rainfall duration is not more than 8 to 10 hours with no rainfall on the previous and succeeding days.

11.3.2. Assuming, therefore, a rainfall of 12.5cm (5") and 80% of it as run-off and the whole area to be drained in 3 days which is the capacity of crops in tolerance for floods the drainage coefficient /sq.km. works out to 0.44 cumec. or say 40 cfs./sq.mile.

Since the distribution of rainfall will not be uniform through out a reduction in the percentage of run-off is proposed as per the table below :-

Sl.No.	Catchment area in sq.miles	Percent of D.C.	D.C. in cusecs/ Sq.mile	Total discharge
1.	0 to 5	Full	40	200 cfs.
2.	5 to 10	90	36	360
3.	10-15	80	32	480
4.	15-20	70	28	560
5.	20-25	60	24	600
6.	25-30	55	22	660
7.	31 and above	50	20	700

The maximum catchment area involved for the main drain is 52 sq.miles. According to the above table percentage of D.C. is 50%. As such, the discharge through the drain would be about 1040 cfs. or 29.4 cum/sec.

The section to be adopted is as under :

Bed slope	-	1 in 3500 ft.
Side slope	-	1½ :1
Bed width	-	9.6 m (31.5 ft.)
F.S.D.	-	2.59 m (8.5 ft.)

Rugosity Coefft. - 0.03

Discharge - 29.4 cum/sec.

This gives a velocity of 2.78 ft./sec. and carry a discharge of 29.575 cum/sec. The other drainage channels are also designed similarly, considering the D.C. applicable to their individual catchment areas.

11.3.3. The other drainage criteria are as below :-

(a) The velocity in the drains is to be taken between 0.6 to 1.2 m/sec.(2 to 4 ft./sec.) so as to avoid chances of silting and weed growth.

(b) A higher coefft. of rugosity shall be taken between 0.03 to 0.04.

(c) Side slopes may be provided according to the characteristics of the soil. Normally 1½:1 should be considered in cutting.

(d) The bed level of the drain should be kept as far as possible in pervious strata so that it may take care of the sub-soil water also.

11.4. <u>Conclusions</u>:

As discussed so far in part I and II as well, water logging is a great menance to the development of lands and it ultimately leads to the shortage of food in the country unless proper care is taken to combat the problem at the initial stages. Irrigation development activities are well progressing in every state in the country. Large scale irrigation works have been taken up and also under progress in India since the starting of 5 year plans, with the intention of growing more food to meet with the large demands of ever increasing population, but proper notice of damage to crops by intensive irrigation has not been taken. It is very essential that drainage of irrigated lands should be considered and implemented before the commissioning of canals so as to prevent damage to the crops by canal irrigation in course of time. A mere irrigation project without provision for adequate drainage of the land will ultimately defeat the very purpose of irrigation and stopping up of food production in the country.

In the case of Chambal project a seperate division has been formed and entrusted with forming proposals and implementation of drainage schemes. The Division has now taken up detailed investigations of the water logged areas for suggesting permanent measures to check the menance of water logging in the area.

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TABLE-IV

S.No.	Name of Scheme	Total area of scheme in acres	Areas in acres Damaged 0-5' B.G.L.	5'-10' B.G.L.	Total	Protected 10'-15' B.G.L.	Safe More than 15' B.G.L.	Remarks
1	2	3	4	5	6	7	8	9
1.	Rajpura	14672	3680	5600	9280	2200	3192	
2.	Baroda	5700	3284	1416	5700	-	-	
3.	Rirnikhera	5032	200	1900	2100	2932	-	
4.	Premsar	19420	3640	10756	14396	3600	1424	
5.	Gohera Southapa	10616	320	4676	5996	1382	3238	
6.	Mangrol	1650	1100	300	1400	250	-	
7.	Sabalgarh	2240	2240	-	2240	-	-	
8.	Semai	12250	2000	7000	9000	-	3250	
9.	Jora-I.	6500	2560	1636	4196	1210	94	
10.	Jora-II	6050	1056	2528	3584	1728	738	
11.	Rithorakalan(Upper)	3690	355	2791	3146	358	186	
12.	-do- (Lower)	5650	3936	1714	5650	-	-	
13.	Anchhaya	3970	229	2083	2312	1658	-	
14.	Kharua	30800	7219	13923	21142	4480	5176	
15.	Ch[illegible]	9910	875	2635	3510	2495	3905	
16.	Chirol	44240	8240	20090	28330	6050	9860	
17.	Mau	16200	6215	5580	11795	2030	2375	
18.	Rampura	20870	2317	9307	11624	2880	6366	
		2,18,460	49,466	95,935	1,45,401	33,253	39,806	

TABLE V

Statement showing yearly water tables below G.L. in feet & declares in wells for Oct. 67 to Oct. 69.

