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ASSESSMENT OF WATERLOGGING IN SRIRAM SAGAR COMMAND AREA

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PREFACE

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. It is expected that when the various irrigation projects are completed, irrigation will be practiced 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 waterlogging 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.

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. After commissioning of the Sriram Sagar Irrigation Project in 1970, there was a general rise in ground water table. The Sriram Sagar command area faces problems of waterlogging resulting from over irrigation & seepage losses through distributory system.

This study is an attempt to assess the areas affected by waterlogging and areas sensitive to waterlogging in the Sriram Sagar command area using Indian Remote Sensing Satellite data. The study has been carried out by Dr. V.K.Choubey, Scientist E of the Institute.

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ABSTRACT

Waterlogging is becoming a serious problem in command areas and although the area affected by waterlogging has been small, it is spreading slowly. Sriramsagar command area has been selected for this study, which is about 120 km north of Hyderabad. This area was chosen because, after the construction of the main canal and subsequent release of water from the canal system, it was observed that in certain regions the groundwater table has risen rapidly.

The groundwater rise in Sriram Sagar command area was also partly due to non-usage of groundwater compared to canal water. This has resulted in making the water of the crops leading to a drastic reduction in their yield. The historical rise in groundwater level is 4.43 to 5.86 m over a period of 10 years. In this study an attempt has been made to make an quantitative assessment of waterlogged area and sensitive areas to waterlogging during pre & post monsoon period in the Sriram Sagar command using remotely sensed and field data.

A rapid and accurate assessment of the extent of waterlogged areas can be made from using remotely sensed data. Visual interpretation of IRS-1A-LISS-II FCC of April 12, May 27, October 6, and November 18, 1989, (path 25, 26 row 55) was carried out to prepare land use, drainage map and delineation of waterlogged area in the Sriram Sagar command area. IRS-1A-LISS-II digital data (CCT's) of April, and October 1989 were analysed to assess the areas affected by waterlogging and the areas sensitive to waterlogging. An attempt has been made to validate the IRS derived waterlogged area with the available water table depth

data and other field informations.

The result obtained from this study indicate that in April and October, 1989, an area of 388 and 540 sq.km was affected by waterlogging and about 698, 802 sq.km area was sensitive to waterlogging, where water table lies in between 0 to 3 m respectively. It is suggested that periodic assessment of waterlogging using remotely censed data should be carried out in the Sriram Sagar command.

The annual rise in groundwater level is 2.0 m to 4.8 m, the rate of rise varies between 0.17 to 1.2 metres per month and the rate of fall varied between 0.25 to 0.84 metres per month.

The IRS data have been proved to be very successful for the assessment of waterlogging. Density slicing and principal component analysis are useful techniques to make an assessment of waterlogged areas in irrigated command area.

1.0 INTRODUCTION

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.

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 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.

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 unfavorable 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 percent of the world 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 centre, 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 21 st century.

The Irrigation Commission in 1972 estimated the utilisable surface and ground-water resources as 8,70,000 million cubic meters, whereas, the actual utilisation was about 1,72,500 million cubic meters 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 meters per year. It is expected that when the various irrigation projects are completed, irrigation will be practiced over at least double the present area. 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 waterlogging 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 unjudiciously, the excess water induces the raising of ground water table. Some times water -logging in the low lying areas is 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 waterlogging and increase salinity. Also the obstruction of natural drainage by way of construction of roads, railways, aerodrums, 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 deserves even in the major and medium irrigation projects. In absence of such drainage system, the problem of waterlogging is created. Another adverse impact of irrigation management is the creation of soil salinity and alkalinity which adversely affect the soil productivity.

Waterlogging in the irrigated command area has been given little attention by the farmers or the administrators. Crop yields have decreased and areas affected by waterlogging have increased over the years because of the lack of an integrated approach to water use management.

Inadequate efficient drainage system in irrigation project, 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 in 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 as 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 agroclimatic conditions.

This report describes the application of Indian Remote Sensing Satellite-1A data in the assessment of waterlogging in Sriramsagar Command Area (Kakatiya Canal upto Maniar dam).

2.0 REVIEW

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.

Out of a total of 40 million hectares (ha) of irrigated area in India, 10 million ha are affected by waterlogging (Vohra, 1980), with about 6 million ha severely waterlogged (Bowonder, 1983). In India, severity of the problem arises due to the size of the average holding is small and hence remedial action involves a large number of water users. This is more so because corrective action in terms of reaching individual farmers and changing their attitudes towards water use is a slow, time-consuming and costly proposition.

The sandy loam soils of the Sriram sagar command area are conducive for easy drainage and the rainfall (955 mm) is enough to leach these soils, the provision made (0-116km) for drainage is small (0.6 percent)

	Rupees in Lakhs	Precent
Main canal including structures	3251	19.2
Lining of Canal	2200	13.0
Distributories	9525	56.1
Field Channel	1889	11.1
Drainage	107	0.6
	16972	100.0

Other factors which intensify the problem of waterlogging are seepage from the canals and distributories and silting up of existing drains. In all the cases only the main canal is lined.

The Working Group on Command Area Development for VII Five Year Plan has recommended that to assess the magnitude of the problem and advise remedial measured pilot projects be undertaken in command area having diverse ground water and soil set up. The aim of these experimental studies should be to assess the general groundwater situations and changes recorded therein after introduction of canal irrigation and to identify preventive and remedial measures and draw up action programme to tackle the situation in a scientific manner.

2.1 WATERLOGGING AS A PROBLEM

Waterlogging is the problem of a rising water table and the consequent increase in salinity of the soil. This has a deleterious effect on the soil fertility. Waterlogging affects agricultural yields in a number of ways:

(1) land cannot be used for more than one season in a year;

(2) land can be used for cultivation of only one crop type;

(3) land becomes a pool of stagnant water and cultivation becomes difficult;

(4) land becomes saline and unfit for sustaining any plant growth.

Waterlogging and soil salinity are closely interrelated. The salts present in the soil in a dissolved state do not evaporate with the soil moisture. Therefore, as moisture in the soil evaporates, the salt content of the remaining water .increases. Irrigation waters unused by plants may percolate down to the water table, which in turn become increasingly salty (Eckholm, 1976). In the absence of any means of draining the irrigated water, the water table begins to rise. Seepage from canals and tanks adds further to the level of the water table, reaching the root zone of the crops.

When saline water reaches the root zone, it inhibits crop growth. Even when the water is not salty, it damages the crop by choking the roots and cutting off the oxygen supply (Eckholm, 1976). Once the water table is within three meters of the surface, water begins to move upward by capillary action. As water reaches the surface and evaporates, a thin deposit of salt will be left behind. As a result, the soil becomes saline. In most cases, a rise of the water table causes secondary soil salinization, either because of high salinity of the ground water or dissolution of solid-phase salts by rising fresh groundwater (Worthington, 1977).

Todd (1956) the changes in ground water levels can be due to natural or artificial means. The changes in external loads induces variation in ground water level. Various external factors affecting are secular and seasonal stream flow, evaporation, atmospheric pressure and tidal effects.

Rao (1986), identified the problem of drainage and suggested the effective drainage measures namely channel resectioning, clearing vegetation from drainage way and sub surface drains. Patel (1989) suggested that water balance should be worked out between the amount of water supplies available at the head work and water required to be diverted for irrigation to the command area and losses in transmission.

The various causes for waterlogging as summarised by Chitale (1991) are i) seepage from unlined canals ii) damaged portions of lined channel beads, iii) blockage of natural drainage due to the net work of canal and roads, iv) poor working of existing surface drainage systems, v) very little utilization of ground water for irrigation, vi) internal flow of subsurface water, and vii) injudicious water management. He expressed that during the phase of irrigation, drainage is generally not provided in most of the developing countries.

Bouwer et al (1990), reported that waterlogging and salinisation of irrigated land are natural hazards of irrigation development especially in the semi-arid climate where irrigation is a must. Much of the waterlogging and salinization of irrigated land is due to the inadequacy of drainage measures and poor maintainence.

Walton (1970) found changes in water level in open wells due to precipitation, evaporation and withdrawal during growing season. He indicated possibilities of developing relationship between these factors.

Agarwal and Malik (1982) studied the water table behaviour of Haryana State by dividing it into two zones, one the in central and south western region with brackish ground water. They found that the average annual rise of watertable ranged from 8 to 68 cm after the introduction of the canal in the central and south-western region while it declines from 10 to 15 cm per year in the good water quality region. The rise in watertable of central south-western region was mainly due to limited exploitation of groundwater, excess rainfall and canal water levels.

Sondhi et al (1987) assessed the ground water resources of a canal command area at Mahi Right Bank Canal (MRBC) for the period 1976-77 to 1979-80. They quantified the different components of ground water recharge using ground water recharge equation and water balance equation. Their study reveled that the average annual recharge to ground water basin during the study period was of the order of 1260 million cubic metres. Part of this a quantity of 500 million cubic metres contribute towards the increase of the ground water storage.

The serious problem of waterlogging arises from a number of factors:

(1) The area under irrigation is increasing, but the rate at which the waterlogged area is increasing is higher than the rate of growth in irrigated areas (Vohra, 1980).

(2) The land affected by waterlogging is comparatively superior in quality as far as agricultural fertility is concerned, since the land lost for agricultural purposes is irrigated land and not uncultivable land.

(3) The critical factor impeding agricultural development in India is lack of water rather than lack of available land. Waterlogging will severely limit agricultural productivity in India (Dopfer, 1979; Allaby, 1977).

(4) Waterlogging is caused by the interaction of a large number of factors such as ground water recharge, drainage surface irrigation, cropping patterns, groundwater pumping for irrigation, soil characteristics and seepage from field channels and distributaries. Hence, once the problem becomes acute, change in any one or two of these factors alone cannot immediately reverse the trend.

(5) Overuse of water results in a decreased efficiency of fertilizers which again is undesirable.

Hence, waterlogging is a serious environmental management problem. Farmers who are not well educated in water management consider water to be synonymous with yield and tend to overuse it, ignoring the long term possibilities of waterlogging and salinity. The extension of irrigation to new areas is a fairly recent activity and thus farmers do not have prior experience in systematic water use management practices. Waterlogging can therefore be identified as a problem of managing a common pool of resources (Baden, 1977). Farmers individually try to maximize their productivity by increased usage of water in their own fields, which ultimately affects the drainage and groundwater level. Their action affects not only individual farmers, but eventually the whole group.

The Government of Andhra Pradesh entrusted the work to Ground Water Department to monitor ground water fluctuation and the change in its quality in Sriram Sagar command area. Accordingly the work of selection of observation wells in the command are was started after completing rapid reconnaissance survey of the project area to know the geology, topography and drainage pattern during April 1972. An area of 65000 hectares between the dam site and Paddavagu II, covering command area in the taluks of Armoor and Metapally was taken up initially. This is the command area of South Canal of the project, otherwise called as Kakatiya Canal.

Groundwater monitoring programme in Sriramsagar Project Command Area was initiated in June, 72 with the aim of locating such areas which are prone to waterlogging, so that necessary remedial measure can be taken up by way of lowering of water lowering of water table. For suggesting the remedial measures studies were carried out on the following lines:

(1) Determination of critical depth of water table which is

controlled by (a) type of crop, (b) type of soil, (c) total dissolved solids present in groundwater and (d) evapo-transpiration rate.

(2) The study or groundwater flow direction in fixing the alignment of drainage net work.

(3) Estimation of horizontal permeability and storage coefficient or specific yield of the shallow formations.

(4) Estimation of vertical permeability at various depths.

(5) Determination of depth to impervious formations.

(6) The study of change in water quality.

(7) Collection of soil types including grain size analysis, soil moisture etc.

A survey conducted by Bownder and Ravi (1983) in the Sriramsagar Command Area indicated that out of 2000 hectares of irrigated area surveyed 400 hectares is severely waterlogged. Only paddy can be grown in these lands and the yields are lower compared to those in non waterlogged areas. Over 100 hectares of land has been rendered completely useless for agricultural purposes. It is difficult to taken up cultivation in these areas as the water table has risen to the ground level and the areas have become marshy.

2.2 REASONS FOR WATERLOGGING

The reasons for its occurrence are as under:

(1) There is overuse of water in many fields, since water is easily available. The water charges are based on area of land and not on the quantity of water used.

(2) Since agricultural extension has not concentrated on water use patterns, farmers are not aware of optimum water use management practices.

(3) None of the distributaries of the main canal have been lined. Because of this, seepages occur, causing a rise in the water table. Although this is a temporary phenomenon, occurring only when water flows through the distributaries, it aggravates the incidence of waterlogging.

(4) Poor drainage facilities have also been responsible, since the facilities provided are inadequate in the wet season.

(5) Although the Groundwater Department has suggested that curtailment of water in waterlogged areas can reduce the incidence of waterlogging farmers are reluctant to accept this advice. They are not aware of the conjunctive use of canal and groundwater.

(6) Although the Groundwater Department has established a demonstration centre in a waterlogged area to show that the conjunctive use of canal and well water can decrease waterlogging, the message has not percolated down to the actual users. Out of 100 farmers interviewed, only 10 expressed awareness of conjunctive water use as a means of reducing waterlogging.

(7) There is a lack of co-ordination between the Agricultural Department, the Groundwater Department and the Irrigation Department, even though the Command Area Development Department is the co-ordinating agency.

(8) Agricultural Department officials, of the Command Area Development Department and farmers are more concerned about immediate or short - term gains and achievements. Even agricultural extension workers tend to underplay the long-term effects and lowering of yields in certain locations in the command areas. The human mind works in such a way as to

project the occurrence of a desirable rather than a negative outcome (De Bono, 1977; Johson, 1979).

(9) Economically poorer sections will tend to discount the long-term effects, in contrast to economically well-off people. Because of this, smaller farmers tend to give very little attention to waterlogging.

Hence, waterlogging is a combined effect of under development, lack of extension education, less than optimal utilization of water resources, stress on short-term gains, poor water management practices, little emphasis on conjunctive water use and a lack of awareness concerning environmental factors.

2.3 REMEDIAL MEASURES

Though a number of other command areas in India have waterlogging in more severe forms, no corrective steps are being planned (Report of Irrigation Commission, 1972). In the case of the Sriram Sagar project, because of the stipulation of the World Bank, a Ground water Monitoring Cell has been established, which has been studying the incidence of waterlogging and its increase in terms of area. No system has been planned for corrective action nor have funds been allocated specifically for this purpose. In fact, the Irrigation Department has not been taking any initiative in corrective action since their objective is to provide water and not the conjunctive use of water. Environmental conservation programme (such as soil protection, remedies of waterlogging and afforestation) have not been integrated with development programme in the command area.

Temporarily reducing canal irrigation with the simultaneous withdrawal of groundwater through pumping is the main solution. Varying the release or flow of canal waters and encouraging supplementary irrigation from wells are other alternatives. This is difficult to implement because farmers do not like to reduce the usage of canal water since they perceive water as a scarce and critical input Only through demonstrations and agricultural extension programme. Agricultural extension workers are not trained in water use management, conjunctive water use and optimal water use; hence, agricultural extension does not cover these aspects. Furthermore, the number of extension workers available for given area is small, so existing workers emphasize production issues and pest management rather than water use. The existing demonstration centre cannot cater for the needs of the whole command area. Benchmark surveys must be conducted to study the effect of waterlogging on different soil types on a long-term basis coupled with cropping patterns. In a canal irrigated area with field-to-field, irrigation extension education on conjuctive use of water can have only a salutary effect. At the design stage itself, separate field channels must be provided to various farms if water usage is to be efficient.

Technically, drainage must be provided, as well as lining of distributaries. Drainage water use must be improved since it can be used for unirrigated area. Here again, the funds provided for drainage have been totally inadequate. Unless the distributary canals of the project are lined, the solution to the problem will remain elusive. Every year, a part of the distributary should be lined. The World Bank must examine these issues in detail in its evaluation.

Application of fertilizers more suitable to waterlogged areas. must be promoted. For this extension education among the farming community may be necessary Fertilizers such as ammonium chloride are tolerated by plants in larger doses in waterlogged areas. This is ideal for waterlogged soils where sulphate fertilizers tend to produce sulphate injury and poor crop growth.

On the whole, the solution to waterlogging lies mainly in intensive agricultural extension programme comprised of training and education in water-use management practices. for this, extension workers must be trained in water use management at all levels. It can be seen from Table 4 that perceptions of waterlogging as well as perceived solutions to the problem are very different among various groups. Environmental management programme should include training of soil scientists, administrators, civil engineers and decision-makers, to make them aware of the long-term implications of misusing land and water.

(1) Waterlogging is caused by an intricate play of factors such as farmers attitudes, soil characteristics, withdrawal of groundwater, irrigation and cropping practices, provision of drainage and farmers' education on conjunctive use of water. It will be difficult to contain waterlogging by simple technical approaches since waterlogging is an environmental problem caused by underdevelopment, lack of education and stress on immediate economic benefits.

(2) Although groundwater levels are being monitored because of the stipulation by the World Bank, no corrective action has been envisaged so far. Funds must be allocated specifically for environmental protection and conservation in terms of water-use management, which are long-term oriented objectives.

(3) Intensive education on farmers seems to be the only long-term solution, but this action is slow and costly. In new command areas, farmers' education should be started before the onset

of irrigation. Funds must be allocated to such education and demonstration programme.

