A CASE STUDY ON PROTECTIVE IRRIGATION IN A CANAL COMMAND AREA

A DISSERTATION

submitted in partial fulfilment of
the requirements for the award of the degree
of
MASTER OF ENGINEERING
in
IRRIGATION WATER MANAGEMENT

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CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in this dissertation entitled, **"A CASE STUDY ON PROTECTIVE IRRIGATION IN A CANAL COMMAND AREA"**, in partial fulfillment of the requirement for the award of the degree of Master of Engineering in Irrigation Water Management of the University of Roorkee, is an authentic record of my own work carried out from July 16,1999, to January 2000 under the supervision of **Dr. G.C. Mishra,** Professor, and **Prof. R.P. Singh,** Visiting Professor, WRDTC, University of Roorkee, Roorkee.

I have not submitted the matter embodied in this dissertation for the award of any other degree.

Dated: Jan. 28 ,2000

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CERTIFICATE

This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

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SYNOPSIS

Protective irrigation means irrigation with limited quantity of water spread thinly over as large area as possible so as to protect crop from total failure. The issue of protective irrigation in the Command of Right main distributary of Deoband Branch Canal (U.G.C. System, U.P.) has been analysed using ground water balance study. For water balance study a lumped ground water balance model has been developed to assess the ground water potential for conjunctive use of available surface water and ground water.

The study area covers an area of 5890 ha. Surface irrigation supplies to the area are provided through right main distributary and its branches. Right main distributary takes off from Deoband branch canal at a chainage of 7.26 km. Ground water is also utilized substantially for irrigation purpose through a large numbers of private tube well, state tubewells and pump sets.

Crop water requirement has been worked out on the basis of existing cropping pattern in the command of right main distributary. The deficit between available surface water and crop water requirement has been calculated. The present surface water only irrigates 70 percent of command area. The remaining 30 percent is being supplemented by ground water.

Ground water balance study indicates that there is an annual rise of 24 cm in ground water level for the existing cropping intensity 144% and normal rainfall. For 170% cropping intensity and normal rainfall the annual rise will be 6.3 cm. Thus more area can be irrigated without causing mining of ground water. There is an excess canal supply during monsoon period (July to September). If the excess supply in the above month is not given, there is annual fall of ground water level by 4.5 cm. In the case of drought period, and existing cropping intensity of 144%, water level falls by 49.5 cm.

Thus the ground water can protect the crop during drought period without causing excessive mining.

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CHAPTER-1

INTRODUCTION

1.1 GENERAL

Water, a vital resource for all development activities, is becoming a scarce commodity as the growth process, expansion of economic activities and increasing population have inevitably lead to an increasing demand in agriculture, industries, drinking water and other domestic requirements. Therefore, it has become imperative to take into consideration all water resources and facilities in order to satisfy present and future demands for water.

Irrigation plays a major role in Indian agriculture. Since independence many millions of hectares has been brought under new irrigation systems. In spite of massive investment in the development of irrigation sectors in India, the desired level of output by way of agriculture production from the created irrigation facilities has not been achieved. Enormous irrigation potential has been created in India at considerable cost under a large number of major medium and minor irrigation projects. There is a much gap between ultimate irrigation potential, created irrigation potential and utilization of created irrigation potential. A scenario of irrigation potential in a few states as compared with India has been given in Table 1.1. A very important reason for this poor performance is protective irrigation. This usually means large command area, high duties and low intensities. Since surface water is not distributed uniformly in time and space, additional benefits will be obtained if surface and ground water systems are planned and operated taking into consideration the advantages offered by conjunctive use of both.

1.2 NEED OF THE STUDY

Al present right main distributors of Deoband branch canal of U.G.C. does not have adequate water for the entire command, specially in Rabi season. Alternative is either to reduce the irrigable area or to select irrigable area based on optimal returns per unit of land and water. In either case there is no justification for having a large command when many locations do not receive any water under the present situation but practically it may not be possible to cut down the existing large command in view of established right for use of canal water more than a century. It is equally important to have conjunctive use of ground water and surface water to make the existing irrigation system responsive to the requirement of modern irrigated agriculture.

1.3 OBJECTIVES AND SCOPE OF THE PRESENT STUDY

The determination of optimal allocation of surface and ground water resources is the basic objective of the present study.

The objective of the present study, therefore are:

1. To determine available surface water and existing crop water requirement.
2. Determination of deficit between available surface water resources and crop water requirement.
3. The deficit of water is to be met out by ground water based on a ground water balance study.

1.4 SCOPE OF STUDY

The basic component of the system in the proposed study area are:

1. Crop pattern representing the water demand component.

2. Ground water with its dynamic characteristics of response to different conditions of recharge and withdrawal.

3. The basic purpose of a groundwater model is to forecast the changes in the ground water level that will occur due to external changes such as introduction of cropping intensity and recharge pattern.

4. Finally the study deals with how the protective irrigation can be more efficient by the conjunctive use of ground water and surface water.

Table-1.1: Irrigation Potential (upto 1990)

Item	**National all India average (lacs ha.)**	**Bihar (lacs ha.)**	**U.P. Lacs ha.)**
A. Ultimate irrigation potential			
(a) By major and medium irriga-Tion project	584.74	65.00	125.00
(b) By minor irrigation projects	571.40	59.00	132.00
(c) Total	1156.15	124.00	257.00
B. Created irrigation potential	329.11	27.15	71.66
(a) By major and medium Irrigation projects [percentage w.r.t.A(a)]	(56.28%)	(41.77%)	(57.33%)
(b) By minor irrigation project [Percentage with respect to A(b)]	466.05 (81.56%)	44.28 (75.05%)	166.42 (126.07%)
(c) Total a + b [% w.r.t. to A(c)	795.16 (68.78%)	71.43 (57.60%)	238/08 (92.64%)
C. Utilisation of created irrigation potential			
(a) In major and medium irrigation project [% w.r.t. B(a)	278.75 (84.70%)	22.26 (93%)	59.48 (83%)
(b) In minor irrigation project (lakh ha) [% w.r.t. B(b)]	430.42 (92.35%)	39.91 (90.13%)	151.42 (91.23%)
(c) Total a + b [% w.r.t. B©]	709.17 (89.19%)	65.16 (91.22%)	210.90 (88.58%)

Source : Walmi, Patna

INDEX MAP OF STUDY AREA

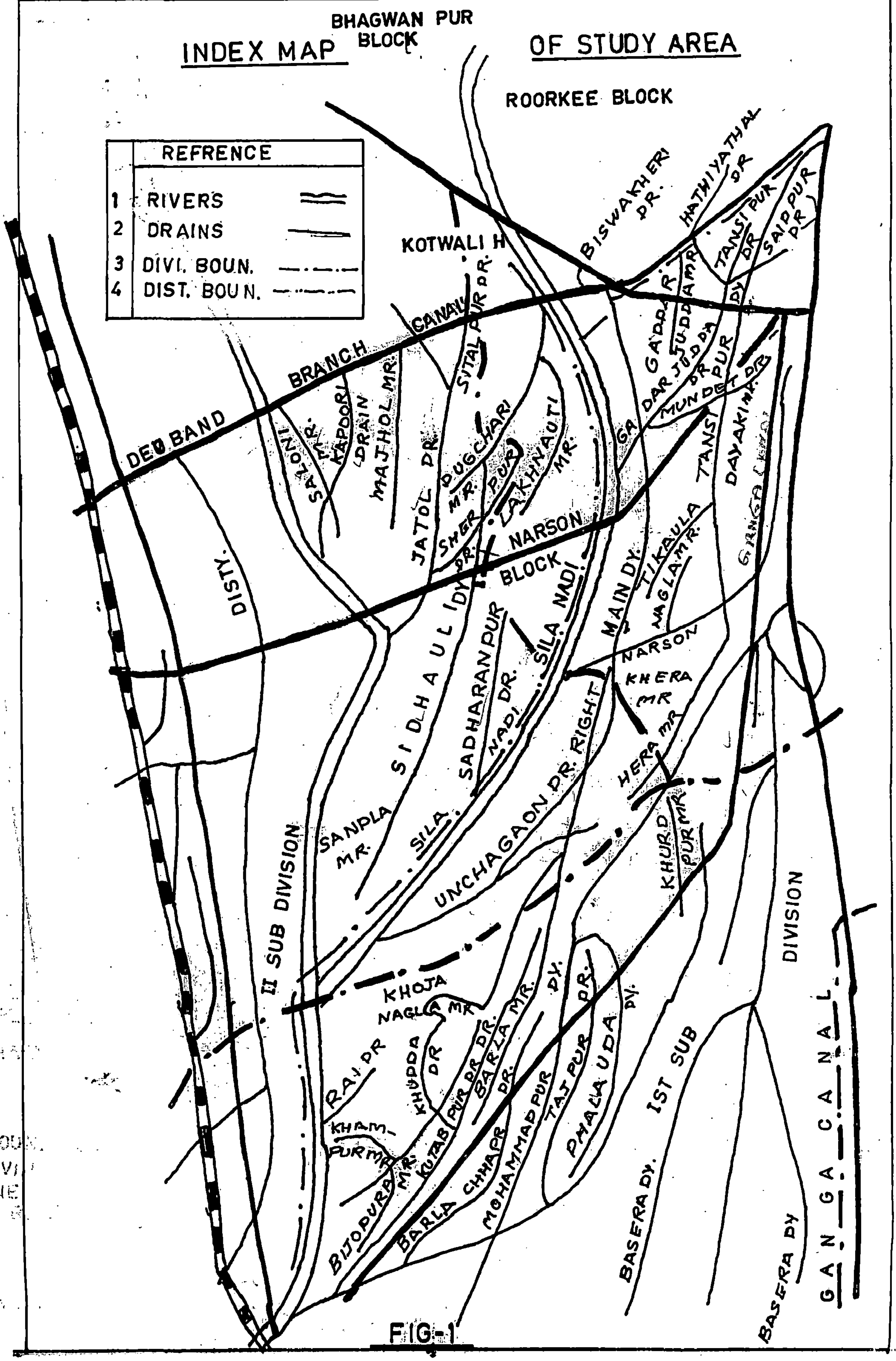


FIG-1

CHAPTER-2

OPERATION, PROBLEMS AND CONSTRAINTS ON U.G.C.

2.1 BACK GROUND OF UPPER GANGA CANAL SYSTEM

The well recorded severe famine is 1837 in Ganga. Jamuna doab drawn the attention of British Canal Engineers to protect this agricultural land against recurring droughts. Caption Proby Thomson Cautely a royal artillery officer, first prepared the project of upper Ganga Canal in 1838 with a proposal to take out a canal from Ganga near Hardwar and brought it in final form by 1841.

At the time of commencement of U.G.C. project; there was no science of soil mechanics and the knowledge of hydraulic engineering was also in primitive stage. Foreseeing the constraints and limitations, the project works were ultimately taken up with full swing in 1848 only after large and through scruitinies, and the canal commissioned on 8th of April 1854 with a head discharge of 189 cumcs at Mayapur (Hardwar) the zero point of the canal system.

The upper Ganga Canal being an oldest and major irrigation system in Ganga-Yamuna enter basin in Uttar Pradesh, is run of the river scheme and was designed primarily as a famine relief measures/protective irrigation during Rabi. A temporary diversion bund was constructed every year immediately after the monsoon to feed U.G.C. The bund happened to be washed away on the commencement of monsoon. As irrigated agriculture developed and there was a demand water for Kharif crops, a permanent weir, known as Bhimgoda weir, was constructed across the Ganga at Hardwar in 1922 to direct the water flow in U.G.C. The capacity of U.G.C. was increased from time to time and designed capacity of canal had been raised to 297.00 Cumecs after carrying out minor modification in some of masonry works like lowering the bed level to pass extra discharge without excessive afflux. Bhimgoda weir was replaced by a modern barrage in 1985-86.

Ganga canal started irrigation during the year 1855-56. The distribution of water on Ganga Canal started with simple measure to irrigate 220 acres from 1 cusec for wheat with four watering of 12.5 inches adding 20% for absorption and evaporation making a water depth of 15 inches. "Payamanah Panika" was unit in earlier day for measuring the water and it was equal to nearly 1 cubic ft/see No single outlet was more than four "Payamanah".

U.G.C. was aimed to cover as much area under its command as could be technically and economically feasible. Main canal was a continuos running canal but its off takes were alternative running channels according to predetermined and preceded roster. The cultivators started obstructing weaker section of the peasantry from the use of canal water which resulted in the disputes between them.

For better distribution and management of water within an outlet command the practice of "warabondi was introduced in this canal system as back as 1880. In order to solve the day today problems in running of canal and fair distribution of water among the cultivators, Northern Indian Canal and Drainage Act of 1873 was introduced. The rules for Osrabardi has worked very well over a long period of a century in spite of ever increasing demand of irrigation water for the extensive irrigated agriculture developing in the command of U.G.C.

2.2 LAY OUT AND SALIENT FEATURE OF RIGHT MAIN DISTRIBUTARY

The upper Ganga main canal takes off from the right bank of river Ganga at hardwar with originally designed discharge of 191.37 cumecs and gradually increased to

242.35 cumecs (1938) which was latter remodeled to draw 311.48 cumces (1954) at Mayapur due to increase in demand till 1951. The Deoband branch with a design discharge of 24.77 cumces takes off from 35.342 Km. Of the upper Ganga Canal. Right main distributary takes off from Deoband branch canal at 7.26 km. This system was projected at the end of nineteenth century after exercising saving of water from other branches and projection of L.C.C. system (1878).

