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# ASSESSMENT OF WATERLOGGED AREA IN IGNP STAGE - I BY REMOTE SENSING TECHNIQUES

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# PREFACE

For proper planning of drainage in the command particularly of major/medium irrigation projects detailed soil survey to deliniate the areas prone to waterlogging is a pre-requisite. The degree of risks and magnitude of waterlogging and salinity coupled with the time frame within which these problems are likely to arise have then to be identified with a reasonable degree of accuracy. The results of such study have to be used as an input for surface or sub-surface drainage study. Whereas detailed studies for some selected command areas with the help of models could be carried out, for the purpose of overall planning, study along a profile extending from watershed to the streams using strip models at various selected locations to identify waterlogging problems would be adequate. Such studies would provide an insight into the extent of problems from use of excess water and variations in ground water table, that are likely to arise under an operational irrigation project.

As a common, many of the irrigation commands are beset with local depressions, low lying areas which are prone to stagnation of water. Such conditions exist even in non-irrigated lands. When such lands are brought under irrigation, their problems get aggravated to a large extent due to leakages and surplus tail discharges of canals. Sometimes highly exaggerated figures of such problems are reported or the problem remains unnoticed.

The IGNP is a gigantic and ambitous project of National inportance which aims to bring under irrigation 2.02 million hectares of land in most desertic part of Rajasthan. It has been reported that the rate of rise of water table in the stage I has varied from 0.7 to 1.17 meters during the period 1981 to 1990 with a mean of 1.10 meters per year. Thus the rate of water table rise is indeed alarming in the IGNP command. It is therefore, desirable that a reasonable broad assessment of actual irrigated land affected by waterlogging is made.

This study is an attempt to present the actual area affected by waterlogging in the IGNP stage I, using remotely sensed data coupled with field informations. The study has been carried out by Dr.V.K.Choubey, Scientist 'C' of the Institute.

(S.M.Seth)
Director

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ABSTRACT

Irrigation projects involving interbasin transfer of water without adequate drainage has disrupted the equilibrium between the ground water recharge and discharge resulting in accretions to the ground water table. The IGNP stage I command area faces problems of waterlogging resulting from overirrigation, seepage losses through distributary system and Gaggar depressions. The study was undertaken to delineate waterlogged area in IGNP stage I command using landsat imagery.

A rapid and accurate assessment of the extent of waterlogged areas can be made from using remotely sensed data. Visual interpretation of Landsat FCC, (path 140 row 40) of March 16,1990 at 1:250000 scale was carried out for mapping of waterlogged and irrigated area of IGNP stage I in Rajasthan. An attempt has been made to correlate the Landsat derived waterlogged area with the available water table depth and electrical conductivity data. It was observed that few areas which were not indicated by water table depth data as waterlogged could be identified on the imagery.

In the year 1981, Tibi (primarily between main IG canal and Gaggar diversion channel) and Baropal sector north of Gaggar depressions were sensitive to waterlogging (water table 1.5 to 6.0 meters) affected area was 742 sq km. The sensitive area in these two sectors has progressively grown and by the year 1988 coalesced to form a continuous tract. As of year 1990 the area sensitive to waterlogging was 1980 sq.km, which constitute 24.76% of the studied command. Additionally as on March 1990, 170 sq.km area has water table at a depth less than 1.5 meter from surface and another 81.75 sq.km has stagnating water.

## 1.0 INTRODUCTION

Water being the vital requirement for the successful raising of the crops,its availability in optimum quantity in the root zone,particularly at the critical stages of the crop growth is essential.Such moisture requirement of crops can either be met from precipitation through surface flow or from ground water.For the kharif crops though most of the moisture is met through rainfall,it being erratic both in time and space and confined in most part of the country to four rainy months i.e from June to September, requires some support.To raise the crops in the non-rainy months and to meet the moisture requirement when rains have failed,the necessity of irrigation has been felt.Moreover consequent upon the spurt of country's population,there was an urgent need for increasing the agricultural production from the available land resources.This has necessitated the development of adequate irrigation facilities in the country.

In India, rainfall is generally confined to 3-4 months in a year. Its distribution over the country is highly skew viz.100 mm in West Rajasthan to over 11000 mm at Cherapunji in Meghalaya. On the top of all these unfavourable features, annual variation of rainfall is also highly uneven. The areas receiving less rainfall is also highly uneven. Various attempts have been made since the First Irrigation Commission (1901-03) to assess the water resources of India. The average annual natural run-off available in India is estimated to be 1880 cubic km. for the main land. Out of this, the utilisable water from surface structures is about 690 cubic km. Similarly, the Central Ground Water Board has estimated the possible utilisation from ground water as 418 cubic km. Thus, the assessed surface water resources of India are about 3 per cent of the world's surface water resources, whereas the country's population is about 16 per cent of world population. As such, the water resources in India are limited and for the ever growing population and increased number of industrial centres, unless a systematic attempt is made for the proper planning and management of water resources, the country will have serious problems in water availability to various sectors by the early 21st century

India has very large and ambitious plans for the development of irrigation and,which are indeed very essential for diversifying agriculture as also for increasing and stabilizing crop production. According to the Planning Commission (1974), the actual utilization of the irrigation potential was 22.6 million hectares in 1950-51 at the beginning of the era of planned development which rose to 36.0 million hectares in 1968-69 and 43.1 million hectares in 1973-74 against the ultimate irrigation potential of 107 million hectares from both surface and ground water. The Irrigation Commission in 1972 estimated the utilisable surface and ground-water resources as 8,70,000 million cubic metres; whereas, the actual utilisation was about 1,72,500 million cubic metres in 1950-51, which had risen to about 3,37,000 million cubic metres by March,1974. The utilisable surface water of the country is estimated as 66.6 million hectare meters and groundwater as 20.4 million hectare metres per year. It is expected that when the various irrigation projects are completed, irrigation will be practised over at least double the present area. This is what it should be if the country has to make economic progress quickly. But if the intelligent use of water is not pre-planned, the dreadful history may repeat itself with all its attendant havocs of seepage, rise in water-table, widespread water-logging and salinity. Irrigated agriculture instead of ensuring prosperity and economic stability may threaten the very security of the land. Waterlogging throws a challenge to irrigated agriculture. The success depends how we take up that challenge and save our national heritage, the soil, from deterioration.

Under irrigated conditions, farmers do uncontrol irrigation thereby the excess water is added to the ground water table. With subsequent irrigation done injudiciously, the excess water induces the raising of ground water table. Some times water logging in the low lying areas are also created due to seepage from irrigated upland and seepage from canal system. Over irrigation by canal water with inadequate water management practices further aggravates the situation which culminates into water logging and increase in salinity. Also the obstruction of natural drainage by way of construction of roads, railways, aerodrams, various structures, etc., causes the ponding of monsoon run off on the upstream of the structures. This has happened at many places which in turn has disturbed the surface hydrology of the areas. The cultivation of intensive irrigation without adequate drainage facilities contributes substantially to ground water table. Although irrigation and drainage both should go hand in hand, the drainage aspect has not been given much attention that it deserve even in the major and medium irrigation projects. In absence of such drainage system, the problem of water logging is created. Another adverse impact of irrigation management is the creation of soil salinity and alkalinity which adversely affects the soil productivity.