(4) Changing agronomic practices and changes in fertilizer application can prove to be viable solutions to waterlogging. Crop rotation and using new genotypes of seed (not susceptible to waterlogging) or higher water regimes are also possible solutions that can be implemented.

(5) Waterlogging is a problem that is difficult to perceive and understand for inexperienced farmers not well versed in irrigated agriculture methods. Concepts like efficient use of water, together with conjunctive and optimal uses of water, should be taught to children in schools. Water is a scarce resource in the tropics of South-East Asia and every effort should be made to correct its misuse and overuse.

(6) Waterlogging can be considered as a common resource management problem; hence, corrective action initiated only by governmental agencies may be ineffective. Public participation and involvement of voluntary agencies in remedial action must be sought. Farmers participation should be promoted and incentives provided for farmers applying remedial measure.

(7) Environmental management training should be given to decision makers and administrators, highlighting the fact that water and soil are long-term capital assets and any deterioration in their quality is likely to be counterproductive.

2.4 REMOTE SENSING

Remote sensing techniques have the potential to overcome the manpower and fiscal restrictions that now limit large scale mapping of waterlogged area. Visible and near infra-red multispectral images are the most useful data currently available to map vegetation pattern, waterlogged areas, dry soils etc., and corresponding hydrological processes at regional and global scale. There are limitations in applying the multispectral image data to ground based measurements that are used to characterise hydrological data and bridging from the scale of local field measurement to regional scale. The foremost limitation arises because field measurement of the hydrological parameter do not have to be concerned about reflected solar radiation, however to make use of remotely sensed data it is essential to understand the correspondence between scene radiance as recorded in multispectral images and field parameters such as water table depth and vegetation cover, species, developmental stage and soil type etc. Remote sensing survey could be conducted to study the effect of waterlogging on different soil types on a long term basis coupled with cropping pattern.

The experience at National Remote Sensing Agency Hyderabad, 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 multi-temporal 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 gray 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.

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.

Choubey (1993 & 1994) had conducted a study to assess waterlogged in Indira Gandhi Nahar Pariyojna stage I and Tawa command area using remotely sensed data and concluded that rapid and accurate assessment of the waterlogged area can be made by the use of remotely sensed data.

No attempt has been made so far by A.P Irrigation and Ground Water Departments and other organisations to assess and monitor waterlogging problem in the Sriram Sagar command by remotely sensed data.

3.0 STATEMENT OF PROBLEM

The Agricultural Department as well Command Area Development Authority do not consider waterlogging a serious problem since they see it only in terms of total agricultural production. Since total production. Since total production has not been decreasing they have very little concern for waterlogging. Though the Command Area Development Authority is the agency for co-ordinating, education, planning and agricultural production, long-term consequences are discounted as long as the short-term outputs are not affected.

Farmers who have no experience in overcoming waterlogging tend to neglect the severity of the problem, even though the The Groundwater Department educate farmers how to overcome waterlogging but, in spite of this, farmers have been very slow to respond to this advice and demonstration. The means to reduce such risks lie in intensive education and information transfers at the non-technical level. Without farmers understanding the severity of the risk caused by waterlogging, their participation is likely to be poor in all remedial action recommended.

Results of the studies undertaken in the country, demonstrate the usefulness of remote sensing techniques for the assessment and monitoring waterlogged areas. A rapid and accurate assessment of the waterlogged area can be made by the use of remotely sensed data.

No attempt has been made so far by A.P Irrigation and Ground Water Departments and other organisations to assess and monitor waterlogging problem in the Sriram Sagar command by remotely sensed data. In this study an attempt has been made to evolve a methodology for the assessment of waterlogging in the SRS command area. Visual interpretation of IRS-1A-LISS-II, false color composites have been used for the preparation of land use, drainage and waterlogged areas mapping. Digital image analysis has been done by ILWIS image processing system for IRS-1A-LISS-II data of April-May and October-November 1989 for the assessment of waterlogged area and the sensitive areas for waterlogging.

4.0 STUDY AREA

4.1 SRIRAM SAGAR PROJECT

In this study, waterlogging in the command area of the Sriramsagar (SRS) Project has been assessed. The SRS project across the River Godavari at Pochampad is about 5 kms upstream of Soan Bridge on the Hyderabad-Nagpur national highway. The catchment area of the dam is 91,750 sq. km; the water spread of the reservoir is 453 sq. km, with a capacity of 3.17 TM cubic metres (Subramanyam, 1979). The reservoir utilize 1,869 TM cubic metres of water and irrigate 0.23 million hectares of land in the districts of Karimnagar and Nizamabad, of which one-third would be under wet cultivation and the rest under dry crops such as maize, jower, chillies and pulses.

The command area of the SRS Project consists of undulating terrain with numerous granite rocks. The area is comprised of prominent ridges and valleys formed by gully erosion; it slopes towards the River Godavari and is drained by many small streams that empty into the Godavari and its distributaries. The majority of the soils are sandy loams. Though soil conditions support easy drainage, there are a number of low-lying areas requiring systematic drainage facilities.

The basement is shallow 8 to 10 m and the weathered and fractured granite aquifer has a transmissivity 30 to 200 m/d. The quality of groundwater suitable economical where the transmissivity of the aquifer is less than 100 m /d and where the basement is near the ground (Murty, 1990).

4.2 LOCATION

Sriram Sagar Project is one of the important major irrigation projects in Andhra Pradesh and is formed across river Godavari (Photograph 1). The project has an extent of 178000 ha cultivable command area covering the districts of Karim Nagar and Nizamabad (Fig.1).

4.3 PHYSIOGRAPHY

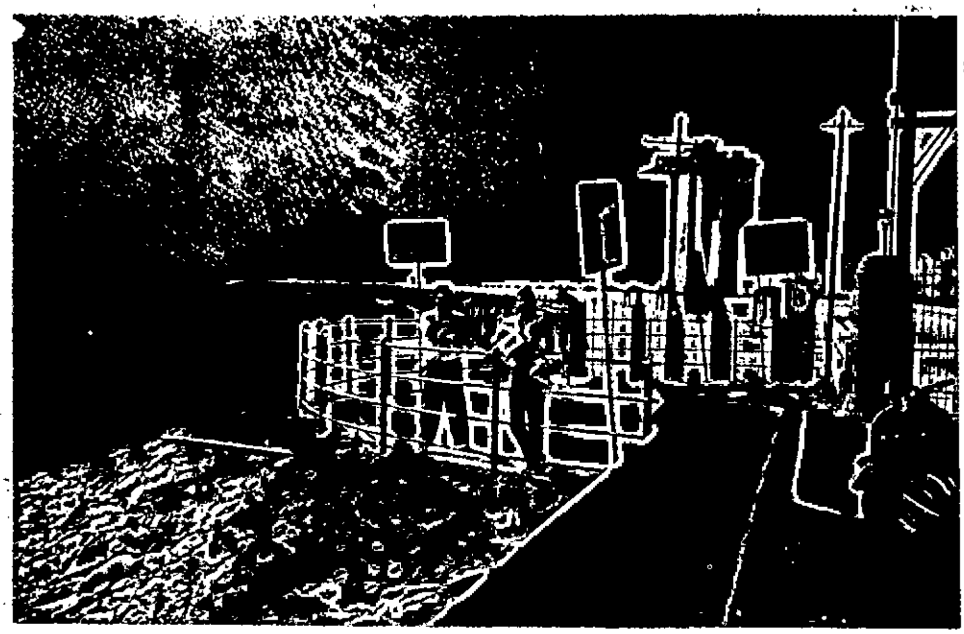
The area is drained towards Godavari river. The drainage pattern is dendritic (Fig. 2). Undulating topography is characteristic of the area and hence distributaries are aligned on ridges (Fig. 3) About 95% of the area has a slope less than 1.5% (G W D 1992). The maximum and minimum elevation of the area are 300 and 200 m above mean sea level respectively. The normal monsoon rainfall in the area is 986mm.

4.4 SOILS AND CROPPING PATTERN

The predominant soil type of the area is red sandy loams of good permeability. The black sandy, silty loams are found to occur in low lying areas stretching along the streams and also in the irrigation tank commands. Paddy is the principal crop grown extensively in the areas receiving canal water and also tank water. Sugar cane is found grown sparsely. In areas not receiving canal water, paddy and I.D. combinations are grown under well irrigation.The I.D crops generally grown are turmeric, maize, groundnut, chilies, red grams and sesamum (GWD, 1992).

4.5 HYDROGEOLOGY

The main rock types occurring in command area are pink and gray granites, with fine to coarse grained texture (Fig.4). Most of the ridge and relief areas are developed into poorly to moderately weathered formations. Low lying and plain areas are developed into moderately to highly weathered formation. The



Photograph 1. Sriram Sagar Project dam site

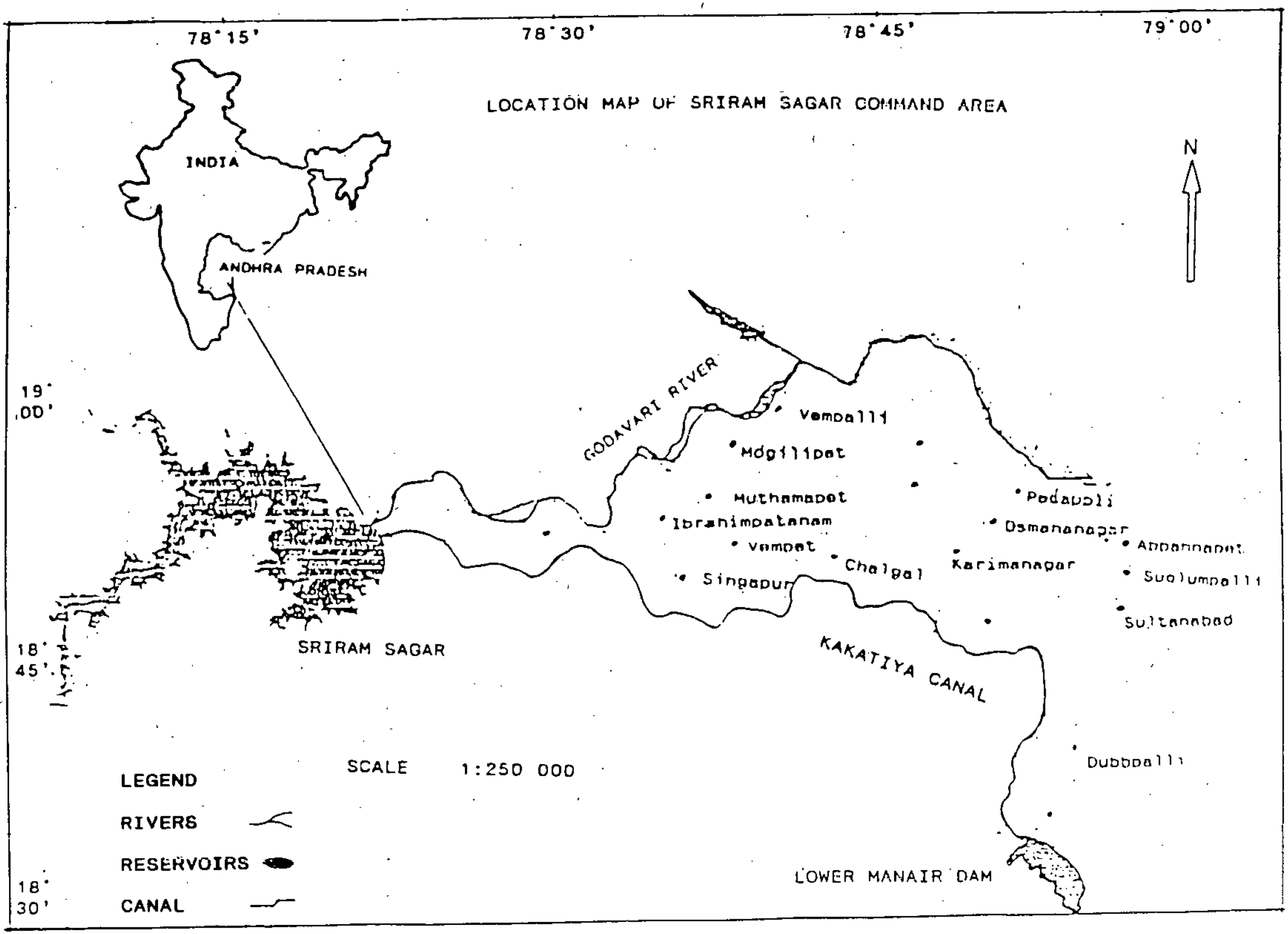


Fig. 1 Location map of Sriram Sagar command area.

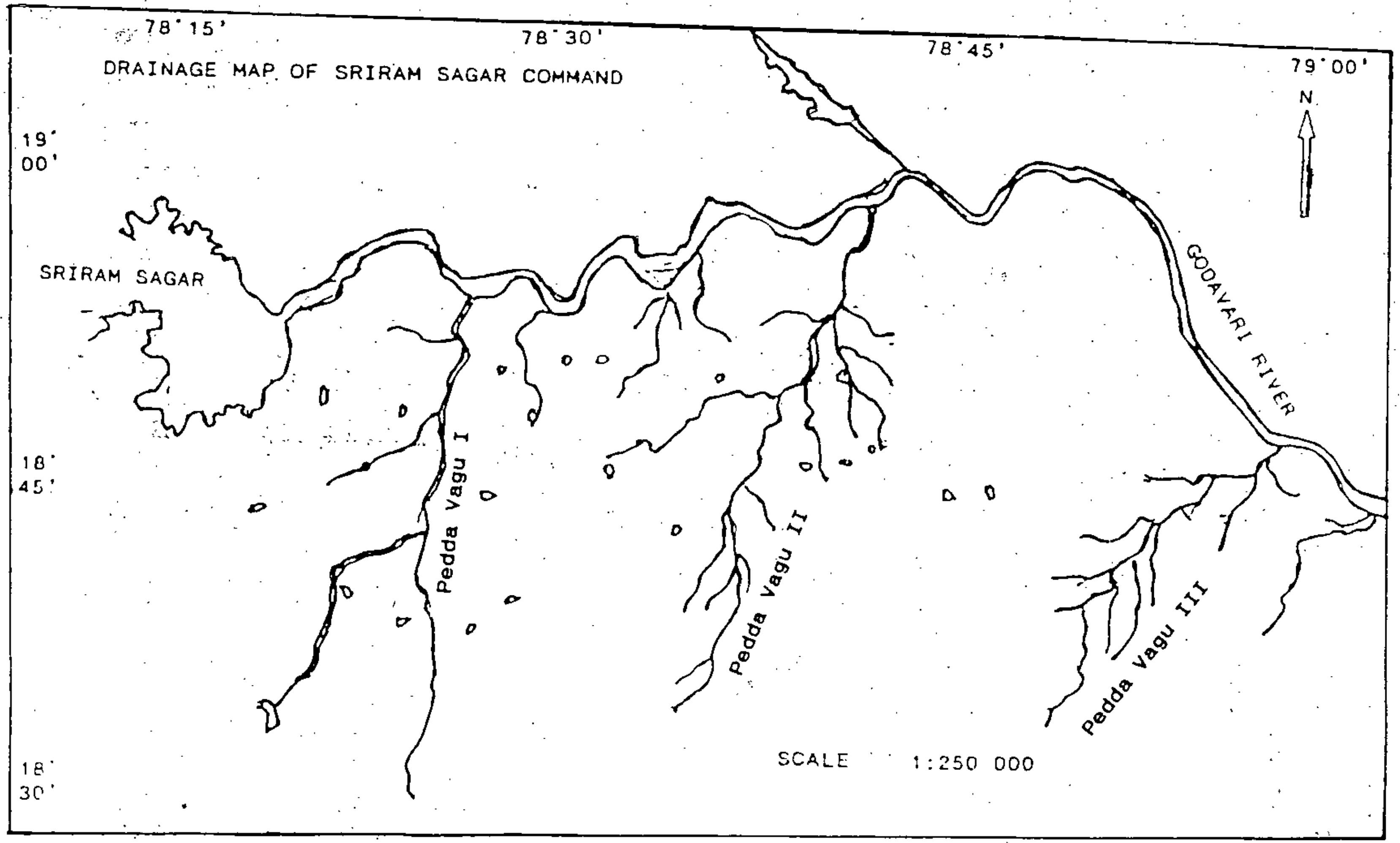


Fig. 2 Drainage map of Sriram Sagar command.