Salient features for Right main distributary

Table: 2.1

Sr. No.	Off taking channels	Off takes points	Tail point Km.	Design capacity Cumecs	Actual Capacity Cumecs	C.C.A. Ha.
	1	2	3	4	5	6
1	Right main distributary	7.26 of Deoband branch	17.702	2.69	3.4	211
2.	Bhaisani distributary	16.40 of Right main distributary	13.60	1.22		2237
	(a) Khoja Nagla minor	5.60 of Bhaisani dy.	4.00	0.25		568
	(b) Bijapura minor	10.32 of Bhaisani dy.	1.72	0.84		138
	(c) Khampur minor	10.69 of Bhaisani dy.	2.60	0.056		128
3.	Barla minor	17.70 km of Right main dy.	7.25	0.339		708
		Total	46.87			5890 ha

2.3 OPERATIONAL PRACTICES IN THE UPPER GANGA CANAL SYSTEM

2.3.1 Operation of main Canal in Monsoon period

Since uncontrolled discharge carrying silt and floating debris is received at Mayapur from the ungated old supply channel, so operation of main canal during monsoon requires great vigil. The religious sanctity and commitments do not permit construction of a gated regulator on the old supply channel which feeds the Har-Ki-pauri sacred pond of Hardwar.

Following precautionary measures are to be adopted in operation of main canal during monsoon period.

1. Main canal should be closed whenever the silt content below silt rejector (constructed in 1975 at Km 2.2) exceeds 7.5 gms/lit (7500 ppm) or continues to remain above 5.00 gms/lit for more than 24 hours.
2. The canal should be reopened only when the silt content goes down below 5.0 gm/lit in the supply channel.
3. The U.G.C. should be closed from head whenever the flood discharge in the river Ganga is in excess of 5667.33 cumecs (2,00,000 (cusecs) .

Main canal should not be run with less than 184.19 cumecs (6500 cusecs) from head during monsoons when silt content in water is high as it is likely by to deposit silt in canal bed.

It would be worth while to mention here that during July 1970 there were heavy land slide in Alakhananda valley, in the catchment of Ganga river, which brought down heavy detritus at Bhimgoda works and heavy sediments entered in the U.G.C. which reduced the discharging capacity of U.G.C. from 297.0 cumecs to (10500 cusecs) to 99.18 cumecs (3500 cumes) causing 2.74 m (9 ft) depth of silt at the head of canal and 1.22 m (4 ft) near Pathari at km 11.26. The canal had to be closed during monsoon for desilting operations. As a result of above experience, the standing regulation orders were drastically revised and reissued in June 1972.

In revised regulations the following points were introduced

(a) The practice of taking x – section

(b) Observation of silt content at various points of entry/exit.

(c) Closing of U.G.C. when silt content was high.

(d) Closing canal during high flood intensity.

(e) Structural modification for improving regulation and a silt ejector was constructed at km 2.2 in the year 1975-76.

These measures have improved the situation to some extent and main canal has been running with the above pre-cautionary measures to meet out Kharif demand.

2.3.2 Operation of Main Canal During Non-Monsoon Period

The major part of monsoon rainfall is generally over by end of August and the silt content in the river water falls to about 1000 ppm during September. During non-monsoon period when silt content goes down below 1000 ppm and the available supplies are much shorter than the canal capacity, all available supply should be diverted in to main canal for irrigation and other requirements.

The weekly regulation day at the head of U.G.C. at Bhimgoda is fixed as Wednesday and the regulation is carried out between 6.00 A.M. and 8.00 A.M. All gauges at the head are read at 6.00 A.M. 12.00 noon and 6.00 PM. The gauges are recorded in a gauge register by the signallar in-charge and reported by canal telegraph to J.E./A.E./E.E./S.E. and to others as per special instructions. The canal is 291.91 km long and the effect of head regulation reaches the tail in about 3 days. The regulation of the heads of off taking channels in the main canal is carried out on the day and time when the effect of change at Bhimgoda reaches the particular site.

REGULATION OF CONTROLLING POINT

Cross regulators on U.G.C are required to raise the water levels in the main canal during lean supplies (usually from mid- November to mid–May) to feed the off-taking channels as per authorized discharges or to operate the escapes and hydropower stations.

LOWERING AND RAISING WATER LEVELS IN U.G.C.

When an unlined canal is opened after a long closure, sudden increase in the gauge and discharge would cause high velocities which are likely to cause scours in bed particularly when any type of obstruction is encountered also damages to the banks. Hence the gauge should not be raised by more than 6" every half hour. Like wise where U.G.C. is being closed the reduction in gauge should not be more than 6" every half hour.

OBSERVATION OF DISCHARGES

Observation of canal discharges is important for efficient regulation of any system and equitable distribution of water and also provides a tool for the health of canal. It helps in monitoring the seepage losses in different reaches and different seasons.

Similarly discharge of branches and distributaries off-taking from main canal should also be observed frequently to determine if any of the off-taking channels are drawing less or excessive discharges. This enables distribution of water more equitably. The main canal has a regular gauging station at Dhanauri Dam (kms. 21) for proper gauge discharge observations.

SEEPAGE LOSSS

Although there is a large variation in the seepage losses with climatic and physical conditions, yet it seems that, in general the seepage are of considerable magnitude. Variations are sometimes attributed to changing weather conditions such as temperature, wind velocity and with the condition of canal system. The losses due to evaporation in the canal are of very small magnitude compared to the total losses and are therefore, normally neglected. The two most common methods of determining seepage losses in offtakes are ponding method and. Inflow–outflow method but main canal losses are now measured by tracer technique method. Average seepage losses in the U.G.C. have been observed to be about 1.5 cumecs per million m^2 of wetted surface or as given below. Since the water profile in the system has been kept comparatively at lower levels, the losses as observed in U.G.C are nomally on lower side/

Main canal	- 1.5 cumecs/$10^6 m^2$
Branch canal	- 1.96 cumecs/10^6 m^2
Distributary and minors	- 1.21 cumecs/10^6 m^2

2.3.3 Operation of Branches, Distributaries and Minors

NECESSITY OF ROTATION RUNNING

The U.G.C. has a head design discharge of 297.00 cumec between mid – May and mid – November the river supplies are in excess of 297.00 cumec, but when the river supplies dwindle, the discharge goes down to about 127.515 cumec in Feb/March. In these circumstances, while the main canal runs continuously, the branches and distributary have to be run in rotation.

ALLOCATION OF SUPPLIES

The S.E. I.W. circle – I (Ganga), Meerut has been authorised to manage the inter circle and inter divisional distribution of water on the principles laid down in C.E.'s order (Appendix -) He convenes meetings of the concerned, S.E.'s in October/November to assess and decide the likely availability of water for utilisation in U.G.C as per its share and makes weekly allocation to each S.E. who in turn decides the plan of operation of Branches/Distributaries in his circle.

The executive Engineer after knowing his anticipated share of water in each week, prepares a plan of running the different distributaries in his division. These plans have to be prepared such that there is equitable distribution of water in regard to quantity and timing of supplies on different channels cattering for the crop pattern developed. Since the water available is less than requirement, a rotational running of various distributaries has to be planned. There are weekly osrabandi on outlets and hence the channels are run for one week or multiples there of at a time. The system of planned and rotational running to match the availability of water with the requirement in a most equitable manner is called the "Rostering" of the channels.

PREPARATION OF ROSTERS AND THEIR PUBLICITY

While the total availability of water in a division is fixed according to the share, the roster of running of different channels is prepared in consultation with District Agriculture Officer. After the roster has been finalized, the same is got printed in the form of a weekly running chart for the entire crop season for all the distributaries and minors in the division and is supplied to district and block level officials, Gaon Sabhas etc. for information and wide publicity so that the farmers may know as to when water will be available to their outlets and they may plan their supplemental irrigation requirements and agricultural operations accordingly.

ADJUSTMENT IN ALLOCATION AND ROSTERS

While planning the roster an attempt should be made to run the channels with full supply discharge and, if necessary, with a little higher gauge to utilize and distribute the allotted share of discharge in selected channels without having to surrender the share or run any channel with partial discharge.

In actual practice the river supplies may be in excess of or less than that assumed in the planning stage for each week. If any division/circle does not need the allotted supplies due to slack demand or is not ready otherwise, the distribution authority has to decide whether the quantity of water surrendered could be reallocated to it in subsequent weeks or should lapse. Normally no water is allowed to be escaped during Rabi period, when the supplies are much shorter than the demand. In view of in built flexibility of demand in large command, the supplies of any division can conveniently be utilized in other divisions and adjusted in the share allocated in rosters.

2.3.4 Operation of Outlets

The distribution of water from the outlet amongst the beneficiaries of the outlet command is done by enforcing weekly osrabandi or warabandi in which time and sequence is allocated to each land holder to the area commanded, outlets ventage is fixed on the basis of requirement of water for various crops proposed for irrigation.

The outlets are ungated and they are designed to run continuously so long as the channel runs in the roster. Thus there is no operational control on the outlets and majority of outlets on U.G.C. are pipe outlets, normally submerged acting as non-modular outlets.

2.3.5 Operation of Escapes

The escapes are operated with the help of head regulator. For efficient operation and quick reduction in canal discharge there is a cross regulator in the parent channel with the help of which emptying of the canal is hastened even in low discharge and flow of water downstream of cross regulator reduced almost to zero depending upon the capability of the escape and the discharge being received at the site of escape. The discharging capacity of all the escapes should be determined by actual observation of discharge at the first available opportunity so that the constraint of the system is known. Normally there has been gradual reduction in the capacities of many escapes.

Whenever an escape is opened during winter rains or in an emergency, the canal signaler should inform his Executive Engineer and seek instructions so that the water being wasted could be utilized by opening the closed channels in the regime if so required, in his own division or in other division.

2.4 PROBLEMS AND CONSTRAINTS IN U.G.C. SYSTEM

2.4.1 Problems

Due to multiplicity of regulation points and canal system being old, the problems in the U.G.C. specially in upper reaches of the system are quite fascinating and pose a challenge to the operation and maintenance staff. The major problems are as discussed below :

a) Sediment entry into U.G.C.

There is a serious problem of sediment entry in to U.G.C. at its head far in excess of its carrying capacity, during monsoons. Substantial portion of the sediment load gets entrapped in the available deep pools in the canal bed in head reaches and the remaining gets deposited in the lower reaches, specially above power stations. The deposited sediment gets washed out to some extent and carried by the canal to further low reaches, during clear water running resulting in the permanent deposition in the canal bed and reduction in its carrying capacity. To control the intensity of sediment problem in main canal, a silt ejector has been added at the km. 2.2 which is operated with an efficiency of nearly 30% to eject out substantial coarser bed load.

b) Dhanauri Level Crossing

Ratmau torrent crosses U.G.C. at 21 km almost at right angle to the canal. In order to regulate the supplies of the torrent and the canal at level crossing two regulators have been constructed. The upstream and downstream floor level of the escape regulator were kept at the same level when it was constructed. After operating for last more than 140 years, the average slope of the torrent has been reduced from 1.5 m/km to 0.53 m/km in the downstream reach. Floods varying from 850 cumecs to 2265 cumecs passed through the escape regulator. Heavy damages were observed on the upstream as well as on the downstream of the floor which were subsequently repaired. The canal has to be kept closed for several days during massive repair. During non-monsoon, clear water escaping downstream having more tendency to pick-up silt, causing retrogression year to year. In order to negotiate the severe retrogression, a fall followed by a stilling basin was added first in 1920 again 1967. Due to continuous retrogression in the down stream reach of the torrent, the bed has lowered by about more than 10 meters. As such to negotiate the retrogression developed, another falls may have to be provided. The regulator at this work is quite tricklish and need careful operation at all the time. The sediment entering into the canal is quite fine and easily washed down on subsequent running.

c) **Drainage System in U.G.C. Command**

Since there was great awareness to canal Engineers for proper drainage of canal command during construction and operation of old canal system in long past. U.G.C. system consist of fairly planned surface drainage arrangement but basically for draining storm water. Although U.G.C. system was primarily designed and constructed for protective rabi irrigation and kharif irrigation was subsequently developed, but due to quite favourable characteristics of Doab land, there is no appreciable underground drainage problem in U.G.C. command. However, some drainage problems in the command exist which are as below :

i) Higher water table in reaches where canal is in embankment.

ii) Some surface depressions where water collects.

iii) Obstruction of natural drainage by activity of local population.

In general, natural drainage of land is very good in northern districts and satisfactory in southern reaches. However, the natural drainages have been hampered by local persons activities. Irrigation intensities and specially development of paddy irrigation and induction of more water in the command during monsoons and fast increase in population have affected the drainage characteristics in the command.

d) **Escapes**

The head of escapes are not clubbed with falls which affects the operational efficiency. The existing escapes have get silted up in the large number of cases and their operating capacity has gone down to 50% in many cases. The tail falls are in a distress condition and need repairs/reconstruction, being in use for a large period and negligence in maintenance due to general shortage of maintenance funds.

e) **Communication System in U.G.C. Command**

For proper regulation of a canal system, a telegraph system connecting 70 stations and some telephone system, having 330 km route length containing 51 stations has been provided for U.G.C. area. The system is maintained by P & T Department and expenditure is borne by IDUP. The maintenance and operation of communication system is extremely poor and large portion remain ineffective throughout the year. Even during light rains, this system gets out of order. The system is to be replaced by modern system is connect all the important regulation points.

f) **Service Road**

Although major length of conveyance and distribution channels in U.G.C. system have been provided with motorable service roads but being unmettaled these roads can not be used round the year and specially during monsoons. Increasing discipline in the large number of users specially with their increase in need of use these roads and falling standard of maintenance the service roads of even main canal and branches are in real bad shape for proper and convenient driving for inspection.

g) **On Farm Problems**

In addition to above major problems there are following another problems :

(i) Outlet in general draw lesser water than their designed discharge, operating on middle and tail reaches.