Inadequate efficient drainage system in irrigation projects, lack of surface and sub-surface drainage and poor maintenance, over irrigation and growing water intensive crops are some of the major causes of poor realisation of benefits from the canal irrigation systems. Many of the irrigation projects have not succeeded in producing the projected yields for the simple reasons that drainage for controlling the salinity and waterlogging was not considered as an integral part of the irrigation system. The National Commission for Irrigation (1972) and National Commission on Agriculture (1976), Ministry of Agriculture (1985) reported waterlogged area in India is 4.84,6.00 and 8.53 m.ha respectively.However Ministry of Water Resources (1991) has estimated 2.46 m.ha waterlogged area. It is now a recognised fact that investigation should be undertaken for all major projects at the planning stage itself to evaluate the likely impact of irrigation on the extent of possible rise of ground water table and more so in regard to the possibility of waterlogging and drainage congestion in the irrigation commands so that, if necessary, remedial measures are incorporated as an integral part at the stage of project formulation itself. Provision of drainage is thus infact an inbuilt safety device against the hazards of water delivery system. The extent, type and methodology of drainage provision, however depend upon the type of irrigation to be adopted, the cropping pattern, the type of soil, water management practices being followed and agro-climatic conditions.

## 1.1 OBJECTIVES:

The main objective of the study was to delineate the area which are vulnerably critical and waterlogged in IGNP stage-I using Landsat imagery.

## 2.0 REVIEW

Waterlogging whether it is due to surface flooding or rise in ground water,inflow and outflow ratio plays an important role.The stagnation of surface water may be usually as a consequence of a low infiltration rate of the soil in combination with rainfall intensities and insufficient surface water drainage.It may also be on account of innundation of back flow or flood in rivers.However, high ground water levels are connected with high infiltration intensities and exfiltration of ground water as a result of restricted or stagnating subsurface flow.

Soil conditions, temperature and its distribution, rainfall and its distribution, the ground water regime, existing forest cover and existing tanks and minor rivers and drains are all features which need to be paid attention while formulating an irrigation project. This will normally require that a command is regionalised into components. Even in the Indira Gandhi Nahar Project area in Rajasthan, where the initial feeling and intuitive sense was that of regional homogeneity of the proposed command in the Phase-II area. The available data showed that the average annual rainfall varied only by 40-42 per cent during 1930-60 but there were years when these variations could be in the range of 928.24 per cent. While a considerable part of the command had a depth to below ground water table of over 40 metres, area with levels below 20 metres was not unsubstantial. Also, there were pockets of critical hard pan area. With such conditions, regionalisation, aquifer and other studies have now been done for the IGNP Phase-II Commands.

## 2.1 MONITORING OF WATERLOGGING WITH REMOTE SENSING TECHNIQUES

Waterlogging is the major land degradation processe that restrict the economic and efficient utilisation of soil and land resources in command areas. Reliable and accurate mapping of areas affected by waterlogging with its location and extent can be extremely useful in chalking out suitable water management strategies and also to undertake remedial measures to prevent their advancement. Remote sensing techniques have shown great scope for providing a quick inventory of waterlogged soil and its monitoring. The areas that are not yet waterlogged but have an early potential for waterlogging could also be delineated through the use of remote sensing.

The experience at National Remote Sensing Agency Hydrabad, shows that the soils affected by salinity/alkalinity and waterlogging could be successfully mapped using Landsat data. It was observed that the highly saline soils with EC of 12 m mhos $cm^{-1}$ and above showed higher spectral reflectance than the moderately saline soils because of the encrustation of soluble salts on the soil surface (Venkataratnam, 1980). The normal soils give low spectral reflectance in the visible bands and high reflectance in the NIR bands due to presence of vegetation. Because of the difference in spectral reflectances in different bands atleast two degree of soil salinity apart from normal soils could be delineated.

Many crops growing in soils sensitive to waterlogging exhibit marked visual symptoms of moisture stress. Waterlogging may also influence leaf colour, physiological structure, leaf thickness and other properties. Black and white infrared film as well as multiband photography have been used in detecting waterlogging. The near infra-red (NIR) wavelength have been shown to exhibit best tonal contrasts for detecting the waterlogging and salinity as registered by plants. Thermodynamic activity of water gets reduced if the soil solution is saline. As a result the rate of water uptake by plants decreases and hence reduction in stalk water content. Consequently, transpiration rate is reduced and the accompanying temperature decreases. In some cases based on the conditions of crop growth, saline and alkaline soils can be differentiated especially using multitemporal data. For example, wheat crop is not much affected by salinity, while sodicity affects the crop more resulting in sparse crop growth. After the harvest, the saline and alkaline soils are rendered grey in FCC. Healthy leaves record high IR reflectance while unhealthy ones have low reflectance.

Results of the studies undertaken in the country so far, clearly demonstrate the usefulness of remote sensing techniques in detecting and monitoring waterlogged and saline/alkaline soils. Some of the studies are discussed below. Computer aided analysis of waterlogged and salt affected lands helped delineating two categories of waterlogged and self-affected lands in the Indo-Gangetic Plains (Balakrishnan 1986. Sahai et al., (1982) carried out a study in the Ukai Kakrapur command area using multidate, multi-season Landsat imagery to delineate waterlogged and salt-affected areas. The study was continued to operationalise the technique and the changes which have taken place during 1972-1977 were observed (Kalubarme et al. 1983). Sidhu et al. (1991) using Landsat imagery delineated two levels of salinity and waterlogged areas whereas with aerial photographs, three levels were identified on waterlogged and salt affected soils in Punjab.

One of the serious drawbacks that hamper the developmental progress of the command areas is the lack of drainage. Remotely sensed data can assist in detection of unfavourable drainage conditions and location of drainage channels particularly in waterlogged areas.Wherever open drainage ditches are present,they can be readily distinguished by dark tones reflecting the lower temperatures of the water surfaces in relation to the land.The lines of buried field drains can also be detected as a result of wetter soil conditions along these subsurface channels.Wet soils are dark in visible images and radar data at wavelength in excess of 20cm has some ability to integrate subsurface moisture level (Barret and Curtis,1982)

Enormous irrigation water is being lost through seepage in water conveyance in command areas thereby causing water shortage in the tail end reaches. Particularly the problem is serious in highly permeable lateritic zones. Airborne thermal infra-red images would yield precise information for detecting seepage in canals which would be deciphered in dark tone. This would permit us to take corrective measures in the critical reaches by way of lining. Remote sensing data also makes is possible to identify weed growth in canals and detect breaches in levees and unauthorised diversion/use of irrigation water. Canal silt deposition can also be identified, if turbidity levels are significant information on all of the above would be helpful in the maintenance of canals.

## 3.0 INDIRA GANDHI NAHAR PARIYOJNA STAGE I

The post independence era of the country has witnessed rapid strides in creation of irrigation potential, resulting in substantial increase of agricultural production. The IGNP with a command area of 15.43 lacs hectare is the largest irrigation and drinking water project to cater five districts in north western Rajasthan (Fig.1).The main canal gets water from the river Sutlej in Punjab through a feeder canal which takes off from Hari Ka Barrage, constructed at a point down stream of its influence of rivers Beas and Sutlej. The salient features of the IGNP are given in table 1.