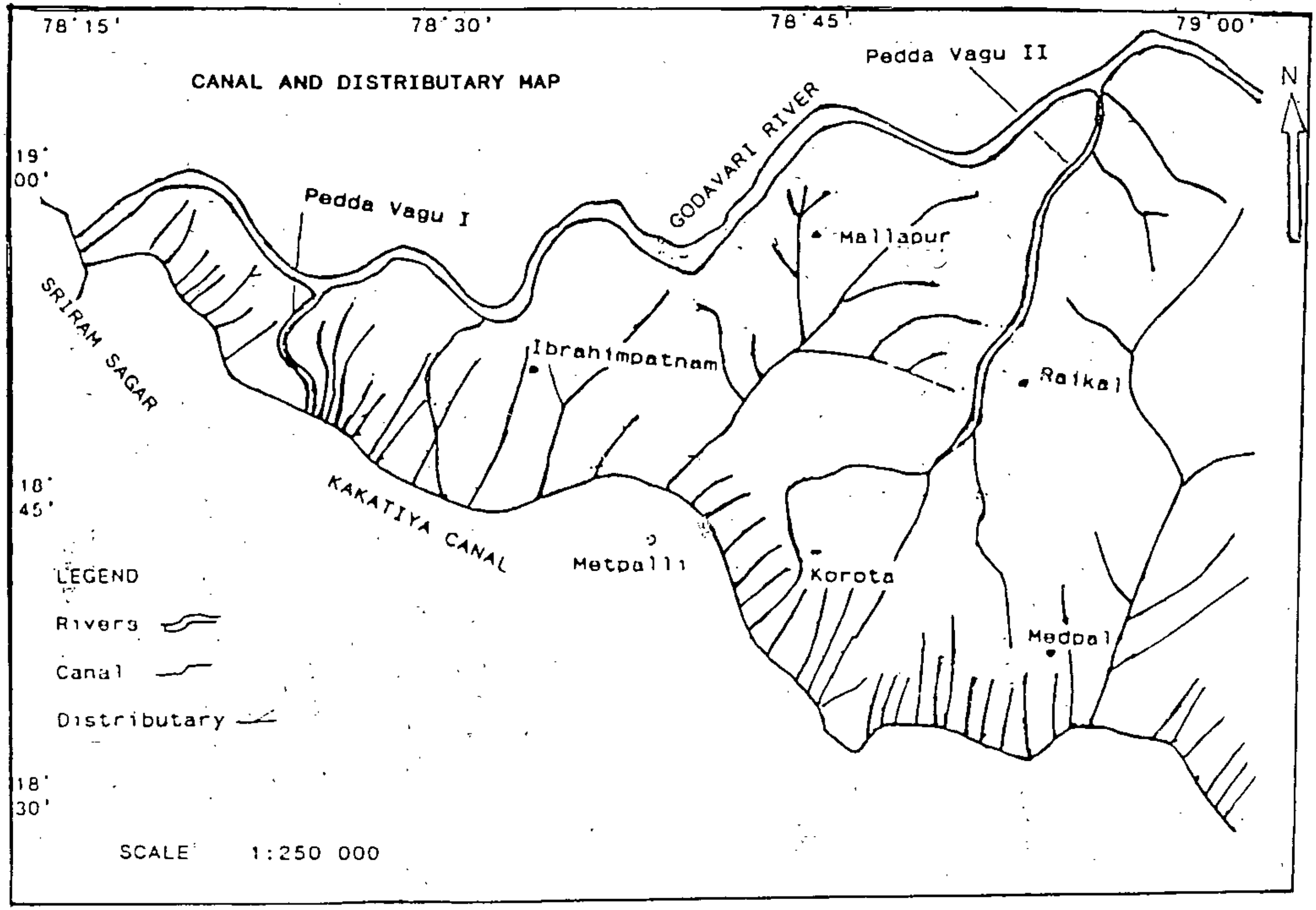


Fig. 3 Canal and distributary map of Sriram Sagar command (Source: A.P Ground Water Deptt. Hyderabad).

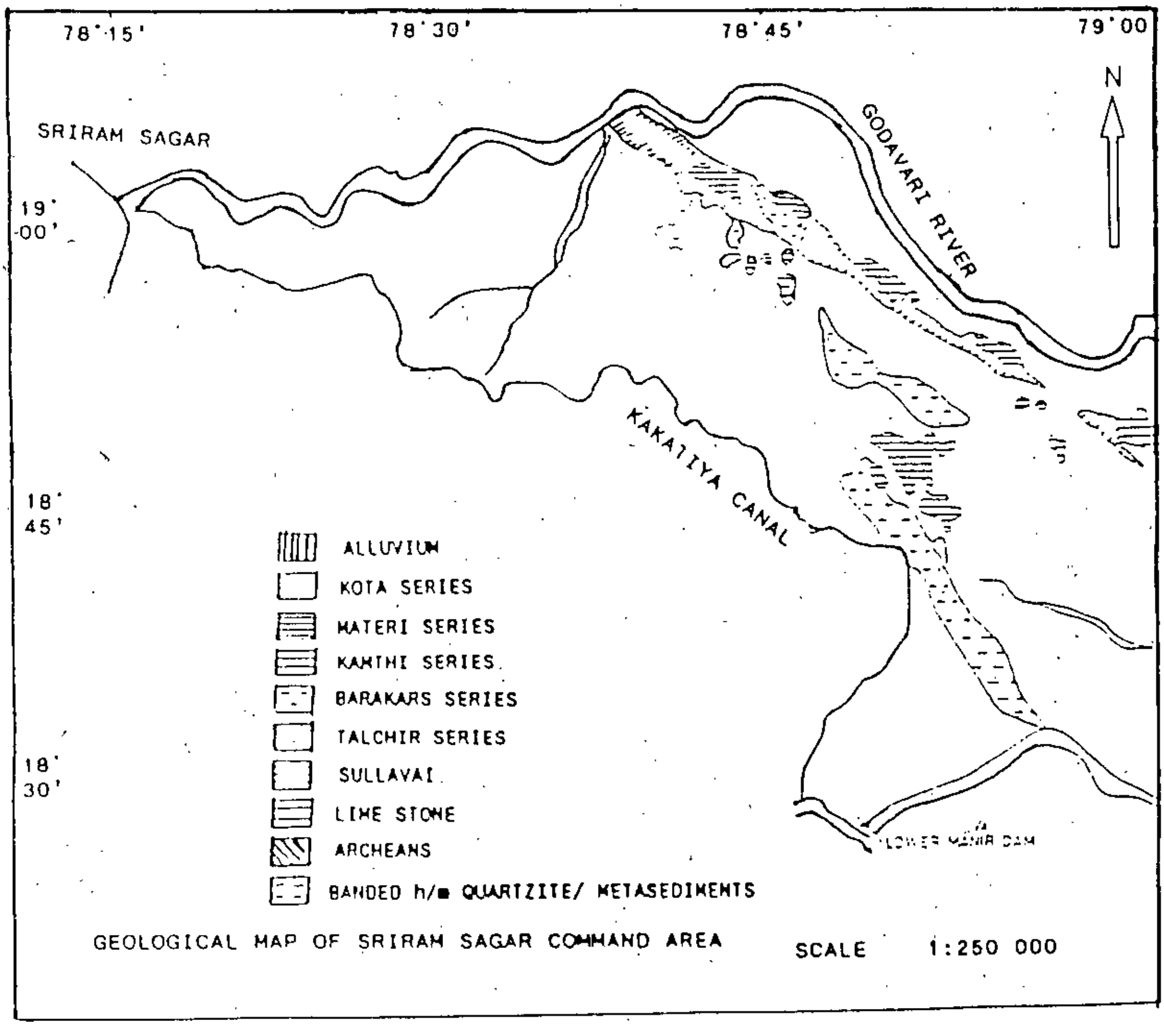


Fig. 4 Geological map of Sriram Sagar command area
(Source: A.P Ground Water Deptt. Hyderabad)

thickness of weathering extends upto 11m. It is observed that weathering intensity decreases with depth and generally basement is encountered without fracturing. Hence dug wells are feasible and bore wells are not feasible in general (GWD, 1992).

Water table varies from ground level in canal fed areas to 10 m in tail end areas. In the areas receiving canal supplies, the wells existing prior to the project are not being put to use now. These areas are under sugarcane cultivation. Wells are found to be excavated to maximum depths 2.5-4.0 m to meet the water demand during canal off season. Where as in the tail-end areas wells are used in both the seasons (GWD, 1992).

4.6 WELL YIELDS

The wells of different sizes and depths are constructed to suit the land holdings and cropping pattern. The well yield ranges from 120 m / day to 3.0 m / day as shown in the table below. The average well yield of 6 m diameter well are:

Category	Kharif	Rabi
Head reach	120	60
Middle reach		
Tail end areas	60	30

(Source : Ground Water Department report, 1992).

4.7 WELL DENSITY

The well density and ground water draft (for 90-days pumping at rabi daily Yield) has been reported in the localised command in the respective head reaches, middle reaches and tail-ends and existing number of wells in the areas (Shetty, 1995).

	Well density	Ground water draft
Head reach	0.2068 per Hectare	0.540 Ha-m
Middle reach	0.1791 per Hectare	0.540 Ha-m
Tail end	0.1547 per Hectare	0.225 Ha-m

5.0 METHODOLOGY

5.1 DATA USED

Following Indian Remote Sensing Satellite data were used in this study.

S.N.	Path Row	CCT/FCC	Date	Scale
1.	25-55 A1,A2	FCC	12 April 89	1:250,000
2.	26-55 B1	FCC	27 May 89	1:250,000
3.	25-55 A1,A2	FCC	18 Nov. 89	1:250,000
4.	26-55 B1	FCC	6 Oct. 89	1:250,000
5.	25-55,26-55	CCT	12 April 89	
6.	25-55,26-55	CCT	6 Oct. 89	

Survey of India Topographical maps 56 N,I,J and M (1:250,000 scale) were used.

5.2 ANALYSIS

A remotely sensed multispectral image encoded information on the properties of the surface materials. In addition to these potential inputs, every pixel may include information on a mixture of surface material.

IRS-1A-LISS-II false color composite (path 25 & 26 row 55) of April 12, May 27, Oct.6, Nov.18, 1989 were visually interpreted to prepare land use/cover map, drainage pattern and map showing waterlogged area in the command.

The objective of image analysis is to link image spectra to dominant scene components or to spectral characteristics of wetlands, dry soil and vegetation. Gray level analysis and principal component analysis techniques have been tested in the semiarid Sriramsagar command areas upto Manair dam for the assessment of waterlogging using IRS images and insitu spectral data. Although standing water has a characteristics reflectance in the visible and near infra-red using conventional image processing method.

IRS-LISS-I computer compatible tapes of April 12 and October 6, 1989, were analysed by ILWIS image processing system to assess waterlogged area in the command during pre and post monsoon period.

To ensure that the areas with multicropping pattern do not get misclassified, crop calendars of all the crops grown in the area were checked on the date of imagery.

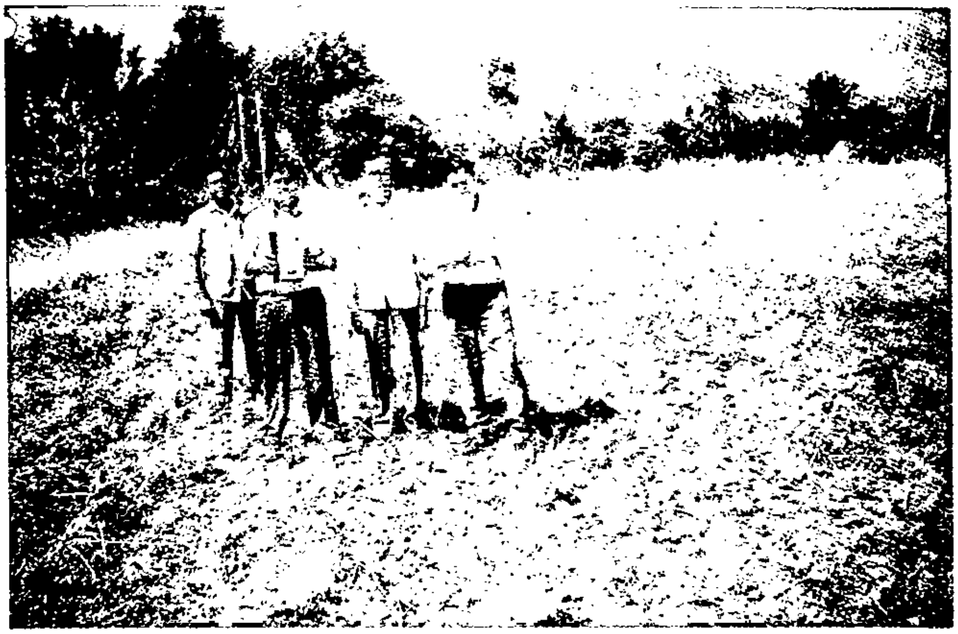
Subscene of Tawa command area extracted from IRS computer compatible tapes for April and October 1989. ILWIS image processing system has been used for image analysis. Band ratioing, density slicing and principal component analysis has been carried out for all the scenes.

Initially all the four bands were used in analysis, however infra-red Band 4 was selected for density slicing. Waterlogged areas in the command were identified and mapped during April and October 1989.

The first step was to chose pixel from the image that best represent specific parameter of the surface material such as soil, wetland, water and vegetation.

Radiometric data of water and soils from different sites in the command area have been collected (Photograph 2, 3, 4 and 5). The low radiance for water and dry soil as the highest radiance values were used to obtain the corresponding IRS pixel values.

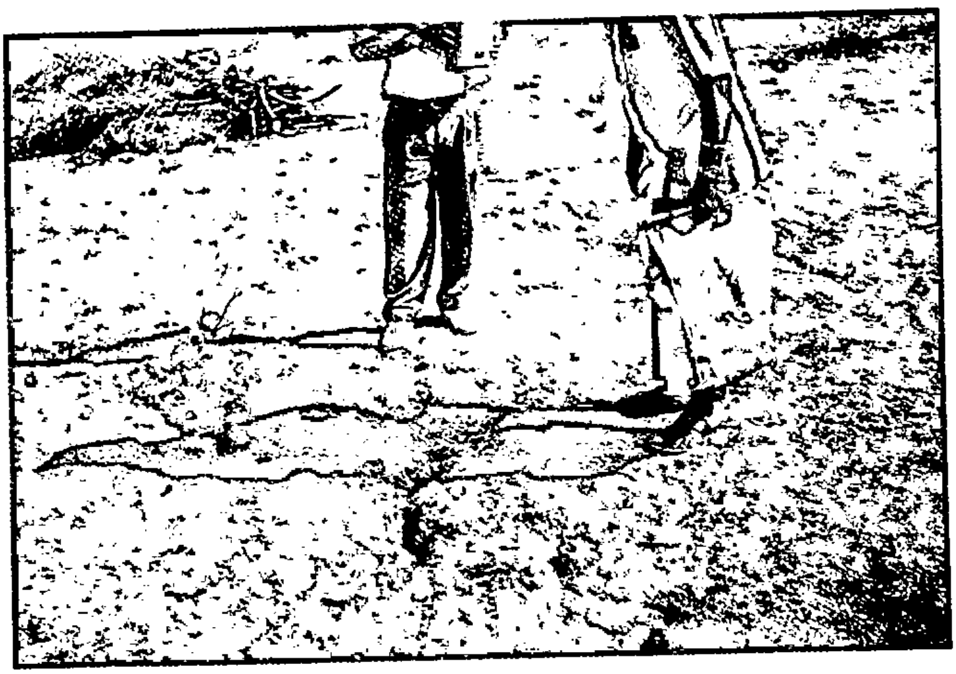
Topographic information is a basic requirement for the



Photograph 2. Radiometric measurements of soil at Cha?ga? form in Sriram Sagar command area

Photograph 3. Radiometric measurements of water at Sultanabad tank in Sriram Sagar command area

Photograph 4. Radiometric measurements of rice crop at Suglumpalli in Sriram Sagar command area



Photograph 5. Radiometric measurements of waste land (dry soil) at Appannapet in Sriram Sagar command area

assessment of waterlogging in the irrigated command. Contour map at a interval of 20 meters was drawn from Survey of India toposheets and prepared a digital elevation map (Fig. 5).

Density slicing and principal component analysis techniques have been primarily used to map standing water and vegetation in command area. The standing water and vegetation cover maps reported herein were prepared from IRS images using spectral analysis and calibrated by field reflectance spectra. The resulting images were then further calibrated to field measurements of plant cover together with other dry and wet soils. Cluster analysis was used to determine the relationship between radiance for IRS images taken at different times. Finally results were compared to data and maps collected from Ground Water Department, Govt. of Andhra Pradesh, Hyderabad.

A field trip was made in the month of March-April 1996 to carryout field checks, radiometric, tensionmeter (Photograph 6) measurements and collection of hydrometeorological and ground water table depth data.