Sl. No.	Well No.	Proposed Drainage Scheme	Depth of water table below G.L. in feet Oct.67	Oct.68	Oct.69	Declinies table fro, 1967 to 1969 in Oct. in feet.	Remarks
1.	54F-3B-62	Mangrol	2.00	0.47	1.22	(+) 0.88'	Rise
2.	" "-61	"	5.00	4.11	3.78	(+) 1.22'	"
3.	" "-47	"	9.25'	6.25	6.25	(+) 3.00'	"
4.	" "-60	"	7.25'	5.10	4.85	(+) 2.40'	"
5.	" "-48	"	14.00'	9.31	9.39	(+) 4.61'	"
6.	" "-64	"	1.50'	1.48	0.98	(+) 0.52'	"
7.	" "-59	"	2.50	3.08	1.58	(+) 0.98'	"
8.	" "-58	"	4.00	3.76	3.25	(+) 0.75'	"
9.	" "-29	Sabalgarh	6.11	4.11	3.44	(+) 2.67'	"
10.	" "-19	"	0.62	2.45	0.21	(+) 0.41'	"
11.	54C-3C-9	Baroda	5.13	5.00	4.51	(+) 0.62	"
12.	" 28-5	"	3.20	3.95	3.05	(+) 0.15'	"
13.	" " 9	"	1.87	0.53	0.62	(+) 1.25'	"
14.	" " 11	"	13.82	10.21	9.91	(+) 3.91	"
15.	" " 17	"	8.14	5.26'	4.69	(+) 3.45	"
16.	" " 18	"	25.21	14.71	12.95	(+) 12.34	"
17.	" " 59	"	13.54	11.12	9.95	(+) 3.59	"
18.	" " 22	Hirnekhera	11.29	8.54	7.04	(+) 4.25	"
19.	" " 30	Premsar	16.37	11.87	8.87	(+) 7.50	"
20.	" " 26	"	8.29	7.37	7.13	(+) 1.16	"
21.	" " 32	"	7.92	5.17	6.67	(+) 1.25	"
22.	IC-4	Gohera	18.16	14.72	16.43	(+) 1.73	"

TABLE VI. Statement showing rise in water table due to rains only in wells which are away from Canal having no effect of canal.

S.No.	Well No.	Location (Village)	Water table below Ground level in feet: Observed by G.S.I. in 5/62	Observed by Drainage Dn. Sabalgarh in 5/67	5/68	5/69	5/70	Declines between 1962 and 1970	Remarks
1	2	3	4	5	6	7	8	9	10
1.	54F3B6	Pura Attar	88.49	82.25	78.83	73.30	60.80	27.69'	Rise
2.	-do-5	Ramgarh	88.42	80.58	71.25	68-53	58.45	29.97'	"
3.	-do- 4B3	Pura Jatoli	53.66	50.00	48.00	47.36	43.44	10.22'	"
4.	-do- 3B8	Kulholi	16.73	15.66	11.99	14.24	12.24	4.29'	"
5.	-do- 307	Kherakalan	41.88	37.34	34.00	33.99	30.82	11.06	"
6.	-do- 3B3	Kherla	17.49	16.50	14.55	16.47	13.13	4.36	"
7.	-do- 4B2	Gulali	15.61	15.00	14.67	17.83	15.50	0.11	"
8.	-do- 3C4	Debokheri	146.48	144.25	142.80	139.80	135.80	10.68	"
9.	-do- 4A1	Rirpur	29.00	-	-	28.76	25.09	4.09	"
10-	-do- 3C16	Sikroda	31.83	31.75	27.50	28.25	30.76	1.07	"

