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The New Irrigation Era

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The New Irrigation Era

APRIL 1979

VOL. XVII—ISSUE No. 2

UPSTREAM VIEW OF KARUPPANAD[illegible] DAM

THE NEW IRRIGATION ERA

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CONTENTS

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EDITORIAL

There are a number of tanneries in the Pernambut basin and agriculture in this area is affected to a very great extent since the effluents let down in the streams are not treated for their pollution, No practical solution was evolved in this regard. On account of this, the area in and around the tanneries are found less suited for agricultural purposes. Some of the areas are converted to Cocoanut groves and farmers are facing a state of scarcity and poverty. Er. K. Ramalingam in his article "HYDROGEOLOGICAL STUDY IN PERNAMBUT BASIN OF TAMIL NADU" has suggested some schemes such as recharging from wells and from the proposed Bathalpalli Reservoir which will flush the ground and fields irrigated.

In the second article "TREATMENT FOR SEEPAGE THROUGH A EARTH BUND OF A MAJOR TANK" by Er. C. F. Martis, has explained remedial measures—proposed to ensure satisfactory solution for seepage in earth bund of a major irrigation tank in Tamil Nadu. This article will be much beneficial to the engineers especially to those who are engaged in the maintenance of age old irrigation tanks and other irrigation works.

Er. C. F. Martis, has also contributed another article, namely "DESIGN OF DAM OVER ROCKY FOUNDATION AT DIFFERENT ELEVATIONS". Generally earth dams are constructed where rock is not available and earth of good quality is available in sufficient quantity within economical leads. Construction of an earth dam will be much cheaper than a masonry dam. In certain cases when rock is met with at surface or even at lower levels additional precaution will have to be taken. Under such conditions earth dam is proposed and construction of masonry non spillway dam will be costly. In this article the author describes different cases and is brought out for the benefit of readers.

Construction of weirs and barrages across rivers having permeable foundations involves the formation of deep cut off walls of concrete. The fourth article "FORMING R.C.C. CUT OFF FOR WEIRS AND BARRAGES BY BENTONITE PROCESS USING A GANG DRILL" presented by Er. C. G. Jeyaraman, and Er. V. V. Ramachandran, explains in detail how the difficulties, such as dewatering, shoring, strutting, laying concrete in deep narrow trenches, etc., encountered in the old conventional method can be overcome by the use of VAK gang drill and for forming R.C.C. diaphrams to act as cut off walls by the Bentonite process.

Fifth article is the "REPORT OF THE STUDY TEAM ON IRRIGATION PRACTICES IN PUNJAB, HARYANA AND RAJASTHAN". The team leader was Er. B. A. Jeyapalan, Chief Engineer (Investigation) P.W.D. This report explain in detail, the geographical features, Development of Irrigation, Irrigation Management, Ground Water Development, Water logging and drainage problems, Command area development, Irrigation Legislation, Water rates, etc., of the Punjab, Haryana and Rajasthan region. This report will be much useful for Engineers, engaged in the Irrigation works.

This journal also includes an important technical circular issued by Er. B. A. Jeyapalan, Chief Engineer (Investigation) on "IRRIGATING HIGH DUTY CROPS—CANAL MANAGEMENT" which gives a clear idea of the design of channels and distribution of water for dry crop irrigation with particular intention to eliminate wastage of water caused by failure of farmers in availing night irrigation especially during good years.

Executive Engineers in-charge of regulation in the existing irrigation systems are specially requested to contribute articles on the defeciencies in the present mode of operation and maintenance of these systems and possible remedial measures and other improvement that could be carried out in order to improve the efficiences of these systems. Such articles will be of valuable help in formulating modernisation proposals of old irrigation systems which is very much necessary for our state which has almost exhausted its new irrigation potential.

In conclusion, the Editor thanks all the authors of the articles published in this issue for their valuable contribution and kind co-operation. All the engineers are kindly requested to send as many articles of technical importance as possible for future publication in this journal.

EDITOR.

HYDROGEOLOGICAL STUDY IN PERNAMBUT BASIN OF TAMIL NADU

By

Er. K. Ramalingam, B.E. *

1. Location:

Pernambut basin is located on the latitude of 12°-56' North and 78°-43' East. This lies in the extreme North-Western part of the Gudiyatham Taluk of the North Arcot District in Tamil Nadu (Fig. 1.). The basin is situated at an average elevation of 1,200 feet above mean-sea level amidst hills and is drained by the stream called Kanar which is tributary of Malattar which joins the river Palar. This area is covered by the toposheet No. 57 L/9 of Government of India. It receives an annual average rainfall of 840 m.m. of which 460 m.m. falls in the South-West monsoon and 380 m.m. falls in the North-east monsoon. It has a maximum temperature of 45°C in summer and a minimum of 20°C in summer. In winter it has the maximum and minimum of 32°C and 15°C respectively. The area is covered all around by low hills covered with forests. The basin has a drainage area of 98.76 Sq. Km. and the drain has an average bed slope of 1/300. The physiographic features of the area are shown in Fig. (2).

2. Geological Features :

Top crust consists of red sandy soil and Kankar for depths ranging from 0.75 m. to 5.6 m. Below this lies a strata of highly weathered hornblende granitic gneiss and charnockite for depths ranging upto 25 m. as evidenced from wells. The depths of wells in this basin range from 15 m. to 25 m. and they are lined with exposed brick stenning in steps of 1.3 metres tapering down to the water level where the diameter is generally 5 m. The depths have been confirmed at variuos places by depth probes with terrameter (Fig. 8). But it could not be done at very many places due to the ground water being polluted from tannery-wastes. From a study of the field, many dykes and a faults were suspected. The aerial photo-maps and satellite imageries were then collected and the position of these features could be identified and confirmed at site. They are shown in the enclosed geologic map (Fig. 3). But the dykes could not be traced along the entire length either physically or with the aid of magnetometer due to lack of magnetic contrast.

3. Hydrogeological Features :

3.1. This area has been selected by the A.R.D.C. for an intensive investigation, being an over developed block. 20 wells have been selected for observation of water levels. Maps have been drawn showing (*a*) M.S.L. of the ground level contours (Fig. 4) and (*b*) the depths of water levels as guaged in August 1978 (Fig. 5).

3.2. The map of water-level (M.S.L.) contours shows the streams of ground-water flow to be following the surface vallies and the slope of the ground-water varies from 1/250 to 1/300 which almost tallies with the slope of the drain-bed. The map of the contours of the water depth below the ground indicates very interesting features It reveals a shallow water-mound at the village of Sattugudi where the water is available from 10 to 20' below ground. This water-mound has got its hydraulic continuity with the lower area cut-off by a dyke which almost stalks across the entire valley. This is acting as a powerful barrier and is bestowing plenty of water and agricultural prosperity to the area North of this line and denying the same to the area South of this line. The entire cultivable area lying North of this area is bearing 2 to 3 crops every year. The Southern area having 6 villages and a cultivable area of 6,900 acres are living under conditions of water scarcity and economic backwardness.

3.3. The same map also shows two deep pits at extreme right and left ends where the grounds water has sunk down below 60 feet, evidently due to over extraction to meet the agricultural demands. Between these two zones, lies the rolling plans where the ground water is available at 20 to 30 feet depths, without showing such inclination to decline. This anomalous situation of the ground-water is reflected in the ground surface, where the deep pit zones are found covered with lush fields and the central zone is left barren with a few coconut groves here and there. This queer situation was analysed deeply and enquired into thoroughly and followed up by water-quality studies. This revealed the presence of about ten tanneries in the central zone. The tannery wastes containing excessive salts and toxic dischromate chemicals are finding their way (with some pretences to treatment) into the ground water. The water samples have been collected from the observation wells and their electrical conductivity assessed. The resulting contours are shown in the Fig. (6). If the map of water depth contours is superimposed over the water quality map, it can be easily seen that the deep-pit areas are only the areas left unpolluted and hence put to the plough. The central zone and the southern-most zone have got polluted beyond the tolerance limit of 4,500 micromhos per cm. and hence the cultivation has slowly become extinct. Here again the same dyke is playing a useful roll in preventing the spread of pollution northwards to the villages of Sattugudi and beyond.

3.4. Another set of dykes has been identified and marked in the map. These two lines of dykes are acting as barriers in the hydro-geological continuity as can be seen from the longitudinal section drawn in the North-South direction covering about 10 wells (Fig. 7). But for these dykes the ground-water from the Northern areas would have found an uninterrupted flow down South and mitigated the levels of pollution and increased the extents of irrigation. Perhaps the area North of Sattugudi might have lost its present affluence of water.

4. Agricultural Practice :

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4.1. In the area North of the village Sattugudi all the cultivable land has been brought under plough and farmers are happily turning out at least 2 wet crops with

* Superintending Engineer, Ground Water Circle, Tamil Nadu P.W.D., Madras-17.

frequent possibility of a third day crop. The area South of Sattugudi (and the dyke) is undergoing a progressing agricultural and economic decline. The tannery wastes have spoiled all the wells upto the very end of the basin and the farmers had converted all their lands initially into coconut groves which could tolerate salinity a little. But the pollution has of late reached such a hight state of salinity that even the coconuthave started reacting violently and the farmers are facing a state of scarcity and poverty. The following is the well and general census:—

Number of villages	6
Population	21,260
Number of energised wells	602
Number of bullock-bailing wells ..	557
Total cultivable area	6,892 acres.

These figures show that there is one well for every 6 acres and 18 persons. This intensity is equal to that of Pernambut block containing 65 villages which is the most highly extracted block in the North Arcot District which again leads all the districts in the State in the number of wells and in the extent of well irrigation.

4.2. The following statement gives the irrigation ayacut figures in the various villages in this basin:—

Serial number and Village name.	*Total geographical area in acres.*	*Area cultivable in acres.*	*Area irrigated during 1977 in acres.*	*Percentage of area irrigated over cultivable extent.*
(1)	(2)	(3)	(4)	(5)
1. Pernambut ..	4,302	4,263	859	20.1
2. Erikuthi ..	899	643	379	59
3. Kothapalli ..	672	574	191	33.3
4. Chinnadamala Cheruvu.	1,242	967	533	55.1
5. Pallalakuppam	155	115	54	47
6. Erukkampattu.	1,197	330	409	123.9

This statement shows how the villages of Pernambut and Kothapalli have been severely affected. The village of Erukkampattu which is as the Western end of the basin is continuing to enjoy the old gifts of plenty in water and cultivation. This is supported by the presence of the deep pit of ground-water in this zone. Similar is the case of the villge Erukuthi which has not yet been affected by pollution.

5. Hydro-geological Parameter :

5.1. Specific yield of the weathered granitic gneiss or charnockite:—

A group of 4 energised wells were taken up and their hydrology studied over 35 days of pumping. The observations were taken at intervals of about 12 days. The actual quantities of water pumped out were calculated from the particulars of consumption of electrical energy correlated with the tests to determine, the capacity of each pump for every one kilowatt hour. The entire operation was observed to have lowered the ground water level by 0.88 metre over an area of 1,53,450 m. taking out a quantity of 7,477 m^3 of water. This gives us a specific yield of 5.6 % for the strata of highly weathered granite gneiss.

5.2. Pump Test results of wells :

Tests were conducted from three wells for about 2 hours and the levels of decline and recovery were observed. The following results were obtained:—

	Well No. 23.	*Well No. 21.*	*Well No. 25.*
(1)	(2)	(3)	(4)
(*a*) Transmissivity T ..	743	352	1,530
(*b*) Permeability K ..	45	17	34
(*c*) Recuperation in first hour in gallons.	1,794	2,236	3,830
(*d*) C/A value in 30 number in gpm./ft.	0.35	0.31	0.05
(*e*) C/A value in 60 number in gpm./ft.	0.23	0.11	0.05
(*f*) Annual ground water extraction in Ac. ft.	17.8	9.6	12.5

5.3. Infiltration Test and Seepage Tests :

Tests conducted in a similar formation at Gudiyatham at 16 Km. distance from this area had given an infiltration rate of 17 mm. per hour. Similarly seepage tests were conducted from irrigated fields and tanks. We got the readings of 6 to 8 mm. per day from the tanks and 8 to 10 mm. from the irrigated filelds. The maximum evaporation had been observed to be 11 mm. per day in the month of September and the minimum is 1 mm. in the month of December.

5.4. Recharge analysis :

Soil moisture calculations have been done for a normal year for the station of Gudiyatham lying at 16 Km. from this area. This has given us a soil moisture accumulation of 17% over the annual precipitation of 840 mm. For the same station the ground-water fluctuation in the wells had been correlated with the precipitation over the years 1971 to 1977, and it has been found for a specific yield of 5.6% the return is likely to be in the order of 24%. Every 1 cm. of rain-fall falling beyond the first spell of 10 cm. of rainfall is likely to yield 2.4 mm. of ground water and raise the water levels in the wells by 43 mm. Recharge observation and calculation are also under way based on the actual soil-moisture and on the actual run-off from the basin. These will be available at the end of March 1979.

6. Problems and remedies :

The farmers in the basin are not in a position to eliminate the tanneries and save their crops as the former is providing them with a stable income. The tanneries are not in a position to treat the effluents and leave them down in a safe state as no practical method seems to have been evolved, as yet, either by the industry or the Government. Under these circumstances the people are only requesting for some schemes to flush down their ground-water continuously and restore the old conditions of cultivation. This is possible through the schemes described below :—

6.1. Recharging from wells :

Fifty number of wells could be sunk in the area of water-mound noticed above the Sattugudi village and water could be pumped out from them and brought in open channel or the conduits to cultivate about 1,000 acres. The flow in the channel or the seepage from the fiields is likely to flush the ground.

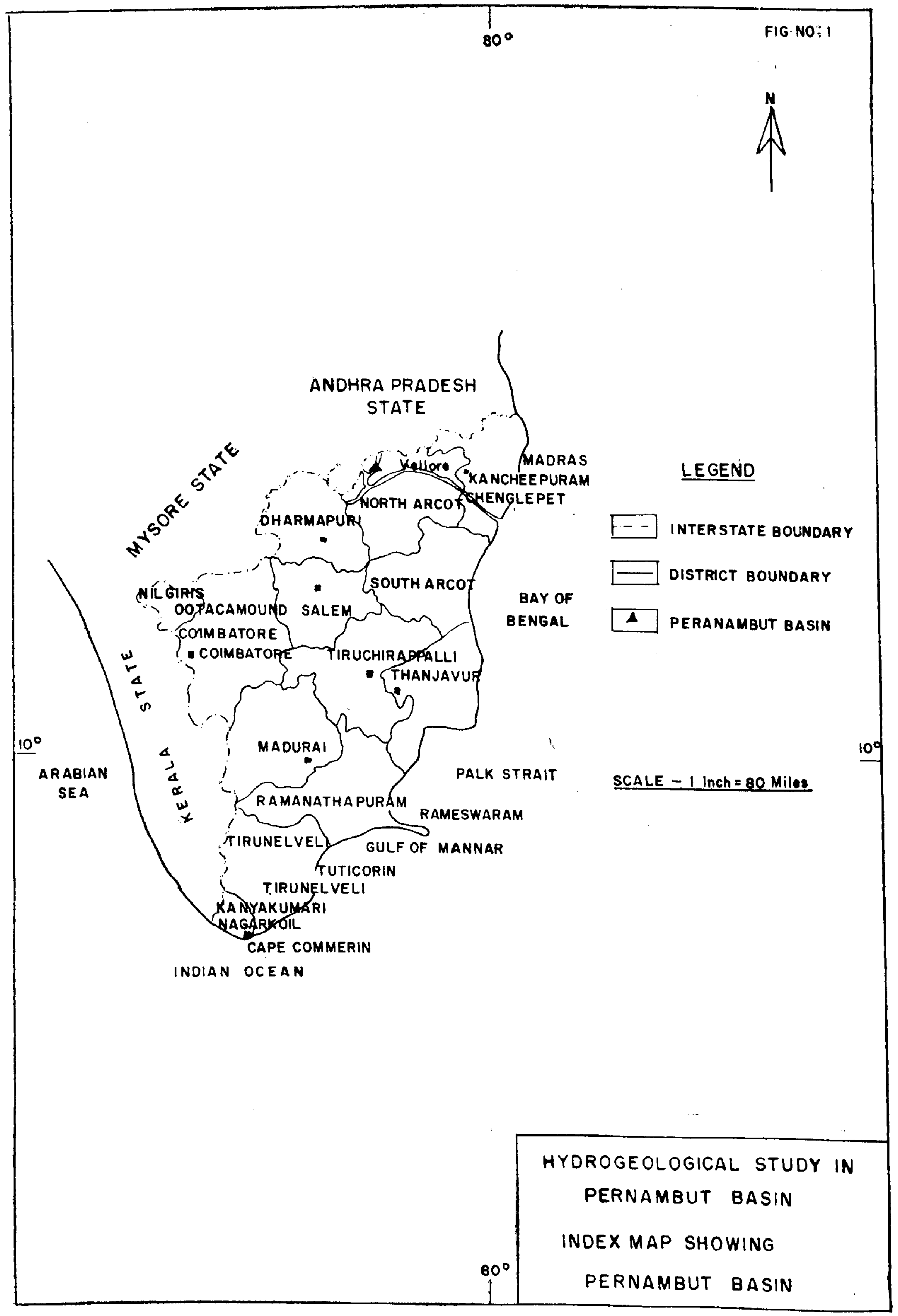
6.2. Recharge from the proposed Bathalapalli Reservoir :

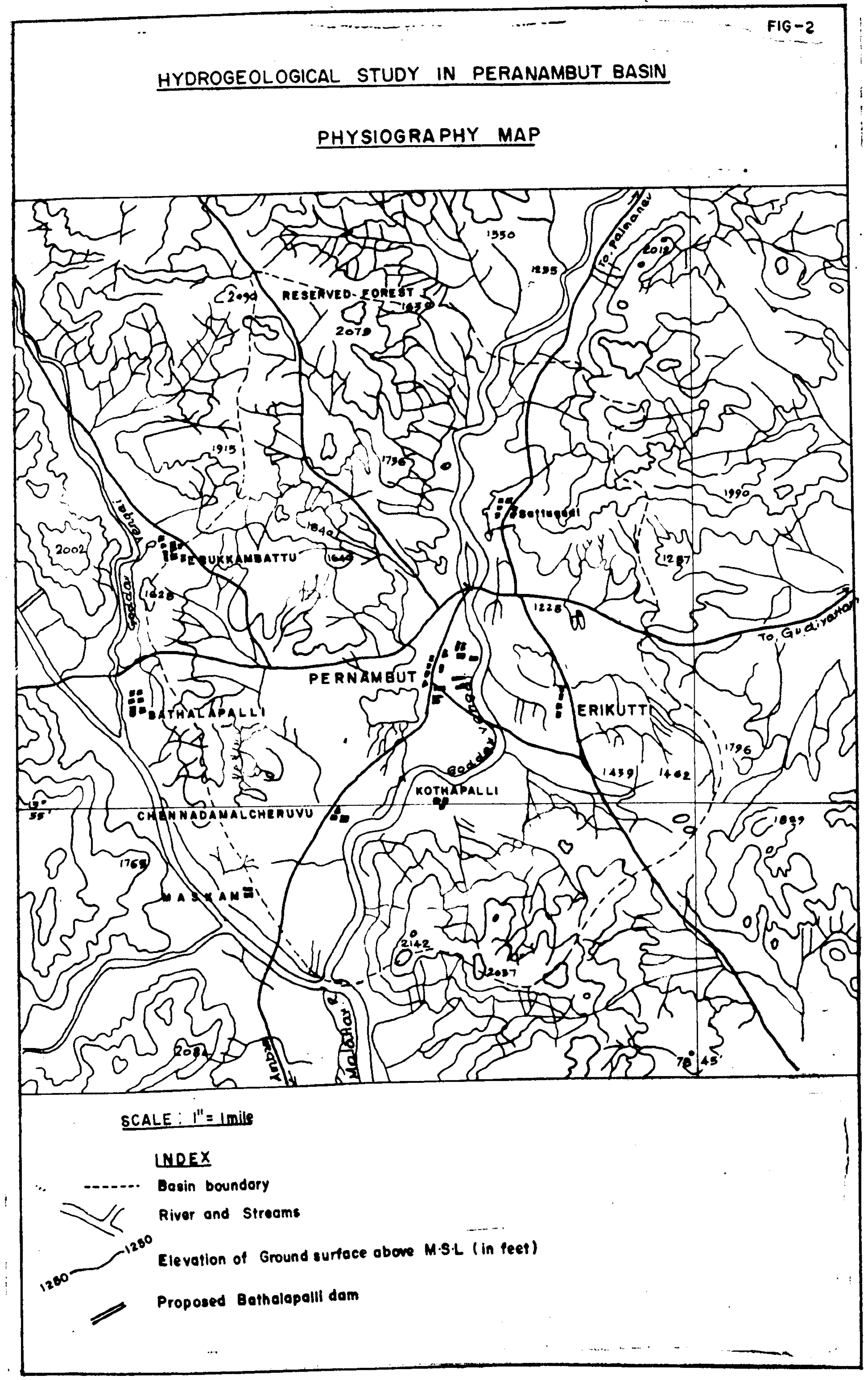
The local people have been pressing for the construction of a reservoir across Malattar near the village of Bathalapalli. The scheme has been partially investigated and is likely to be taken up after obtaining the permission from the Andhra Pradesh Government for some small areas likely to be submerged under this reservoir. When this reservoir comes up, a channel can be brought at an elevation of 1,200 feet above M.S.L. into this basin and either stored in the two obselete tanks or directly fed to wet fields for purposes of flushing the ground and irrigating these fields.

DO YOU KNOW THAT

1. Agricultural produce which includes cereals and vegetables, etc., will be of the order of about 50000 M.T./year for the entire world. Present production of cereals alone is about 1300 M. Tonnes/year.

2. In India maximum production potential is about 4500 M.T/year of Agricultural produce. During 1978 India has produced 125 M.Tonnes of cereals. Even if we add all crops produced the total will be about 500 M.Tonnes.


FIG·NO: 1
80°
N
ANDHRA PRADESH STATE
MYSORE STATE
KERALA STATE
Vellore
MADRAS
KANCHEEPURAM
CHENGLEPET
NORTH ARCOT
DHARMAPURI
NILGIRIS
OOTACAMOUND
SALEM
SOUTH ARCOT
COIMBATORE
COIMBATORE
TIRUCHIRAPPALLI
THANJAVUR
BAY OF BENGAL
MADURAI
PALK STRAIT
RAMANATHAPURAM
RAMESWARAM
TIRUNELVELI
GULF OF MANNAR
TUTICORIN
TIRUNELVELI
KANYAKUMARI
NAGARKOIL
CAPE COMMERIN
INDIAN OCEAN
ARABIAN SEA
10°
10°
60°
LEGEND
INTERSTATE BOUNDARY
DISTRICT BOUNDARY
PERANAMBUT BASIN
SCALE – 1 Inch = 80 Miles
HYDROGEOLOGICAL STUDY IN PERNAMBUT BASIN
INDEX MAP SHOWING PERNAMBUT BASIN


FIG–2
HYDROGEOLOGICAL STUDY IN PERANAMBUT BASIN
PHYSIOGRAPHY MAP
RESERVED FOREST
To Palmaner
To Gudiyattam
PERNAMBUT
BATHALAPALLI
ERIKUTTI
KOTHAPALLI
CHENNADAMALCHERUVU
MASKAM
1550
1295
2018
2079
1915
1756
1990
2002
1228
1287
1796
1439
1462
1768
2142
2084
78° 45'
SCALE : 1" = 1mile
INDEX
Basin boundary
River and Streams
Elevation of Ground surface above M·S·L (in feet)
1250
1250
Proposed Bathalapalli dam

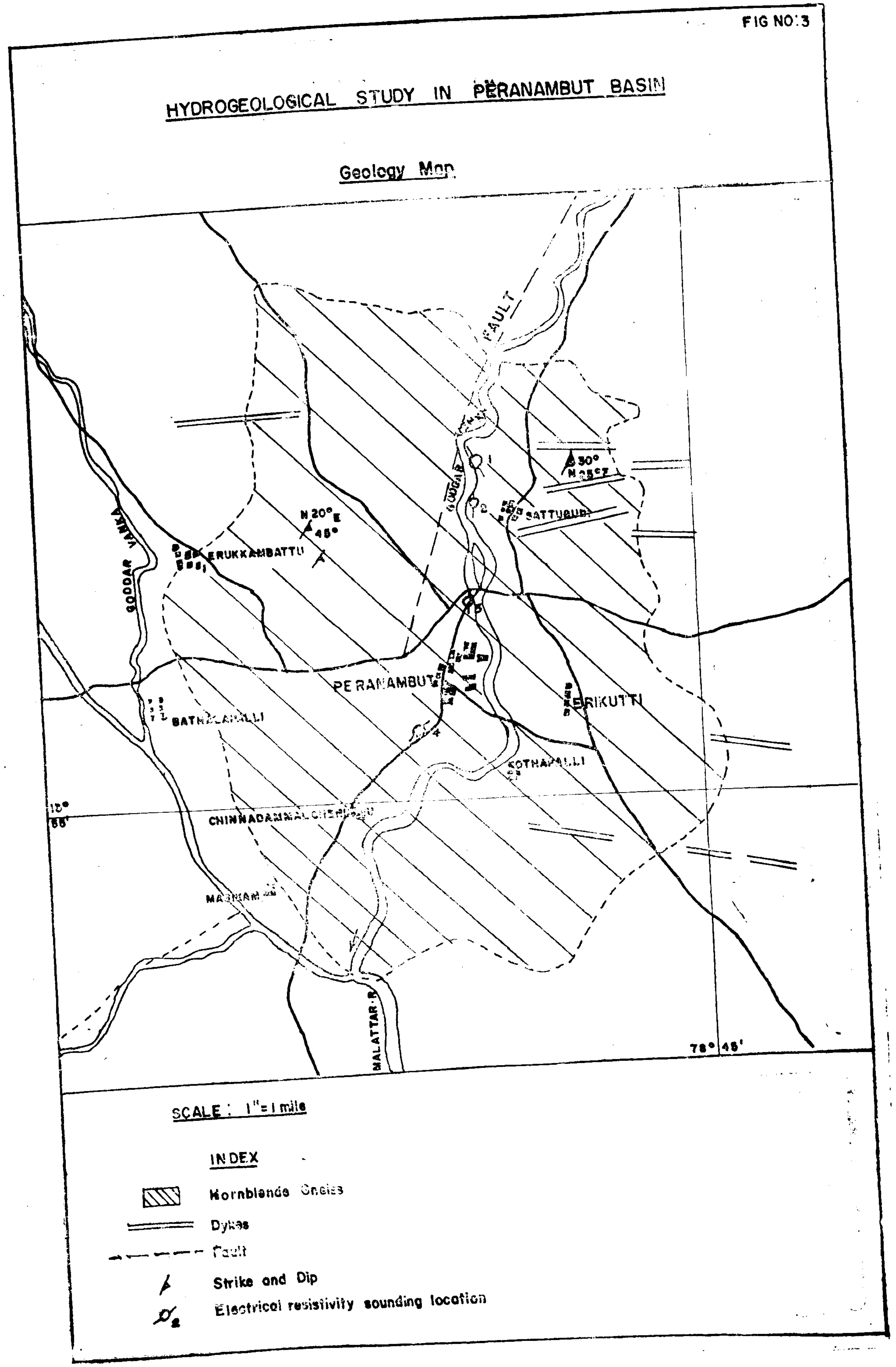


FIG NO: 3
HYDROGEOLOGICAL STUDY IN PERANAMBUT BASIN
Geology Map
FAULT
GODDAR
SATTUGUDI
N 20° E
45°
GODDAR VANKA
ERUKKAMBATTU
PERANAMBUT
ERIKUTTI
BATHALAPALLI
KOTHAPALLI
CHINNADAMMALCHERUVU
MASIKAM
MALATTAR R.
78° 45'
SCALE : 1" = 1 mile
INDEX
Hornblende Gneiss
Dykes
Fault
Strike and Dip
Electrical resistivity sounding location