The entire project comprising of main canal, nine branches, three lift and 21 district distributaries will be 7150 km long after completion. The project has been divided in two stages. Under first phase Rajasthan feeder, the main canal upto 195 km and the Suratgarh low level and Namshera branches were completed. The infrastructure builtup and development in stage I is of the project is at a highly advanced stage. The work of second stage which consists of the construction of remaining portion of the main canal from Chhatargarh to Mohangarh is now progressing.

## 3.1 GEOLOGY:

The geology of the area is completely concealed under the thick blanket of dunal sand and alluvium, no rock exposures are exposed on the surface. The lithologs of deep bore holes, dug cum bore hole and piezometers in the area reveals that stratigraphical unit in the area ranges in age from alluvium of quanternary group consolidated sedimentaries of palaeozoic group (Fig.2). A generalised succession of rock units encountered in the area is given below.

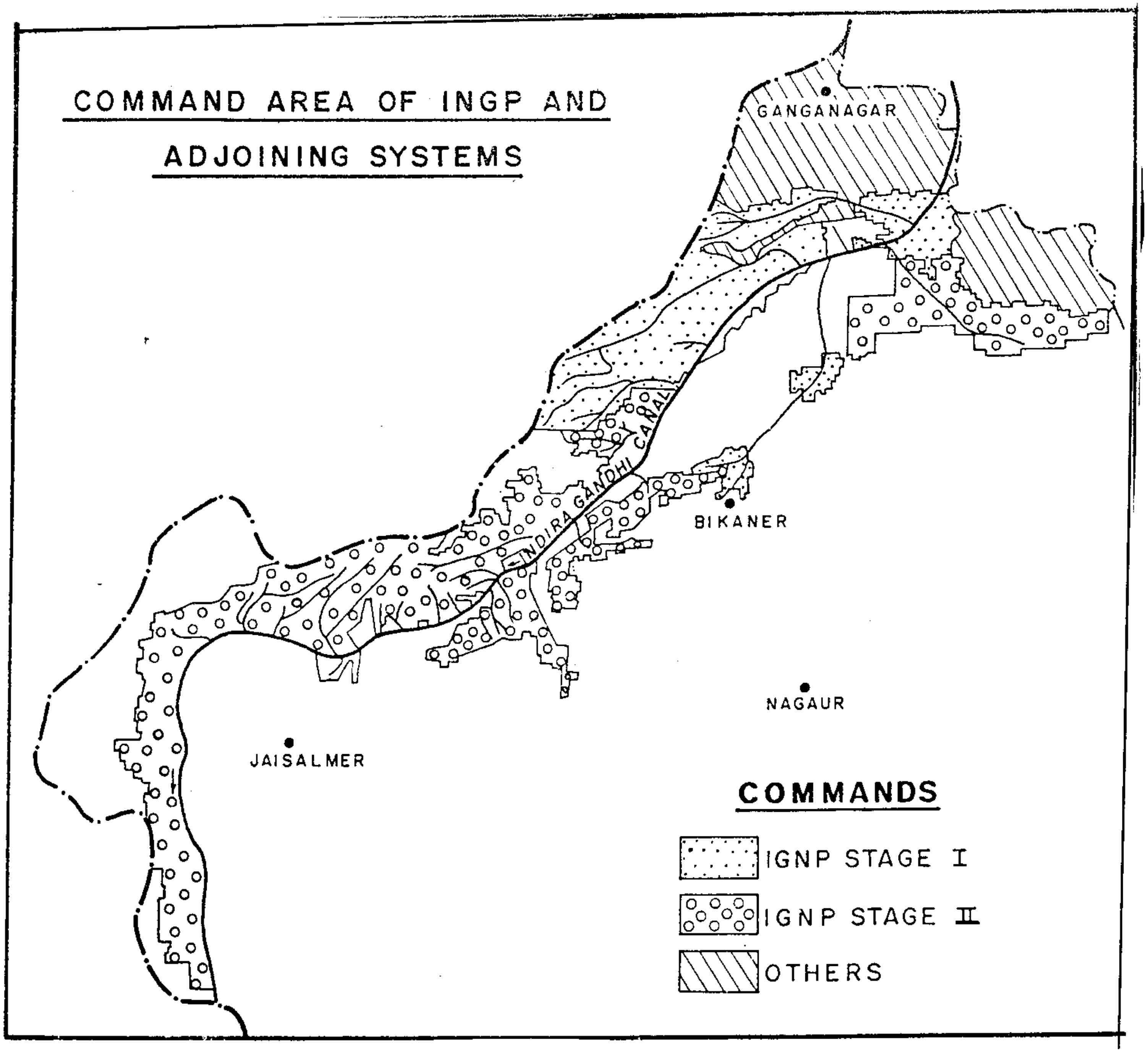

COMMAND AREA OF INGP AND
ADJOINING SYSTEMS
GANGANAGAR
BIKANER
NAGAUR
JAISALMER
INDIRA GANDHI CANAL
COMMANDS
IGNP STAGE I
IGNP STAGE II
OTHERS

Fig.1

Table 1: Salient features of the IGNP

| S.No. | Particulars | Unit | Stage I | Stage II | Total |
|---|---|---|---|---|---|
| 1. | Feeder canal | km | 204 | --- | 204 |
| 2. | Main canal | km | 189 | 256 | 445 |
| 3. | Distribution system | | | | |
| | 3.1 Flow area | km | 2618 | 3152 | 5895 |
| | 3.2 Lift area | km | 332 | 1960 | 2292 |
| | Total | | | | |
| 4. | No. of lift | no. | 1 | 6 | 7 |
| 5. | Culturable command area | | | | |
| | 5.1 Flow area | lac.ha | 4.79 | 7.0 | 11.79 |
| | 5.2 Lift area | lac.ha | 0.46 | 3.12 | 3.58 |
| | Total | lac ha | 5.25 | 10.12 | 15.37 |
| 6. | Intensity of Irrigation | Percent | 110 | 80 | |
| 7. | Irrigation potential on full development | | | | |
| | 7.1 Flow area | lac.ha | 5.27 | 5.60 | 10.87 |
| | 7.2 Lift area | lac.ha | 0.51 | 2.49 | 3.0 |
| | Total area | lac.ha | 5.78 | 8.09 | 13.87 |
| 8. | Water allowance (per 1000 acres) | cusec | 5.23/<br>4.10 | 3.0 | |