MAP SHOWING CHAMBAL VALLEY DEVELOPMENT

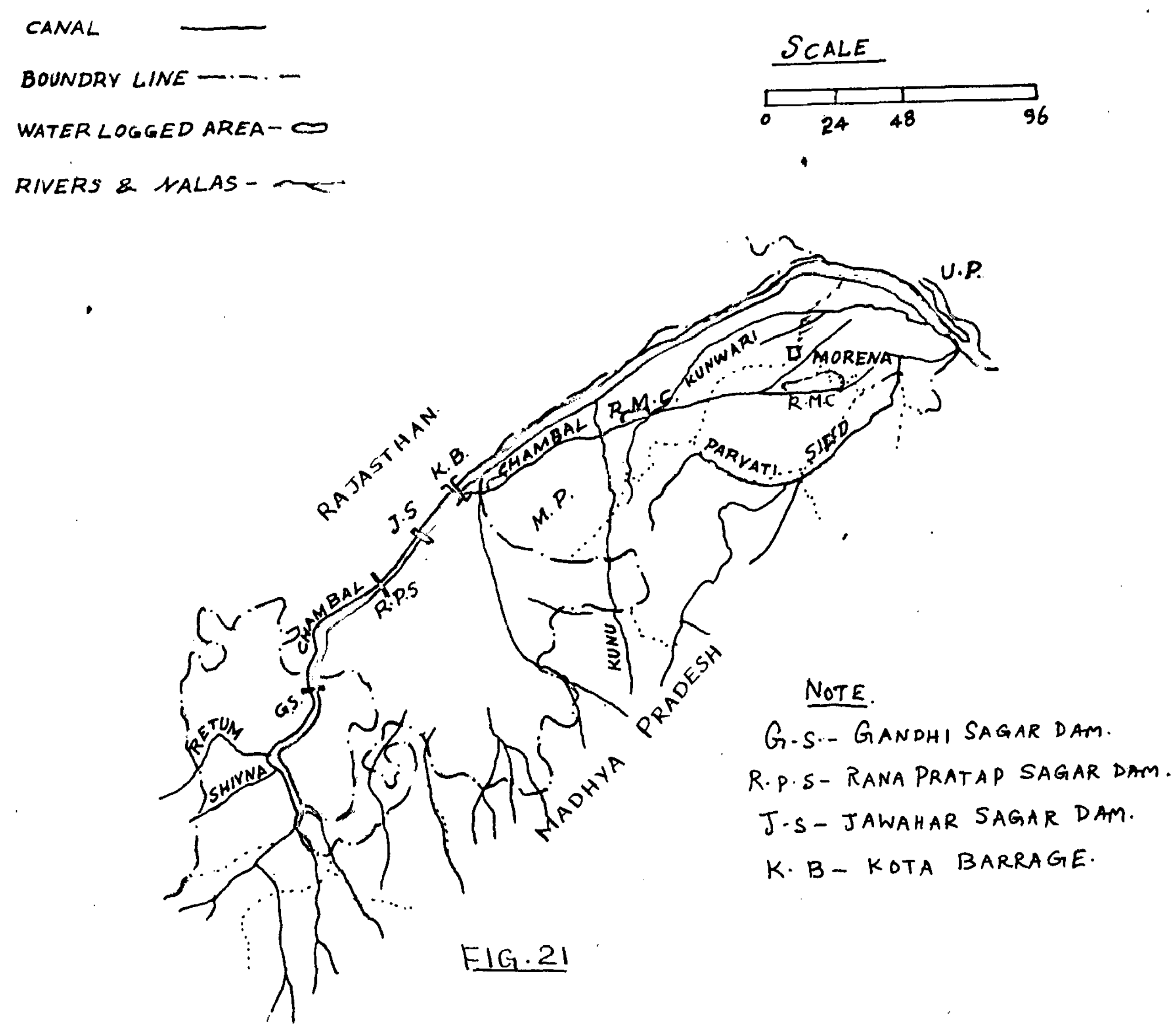


FIG. 21