(ii) Head reach channels get more water as compared to middle and tail reach channels.

(iii) The intensities of irrigation are much higher in head reach in comparison to tail reach.

(iv) Head reaches have more warabandi than the tail reaches.

(h) Monitoring and Evaluation Problems

(i) Daily gauges at head and tail of distributary or minor are taken by Patrol and reported to S.D.O. weekly or 10 – daily reports of supply pattern are not compiled to compare planned and actual patterns. If gauge at tail of channels is O.K. it is assumed that everything is correct. However, if the end point is not right, one does not know where to look for problem in upstream.

(j) No periodic reports on cropping patterns and cropping intensities are compiled to check the locational equity. There are no restrictions on cropping patterns. Irrigated areas at the end of season are measured for assessment of water changes.

(iii) Irrigation programmer are not formed before and after the season. However, at the end of each season, depth of water supplied over mixed crop are worked out to know the status of water consumption. There is variation in depth of water used in particular season from year to year.

(iv) As there is no control on cropping pattern and cropped area, the question of forming water release programme as per the sanction given and demand of crop does not arise. Only at the start of season roster showing weeks on & off is listed. It is also not followed strictly.

(v) Ground water levels are not monitored.

(i) **Incentive to Irrigators**

In warabandi system there is no incentive to the irrigators. As the charging is on the area basis, farmers do not use water economically. On the contrary, the farmers who takes initiative of spreading the water over greater area in an attempt to make the economical use of water has to pay relatively higher water charges but the careless irrigator enjoy the advantage of paying less water charges as compared to volume of water utilized by him. However increase in intensity of crops round the year and shortage of surface supplies the economy in use of water can be exercised if farmers are exposed and trained about it.

(k) **Scope for Malpractices :**

Although warabandi system involves less human interference in operation still no of malpractices are observed as given below :

(i) Selling or subletting of water

(ii) Applying water outside the outlet area.

(iii) Taking water out of turns

(iv) Dismantling water course

(v) Enlarging the size to outlet and tampering with the outlet.

(vi) Cutting canal banks.

But being in practice over a long period it has proved normally quite successful in distribution of water in large number of users without any formal water users associations.

2.4.2 Constraints

Constraints prevailing in U.G.C system are given as under :

2.4.2.1 Engineering Infrastructure Constraint

There are four major C.D. works in the upper reach of U.G.C. (between Hardwar & Roorkee). Their present status is different than the designed condition affecting the type and capacity of water flow in to main canal. These structures are major constraints in the U.G.C. system which can not be relied for prsent irrigation demands. Their present status have been discussed below.

(a) ***Ranipur superpassage*** : At the time of construction of Ranipur superpassage there was 2.744 m (') fall in U.G.C. at this site. When Pathri power house was constructed, the tall was eliminated. On account of this, the flow under the superpassage is not free and arches are submerged. Thus the original work which was designed initially for free flow condition is now working under partial system condition and arches are subjected uplift pressure. Canal has been syphons at the new crossing on parallel canal under construction.

(b) ***Pathri Superpassage*** : During the closure of U.G.C., it has been observed that there are cracks in the arches of first and last spans of the superpassage. A part from these, there is a problem of accretion in this super passage. This problem has now been solved with innovative and bold efforts of canal Engineers by strengthening the old crossing as per requirements of existing accretion and taking suitable measures in new crossing on parallel canal..

(c) *Dhanauri Ratmau Level Crossing* : At Dhanauri whenver the floods of the order of 1700 cumecs or more have passed, the downstream floor of Dhanauri got damaged and there was problem of retrogression downstream of the dam through major repairs were carried out on this work during 1924, 1947 and 1967. The works are still in vulnerable operative conditions and do need careful operation. However, aqueduct crossing has been provided on new canal which may eliminate major operational problems.

(d) *Solani Aqueduct* :The safety of Solani aqueduct was examined by experts committees. The reports of the committee consisting of Dr. Jai Krishna and Dr. O.P. Jain has recommended that there is an ample margin of safety even if the water depth in the aqueduct is increased by another 3 to 4 ft, but in practice it is not possible to increase gauge of canal. However, the studies conducted by U.P. I.R.I., Roorkee indicate that the aqueduct may not be quite safe. At present not more than 255 cumecs (9000 cusecs) can pass through aqueduct safely, which is major constraint in the U.G.C. system.

However, in view of rehabilitation of U.G.C. up to Roorkee, the problems at major cross drainage works would be eliminated.

2.4.2.2 Agriculture Constraints

The farmers in the upper third of U.G.C. system are growing sugarcane in substantial area. The sugarcane zone being near the head of the canal have always used more than their fair share of irrigation water; which has made the irrigation service to the lower part of command even more unreliable and untimely. No control has been exercised by IDUP to consume more water in upper reaches in Sugarcane zone.

2.4.2.3 Availability of Water

In Kharif season, there is ample water available to meet the requirement of paddy from July to mid - September. Periods of shortage are likely to occur normally in Ist fortnight of October. Shortage in other fortnights may also occur occasionally when their is long dry spells during monsoon and demands are higher in wide spread in large commands.

In Rabi season, there is always shortage of available water. Due to variability of available river flows for number of years, the rostering of canal is not generally followed. The farmers are unaware of the period and interval in which they will get next watering. Due to this farmers are not able to make agronomic activities with irrigation. Thus, the water delivery at present is in adequate, unreliable and uncertain to meet the continuos increasing demands of H.Y.V. These inculcation are however being met with by use of ground water by users with there own means.

2.4.2.4 Social Constraints

It is rather unfortunate that the spirit of cooperation and self discipline is still not generated among the farmers specially in northern part of India. Farmers belong to making social groups, religion, caste, sub-caste, village etc. unsocial practices have been adopted by the cultivators specially during drought and periods of keen demand.

2.4.2.5 Administrative Constraints

At present as administrative constraints there is no restriction on area irrigated and types of crops in water use policy. However, there is need of policy regarding limited surface water use for sugarcane during the Rabi period which may be supplemented by ground water. Thus Rabi irrigation should get priority over sugarcane, Existing canal act and laws need to be reviewed and amended by experienced professionals. The water rates are also not updated and are too low, seeing the rates of water consumed and the operation and maintenance expenses involved.

2.4.2.6 Financial Constraints

Continued reduction in the maintenance grants has resulted in the deterioration of channel and its structures to such an extent that efficient running of U.G.C. canal has become difficult as their carrying capacity has gone down., the service life of existing system can be increased if proper maintenance is carried out in time and is not allowed to defer due to shortage of funds. The management capabilities of organization responsible for operation and maintenance has also gone down to seeing the present needs efficiently.

Reviews by frequent examination by experienced experts professionals of the system is essential to restore the severe damages/deficiencies and maintain their desired capabilities of the system, similar practice adopted on surface irrigation systems in U.S.A. by USBR.

CHAPTER – 3

DETERMINATION OF CROP WATER REQUIREMENT

3.1 STUDY AREA

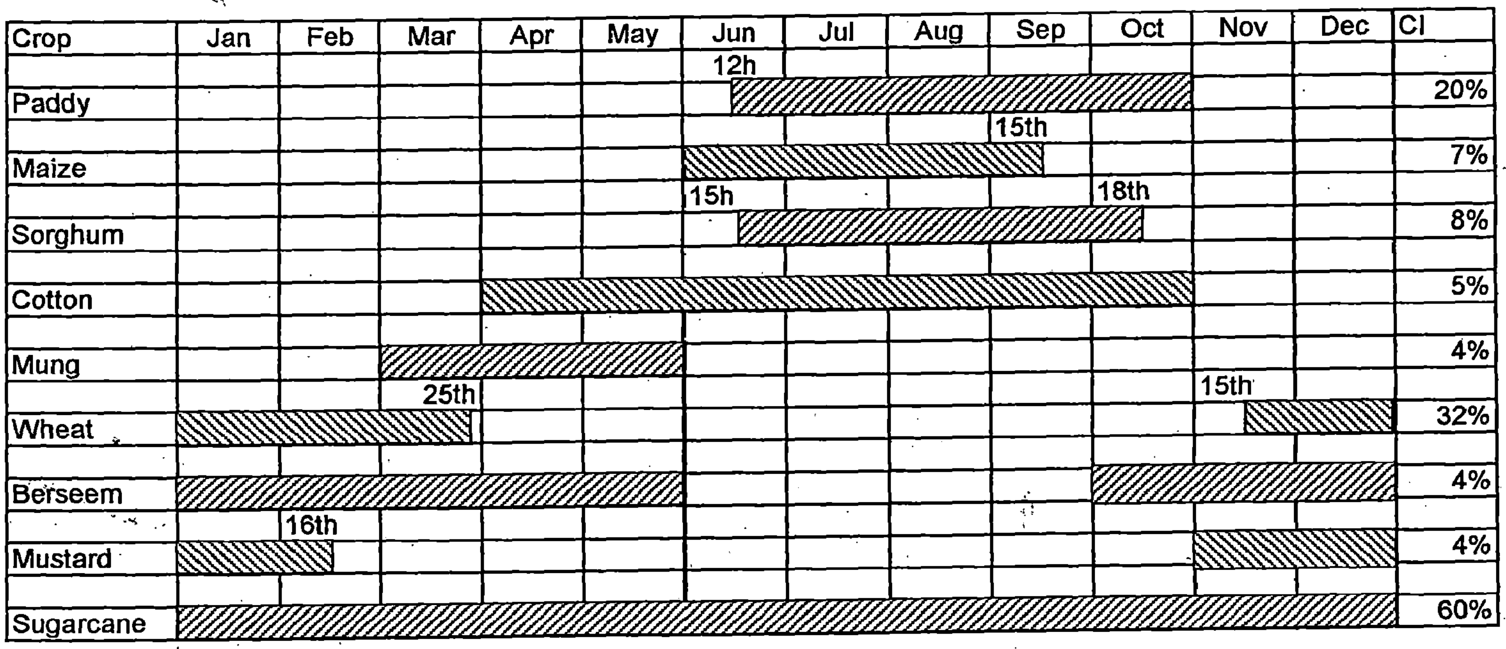
The study area is located within Narsan, Deoband and Purkaji blocks of Hardwar, Saharanpur and Muzaffarnagar districts respectively. The area is irrigated from right main distributary which off-takes from Deoband branch canal at chainage 7.26 km. Its discharge capacity at head at present is 3.4 cumecs. The total C.C.A. of right main distributary is 5890 ha.

There are two main irrigation seasons, April to September (Kharif) and October to March (Rabi). In Kharif seasons crops grown are Paddy, Maize, Sorghum, Cotton, Mung and in Rabi season Wheat, Berseem, Mustard crops are cultivated. Sugarcane is a perennial crop.

The surface irrigation is done by the canal network as mentioned above. It is being supplemented by ground water drawn through state tubewell, private tubewell and pump sets. Due to non-availability of adequate surface water supply "rostering" of system is being followed.

The data collected from Ganga Canal Division, Muzaffarnagar for Kharif and Rabi 1994-99 period have been used in computation of crop water requirement in the study area.

CROP CALENDER (existing)



3.2 EXISTING CROPPING PATTERN DURING KHARIF AND RABI

Sl.No.	Crop	Cropping Intensity
1.	Paddy	20%
2	Maize	7%
3	Sorghum	8%
4	Cotton	5%
5	Mung	4%
6	Wheat	32%
7	Berseem	4%
8	Mustard	4%
9	Sugarcane	60%
Total		144%

3.3 COMPUTATION OF ETc

ETo can be computed by climatological method, pan evaporatin method, modified penman method and Hargreeves method – modifed Penman method has been used for the present study.

In the modified Penman ETo is computed by the following equation.

$$ETo = C \frac{W.Rn}{\text{Radiation term}} + \frac{(1-W).f(u).(e_a - e_d)}{\text{Aerodynamic term}}$$

Where

ETo = Reference crop evapotranspiration in mm/day

Part A : (1-W). f(u) (e_a-e_d) is aerodynamic factor

Part B : WR_n – Radiation factor

Part C : "C" is the correction factor.

Part A : (1-W) .f(u). (e_a-e_d)

(i) e_a = saturated vapour pressure at mean air temperature in millibars, varies with T mean in 0°C.

(ii) e_d = actual vapour pressure in millibars

$$e_d = \frac{e_a x R_H \text{ max.}}{100},$$

R_H max. = Maximum relative humidity.

(iii) (e_a-e_d) = vapour pressure deficit in mbar arithmatically calculated

(iv) f(u) = wind related function from table No. 7 of F.A.O. 24.

$$f(u) = 0.27\left(1+\frac{U}{100}\right)$$

U = wind velocity in km/day at 2 m height from ground (known)

(v) (1-W) = Temperature related weighing factor (Table 9 of F.A.O. 24).

Part B : $W.R_n$

R_n = Net radiation in mm/day

$= R_{ns} - R_{nl}$

where,

R_{ns} = Net short wave radiation in mm/day

R_{nl} = Net long wave radiation in mm/day

$$R_{ns} = (1.0 - \alpha)(0.25 + 0.5 \frac{n}{N}) Ra$$

Where,

α = reflection factor = 0.25 for most of crops

n = mean actual sunshine hrs per day

N = Maximum possible sunshine hrs per day.

Ra = Extra – terrestarial radiation in mm/day

$$R_{nl} = f(T).\ f(ed).\ F(\frac{n}{N})$$

f(T) = σTK^4 [$\sigma = 2.01 \times 10^{-9}$ (Table – 13 F.A.O. 24.)

f(ed) = $0.34 - 0.044\sqrt{ed}$ (Table 14 F.A.O. 24.)