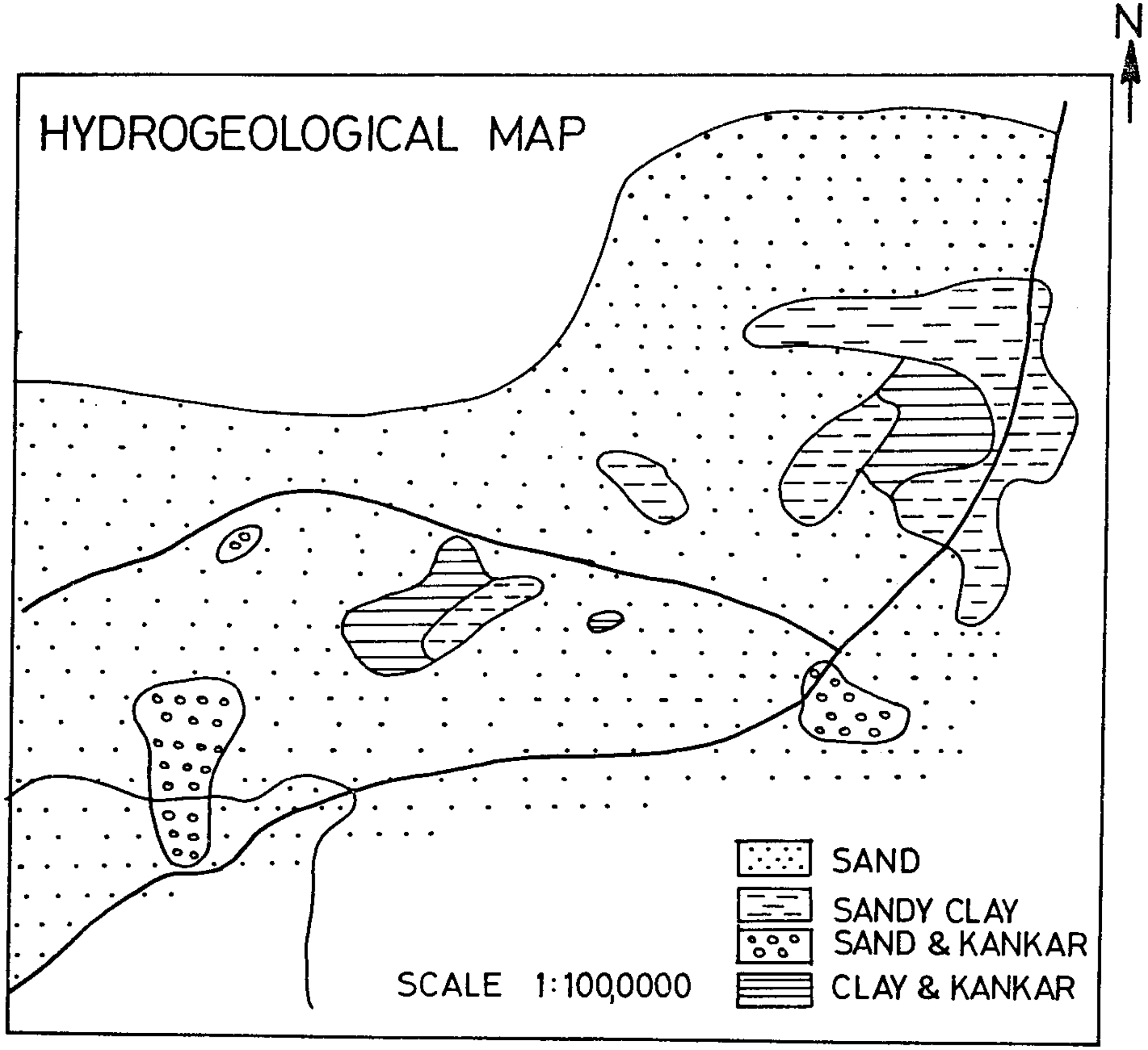

N
HYDROGEOLOGICAL MAP
SAND
SANDY CLAY
SAND & KANKAR
CLAY & KANKAR
SCALE 1:100,0000

Fig. 2

|  |  |  |
|---|---|---|
| Quaternery | Recent to Pliestocene | Blown sand very fine well sorted and rounded sand, silty clays and kankar, with frequent lenses of medium to coarse sand. |
|  | UNCONFORMITY |  |
| Paleoozoic | Upper Vindhyan | Consolidate, ferruginous fine grained sandstone with shale intercalations. |

Palezoic (Upper Vindhyan) :

Central Ground Water Board, Raja a Ground Water Dept. and CAD studied the lithological logs of zometers/tube wells at different places in the study area, reveal that consolidated sedimentary formations belonging to vindhyan system are encountered at depth beyond 155 meters and are found to be the oldest sequence encountered in the area. It is represented by sandstones which are consolidated, ferruginous, fine grained and micaceous in nature. The sandstones are frequently found to be intercalated with reddish brown shales.

Quarternary Group Pliestocene to Recent Alluvium:

It includes an unconsolidated to loosely consolidated fluviatile sediments comprising of sand, silty clay and kankar with frequent lenses of medium to coarse sand (Fig.2). These sediments are heterogenous in nature, vary both laterally and vertically in characters. Alluvium has attained varying thicknesses between 120 to 200 meters and lies over the vindhyan unconfirmity. The sand horizons from the principal water bearing horizon which local cultivators tap by sinking dug-cum bore wells and developing cavities. A study of tube well and dug-cum bore wells reveals that in most of the wells, sand horizons varying from 20 to 35 meters have been tapped (status report 1992).

## 3.2 CAUSES AND EFFECTS OF WATERLOGGING IN IGNP STAGE I

The introduction of surface water irrigation on an extensive land surface significantly changes the recharge regime to the underlying ground water system. This occurs due to deep percolation losses from conveyance channels and return flow of irrigation. The additional recharge could not be completely disposed off by lateral flow and the surplus water is being taken into storage, resulting in a persistent rise of water table. In the absence of compensating ground water abstraction the ground water approaches land surface and to some extent will be disposed off by evaporation. At this stage, related hazards of waterlogging and secondary soil salinisation become evident on the surface. the rising water has detrimental effect on field crop production until water levels reach a critical stage. Thus a surface irrigation system enjoys a grace period before provision of any ground water drainage becomes necessary. The grace period is certainly dependent on initial depth, rate of rise, fillable storage capacity of the aquifer. Waterlogging and secondary soil salinisation conditions if occur, the results would be disastrous. At first instance reduction in crop production/yield is observed which is followed by restrictions on the types of crops, and ultimately may lead to the abandonment of previously productive land.

Several agencies, including the World Bank, CAZRI, UNDP, WAPCOS. Ground Water Wing of CAD and CIDA have studied the waterlogging conditions. Recently Canadian International Development Agency through its RAJAD project has shown considerable interest in drainage studies, with the objective to generate conceptual plans for a long term solution to the problem of waterlogging and salinity in the command area of IGNP (Status report 1992).

Irrigation in stage I started from the year 1961 with coming into operation of Rawatsar and Navrandesar system of IGNP. The commanded area has grown steadily since then to reach 50% of maximum potential by the crop year 1975-76 and close to full potential by year 1986-87.The major causative factors responsible for the development of waterlogging in command area of IGNP are:

(1) Lack of onform development facilities such as field drain, land shaping etc., resulting in poor water utilisation and its applications.

(2) Structural inadequacy in water delivery system such as uncontrolled supply from direct outlets etc.

(3) Sparse use of ground water due to poor quality.

(4) Hydrological barrier layer to shallow depth, resulting in the formation of perched water bodies, sub-surface formation, impasto gypsum layer etc, which impoverish the rate of infiltration, eventually.

(5) Inundation of depression through Ghaggar flood diversion channel.

(6) Introduction of irrigation system at high water allowance i.e. 5.23 cusecs/1000 acres.

(7) Lack of comprehensive soil investigations for proper assessment of land irrigability and drainage capabilities.

(8) Seepage losses from some canals.

(9) Application of excessive water by farmers.