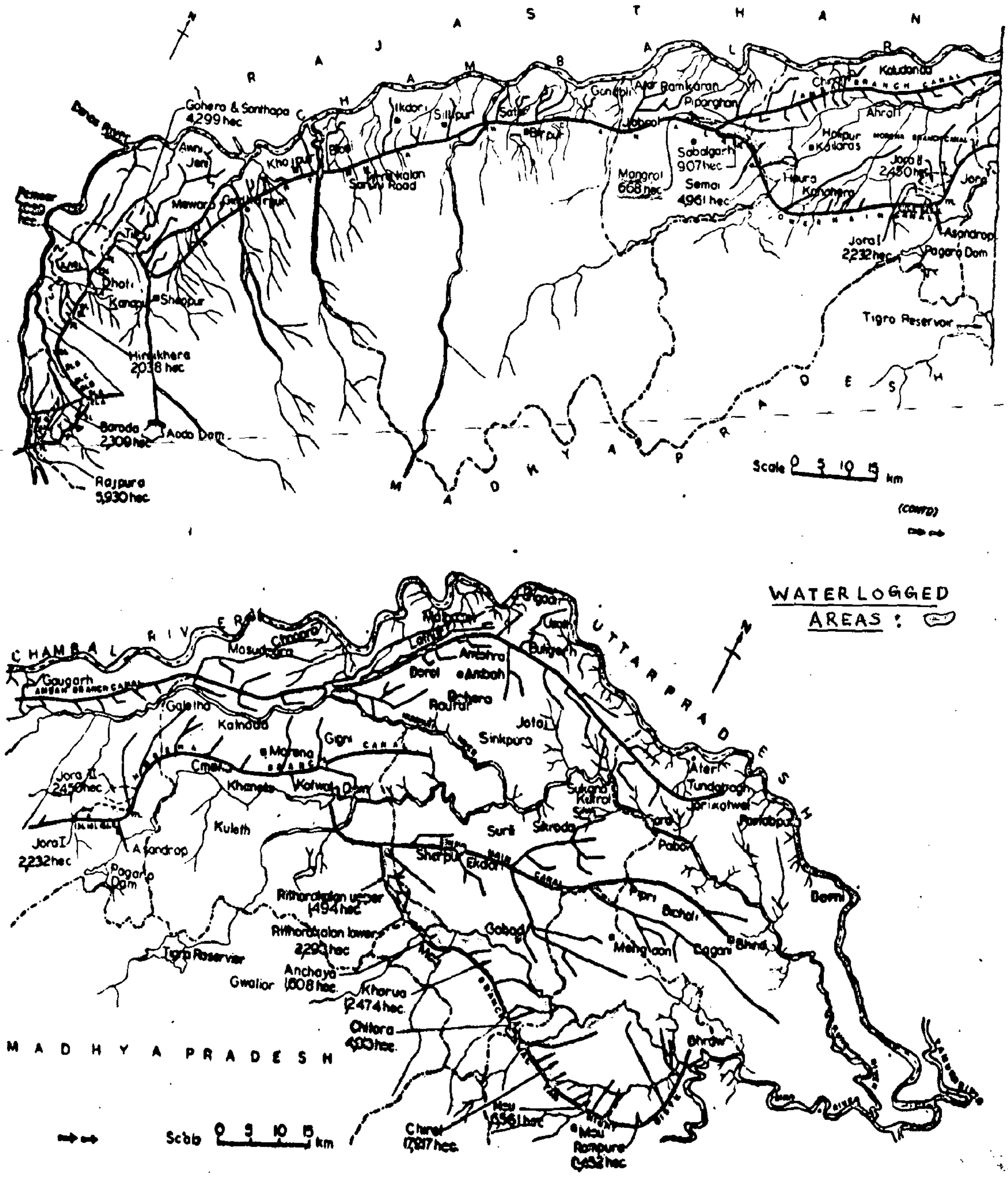


FIGURE2.2: Index Map of Chambal Valley Development.