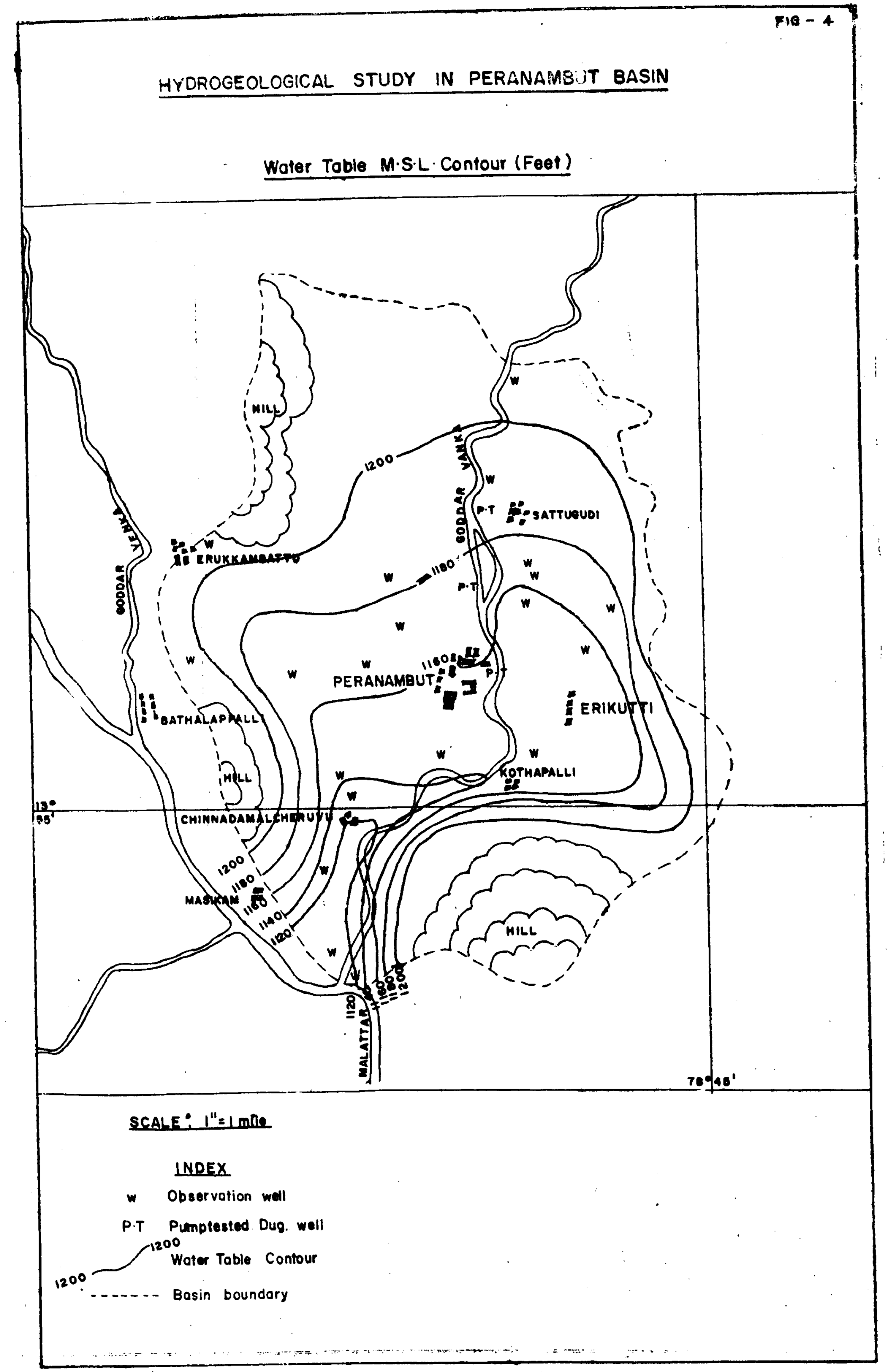


FIG - 4
HYDROGEOLOGICAL STUDY IN PERANAMBUT BASIN
Water Table M·S·L· Contour (Feet)
HILL
GODDAR VANKA
SATTUGUDI
ERUKKAMBATTU
1200
1180
1160
PERANAMBUT
ERIKUTTI
BATHALAPALLI
KOTHAPALLI
CHINNADAMALCHERUVU
MASIKAM
1140
1120
MALATTAR
78° 45'
SCALE : 1" = 1 mile
INDEX
w Observation well
P·T Pumptested Dug. well
Water Table Contour
Basin boundary

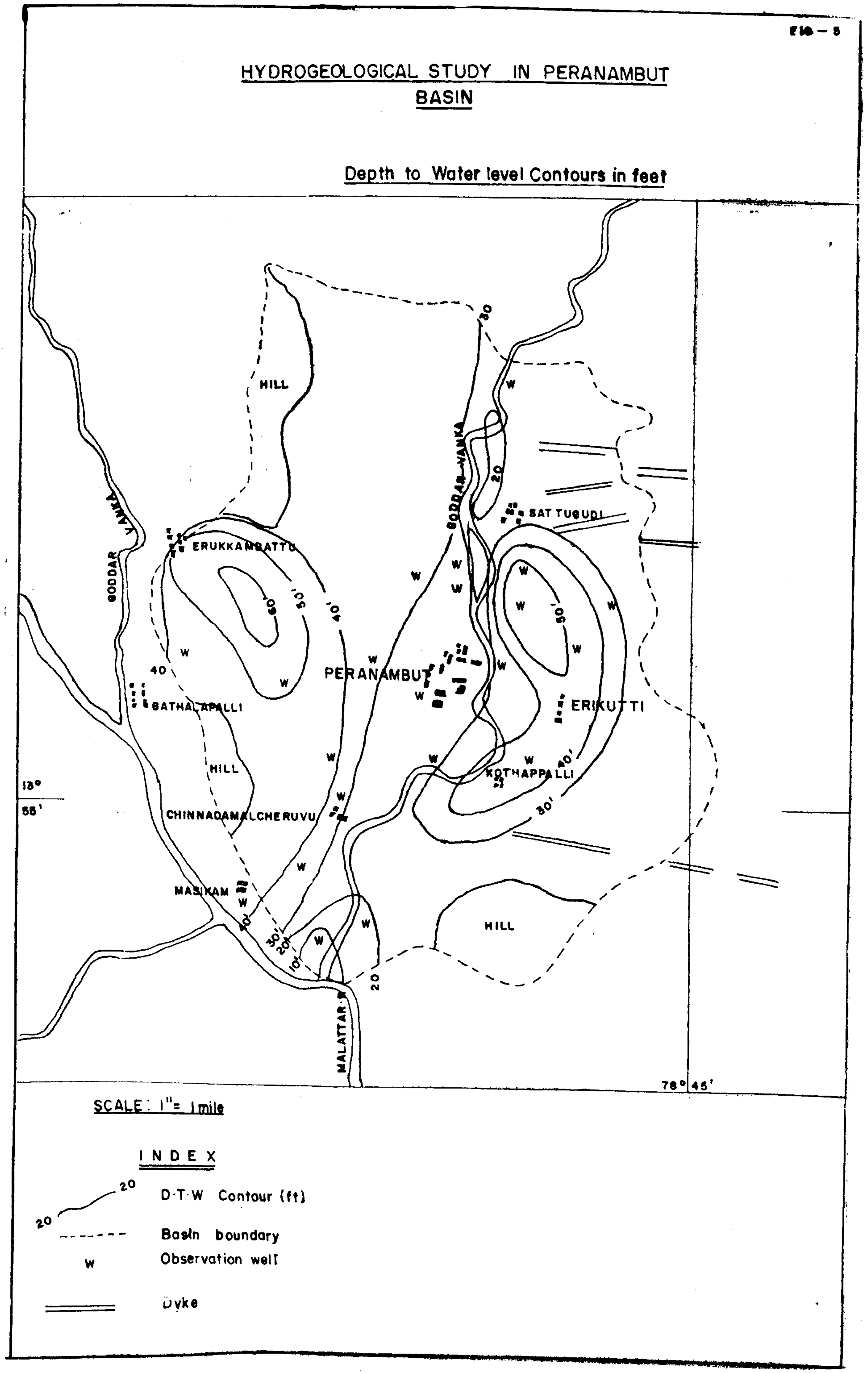


FIG-5
HYDROGEOLOGICAL STUDY IN PERANAMBUT BASIN
Depth to Water level Contours in feet
HILL
GODDAR VANKA
ERUKKAMBATTU
PERANAMBUT
SATTUGUDI
ERIKUTTI
BATHALAPALLI
HILL
CHINNADAMALCHERUVU
KOTHAPPALLI
MASIKAM
HILL
MALATTAR
13°
55'
78° 45'
SCALE: 1"= 1mile
INDEX
D·T·W Contour (ft)
Basin boundary
Observation well
Dyke

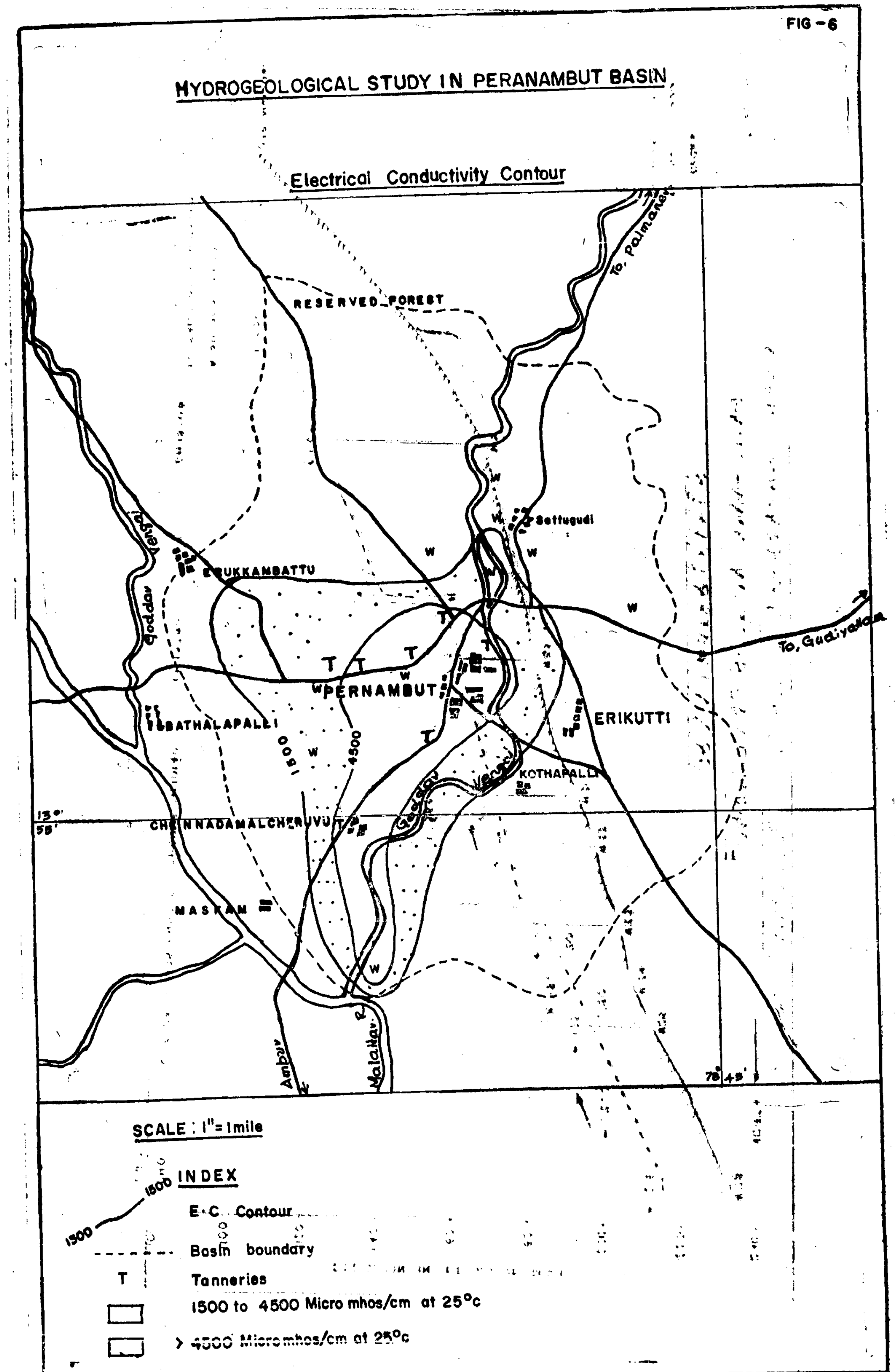


FIG-6
HYDROGEOLOGICAL STUDY IN PERANAMBUT BASIN
Electrical Conductivity Contour
RESERVED FOREST
To, Palmaner
Sattugudi
ERUKKAMBATTU
PERNAMBUT
ERIKUTTI
To, Gudiyatam
BATHALAPALLI
KOTHAPALLI
CHINNADAMALCHERUVU
MASIKAM
Ambur
Malattar R
13°
55'
78° 45'
SCALE: 1"=1mile
INDEX
E·C Contour
Basin boundary
Tanneries
1500 to 4500 Micro mhos/cm at 25°c
> 4500 Micromhos/cm at 25°c

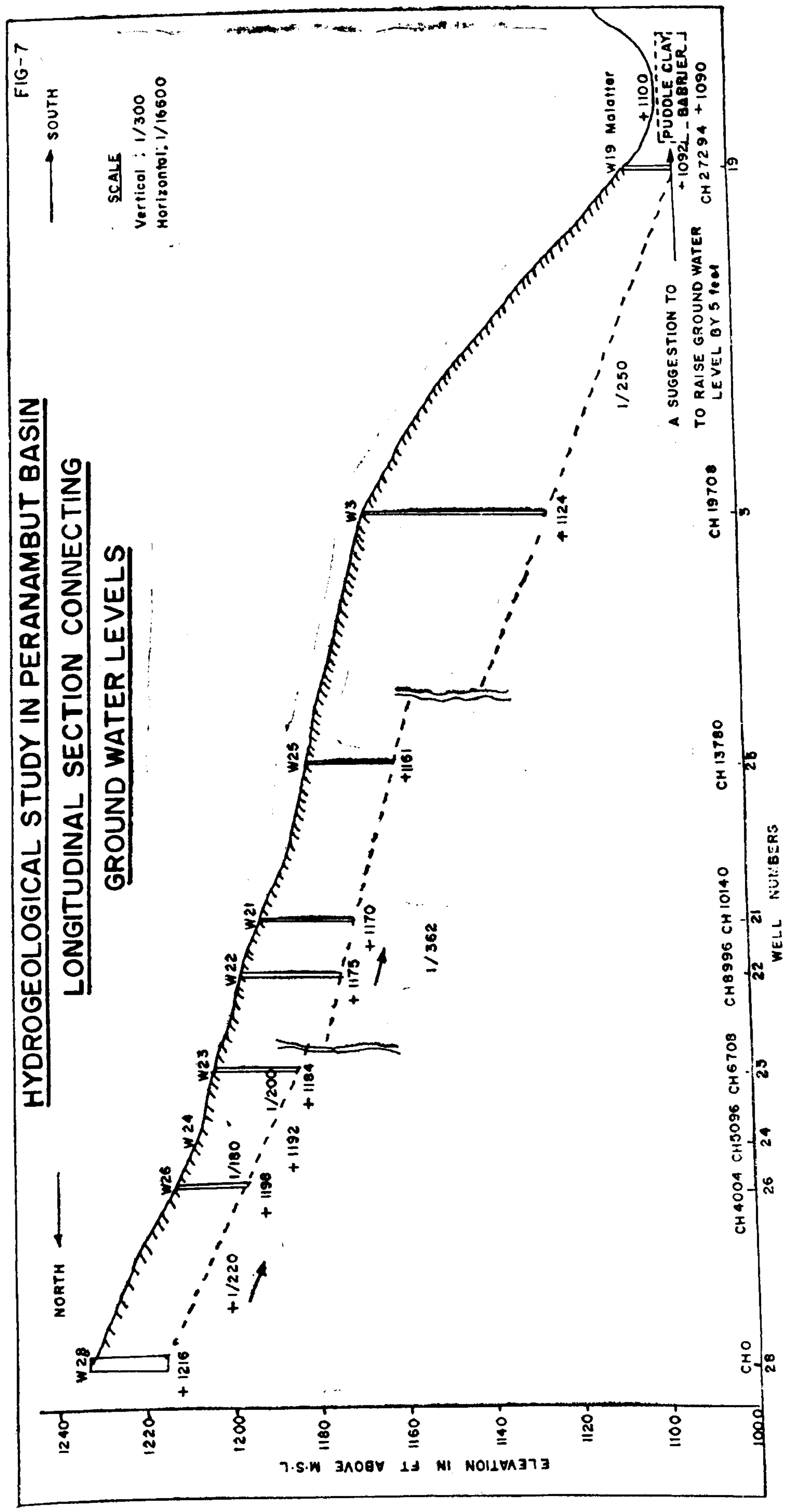
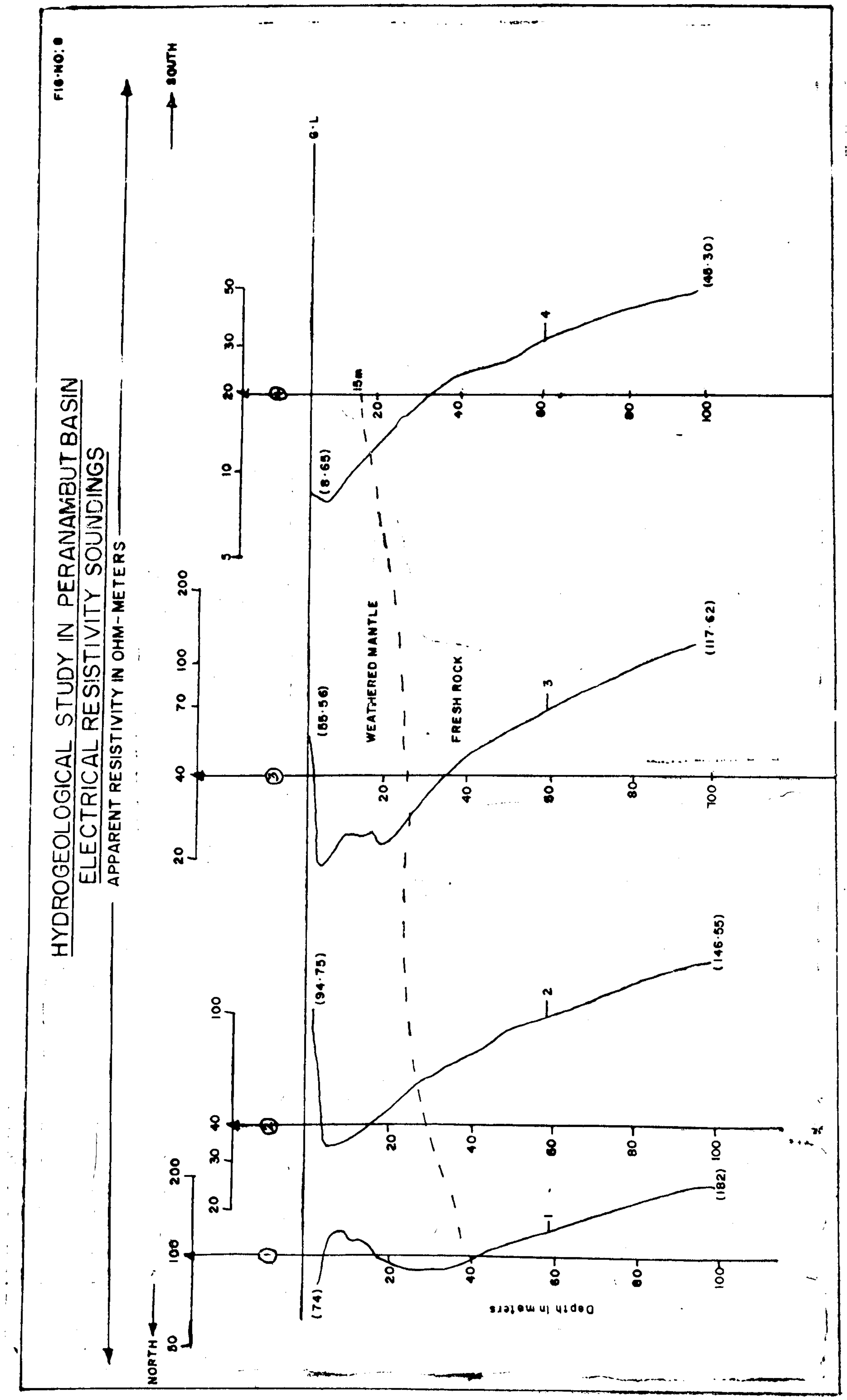


FIG-7
HYDROGEOLOGICAL STUDY IN PERANAMBUT BASIN
LONGITUDINAL SECTION CONNECTING
GROUND WATER LEVELS
SCALE
Vertical : 1/300
Horizontal: 1/16600
SOUTH
NORTH
A SUGGESTION TO
TO RAISE GROUND WATER
LEVEL BY 5 feet
PUDDLE CLAY
BARRIER
W19 Malatter
ELEVATION IN FT ABOVE M.S.L
WELL NUMBERS


FIG·NO: 8
HYDROGEOLOGICAL STUDY IN PERANAMBUT BASIN
ELECTRICAL RESISTIVITY SOUNDINGS
APPARENT RESISTIVITY IN OHM-METERS
NORTH
SOUTH
G.L
WEATHERED MANTLE
FRESH ROCK
Depth in meters

TREATMENT FOR SEEPAGE THROUGH AN EARTH BUND OF A MAJOR TANK

By

Er. C. F. MARTINS, B.E. *

In Tamil Nadu there are various irrigation works which were executed several years back on norms and standards prevalent during those days. In course of years, due to constant usage and deterioration in materials, want of maintenance due to financial stringency and depradation caused by local inhabitants, etc., these works have reached a critical or dangerous stage of stability. These works can be classified into various categories like regulators, diversion weirs, masonry weirs, storage tanks with earth bunds, etc. In this article, it is proposed for the information and knowledge of departmental engineers especially in Tamil Nadu the case of a major tank bund through which seepage was taking place even from a high level with reference to the water level in the tank. The salient particulars of this tank are given below :

Water spread area	118.55 sq. miles
Catchment area—free	7.1 sq. miles
Combined	17.83 sq. miles
Maximum flood discharge ..	3,220 cusecs
Length of earth bund	7,390 m
Maximum height of earth bund.	8.61 metres
Ayacut area	5,436 acres.

In the earth bund of this tank, it was found that when there was water in the tank, seepage was taking place through the bund with hardly any loss of hydraulic gradient and the seepage was of a heavy nature causing panic among the local officers and the inhabitants. It was also observed that though gravelly soil with sand bags were dumped in the rear slope to arrest the seepage, even this could not with stand the seepage and both the gravel and the sand bags were washed away. It was an alarming situation and would have been serious if the water level in the tank had risen further. Immediate investigation was taken up to study the cause of such seepage and propose necessary treatment for the same.