Photograph 6. Tensionmeter measurement and collection of soil sample in Chalgal form

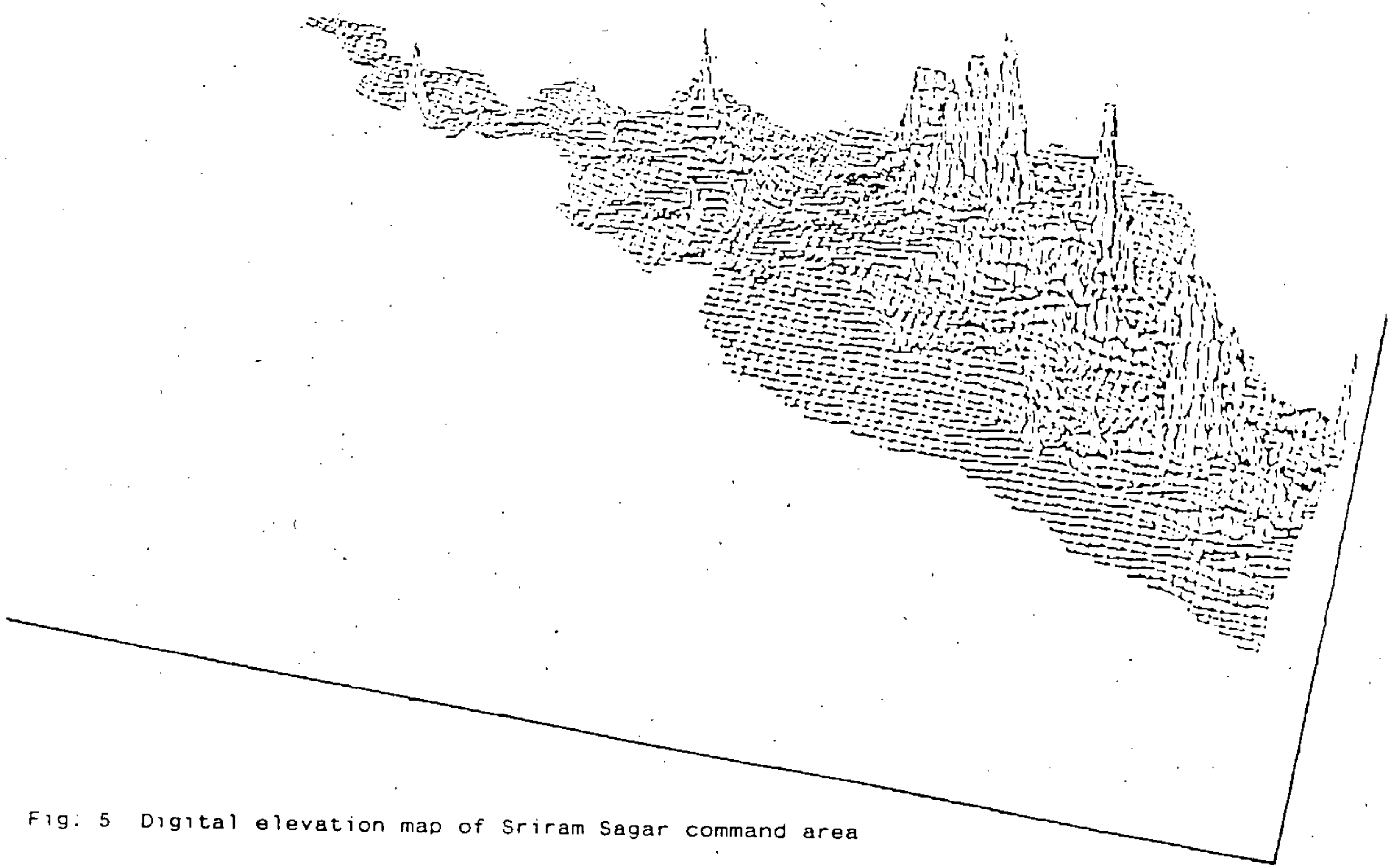


Fig: 5 Digital elevation map of Sriram Sagar command area

6.0 RESULTS AND DISCUSSIONS.

The irrigation canal of the SRS Project was commissioned in 1970. The water table levels in the command area have been rising since that time, with an increase of 19 cm per year over the entire command area.

The area is nearly semi-arid. The soils in the area are classified as loamy sands, silty loams, and silty clay loams. Loamy sands having high percentage of coarse particles show low field capacity and porosity whereas silty clay loams having low percentage of coarse particles show high field capacity. Thus the porosity and field capacity increase as the percentage of fines increase. The infiltration rates varied from 0.012 - 0.12 cm/hour for paddy land with standing crop to 3.7-8 cm/hour for dry land.

The area is covered by exposures of rocks on the northern and northwestern parts. In the southern part of the area, various types of granites having joints in NNW-SSE direction are found. Ground water occurs in the weathered and fractured portion of the granitic rock under unconfined to semiconfined conditions (Murty 1990). Aquifer tests were carried out by Murty (1990) on twenty boreholes. The transmissivity values varied from 30-200 m/d indicating the heterogeneous nature of the medium. Murty (1990) has also conducted geoelectrical investigations to study the layering of the subsurface and to determine the depth to the basement. The studies indicate that the depth to the granitic basement is very shallow and rarely exceeds 16 to 18 m, otherwise the mean depth in the region is about 8 to 10 m. This could be one of the reasons for the parts of the command area threatened by waterlogging. The elliptical shape of anistoropy diagram clearly shows the presence of large fracturing at depth.

6.1 GROUNDWATER MONITORING

The Government of Andhra Pradesh initiated the ground water monitoring studies in Sriramsagar project Command area having a localised ayacut of 2.70 lakh hectares under the Kakatiya canal upto 234 km. length from Sriramsagar Project Dam site to beyond Lower Manair Dam upto DBM -31 covering part, of the Nizamabad, Karimnagar and Warangal districts (Fig.1). Ground water monitoring is carried out by measuring the water levels in 345 observation wells established in the command Area.

Based on the Hydrological data it is reported that 228 (66.10%), 109 (31.59 %) and 79 (22.90%) observation wells are showing waterlogged conditions in October, April 1989 and June 1988 respectively. The percentage of the wells falling under waterlogging and prone to waterlogging etc., are shown in the table 1.

The depth to water levels below ground level map showing waterlogged area, prone to waterlogged area and normal area for the period April and October, 1989 are shown in Fig. 6 & 7 respectively.

There is a rise in depth to water levels in most of observation wells and fall in a few Observation wells during the months from June '89, October 89 in the command area , In October 89 the depth to water levels varies from 0.05 to 12.10 m. below ground level. The Hydrological investigations reveals that in 228 observation wells are falling under waterlogging conditions

Table 1. Waterlogging condition during October, April and June 1989.

Sl. No.	DTWL. range in 'm'	No. of wells falling.	% of Ob. wells falling	Remarks.
October 1989				
1.	0-3	228	66.10	Waterlogging
2.	3-6	98	28.40	Prone to water logging
3.	Above 6	9	2.61	Normal
	Not measured	10	2.89	-
		345	100.00	
April 1989				
1.	0-3	109	31.59	Waterlogging
2.	3-6	145	42.03	Prone to waterlogging.
3.	Above-6	90	26.09	Normal
4.	Not Measured	01	0-29	-
		345	100.00	-
June 1988				
1.	0-3	79	22.90	Waterlogging
2.	3-6	152	44.06	Prone to Waterlogging
3.	above-6	112	32.46	Normal.
4.	Not measured	2 (dry)	0.58	-
		345	100.00	

(Source: Groundwater Department, Govt. of A.P)

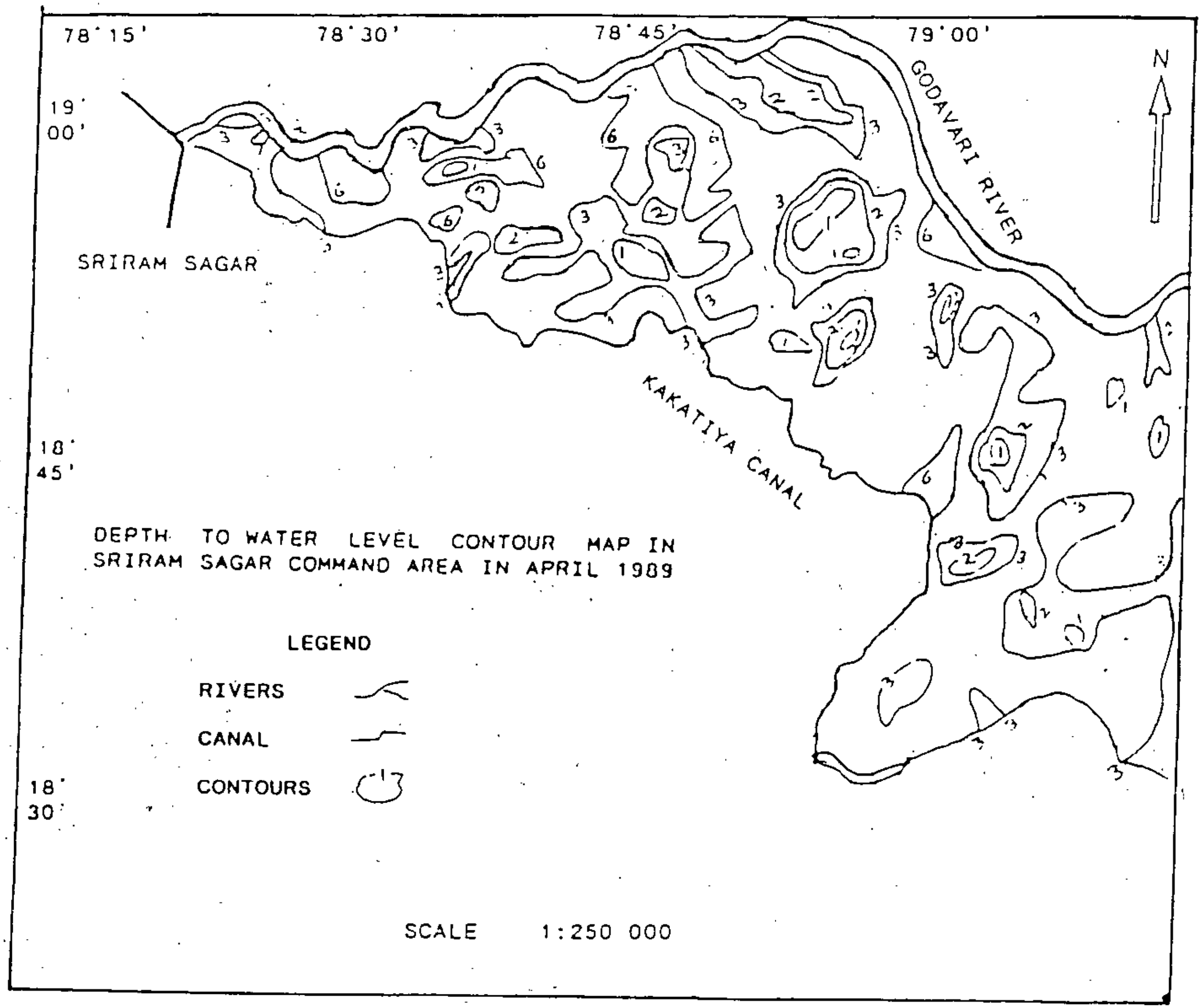


Fig. 6 Ground water level in April 1989 in the command (Source: A.P Ground Water Deptt. Hyderabad).

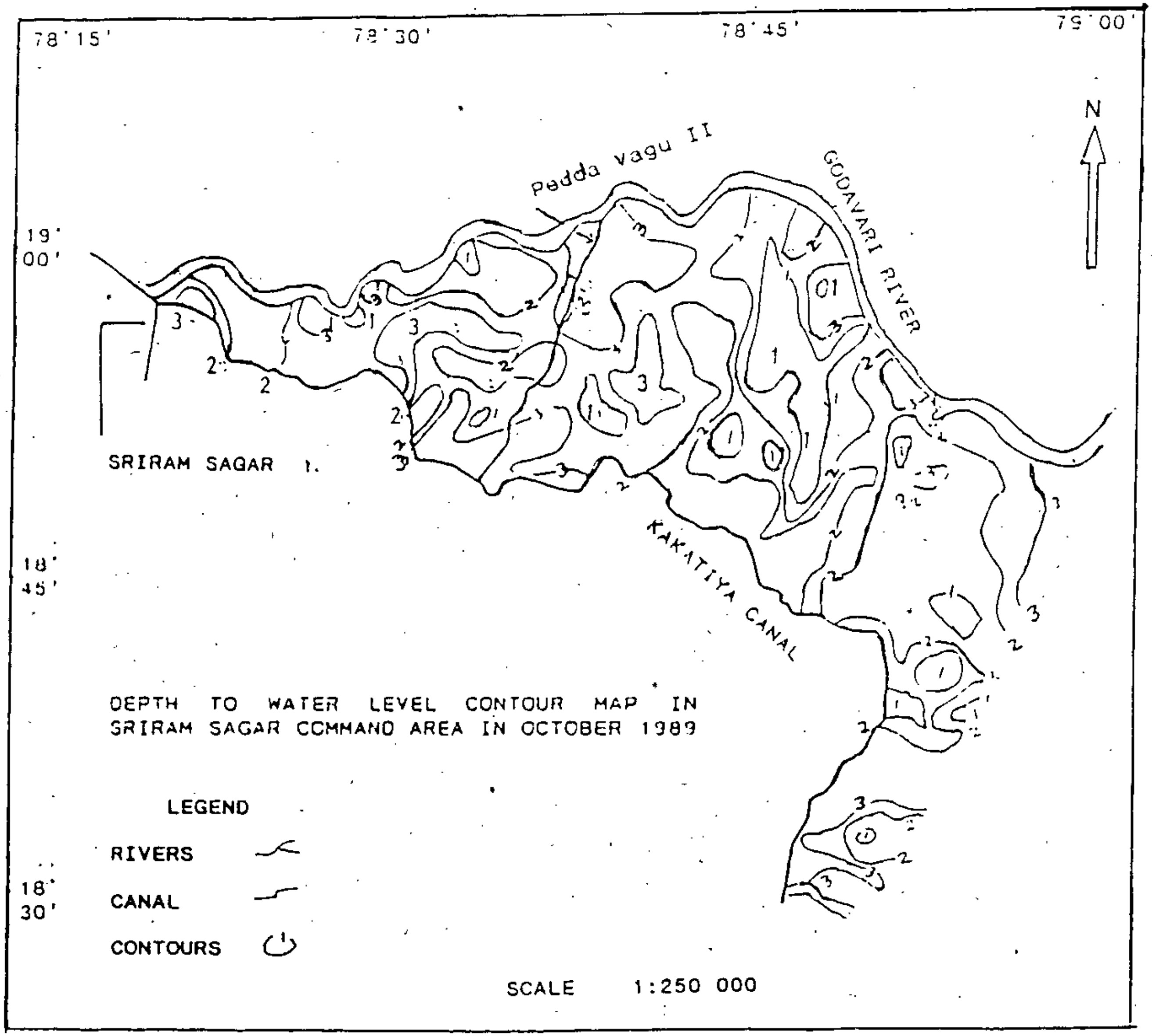


Fig. 7. Ground water level in October 1989 in the command (Source: A.P Ground Water Deptt. Hyderabad).

during October 89. The base flow of 12 stream flow check points is measured in the command area during October 89 ranges from 0.109 to 52.625 m /sec.

The range of rainfall group for the study area which have a probability occurrence of 75% or more probability of getting rainfall in the group range of 700-800 mm (Shetty, 1995). In general the rainfall in the study area is dependable and can be considered as adequate.

The effect of the water table on yields is crop-specific. Wheat and sugarcane are affected when the water table is within 0.6 meters; maize, bazra and cotton are sensitive to a water table within 1.2 meters; gram and barley within 0.9 meters. For other crops, the critical depth is 1.5 meters (National Commission on Agriculture, 1976). The areas where the water table level is between 1-3 meters are considered as areas prone to waterlogging. In irrigated areas, it is desirable to keep the average water table well beyond the capillary range of 3 meters, if not deeper. hence, it is desirable to keep the water table below 3 meters below the surface, then the area is free from waterlogging. Hydrograph of selected observation wells (Fig. 8), indicate that the water level in the observation wells have shown an increasing trend. The areas free from waterlogging have been decreasing in the command area. The problem will become severe in many locations depending on the topography, water use pattern, water withdrawal rates and drainage rate (Bowonder and Ravi 1983).

6.2 IRS-1A-LISS AND FIELD DATA ANALYSIS

IRS-1A-LISS-II false color composites (FCC) of April 12, May

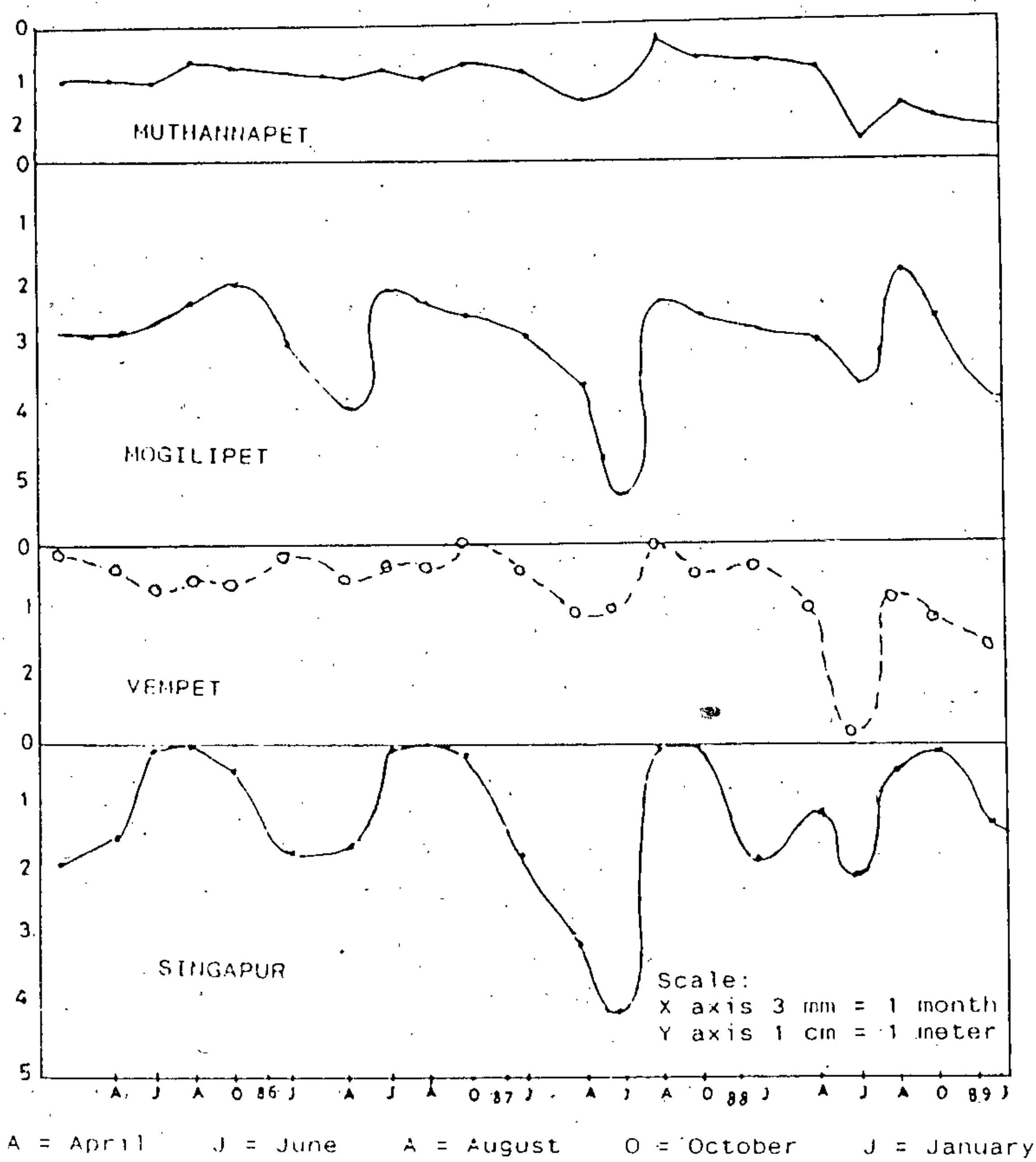


Fig. 8 Hydrograph of selected observation wells
(Source: A.P Ground Water Deptt. Hyderabad)

27, Oct.6 and Nov.18, 1989 were visually interpreted to prepare land use/cover map, drainage map and delineation of waterlogged areas in the command. The computer compatible tapes (CCT) of April 12 and October 6, 1989 were analysed to assess waterlogged area in the command during pre and post monsoon period.