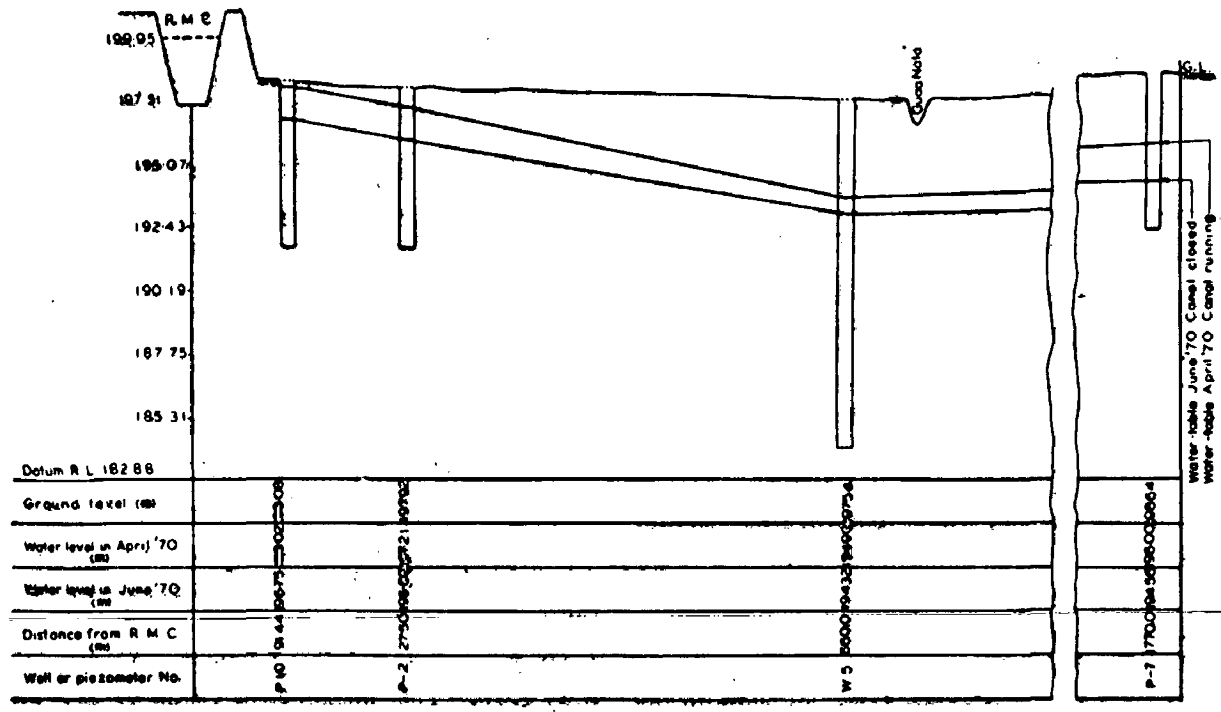


FIGURE 23: Graph showing the contribution of canal in rising the water-table.