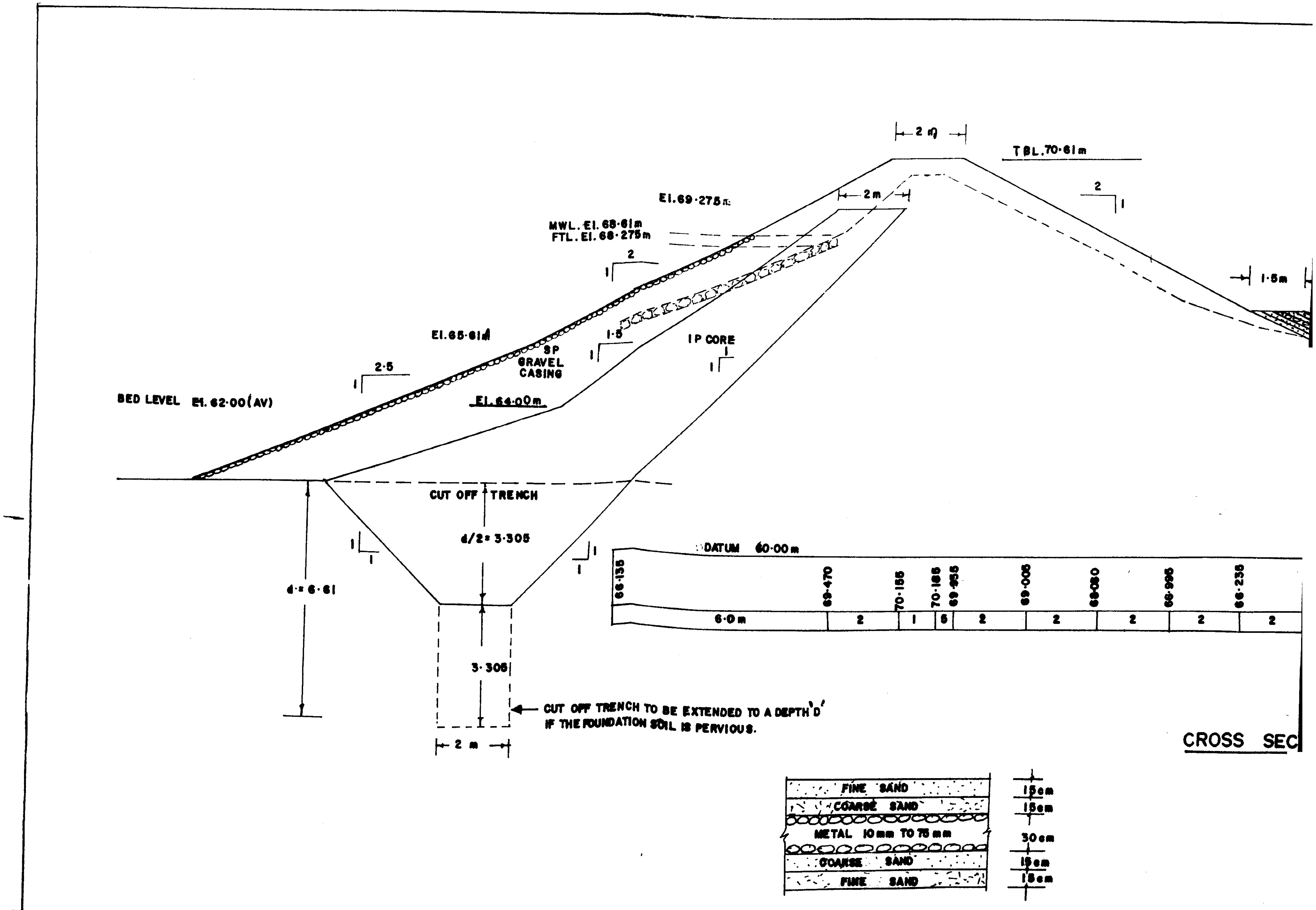
It was understood that this seepage was taking place since some years back and it has gradually increased to an alarming proportion now. Soil samples were taken of the bund even below foundation level. (Soil samples could not be taken then in the tank at the toe of the bund as there was water. It is proposed to take these samples later and analyse the soils.) It was found that in the bund itself, the soil is of a sandy nature and the percentage of sand content is ranging from 20 to 84%. It was concluded therefore, that during the course of several years, the fines in the bund have slowly got washed away and now only coarse sandy soil alone is left behind. This bund seems to be of homogeneous nature without a clayey core in the hearting section and an impervious cut-off trench in foundation. Water was seeping through the bund at all levels practically from a few feet below the

water level in the reservoir right down to the ground level on the downstream side. It was dangerous to leave this dam in that stage and immediate remedial measures were proposed.

Remedial measures (*a*) Method of treatment:

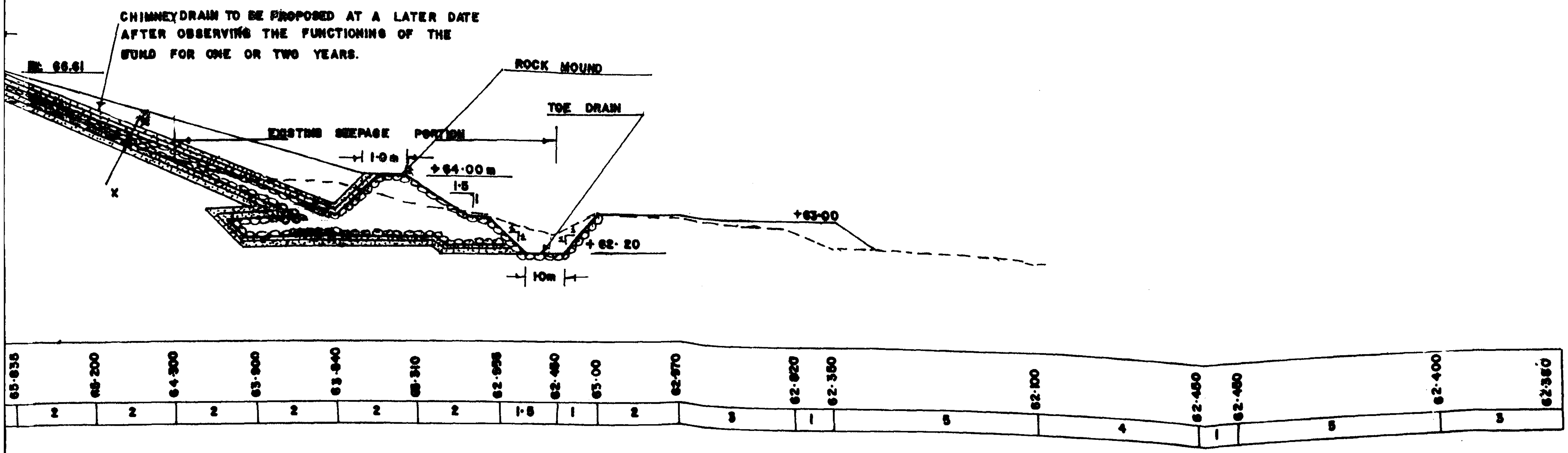
As it was not possible to reconstruct the whole bund as a zoned embankment and provide a cut-off trench to a depth equal to the height of the water as the foundation soil was sandy which would mean constructing a new reservoir its lf. Therefore, it was decided to do the minimum work which will ensure satisfactory solution to the problem. Therefore, a clayey core was proposed in front side of the earth dam with minimum trimming of the existing slope of the earth dam. The existing earth bund has revetment in front with jeddy stones which has to be dismantled in the first instance. After trimming the front surface to the required slope the clay core 2 M *wide* at F.T.L. and with $1\frac{1}{2} : 1$ slope has to be formed up to ground level with a cut off trench as shown in the Fig. enclosed, to be provided in front. The clayey material to be used in this core should be impervious in which a clay content more than 25% up to 45% should be available. The cut-off trench should be provided for a maximum depth D/2, if a good soil is met with at that depth or to go upto a depth D where D is the depth of water above ground level. This cut-off trench was suggested as it will be costly to provide a clay blanket extending to 10 to 12 times the depth of water and for the minimum thickness of 1 metre. Over this clay core, it was proposed to provide casing soil of minimum thickness 1 metre at top with 2 : 1 slope for the front to ensure required stability. Adding this, extra zones in front will give protection to the earth dam, as this will prevent seepage of water through the earth dam in future. The dismantled revetment stones will be reused again to provide revetment in front on the new casing soil layer now proposed. On the downstream side, it was proposed to provide a zoned horizontal filter with a rock toe and

* Retired Superintending Engineer, P.W.D., Tamil Nadu.



SECTION XX

SCALE 1 : 30



TION AT L.S. 5770

SCALE 1:100

INDEX

- - - - EXISTING PROFILE.

—— IMPROVEMENTS PROPOSED.

13/11/78

SUPERINTENDING ENGINEER, PWD,
DESIGNS CIRCLE,
MADRAS-5.

TREAT MENT FOR SEEPASE
THROUGH EARTH DAM

toe drain. This toe drain will be graded in such a way so that it will discharge into the existing culverts in the road easily. Because of the panchayat road going parallel to the toe of the bund, it was not possible to provide a bigger filter. Casing soil will be dumped in the rear slope of the dam to cover up the filter up to the rock toe as shown in the figure enclosed. Gravel is proposed to be used for the casing from the stability consideration and gravelly soil is available in plenty locally. This is the minimum treatment proposed now in order to keep the cost down as this will meet the requirements. It will be better if a Chimney drain is provided as marked in the drawing to take care of the possible seepage coming at higher level. But in order to keep the cost down for the present, this Chimney drain will be proposed at a later date after observing the functioning of the bund for one or two years. The section of the bund has been analysed for stability both upstream and downstream and the factor of safety obtained, i.e., 1.89 and 2.96. The parametres adopted for the analysis based on the soil particulars for the existing soil in the bund, proposed hearting soil and casing soil are given below *vide* statment enclosed.

Filter :

In the existing structure no filter has been provided. Therefore, it will be difficult to provide a filter as is normally done in an earth dam. To reduce cost, it is proposed to provide a minimum filter both horizontal and inclined to the extent possible without having the necessity to dismantle too much of the existing bund. The details of filter provided is shown in the figure enclosed.

The following specification is to be adopted for the zoned filter.

The material of the filter is screened sand and gravel of suitable size satisfying the following :—

1. $\dfrac{D_{15} \text{ of filter material}}{D_{15} \text{ of material to be drained}}$ 4

2. $\dfrac{D_{15} \text{ of filter material}}{D_{85} \text{ of base material to be drained.}}$ 4

The author wants to acknowledge the help given by the staff of the Designs Circle in preparing the drawings and detailed designs for this work.

STATEMENT.

SOIL PARAMETERS.

Type of soil.	*Submerged density kg./m3.*	*Dry density kg./m3.*	*Saturated density kg./m3.*	*Moist density kg./m3.*	*Cohesive stength kg./m3.*	*Specific gravity.*	*Angle of internal friction.*	*Moisture content.*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Gravel	1,261	2,016	2,261	2,298	2,012	2.67	23	14%
Existing bund material ..	1,210	1,961	2,210	2,196	2,693	2.61	25	12%
Hearting soil	1,064	1,797	2,064	2,120	3,355	2.45	17	18%

DESIGN OF EARTH DAM OVER ROCKY FOUNDATION AT DIFFERENT ELEVATION

By

*Thiru C. F. Martis, B.E.**

Generally earth dams are constructed where rock is not available and only earth is met with for considerable depth. Construction of an earth dam is comparatively found to be much cheaper than a masonry dam as generally earth of good quality is available in sufficient quantity within economical leads. But in certain cases where rock is met with at surface of even at lower levels within depth D where D is the height of water at that chainage, additional precautions will have to be taken for the construction of earth dams in such conditions, if construction of masonry non-spillway dams become very costly.

Case 1 :

Where rock is met with at the surface.

In such a case the top weathered surface has to be removed for the entire width of the dam and the earth dam can be constructed on the rocky surface. But care should be taken to consolidate the earth properly so that no space is left, between the rock and the earth. For this all sharp edges and pointed surfaces to be smoothened. For the cut-off trench, the hard rock should be depressed in the form of a dish as shown in the sketch (Fig. 1). A masonry or concrete cut-off may be provided if necessary. But grouting should be done in the cut-off trench for more than depth D where D is the depth of water at the section. Though effective grouting along the cut-off trench may suffice to provide an impermeable barrier against seepage but in course of time this may get destroyed slowly and therefore it is better to grout the whole base of the dam to provide ample safety.

Where the rock level met with is below ground level but less than the depth of cut-off trench proposed, same design for foundation can be adopted. The cut-off trench can be provided upto the rock level and this can be keyed into the rock properly. But if the soil between the rock level and the ground level is either sandy or fatty clay, then additional precautions to be taken from the point of view of stability of dam or seepage condition. In this case additional precautions to be taken are as follows :—

(*a*) *For the sandy soil* :

The cut-off trench section can be made larger to prevent the water to penetrate through the same and this cut-off trench should be properly keyed into the rock. To prevent the sand from escaping from the foundation a filter in the rear and revetment with gravel backing in front to prevent the sand slipping under the foundation into the toe drain. A filter for the toe drain may also be provided.

(*b*) *For clayey soil* :

Stability has to be checked by drawing the slip circle through the foundation. If the soil is of light type there is a possibility of settlement of dam and the soil below being forced out by the over burden.

The base of the bund may have to be widened or if necessary soil may have to be stabilised by grouting methods, viz., lime, fly ash, sand, etc.

Case 2 : Where rock is met just below cut-off trench :

The depth of cut-off trench is decided on the type of soil available in foundation. If the type of soil is pervious and no rock is met with the cut-off trench has to be taken to a depth D where D is the depth of water. In such a case clay blanket is provided upstream as per design consideration. The clay blanket provided should be sufficient to reduce the exit gradient of the seepage of water within safer limits. Very often, the clay blanket is a very costly work especially when the dam is a long one and some capacity of the reservoir is also lost thereby. If good clay is also not available within reasonable lead, a comparative of the cost can be made with an alternate type of design explained below.

The proposal is to have a masonry core of minimum thickness over the rocky bed with earth backing in both sides (*Vide* Fig. 2). The earth need not be of any special specifications. The earth excavated from foundation including rock or boulders can be utilised to give sufficient backing on both faces. Only fatty clay or any organic matter has to be avoided. If sand is used, sufficient precautions is to be taken to contain the sand without slipping. This method can be adopted where rocky strata is met with at any level from the surface upto depth D where D is the depth of water provided that stone and sand required are available at reasonable rates.

By utilising the excavated earth great economy can be effected and special consolidation is also not necessary for this work. If any rocky soil or rock is available from excavation this can be used advantageously for providing riprap upstream or more usefully dumped in the rear. If by chance the earth gets washed out by rain, fresh earth can easily be dumped to make up the deficiency. It will be better during construction to utilise the stoney earth and hard rock available to dump in the rear of the masonry core as that will give stability even if the earth in front is erroded to some extent. Further, the angle of internal friction for rocky type of soils and rock is more than ordinary soils and therefore the core wall will be more safe for these soils. The earth slope for the casing soil can also be made more steeper than in the conventional earth dam.

This type of construction will be more suitable where foundation rock is sloping both longitudinally as well as on both sides of the centre line (*vide* figure Nos. 3 and 4). Hence in the conventional earth dam as the earth slope required is flatter, the base of the earth dam gets increased and the dam has to be provided with a rock toe as shown in figure No. 3. For the conventional earth dam a rock toe may be necessary at both the front and rear toe to

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prevent the earth slipping. But with a masonry core and rocky earth dumped in both sides, this rock toe will not be necessary.

In figure 4—a composite section using excavated earth explained above is shown. The design criteria to be adopted for this type is as follows: —

(1) Stability of the core and earth section to be calculated for saturated earth pressure when the reservoir is F.R.L.

(2) Same as above when 25% of the earth in the rear has been washed away by rains. It is enough if 50% only is taken rocky type of soils and boulders are proposed to be as dumped in the rear. This type of soil has greater angle of internal friction.

(3) When the reservoir is empty stability of the core wall to be calculated from the pressure of the saturated earth (by rain) to be taken into account with only 75% of the earth ailable in front.

Advantages :

(1) The filter and rock toe can be completely omitted.

(2) Excavation of cut-off trench and refilling with good soil is saved. Nominal masonry core wall that will be provided for a conventional earth dam over a rocky bed will be redundant.

(3) Front rip rap or revetment may not be necessary if stoney earth is dumped in front.

NOTE.—In the figures, the slope provided is only tentative, actual design have to be made for the earth dam section. The top width of earth dam to be decided either from functional requirement or stability consideration. Detailed design particulars are not furnished as these are well known to Civil Engineers. The correct choice for the type of section to be adopted depends mainly on cost consideration, other considerations also may have a play in this choice.

The author acknowledges with gratitude the help given by the staff of Design Circle in preparing the detailed drawings, etc.

DO YOU KNOW ?

THAT lake Mead, in back of Hoover Dam, largest man made lake in the World, contains enough water to cover the entire State of New York to a depth of 1 foot?

THAT Hoover Dam contains enough concrete to form a monument one city block square which would tower above the Empire State Building (1,248 feet) in New York City?

THAT the three highest concrete dams in the world were built by the Bureau of Reclamation? They are Hoover, Azizona-Nevada (726'-0"), Shasta, Calif (602 feet) and Grand Coulee, Wash (550'-0").

THAT the Hungry Horse Dam got its name from two Horses who were lost and were almost starv.d to death during winter of 1900-1901?

THAT water fall plunging over the Grand Coulee Dam spill way at the peak of the years flow is the second largest waterfall in the world, when compared on the basis of horse power?

Compiled by the Editor.

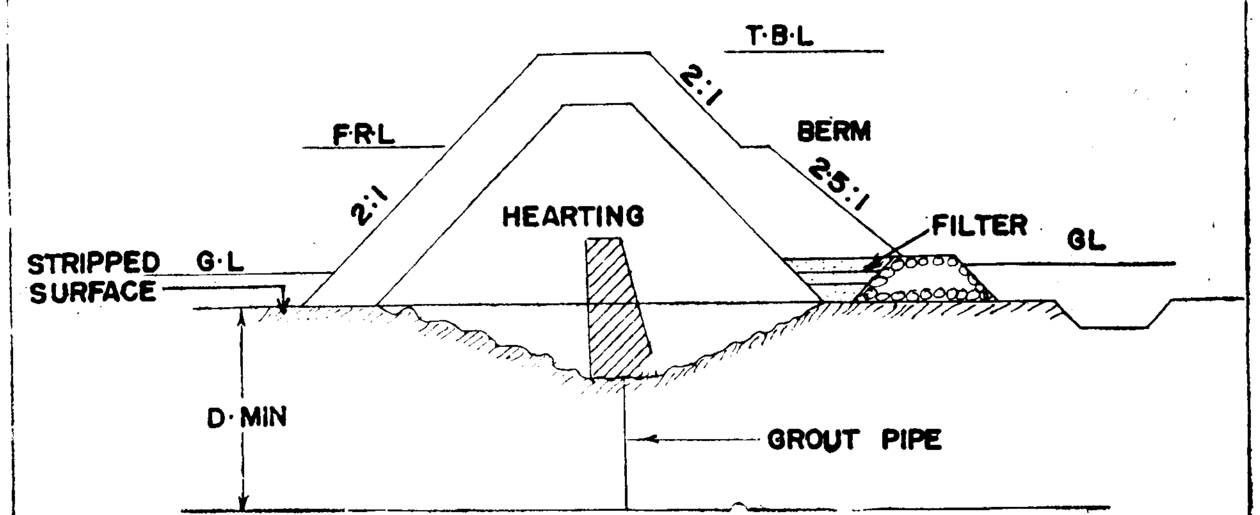


FIG. 1

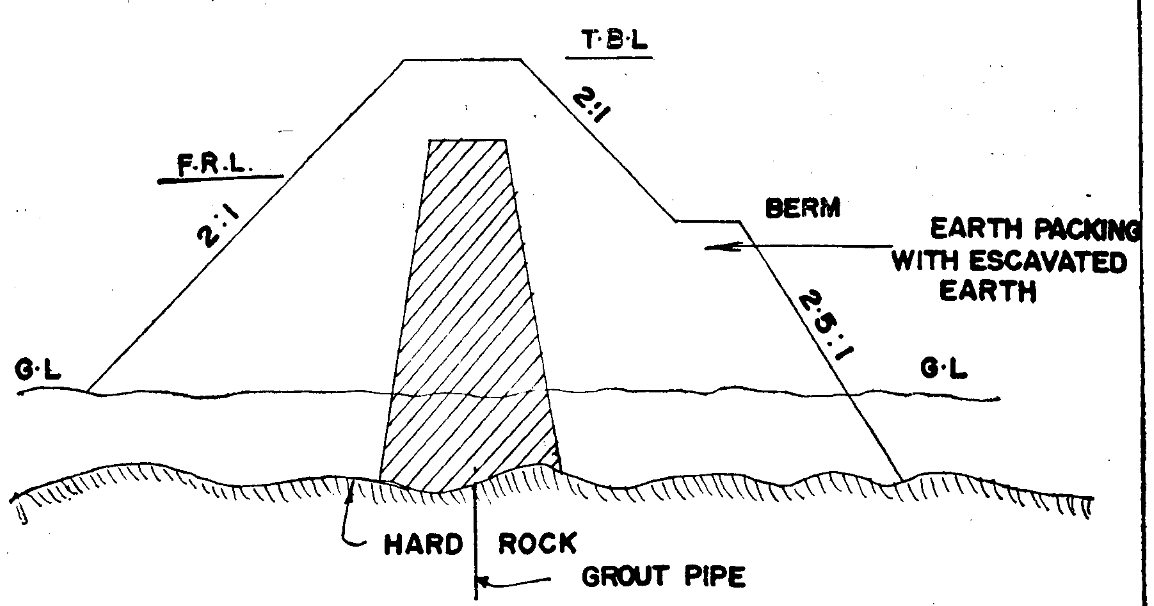
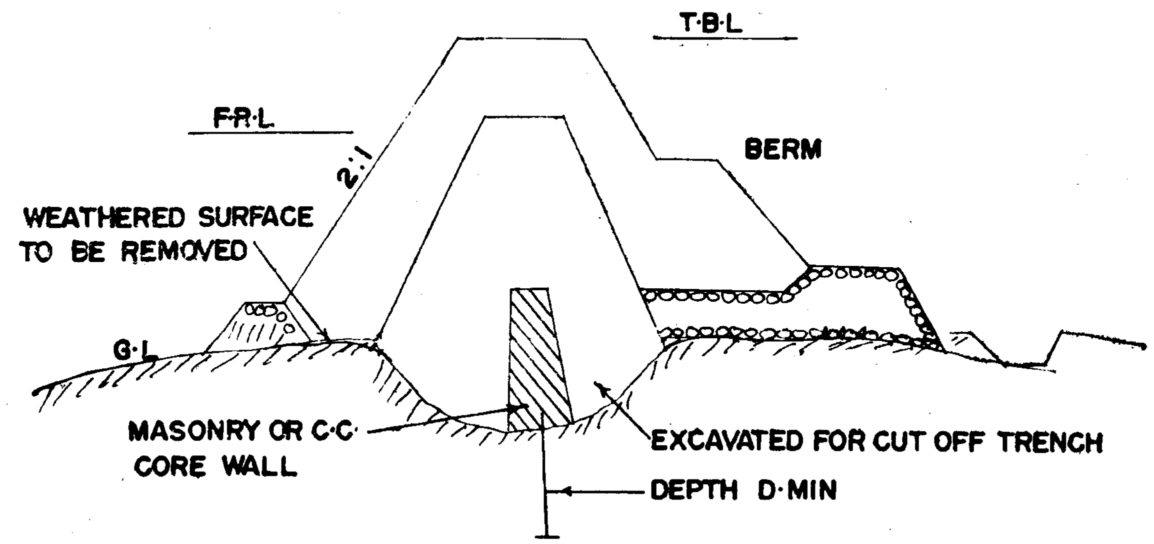
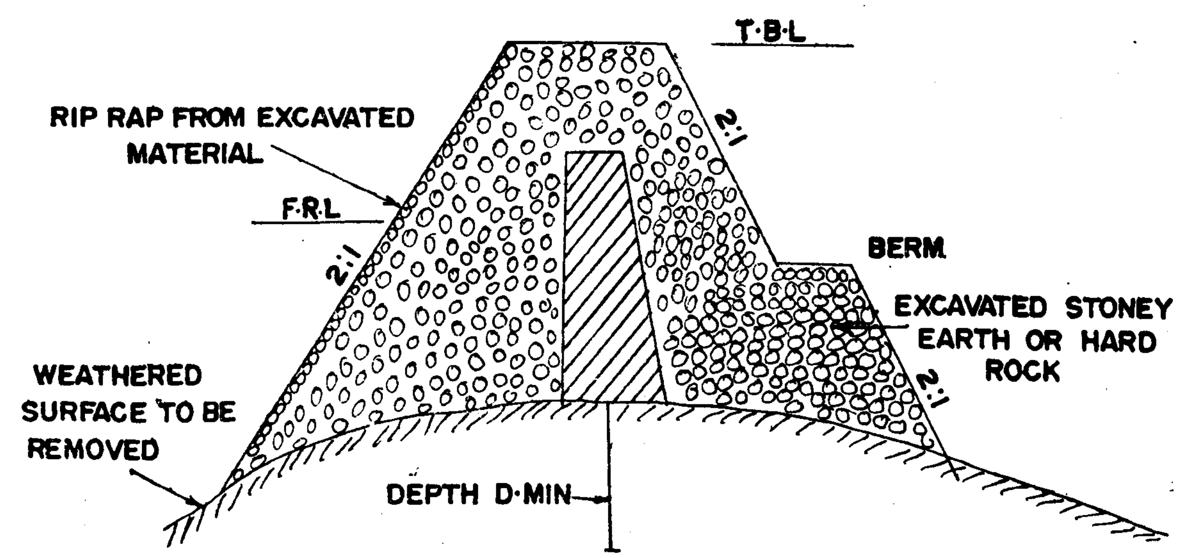


FIG: 2



EARTH DAM ON ROCKY SLOPING SURFACE

FIG: 3



COMPOSITE DAM ON SLOPING ROCKY SURFACE USING EXCAVATED EARTH

FIG: 4

FORMING R.C.C. CUT OFF FOR WEIRS AND BARRAGES

BY BENTONITE PROCESS USING A GANG DRILL.

By.

*ER. C. G. JEYARAMAN, B.E., M.I.E.

AND

*ER. V. V. RAMACHANDRAN, B.E.

1. Introduction:

1.1. Construction of weirs and barrages across rivers having permeable foundations involves the formation of deep cut off walls of concrete. In the construction of the barrage across Cauvery at Upper Anicut and in the reconstruction of Thirukkoilur Anicut across the River Ponniar, cut off walls of depth ranging in depth 3.5 M to 5 M. had to be formed. The beds of these rivers were of coarse sand and with high water table even during the dry summer months. The cut off walls were of cement concrete of mix 1:2:4, 0.60 M. thick provided with nominal reinforcements on both faces. The formation of such a R.C.C. diaphragm cut off is made easier and quicker by the adoption of the Bentonite process. The process requires a drilling machine to drill the trench and simultaneously fill it with Bentonite slurry to occupy the drilled space. An ordinary power drill can be suitably adopted for the purpose. But a gang drill which can simultaneously drill four holes adjacent to each other will make the process much simpler and quicker.

2. The Conventional Method:

2.1. Open excavation of the trench for laying the concrete for the cut off wall was found to be very difficult both due to the instability of the sides inspite of the flat slopes adopted and the heavy seepage of water. Even after engaging a large number of pumps, it was very difficult to dewater the trench and keep it in a dry condition for placing the concrete. Apart from the difficulties caused by the unstable side slopes of the trench, elaborate and costly shuttering arrangements had to be made for the placing of concrete.

3. The New Method.

3.1. The above difficulties were overcome both in the Cauvery Barrage Work and the Thirukkoilur Anicut Works by adopting the Bentonite process for forming the concrete cut off. The process involves drilling a trench of 0.60 M. width and filling it with bentonite slurry. The bentonite slurry occupies the space of the drilled trench and prevents the sides from collapsing. The grill is lowered in position and concrete is placed by "Tremie" process through steel pipes. The bentonite slurry which is replaced by the concrete rises up to the surface which is collected and reused. Thus the problems of heavy dewatering, slipping of the sides of excavation, etc., were solved.