$F(\frac{n}{N}) = 0.1 + 0.9 \frac{n}{N}$ (Table 15)

Part C : "C" = Adjustment factor to compensate for the effect of day and night weather conditions.

ETo = (Part A + Part B) Pat C.

The value of ETo have been calculated for each month on the basis of climatological data recoded at Roorkee meteorological Station and are shown in Table 3.1.

The K_c = coefficients for different crops in different months given by FAO have been used. In determination of Kc _ coefficient, the mustard and Berseem have been considered equivalent to Cabbage and alpha – alpha respectively.

Determination of net irrigation requirement (N.I.R.) :

N.I.R. = ETc + special needs (excess irrigation) – effective rainfall.

Special needs are the requirement during land preparation, pre-plantation and at nursery stages.

Effective Rainfall : For calculation of effective rainfall, U.S.D.A. SCS method (page 75 of F.A.O. 24) has been used.

Gross Irrigation Requirement :

$$\text{F.I.R.} = \frac{\text{N.I.R.}}{\text{Field application effiiency}}$$

Gross Irrigation at the head of distributary

$$\text{G.I.R.} = \frac{\text{F.I.R.}}{\text{Conveyance effiiency}}$$

Conveyance efficiency 75% and field application efficiency 80% has been taken. G.I.R. for different crops in their respective growing period has been calculated and given in Table 3.2 to 3.10 and finally G.I.R. of all the crops have been been calculated are shown in Table 3.11.

Available surface waterat head has been calculated on the basis of actual running days of the canals and discharge which are shown in Table 3.12.

There is total 1678.86 ha.m. deficit of water between surface water supply and crop water requirement. At present surface water meets only 70 percent of requirement, the remaining 30 percent is being supplemented by ground water. Therefore groundwater balance study has been described in the next chapter – 4 to assess the ground water potential for sustained yield.

TABLE:3.1

Potential Evapotranspiration(ET0) by Modified Penman method

Country:India — Meteo.station:Roorkee

Altitude:274 m — Co-ordinates: 29.51 North latitude, 77.53 East longitude

Month	Max. temp. 0c	Min temp. 0c	Humidity %	Wind km/d	Sunshine(hr)	U day m/s	U day night	E T0 mm/d
Jan	20.1	6.6	73	69	6.9	1.9	1.2	1.7
Feb	22.9	8.7	65	78	7.7	2.6	1.2	2.4
Mar	28.7	13.1	51	86	8.4	3.2	1.3	3.7
Apr	35.2	18.2	39	104	9.7	3.5	1.3	5.3
May	39.4	23.6	35	121	10.8	3	1.3	6.7
Jun	38.5	25.9	49	121	9.6	3.2	1	6.6
Jul	33.3	25.5	77	95	6.2	2.8	1	4.7
Aug	32.3	25	79	78	6.1	2.4	1.3	4.2
Sep	32.4	23.4	76	69	7.8	2.2	1.3	4.1
Oct	30.9	17.2	70	60	9	1.4	1.3	3.5
Nov	26.5	10.1	68	52	8.4	1.8	1.7	2.3
Dec	22	6.8	73	60	7.7	1.7	1.3	1.7

Note: 30 yr. Average value of climatic data

TABLE:3.2

Date of sowing: 15th Nov. **Crop: Wheat** Duration: 130days

1 Particulars	Nov(15 days)	Dec.	Jan	Feb	Mar(25 days)
1 Eto(mm\day)	2.3	1.7	1.7	2.4	3.7
2 Eto(mm\month)	34.5	52.7	52.7	67.2	92.5
3 Kc	0.39	0.71	1.09	0.99	0.44
4 Etc= Kc.Eto	13.46	37.42	57.44	66.53	40.7
5 Special needs	100	0	0	0	0
6 Eff. Rainfall(mm)	0	0	21	40	12
7 N. I. R.(mm)	113.46	37.42	36.44	26.53	28.7
8 FIR(mm)	141.83	46.78	45.55	33.16	35.88
9 GIR(mm)	189.1	62.37	60.73	44.22	47.83

TABLE:3.3

Crop: Berseem

Date of sowing: 1st oct. Duration: 240 days

S. N.	Particulars	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
1	Eto(mm\day)	3.5	2.3	1.7	1.7	2.4	3.7	5.3	6.7
2	Eto(mm\month)	108.5	69	52.7	52.7	67.2	114.7	159	207.7
3	Kc	0.35	0.5	0.7	1.1	1.13	0.95	0.7	0.6
4	Etc=Kc.Eto	37.97	34.5	36.89	57.97	75.94	108.96	111.3	124.62
5	Spec.needs(mm)	75	0	0	0	0	0	0	0
6	Eff.rainfall(mm)	30	0	13	21.28	41	20.2	30	19
7	N.I.R.(mm)	82.97	34.5	23.89	36.69	34.94	88.76	81.3	105.62
8	FIR(mm)	103.71	43.13	29.86	45.86	43.68	110.95	101.63	132.03
9	GIR(mm)	138.28	57.5	39.82	61.15	58.23	147.93	135.5	176.03

TABLE:3.4

Date of sowing: 1st Nov. **Crop: Mustard** Duration:107 days

S. N.	Particulars	Nov.	Dec.	Jan.	Feb.(16days)
1	Eto(mm\day)	2.3	1.7	1.7	2.4
2	Eto(mm\month)	69	52.7	52.7	38.4
3	Kc	0.3	1	0.97	0.55
4	Etc= Kc.Etc	20.7	52.7	51.12	21.12
5	Special needs(mm)	75	0	0	0
6	Effec.rainfall(mm)	0	13.4	21.8	21.12
7	N,I.R.(mm)	95.7	39.3	29.32	0
8	F.I.R.(mm)	119.63	49.13	36.65	0
9	G.I.R.(mm)	159.5	65.5	48.87	0

TABLE :3.5

Crop: Rice

Date of sowing: 18th June

Duration: 135 days

S.N.	Particulars	June(12days)	July	August	Sep	Oct
1	ETO(mm\d)	6.6	4.7	4.2	4.1	3.5
2	ETO(mm\m)	79.2	145.7	130.2	123	108.5
3	Kc	1.1	1.1	1.1	1.1	1.06
4	Etc= Kc.ETO	87.12	160.27	143.22	135.3	115.01
5	Special needs	100	225	0	0	0
6	Effe.rainfall	25.65	155.48	123.03	121.16	52.13
7	NIR (mm)	161.47	229.79	20.19	14.14	62.88
8	FIR(MM)	161.47	229.79	20.19	14.14	62.88
9	GIR(MM)	215.29	306.39	26.92	18.85	83.84

TABLE:3.6

Crop:Maize

Date of Sowing: 1st June Duration: 107 days

S. N.	Particulars	June	July	Aug	Sep(15 days)
1	Eto(mm/day)	6.6	4.7	4.2	4.1
2	Eto(mm/month)	198	145.7	130.2	61.5
3	Kc	0.3	0.67	1.08	0.81
4	Etc=Kc.Eto	59.4	97.62	140.62	49.82
5	Special Needs	75	0	0	0
6	Effective Rainfall	42.52	97.62	130	46
7	N. I. R.(mm)	91.88	0	10.62	3.82
8	FIR(MM)	114.85	0	13.28	4.78
9	GIR(MM)	153,13	0	17.7	6.37

TABLE:3.7

Date of sowing: 15th June | Crop: Sorghum | Duration: 125 days

S. N.	Particulars	June	july	Aug	Sep	Oct
1	Eto(mm\day)	6.6	4.7	4.2	4.1	3.5
2	Eto(mm\month)	99	145.7	130.2	123	63
3	Kc	0.34	0.53	0.99	0.98	0.6
4	Etc= Kc.Eto	33.66	77.22	128.9	120.54	37.8
5	Special needs	75	0	0	0	0
6	Effective Rainfa	30	69	120	118	32
7	N. I. R.(mm)	78.66	8.22	8.9	2.54	5.8
8	FIR(mm)	98.33	10.28	11.13	3.18	7.25
9	GIR(mm)	131.1	13.7	14.83	4.23	9.67

TABLE:3.8

Date of sowing:1st April | Crop: Cotton | Duration: 214 days

S.N.	Particulars	April	May	June	July	August	September	October
1	Eto(mm\day)	5.3	6.7	6.6	4.7	4.2	4.1	3.5
2	Eto(mm\month)	159	207.7	198	145.7	130.2	123	108.5
3	Kc	0.4	0.7	1.06	1.06	0.99	0.89	0.8
4	Etc= Kc.Eto	63.6	145.39	209.88	154.44	128.89	109.47	86.8
5	Special needs	75	0	0	0	0	0	0
6	Effective rainfall	26	0	58.96	134.28	120	102.25	36
7	N.I.R.(mm)	112.6	145.39	150.92	20.16	8.89	7.22	50.8
8	FIR(mm)	140.75	181.74	188.65	25.2	11.11	9.03	63.5
9	GIR(mm)	187.67	242.32	251.53	33.6	14.82	12.03	84.67

TABLE:3.9

Crop: Mung

Date of sowing: 1st March Duration:92days

S. N.	Particulars	March	April	May
1	Eto(mm\day)	3.7	5.3	6.7
2	Eto(mm\month)	114.7	159	207.7
3	Kc	0.3	1.24	1.1
4	Etc= Kc.Eto	16.65	197.16	228.47
5	Special needs	75	0	0
6	Effective rainfall(	16.65	34	20.32
7	N.I.R.(mm)	75	163.16	208.15
8	FIR(mm)	93.75	203.95	260.19
9	GIR(mm)	125	271.93	346.92

TABLE:3.10

Date of sowing: 15th Feb.					Crop: Sugarcane				Duration: 365 days			
S. Particulars	Feb	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.
1 Eto(mm\day)	2.4	3.7	5.3	6.7	6.6	4.7	4.2	4.1	3.5	2.3	1.7	1.7
2 Eto(mm\month)	31.2	115	159	208	198	146	130.2	123	109	69	52.7	52.7
3 Kc	0.38	0.44	0.52	0.69	0.85	0.95	1.02	1.04	1.03	1	0.88	0.83
4 Etc= Kc.Eto	11.86	50.5	82.7	143	168.3	138	132.8	128	112	69	43.38	43.74
5 Special needs(ı	75	0	0	0	0	0	0	0	0	0	0	0
6 Effect. Rainfall(ı	26.93	17	28	16.4	51.88	133	127	108	38	0	14.3	21
7 N. I.R.(mm)	59.93	33.5	54.7	127	116.4	5.42	5.8	19.9	73.8	69	29.08	22.74
8 F. I. R.(mm)	79.91	44.6	72.9	169	155.2	7.23	7.73	26.6	98.3	92	38.77	30.32
9 G. I. R.(mm)	90.8	50.7	82.9	192	176.4	8.21	8.79	30.2	112	104.6	44.06	34.45

TABLE:3.11

Gross irrigation Requirement(G.I.R.) of Right Main Distributary Command.

Total C.C.A.=5890 ha.

(ha.m)

Crop	CCA(%)	Area(ha.)	Jan.	Feb.	Mar.	Apr.	May.	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1 Kharif															
Paddy	20	1178	-	-	-	-	-	253.6	360.93	31.71	22.21	98.76	-	-	767.22
Maize	7	412.3						63.14	-	7.3	2.63	-	-		73.07
Sorghum	8	471.2						61.77	6.44	6.99	1.99	4.56	-	-	81.77
Cotton	5	294.5				55.27	71.36	74.08	9.9	4.36	3.54	24.94	23.37	-	266.82
Mung	4	235.6			29.45	64.06	81.73	-	-	-	-	-	-	-	175.24
2 Rabi															
Wheat	32	1884.8	114.46	83.35	90.15	-	-	-	-	-	-	-	356.42	117.55	761.93
Berseem	4	235.6	14.41	13.72	34.85	31.92	41.47	-	-	-	-	32.58	13.55	9.38	191.88
Mustard	4	235.6	11.51	-	-	-	-	-	-	-	-		37.58	15.43	64.52
3 Perennial															
Sugarcane	60	3534	119.06	313.8	175.2	286.3	664.4	609.5	28.38	30.36	104.29	386.16	361.25	152.24	3230.94
Total	144	8481.6	259.44	410.8	329.7	437.5	859	1062	405.67	80.72	134.66	547	792.17	294.6	5613.39

TABLE:3.12

Deficit of water in right main distributary command in ha.m   Total CCA=5890 ha

S. N.	Particulars	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	Total GIR(ha-m)	259.44	410.82	329.67	437.54	858.99	1062.11	405.67	80.72	134.66	547	768.8	294.6	5590.02
2	Running days of canal	8	11	11	14	21	21	21	13	13	11	7	8	159
3	Discharge of canal (Cumecs)	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	
4	Delivery of canal (ha-m)	235	323.14	323.14	411.26	616.9	616.9	616.9	381.89	381.89	323.14	205.63	235	
5	Deficit of water (1-4)	24.44	87.68	6.53	26.28	242.09	445.21	0	0	0	223.86	563.17	59.6	1678.86

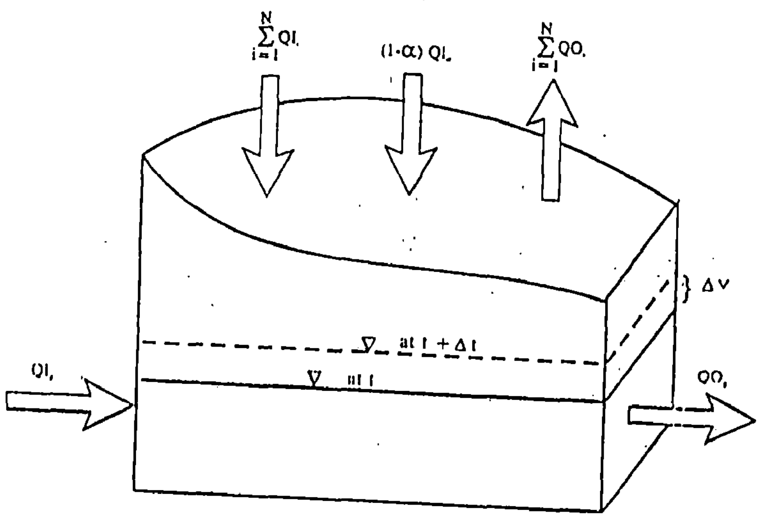
CHAPTER-4

A WATER BALANCE MODEL

4.1 INTRODUCTION

Water balance model is mainly a book keeping procedure which estimates the balance between the replenishment of water from precipitation and other sources and outflow of water by evapotranspiration, effluent seepage and ground water withdrawal. Water balance study of an area is useful to find the status of water resources utilization.