The area where water table is between 1.5 M.b.g.l. and 6.0 M.b.g.l. is considered as potentially sensitive areas, the area where water table is between 1.0 and 1.5 in b.g.l. is considered critical area, and the area where there is a loss of agricultural production and where water accumulates in the low lying areas, is considered as waterlogged. The following areas have been demarcated by CAD on the basis of ground water monitoring concluded in the year Sept.1991, in an area of 5,25,000 hectare in stage I.

| Type of area | Total area in hact. | % of the total command area |
|---|---|---|
| Potentially sensitive area (6.0 m.b.g.l.) | 202700 hact. | 38.60% |
| Critical areas (1.0 to 1.5 m.b.g.l.) | 22000 hact. | 4.1% |
| Waterlogged | | |
| 1. Stagnant water | 4350 hact. | 2.6% |
| 2. Water table lies between 0.5 to 1.0 m.b.g.l. | 9400 hact. | |
| | 13750 hact. | |

## 4.0 METHODOLOGY

Landsat TM False Color Composite (path 149 row 40) of March 16,1990 pass was used in this study. Though post monsoon passes of Oct/Nov. would have been more useful for the assessment of waterlogging. The same was not possible as the scenes were found to be cloud covered. Landsat FCC on 1:250 000 was studied for land use/cover mapping and delineation of irrigated, waterlogged areas in the IGNP stage I. A land use/cover map depicting irrigated cropped land, barren land and standing water area has been prepared. Electrical conductivity (Micro siemens cm at 25 C) and water table depth data were transferred on the maps.

Waterlogged areas were identified on the basis of following indicaters:

i. Presence of high soil moisture

ii. Standing shallow surface water

iii. Presence of perennial vegetation.

The presence of high soil moisture and shallow standing water indicated by bluish tone on FCC. The perennial vegetation could be identified from its characteristic pink or red on FCC. To ensure that the areas with multicropping pattern do not get misclassified, crop calenders of all the crops grown in the area were checked on the date of imagery i.e. March,16,1990.

## 5.0 RESULTS AND DISCUSSIONS

Waterlogging whether it is due to surface flooding or rise in ground water, inflow and outflow ratio plays an important role. The stagnation of surface water may be usually as a consequence of a low infiltration rate of the soil in combination with rainfall intensities and insufficient surface water drainage. It may also be on account of inundation of back flow or flood in rivers. However, high ground water levels are connected with high infiltration intensities and exfiltration of ground water as a result of restricted or stagnating subsurface flow.

### Over-irrigation in Stage I:

The total culturable command area in upper part of Stage I is 0.37 Mha. With stipulated crop intensity of 110 per cent the gross crop area comes to 0.407 Mha. Since the soils and lands here were better suited to irrigation, the development was fast. It can be seen from the fact that even by the year 1974-75, as against a created potential of 0.29 M ha, 0.26 M ha was commanded. By year 1984-85,of the 0.405 Mha potential area, 0.377 M ha were commanded. For example,as against a potential of 0.172 M ha created here,only 0.037 Mha were commanded. As against this the canal system continued to draw 60 to 65 per cent of the alloted share for the entire command.In other words only about 30 percent of the command area was consuming 60 percent of the water. A rough estimate by a consulting agency (D.R.G., 1987-1988) showed that for Navrangdesar, Rawatsar and Anupagarh systems of Stage I, the delta of irrigation was mostly between 0.9 to 1.10 metres during Kharif and 0.75 to 0.85 during rabi season. A rough calculation for entire Stage I also presented a similar picture. This is far more than the stipulated mean value of 0.51 metres. The situation of over-irrigation had arisen due to consideration of the government to make a maximum use of its allotted share of water and natural tendency amongst the farmers to use a larger quantity of irrigation water than that necessary.

In the early stages of development, the authorities had permitted temporary direct outlets from main canal in interest of a rapid development. However, because of local opposition these were not removed and thus continue to draw unlimited supply of water.

### Seepage losses from the distribution system:

Though the entire distribution system right into the farm out-let is lined, seepage from the system is substantial and contributing to the adverse hydrological regime. The presence of pools of stagnating water along the main canal and to an extent along the Suratgarh Branch and few of the distributories is an evidence of this . A pocket of high water table along the Anupgarh Shakha is primarily due to excessive seepage. The problem is mainly due to stretches of defective lining or damage incurred during running of the canal.

Seepage from Ghaggar Depressions:

In order to protect crops in the fertile and productive Ghaggar Bed, the flood water from Haryana into the river was directed into a series of inter-dunal depressions which lie to the south of the eastern part of Stage I command. Because of a hydrological barrier and a natural gradient, the seepage from these depressions is a major contributor to the water-table rise and inundation of a substantial area of the irrigated command. Since the seepage water is also saline, it is bringing in large quantity of soluble salts into the command. An area of about 7,000 Ha has been rendered water-logged and highly saline and another 15,000 ha is made critical in this respect.

## 5.1 EXTENT AND MAGNITUDE OF WATERLOGGING

The land use/cover categories such as irrigated cropped land,barren land,scanty vegetation in sand,waterlogged areas and canal network delineated from Landsat imagery of March 1990, are shown in Fig. 3. The spatial distribution of waterlogged area and other land use categories were measured by digital planimeter.

Irrigated cropped land covers about 301.25 sq.km area. This includes standing crops, horticulture and pastures during March 1990. The crop land and pockets of scanty vegetation in sand are mostly confined to the canal system. Barren land occupy 48.5 sq.km area which is generally permanently unsuitable for