4. The Machine and its Description :

4.1. Any power drill with a rotary cutter of 0.60 M diameter can be adopted for this purpose. The work will involve drilling a series of holes of 0.60 M diameter closely spaced and overlapping each other resulting in a long trench of 0.60 M. width. However a gang drill was specially manufactured to order by VAK ENGINEERING COMPANY, MADRAS and used in Thirukkoilur Anicut. This drill is suitable for the formation of cut-off trench of 0.60 M. width up to a depth of 6 M. This machine can drill 4 closely spaced bores 0.60 M diameter up to 6 M depth to form a trench of 0.60 M. width and 2.5 M long. It is designed for working in alluvial and sandy soils.

4.2. The machine consists of four rotary tables four water swivels, and four Kelleys powered by Leyland Diesel Engine of 84 H.P. capacity. All the four rotary cutters are connected to the common mast and work simultaneously. The frame of the machine is made of sturdy structural steel suitably braced and electrically welded. The machine is mounted on pneumatic tyred wheels for transporting from place to place. The machine consists of four heavy duty rotaries with gearbox capable of handling 3½" square kelly. This is powered by the engine through 'V' belt and chain drives. Each rotary is provided with a dog clutch for disconnecting the drive. There is also a master dog clutch which disconnects all the four rotaries simultaneously. The prime mover is an ALU 370 Leyland Diesel Engine of 84 H.P. The mud header pipe is mounted on to the main frame by clamps. It is provided with two inlet connections for feeding the Bentonite solution into the four water swivels. Isolating valves in the mud header are also provided to regulate the flow of Bentonite solution into the water swivels. The water swivels are 1½" diameter bail type swivels provided with heavy duty thrust bearings. The water swivel combination bracket is fabricated out of heavy structural steel suitably braced. The water swivels are mounted on this through pins. There is also provision for disconnecting the water swivel in case one bit strikes rock. A heavy duty winch with drums on either end and mounted on heavy duty bush bearings is provided for raising and lowering the derrick and also to hoist and lower the water swivel bracket while drilling.

4.3. All the controls like starting buttons, engine, clutch, master clutch for all the four rotaries, brake for winch, etc., are grouped together on the right side of the machine so as to be easily accessible to the operator. Figure 1 shows the various parts of the drill.

4.4. **Method of operation.**—For operation at site, the tyred wheels have to be removed and the drill dismantled. The drill will have to be reassembled and mounted on cast iron table provided with wheels which can travel over 70 lb. rails. The rails are laid for about 100' length over country wood sleepers, and fixed in position by

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dog spikes. The gauge of the Mail should be 116 inches. As the pneumatic tyred wheels cannot withstand vibration of the drilling operations, mounting on rails is necessary. Movement over rails is also helpful for ensuring perfect alignment of the cut off trench. The rail line for the movement of the drill will be fixed over country wood sleepers spaced at 3'0" intervals using iron spikes. The sleepers will not be continuous under both the rails. Separate sleepers will be provided for each rail on either side of the trench. The line of four cutters will be along the centre line of cut off. The whole table with wheels having drill assembly is lowered on the rails by jack. The wheels of the drill are locked by key bar to prevent movement of the drill while drilling.

5. The Process.

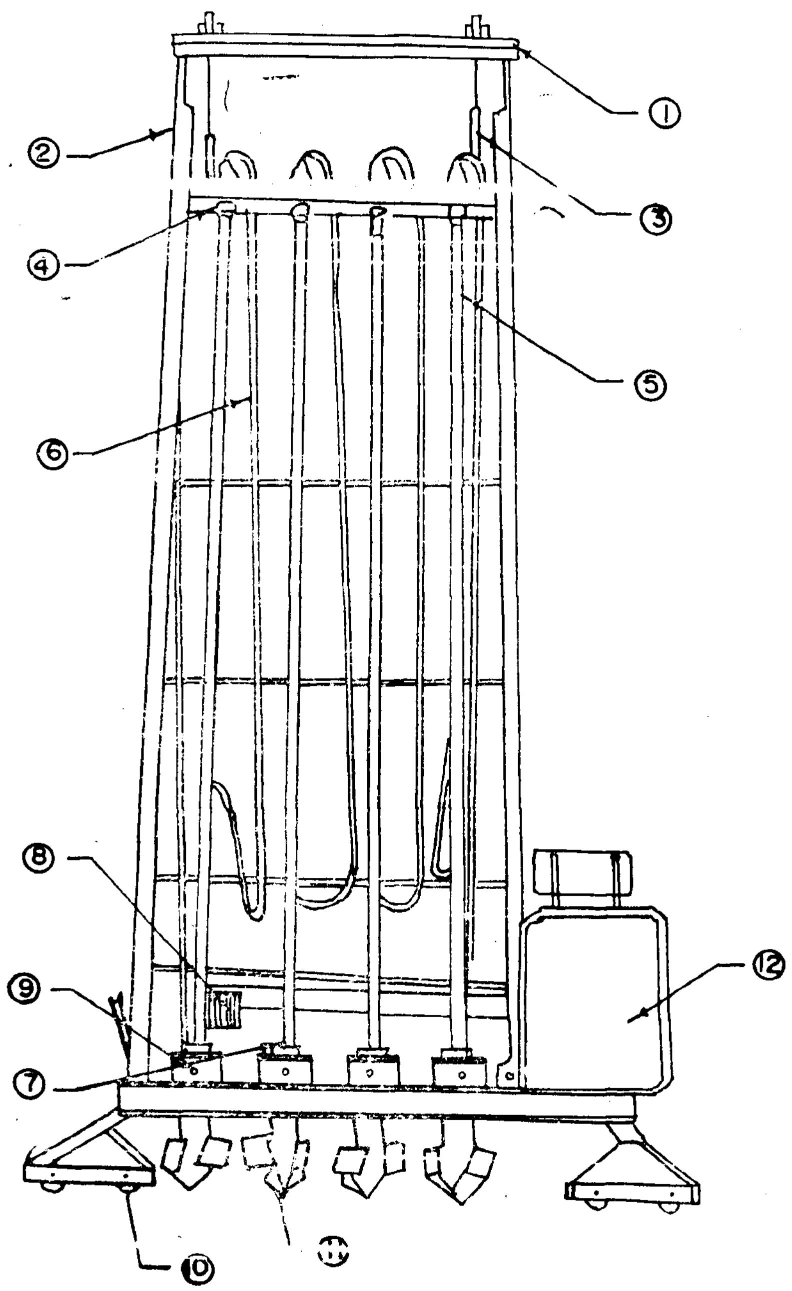
5.1. The bentonite powder of the specified quality is to be mixed with fresh water in the slurry tank. The bentonite slurry will be fed into the common slurry pipe which will pass on to each of the four kelleys. A tank of size of 20' x 10' x 2' with a central partition wall may be constructed using brick or sand cement blocks to one side of the drill. The top of the tank may be kept at ground level. The bentonite powder shall be mixed with water to give approximate density of 1.5 to 1.75. The solution may be well stirred manually with wooden sticks and paddles. 2 Nos. of 7.5 H.P. motors coupled with Sp. 3L mud pump are used to pump the bentonite slurry and feed it into the mud header of the drill which will feed the water swivels. The slurry will jet through the four kelleys and gush through each cutter during drilling. The bentonite slurry occupies the drilled portion and maintains it without collapsing for about 6 to 7 hours. Within this time the grill can be lowered in position and concrete laid by TREMIE process through steel pipes. The flow and the pressure of the bentonite solution in each cutter should be maintained uniformly as far as possible as otherwise drilling will not be uniform. *See* Figure 2 for the arrangements.

5.2. The bentonite slurry spilling over from the trench during drilling will contain sand drilled from the trench and will flow to the mud tank which is just below ground level. The sand will be removed manually before it reaches the tank, so that the bentonite slurry can be recycled for further use. The consumption of bentonite is about 50 bags for 16 feet length of trench.

5.3. The VAK drill will cut four holes of 2 ft. diameter in the first instance. By having suitable cross cuttings as shown in Figure 3, a trench of 8'0" length of 2 ft. wide can be cut. The drill will then be pushed along the rail by manual labour by levering with crow bars, etc. Two stays on each side keep the mast vertical and in position. Also after completing drilling for the required depth, some time is allowed to wash out the sand drilled. The cutters are raised and locked up to prevent falling into the trench. Graduation marks indicate the depth of drilling at each stage.

6. Conclusion:

6.1. This type of drill can be advantageously used in sandy river beds for forming R.C.C. diaphragm to act as cut off walls by the bentonite process for weirs, barrages, retaining walls, and other structures. The huge problem of dewatering, shoring, and strutting, the difficulties in placing concrete in deep narrow trenches, etc., can be avoided. The R.C.C. diaphragm can be formed in a short time and this is a decided advantage in sites where the available working season is short.



1. MAST HEAD
2. MAST (DERRICK POST)
3. WATER SWIVEL
4. W.S. COMBINATION BRACKET
5. KELLY
6. RUBBER HOSE
7. ROTARY DRILL HEAD
8. HOISTING DRUM
9. CONTROLS
10. RAIL ROLLER
11. DRAG BIT
12. ENGINE

VAK GANG DRILL

Fig. 1

U.R.P.

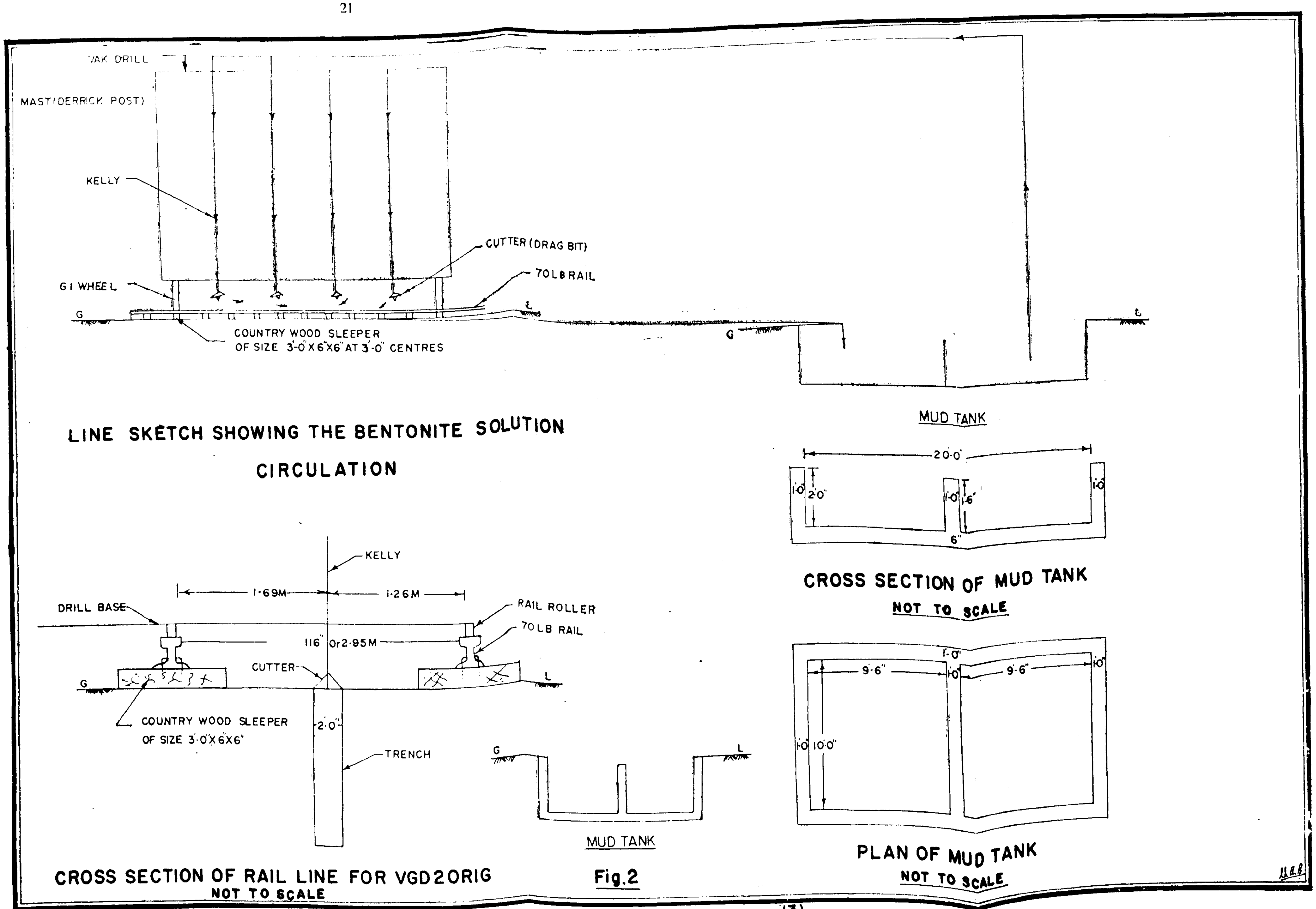
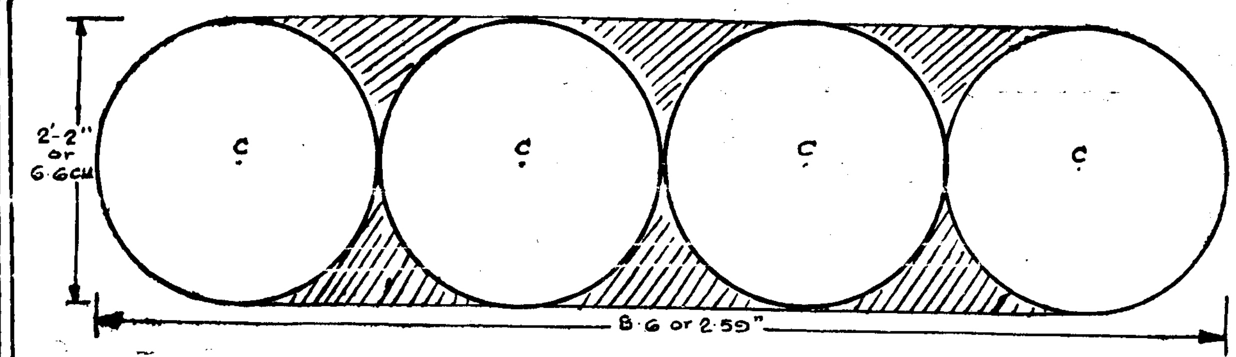
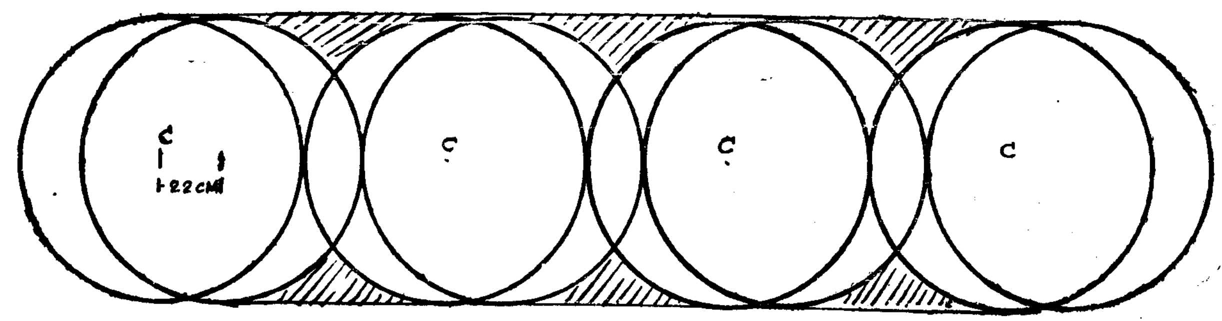

YAK DRILL
MAST(DERRICK POST)
KELLY
CUTTER (DRAG BIT)
70LB RAIL
GI WHEEL
G
L
COUNTRY WOOD SLEEPER
OF SIZE 3'-0"X6"X6" AT 3'-0" CENTRES
LINE SKETCH SHOWING THE BENTONITE SOLUTION CIRCULATION
MUD TANK
20'-0"
1'-0"
2'-0"
1'-6"
6"
CROSS SECTION OF MUD TANK
NOT TO SCALE
KELLY
1·69M
1·26M
DRILL BASE
RAIL ROLLER
70LB RAIL
116" Or 2·95M
CUTTER
COUNTRY WOOD SLEEPER
OF SIZE 3'-0"X6"X6"
2'-0"
TRENCH
9'-6"
10'-0"
PLAN OF MUD TANK
NOT TO SCALE
CROSS SECTION OF RAIL LINE FOR VGD20RIG
NOT TO SCALE

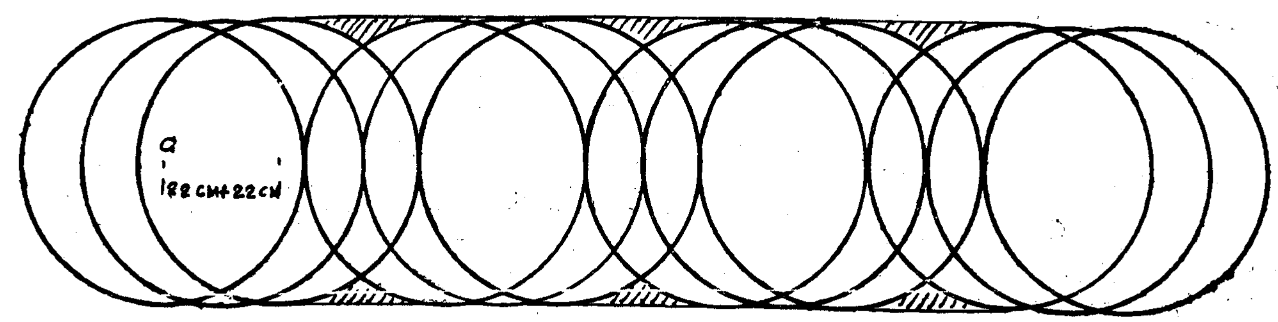
Fig.2



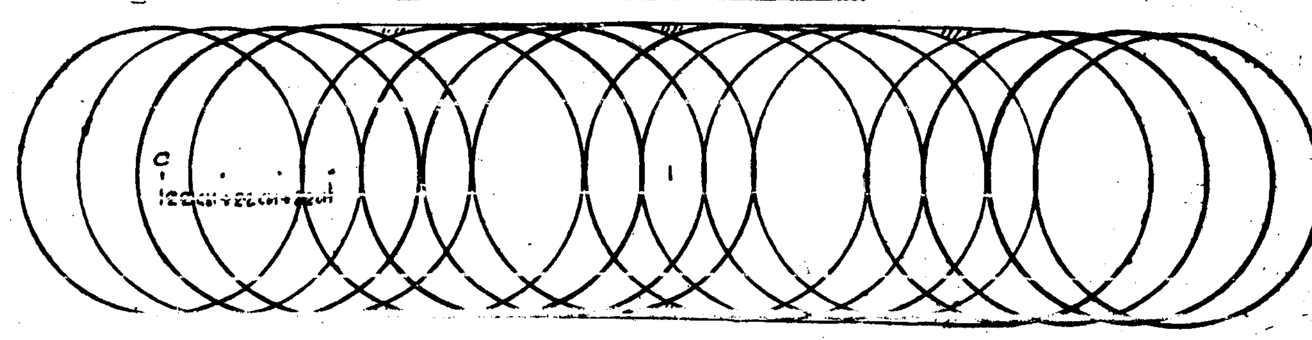
1ST OPERATION



CROSS CUTTING NO.1



CROSS CUTTING NO.2



CROSS CUTTING NO.3

DRILLING PROCESS BY VGD20.RIG
Fig 3

REPORT OF THE STUDY TEAM ON IRRIGATION PRACTICES IN PUNJAB, HARYANA AND RAJASTHAN

By

ER. B. A. JEYAPALAN, B.E.*

INTRODUCTION.

Having exploited the surface water potential fully there is very little scope in Tamil Nadu for undertaking large new works for extension of irrigation. Emphasis is therefore now placed on modernising the existing irrigation systems with a view to reducing losses and optimising the use of water. In this context a study of water balance indicating the types of demands and sources of supply acquires significance for exploring and identifying the specific areas in which improvements could be effected.

During the regional meeting held on 12th February 1976 at Madras to review the Command Area Development Programme in the Southern States, Thiru B. Sivaraman, Member, Planning Commission stressed the need for introducing Command Area Development Programmes in the State and suggested that the State Engineers may be sent to the northern States in the Indus Basin to study their irrigation practices where according to him the duty of water is higher than in Tamil Nadu.

The Government of Tamil Nadu in their G.O. No. 572, Public Works Department, dated 12th April 1977, therefore constituted a Committee of Experts drafted from the Departments of Public Works and Agriculture to visit certain irrigation works in the northern States of Haryana, Punjab and Rajasthan to study the irrigation practices in vogue there, the improvements they have effected and the beneficial results realised. This team went round these States during 20th April 1977—29th April 1977 and submitted their report.

In continuation, the Government nominated a Second Expert Team of officers with Thiru B.A. Jeyapalan, Chief Engineer (Investigation) as the team leader for a similar study in their G.O. No. 1613, dated 24th October 1977 as amended in Memo No. 101364/NI'76/22/8th December 1977. The officers who constituted the team are as below :

1. Thiru B. A. Jeyapalan, Chief Engineer (Investigation) Team Leader.

2. Thiru A. Mohanakrishnan, Senior Deputy Chief Engineer (Irrigation).

3. Thiru G. Chidambaram, Director of Evaluation and Applied Research.

4. Thiru K. M. Nachiappan, Divisional Agricultural Engineer.

5. Thiru Narayanan, Joint Director of Agriculture.

The team leader sent advance intimation to the Chief Engineers, Irrigation of the respective State Governments informing them of the areas of interest to the visiting team. The Chief Engineers of host States had drawn a tour programme very imaginatively. The tour programme covered visits to all the major irrigation projects, field studies which included field distribution systems, command arear development, modernisation programmes, ground water supplementation works and included detailed discussions with the respective Chief Engineers and other officials. The team wishes to record its deep sense of appreciation of the excellent arrangement made by the Chief Engineers of Punjab, Haryana and Rajasthan which made is possible for the team to cover so much within a very short time. The team also records its gratitude to the Government of Tamil Nadu for organising this tour. Such tours of officials if organised on a continuous basis every year to visit other states would be very beneficial in making a comparative study besides helping in broadening the perspective of senior level officials. The observations of the team are given in the succeeding chapters under appropriate heads.

GEOGRAPHICAL FEATURES OF THE REGION

The Valley of Indus is fed by the five tributaries of the mighty rivers, viz., Jhelum, Chenab, Ravi, Beas and Sutlej all of which have their origin in the Himalayan ranges. The Shivalak and the lower ranges of the Himalayas with their snow capped peaks feed these tributaries which are almost perennial. The rivers flow in deeply carved gorges through the mountainous ranges but once down the hills, they drain a plain area comparatively flat for large expanse.

Himachal Pradesh, Punjab and Haryana are contiguous States to the east of Pakistan. Most part of the Himachala Pradesh is hilly and enjoys salubrous climate. In south eastern parts of the State we have some plains. On the western end of the State flows the River Ravi while the river Beas runs among gorges almost in the Centre of the State, River Sutlej is towards the South. All these three rivers enter the State of Punjab.

West Punjab is essentially a country of rich plains except for a small area on the north eastern zone where we see the low folds of the Himalayan ranges and a higher plateau. The river Ravi flows along the north western boundary of the State and enters Pakistan while the River Beas a little to the east is joined by the River Sutlej at a place called Harike and thereafter flows into Pakistan again at the western end. But the entire State is well spread with a network of irrigation canals fed from these rivers except for a very narrow strip on the north east where the ground is high.

*Chief Engineer, P.W.D. (Investigation) [TEAM LEADER.]

The State of Haryana spreads to the east and south of the State of Punjab. River Jamuna forms the eastern boundary of the State. River Ghaggar forms the western boundary while Rajasthan lies to its South. This State is also mostly in the plains and is served by irrigation canal system emanating from the Rivers Sutlej, Ghagger and Jamuna. Towards the Southern end, the ground is rising and a narrow strip in the Bhiwani and Mohindergarh areas south west of Delhi is not served by the gravitational canal system being uncommandable.

Rajasthan is more extensive than any of the three States but is less fertile. In continuation of the uplands in the southern tip of the Haryana State lie the Aravalli ranges traversing along North east-South east in the middle of the State. To the west of these hill range is the desert region, plain and sandy. To the east of this range flow the River Chambal and its tributaries whose valleys are better developed wherein lie the historic cities of Udaipur, Chitorgarh, Kota, Ajmir and Jaipur.

Rainfall:

Rainfall in this region is rather low except in areas close to the mountainous tracts and is in the order of 300 to 400 mm. in the plain and about 1600 mm. at the foot of the hills. Most of the rains fall during the South West monsoon period June to September termed the 'Khariff period'. The rainfall goes still further down as we proceed towards south. In Rajasthan, the zone to the west of the Aravalli hill range which is also the rain-shadow area is practically a desert with scanty rainfall and is termed the Thar desert of India.

The climate is generally semi arid and is characterised by extremes of summer heat and winter cold.

River wealth:

The prosperity of the region is mainly due to the Rivers Ravi, Beas, and Sutlej of Indus Valley and Jumna of Ganges Valley which drain the southern slopes of the Himalayan ranges. These rivers taking their source from the snow capped peaks of these high mountains are kept flowing through summer by the melting snow while they swell and flow in floods with the onset of the South west monsoon from June to September. Flows continue beyond during winter also called the 'Rabi season'. The perennial flows have made it Possible to develop irrigated agriculture for two crops mainly and even three crops in some places.

Punjab, the valley of the five tributaries in the North and the Cauvery delta in Tamil Nadu in the South are said to be the places where irrigation was first practised in ancient India. The perennial rivers have been the sources of several irrigation systems which have been developed over centuries with a net-work of canal system spread over areas not bound by States of Punjab and Haryana.

According to the International Indus Water Treaty concluded between India and Pakistan, the waters in the tributaries Jhelum and Chenab were allocated entirely to Pakistan while India was entitled to all the waters in the other three tributaries Ravi, Beas and Sutlej while they flow in the Indian Territory. Partition of the country made India to expedite River Valley Projects within its territory with a view to developing hitherto unirrigated and backward areas in their states.