Process level models i.e. models used for evaluation of (i) seepage from a canal reach, (ii) surface runoff originating from rainfall (iii) infiltration and its redistribution due to rainfall (iv) evapotranspiration from the root zone,(v) irrigation return flow and (vi) influent and effluent seepage from stream are integrated in a water balance model. The integrated model can either be a lumped one or a distributed one.



Controlled Volume for a Lumped Water Balance Model

Considering the saturated control volume, the following ground water balance equation has been proposed by Khan (1980)

$$\sum_{i=1}^{N} QI_i + (1-\alpha)QI_{ir} + QI_g - \sum_{i=1}^{N} QO_i - QO_g = \frac{\Delta v}{\Delta t}$$

In which,

$\sum_{i=1}^{N} QI_i$ = total inflow into the saturated control volume comprised of recharge from precipitation, influent seepage from stream and artificial recharge;

QI_g = the groundwater inflow from adjacent section;

QI_{ir} = the total quantify of water applied for irrigation;

$\sum_{i=1}^{N} QO_i$ = the total outflow from the control volume comprised of pumpage; effluent seepage and evapotranspiration from shallow water table;

QO_g = the groundwater outflow to the adjacent section;

α = the irrigation efficiency over the domain which is unknown;

Δv = the change in volume of water within the control volume during time Δt which is equal to integration of change in water level multiplied by specific yield. Δv can be computed either using a distributed ground water flow model or by direct measurement.

Ground water level data, stream cross section and stage data, water spread area of the tank, aquifer parameters and water supplied for irrigation are required to carry out the water balance. From this equation only one unknown quantity can be estimated.

The area of interest for the present study is the command of right main distributary which is off taking from Deoband branch canal at chainage 7.26 km. The distributary has a culturable command area (C.C.A) of 5890 ha. For water balance study the area bound by river Kali in the West side, Ganga Canal in the East side, Deoband branch canal in the North, and a decomposed aquifer boundary in the South has been considered. The zone bound by the above boundaries has an area of 3.804032 x 10^8 ha. The area is comprised of three community blocks viz. Gurukul Narsan, Deoband and Purkaji of Haridwar, Saharanpur and Muzaffar Nagar districts respectively.

4.2 HYDROLOGICAL AND GEOHYDROLOGICAL FEATURES OF THE STUDY AREA:

4.2.1 Climate and Rainfall

The area experiences moderate type of sub-tropical and monsoonic climate. The temperature rises upto $40^{O}C$ in in summer and falls down to $2^{O}C$ in winter. Monsoon generally sets towards the end of June and lasts till the end of September. Most of the precipitations occurs during the months of July, August and September. The winter rains are scanty. The water balance has been carried out considering normal rainfall. The monthly average rainfalls for the study area has been worked out on the basis of rainfall observed at Roorkee observatory station. The monthly average rainfall have been computed considering rainfall data of five years which are given in Table 4.2.

4.2.2 Drainage System of the Area

The area is drained by the river Kali Nadi. The discharge data of Kali Nadi near the study area are not available. Therefore, a gradient of 1 in 500 has been assumed to compute the effluent seepage to the river. The details of drainage path are shown in index map.

4.2.3 Ground Water Condition in the Study Area

Groundwater in the study area occurs under shallow water table condition. The main aquifers of the region are sand beds. Most of the aquifers are generally in unconfined to semi-confined conditions. Main source of replenishment to ground water reservoir is rainfall which occurs during monsoon. The water table therefore, rises during monsoon due to recharge from rainfall. During the non-monsoon period the water table goes down due to withdrawl from the ground water reservoir. The water table rises to the highest level immediately after the monsoon and declines to the lowest level during the month prior to the monsoon.

4.2.4 Water Table map

Ground water contours showing points of equal elevation of water table for the month of June and October in the year 1995 - 1996 are presented in Fig. 3 to 6 of the water table contours indicate that the ground water table slopes from study area to south-east direction. Average water table slope is about 1 in 500.

4.2.5 Aquifer Characteristics

The usefulness of an aquifer as a source of water largely depends on its specific yield and transmissibility. Pumping test has been conducted within the area by Ground water department Roorkee division in the year 1991. Specific yield is found to be 16% and transmisivity to be 521.00 m^2/day in Rankhandi village of Deoband block. But the average transmisivity of whole study area is higher than the test value. The average value of whole study area, transmissibility has been reported to be 1521 m^2/day.

4.3 WATER BALANCE METHODOLOGY

The study area is divided into a number of rectangular grids. The grid size is 800 x 1052 m in x and y direction respectively. In the study area there are 25 no. of rows and 22 no. of columns. J represents column and I represents row.

4.3.1 Recharge from Rainfall

Recharge due to rainfall depends upon several factors such as characteristic and thickness of soil, topography, vegetable cover, land use, depth to water table, intensity, duration and seasonal distribution of rainfall and air temperature. Recharge from rainfall, therefore varies in space and time. No field study has been conducted in the project area to estimate recharge due to rainfall. The U.P.I.R.I. conducted a study in Western U.P. which is applicable to the study area. The empirical relation suggested by U.P.I.R.I is

$$Rr = 3.47\,(R-38)^{2/5}$$

where,

Rr = Rainfall penetration in cm.

R = normal annual rainfall in cm.

The relationship is based on the study conducted in five small doabs in western U.P.

4.3.2 Seepage from Canal

The rate of seepage from unlined canals depends upon the channel dimension of the canal and drainage conditions and coefficient of permeability of subsoil. For calculation of seepage loss the wetted perimeter was worked out on the basis of cross-section of each channel. Seepage rate through upper Ganga canal is 1.5 m^3/see/10^6 sq.m. of wetted perimeter. For Branch canal and distributary/minor the seepage rate is 1.96 and

1.21 m^3/see/$10^6 m^2$ respectively. These seepage rates are based on the results of study carried out by U.P.I.R.I. Roorkee in this region.

4.3.3 Irrigation return flow

Irrigation return flow depends upon type of soil up to water table, depth to water table, method of irrigation, frequency of irrigation and hydro-meterological parameters.

The irrigation return flows for different crops have been assumed as -

Crop	Percentage
Paddy	40
Maize	15
Sorghum	15
Cotton	15
Wheat	25
Berseem	15
Mustard	15
Mung	15
Sugarcane	30

4.3.4 Subsurface Inflow

Looking at the water table contours, it is found that lateral subsurface inflow is taking place from top. The study area is bound by Deoband branch canal in the north. This inflow is assumed to be half of the seepage from Deoband canal.

4.3.5 Subsurface Outflow

The water table contour shows that some part of outflow is taking place from study area to Kali nadi and another part under the main Ganga canal towards the river

Solani. There is also outflow towards south of the study area. The outflow from basin has been calculated using Darcy's law. The gradient of flow has been taken as 1 in 500 and transimissivity has been taken as 1521 m^2/day.

4.3.6 Withdrawl from Groundwater Reservoir

With drawl from groundwater reservoir in the study area is done through state tube well, private tube well, pump sets and other means. It is assumed that any deficit in surface water supply to meet the crop water requirement is met by ground water withdrawal.

4.3.7 Results of the Water Balance Model

Considering all components of inflow i.e. seepage from canals, recharge from rainfall, replensihment from irrigation return flow and ground water inflow at the northern boundary, and all the components of outflow, i.e. ground water outflows taking place through the eastern, western and southern boundaries, and pumping as per crop water requiement, monthly water balance has been carried out starting from the month of January.

The recharge due to precipitation during normal rainfall year, (1994 to 1998) is 215.05 mm which is about 16.7 percent of annual rainfall. While the recharge in drought year 1987 is only 97.198 mm which is about 14.49 percent of annual rainfall. Results have been presented for the following five cases :

1. Existing cropping intensity = 144% and rainfall is normal.
2. Excess surface water is not supplied more than crop water requirement and rainfall is normal.
3. Cropping intensity is 170% and rainfall is normal.

4. Cropping intensity is 144% (existing) and rainfall corresponding to the drought year 1987.

5. Cropping intensity of 170% (proposed) and rainfall corresponding to the drought year 1987.

The hydrograph of average water level for each cases are shown in Fig. 4.12 to Fig. 4.16. The details of water balance components are given in Table 4.3 to 4.7. The results of water balance for different cases are given in Table 4.1.

Table 4.1 status of water level position at the end of December for different hydrological conditions and Cropping Intensity.

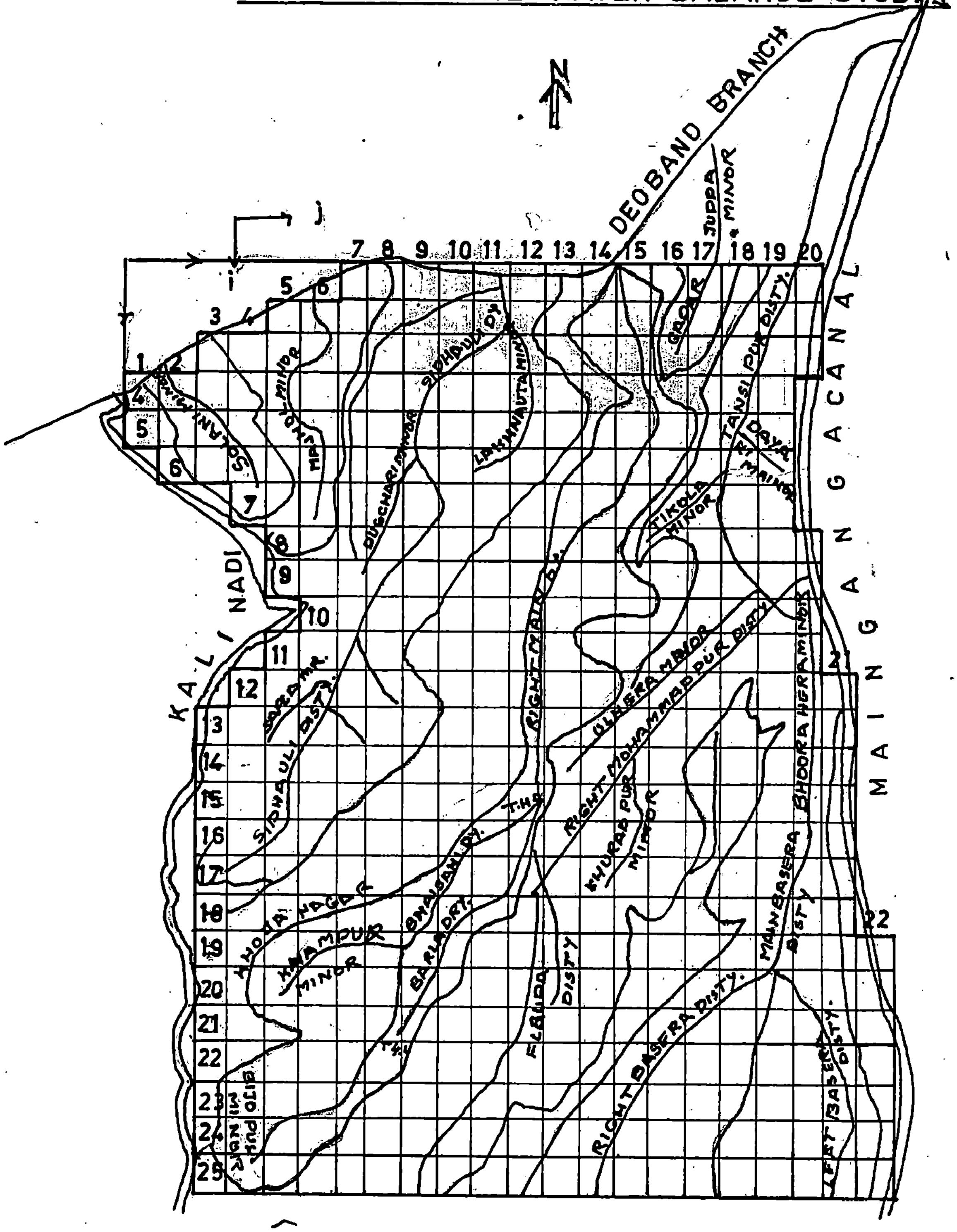
Case	Water table position at the end of December with respect to the position prevailed during beginning of January of previous year	
	Rise (cm)	Fall (cm)
1	24.1	-
2	-	4.5
3	6.3	-
4	-	49.5
5	-	67.3

From the water balance study it is ascertained that the cropping intensity can be increased up to 170% and there is sufficient ground water available to support this increased cropping intensity. The excess water more than crop water requirement supplied causes recharge to ground water. If this excess water is not conveyed in the canal a ground water mining of 4.5 cm occurs even for 144% cropping intensity. If the excess water is conveyed cropping intensity can be increased from 144 to 170% without causing groundwat er mining.