6.2.1 LAND USE/COVER MAP

A land use/cover map has been prepared from IRS FCC at a scale of 1:250 000. The command area has been categorised into land use classes (Fig. 9).

The agriculture land (cropped) appears reddish to brownish in colour with smooth texture in plain areas. The cropped and fallow land occupy about 2185 sq. km in command area. Forest areas (349 sq. km) showed bright red color and coarse texture and observed in a hilly terrain. Water bodies such as reservoir, pond, waterlogged area can be identified in FCC by deep blue color with smooth texture.

6.2.2 MAPPING OF WATERLOGGED AREA

False color composite (FCC) and infra-red Band 4 of October 6, and November 18, 1989 were visually interpreted to delineate waterlogged areas (standing water) in the command (Photograph 7) and a map showing waterlogged area during October-November 1989 (post-monsoon) has been prepared (Fig. 10).

Waterlogged areas were identified on the basis of, presence of high soil moisture; standing water; 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. The crops grown in the area were checked on the dates of imagery.

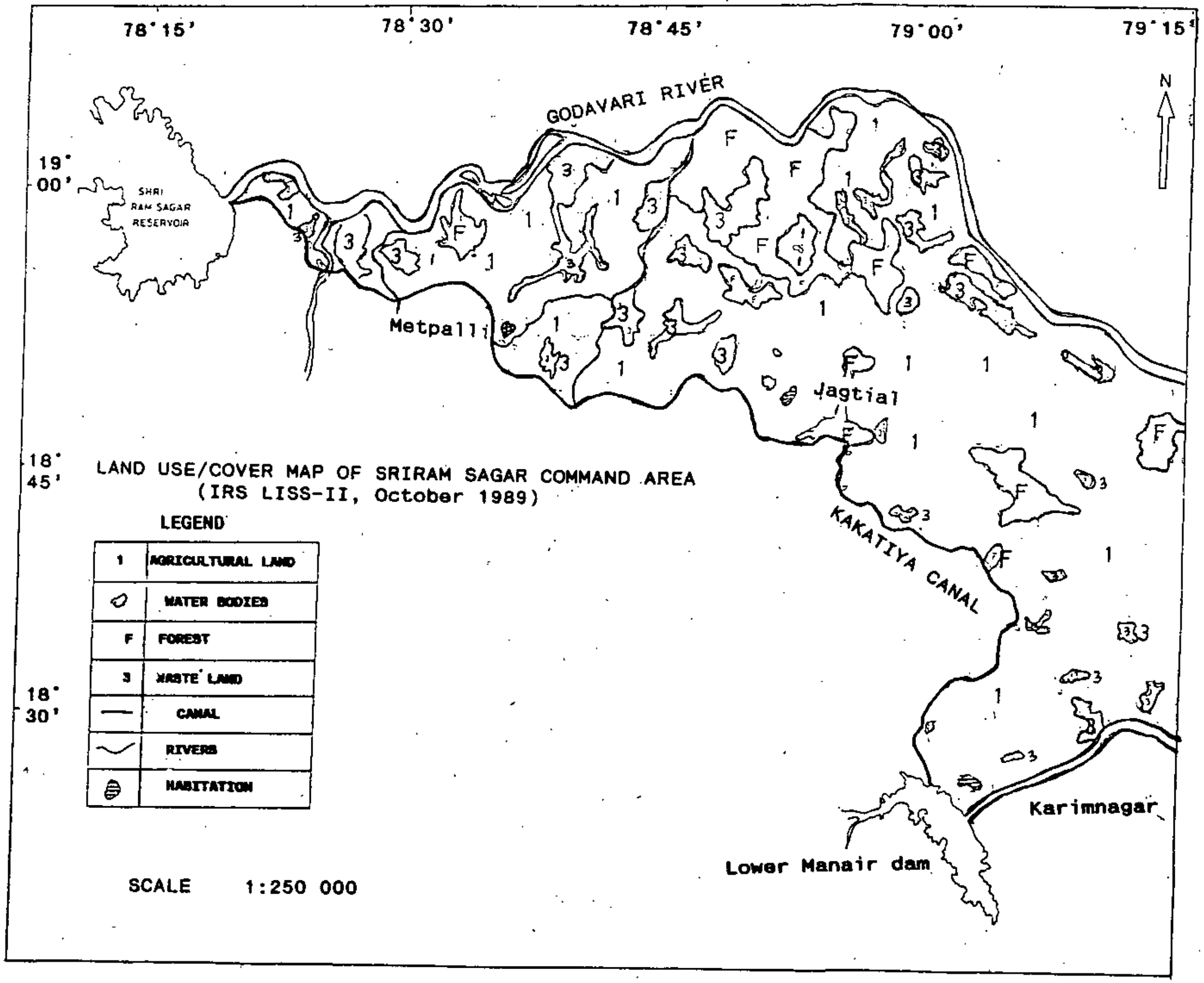
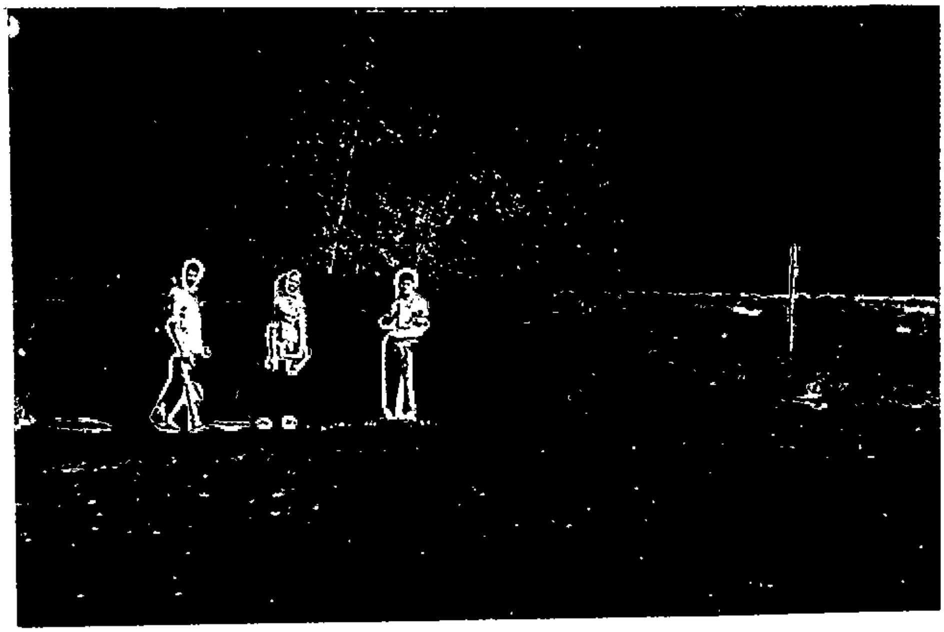


Fig. 9 Land use/land cover map of Sriram Sagar command area.



Photograph 7. Waterlogged area with weeds at Dubbapalli site

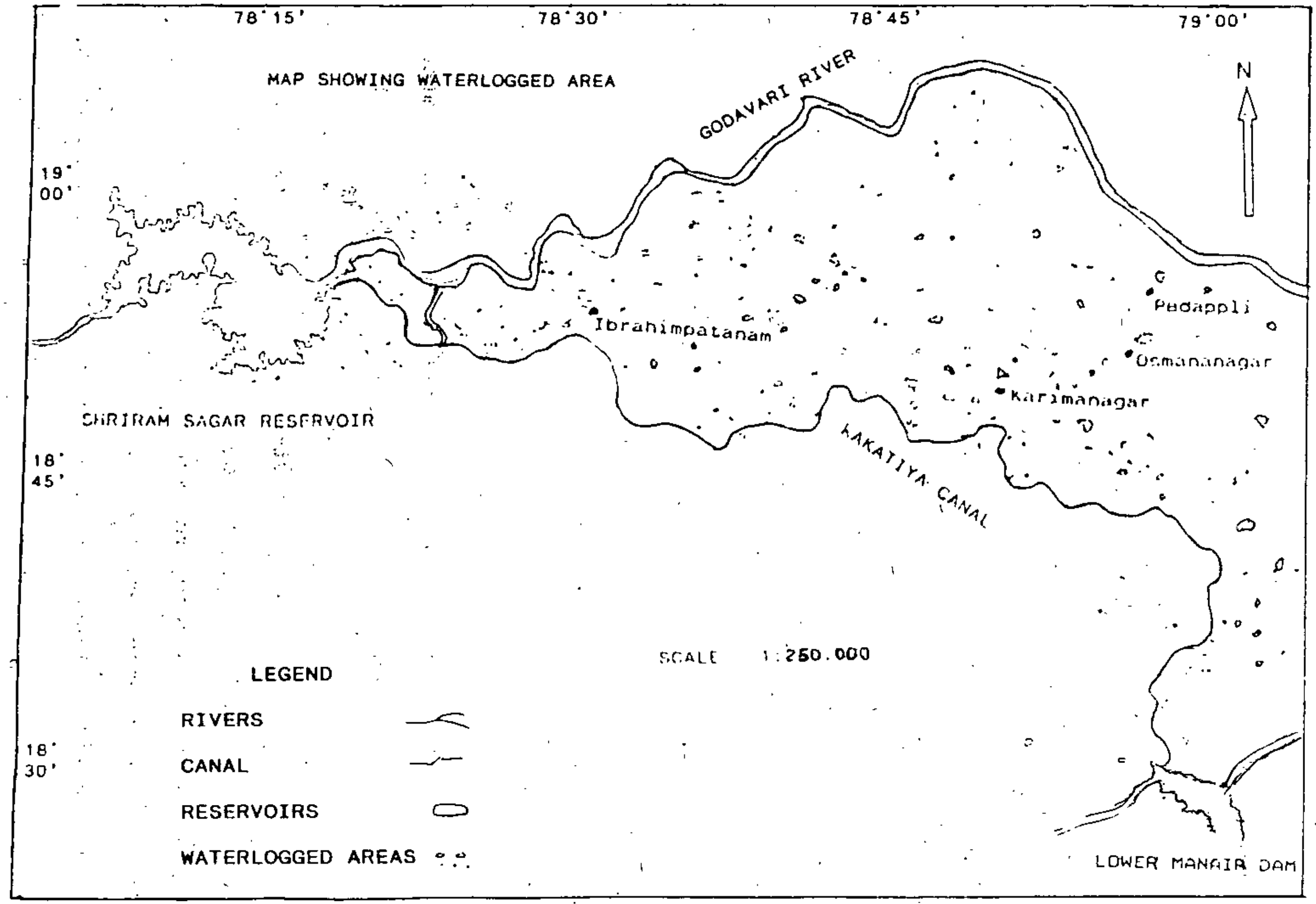


Fig. 10 Map showing waterlogged area (October 1989)

6.2.3 DRAINAGE MAP

Drainage map of the command area has also been prepared from FCC (Fig. 2). The Godavari river is perennial river outside the command area rest are the seasonal rivers. The command area is drained towards Godavari river and the drainage pattern is dendritic.

6.2.4 IMAGE ANALYSIS

Subscene of Sriram Sagar command area extracted from CCT for April and October 1989 scenes. ILWIS image processing system has been used for image analysis. Density slicing and principal component analysis for both the scenes were carried out. IRS data of April and October 1989 chosen to select minimum and maximum pixel values range for the density slicing using infra-red band 4.

It has been observed that in April 12, 1989 (premonsoon) scene, the pixel values for the deep clear water of the reservoir were in the range of 9-15 in infra-red band 4, whereas on the periphery of the reservoir, pixel values were in the range of 15-20. The same pixel range 15-20 was observed in ponds and rivers. Therefore for density slicing the pixel range of 9-20 was applied to band 4 for April 1989 scene of command area to delineate waterlogged areas. The output image exhibited waterlogged area (standing water) in the command area (Fig. 11).

On the other hand during post-monsoon month October 6, 1989, scene the pixel range for water observed between 10-25, which was used in density slicing to map waterlogged area (standing water) in post monsoon October 1989 (Fig. 12).

During visual interpretation and image analysis 20 locations

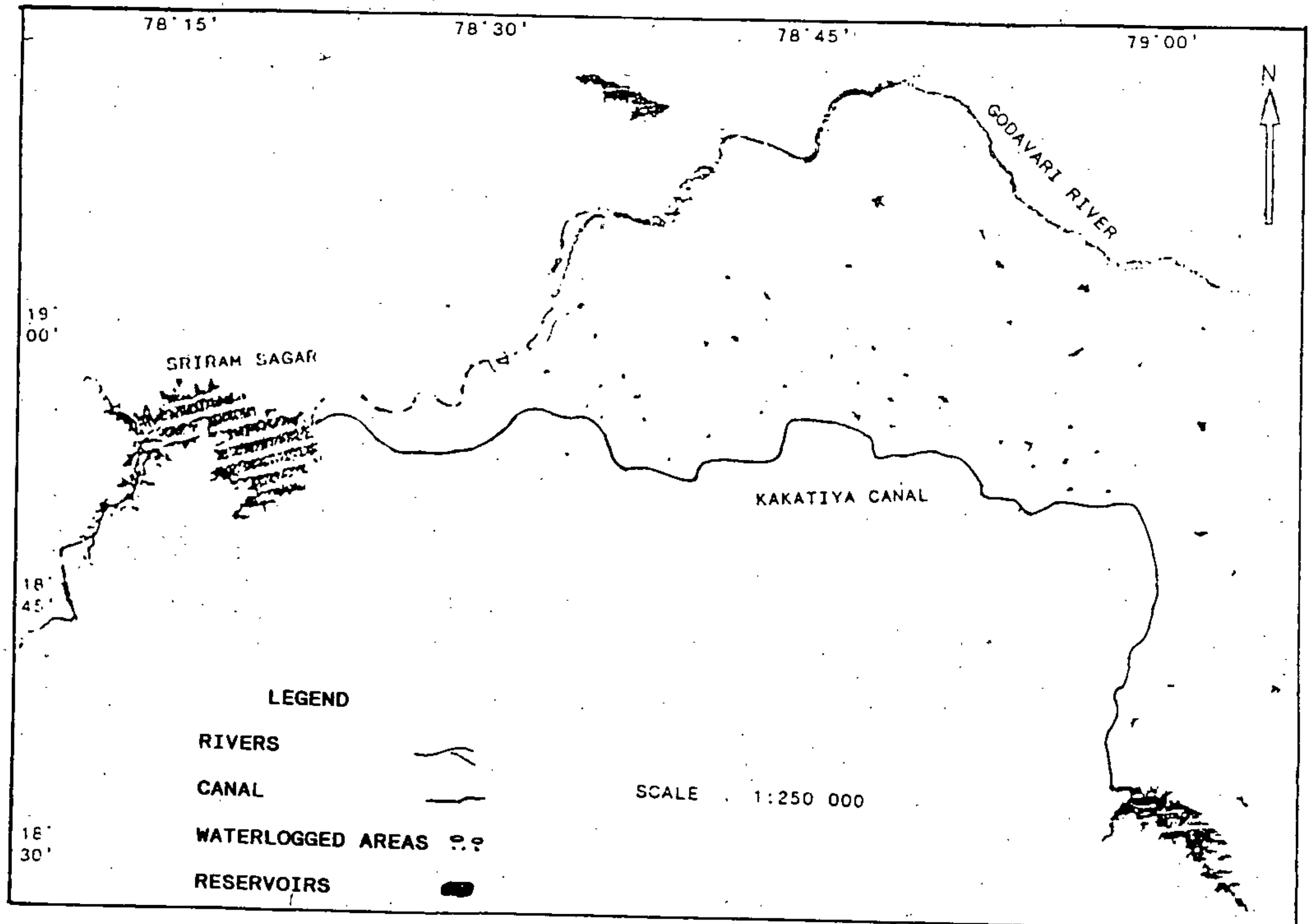


Fig. 11 Map showing waterlogged area (standing water) in the Sriram Sagar command area in April 12, 1989