The water potential in these rivers available to India is roughly assessed as below:

River Ravi	..	..	6.48	MAF	282	TMC
River Beas	..	..	12.94	MAF	564	TMC
River Sutlej	..	..	12.81	MAF	558	TMC

The giant Bhakra Dam across Sutlej, the Pandoh Dam and the Beas Sutlej Link, the huge Pong Dam that has come up on Beas, and the proposed Thein Dam across Ravi for Ravi-Beas Link are all major irrigation projects that were executed after Independence to create an excellent water grid in the area. These have also made possible substantial production of power to be added on to the power grid.

Soil :

Though a detailed study could not be made of the soil classification in these States, the team could see that in the cultivated plains the soil is significantly uniform over vast streaches and this has made it possible to plan for the same type of crop in a season over large areas. Irrigation planning has been made simpler.

Agriculture :

The cropping pattern is decided by the seasonal variation. Khariff is the main cropping season which is between the months of April and September and which also coincides with their monsoon, viz., the South West monsoon. Wheat continues to be the main crop though the tendency towards rice cultivation is significantly seen in recent times. Sugarcane is another important crop that is catching up. Rabi season is between 1st October and 31st March which is to be considered their second crop period when they go in for dry crops like groundnut, cotton, oil seeds, pulses and fodder, etc. In some areas they also practice mixed cropping. Sometimes the cropping season overlaps in between Khariff and Rabi and is termed as Zaid Khariff and Zaid Rabi. Agricultural practices in Punjab are very much modernised, mechanised and bring in good yields.

A camparative picture of agro climatic conditions, land use and irrigation potentia in these states together with Tamil Nadu is presented below :

Serial number and Description.	*Unit.*	*Himachal Pradesh.*	*Punjab.*	*Haryana.*	*Rajasthan.*	*Tamil Nadu.*
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1. Geographical Area	'000 ha	5,567	5,036	4,422	34,222	13,007
2. Population	Million	3.43	13.47	9,97	25.73	41.10
3. Avereage Annual Rainfall	mm.	1,530	6,40	7,50	300 to 700	9,80
4. Total surface water Resourses	M.cu.m.	16,503	39,755	12,500	20,505	22,074
	T.M.C.	583	1,405	442	725	780
5. Net Area Sown	'000 ha	544	4,053	3,565	15,179	6,169
6. Percentage of net area Sown to Geographical area	Per cent.	9.77	80.48	80.62	44.35	47.43
7. Net area irrigated by—						
(*a*) Canals	'000 ha	..	1,292	951	756	884
(*b*) Tanks	'000 ha	..	..	1	270	898
(*c*) Wells and Tubewells	'000 ha	1	1,591	575	1,083	774
(*d*) Other Sources	'000 ha	90	5	5	23	36
(*e*) Total	'000 ha	91	2,888	1,532	2,132	2,592
8. Percentage of total net area irrigated to net area sown	per cent.	16.73	71.26	42.97	14.05	42.02

DEVELOPMENT OF IRRIGATION.

It is said that civilisations start on the banks of rivers and the basin of the five rivers, Punjab, is no exception to the Irrigation started in this land through a system of 'innundation canals' in the plains and "kools" in hilly areas. During flood times when the rivers swelled and overflow their banks, flood waters were led through large size canals to flow over land and inundate the entire area. Water soaked through the soil heavily and the soil moisture built up was normally sufficient to grow a crop. This method is of course crude as uncontrolled flows at times lead to damages with the attendant evils of uncertainty and risk.

Mohammedan Era :

With the coming of the Mohammedan rule, emperors like Akbar, Shahjehan and Aurangezeb who were responsible for such magnificent structures as the Taj and the Red Fort also paid attention to water supply and Irrigation.

A net work of canals fed by innundation canals was dug to carry waters to interior areas and systems of controls were introduced wherever possible. At the river end, temporary bunds were raised for diversions when the river floods receeded. Upper Bari Doab canals in the basin of Ravi, the Shah Nehar canals in the basin of Beas, the Sirhind canals in the basin of Sutlej and the Lower Chenab canals in that basin now in Paksitan have all developed during this period and irrigation shows a steady development. River Sutlej, which by its very name means a river of hundred canals (Sath-lej) shou'd have flown through several canals for irrigating the lands on its banks.

British Period :

The British soon after consolidating their hold on the land, paid attention to irrigation and agriculture. The second half of last century showed a boom in the development of irrigation and hydraulic structures all over India. While Sir Arthur Cotton was busy in planning and executing large diversion works across Godavari, Krishna and Cauvery developing lengthy canal lines in the south, Col. Cotley was excavating the wide Ganga and Yamuna canals in the Ganga Basin in the north. Col. Cotley was planning irrigation projects in the Punjab and Sind Valley.

The first project called the Lower Chenab Project which now lies in Pakistan territory was executed by floating capital in England. The Upper Bari Doab System was improved in 1859 and the Sirhind Canal System in Sutlej developed in 1973. By 1914 they had as many as 14 well developed irrigation systems in the region and at that time it was the largest irrigation endeavours in the World. By 1928 they had created four well designed diversion headworks in those rivers and 27 canal irrigation systems. The inundation system of irrigation has by now developed into well regulated and controlled canal irrigation system encompassing larger areas of cropped land.

Large scale irrigation, and the net work of perennial canals soaked the alluvium to large depths and gave rise to water lagging and salinity problems. This affected cropping large ly and the irrigation intensity came down considerably. The drainage problem became very acute giving rise to a full fledged drainage circle, in 1934.

Post Independence period :

Partition of the country brought in major disturbances in the irrigation systems in this region. A large chunk of well developed irrigation net work in Punjab and Sind went to Pakistan leaving behind comparatively under developed upland areas with very few working irrigation systems.

Strategy in creating irrigation potential itself had to change. Since all these five rivers enter Pakistan and since India had retained the right to use the entire flows in three of the rivers when they flow in her territory the need arose for creating storage on these rivers and link them into a well planned grid for maximum utilisation. Thus, the first major storage was created at Bhakra on Sutlej, later came the Pandoh and Pong on Beas and the Thein on Ravi is in the making.

MAJOR IRRIGATION PROJECTS.

The Bhakra Nangal Project :

At Bhakra in the Himalayan foot hills where the river Sutlej flows in the narrow gorge, a high all concrete dam has been built to create a huge reservoir. The dam is 740 feet (225.5 M) high, highest in the world when it was built and just 1,700 feet (518·6 M) long. 4.2 million cubic metres of concrete poured over a period of eight years of non stop work at the rate of 400 tons per hour has moulded this dam. The reservoir thus formed (called Gobind Sagar) is 60 miles (96.56 Km.) in length, 65 sq. miles (168.35 sq. km.) in area and has a total storage capacity of 8 million acre feet (9.87 lakhs hect. metres) of which the live storage is 6.35 M acre ft. (7.81 lakhs hectometres). The live capacity of our Mettur Reservoir, the largest in our Tamil Nadu State, is 2.15 M. acre ft. It is also interesting to note that out of a total 22,000 sq. kilometres of catchment area for the basin at Bhakra, only 8,000 sq. miles lie in India the rest is in Tibetian region.

Though conceived as early as 1908 by the then Governor of Punjab Sir Louis Dane this mammooth Project, was taken up for detailed investigation only after independence. The first bucket of concrete was placed by the first Prime Minister of India Shri Jawaharlal Nehru on 17th November 1955. The dam was completed in all respects by 1963.

The gigantic power houses built one on each flank below the dam utilise this high head and large storage. The power releases and the discharges through the sixteen river outlets in the dam flow down the river Sutlej to be picked up 13 km. below Bhakra at the diversion dam at Nangal 95 ft. (28.95 M) high and 1,000 ft. (304.30M) long from where the Nangal Hydel channel 40.47 miles (64.48 Km.) takes off with a discharge capacity of 12,500 cusecs (353.75 cu.metres). On this Hydel canal are located two more power houses one at Ganguval and the other at Kotta.

Still further down the river Sutlej, the old Rupar Head Works built in 1882 has been remodelled and improved as a barrage to send a discharge of 12,650 cusecs in the Sirhind canal which forms a major canal system having about 37.52 lakhs acres (15.14 lakhs hectares) under its command, benefitting Punjab and Haryana States. A new canal called the Bist Doab Canal was excavated on the right flank with a discharge capacity of 1408 cusecs to irrigate an ayacut of 1.60 lakhs acres (0.41 lakhs hectares).

The Nangal Hydel channel carrying 12,500 c/s. tails into the Bhakra Main line canal. This main canal is 1,100 Km. long and has more than 3,400 Km. of minors and distributories and provides irrigation to Punjab, Haryana and Rajasthan States.

The Beas — Sutlej Link Project :

This is an interesting river grid recently completed. A 260 ft. (79.2 M) high dam has been constructed at Pandoh across River Beas meant to divert 7,500 c/s. of Beas water into the river Sutlej above Govindasagar. The water conductor system starts as a tunnel for the first 13·2 Km. length up to Baggi where control structures have been erected and the possibility of power development using the head available is under contemplation. Thereafter the flow is in an open channel for 11.8 Km. up to Sundernagar where it enters a balancing reservoir. Below the balancing reservoir is again 12.3 Km. length of tunnel carrying the flows to Dhehar Power House which houses generators of large capacities and utilises a head of 320 metres. The tail race waters of the power house immediately join the river Sutlej above Govindasagar thus augmenting the utilisable flows of the River Sutlej.

This additional flow into Sutlej besides augmenting the Govindasagar capacity for power generation through its two power houses has made it possible to plan a parallel hydel channel called Anandapur Sahib Hydel channel parallel to the Nangal Hydel channel also carrying two power plants, corresponding to Ganguval and Kotta Power Houses. Thereafter the Bhakra Main line canal and distributories absorb the additional flows for extensions of Irrigation in these States.

Certain features of Engineering interest which were observed by the team are as under:—

1. Both the Pandoh dam and the Balancing reservoir bund at Sundernagar are made of rock fill materials fully utilising the excavated material and also the materials locally available including the cobbles and gravel in the several zones carefully designed.

2. The spillway of the Pandoh dam and the intake structure with a long divide wall in front to screen large size bed silt entering the tunnel have been made after hydraulic model experiments.

3. At the Baggi control structure where the flow section changes on from tunnel to the open hydel channel, the energy dissipation arrangements made have proved inadequate for different operations of the tunnel vents and the concrete floor is getting badly scoured. Patch repairs with epoxy concrete is being tried.

4. The Sundernagar balancing Reservoir has been formed as an artificial lake by raising rockfill enbankments all around and is shallow in depth. It is served by a morning glory spillway.

5. The huge shaft at the end of the Sundernagar Sutlej tunnel above the Dehar Power House is quite high mined through the rocky hill and is designed as a differential surge shaft.

6. The bye pass structure from the huge shaft is a steep R.C.C. chute where flow velocity exceeds 80 ft./sec. and ends in a flip bucket throwing the waters up in the air to fall heavily on the Sutlej river bed.

The Beas Sutlej Link Project costs about 440 crores of rupees and has been fully financed by the World Bank Aid.

The Beas Dam at Pong :

Below Pandoh on the river Beas another huge reservoirs has been created by the construction of the Beas Dam at Pong. This dam looks like a man made hill lying across the natural hills holding up the waters. This is the highest rockfill dam so far constructed in the country 133 m. high (435 ft.) and has been designed and constructed exclusively by Indian expertise. The rockfill type of dam was considered most suitable for this site keeping in view the nature and structure of the foundations availability of materials and the location of the dam in a highly seismic zone. It has involved excavation of 30 million cubic metres of rock, pacement of 35 M cubic metres of the embankment fills and 11·3 M cub. Metres of reinforced cement concrete. The fill material placed in the dam is about 9 times the volume of concrete placed in the Bhakra Dam.

The catchment area below Pandoh Dam with the snow peaked Dharmashala ranges of Himalayas and the surpluses at Pandoh are enough to fill the Beas reservoir having a gross storage of 6.95 million acre feet (302.7 TMC) and a live storage of 5.91 million acre ft. (257.4 TMC.). The Beas Dam consists of the following principal structures:—

1. An earth-*cum*-rockfill dam 133 M. (435 ft.) high from the deepest foundations and 1876 m. (6,155 ft.) long.

2. Five concrete lined tunnels excavated through the hills of 9.14 m. (30 ft.) finished diameter and having an aggregate length of about 5,000 m. (16,400 ft.). These tunnels initially used for diverting the river to enable work on the main dam are now being utilised has irrigation outlets and power penstocks.

3. A concrete chute spillway with six large sized radial gates has been provided on the left side of the dam for a maximum surplus of 12,375 cusecs (4,37,300 cusecs)

4. A power plant with an initial capacity of 240 MW (4 units of 60 MW each) with a provision for the addition of 2 more units of 60 MW each.

The work on the dam proper was commenced in 1965 and completed in 1974. The reservoir storage stabilises the ayacut in the Beas and Sutlej Basins and would provide perennial irrigation to large tracts of Rajasthan besides improving the water availability in Punjab and Haryana States. This dam serves also as a major flood control structure. The project cost of Rs. 260 crores is met by the beneficiary States of Rajasthan, Punjab and Haryana in the ratio of 58.5 : 24.9 : 16.5.

The successful completion of this large dam should be considered as an engineering feet considering the geological features of this site, the extensive subsurface explorations that had to be done and the large scale treatment of the foundations by drilling and grouting. The construction of the reinforced concrete chute spillway on the available rocky foundations with a net work of drainage galleries down below for periodical grouting and sealing the seepage needs special mention.

Immediately below Beas Dam at Pong the Shah Nahar barrage is under construction for the development of irrigation under the Shah Nahar and other connected systems besides power production through four small power houses in the run of the canal.

The Harike headworks below the confluerce of Sutlej with Beas serves to send out feeders to augment supplies in Sirhind canal system and also the Bhakra Main canal continuing as the great Rajasthan Canal.

Ravi Beas Link :

The headworks at Madhopur across River Ravi diverts waters into upper Bari Doab Canal system perhaps the oldest of the irrigation systems in this region with a head discharge of 8,500 cusecs. It is by the observations in this canals system that the famous regime theory of canal design was formulated by Robert Kennedy. The River Ravi carries comparatively larger percentage of silf.

The Madhopur Headworks had been improved as a barrage and a new link canal to carry a maximum discharge of 10,000 cusecs has been dug up to carry Ravi waters when in floods through a natural course to link with Beas as a part of the River grid. This discharge from Ravi River over and above the requirements of the Upper Bari Doab Canal flows down the Beas to Harike headworks to be fed into the Ferozpur and Rajasthan feeder canals. Otherwise this would be flowing down the river Ravi into Pakistan and India would be losing water potential due to her.

There is also a proposal to create a storage on Ravi 24 Km. upstream on Madhpur Headworks by constructing the "Thein Dam" to form a reservoir of 2.98 Million acre feet (129.8 TMC) gross storage and 1.90 Million acre feet (82.8 TMC) live storage.

Additional Water potential and Power Potential due to the river grid :

Enormous power potential has been built up in this region with the execution of these large projects. This has made available cheap power in the area which has triggered of industries large and small and liberal use of power for various agricultural operations.

Large water storages and distribution through long river canals has stabilised irrigation in the region, improved water availability in the existing systems and has also brought under command substantial extents in the States of Punjab and Haryana and also the dry and arid State of Rajasthan.

ADDITIONAL POWER POTENTIAL DUE TO THE RIVER GRIDS.

Name of the system.	*Present Potential Developed.* MW	*Future potential.* MW	*Total.*	*Cumulative total.* MW
(1)	(2)	(3)	(4)	(5)
Bhakra Nangal Project—				
Bhakra Left Power House	5 × 90 = 450			
Bhakra Right Power House	5 × 120 600			
Ganguval Power House on Nangal Hydel channel ..	2 × 24 + 1 × 29 = 77			
Kotta Power House on Nangal Hydel channel	2 × 24 + 1 × 29 = 77		1,204	1,204
Beas Sutlej Link Project—				
Dehar Power House	4 × 165 = 660	2 × 165 = 330		
Beas Dam Power House at Pong	4 × 60 = 240	2 × 60 = 120		
Power Houses on Anandpur Shaib hydel channel ..	2 × 33.5 = 67 2 × 33.5 = 67			
Power Houses on Mukerian channel	3 × 15 = 45 3 × 15 = 45 3 × 19.5 = 58.5 3 × 19.5 + 58.5		1,691	2,895
Ravi Beas Link :				
Upper Bari Doab Hydel Channel Power House	3 × 15 = 45	3 × 15 = 45		
Thein Dam Power House (Proposed)	6 × 70 = 420		510	3,405
Secondary Power possible due to integrated operation of the river grid.			792	4,197

PRESENT INSTALLED CAPACITY OF ALL POWER HOUSES IN TAMIL NADU.

For Comparison—

Hydel	1,224
Thermal	540
Total	1,764

ADDITIONAL IRRIGATION POTENTIAL CREATED BY THE RIVER GRIDS.

	Restricted Perennial. (lakh acres)	*Non-Perennial* (lakh acres)	*Perennial.* (lakh acres)	*Total CCA.* (lakh acres)	*Additional annual irrigation.* (lakh acres)
(1)	(2)	(3)	(4)	(5)	(6)
Bhakra Nangal Project—					
Punjab	11.70	6.00	3.64	21.34	13.6
Haryana	4.18	..	23.89	28.07	16.7
Rajasthan	..	..	9.20	9.20	5.7
Beas Sutlej Link—					
Punjab					
Haryana			13.00	13.00	
Rajasthan					
Beas Dam at Pong—					
Punjab					
Haryana					10.00
Rajasthan			30.00	30.00	
Ravi Beas Link—					
Punjab				4.00	
				105.61	46.00
Total area benefitted by additional irrigation				151.61 lakh acres.	

IRRIGATION MANAGEMENT.

Water Allowance :

'Duty' of water is universally accepted as a measure of irrigation. It is the ratio of water supplied to the area of crop matured. Three factors are important in the concept of 'duty' (1) place of measurement of supply, (2) period of supply and (3) rate of supply. If one cusec of water flowing continuously over the entire crop period as measured at a point of supply provides adequate irrigation to sustain and bring to fruition crops in 'X' acres of land the 'Duty' of water in that irrigation is said to be 'X' at the point of supply. This measure of irrigation assumes that water is assured for the crops from the very start of cultivation to the harvest time according to the periodical requirement.

This 'duty' has been the measure in the Tamil Nadu irrigation practice also. Our duty at the head is in the order of 60 to 70 for rice 120 for wheat and similar dry crop and so on, variations depending upon the systems, nature of soil, etc. The crop period varies from $4\frac{1}{2}$ months to 6 months for rice depending upon the variety and similarly for other crops also.

In the States of Punjab and Haryana the measure of irrigation is "Water Allowance". It is the designed number of cusecs of outlet capacity per thousand acres of culturable command area of land under that outlet. This yardstick of measurement is different in connotation from 'duty'. It is a measure assumed for design purposes and is mainly dependent on the water availability and the land under command. The adequacy of irrigation water supplied is not questioned. The coverage of the entire culturable command area under the outlet by irrigation is also not obligatory, neither possible.

This has given rise to the concept of intensity of irrigation. The culturable area under command of an irrigation sluice or outlet is called the chuck. If a farmer owns X acres of land in that chuck, with the water made available to him on the basis of 'Water Allowance' he is free to utilise the water supplied in an extent of aX acres according to the water requirements of the crops he has chosen to grow and he can also rotate the irrigated area over the years from within the total area of ownership namely X. The area to be irrigated during the year per 100 acres of cultivable command area on a particular channel is termed as the irrigation intensity of the channel as a percentage. The interesting feature that has been observed by the team is that the farmer very rarely leaves the land fallow. When he irrigates 'aX' acres he cultivates a rainfed crop in the rest of his area, viz., (X—aX) and supplements the rainfall by lift irrigation from tubewells sunk in his own land. The large and deep alluvium serves as a dependable source of ground water in shallow depths for the benefit of the people in this region.

Depending upon the water availability, the irrigation systems are classified as perennial, restricted perennial and non-perennial. In perennial zone the irrigation supply is run for all the year round whereas in restricted perennial the irrigation water is made available through the year except for the months of heavy rainfall, viz., July and August. In non-perennial zones the irrigation supply runs during kharif only, i.e., for one main crop only. It may be stated at this juncture that in Tamil Nadu we have perennial irrigation only in very few areas under the old Cauvery and Tambaraparani systems and all the rest including the new irrigation provided through the Five-Year Plans is only non-perennial, i.e., for one crop only.

Thus if in a chuck in the perennial zone the water allowance is 2.75 cusecs and the intensity of irrigation is 60% it would mean that with the irrigation water supplied 60 X 1000/100 X 2 or 300 acres only had the benefit of irrigation through the 2·75 cusecs flowing through the crop period. Measured as duty it works out to 109, which is no different and in fact lower than the figure of 120 we adopt for dry irrigation like that of wheat. Thus the team saw to its surprise that the so called economical use of water is really no better than our management.

A particular distributory called Shengwal in the Shah Nehar Canal System was examined by the team. This system is a very old one stated to be working at a very low duty perhaps comparable to our Kodiveri System in Bhavani. Cultivation particulars are as under for the past fasli.—

Season.	*Period.*	*Actual area cultivated.*	*Crop.*
Kharif	16th April 15th September.	5,066 acres	Mostly rice.
Rabi	16th September 15th April.	4,686 acres	Mostly wheat or maize two crops.

The gross area under the distributory is 9,050 acres and cultivable command area 8,780 acres. The distributory is a perennial one carrying 54 cusecs all the year round. This works out to 7.10 acres/Mcft. for rice and 9·48 acres/Mcft. for wheat or maize. This is against the 'duty' we are providing for in our recent S.M.I.P schemes as per the recommendation of the task force namely 6 acres/Mc ft. for wet and 12 acres/Mcft. for dry irrigation. In one outlet under this distributory having a cultivable command area of 104 acres, discharging 2.51 cusecs for perennial irrigation they had 48 acres only cultivated in kharif and another 48 acres in Rabi which works out to a duty of 19 for wet and 38 for dry irrigation which is of course very low.

Evaluation of this concept of "Water allowance" seems to have an historic background according to Dr. Uppal of Punjab Agricultural University. When the British planned expansion of irrigation systems in this region in the middle of the last century they found that large extent of crown lands were within command. The very mention of extending the canal system in the area boosted up the land cost. The Government started selling this land with prospective irrigation benefits in public auction at high cost which for a part went to meet the cost of the scheme which was sought to be mobilised by private investments in England. It suited them to include all the area that could be commanded in the ayncut irrespective of the water availability. The objective was to spread the benefits then and seek revenue rather than ensure adequate benefits by planning for intense irrigation. The irrigation was more protective rather than productive. When increased water potential was available through major projects and river grids the same measure of irrigation namely 'Water Allowance' was adopted in the new areas brought under irrigation. The allowance was of course fixed at a slightly higher level. In many cases the water allowance of the existing systems was also raised.

For instance, in the Bhakra Nangal Project the water allowance and intensity stipulated for new areas was as under.—

	G.C.C.A. (lakh acres).	*C.C.A. (lakh acres).*	*Water allowance distributory head (per 1,000 acres).*	*Intensity of irrigation (%).*
Perennial	42·56	36.73	2.75	62
Restricted perennial	18.33	15.88	2.25	45
Non-perennial.	6.67	6.00	3.50	35
	67.56	58.61		

In the existing irrigation systems, the Sirhind Canal System was provided with additional flows raising the intensity of irrigation from about 40% to about 71% a little higher than even the 62% stipulated in the project design.

Warabandhi and Water Regulation :

Warabandhi is an interesting system of self discipline practised by the farmers of this region which came into vogue perhaps during the Moghul period and which is still practised by and large through voluntary co-operation and at times through intervention and mediator by the officials of the irrigation department.

Under the system outlets are fixed in the Irrigation systems normally on the following considerations :—

(*a*) discharge through one outlet as per the water allowance decided for the system is not less than one cusec and not more than 2.75 cusecs;

(*b*) as far as possible no outlet is proposed to serve lands in more than one village in order to avoid disputes; and

(*c*) The culturable command area under one outlet is called a chak and a chak is normally around 300 to 350 acres.

Regulation of irrigation flows in the canals, distributories and minor is with the Irrigation Department of the State. Below the outlet the distribution of flows to the individual holdings is by the farmers themselves following the Warabhandi system. In this system the period of rotation of flows is fixed as one week (one wara). The time duration of flows to which an individual with his holdings in a chak is entitled out of the 168 hours in the week is in the same proportion of the extent of his holding bears to the total cultural command area of chak. Thus the flow is maintained all through the week and is zealously utilised day and night by the farmers promptly taking their turn. Each farmer knows his timing on the specified day of the week and plans for irrigation in his fields.

On-farm irrigation is through water courses jointly excavated within the chak by the beneficiaries and not from field to field as is the case in some systems in our State. Discharge outlets are also so designed either as an open flume type or adjustable proportional module type so that the outflow is only dependent on the water level in the Government controlled irrigation channel and practically independent of the water level in the water course. The consequences of this system of irrigation is that as long as the designed water level is maintained in the regulated irrigation channel the designed discharge of the water course flows down and this flow is utilised by only one farmer at a time in the chak. It is for the farmer to irrigate as much area of his holding as is possible with reference to the nature of crop he has grown, since as has been already explained the water allowance is inadequate for irrigating the entire area under the chak. Of course he pays water rate only for the actual area he irrigates through the canal waters.

Water rate Assessment :

The Irrigation Engineers, besides being in charge of execution, maintenance of the canals also serve as canal officers and wield a lot of administrative powers.

The Canal Officers manage the distribution of water to the fields and also assess water charges for them. For revenue assessment, each canal officer is assisted by a unit of revenue officers directly working under the control of the Irrigation Department. The organisational pattern is given below :

Executive Engineer
or
Divisional Canal Officer

Deputy Collector
Zilledar
Patwari or
Irrigation Booking Clerk

Sub Divisional Officer or
Sub Divisional Canal Officer
or Assistant Engineer
Overseer

The Deputy Collector works under the Executive Engineer. The Zilledar and his unit are administratively controlled by the Assistant Engineer. The overseer is let alone with engineering functions.

Since water rate assessment is only on the actual land area irrigated by the ryot and also on the nature of the crop, the patwari keeps account of cropwise area under each chak and prepares statement of water rate assessment to each holding. Irrigation bookings are checked by the Zilledars and by surprise by Sub-Divisional Canal Officer and Divisional Canal Officers who are expected to check a certain percentage of booking. Complaints of wrong bookings are there which are dealt with by the Sub-Divisional and Divisional Canal Officers. The assessment statement thus prepared and checked is sent by the Executive Engineer at the end of the irrigation season to the District Revenue Officer and the Commissioner for collection.