For drought condition and existing 144% cropping intensity a ground water mining of 49.5 cm will occur. For a cropping intensity of 170%, a mining of 67.3 cm will occur for drought condition.

The position of available surface water and crop water requirement in each cases are shown in Fig. 4.7 to 4.11.

DOMAIN OF THE WATER BALANCE STUDY.



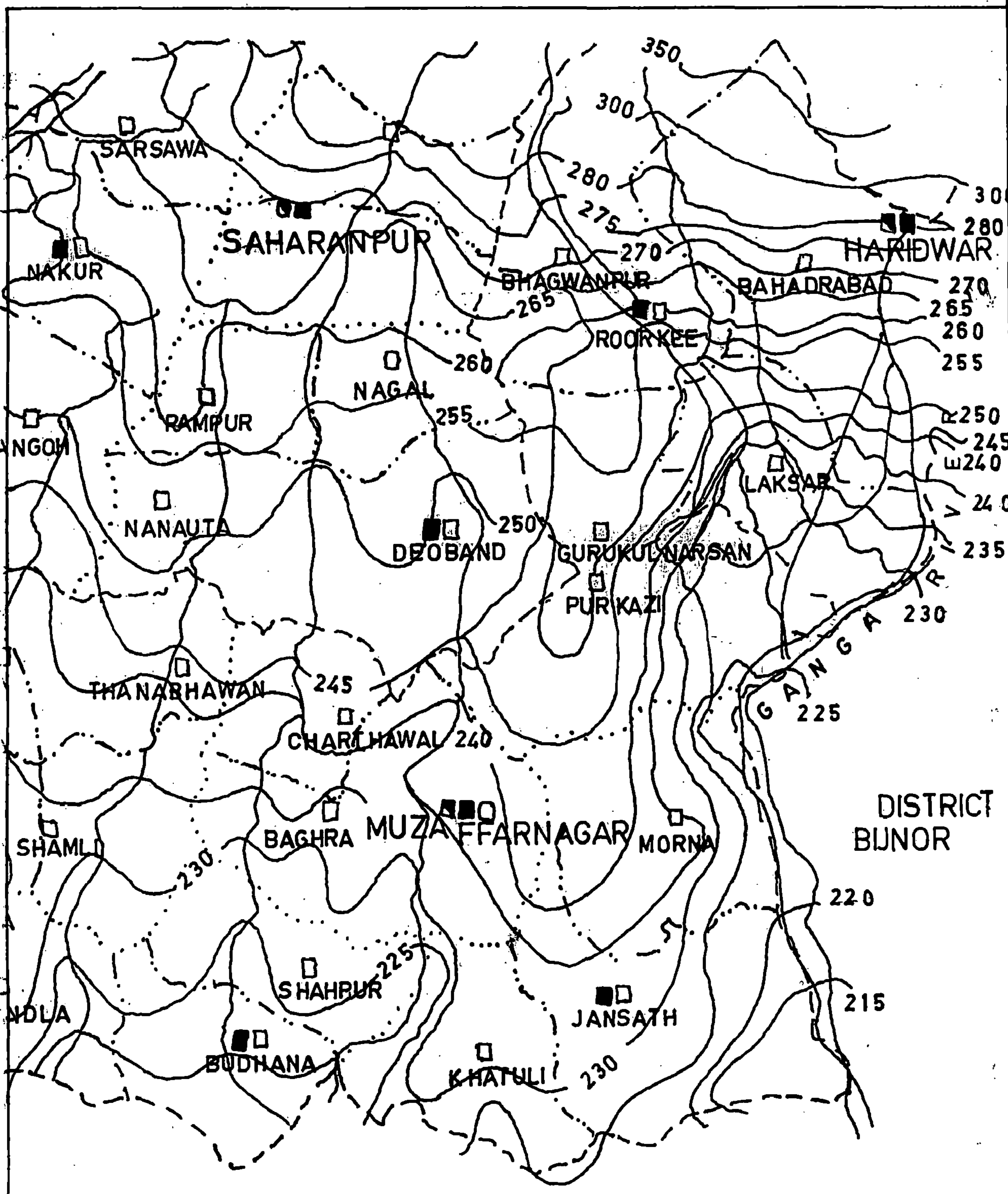
SCALE 1" = 2 MILE

H = 800 M

V = 1052M

GRIDE AREA = 84.16 Ha.

FIG.-2

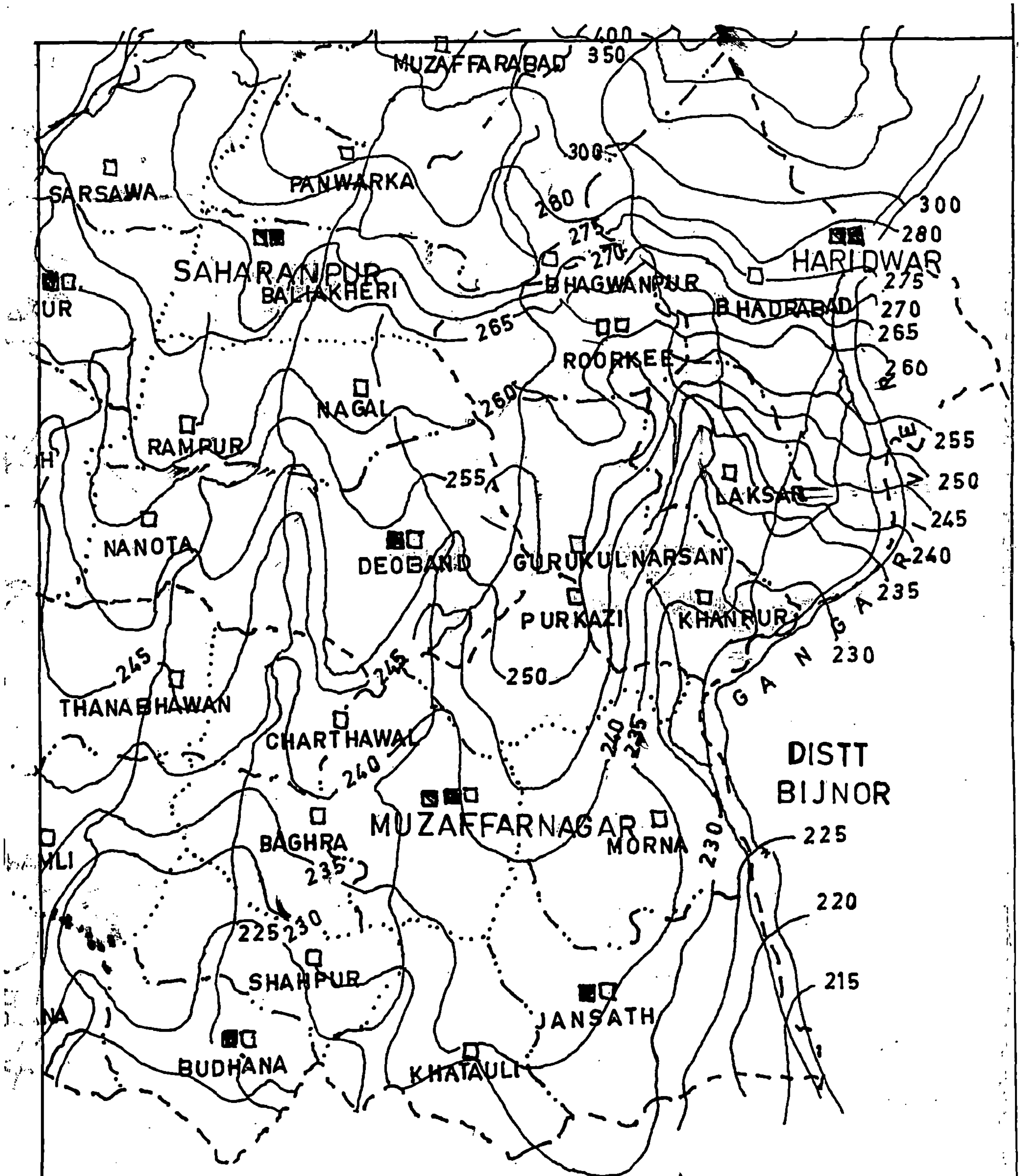


PREMONSOON SPRING LEVEL CONTOURS 1995

SCALE 1" = 8 MILES

FIG - 3

REFRENCE	
1	RIVERS
2	DRAINS
3	DIVI. BOUN.
4	SUB DIVI. BOUN.
5	DISTRICT BOUN.
6	BLOCK BOUN.
7	CANAL INSPETION HOUSE

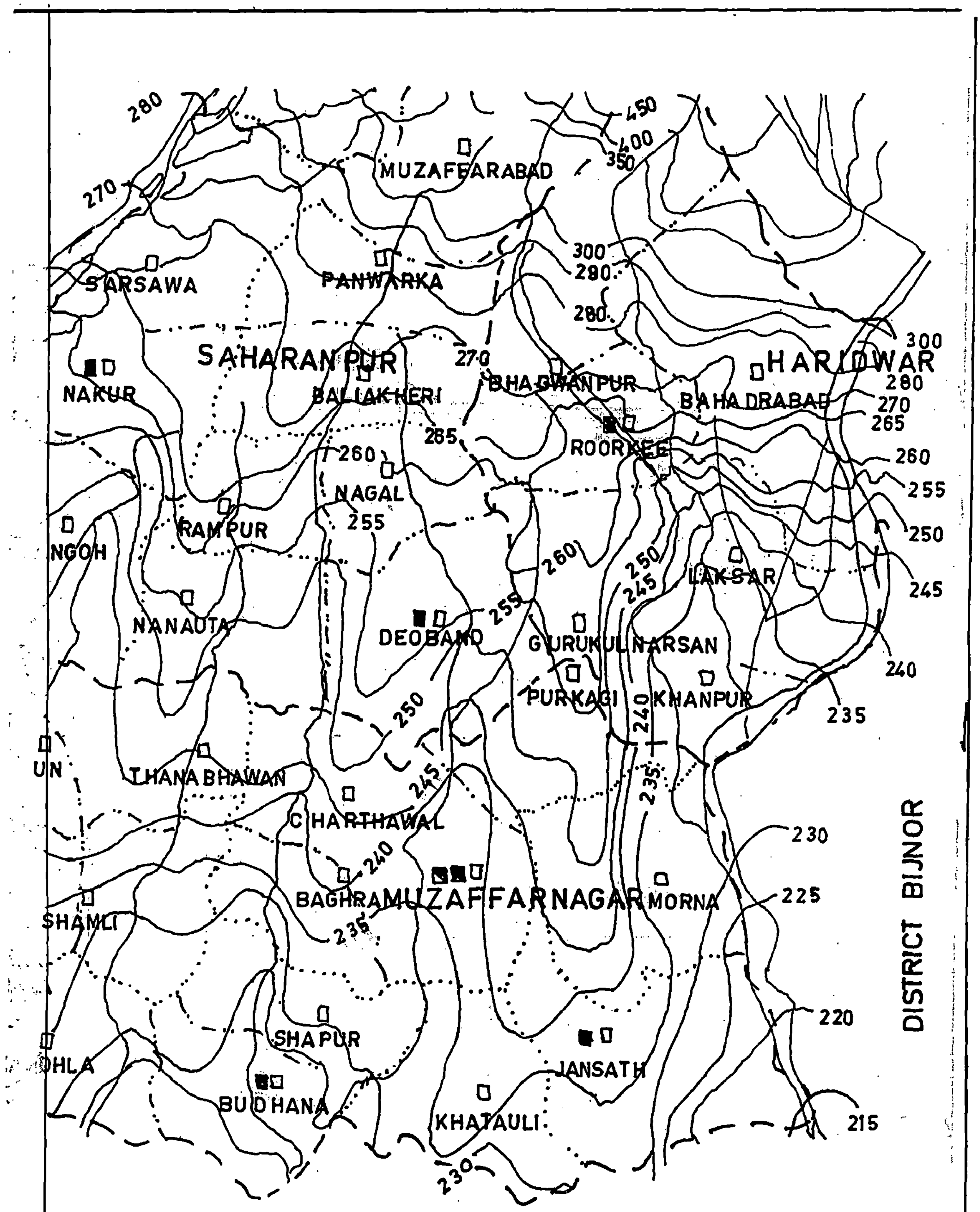


	REFRENCE	
1	RIVERS	
2	DRAINS	
3	DIVISION BOUN.	
4	SUB DIVI. BOUN.	
5	DISTRICT BOUN.	
6	CANAL INSPECTION HOUSE	
7	BLOCK BOUN	