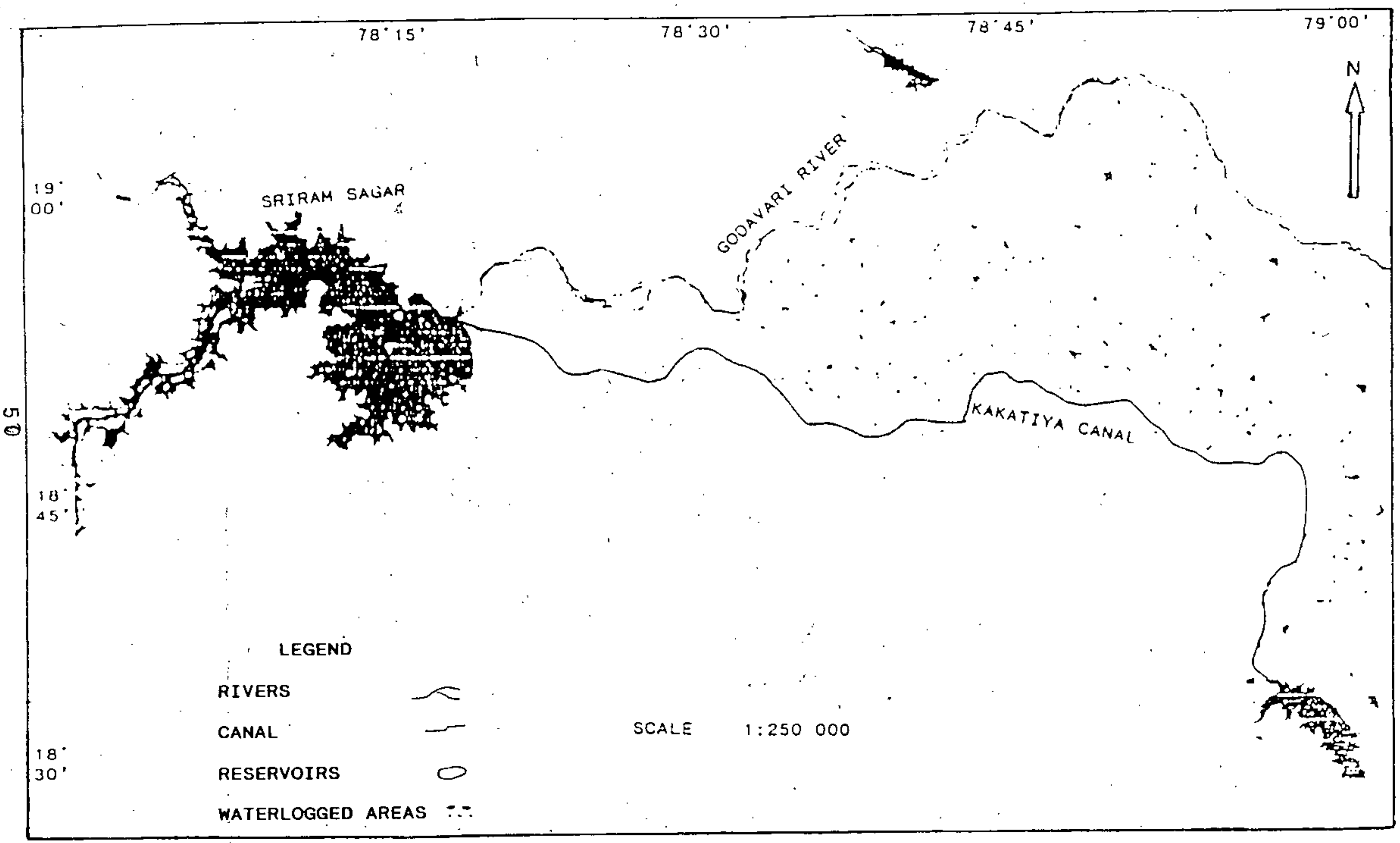


Fig. 12 Map showing waterlogged area (standing water) in the Sriram Sagar command area in October 6, 1989.

were identified for the field verification (Fig. 1). A field survey was carried out in the month of March 1996, for the field verification, radiometric measurements and data collection. It was found that 96 per cent of the waterlogged fields have slope less than 0.5 percent.

Certain pockets are waterlogged (stagnating water) to such an extent that the cultivation is not possible. About 388 sq.km of cultivable land is waterlogged (Fig. 11) due to excessive irrigation.

6.3 GROUND WATER LEVEL ANALYSIS

The groundwater levels vary from 160 to 290 metres above mean sea level. The gradient is from Southwest to Northeast. However, there are local depressions with smaller gradients. Groundwater level in the year 1989 is higher than the groundwater level in year 1976 due continuous increase of recharge. The rate of increase of groundwater level in post-monsoon in the study area is higher as compared with the pre-monsoon groundwater level. Since the groundwater is recharged mainly through precipitation and surface irrigation, the over-irrigation year after year has led to increase in the groundwater level. It is also reported that irrespective of recharge and exploitation situation, groundwater regime attains the same level after the monsoon. This is due to the limited storage capacity of the granite aquifer compared to the recharge potential of the command area. The local topographic situation and the aquifer characteristics govern the groundwater levels during post-monsoon period in such situations. This kind of trend is seen especially in the head reaches and middle reaches. Wells located in the tail end have the tendency of waterlogging conditions developing in the monsoon (Shetty, 1995).

The depth to water table contour map for the premonsoon and postmonsoon seasons, 1989 is presented in Figure 6 and 7. The depth to water table varied between 0.00 m to 6.0 m during premonsoon period. During post monsoon period the water table varied between 0.00 to 3.0 m. The effect of precipitation to the aquifer is reported with a time lag in most of the wells. The annual rise in groundwater level is 2.0 m to 4.8 m, the rate of rise varies between 0.17 to 1.2 metres per month and the rate of fall varied between 0.25 to 0.84 metres per month.

The examination of the historical well hydrographs for the period 1983 to 1989 (Fig. 8), and considering critical depth, the area is identified as prone to waterlogging.

The hydrogeological studies carried out by Ground Water Dept. Govt. of Andhra Pradesh revealed that the water table fluctuates between 6 to 10 metres, and the general gradient of the groundwater is towards northeast. The ground water occurs in isolated basins under unconfined to semiconfined conditions.

The change in storage of groundwater in an aquifer is reflected by change in groundwater level. Usually change in groundwater storage is a seasonal phenomenon. The water levels in the wells have been reduced with respect to mean sea level. The average fluctuations of the water levels between pre-monsoon and post-monsoon varied from 2 m to 3 m.

6.4 SENSITIVE AREAS TO WATERLOGGING

Vegetation is an indicator of soil moisture and ground water level. In order to identify the potential sensitive areas to waterlogging (water table depth between 0-3 m), pixel ranges of the response values of vegetation pattern during pre and post monsoon period such as April and October 1989 were computed. Vegetation response values (DN) taken from periphery of the water bodies, canal and depression areas of the command, pixel values of dense forest area were not taken into account. Pixel ranges were determined and used in gray level slicing and principle component analysis for April and October 1989 scenes separately. The crop calendar of all the crop grown in the command area were checked on the dates of images i.e April and October 1989.

In order to identify the areas sensitive to waterlogging during pre-monsoon period, April 12, 1989 image data were analysed. For the density slicing, pixel values representing vegetation pattern in the command area were identified and three pixel ranges 20-30; 20-32; 20-34 were determined, where gound water level lies between 0-1; 0-2; 0-3 respectively. The areas sensitive to waterlogging (0-3 m) obtained for all the three pixel ranges were varified in the field and shown in Figures 13 a, b and c respectively. Such areas are the extension of standing water areas in low lying terrain follow the general slope of the terrain, which is in the North direction.

Similarly, areas sensitive to waterlogging during post-monsoon period, pixel ranges from October 6, 1889 scene were determined and gray level slicing was performed. The waterlogged and the areas prone to waterlogging obtained from pixel ranges 10-30 and 10-35 are shown in Fig. 14 a and b.

Principal component analysis incorporate spectral information from number of bands simultaneously, thus accessing the high sensitivity to clear water in the blue to green

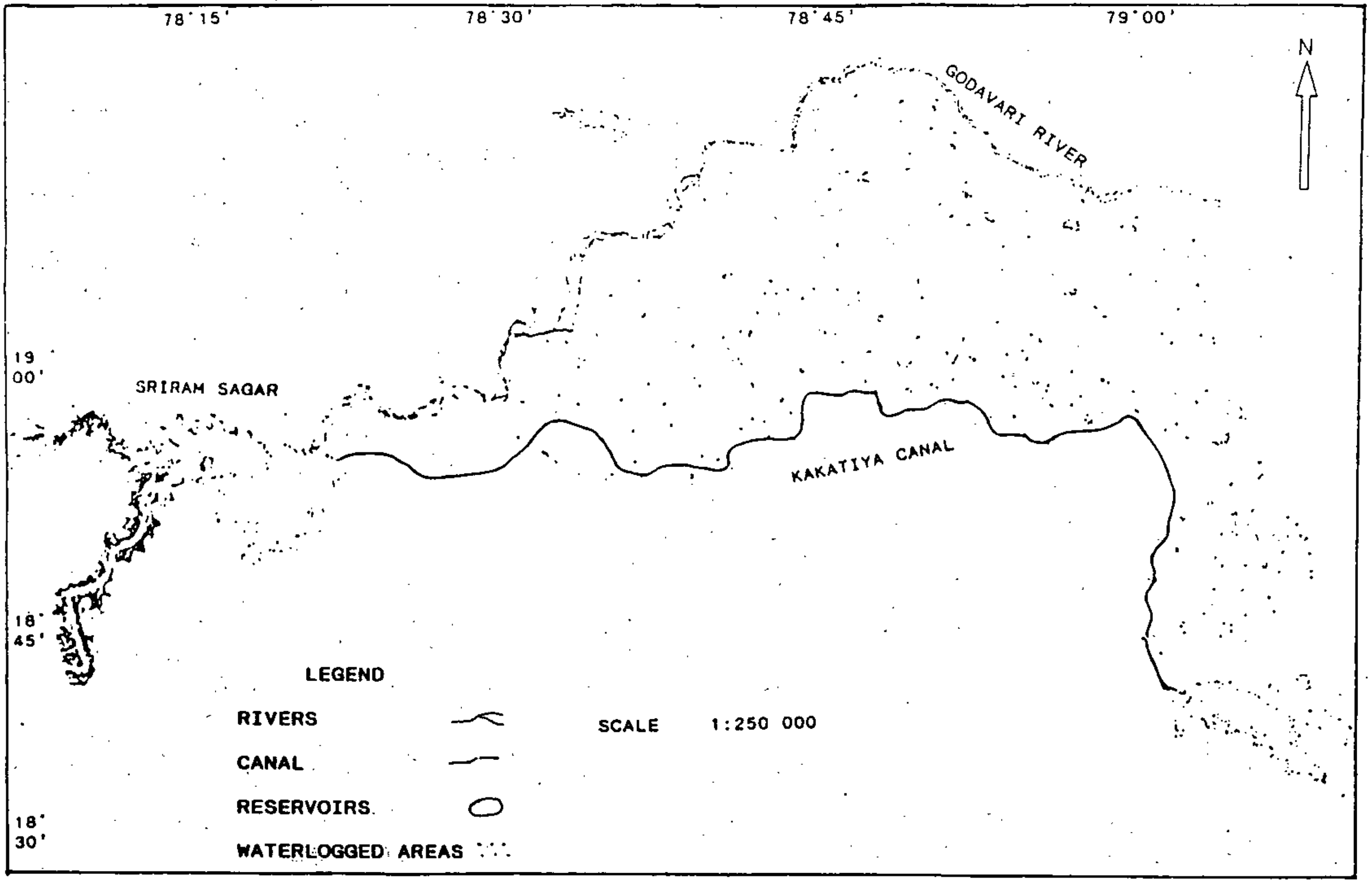


Fig. 13 (a) Map showing waterlogged and vegetation areas (water table 0-1 m) in the Sriram Sagar command in April 12, 1989.

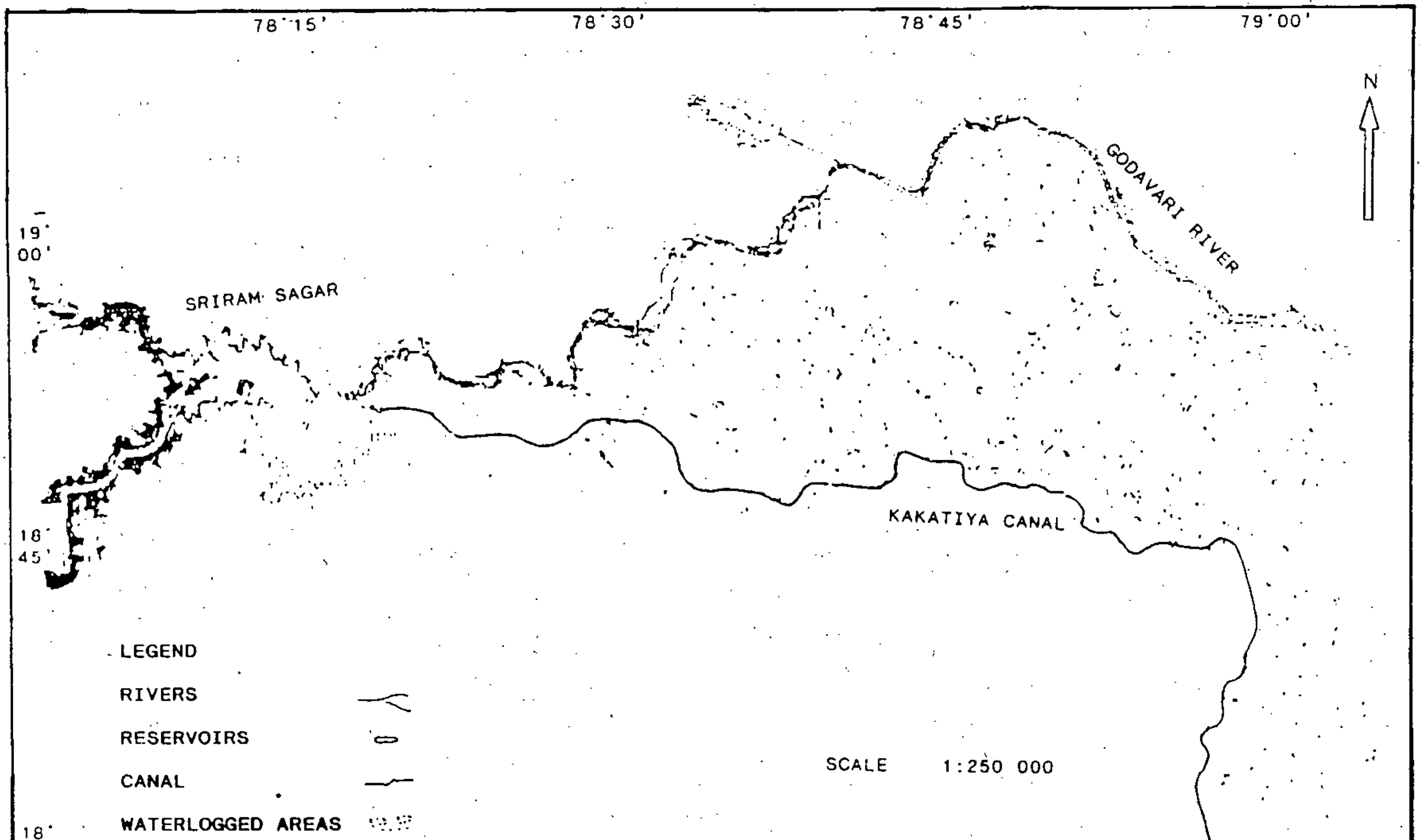


Fig. 13 (b) Map showing waterlogged and vegetation areas (water table 0-2 m) in the Sriram Sagar command in April 12, 1989.