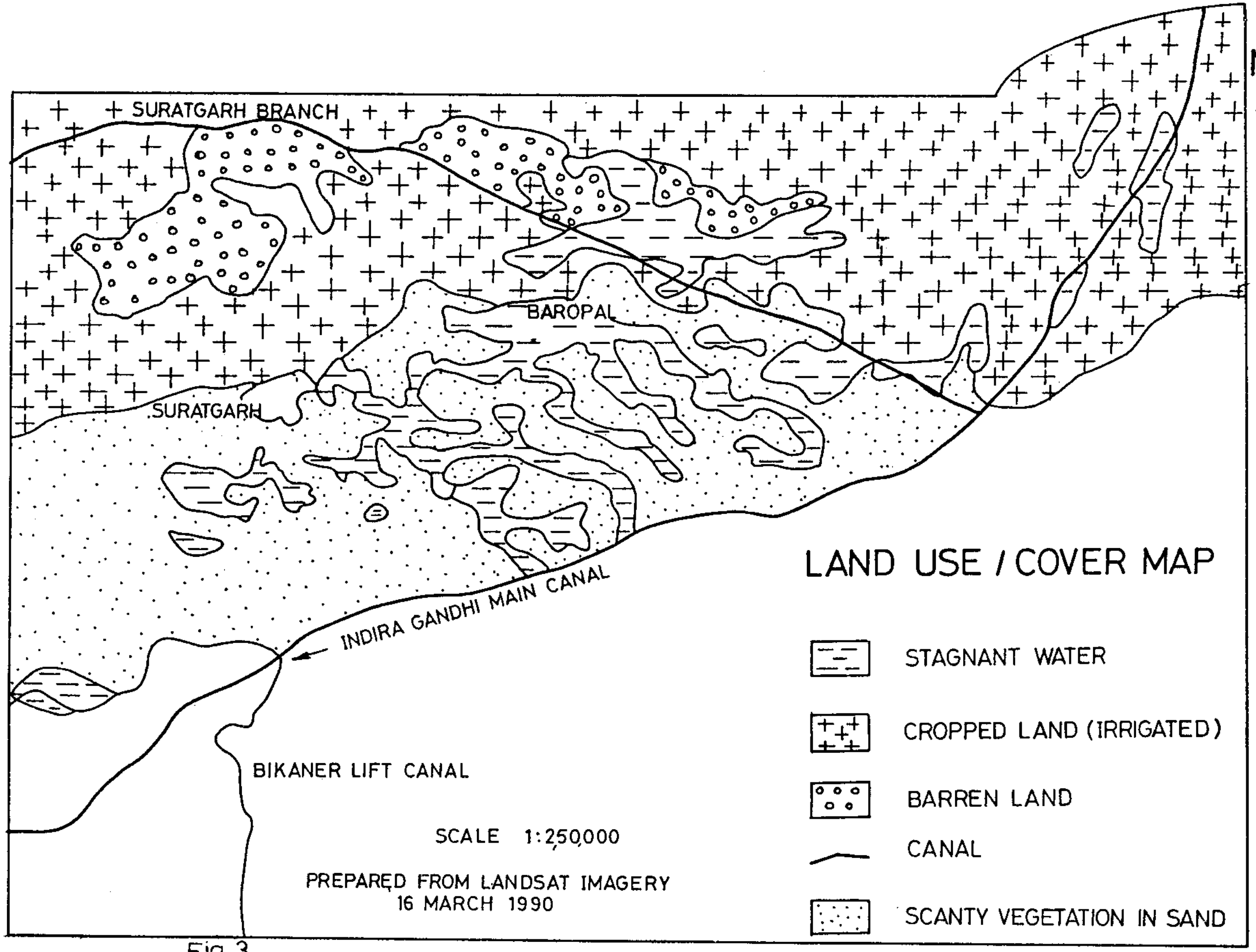

N
SURATGARH BRANCH
BAROPAL
SURATGARH
INDIRA GANDHI MAIN CANAL
BIKANER LIFT CANAL
LAND USE / COVER MAP
STAGNANT WATER
CROPPED LAND (IRRIGATED)
BARREN LAND
CANAL
SCANTY VEGETATION IN SAND
SCALE 1:250,000
PREPARED FROM LANDSAT IMAGERY
16 MARCH 1990

Fig.3

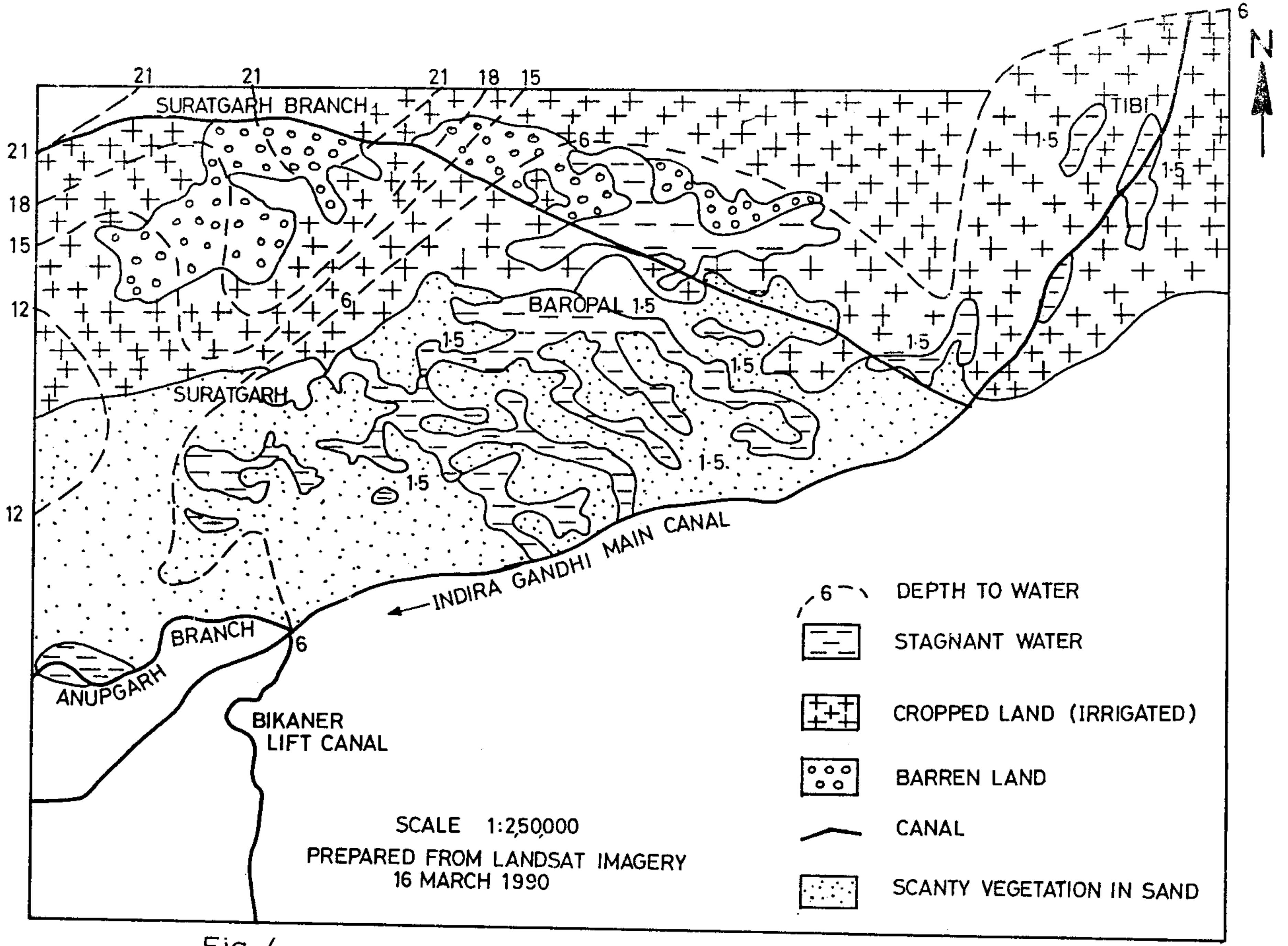
productive use.The command area is divided into two broad regions namely Tibi (primarily between main IG canal and Gaggar diversion channel) and Baropal sector north of Gaggar depressions (Fig.3). In the year 1981,these two pockets were sensitive to waterlogging (water table 1.5 to 6.0 meters) affected area was 742 sq km. As on March 1990,170 sq.km area has water table at a depth less than 1.5 meter from surface and another 81.75 sq.km has stagnating water (Fig 3).

## 5.2 CORRELATION WITH WATER TABLE DEPTH AND ELECTRICAL CONDUCTIVITY

The conventional practice in command area for observing the waterlogged area is to take observation in the existing open well at regular intervals. Presently monitoring is being done in an area of 11300 sq.km through a network of 486 piezometers. The piezometers (486 nos) and recording wells (20 nos) are being monitored quaterly and monthly respectively and water quality analysis is being done half yearly by CAD.