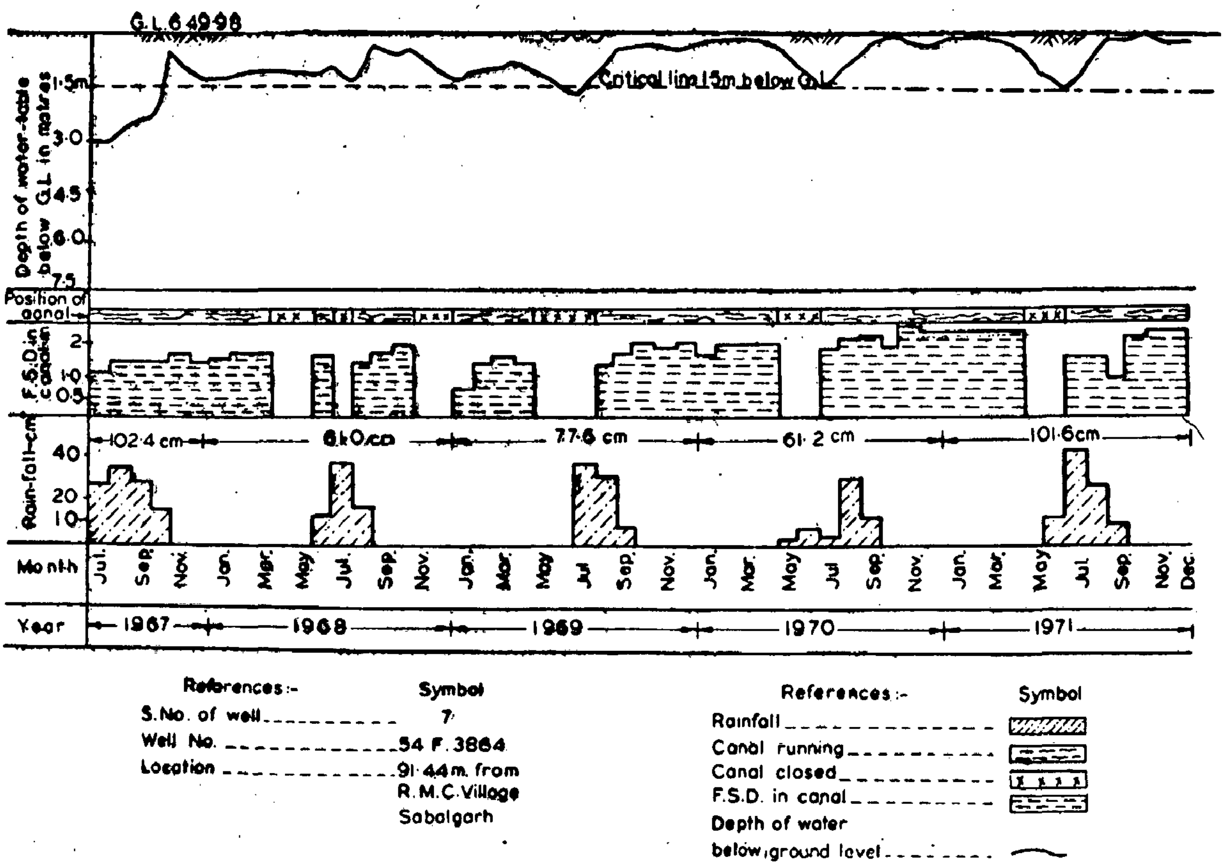


FIGURE 24: Mangrol Drainage Scheme—Graph showing water-table below ground level from 1967.

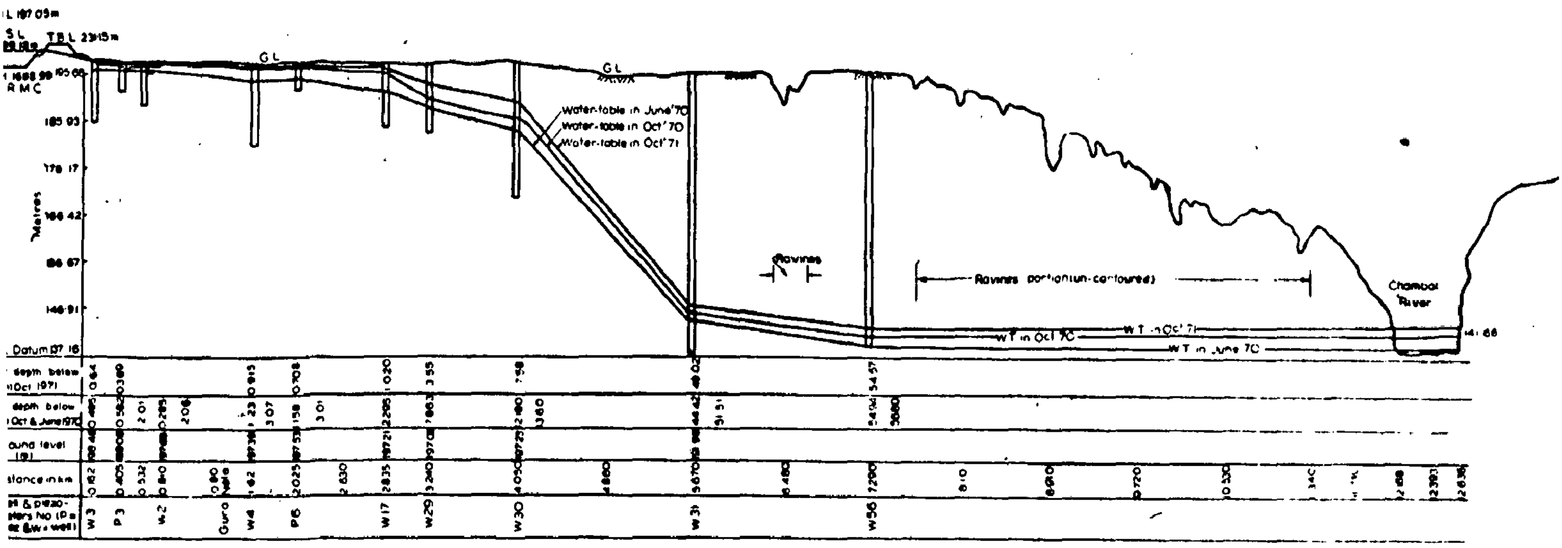


FIGURE 25: Cross-section from Right Main Canal to Chambal River showing Water-table October 1970 and June 1970-71.