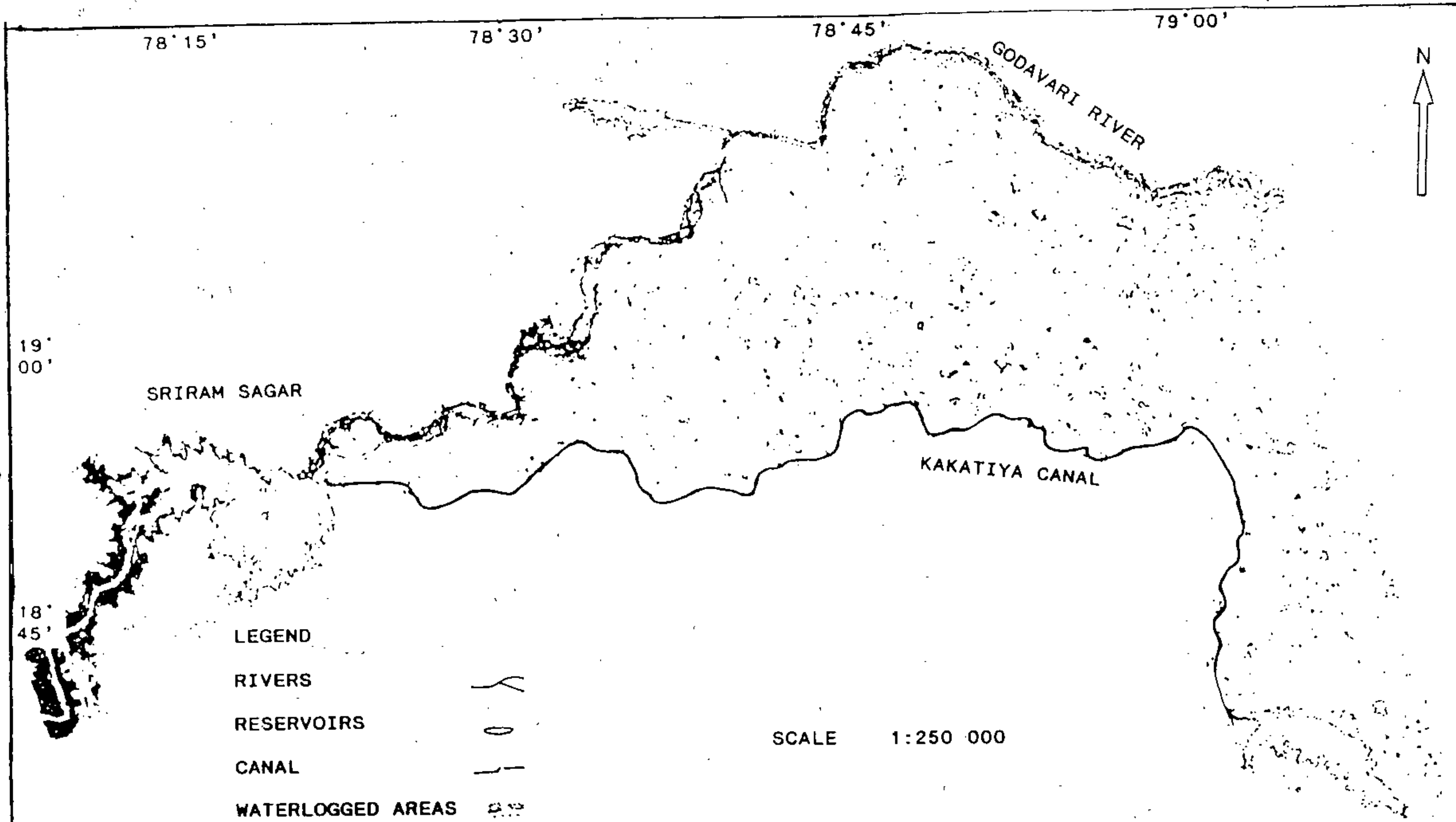


Fig. 13 (c) Map showing waterlogged and vegetation areas (water table 0-3 m) in the Sriram Sagar command in April 12, 1989.

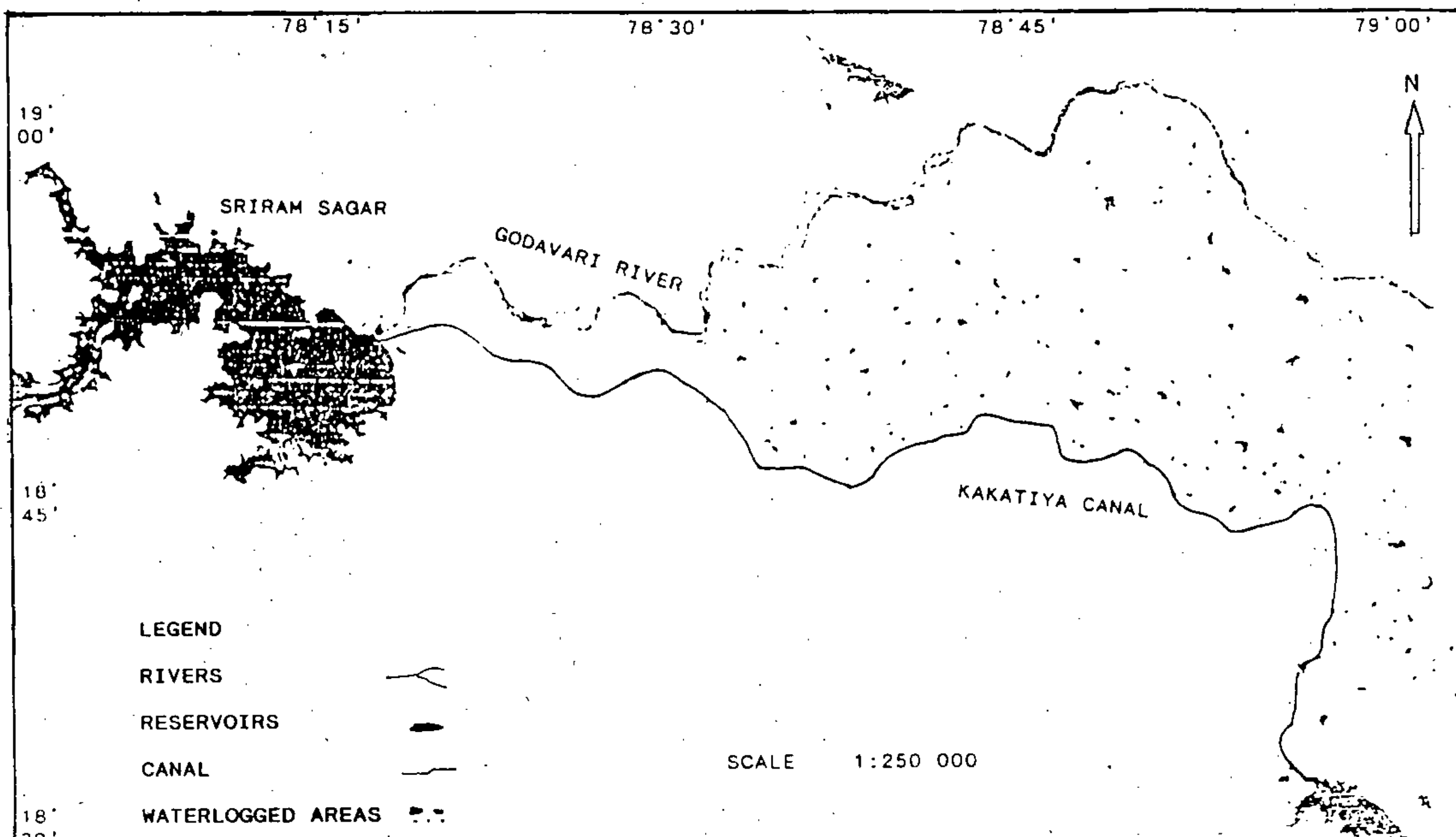


Fig. 14 (a) Map showing waterlogged and vegetation areas (water table 0-1 m) in the Sriram Sagar command in October 6, 1989.

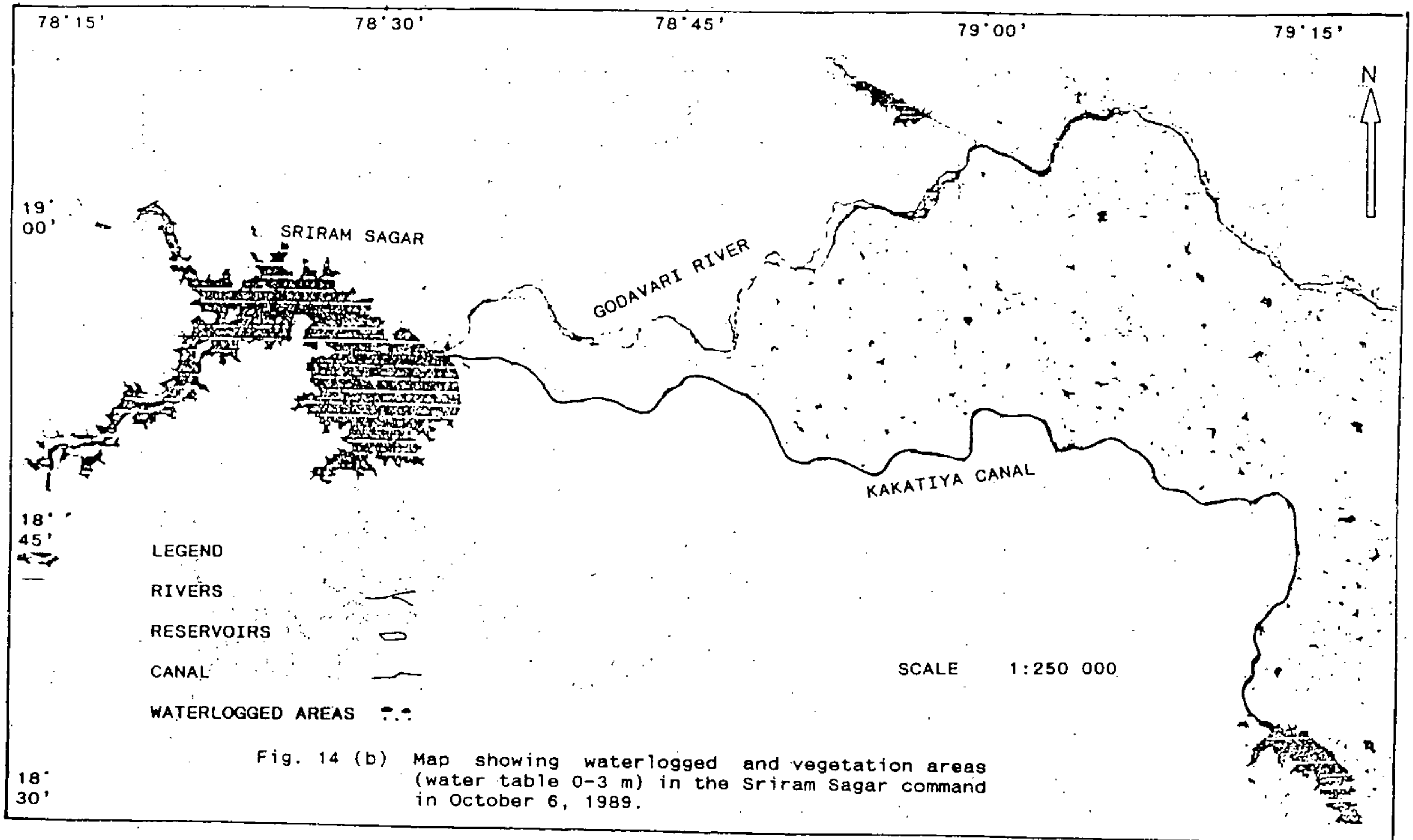


Fig. 14 (b) Map showing waterlogged and vegetation areas (water table 0-3 m) in the Sriram Sagar command in October 6, 1989.

wavelength and the high sensitivity to wet soils in the red and near infrared wavelength. It has been difficult to identify the areas likely to be affected by waterlogging in near future (where water table depth lies 0.5 to 3.0 m). Thus multispectral images have been of limited use in mapping potential waterlogged area in arid and semi arid area. However green sparse vegetation in lowlying areas and along the canals, distributaries could be mapped to assess sensitive area to waterlogging. The principle component analysis for post-monmsoon image of October 6, 1989 was carried out. The first eigenvector (PC 1) account for most of the variance in the data. Three pixel ranges 103-119; 103-121 and 103-121 were chosen from the PC 1 analysed images and the masking function was applied to map water and vegetation pattern in the command area. One classified image for the each pixel range was obtained and shown as Figure 15 a, b and c.

The water table depth data were transferred on the waterlogged areas map prepared from April and October 1989, IRS data. Area having water table depth at 1 to 3 m from surface are considered as potential sensitive areas for waterlogging.

Traversing the command area it was noticed that the natural drains are infested with Ipomea aquatica and occasional aquatic weeds. These obstructions not only caused silting but drastically reduced the carrying capacity of the drains.

Based on the field observations, maps showing waterlogged areas were finalised. It has been found that in pre-monsoon April and post-monsoon October 1989 images, pixel ranges 9-20, (standing water), 20-30; 20-32; 20-34 and 10-25 (standing water), 10-30 and 10-35 respectively, are the manifestation of surface (soil moisture and vegetation) suitable for the assessment of

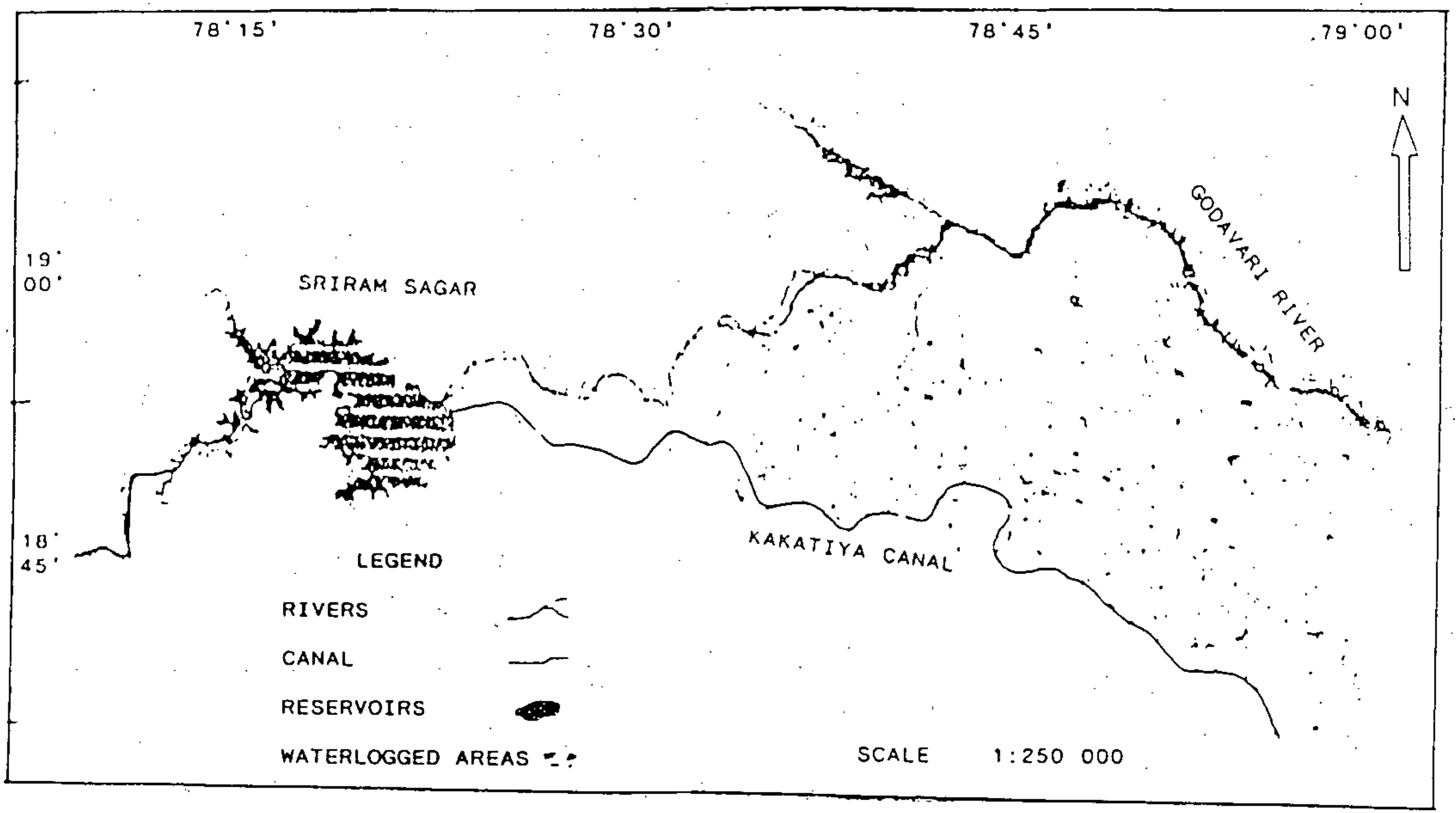


Fig. 15 (a) Map showing waterlogged and vegetation areas (water table 0-1 m) in the Sriram Sagar command in October 6, 1989 (using Principal Component Analysis).