Based on the Ground water table and EC distribution observations obtained from CAD, maps were prepared indicating water table depth and EC contours on Fig.4 and Fig.5 respectively. The areas falling within 0 to 1.5 m generally indicate waterlogged areas. In order to ascertain the extent of such waterlogged areas,collection and analysis of soil and water samples is desirable. The conductivity contours shown in fig. 5 indicate that conductivity values in the waterlogged areas is very high (4000 to 8000 us/cm at 25 C) which suggests the presence of highly saline soils.

The Tibi Sector includes parts of Indira Gandhi Canal, Bhakra Canal and Ghaggar Canal Commands and baropol Sector falls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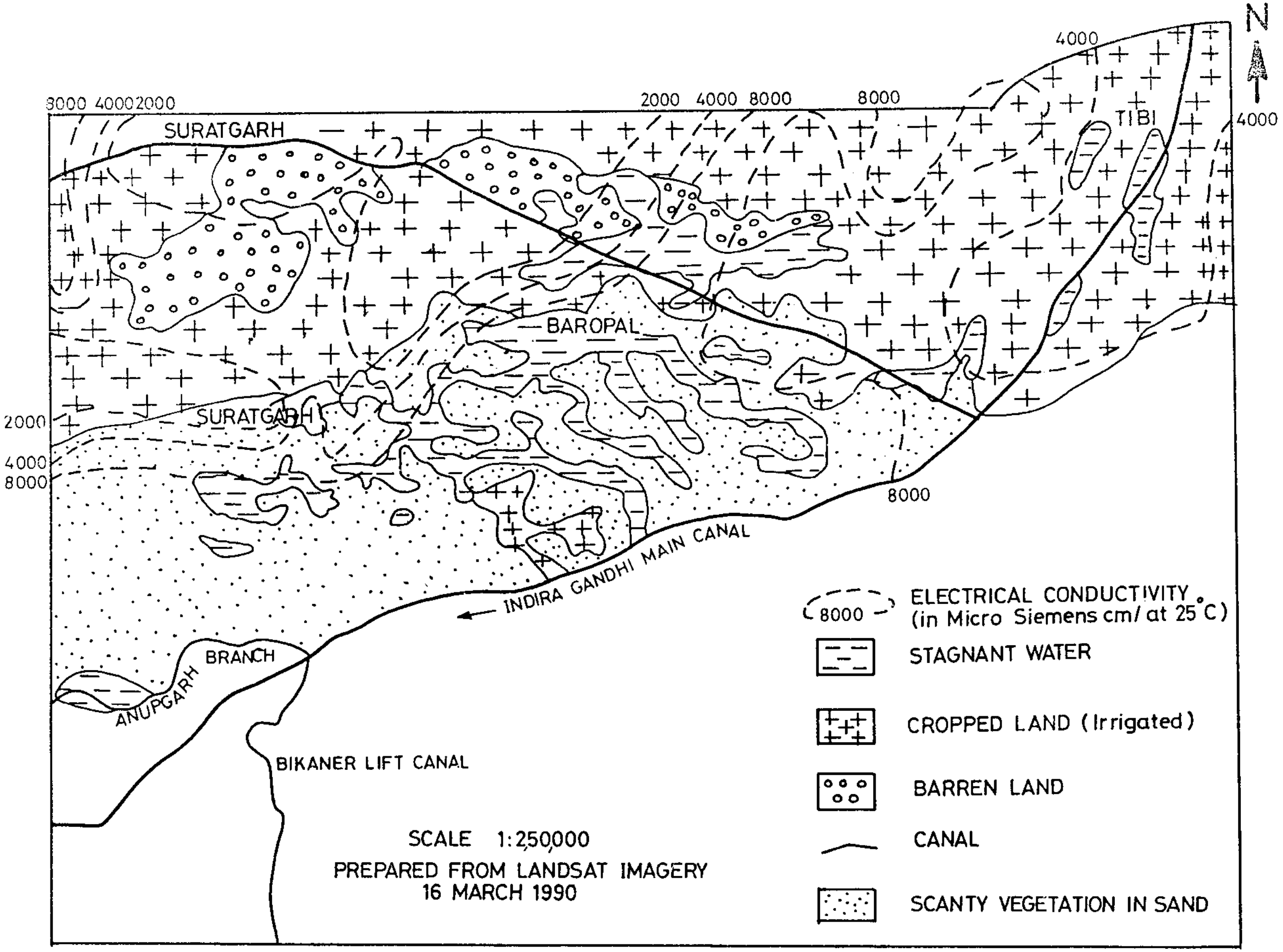
12
INDIRA GANDHI MAIN CANAL
BRANCH
6
ANUPGARH
BIKANER
LIFT CANAL
6 DEPTH TO WATER
STAGNANT WATER
CROPPED LAND (IRRIGATED)
BARREN LAND
CANAL
SCANTY VEGETATION IN SAND
SCALE 1:2,50,000
PREPARED FROM LANDSAT IMAGERY
16 MARCH 1990

Fig. 4



SCALE 1:250,000

PREPARED FROM LANDSAT IMAGERY
16 MARCH 1990

Fig. 5

under the command of Indira Gandhi Canal. But the southern part of this sector is surrounded by line of depression which are filled up with flood waters from Ghaggar river through Ghaggar diversion Channel. The main causes of waterlogging are deep percolation of canal water and seepage from Ghaggar depressions.

Water table in Ghaggar bed and command of Indira Gandhi Nahar Pariyojana State-I in Sriganganagar district during the period from 1981-90 revealed that the water table is continuously rising, with the rate varying from 0.20 m to more than 2.0 m with an average rate of 0.80 m per annum. In some areas, water table has risen to depth less than 6.0 m from land surface. Two such areas have been reported in Tibi Sector, east of Hanumangarh district and Baropal Sector, east of Suratgarh district having waterlogged area of 57,200 th.ha and 56,700 th.ha respectively in 1984, rendering 8,700 th.ha of land out of cultivation (Status report 1992).

The sensitive area in these two sectors has progressively grown and by the year 1988 coalesced to form a continuous tract. The progressive increase over time of the sensitive area is given in table 2. As of year 1990 the area sensitive to waterlogging was 1980 sq.km, which constitute 24.76% of the studied command (Fig 6). Additionally 170 sq.km area has water table at a depth less than 1.5 meter from surface and another 81.75 sq.km has standing water (Fig 3).

The water level records from Sept. 1981 to Sept. 1991 shows that the average annual rise in the area is 0.67 meter (table 3). The suggests that barrier layer, if any, is not a continuous structure. At places salt encrustation is evident on the surface mainly due to alkaline soils IGNP command (status report 1992).