The Revenue Unit under the Executive Engineer also sorts out disputes in the working of the Warabandhi system among the Zameendars (Land lords) who normally decide the issues among themselves. The length of turns is strictly regulated by the Common village clock and is generally supervised by the Patwaris and the revenue staff. In cases where Warashikai (taking water out of turn) is reported, canal officers deal with the case and order penalties. The Canal Officers have also majesterial powers under the Act to hear cases and settle disputes arising out of water course alignments, framing of Warabandhi and water usage and they issue orders.

This entrustment of powers for booking water rates for irrigation with the organisation which is responsible for issuing waters for irrigation is a notable feature in irrigation management in this region. This is conducive to better water management. In Tamil Nadu the irrigation department concerns itself only with the creation of water potential and running of the canal system, the water distribution and water rate assessment being left to the Revenue Department.

The irrigation practice in the northern region is also advantageous in another sense that the Zameendars or landholders are now accustomed to the sharing of water according to the availability in the chak and paying for water drawn. There is no commitment for adequate protection and hence the theory of riparian rights has not grown to be a rigid frame restricting the future developmental methods. The system is very close to the concept of sale of water for irrigation needs and will be easily adaptable when in future we are forced to resort to issue of water for irrigation on volumetric basis. In this respect Tamil Nadu irrigation practice is totally different and not easily amenable to modifications.

GROUND WATER DEVELOPMENT.

All the three States of Haryana, Punjab and Rajasthan lie in the great Indo-Gangetic Plains. It is a deep alluvium. The over land is a vast expanse of flat country, except for parts on the north east of Punjab, south of Hariyana and scattered all over from Bharatpur to Kota in Rajasthan, which are undulating to hilly in topography. The rivers, coming out of Himalayan ranges into these plains, therefore, make meandering courses. Their beds in the plains are wider with less clearly marked out banks. They are used to changes and shifts in thier courses. It was reported that the River Beas has, within the last century or so, stopped short of its confluence point with the river Sutlej and entered it at a point about a hundred miles upstream. One huge flash flood river Ghaggar, which forms the western boundary of Haryana with Punjab, after it leaves Haryana and Punjab, is lost, so to say, in the desert sands of Rajasthan.

Hence this flat region of very deep alluvium is, as goes with most alluvium formations, a good ground water reservoir.

Irrigated agriculture has been, until recently for all practical purposes, from diversion of river flow and from inundation to an extent. Only in the recent past has ground water development increased, almost tremendously in Punjab, through private and State efforts for irrigation. In the Irrigated tract conjunctive use of ground water and surface water is achieved to a significant extent, mainly because the supplies through canal systems are inadequate and the large potential of groundwater in the deep alluvium is easily extracted through shallow tube wells. Power being cheap a larger number of private tube wells have come up in the ayacut area supplementing canal irrigation.

Haryana :

In the case of Haryana, groundwater development has been attempted to augment the Western Jamuna Canal (W.J.C.) flow. This canal flow is subject to such extreme fluctuation of 1,800 cusec to 9,000 cusec that the channels of this system run for eight days and remain closed for as long as a period as 32-40 days, resulting in withering of crops and consequent yield reduction. The State has therefore undertaken a huge groundwater exploitation project. A systematic State effort in exploitation of ground water was conceived in 1969 to augment this canal flow from groundwater. The Yamuna Ground Water Basin is very rich in sweet water upto great depths. As early as 1948-55, deep tube wells (256 in numbers) were installed. 128 more were added in 1966-71. Then came very deep exploratory tube wells to depths upto 2,000 feet in an area of 15 to 30 km. width and 80 to 100 km. length belt from Yamuna Nagar to Munak, lying between river Yamuna and the Western Yamuna Canal. Their estimation within this areas was 2.5 to 7 cusec from each well and a total potential of 3,300 cusec. However, as a measure of caution, they have only about 500 cusec discharge, from 160 wells.

All these groundwater discharge is collected into a large lined canal called Augmentation canal. This Augmentation canal is about 75 km. in length. It was originally intended to save the great seepage loss that occurs, in the head reach of the existing old Western Jamuna Canal. The loss is estimated at about 469 cusecs. This Augmentation canal is designed to carry about 4,000 cusecs.

This groundwater basin is a narrow strip running along the river Yamuna. How far therefore does this ground water exploitation forms an indirect pumping of river Yamuna will be of interest. One incidental benefit is that this depression of the water table released this belt of land which was once a chronic water logged area in Haryana.

Punjab :

In the case of Punjab, the development and sustenance is largely on private initiative. Many factor shave contributed to the growth of groundwater development in Punjab, the chief amongst them being (a) the need to supplement the canal supply owing to its thin and inadequate supply under 'water allowance" system of irrigation (b) lack of distribution for water rate levy on the basis of duration of supply, i.e., whether an individual farmer has used it only once or for the whole season (c) rigidity of time scheduling of water delivery (though unavoidable) under "Warabandhi" system

of water drawal under which individuals cannot hope to draw water at other than the prefixed time points (d) fixed tariff for power consumption for irrigation in the case of Punjab at Rs. 13-50 H.P. per month.

The State effort in Punjab in ground water exploitation does not appear to be as pronounced as in Haryana. Punjab does have a State Tube-well Corporation. It presently has about 500 numbers of tube-wells running. These tube-wells supply water to the neighbouring farmers at cost.

Presently, the rate is Rs. 0.34 per unit consumption of electricity. It works out to about Rs. 3 ro 3.5 per acre. The one disadvantage these tube wells suffer is the inherent inadequacy of Government management and difficulties to the farmers apart from the inconvenience of "warabhandi" system of water supply to the farmers around. Private tube-wells are now successfully competing with the State owned tube wells. Private wells supply water at Rs. 3 per hour. Even though its coverage is less (about 0.20 acres per hour) than that of a State tube-well (about 0.50 acres per hour) the demand on private tube-wells is understood to be on the increase, owing to the reasons stated above.

One well visited was No. 28 of Tube-well Division at Molair-Kotla in Sangraur District. It was installed in 1952-53. It is about 400 feet deep, fitted with a 20 H.P. turbine pump. It was designed for about 700 acres. It now serves only about 134 acres (as per Rabi 1978).

One part of Punjab, the South Western diagonal half, is not good for groundwater exploitation, because of its bad quality. As a result, the farmers here make the best use of canal water.

On the whole the ground water development in Punjab is good. It may be of interest to note here that the new city of Chandigarh receives its water needs, entirely from groundwater, as of now. It is however, learnt that groundwater is being depleted fast and may have to be supplemented by surface source in a not too distant future.

Rajasthan :

In the case of Rajasthan the whole picture relating to the ground water exploitation appears to be still in the making.

WATER LOGGING AND DRAINAGE PROBLEMS.

Lying almost entirely within the great Indo-Gangetic Plains, these States of Punjab, Haryana and Rajasthan are prone to the problems of water logging and drainage. The land is flat. The landfall is little. The rivers meander Shifting of river courses is not uncommon. The Soil is deep, alluvium. The surface drainage courses are ill defined, shallow, wide and sluggish.

Punjab :

The problem begins with lack of surface drainage facilities. This is a problem nearly uniformly faced by all the three States. It is caused largely if not entirely by the topographical feature of this part of the country, it being flat with little fall. The problem became (according to Dr. Uppal, Emeritus Scientist, Punjab Agricultural University, Luddhiana) pronounced with the beginning of extensive cultivation made possible by irrigation system and newer and newer net work of roads. Because of the shallow, wide spread, sheet flow nature of land drainage of the land, more as impediments; even standing crops the drainage outlets provided across the roads acted, because of their inadequacy coupled with flat topography only aided the impediment to the surface drain flow.

As early as before 1930, this problem was severely felt. As a result a large scale (on the present Punjab side in particular) drainage work was planned. A full fledged drainage circle was created as early as 1934. Drainage work was so planned as to see that every block of land has its surface drainage outlet into a common drainage channel and, through a wide net work, most of it goes into the flash flood river Ghaggar.

There is a separate organisation to take care of these drainage works. With the increasing availability of irrigation water resulting in consequent increase in the water allowance, the surface drainage problems are also on the rise. Nevertheless, as far as Punjab is concerned this surface drainage problem can be said to have been tackled to a point that it can not pose any threat to agriculture.

Haryana :

The problem does not appear to have been solved in Haryana to the extent that it has been in Punjab. All the same, Haryana's efforts seem to be with twin aims, that is, while it solves the drainage problems, it tries to convert it into an asset. For example, the deep well pumping from some 160 wells in the area between river Yamuna and the Western Jamuna Canal, as part of the Augmentation Canal Project, has resulted in the reclamation of 5,000 to 10,000 acres of chronically water logged areas.

Likewise, the states surface drainage problem has a new dimension added to it with Delhi's ring bund around part of the city. The ring bund is a flood protection embankment. It is necessary for Delhi to have it. It has however blocked or restricted the natural path of surface drainage flow from Haryana. As a result extensive area in Hariyana continue to be water logged during monsoon months. Now it is learnt that Haryana has planned to pump these waters into their lift irrigation canal system so that it will add to its irrigation potential while solving the drainage problem.

Hence the approach of Haryana towards its drainage problem is very interesting and worth studying in greater detail and depth for adoption in our State.

Haryana has the Central Soil Salinity Research Institute at Karnal which is doing an excellent work on reclamation and use of saline and alkaline soils resulting from water logging.

Rajasthan :

Mention was made earlier about The Ghaggar river, carrying flows from Punjab. Inevitably what has been a solution to Punjab has already become a problem to Rajasthan. The river Ghaggar which only used to carry flash floods into the Rajasthan sand dunes which dissipated them now has to carry this increased drainage flow also. The sand dunes which could dissipate the flash floods in the past very well and maintain a kind of equilibrium is no longer able to continue with the increased flow. As a result, the disposal of the Ghaggar flow in Rajasthan has become a serious problem possibility. (It was reported that, contrary to the belief on the capacity of the sand dunes for limitless absorption of the flow from Ghaggar, an underlying widespread hard pan has put a limit on the capacity of the desert sand to dissipate the flow). As a result, the State of Rajasthan is planning to make use of these waters of the desert lakes for irrigation so that it can not only add to its irrigation potential but can also solve this drainage problem. The State even expect the neighbouring States of Punjab and Haryana to share its cost because Rajasthan only solves a problem transferred by the other two States.

When this is attempted and done, it will be a good example of inter-State efforts towards solving common problems for the continued betterment of all the three States.

The drainage problems of Rajasthan seems however to be concentrated in its Chambal Command Area of over half a million acres.

The problems of Chambal Command Area have become very widely known because of its hugeness and the suddenness with which it developed and the interest of U. N. D. P. took by extending help in the form of loan to the project for reclamation and development of the area. While it took some decades in Punjab for its agricultural boom to face the problem of drainages beginning from last century it only took as few as four years in Chambal Command Area to find itself facing the adverse effects of drainage problems. The irrigation facility began available in 1960, i.e., the command area within Rajasthan is 2.84 lakh hectares. Within four years of commencement of irrigation, the project faced the problems of water logging in the form of high water table, increased salinity and choking aquatic weeds in the canals drains and field channels.

Investigations have shown that the ground water table in the project Command Area is held in confined situations and therefore there is no real high water table. Pesched water table develops in the rainy season due to impeded drainage and absence of surface drainage.

Hence after investigation by the State and study by the U. N. D. P., the reclamation programme formulated an integrated development of the command area, consisting of:

(a) realignment and rectangularization of fields in addition to land shaping;

(b) provision of open drainage to remove unwanted excess surface water, and to receive subsoil drainage when required;

(c) providing some economic form of subsoil drainage as a most promising approach to reclamation of saline soils in the alluvial areas, in view of the difficulties in effectively lowering the ground water table by deep drainage and in view of the problems of perched water table;

(d) lining of laterals and field water courses, since the transmission loss of these is estimated at 45 per cent while 18 major canal loses far less in alluvium than was allowed for in the design and as such they are not in need of any lining by and large;

(e) providing free and individual access from every field to the drainage system;

(f) deepening of natural drains including their realignment where necessary to receive new drainage to be provided;

(g) providing regulators in the distributories and minors to effect control over unwanted water;

(h) gate controlling all off take from the canals;

(i) providing every field a frontage to an irrigation supply;

(j) providing a continuous and comprehensive programme of control of emergent and floating aquatic weeds;

(k) providing for the education of farmers of the command area on the methods of land and water management;

(l) providing for the continued care and maintenance of the land development work by the farmers if necessary with suitable statutory provisions.

(m) training of extension staff in improved method of land and water management;

(n) ensuring the availability of aerial photographs, accurate cadestral survey maps for proper planning and evaluation of development works; and

(o) providing other infrastructural facilities such as roads, processing industries godowns and other credit facilities.

In the case of Chambal Command Area an integrated on Farm Development (OFD) work of land consolidation and redistribution, individual drainage outlets and drainage channel, individual irrigation water supply points individual communication access to the consolidated farms, etc., is being carried out systematically without invoking the provisions of the statutory powers by the Command Area Development Authority.

COMMAND AREA DEVELOPMENT

This important phase of any irrigation system utilisation can be best understood in the Command Area Development of Chambal Project. This command area development has been taken up very earnesty in all the three States of Punjab, Haryana and Rajasthan. Possibly, it is again the natural situation i.e., the general landscape of the country and the soil which more than any other factor, has forced the development of the command area.

The picture of project command areas (new ones) in our State is different. Because of the generally undulating topography of the command area and the porous nature of the soil, the arid lands that had received the diverted

water in our State had not created the problems to a scale that the command areas in these northern States (Rajasthan, in particular) had done. It can be said that the problems there have reached a crisis point so that the need for command area development has became great.

Punjab :

Systematic command area development can be said to have started with the enactment in the last century of Canal and Drainage Act of 1873. As already mentioned elsewhere in the report, massive diversion of river waters on to the arid, flat, deep, alluvial lands brought in its wake the problems of water logging and salinity which in turn, adversely affected the irrigated agriculture. The people had even to give up irrigated agriculture, it was reported, as swiftly as they took to it first, because of this problem.

As a first step towards the command area development system wise drainage facilities were planned. For efficient drainage provision and function, the land holding has to be optimised, so to say, in their number and shape so that, in a flat country, the disorderly held and scattered holdings would not prevent the layout of scientific drainage network and its functioning. This major step of land consolidation or rectangularization, as it is called had been carried out relentlessly to perfection.

Punjab appears to be the only State which has provided statewide man made network of drainage system with every individual holding having drainage access from his field into this system. This provision is a major and vital component of the command area development.

Present day development is on modernising aimed at reducing transit loss of water and thus increasing the water availability to the fields. Lining of field water courses on a large scale is an item with this aim. The resulting saving in water is used to increase the "water allowance" and the "cropping intensity".

Haryana :

Command area development made in this State is more or less the same as in Punjab; only the drainage network does not appear to be as complete and wide as Punjab. It is possibily for this reason that while Punjab is reaching a saturation point in bringing all areas to crop (now at 82.60 per cent of the State area net) as well as to irrigated agriculture (now at 71.26 per cent of net area sown), Haryana has still considerable area available for bringing under irrigated agriculture (now at 42.97 per cent of net area sown). And also, whereas Punjab has all the canal irrigated areas under flow irrigation, Haryana has brought large areas (about 6.79 lakhs acres) under lift irrigation in which a canal flow is lifted and relifted at various points to command an otherwise uncommandable high areas. As such, Haryana's need for faster development of command area aimed at economical water use is imperative. Hariyana is therefore taking up field water courses lining on a massive scale not witnessed in the other two States. It was reported that these lining projects are under World Bank aid and the cost-recoverable from the beneficiaries. As a result, intensity of cropping is greatly increased.

According to the Chief Engineer, Haryana, a saving of about 0.30 cusec will be made in every field outlet (chuck) of the water course, which usually carries about one cusec now. The State expects an overall saving of about 1,500 cusecs of water when the programme is completed. The expenditure made on this work is about rupees six crores in 1977–78; the State has a programme for about Rs. 16 crores for 1978–79; its master plan is of the order of over Rs. 200 crores.

During a field visit to one such lining works in progress in Biwani, Haryana, it was learnt that this lining is not planned to every individual's field within the outlet "chuck" command area, for reasons of limiting the cost. Some norms have been fixed and followed since the cost of lining is charged on all farmers within the outlet. It was however learnt that there are cases of tail-end farmers getting supply for the first time after lining, who never used to get it before, even though they were all within the command area. Care is therefore taken to see that a lined course does not fail to carry supply to any one within the command. This lining programme no doubt faces resistance from the beneficiaries because of the recovery-factor but mostly from the head land farmers to whom the lining makes little difference from the point of view of water availability.

Rajasthan :

Command area development is being carried out more comprehensively in Rajasthan, i.e., in its Chambal Project Command Area. It is on an integrated development basis. Never before, it is said has, an irrigation project command area run into so many problems and in so short a time after opening for irrigation as in Chambal Command Area. Within four years of commencement of irrigation, as already mentioned elsewhere in this report, problems of water logging, salinity and choking aquatic weeds had to be faced on a large scale.

It was estimated that about 7 per cent of the 229,000 Ha. of the command area has become saline owing to inadequate drainage and water logging about 5 per cent of the formerly cultivable land has gone out of production and each year this figure increases by 1 per cent.

This problem has been caused by—

1. Poor drainage system and lack of co-ordination between the actual requirements of the crops and the canal flow;

2. Inefficient utilization of irrigation water and lop-sided 'ayacut' development;

3. Lack of required on farm-development before commencement or project water use;

4. Improper maintenance of canals;

5. Growth of aquatic weeds in the canal system and lastly, but importantly;

6. Inadequate agricultural supporting service.

Hence an investigation and study was initiated, with the help of the United Nations Development Programme to—

1. Find means to protect against salinity and water logging;

2. Study the problem of weed control in existing irrigation canals and drains;

3. Design and execute irrigation improvement, land shapping and drainage on pilot areas;

4. Develop proper water management principles for existing water resources and make recommendations for their development; and

5. Develop proper land use patterns and on farm development for the intensification of agriculture.

As a result of this investigation and study the following recommendations were made for the command area development :—

(*a*) Providing open drainage for removal of unwanted excess, surface water and for collection of subsoil drainage when required;

(*b*) Providing free access from every field to drainge system for quick and efficient removal of drainage water;

(*c*) Providing some economic form of subsoil drainage as a most promising approach to reclamation of saline soils in the alluvial areas, in view of the difficulties in effectively lowering the ground water table by deep drainage and in view of the problems of parched water table;

(*d*) Providing a continuous and comprehensive programme of control of emergent and floating aquatic weeds by chemical spraying and mechanical checking and studying the possibility of biological control of weeds with grass carp fish ;

(*e*) Realigning and rectangularizing the fields (consolidation) with proper land shaping and levelling to achieve even distribution of water;

(*f*) Deepening and realigning (where necessary) of natural drains;

(*g*) Providing regulators in the distributories and minors to avoid loss of control over unwanted water and gate controlling all off takes;

(*h*) Providing for proper rigid lining to the canals (limited streetches) and lateral and field water courses on a large scale, since the soils (with montmorillinite clay) of the area reduces loss in main canals while loss in laterals is about 45 per cent;

(*i*) Providing proper cropping pattern (i) with short water needing crops on right main canal commnad areas because of its having to be closed in May, June every year for weed control and repair works and (ii) with crops like sugarcane, fruits and vegetables on the left main canal command area where the water is expected to run hrough out the year.

(*j*) Educating the farmers on proper methods of land and water management and crop production;

(*k*) Training the extension staff in improved methods of land and water management, including cultural practices;

(*l*) Providing approach roads to every farm,

(*m*) Providing infrastructural facilities such as processing industries, godowns, credit facilities; and;

(*n*) Bringing suitable legislation for enforcing the maintenance of on farm development works and community works like drains, etc., by the beneficiary community themselves under joint responsibility.

The command area development programme was commissioned in June 1974. The activities undertaken were (1) irrigation covering lining, weed control, etc., (2) drainage covering survey, planning, designing, construction, etc., and (3) on farm development work covering the rest.

An important feature of this command area development activity is an integration of both works and extension service on the following pattern :—

(*a*) the Government notifies the area for the command area development work. Schemes are prepared including working plans. They hold field meetings with the farmers. All officers (of various departments) are present. They hear the farmers. They try to solve the objections from the farmers and a common concensus is arrived.

(*b*) Then the beneficiaries, are classified as eligibles and ineligibles. The eligibles are helped for loans to meet the cost of On Farm Development Works, from nationalised banks. The ineligible are sanctioned loans by Rajasthan Land Development Corporation at 3 per cent higher interest.

(*c*) The O. F. D. works are then carried out. It includes farm roads, main drains (surface), land shaping, land levelling, etc. The cost of this O.F.D. works comes to about Rs. 2,500 Ha. This Rs. 2,500 includes a crop compensation component of Rs. 150 Ha. paid to the owners and 20 % on engineering works.

(*d*) This also includes part of the major drains cost of about Rs. 900 Ha. Of this Rs. 900 the Government bears Rs. 600 Ha. and the farmers Rs. 300 Ha. Lands are consolidated and rectangularized. As a measure of recognizing the village farmer's emotional attachment to his own parcels of lands, as far as possible, care is taken to see that at least one piece of a farmer's scattered holdings is included in the consolidated holding given back to him.

(*e*) The land shaping and irrigation supply channels, roads, drains, etc., are carried out.

(*f*) The cost is recovered over a period of 15 years with an initial grace period of two years. In the grace period, only interest is collected. During and after O.F.D. an intensive and continuous agricultural extension service is maintained. As a result, per Ha. average yield has gone up to (i) 4.17 T in 1975-76 from 3.38 T in 1974-75 against the World Bank's base production

approved of 2.1 T for paddy and (ii) 2.27 T. for 1975-76 against the base of 1.2 T for wheat. This increased yield was entirely the result of adoption of recommended practices because the non-adopter's yield was poor in the same period at 2.81 T in 1975-76 for paddy and 1.71 T for wheat.

During a field visit, to a village, Binayak, near Dota, one farmer, a retired policeman and now the Village Co-operative Society president, reported 3 to 4 T/Ha. of paddy production after O.F.D. works in his block, against his own 1.5 T yield in the pre project days.

The benefits of this planned Command Area Development works appear to be as immediate as the ill effects were before.

IRRIGATION LEGISLATION.

One unique feature in all the three States is that the Irrigation Department is vested with enormous powers. The Officers of the Department—Canal Officers, Superintending Canal Officer, Divisional Canal Officer—are given executive and to some extent judicial powers in all matters relating Irrigation, navigation and drainage. Though the Warabandi System works fairly smoothly on the basis of common agrreement and mutual co-operation of the farmers, whenever disputes arise the Officers of the Irrigation Department can intervene and settle the issues. Orders issued by the Canal Officer or the Superintending Canal Officer as the case may be in this regard are binding on the farmers. In the matter of land acquisition also the task is accomplished directly by the Officers of Irrigation Department without involving the Revenue Department into the picture. Similarly in the assessment of water rate and issue of demand notices the job is done directly by the Irrigation Department. For collection of water charges the Canal Officers are assisted by revenue staff who work under the direct control of the Irrigation Department. The Deputy Collectors and Zilladars constitute the revenue staff.

Comprehensive legislation has been attempted in all the three States delienating the powers of Irrigation Department officials and duties and responsibilities of the beneficiaries. The North India Canal and Irrigation Act of 1873 is the basic code and, with later amendments is applicable to the Punjab State. The Haryana Government have legislated separately and the enactment is called 'The Haryana Canal and Drainage Act of 1974'. The Rajasthan Irrigation and Drainage Act of 1954 is in operation in Rajasthan. In spirit and content provisions of the Acts in all the three States are more or less similar since they have been patterned on the model of the original Act of 1873.

The Irrigation Act is a comprehensive legislation covering aspects like application of water for public purposes, construction and maintenance of works, supply of water, water rates, recovery of charges, canal navigation, drainage, supplying labour by persons benefited by canal, offences and penalties, etc.

One salient feature of the Act is that in certain respects, the jurisdiction of Civil Court is totally barred and the decisions of the appellate authority in the Irrigation Department and in some cases the Government become final. The following are such provisions.

The Divisional Canal Officer is empowered to prepare, publish and carry out schemes relating to construction, alteration, extension, and alignment of water courses. He can reallot areas served by one water course to another, occupy land for the deposit of soil from water courses and carry out any work which is necessary for the proper maintenance and distribution of supply of water. The Divisional Canal Officer may acquire any land required for implementation of the scheme. He can call upon the share holders to implement certain works at their own cost within a specified period of time failing which the Divisional Canal Officer may proceed to carry out the work himself and the cost can be recovered from the share holders. He can direct the share holders, on execution of the scheme, to take over and maintain the water courses and on failure of the share holders to comply with the direction, he can make arrangements for maintenance of the water course at the share holders' cost. These statutory powers confer a special status on the department.

Consolidation of holdings :

Another sphere in which legislation has been attempted in a comprehensive manner is consolidation of holdings. Land Consolidation and Prevention of Fragmentation Acts have been passed in all the three States. Though the primary purpose of this legislation is to amalgamate and redistribute lands in standard minimum areas that can be profitably cultivated as a separate plot and thereby reduce the number of plots in the holdings, it also helps better water management through the provision of water courses, drains and water channels. Under the provisions of this Act the State Government is empowered to notify any area for the purpose of consolidating holdings, determining the size of the minimum area for each class of land in such notified areas, entering all fragments in the record of rights, offering small fragments to the owners of contiguous survey numbers or taking over by the Government and making a scheme for the consolidation of all holdings in notified areas. In the process of preventing fragmentation and consolidating holding the consolidating authority has to give due consideration to the various kinds of objections to be raised by the owner, tenants, etc. and after settling the disputes has to carry out the consolidation work and prepare a new record of sheets in accordance with the provisions of the Act. The Consolidation Officer is vested with powers in the matters of determining the size of standard area, in fixing the value of land, and in determining quantum and mode of compensation to be paid.

This legislation has proved to be very helpful in command area development works. We heard that consolidation of holdings has been accomplished in a comprehensive manner in Punjab. In Rajasthan the success of Chambal Command Area Development is largely attributable to the legislative backing in respect of consolidation of holdings.