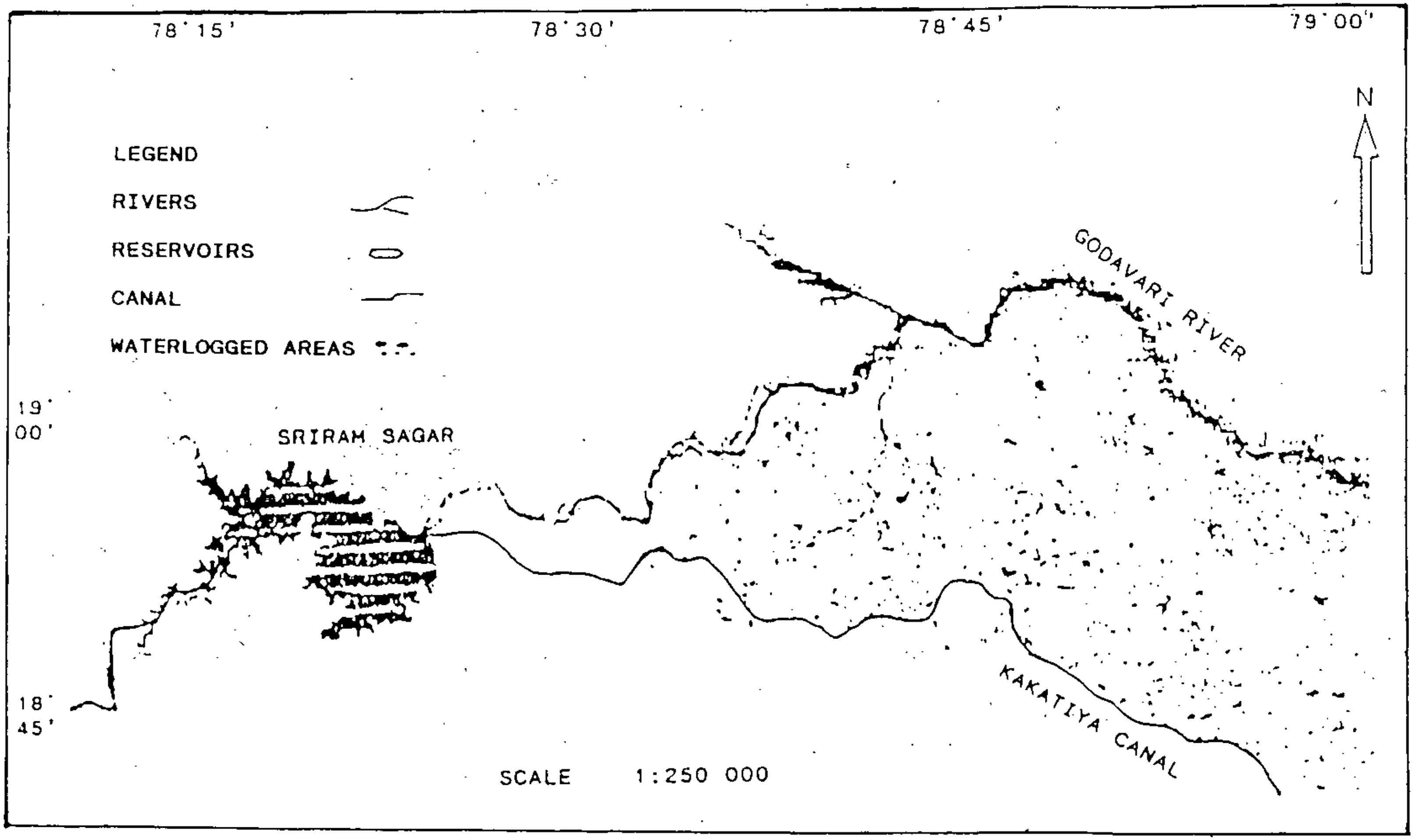


Fig. 15 (b) Map showing waterlogged and vegetation areas (water table 0-2 m) in the Sriram Sagar command in October 6, 1989 (using Principal Component Analysis).

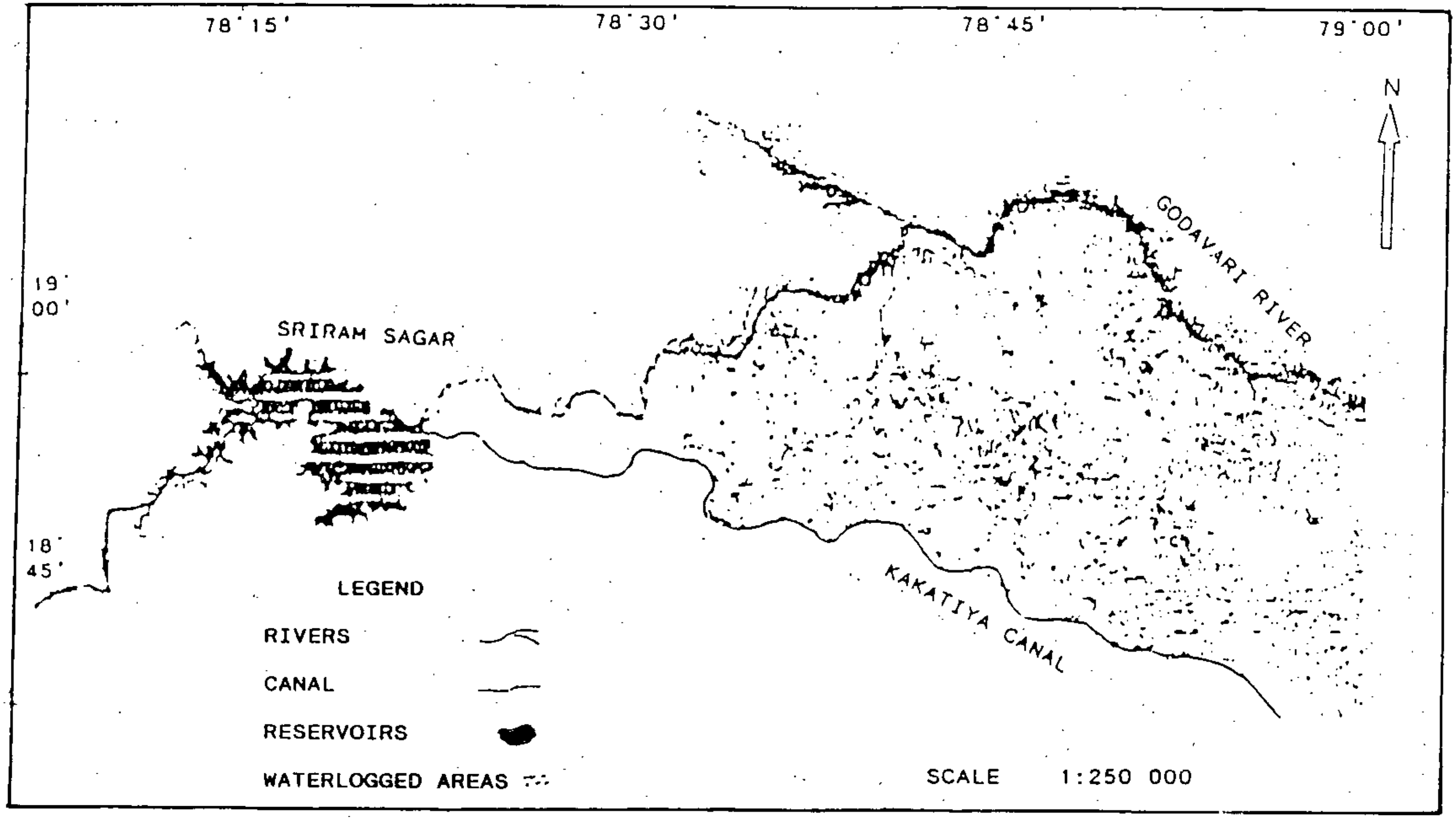


Fig. 15 (c) Map showing waterlogged and vegetation areas (water table 0-3 m) in the Sriram Sagar command in October 6, 1989 (using Principal Component Analysis).

waterlogged areas and sensitive areas for waterlogging. The assessment of waterlogged and the areas sensitive to waterlogging for April 12, and October 6, 1989 are tabulated in tables 2 a & b.

The results obtained from this study indicate that during pre and post monsoon months i.e, April and October 1989, the waterlogged areas (standing water) were approximately 380 and 540 sq.km respectively. Whereas sensitive area for waterlogging was about 698 and 802 sq.km, for April and October 1989 respectively, where ground water table lies in between 0 to 3 m.

6.5 QUALITY OF WATER FOR IRRIGATION

The pH value of water is a measure of hydrogen in concentration of the water sample. The pH value for premonsoon and postmonsoon period varying between 7.21 to 7.85. The ability of a cube of one centimeter side water to conduct an electrical current is called specific electrical conductance or electrical conductivity. EC values between 1460 and 2520 micromhos/cm and total dissolved solids are in the range of 934.3 and 1338.3 mg/l. EC has the range of 172.9 to 395.55 micromhos/cm, and total dissolved solids found to be in the range of 110.73 and 215.43.

During April 1989, the specific conductance (EC) values where depth to water levels are less than or equal to 3.00 m. below ground level and the depth to water levels where specific conductance is very high i.e., more than 2250 micro siemens at 25 C

The EC ranges, number of water samples coming in each range and their percentage are shown in the table 3.

Table 2 a. Waterlogged area (standing water) in Sriram Sagar command obtained from density slicing.

S.No.	Date of satellite overpass	Area Sq.Km
1.	12.04.1989	388
2.	06.10.1989	540

Table 2 b. Sensitive areas to waterlogging

Date	Water table depth (in meters)	Area prone to waterlogging (in sq.km)
12.04.1989	1-3 m	698
06.10.1989	1-3 m	802

Table 3.

Sl. No.	EC ranges micro siemens at 25c	No of water samples.	% of water samples.	Water class for irrigation.
1.	75	112	32.46	Excellent to good.
2.	750-1500	144	41.74	Good to permissible.
3.	1500-2250	63	18.26	permissible to doubtful.
4.	Above 2250	22	6.38	Unsuitable.
5.	Water not collected	4	1.16	
	Total	345	100.00	

The groundwater quality is fit for direct use and need for mixed water management or treatment of water is not required before either for domestic or irrigation use (GWD, 1989).

The variation of water quality parameter values over the study period for the identified wells are also within the permissible limit.

The salinity is reported during postmonsoon season near Jagtial which may be due to leaching of salts from Kharif Irrigation. During the premonsoon season in Veerapuram indicated fluoride concentration 1.25 mg/1. Whereas during postmonsoon season average flouride concentration 2 to 2.5 mg/l was reported. The increase in flouride concentration is attributable to pollution from irrigated agriculture due to the use of phosphatic fertilizers which might have been leached down (Gupta and Gautam 1983).

The groundwater level in the year 1989 of the command area is higher than the groundwater level in the year 1977, due to continuous increase of recharge (Fig. 7 & 16). The increase of groundwater level in post monsoon of the study area is noticeable and higher as compared with pre monsoon groundwater level (Fig. 11 & 12). It is also reported that irrespective of recharge and exploitation situation, groundwater table attains the same level after the monsoon.

The yield of Rice in waterlogged area is lower by 30 percent compared to nonwaterlogged areas. The problem of waterlogging is severe in adjoining non command areas due to seepage. In one noncommand village adjacent to the canal about 40 hectares land has been rendered useless for production.

6.6 Reasons for waterlogging

There is overuse of water in many fields, since water is easily available. The water charges are based on area of land and not on the quantity of water used. Farmers are not aware of optimum water-use management practices. All the distributaries of the main canal are unlined. Because of this, seepages causing a rise in the water table and aggravates the incidence of waterlogging.

6.7 Effect of Waterlogging

During field survey of the command area of SRS Project it has been observed that waterlogging has a serious negative impact on agricultural productivity. Over 388 sq.km hectares have been rendered useless for agricultural production because of waterlogging and it is difficult to undertake cultivation in these locations. The water table has risen to ground level in these areas (stagnating water) (Fig 11 and 12).

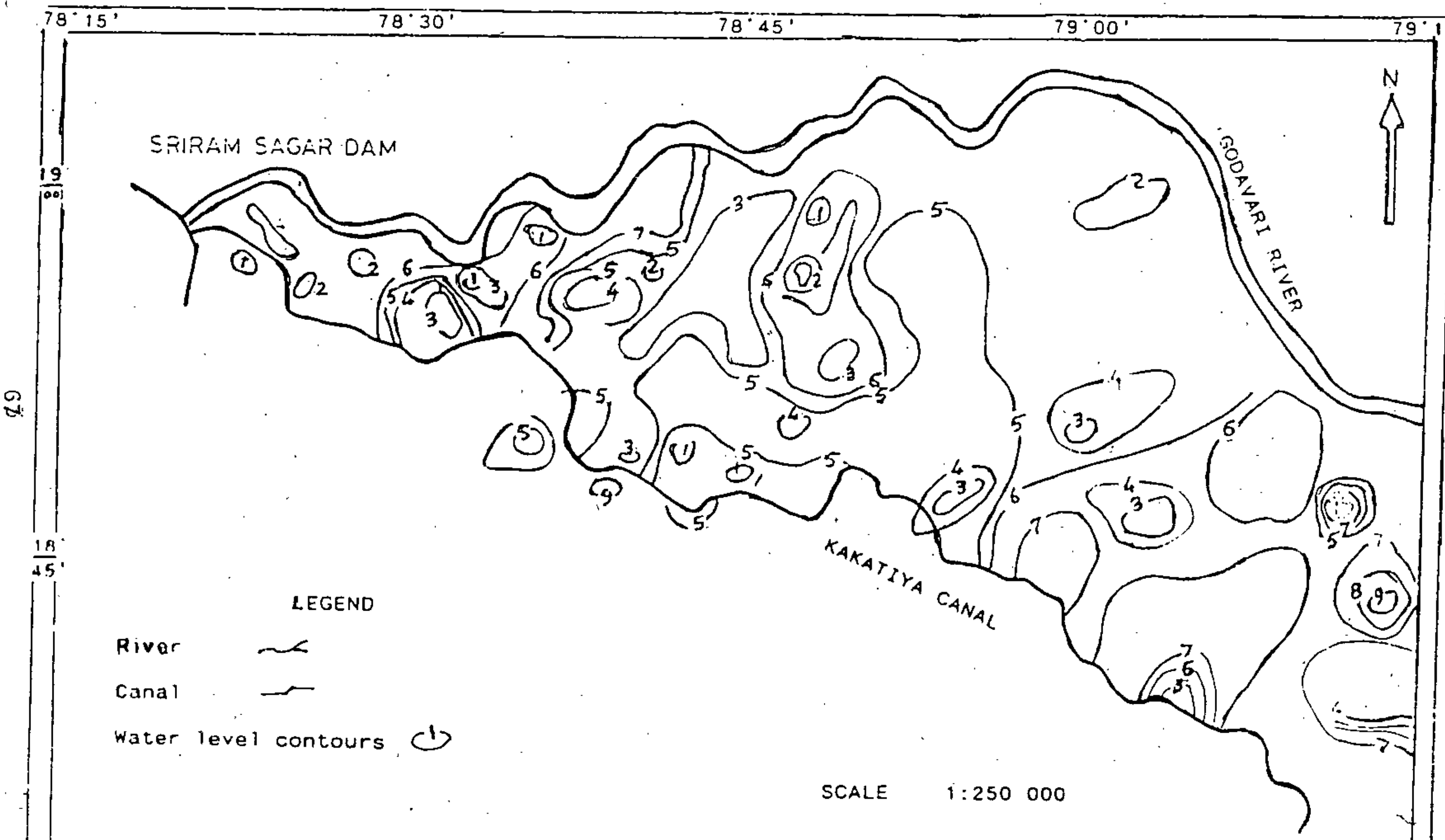


Fig. 16 Water level contour of Sriram Sagar command area in 1977 (Source: Bowonder and Ravi 1983).

The irrigation water requirement for paddy crop in the Kharif season is estimated as 11 cm to 177 cm at 60 per cent efficiency. With the same efficiency, irrigation water requirement for the rabi season is found to be in the range of 167 cm to 211 cm. The crop water requirement for sugar cane in kharif season is 13 cm and 133 to 177cm in the rabi season. In other words total water requirement for the sugarcane crop is 146 and 203 cm. The irrigation water requirement has been reported for the groundnut crop and is found to be in the range of 0 32cm n the kharif season and for pulses, it is 0 if there is a good amount of rainfall, however under the worst condition of rainfall, upto 25 cm is required. In the rabi season, irrigation water requirement is in the range of 35cm to 62cm (Shetty, 1995).

7.0 CONCLUSIONS

This investigation has shown that IRS images have great potential in making rapid and reliable quantitative assessment of waterlogging in the command area. Further investigation may prove a valuable prospect for precise prediction of areas prone to waterlogging. IRS-1A-LISS infra-red band 4 data has been proved to be very useful for the assessment of waterlogging.

Density slicing and principal component analysis are useful techniques for the assessment of waterlogged and the potential area for the waterlogging in the irrigated command area in different seasons. Selection of pixel range based on field informations such as topography (low lying areas) soil moisture and vegetation may help in the identification of sensitive area for waterlogging.

If the appropriate field measured radiometric data available or can be measured based on the spectral characteristics of the water, dry & wet soils and vegetation, then it will be possible to determine degree of soil moisture at different time of the year for the irrigation scheduling and to combat the menace of waterlogging in the irrigated command areas.

The probable reasons for the increase in water level in the command area are: overuse of water; farmers are not aware of optimum water-use management practices; none of the distributaries of the main canal are lined, hence seepages occur, causing a rise in the water table and aggravates the incidence of waterlogging.

The result obtained from this study indicate that in April and October, 1989, an area of 388 and 540 sq.km was affected by waterlogging and about 698, 802 sq.km area was sensitive for waterlogging. It is suggested that periodic assessment of waterlogging using remotely sensed data should be carried out in the Sriram Sagar command.

The annual rise in groundwater level is 2.0 m to 4.8 m, the rate of rise varies between 0.17 to 1.2 metres per month and the rate of fall varied between 0.25 to 0.84 metres per month.

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