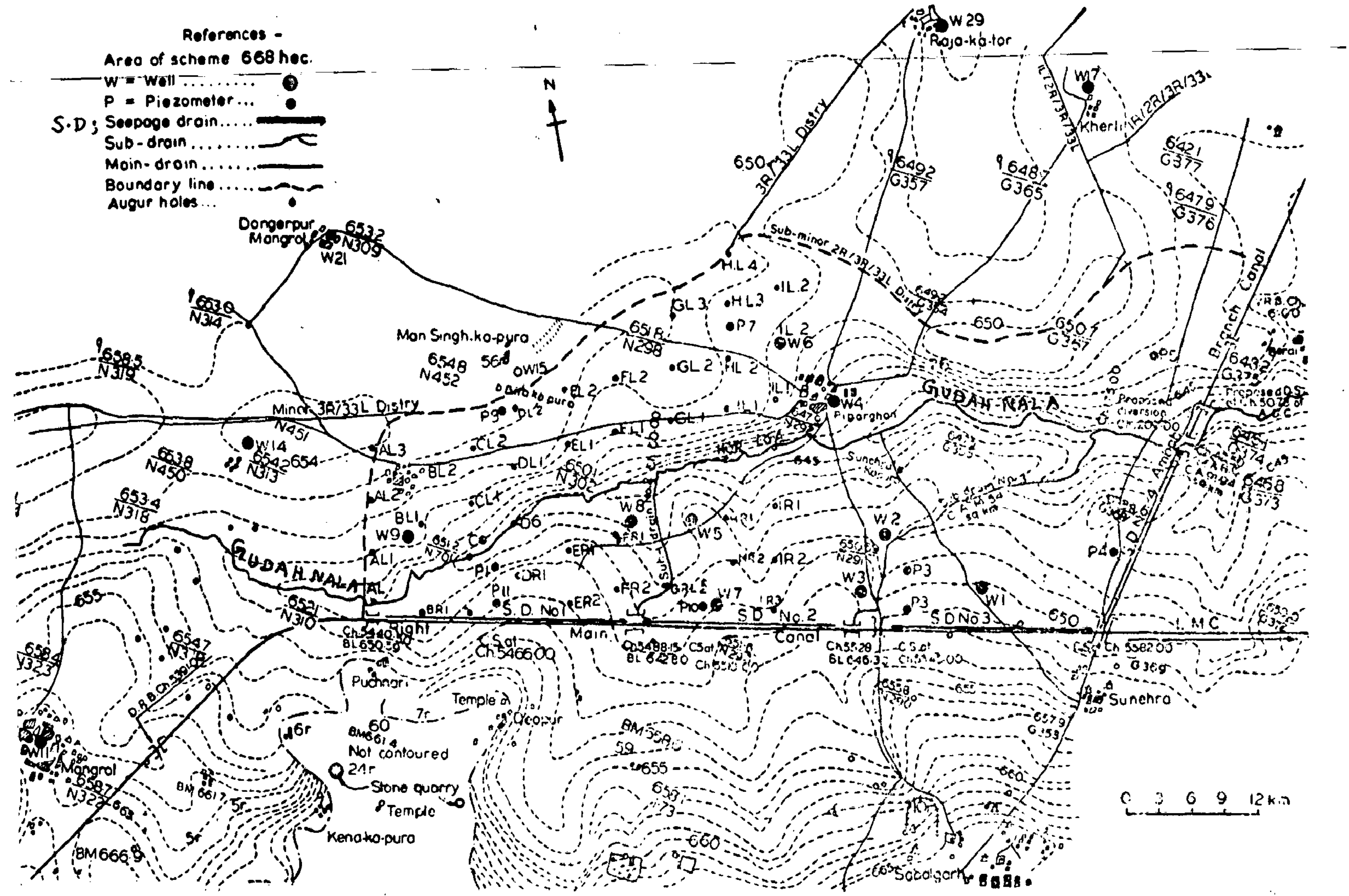
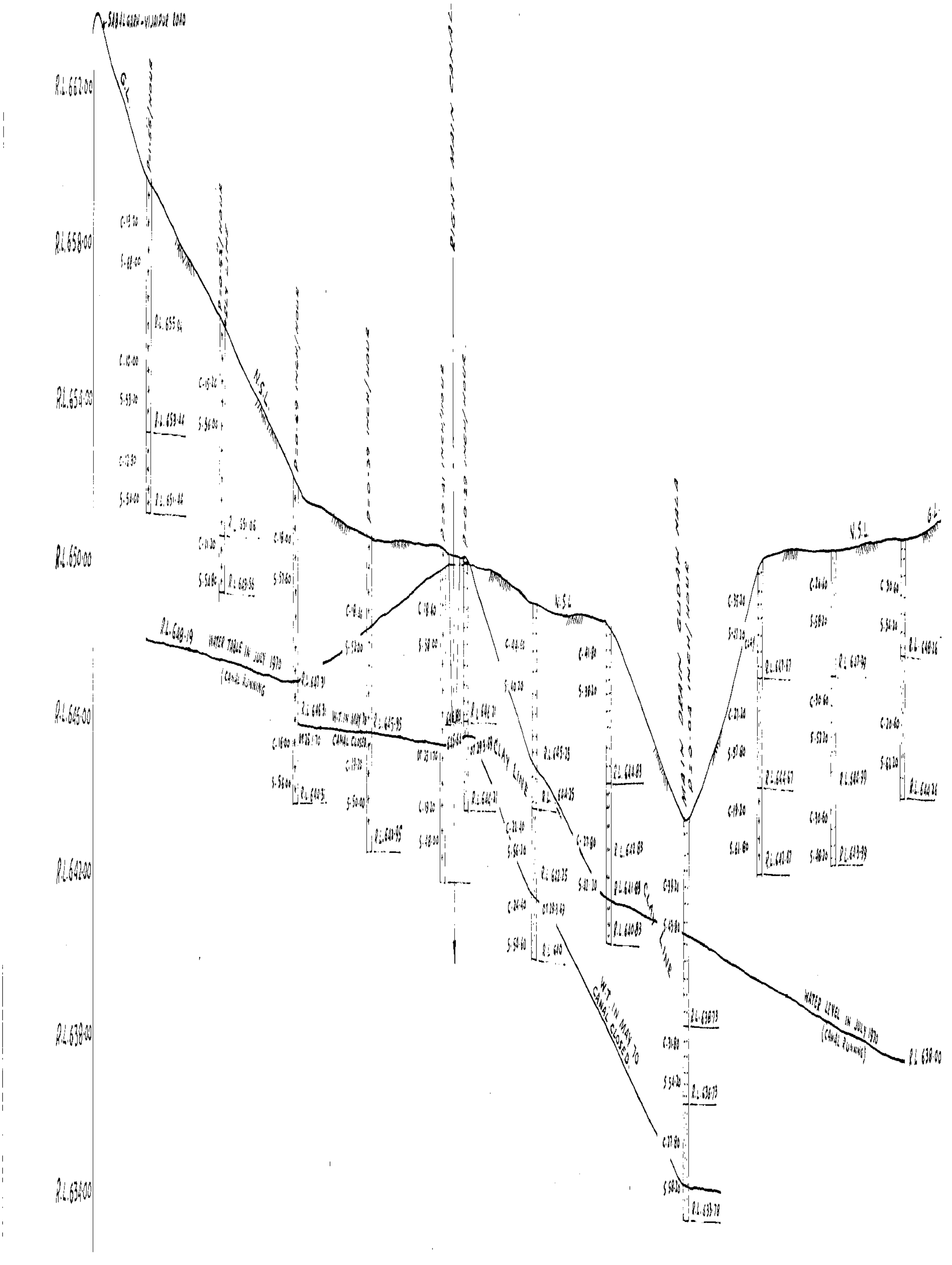