The Chambal Irrigation Project comprising 2·29 lakhs hectares in Rajasthan and with a similar area in Madhya Pradesh had been completed in 1962. The system consists of the three dams namely Gandhisagar in Madhya Pradesh and Rana Pratap Sagar and the Jawahar Dam in Rajasthan and the Kota Barrage which diverts water in the canal system. The 372 kms. long High Main Canal serves 1.27 lakhs hectares in Rajasthan as well as the Madhya Pradesh Command Area. The two main branches—Bundi and Kapren branches of this Left Main Canal (168kms. long) serves 1.02 lakh hectares. Though this project has enabled the farmers to starch from rainfed to assured irrigation certain other problems still remained unresolved. The main problems faced were water logging, salinization, low productivity and inadequate means of transport in the command area. With a view to overcoming these problems and deficiencies a new Command Area Development Project has been designed with the objectives of improving and completing the existing irrigation facilities, constructing drainage works and providing on farm development throughout the project area. The project is in operation since 1974.

The Command Area Development work as has been completed so far is stated to be a great success. Our visit to the area also shows that remarkable improvements have been achieved. It was stated that cultivation intensity has increased by 25 per cent, crop yield particuarly of wheat has doubled and land value has increased many times. Though this impressive performance may be the result of combined efforts in the direction of on farm irrigation improvement, better drainage facility, extension work, better technology and inputs, etc. the necessary preparatory work was done through land consolidation. Land consoldidation has been done in a very scientific manner. The entire command area has been consolidated and redistributed to the farmers avoiding fragmented plots of unecnomic size. The lay out has been drawn in such a way that each field is directly irrigated by a water course and each field directly drains into a course. Each field is also provided with a direct access to road. Land levelling has been done wherever necessary by the project authority. Cost is estimated to be around Rs. 2,000 per hectare which is financed by commercial banks and recovery is done directly by the banks in instalments. Warabandi system is also introduced along with land development. It was stated by the Project Authority officials that land consolidation was accomplished more through their persuasive efforts than by invoking the statutory provisions. Yet, the very presence and backing of legislative provision has made the task easier to the authorities in convincing the ryots and in enlisting their co-operation.

In this connection mention has to made about the 'Model Irrigation Bill' circulated by the Government of India, Ministry of Agriculture in 1976. for adoption by the States. The broad aim of the 'Model Bill' is to consolidate various irrigation laws in each State into a single statute as at present there are different irrigation statutes for different States and in many States there is muitiplicity of laws covering various aspects of irrigation management and administration. The main provisions of the Bill cover the following aspects : application of water for public purposes ; construction of irrigation works including water courses, field channels and field works including water courses, field channels and field drains; regulation of irrigation ; levy of betterment contribution and water rates ; requisition of labour and materials in emergency ; settlement of dispute, drainage and protection of irrigation works including offences and penalties.

Special features of the Bill are simplification of administrative machinery eliminating multiple lines of authority and diversification of control for operation and management of irrigation works. Between the irrigation and revenue departments in the exercise of powers according to the Bill major responsibility is vested with the Irrigation Department and the revenue officials come into the picture only at the stage of revenue collection. The jursidiction of civil courts is barred to a great extent. The 'Model Bill' may be suitably modified in accordance with special circumstances prevailing in the State.

Similar to this, a piece of legislation is called for achieving consolidation of holdings as has been done in the three States covered.

WATER RATES.

The basis for water charges in all the three States is the nature of crops raised. A separate schedule of rates is in vogue for each system and the systems have been classified either on the basis of quality of supply or age of the systems. For example in Punjab the systems have been grouped under five categories for the purpose of water charges. In Haryana there are three categories. This classification has been done presumably on consideration of quality of supply. In Rajasthan, however, systems and sources are classified on the basis of time at which the works were executed. Comparatively speaking water rate structure is more or less uniform in all the three States. The highest incidence is found in Rajasthan and the lowest in Punjab.

Haryana.

Schedule of water rates for irrigation and non-irrigation purposes is given in Annexures I and II. The range is from Rs. 1.50 per acre per crop in the case of fodder crops and in the case of fields where one watering is availed for ploughing but not followed by a crop in the same or succeeding harvest to Rs. 40 in the case of sugarcane. All the systems are classified under three groups.—

(i) Areas covered by Bhakra Canal including Ghaggar and Saraswathi Canals ;

(ii) Areas covered by Western Jamuna Canal, Gurgaon Canal, Rewari, Jui, Indira Gandhi Canal, Birendra Narayan Chakravarti Canal and Chaggar lift irrigation schemes ; and

(iii) Areas covered by lower Choutang Nala Canal (part irrigation).

Between the first and second groups there is virtually no difference in rates except for sugarcane for which the rate is Rs. 40 for the first group and Rs. 34 for the second group. For the third group the rates are roughly one half of the other groups. Only in the case of sugarcane a distinction is maintained between khariff and rabi seasons and the rate is marginally higher for the

latter season. A distinction is maintained between areas benefited by flow irrigation and areas benefitted by lift irrigation maintained and operated by cultivators themselves. For lift irrigation the rates are only 50 per cent of the corresponding rates for flow irrigation.

Punjab

Scheduled of rates for Punjab are given in Annexures III and IV. Crop is the basis criteria for rate fixation but some weight has been assigned for quantity of supply.

Canals are classified under five groups for water rates structure—

(i) Areas covered by Eastern Canal ;

(ii) Areas covered by Bhakra Canal, Bist Doab Canal, Newanghabar Branch, Jullundur Branch, Grey Canals taking off from Sidhwan Branch and Mokhu Canal and Nayawah and Sodhinagar Distributaries taking off from Ferozepur Feeder and Sitwan Branch and Mudki Golewala and Jit Distributaries off taking from Suttlej Navigation Channel of Sirhind Canal.

(iii) Areas covered by Sirhind Canal ;

(iv) Areas covered by Upper Bari Doab Canal ; and :

(v) Areas covered by Shah Nehar Canal.

Sugarcane is charged the highest rate at Rs. 33.28 per crop and the lowest is Rs. 3 applicable to single watering. Variations in rates between different canal systems are not very significant. The differents are only marginal. For example between canals, the highest rate is for sugarcane i.e., Rs. 33.28 in upper Bari Doab Canal and the lowest is Rs. 27 in Eastern Canal. In the sugarcane a distinction is maintained between seasons. Rate for khariff season is marginally lower. Lift irrigation maintained and operated by cultivators is liable for only half the corresponding rate for flow irrigation.

Rajasthan

Schedules of rates are given in Annexures V and VI. Water rate is levied on the basis of the crop raised as in Punjab and Haryana. Sugar cane bear the higher rate of Rs. 40 per acre per crop and the lowest is Rs. 5 for Maize, Bajra and Jowar. But three rate structure are in vogue applicable to three different systems—

(i) All irrigation systems completed after 1952 ;

(ii) All works in operation since 1952 excepting inundation irrigation ;

(iii) Inundation irrigation prior to 1952.

The first category carries the highest rate and third one the lowest. The differences in rates as applicable to works completed before and after 1952 are only marginal. But in the case of inundation irrigation the rates are very low. Inundation irrigation is something peculiar to Rajasthan. Rain water is collected and inundated in fileds for several days and even months and then let out to areas down below. Such inundation is attempted at several points so that water is fully utilised at the end. The fields, after water is drained, are able to raise one crop without any further irrigation sustaining the crop from the subsoil water directly. This is possible in areas where soil is porous and where crops with deep roots but requiring less water can be raised. In Rajasthan, area benefited by such inundation irrigation is stated to be sizeable.

MISCELLANEOUS.

Departmental execution of works :

One salient feature in the execution of these major irrigation schemes in the region is that they have all been carried out directly by the organisation without employing contractors. This is a deviation from the normal procedures adopted in the country of engaging contractors for the execution of works. In Tamil Nadu we switched over to the departmental execution of works during the First Plan period. But we engage petty job-workers and piece-workers for providing labour on works while procurement of materials is done directly by the department. We also take the responsibility for technical details and execution as per plans and the expertise is provided to the department. But the piecework is done on contractual terms by executing agreements.

Even this piecework system has been avoided in the execution of the major irrigation projects in these river grids. Departmental execution was first started in the major Bhakra Project complex. A decision was taken to avoid contractors for the main reason that they wanted to strictly adhere to the schedule of time since it was felt that several imponderables and execution difficulties in tacking the problems of this major endeavour may lead to litigation and consequent loss of time and money. A large organisational set up was created with adequate men and machineries and the whole organisation was geared up to a 24 hour round the clock work divided into convenient shifts. Since this work had American collaboration and was headed by an American Engineer begin with, this was modelled on the American system of division of work with preci responsibilities fixed.

This organisation and the machines worth several crores of rupees which were available after the Bhakra Dam was built, were diverted to Beas Sutlej Link Project.

The authorities admit that there is wastage of labour in this system, the outturn is poor and the problem of labour management gives rise to many difficulties. But they are sure that quality is maintained and they are happy that they are able to plan works methodically and are able to adhere to their programmes and scheduled timings. Though this throws a lot of responsibilitity on the departmental engineers, they get trained in the process and acquire the confidence to face challenges.

Our experience is that the job work system so far adopted which is in between major contractors and the wholly departmental work, is best suited for execution of irrigation works in our State. One imperative need is that we should carefully select men for key posts in the organisation with reference to their experience, technical competence and integrity and once selected and made responsible to do the job, they should be given full powers and enjoy the confidence of the Government in adequate measure.

Water conservation plans—

The northern region has also not made much of headway in water conservation plans. Reduction of canal losses due to seepage is being attempted by lining the canal. Quite a large length of newly made canals have been lined. Several types of lining have been used. But tile lining with sandwitched mortar is the one generally preferred. Thickness and proportion of the mortar mix may vary but essentially the lining design is the same. Recently they are experimenting on replacing part of cement by fly ash.

Recently the Haryana Government have launched a major programme for lining the water courses below the outlet. This is entrusted to the Haryana Tubewells Corporation who by mobilising institution finances are taking up modernisation of water courses below the Government outlet with the consent of the beneficiaries and arrange to recover the cost from them over a period of time. The water courses which so long were maintained by the landholders themselves are now being realigned wherever necessary and lined to save seepage losses. People are generally convinced of the benefit and come forward to have the scheme. Resistance is still there in some quarters which is being ignored when the majority in the chak are agreeable. Above all, the helpful clause of the Irrigation and Drainage Act arm the irrigation officials with sufficient powers to launch development programmes in general.

Water and Power integrated management :

The river grids and canal linkages established during the past few year demand an intelligent integrated management of the major systems for optimum power production and irrigation water use. The Statewise distribution of flows as per the respective agreements is also to be maintained. This is being done mainly by the Beas Boards, an independent body functioning for the execution and operation of these major projects set up by the Central Government with adequate representation from the beneficiary States. The integrated management makes it possible to plan for maximum firm power from the various power houses.

Recommendations :

The study tour to Punjab, Haryana and Rajasthan has helped us in getting a comparative picture of our State in relation to certain aspects of irrigation and in that process to identify some deficiencies. Barring Punjab, the other two States are similarly placed as Tamil Nadu in the matter of surface water potential Haryana has gone in a big way in implementing programmes of Water Conservation and Ground Water supplementation to overcome the immuntable constraint, viz., lack of water potential. Of late Tamil Nadu also is adopting the same strategy but if the results are not very spectacular it is mostly due to certain inherent limitations. With a view to high lighting areas in which action has to be initiated or further intensified in our state the following recommendations are given:

1. Lining of canals is undertaken in certain systems. This has to be extended to other systems and lining work should be carried out up to 25 acres limit. This would help substantially in safe-guarding the interests of tail end ryots and in saving of water.

2. Warabanthi system which is a unique feature of water distribution in an economical way works smoothly in these States. But this system has been in vogue there probably for centuries. Introduction of this system though may be desirable in our State will meet with much of resistance from the farmers who have been used to simultaneous irrigation of all fields so far. However since this system has a number of inherent advantages is worth trial in the new areas which are irrigated for the first time.

3. Assessment of water rate must be done by the Irrigation Department as is the practise in these States. This would help the Irrigation Department to gain better control over water distribution and to maintain rapport with the ryots.

4. The "Irrigation Model Bill" circulated by the Government of India, Ministry of Agriculture may be introduced for legislation after incorporation of suitable modifications on the basis of special circumstance prevailing in our State.

5. Sub-divided and fragmanted pieces of small land holdings are not very conducive to good water management practices. Consolidation of holdings is accomplished in these States with legislative backing. It is time that similar legislation is done in our State also.

6. More attention has to be paid for the creation of better infrastructural facilities. These cover land shaping, avoidance of field to field irrigation, provision of drainage facility and approach roads for marketing. These will have to be undertaken on an adequate scale in the command areas of both old and new irrigation works.

7. The practice in vogue in the States of Punjab, Haryana and Rajasthan is extensive irrigation with inadequate supply in contrast to intensive irrigation in our State with assured supply. In a set up where water potential is very limited, extensive irrigation is a better choice in that the common benefit is more equitably distributed over a wider area besides resulting in avoidance of wastage. This incidently will also encourage conjunctive use of ground water.

8. Water rates should be levied with reference to the nature of crops raised irrespective of sources of supply, viz., by gravity flow or pumping.

ANNEXURE-I.

SCHEDULE OF WATER RATES IN HARYANA.

A. Water rates for the purposes of irrigation from all canals except Lower Ghautang Nala Canal.

Class and Crop.	*Rate per acre.* Bhakra Canal including Ghagger and Saraswathi Canals. Flow.	Bhakra Canal including Ghagger and Saraswathi Canals. Lift maintained and operated by cultivators.	Western Jumna Canal, Gurgaon Canal, Rewari, Jui, Indira Gandhi Canal, Birendra Narayan Chakravarti (Sowani) Canal and Jhajjar Lift Irrigation Schemes. Flow.	Western Jumna Canal, Gurgaon Canal, Rewari, Jui, Indira Gandhi Canal, Birendra Narayan Chakravarti (Sowani) Canal and Jhajjar Lift Irrigation Schemes. Lift maintained and operated by cultivators.	Per crop.
(1)	(2)	(3)	(4)	(5)	(6)
	RS.	RS.	RS.	RS.	
1. Sugarcane (Except on khariff channels).	40.00	20.00	34.00	17.00	Crop.
2. Sugarcane on Kharif channels	33.00	16.50	33.00	16.50	Do.
3. Waternuts	33.00	16.50	33.00	16.50	Do.
4. Rice	30.00	15.00	30.00	15.00	Do.
5. Indigo and other dyes, tobacco poppy spices and drugs.	25.00	12.50	25.00	12.50	Do.
6. Cotton	25.00	12.50	25.00	12.50	Do.
7. Gardens and orchards and vegetables except turnips.	25.00	12.50	25.00	12.50	Gardens and orchards per half year the rest per crop.
8. Bareley and Oats (Except on khariff channels).	27.00	13.50	19.00	9.50	Per crop.
9. Wheat (Except on khariff channels) ...	25.00	12.50	18.00	9.00	Do.
10. Melon, Fibres (Other than cotton and all crops not otherwise specified).	23.00	11.50	23.00	11.50	Do.
11. Maize	20.00	10.00	20.00	10.00	Do.
12. Oil seeds (except rabi oil seeds on khariff channels).	20.00	10.00	20.00	10.00	Do.
13. Oil seeds rabi crops	27.00	13.50	19.00	9.50	Do.
14. All Rabi crops on khariff channels except wheat and gram.	13.00	6.50	9.00	4.50	Do.
15. Wheat and gram on khariff channels ...	12.00	6.00	8.00	4.00	Do.
16. Bajra, Masur and Pulses	20.00	10.00	20.00	10.00	Do.
17. Gram	20.00	10.00	14.00	7.00	Do.
18. Jawar, Chenna, Grass all fodder crops specified in the table below including turnips.	20.00	10.00	20.00	10.00	Do.
19. Watering for ploughing not followed by a crop in the same or succeeding harvest.	3.00	1.50	3.00	1.50	Do.
20. Villlage and Zilla Parishad and Panchayat Samities plantations—					
(i) Any number of watering in khariff	5.00	2.50	5.00	2.50	Do.
(ii) One watering in rabi	5.00	2.50	4.00	2.90	Do.
(iii) Two or more watering in Rabi	10.00	5.00	7.00	3.50	Do
21. Grass—					
(i) Single watering in khariff	5.00	2.50	5.00	2.50	Do.
(ii) Single watering in rabi	5.00	2.05	4.00	2.00	Do.

Water rates for the part of irrigation from lower Chautang Nala Canal.

Class and Crop.	*Rate per acre.* Flow.	*Rate per acre.* *Lift maintained and operated by cultivators.*	***Per crop.***
(1)	(2)	(3)	(4)
	RS.	RS.	
1. Sugarcane, rice and waternuts	20.00	13.00	Per crop.
2. Cotton, indigo and maize	12.00	8.00	Do.
3. Other khariff crops	8.00	5.00	Do.
4. Special rates-single watering before ploughing for Rabi except wheat and gram followed by a crop.	5.00	3.00	Do.
5. Special rates—single watering before ploughing for whreat and gram followed by a crop.	5.00	3.00	Do.
NOTE.—Additional watering after 31st October	4.00	3.00	Per acre. All crops excep fodder crops in cluding turnips.
	2.00	1.50	For fodder crops including turnips.

ANNEXURE-II.

SCHEDULES OF WATER RATES IN HARYANA.

Water rates for the purposes other than irrigation.

Serial number and purposes.	*Rate.*
(1)	(2)
1. Brickmaking and pisewall buildings	Re. 1 per 100 cubic feet.
2. Laying concrete and brick or stone masonry	Re. 1 per 100 cubic feet
3. Metalling Roads	Rs. 84 per mile.
4. Consolidation of Kacha service roads	Rs. 100 per mile per annum for a maximum of 8 watering in ten months from December to September.
5. Water supplied in bulk	Rs. 5 per 2,500 cubic feet
6. Manufacture of charcoal	Rs. 10 per kiln. per season crop, provided kiln is in use
7. Watering road side or avenue trees	Rs. 16 per canal mile of 5,000 ft. per khariff crop. Rs. 32 per canal mile of 5,000 ft. per rabi crop.
8. Sprinkling water on roads in the khariff seaosn	Rs. 32 per mile.
9 Sprinkling water on roads in the Rabi season	Rs. 64 per mile.

ANNEXURE III.

SCHEDULE OF OCCUPIERS RATE IN PUNJAB.

(RATE PER ACRES.)

Name of the crop.	*Eastern Canal.* Flow.	Lift.	Per.	*Bhakra Canal, Bist Doab Canal etc.** Flow.	Lift.	Per.	*Sirhand Canal.* Flow.	Lift.	Per.	*Upper Bari Doab Canal.* Flow.	Lift.	Per.	*Shah Nehar Canal.* Flow.	Lift.	Per.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	RS.	RS.		RS.	RS.		RS.	RS.		RS.	RS.		RS.	RS.	
1 Sugarcane	27.00	13.50	Crop.	33.00 (except on kharif channels).	16.50	Crop.	33.00 (except on kharif channels.)	16.50	Crop.	33.28 (except on kharif channels).	16.64	Crop	27.45	13.73	Crop.
				27.00 (on kharif channels).	13.50	Do.	27.00 (on kharif channels).	13.50	Do.	27.22 (on kharif channels).	13.61	Do.			
2 Water Nuts	22.50	11.25	Do.	22.50	11.25	Do.	22.50	11.25	Do.	22.69	11.34	Do.	23.05	11.53	Do.
3 Rice	19.50	9.75	Do.	19.50	9.75	Do.	19.50	9.75	Do.	19.65	9.83	Do.	19.76	9.88	Do.
4 Indigo and other dyes spices and drugs.	18.75	9.37	Do.	16.50	8.25	Do.	16.50	8.25	Do.	16.64	8.32	Do.	16.47	8.24	Do.
5 Cotton	15.75	7.87	Do.	13.50	6.75	Do.	13.50	6.75	Do.	13.61	6.80	Do.	13.17	6.59	Do.
6 Garden and Orchards	20.62	10.31	Crop ½ year.	20.62	10.31	Crop ½ year.	20.62	10.31	Crop ½ year	20.80	10.40	Crop ½ year	20.58	10.29	Crop ½ year.
7 Melons, fibres (other than cotton).	15.00	7.50	Crop	15.00	7.50	Crop.	15.00	7.50	Crop	13.59	6.80	Crop	1.327	6.59	Crop.
8 Maize	12.75	6.37	Do.	12.75	6.37	Do.	12.75	6.37	Do.	11.34	5.67	Do.	10.98	5.49	Do.
9 (*a*) All Rabi Crops	6.00	3.00	Do.	6.00	3.00	Do.	6.00	3.00	Do.	6.06	3.03	Do.	6.58	3.29	Do.
(*b*) Garden and orchards.	7.50	3.75	Crop ½ year.	7.50	3.75	Crop ½ year.	7.50	3.75	Crop ½ year.	7.58	3.79	Crop ½ year.	8.23	4.11	Crop ½ year.
10 Wheat and gram ...	5.50	2.75	Crop	5.50	2.75	Crop	11.69	6.84	Crop ...	11.79	5.89	Crop	6.04	3.02	Crop.
11 Watering for ploughing not followed by crop in the same or succeeding harvest.	3.00	1.50	Acre	3.00	1.50	Acre.	3.00	1.50	Acre	3.03	1.52	Acre.	3.29	1.64	Acre.

* Bhakra Canal, Bist Doab Canal, Nawanshahar Branch, Jullundur Branch, Grey Canals taking off Sidhwan Branch and Makhu Canal and Mayawah and Sohinagar Distributories taking off from Ferozpur Feeder and Sidhwan Branch and Mudki Golewala Paida and Jit Distributories off taking from Sutlej Navigation Channel of Sirhind Canal.

ANNEXURE IV.

SCHEDULE OF WATER RATES IN PUNJAB.

RATES FOR PURPOSES OTHER THAN IRRIGATION.

I. Shah Nahar Canal—

Water Mills.

(i) Category A ..	Rs. 200.00 per stone per annum.
(ii) Category B ..	Rs. 160.00 per stone per annum.
(iii) Category C ..	Rs. 120.00 per stone per annum.

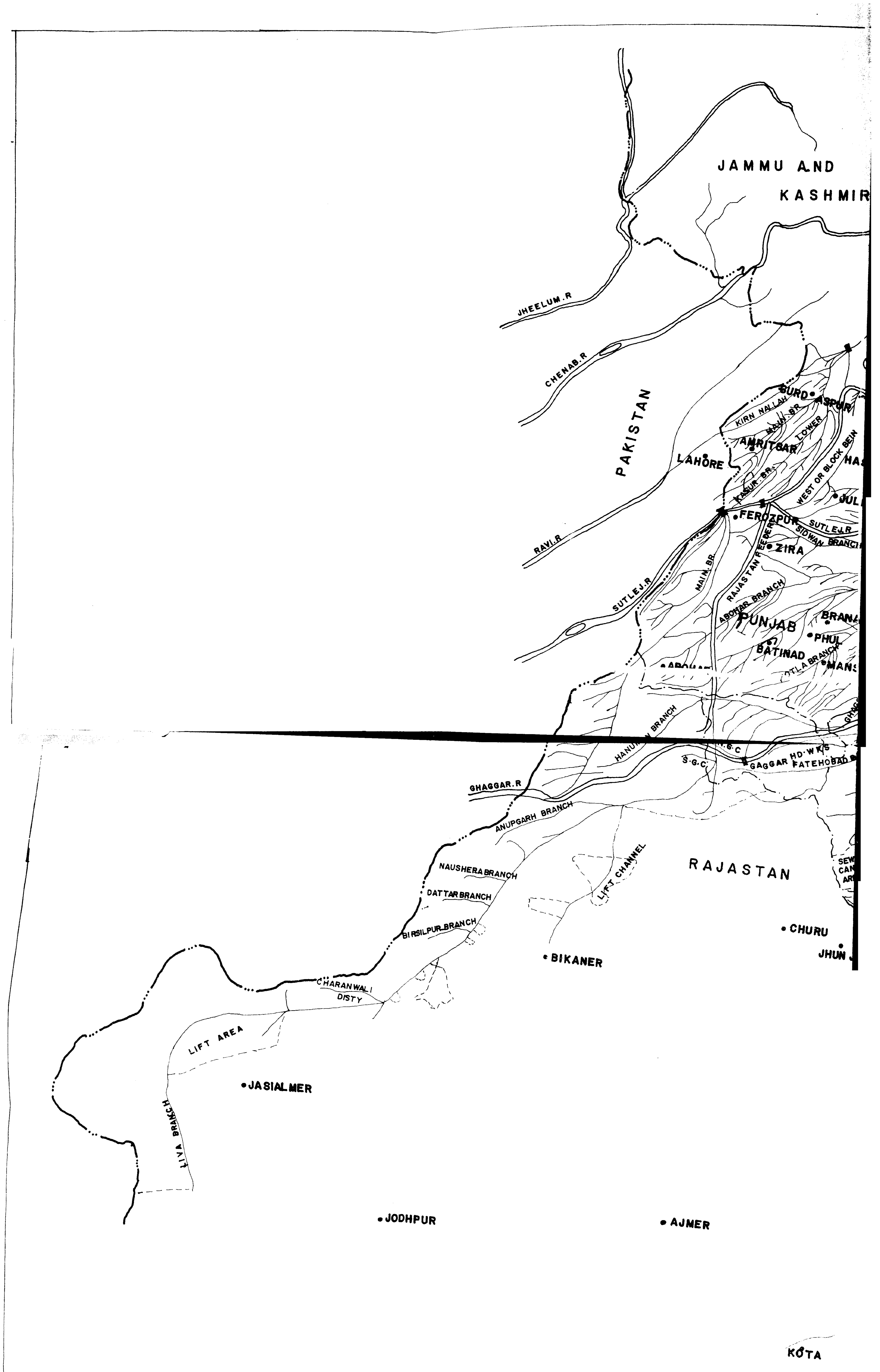
II. Schedule for Miscellaneous Rates applicable to all Canals—

(i) Brick Making ..	Re. 0.56 per 100 cubic feet.
(ii) Laying concrete and brick or stone masonry.	Re. 0.37 per 100 cubic feet.
(iii) Metalling Roads ..	Rs. 30.00 per mile.
(iv) Consolidation of Kacha Service Roads.	Rs. 90.00 per mile per annum for a maximum of 8 watering in the 10 months December to September.
(v) Water supplied in bulk.	Rs. 3.00 per 2500 cubic feet.
(vi) Manufacture of charcoal.	Rs. 4.50 per kiln per season crop, provided kiln is in use.
(vii) Water in road side or avenue trees.	(a) Rs. 7.50 per canal mile of 5000 ft. for kharif crop.
	(b) Rs. 15.00 Rabi Crop.
(viii) Sprinkling water on roads in the kharif season.	Rs. 15.00 per canal mile of 5000 ft.
(ix) Sprinkling water on roads in the kharif season.	Rs. 15.00 per mile.
(x) Sprinkling water on roads rabi season.	Rs. 30.00 per mile.