POST MONSOON SPRING LEVEL CONTOURS 1995

SCALE 1"=8 MILE

FIG-4

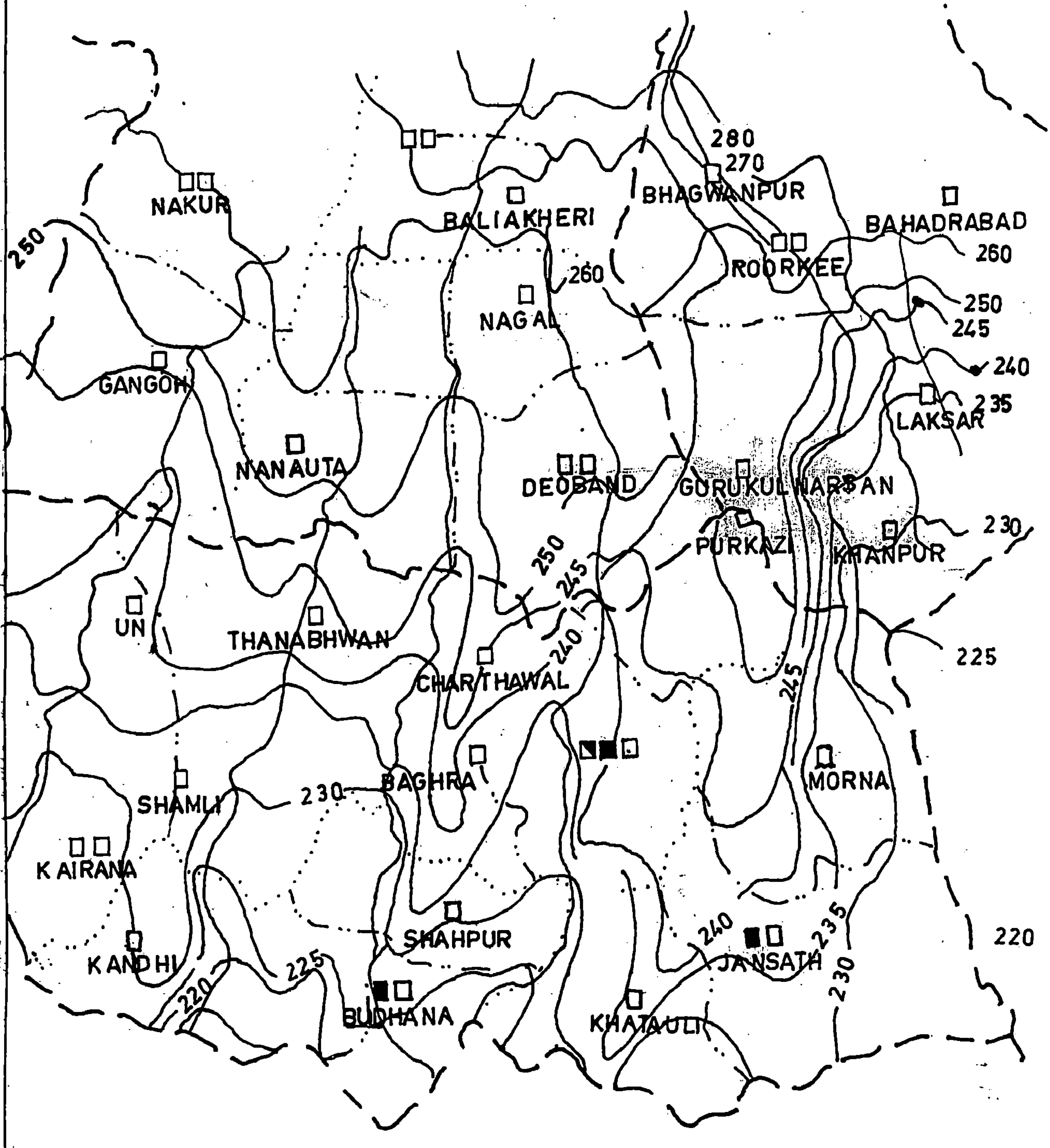


MAXIMUM SPRING LEVEL CONTOURS 1996 (POST MONSOON)

SCALE 1" = 8 MILES

FIG NO. 5

REFERENCES
1 RIVERS
2 DRAINS
3 DIVI. BOUN.
4 SUB DIVI. BOUN.
5 DIST. BOUN.
6 INSPECTION HOUSE
7 BLOCK BOUN.



MINIMUM SPRING LEVEL
CONTOURS (1996 PREMONSOON)

SCALE 1" = 8 MILE

FIG-6

	REFRENCE
1	RIVERS
2	DRAINS
3	DIVISION BOUN.
4	SUB DIVI BOUN.
5	DISTRICT BOUN.
6	CANAL INSPECTION HOUSE
7	BLOCK BOUN.

Fig4.7 Monthly surface water availability and crop water requirement for case1(Cropping intensity144% and rainfall normal)

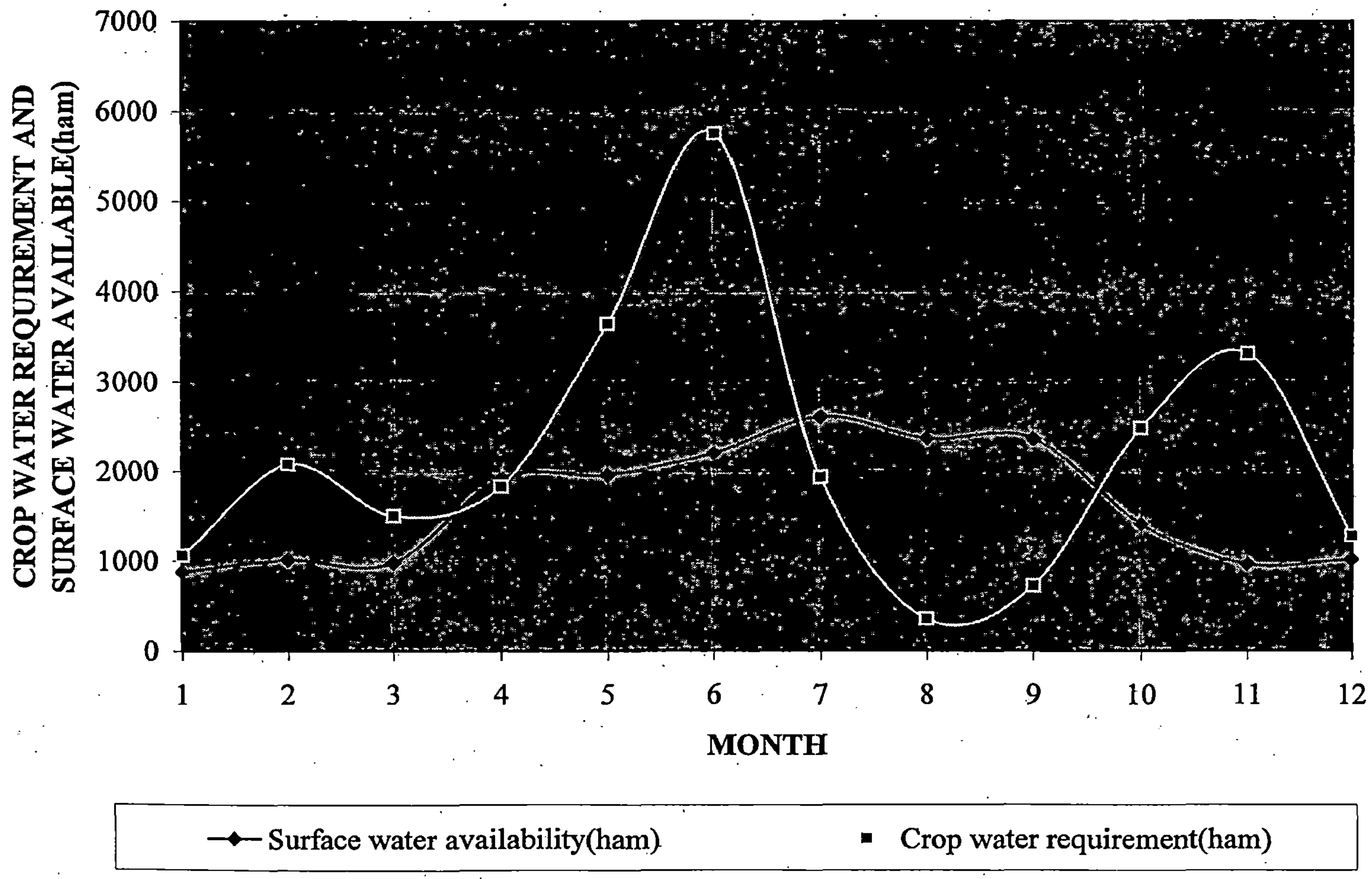


Fig4.8 Monthly surface water availability and crop water requirement for case2.Excess surface water is not supplied more than crop water requirement and rainfall is normal

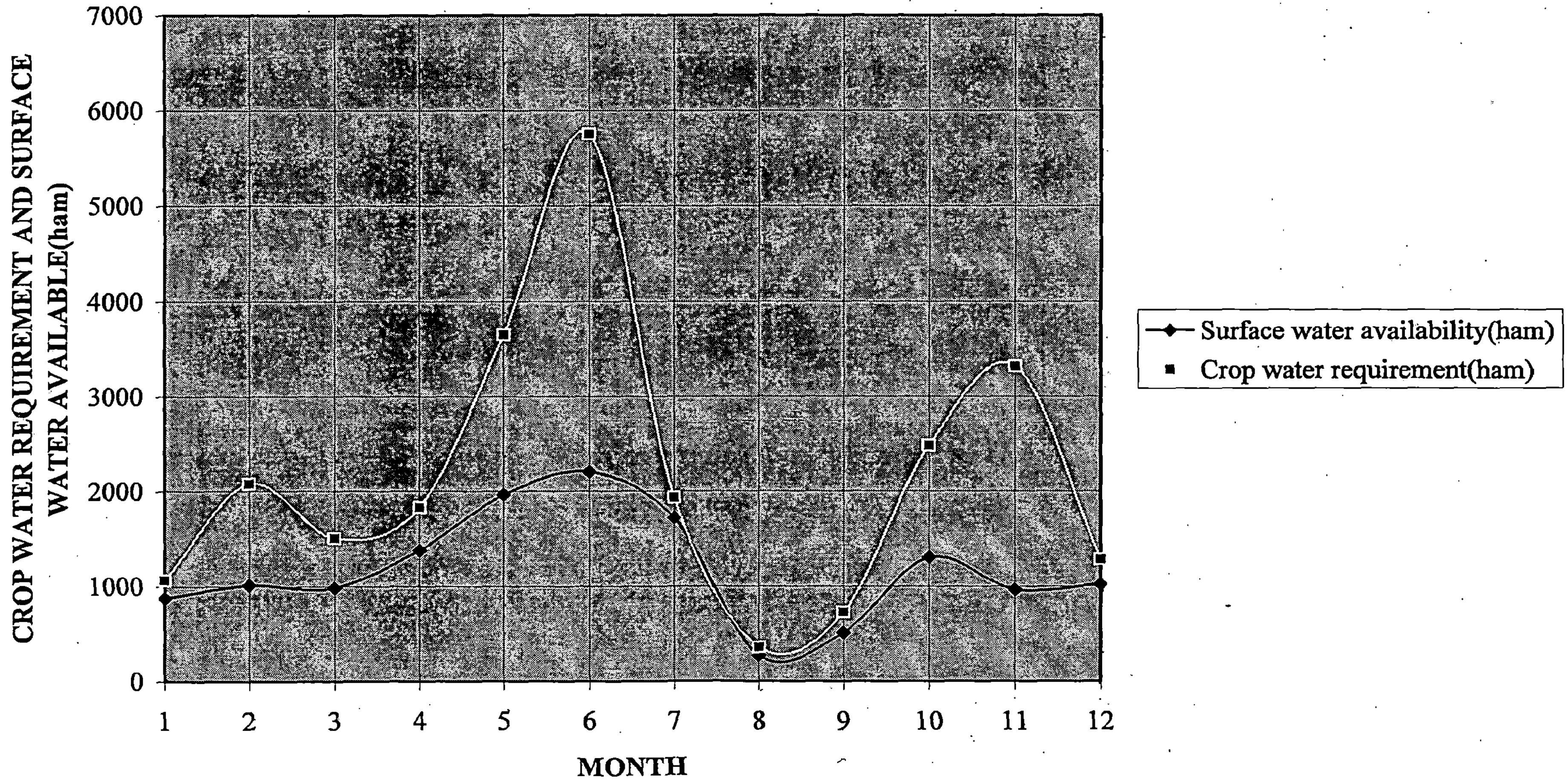


Fig.4.9 Monthly surface water availability and crop water requirement for case3:Cropping intensity 170% and rainfall normal

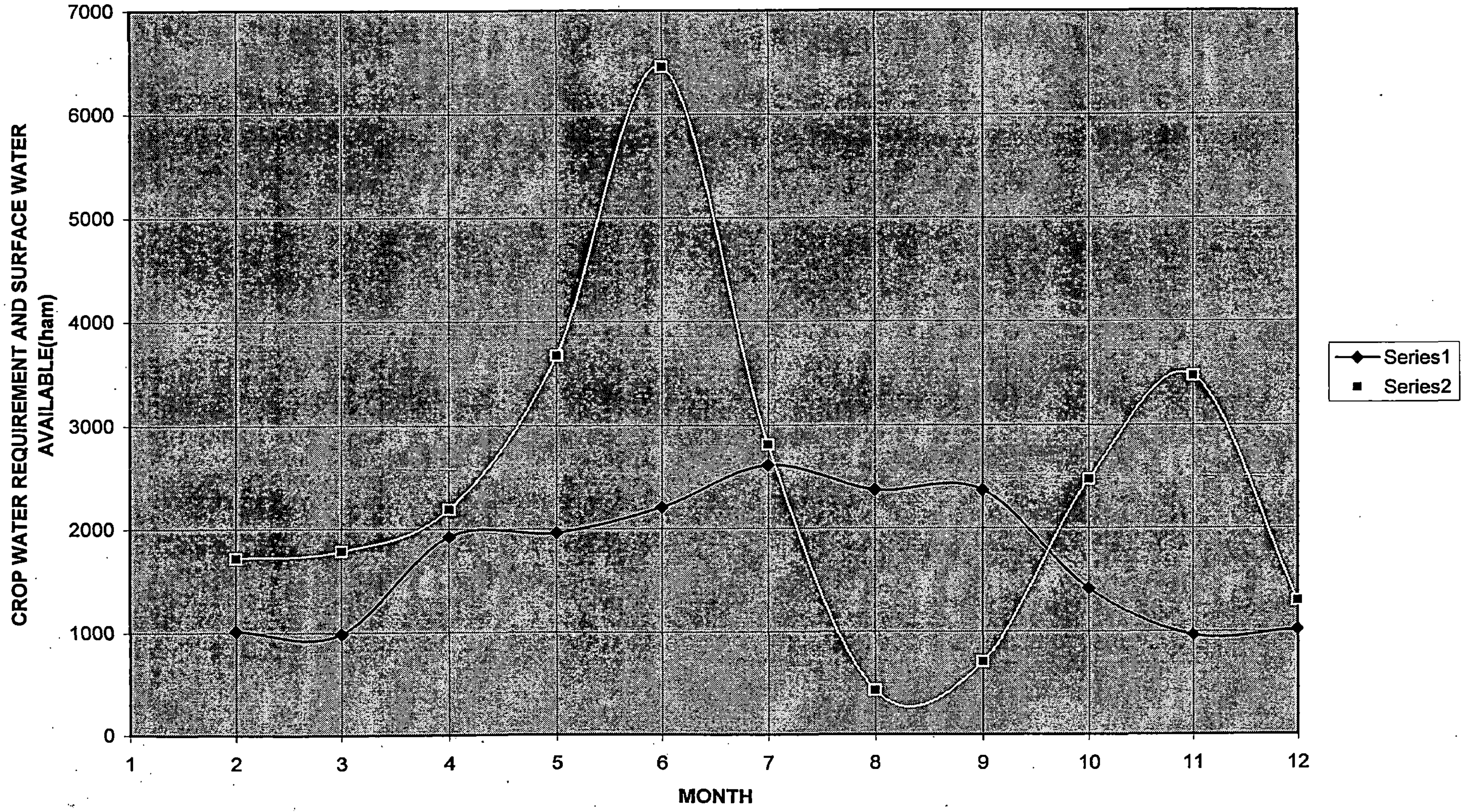


Fig4.10:Monthly surface availability and crop water requirement for case4.Cropping intensity 144%(existing) and rainfall corresponding to the drought year1987