FIGURE 26 Index Plan of Mangrol Drainage Scheme.



GROUND LEVEL	654.00	659.24	656.06	652.37	650.95	650.54	650.21	649.25	648.83	643.73	650.67	650.99	651.26
DISTANCE FROM R.M.C	4950	4100	LINE 3100	2100	1100	100	100	1100	2100	3100	4100	5100	6100
AUGER HOLE NO.	ROAD	H.R.5	RLY. H.R.4	H.R.3	H.R.2	H.R.1	H.L-1	H.L-2	H.L-3	H.L-4	H.L-5	H.L-6	H.L-7

References:

S.NO.	SOIL DETAILS	SYMBOL
1.	SANDY LOAM	
2.	LOAM	
3.	CLAY LOAM	
4.	CLAY	
5.	SANDY CLAY LOAM	
6	PERCENTAGE OF CLAY	C
7.	" " SAND	S
8.	WATER TABLE OF JULY 70	
9.	FIRST STRONG FLOW (F.S.F.)	
10.	PERMEABILITY	P

FIG.- 21

CHAMBAL VALLEY DEVELOPMENT

Mangrol Drainage Scheme.

CROSS SECTION ALONG AUGER HOLES SHOWING SOIL DETAILS IN RIGHT & LEFT SIDE OF RIGHT MAIN CANAL

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