ANNEXURE V.

SCHEDULE OF WATER RATES IN RAJASTHAN.

(1)	(2)	(3)	(4)
	Pre—1952 Irrigation Works.	*Except Inundation Irrigation.*	*Inundation Irrigation.*
	(RUPEES PER ACRE.)		
1 Sugarcane	40.00	35.00	15.00
2 Rice	28.00	16.00	7.00
3 Cotton	25.00	20.00	12.00
4 Maize	12.00	7.00	5.00
5 Bajra	12.00	7.00	5.00
6 Jowar	12.00	7.00	5.00
7 Pulses	15.00	12.00	9.00
8 Garden (per year) ..	50.00 (per year).	34.00	16.00
9 O. Guwar	15.00	12.00	7.20
10 Sunhemp and Crass.	12.00	12.00	9.00
11 Vegetables	20.00	14.00	8.00
12 Other Kharif Crops	16.00	12.00	9.00
13 Wheat	21.00	15.00	9.00
14 Barley	15.00	10.00	7.00
15 Ghochani & Bejar	20.00	15.00	10.00
16 (a) Gram (1st Watering)	14.00	12.00	12.00
(b) Gram (Two and More Wate ing).	20.00	17.00	13.00
17 Palowa	6.00	4.00	..
18 Fodder	12.00	12.00	7.20
19 Oil Seeds	16.00	12.00	9.00
20 Water Nuts ..	25.00	17.00	9.00
21 Indigo and Other Dyes.	25.00	12.00	9.00
22 Tobacco	25.00	15.00	9.00
23 Zeera	25.00	13.00	8.00
24 Lucern and Poppy	25.00	15.00	8.00
25 Other Crops of rabi.	18.00	12.00	9.00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PUNJAB
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NAUSHERA BRANCH
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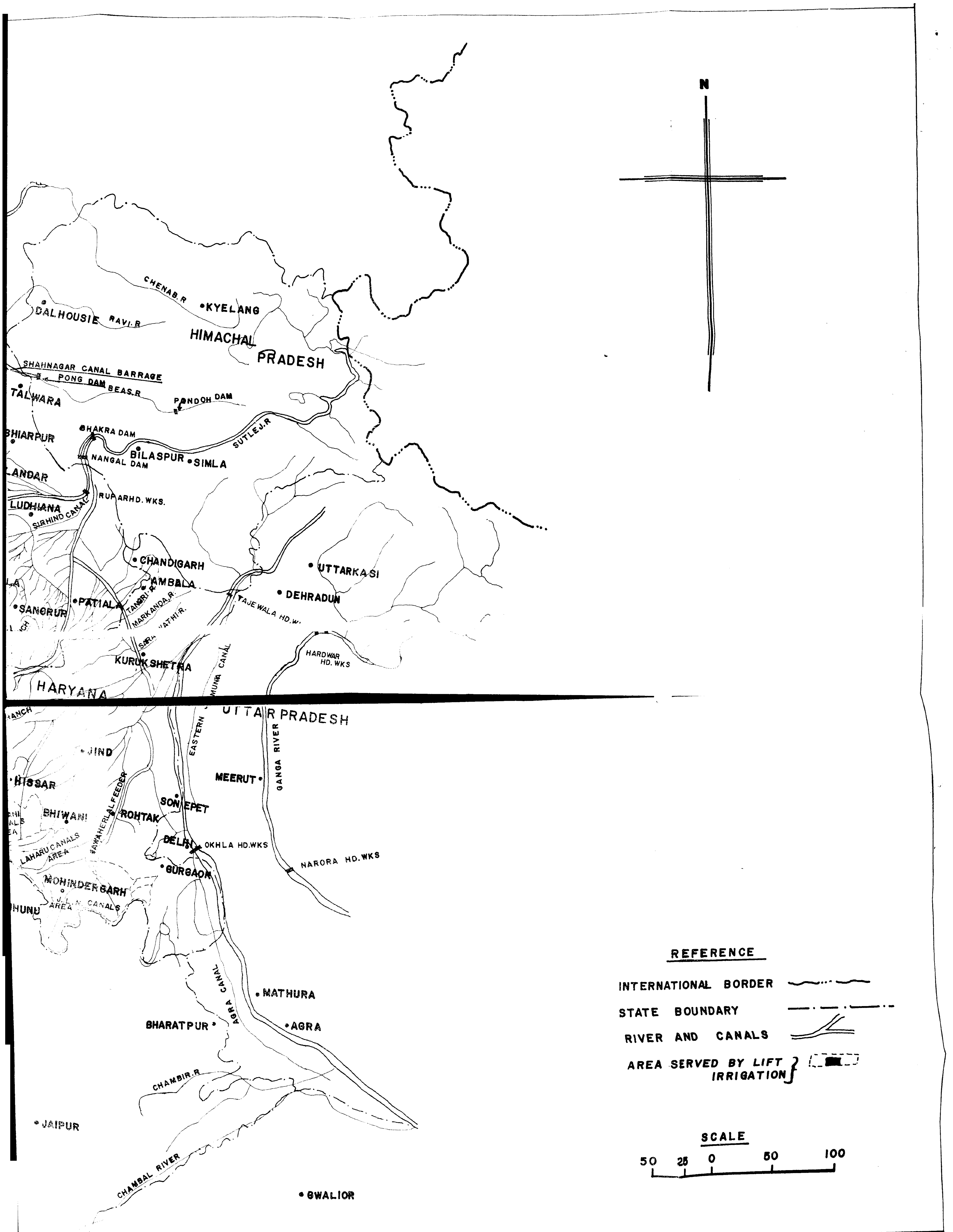

RIVER GRID AND CANAL NET WORK

IN

PUNJAB AND HARYANA

Sd/-

SENIOR DEPUTY CHIEF ENGINEER (I)

" IRRIGATING HIGH-DUTY CROPS AND CANAL MANAGEMENT " *

Tamil Nadu has used up more than 92 per cent of the available surface potential of water (at a dependability of 75 per cent) and it is no longer prudent to go for low duty cropping like paddy. It was as a result of a recognition of this factor and the need to stretch the benefits to as large a section of the populace as possible, that Project proposals submitted during the past two years have been only for irrigation of high duty crops like Cholam, Cumbu, Ragi, etc., popularly referred to as "Dry Crops". The Kelavarapalli and Pambar schemes in Dharmapuri District have been sanctioned for dry crop irrigation.

The method of irrigation of dry crops differs from that of "wet" crops like paddy. The following aspects may be mentioned.— (1) Wet crops require a continuous supply of water (This is the practice obtaining currently) and such a supply is actually harmful to dry crops. It is enough if the dry crops receive a 4" wetting once in 20 days in the absence of rain. This rate of supply can be reduced to a 2" wetting every 10th day.

(2) Since wet crops require standing water, the fields have to be necessarily levelled and shaped suitably. Dry crop irrigation can be practised even on undulating ground. What is required in such cases is a complete and satisfactory wetting. The fields do not even have to be prepared by removing small stones, pebbles, etc.,

(3) While wet crops do require a clayey soil, to help retention of moisture, dry crops can be raised on somewhat porous soils also.

(4) One of the chief points to be considered in dry crop irrigation as such is that when supply is being effected, the water should be supplied quite rapidly to cut down on seepage losses, which are bound to be heavy in porous soils.

(5) Sluices may have to be designed for as low a duty as 12 acres per cuse and should be capable of drawing this supply only for the condition of the full supply level in the parent channel. It is advisable to have the sluices located in cutting with the bed of the rear channel paved with M-150 concrete to a thickness of 6" to prevent lowering the rear bed to obtain a clear overfall condition. It is advisable to so group the ayacut that no sluice feeds less than 12 acres, the discharge being 1 cusec.

(6) Water level is maintained in the parent channel at F.S.L. conditions with the help of regulators. In times of low supplies when the supply through the channel is insufficient, this condition will still obtain, though the interval between wettings will be stretched suitably.

(7) Fields close to the parent channel are likely to get waterlogged and give room for an excuse to raise paddy. But this defect is sought to be overcome in dry crop irrigation by lining the parent channel and cutting off supply periodically. All sluices in the parent channel and wherever necessary in distributaries too, should be provided with shutters with screw gears. The shutter openings should be calculated for various discharges and the screw gearing arrangement should be capable of accommodating even small openings and being made tamper proof in such positions.

A typical case of a recently sanctioned project is analysed in detail, with reference to the sluicewar statement enclosed.

The following are the extents irrigated by the main channel of the project :

		ACRES.
1.	40 direct sluices and tail dam at L.S. 29500 in main canal.	1919.60
2.	Distributary at L.S. 9000	989.88
3.	Branch canal at L.S. 10900	1099.21

Each of the fields in the above ayacut area has to be fed with 2" water once in 10 days in the absence of rains. One of the methods by which this can be achieved would be to go in for a continuous supply at a slow rate even on a 5 long turn keeping open all sluices all the time, as is being done for wet crop cultivation. Adoption of this method for dry cultivation will be harmful to the crop and would lead to serious difficulties in regulation, besides encouraging cultivation of low duty crops. The method is also wasteful of water utilisation in that, ryots, who are generally unwilling to practice right irrig tion continuously and frequently, lead the irrigation water to the nearest drain to go to waste.

It is advisable to shut off supply below a P.W.D. control point completely for a period of 10 days instead of 5 days and allowing water inside this area and hoping for an equitable distribution within, by the ryots themselves- which will be difficult to achieve.

The main canal will be designed as such for a continuous 10 day supply in a 10 days period. The branches will be designed for a continuous 5 days supply in a 10 day period and the direct sluices in the main canal will be bunched in successive equal acreages to be irrigated in each of the 5 days with the entire supply. The main canal will run on a constant section below the offtake o fthe branch canal for most of its length.

Such a design not providing for a tapering section in the main canal, and branches will entail on extra outlay initially, but adoption of this system is essential from the points of view of (1) cutting seepage losses to the minimum (2) contributing to a situation where ryots have an excuse to raise low-duty crops (3) Ease in regulation (4) imposing a discipline on irrigation method by specifying time intervals and (5) making dry crop irrigation generally a success.

* Circular Issued by Chief Engineer (Investigation) Tamil Nadu, P.W.D. 8-78.

Since supply has to be effected once in 10 days to each field, the entire ayacut area has to be bifurcated, each half getting irrigated in 5 consecutive days. The water management (Regulation) of the system should be capable of being handled conveniently and water should be supplied in a rush within the shortest time possible and shut off completely after irrigation.

The most convenient distribution in the present case would be to irrigate the area under all the direct sluices and tail dam (1919.60 acres) in one turn of 5 days and the extent under the distributary and the branch chann: (2089.09 acres) in the second turn.

First turn.

The actual distribution of ayacut for each of the 5 days will not be exactly 1919.6÷5=384 acres, but will very according to the distribution of ayacut among the sluices and the ease in regulation. Thus, the ayacut under the direct sluices will be irrigated as below :—

Day.	*Sluices.*	*L.S.*		*Acreage.*	*Time.*		*Period.*	
		From.	*To.*		*Hrs.*	*Min.*	*From.*	*To.*
(1)	(2)	(3)	(4)	(5)	(6)	(6)	(7)	(8)
First ..	1 to 21	0	11650	342.59	21	25	Monday 10 A.M.	Tuesday 7.25 A.M.
Second ..	22 to 28	11940	19700	389.10	24	20	Tuesday 7.25 A.M.	Wednesday 7 45 A.M.
Third ..	29 to 32	20200	21300	352.47	22	00	Wednesday 7.45. A.M.	Thursday 5.45 A.M.
Fourth ..	33 to 36	22700	24900	383.60	24	00	Thursday 5.45 A.M.	Friday 5.45 A.M.
Fifth ..	37 to Taildam	25300	29500					
	Taildam	25300	29500	448.84	26	15	Friday 5.45 A.M.	Saturday 10.00 A.M.

ON TO TURN I

The supplying channel will, however, be designed to carry the required discharged for the average extent, viz., 384 acres and the period of supply regulated to suit the ayacut served, as indicated in the above statement.

In this case, for feeding 384 acres in 24 hours with a depth over field of 2", the discharge required would be

384 x 4840 x 9 x 1/6 x 1/.0864	..	32.27 cusecs.
T. Losses	.. .. ..	2.61
		34.88 or 35 cusecs.

The main canal will have to be designed for this discharge drown to L.S. 25,000, below which, the section could be reduced taking in to account the offtakes. This result, will, however, have to be correlated with the requirements of the 2nd turn.

Second Turn.

The 2nd turn of five days feds the following extents.

1. Distributary at L.S. 9000—989.88 acres.
2. Branch canal at L.S. 10900—1099.21.

	989.88	acres
	1099.21	
Total ..	2089.09	acres.

Distributary at L.S. 9000.

During the second turn, the distributory will be on continuous supply for 5 days and the average extent to be irrigated would be 990÷5=198 acres per day of 24 hours. The distribution of sluices however permits only the following arrangement :—

Day	*Sluices.*	*L. S.*		*Acreage.*	*Time.*		*Period.*	
		From.	*To.*		*Hrs.*	*Min.*	*From.*	*To.*
(1)	(2)	(3)	(4)	(5)	(6)		(7)	(8)
First ..	1 to 5	0	1555	243	29	30	Saturday 10 A.M.	Sunday 3.30 P.M.
Second ..	6 to 8	2010	2705	180.8	22	00	Sunday 3.30 P.M.	Monday 1.30 P.M.
Third ..	9 to 12	2975	3260	198	24	00	Monday 1.30 P.M.	Tuesday 1.30 P.M.
Fourth ..	13 to Tail-dam excl. 16.	370	4170	186	22	30	Tuesday 1.30P.M.	Wednesday 12 Noon
Fifth ..	16	4160	..	182.08	22	00	Wednesday 12 Noon.	Thursday 10 A.M.

ON TO TURN I

The distributary will have to be designed for carrying the discharge for 198 acres, viz., a quantity of 18.5 cusecs including transmission losses in the unlined distributary. During the first stage all the sluices 1 to 5 irrigating 243 acres will draw 18.5 cusecs amonst them. The individual discharges through the sluices will vary and they have to be suitably designed accordingly. Similar design is called for in respect of the other sluices.

Branch channel at 10900.

This branch has a distribution of ayacut as below :

Distributary at L.S. 575	..	677.84	acres
Distriburary at L.S. 1560	..	369.37	acres
Direct sluices between L.S. 745 and 2355.		52.00	,,
		1,099.21	acres.

It will be advisable to draw simultaneous continuous supply for 5 days for the distributaries instead of supplying them one after another.

The average acreage to be served by this distributary will be 677.84÷5=135.57 acres per day of 24 hours. The distribution of the sluices will permit only the following arrangement :

Day.	*Sluices.*	*Acreage.*	*L. S.*		*Time.*	*Period.*	
			From.	*To.*	*Hrs. Min.*	*From.*	*To.*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1.	3 R and L	950		112.98	20.00	Saturday 10 A.M.	Sunday 6 A.M.
2.	4 R and L	1300		151.63	27.00	Sunday 6 A.M.	Monday 9 A.M.
3.	5 R and L	1780		154.85	27.25	Monday 9 A.M.	Tuesday 12.25 P.M.
4.	6 TD	2525	2750	183.25	32.20	Tuesday 12.25 P.M.	Wednesday 8.45 P.M.
5.	1, 2	0	550	75.13	13.15	Wednesday 8.45 P.M.	Thursday 10 A.M.

The order of supply among the sluices has been deliberately changed in order to allow for regulation changes to be made during convenient hours. Supplying sluices 1 and 2 from 10 AM on Saturday would result in such changes having to be made at odd hours like 11.15 P.M., 1.40 A.M., etc.

The distributary will have to be designed to carry a discharge sufficient to ensure a 2" depth over field over 135.57 acres in 24 hours. i.e., 12 cusecs inclusive of T. Losses in the unlined distributary. This in effect means that, all the 12 cusecs will irrigate the ayacut under each of the sluices 1 L, at any on one time. The tail dam irrigating 183.25 acres will receive the same discharge, but for a longer period.

Distributary at L.S. 1560.

The average acreage to be served by this distributary and the direct sluices in the branch canal will be 421.37÷5=84.3 acres per day of 24 hours. The distribution of the sluices will however permit only the following arrangements :

Day.	*Sluices.*	*L.S.*		*Acreage.*	*Time.*	*Period.*	
		From.	*To.*		*Hrs. Min.*	*From.*	*To.*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	1 L	670		69.7	20.00	Saturday 10 A.M.	Sunday 6 A.M.
	2 L	675		78.46	22.20	Sunday 6 A.M.	Monday 4.30 A.M.
	3 L	860		60.56	17.10	Monday 4.20 A.M.	Monday 9.30 P.M.
	T. Dams	1050		160.65	45.30	Monday 9.30 P.M.	Wednesday 7 A.M.
	Direct Sluices	745	2355	52.00	15.00	Wednesday 7 P.M.	Thursday 10 A.M.

This distributary will have to be designed to carry a discharge sufficient to ensure a 2" depth over field for 84.3 acres in 24 hours, viz., 7.3 cusecs including transmission losses in the unlined distributary. The branch canal will have to draw 12.00+7.30+Transmission losses =20.3 cusecs. Thus the total discharge for the 2nd turn will have to be 20.3+18.84+T Losses in main canal=41 cusecs at the head.

Capacity of Main Canal :

Correlating the discharge figures obtained under both turns, the main canal has to be designed to draw 41 cusecs from the head to L.S. 9000, and 35 cusecs down to L.S. 25000. It can take a reduction in size below this point depending on the offtakes.

Water-management in practice :

In actual practice, due allowance has to be made for factors like time required for operation of sluices, time required for transportation of water, etc. Introduction of such factors is likely to affect the operation schedule marginally. A slight readjustment of the schedule may be made after putting the system to practice or about a month or so.

Typical cases of distribution of water in rear of sluices is discussed below :

I. *Turn.*—Sluices 3 R.L.S. 845—21 ac. This acreage has to be served in a period of 24 hours on the 1st day of the 1st turn. The quantity of water required is 1.85 cusecs. The pipe sluice has to be designed to draw this discharge with F.S.L. in the parent channel. Being less than 25 acres, the formation of field bothies will be done by the ryots themselves in their land. Distribution of water can be tackled at 2 locations each drawing about 1 cusec and feeding 12 acres. The time available for such channel will be suitably apportioned depending on actual acreage. A cultivation committee of ryots will look after irrigation within a 25 acre block.

Sluice 29 *L.S.* 20200—126.88 ac.

This will draw supply on the 3rd day of the 1st turn simultaneously with sluices 30, 31, 32.

This extent of 126.88 acres has to be served in a period of 24 hours. The quantity of water required is 11.2 cusecs. The sluice has to be designed to draw this quantity under conditions of F.S.L. in the main canal. There will be an unlined channel in rear of the sluice and water will be enabled to be drawn through suitable sluices. Each of these sluices will draw w ter for irrigating about 12 acres (1 cusec) 18 acres ($1\frac{1}{2}$ cusecs) or 24 acres (2 cusecs) depending on fields conditions. Within this extent, the ryots have to excavate the bothies and suitably put their fields on turns within the 24 hour period.

Rainfall :

Dry Crop cultivation is practiced by the farmers during the North East Monsoon and if the rainfall were to be good and suitably distributed, there should really be no need to artificially irrigate the crops. Since such conditions do not always obtain in practice, crops wither for want of timely rains. It is here that irrigation helps. Irrigation may actually be said to supplement rainfall in the case of dry crops. The importance of such supplementation only when actually needed will thus be understood. No water should be supplied artificially if there were to be sufficient rains in the ayacut area. Generally, rainfall of $\frac{1}{2}$" and below in any day may be ignored and of $\frac{1}{2}$" to 1" may help put off supply of irrigation water by 5 days and a precipitation of more than 1" can put off supply by 10 days. It is necessary to instal rain gauges in central locations in the ayacut area say one for every 1,000 acres and connect them up by a telephone system to the controlling point. During the monsoon period, rainfall readings may be taken once in 4 hours and the water management suitably regulated. During an year of normal rainfall, the number of wettings could be appreciably less than 12 and the water so saved could be utilised for a second crop.

SLUICE WISE DETAILS.

A. Main Canal (Direct Sluices).

Sluice number.	*Chainage.*	*Name of Village.*	*Total for each sluice.*
(1)	(2)	(3)	(4)
1R	0.250	Marampatty	2.00
2R	0.580	Do.	2.00
		Mittapatty	..
3R	0.845	Mittapatty	21.00
4R	1.660	Mittapatty	3.00
5R	1.710	Obakkavalsai	11.00
6R	2200	Do.	10.00
7R	2835	Do.	18.00
		Pottarajanpatty	18.00
8L	3065	Do.	14.00
		Mundrampatty	
9L	3520	Do.	
10R	3520	Pottarajanpatty	12.00
11R	3935	Do.	
		Mundrampatty	6.00
12R	4850	Do.	
		Kottukaranpatty	15.00
13R	5185	Do.	
		Kundrampatty	4.00
14R	5220	Kottukaranpatty	32.00
15R	6185	Do.	3.00
16R	6445	Do.	5.00
17R	8380	Pavakkal	29.00
18R	9495	Do.	4.00
19R	10600	Do.	
		Kaliaperumal Valasu	69.00
		Puliampally	
20R	11100	Kaliaperumal	18.36
		Puliampatty	
21R	11650	Do.	64.23
22R	11940	Ettipatty	52.03
23L	11940	Do.	25.65
23R	12300	Do.	75.80

(1)	(2)	(3)	(4)
23L	12300	Ettipatty	62.05
24L	12900	Do.	54.71
25L	14000	Do.	16.86
26L	17250	Thambal	14.47
27L	18000	Do.	19.36
28L	19700	Thambal	68.17
29L	20200	Do.	126.88
30L	20500	Do.	102.10
31L	20850	Do.	64.17
32L	21300	Do.	59.32
33L	22700	Vedakattamaduvu	99.30
34L	23450	Do.	79.49
35L	23600	Do.	99.87
36L	24900	Do.	104.4.94
37L	25300	Do.	116.01
38L	26000	Do.	121.10
39L	27800	Melsenkambadi	83.25
40L	28375	Do.	79.98
Tail Dam	29500	Do.	
	Audiyur.		48.50
		Total ..	1919.60

B. 1R Disty. taking of at L.S. 900M(R) of Main Canal.

1R	0185	Pavakkal	10.00
2R	0590	Do.	43.30
3R	1135	Do.	50.00
3L	1135	Do.	50.00
4R	1310	Do.	2.00
5L	1555	Do.	23.00
5R	1555	Do.	63.00
6L	2010	Do.	7.00
7L	2440	Do.	34.00
8L	2705	Puliampatti	
		Ettippatti	139.80
9L	2975	Do.	
		Nallavampatti	122.00
10R	3065	Do.	69.00
11R	3105	Do.	4.00
12R	3260	Do.	3.00
13R	3370	Do.	22.00
14L	3430	Do.	69.00
15R	3765	Do.	12.00
16L	4160	Do.	182.00
Tail Dam	4170	Do.	83.00
		Total ..	:989.88

C. II. R. Disty. taking of at L.S. 575M(R) of Branch Canal.

(1)	(2)	(3)	(4)
1L	5250	Nadupatti	25.30
2L	0550	Do.	42.83
2R	0550	Do.	7.00
3L	0950	Do.	60.07
3R	0950	Ettipatti	52.91
4L	1300	Nadupatti	90.24
4R	1300	Do.	61.39
		Ettipatti	
5R	1700	Do.	86.74
5L	1700	Do.	68.11
6R	2525	Do.	46.61
Tail Dam	2750	Do.	136.64
		Total ..	677.84

D. III R Disty. taking of at L.S. 1560 of Branch Canal.

1L	0670	Kuppanatham	69.70
2R	0675	Nadupatty	78.46
3L	0860	Do.	60.56
Tail Dam	1050	Do.	160.65
		Total ..	369.37

E. Branch Canal at L.S. 10900 M(L) of Main Canal (Direct Sluices).

1R	0745	Nadupatti	3.00
2R	1050	Do.	7.00
3R	1305	Do.	10.00
Taildam	2355	Kuppanatham Bommadasampatty	32.00
			52.00

ABSTRACT.

Canal	..	1919.60	Acres
1R Disty.	..	989.88	,,
2R Disty.	..	677.84	,,
3R Disty.	..	369.37	,,
B.C.	..	52.00	,,
Total	..	4008.69 or 4,000	acres.

INVITATION TO READERS.

Kind attention of Engineers of Tamil Nadu Public Works Department and other readers of the journal "NEW IRRIGATION ERA" is drawn to the meagre response to repeated requests for contribution of articles to the journal.

As all are aware the objective of the journal is two fold, viz., to promote the interest of Engineers and assisting their specialised work by placing before them the different problems of technical importance and ways and means of solving them and secondly to offer to all Engineers to express their own experience in various fields. It is desired that the Engineering fraternity will come forward in large numbers to utilise this medium to its best advantage by offering their valuable contribution.

The scope of articles to the journal can be mostly on Irrigation, but articles which have direct bearing on subjects as noted below are also welcome :—

1. Technical aspects of foundation soils and foundation engineering.
2. Auxiliary works in the fields of irrigation and other water retaining structures and works.
3. Practical solution to hydraulic problems in canals and distribution.
4. Soil erosion problems and conservation and reclamation.
5. Silt problems in rivers and reservoirs.
6. Sanitation and Public Health Problems–Possibilities of utilisation of sewage.
7. Inland water ways, navigation, fishing schemes and protection of land against sea erosion, etc.
8. Problem of drainage in deltaic tracts and entrance of rivers into the sea.
9. Run-off studies in catchments and evaporation studies.
10. Other subjects.

The Executive Engineers of the State Public Works Department are specially requested to encourage their Subordinate Officers to come forward with articles and enable the journal to flourish and serve a good cause.

The Engineers of other departments are also requested to contribute articles liberally.

Editor.

CLOSE UP VIEW OF VAIGAI PICKUP ANICUT