# GROWTH OF AREA SENSITIVE TO WATERLOGGING

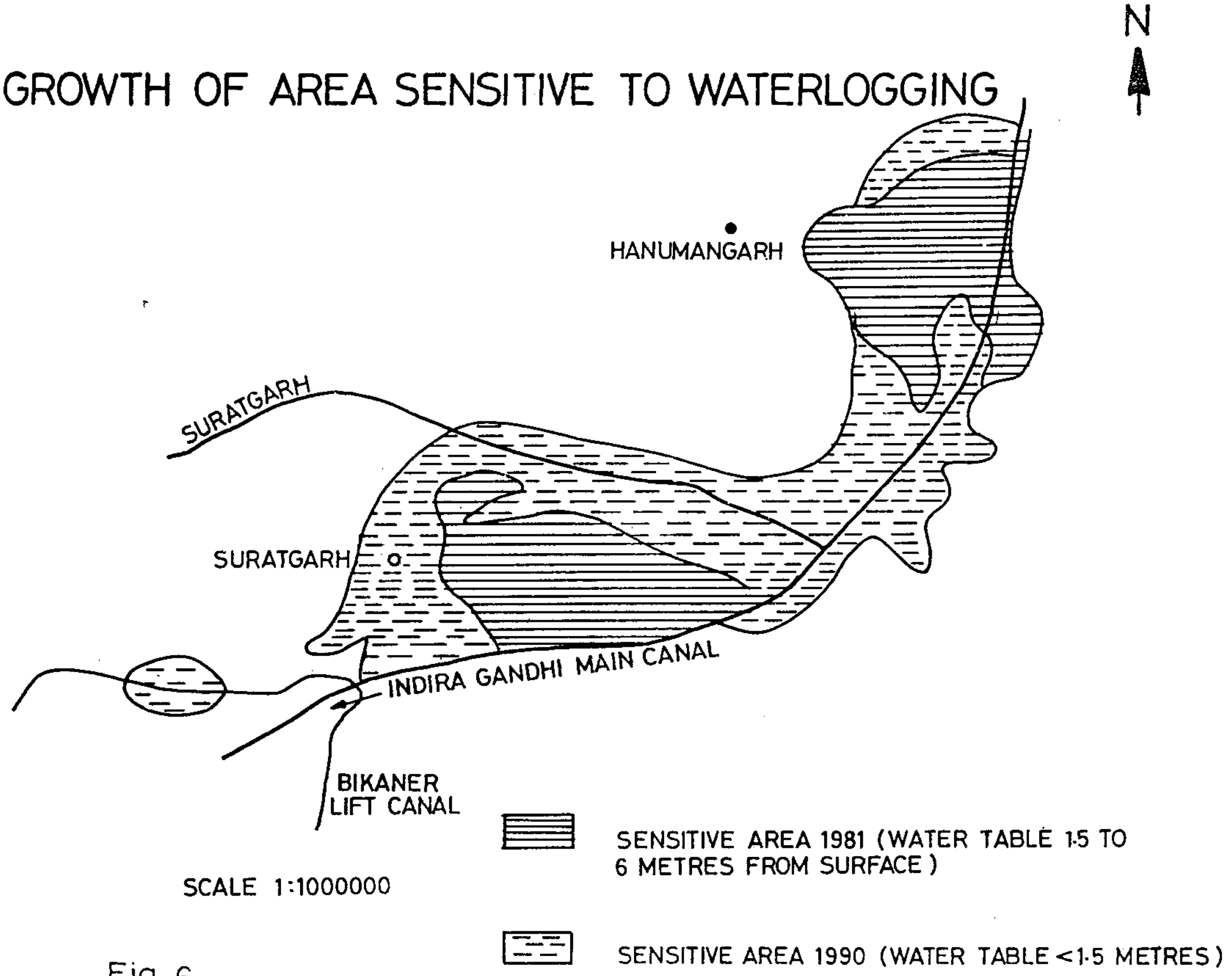


Fig. 6

Table 2

Increase in potentially sensitive areas in IGNP Stage I

| Period | Tibi Sector | Baropal Sector | Vijaynagar Sector | Total | |
|---|---|---|---|---|---|
| | | | | Area in sq.km. | Area in % of total project |
| Sept.,81 | 402 | 340 | -- | 742 | 9.27 |
| Sept.,82 | 440 | 392 | -- | 83 | 10.40 |
| Sept.,83 | 491 | 437 | -- | 928 | 11.60 |
| Sept.,84 | 572 | 567 | 95 | 1234 | 15.42 |
| Sept.,85 | 600 | 606 | 105 | 1311 | 16.20 |
| Sept.,86 | 680 | 640 | 116 | 1436 | 18.20 |
| Sept.,87 | 440 | 340 | 56 | 836 | 10.45 |
| Sept.,88 | Both area joined together 1795 sq.km. | | 65 | 1860 | 23.25 |
| Sept.,89 | -do- | 1840sq.km. | 72 | 1912 | 24.15 |
| Sept.,90 | -do- | 1905sq.km. | 75 | 1980 | 24.75 |

Table 3: Mean rise of water table in stage I of IGNP and adjoining area of other commands for the years 1981-1982 to 1989-1990.

| Command | 1981 to 1982 | 1982 to 1983 | 1983 to 1984 | 1984 to 1985 | 1985 to 1986 | 1986 to 1987 | 1987 to 1988 | 1988 to 1989 | 1989 to 1990 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|
| IGNP stage I | 0.92 | 1.02 | 1.14 | 1.17 | 1.16 | 0.07 | 0.90 | 1.05 | 1.07 | 1.10 |
| Ghaggar flood plain | 0.50 | 1.17 | 1.06 | 1.11 | 1.02 | 0.60 | 0.85 | 0.98 | 0.96 | 0.85 |
| Gang canal | 0.33 | 0.60 | 0.83 | 0.79 | 0.77 | 0.62 | 0.55 | 0.70 | 0.67 | 0.64 |
| Bhakra canal | 0.58 | 0.87 | 0.91 | 0.87 | 0.79 | 0.80 | 0.82 | 0.89 | 0.72 | 0.81 |
| Depressions | 1.08 | 0.93 | 0.68 | 0.80 | 0.80 | 0.70 | 0.78 | 0.90 | 0.86 | 0.84 |
| Average | 0.68 | 0.92 | 0.92 | 0.95 | 0.91 | 0.68 | 0.74 | 0.90 | 0.86 | 0.85 |

All observations for the month of September

Source: Project Officer, Ground Water Wing, CAD, KNP, Bikaner.

Hydrogeological studies were carried out by the State Ground Water Department for examining the feasibility of lowering water table by vertical drainage system can be effective for lowering the water table in Tibi and Baropal sectors by way of constructing battery of tubewells at 1000 m apart. The saline drained water in major part of the area has to be blended in predetermined ratio with the canal water at selected points in such a way that the water after blending is suitable for irrigation. The operation of these tubewells is proposed to be synchronised with the flow cf canals. Consequently the Government of Rajasthan formulated a proposal for vertical drainage pilot project for anti-waterlogging measure in IGNP Stage-I in the district of Sri Ganganagar, during October, 1986, covering an effective area of 1.125 th.ha.

## 6.0 CONCLUSIONS:

IGNP stage I command area faces problems of waterlogging resulting from overirrigation,seepage losses through distributary system and Gaggar depressions.

A rapid and accurate assessment of the waterlogged area can be made by the use of remotely sensed data. Low-lying lands which were not indicated by water table observations as waterlogged could be identified on the satellite imagery.

In the year 1981, Tibi and Baropal sector were sensitive to waterlogging and the affected area was 742 sq km. The sensitive area in these two sectors has progressively grown and in the year 1990 the area sensitive to waterlogging was 1980 sq.km, which constitute 24.76% of the studied command. Additionally as on March 1990, 170 sq.km area has water table at a depth less than

1.5 meter from surface and another 81.75 sq.km has stagnating water. The water table is continuously rising, with the rate varying from 0.20 m to more than 2.0 m with an average rate of 0.80 m per annum.

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