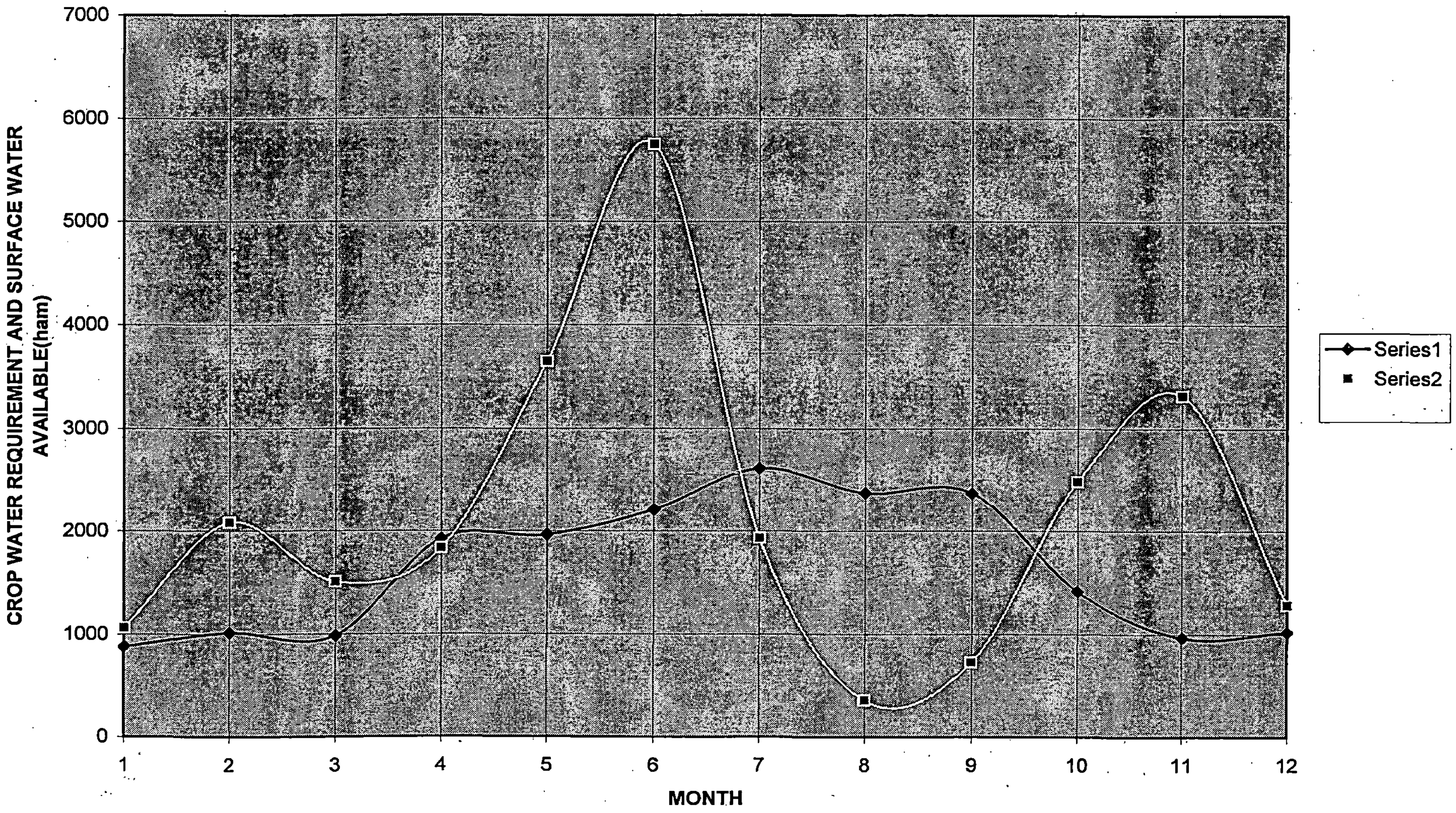


Fig4.11 Monthly surface water availability and crop water requirement for case5.Cropping intensity 170%(proposed) and rainfall corrwsponding to the drought year 1987

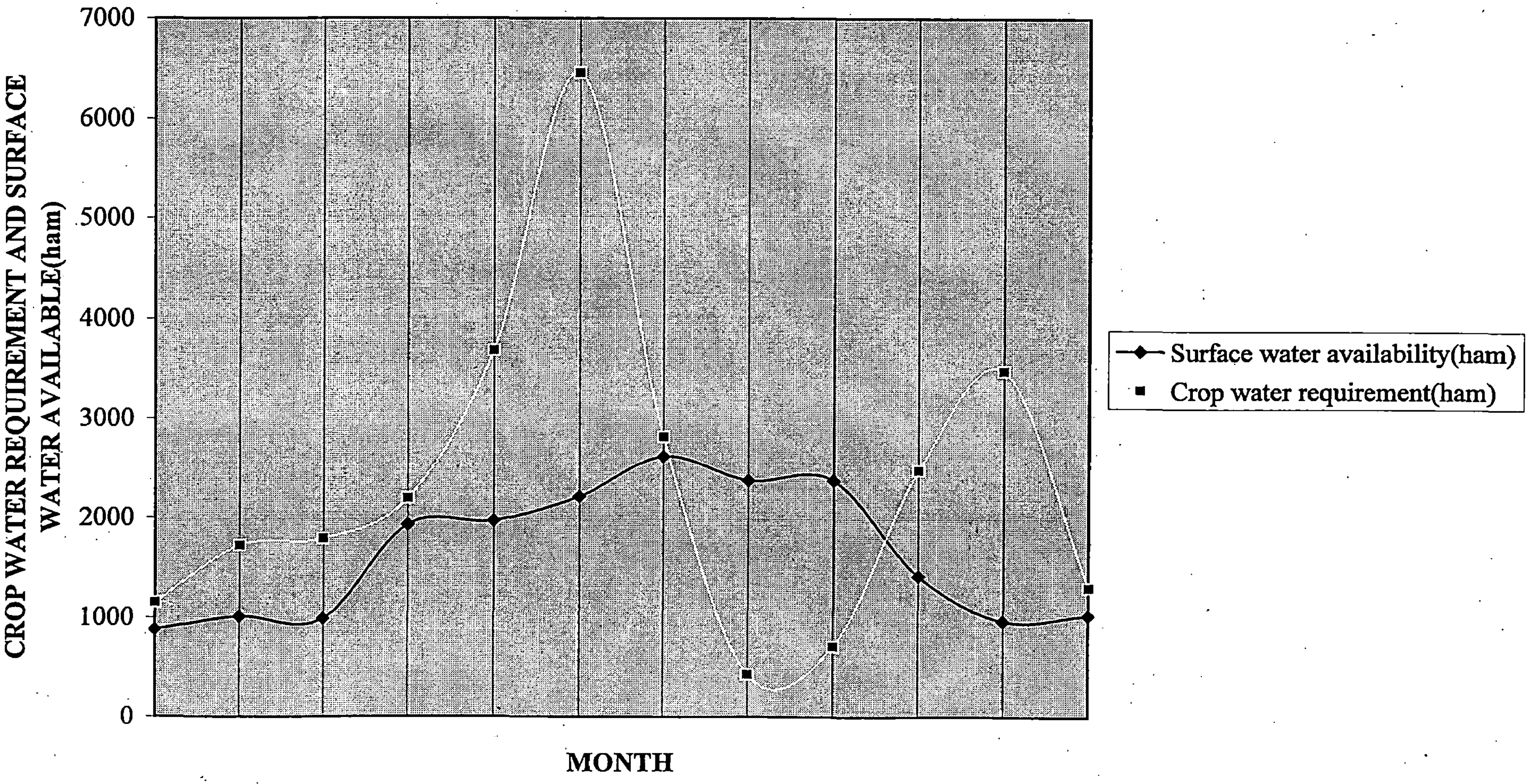


Fig.4.12:Hydroph of average water level for case 1:Existing cropping intensity 144% and normal rainfall

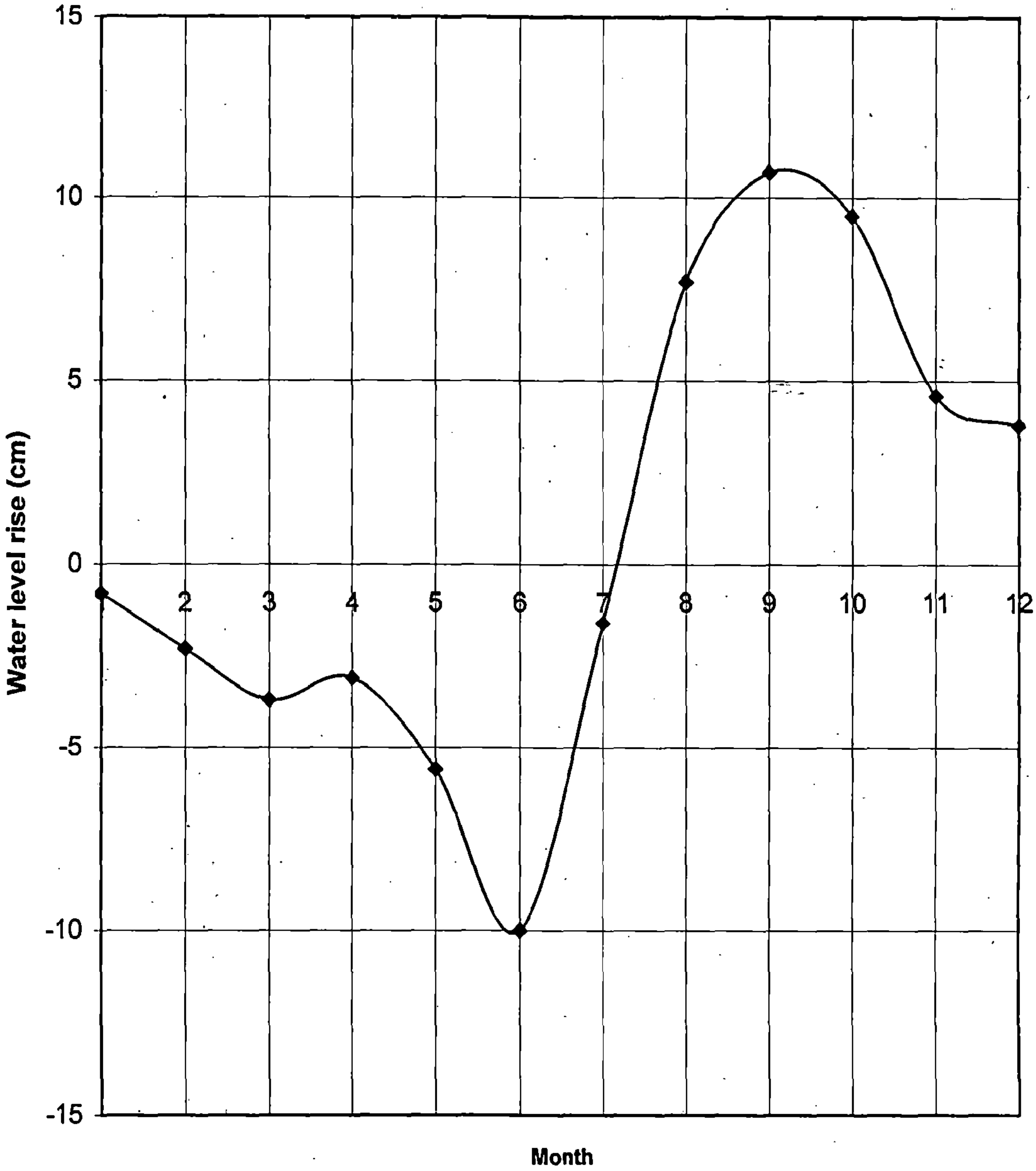


Fig.4.13:Hydrograph of average water level for case2:Excess surface water is not supplied more than crop water requirement and rainfall is normal

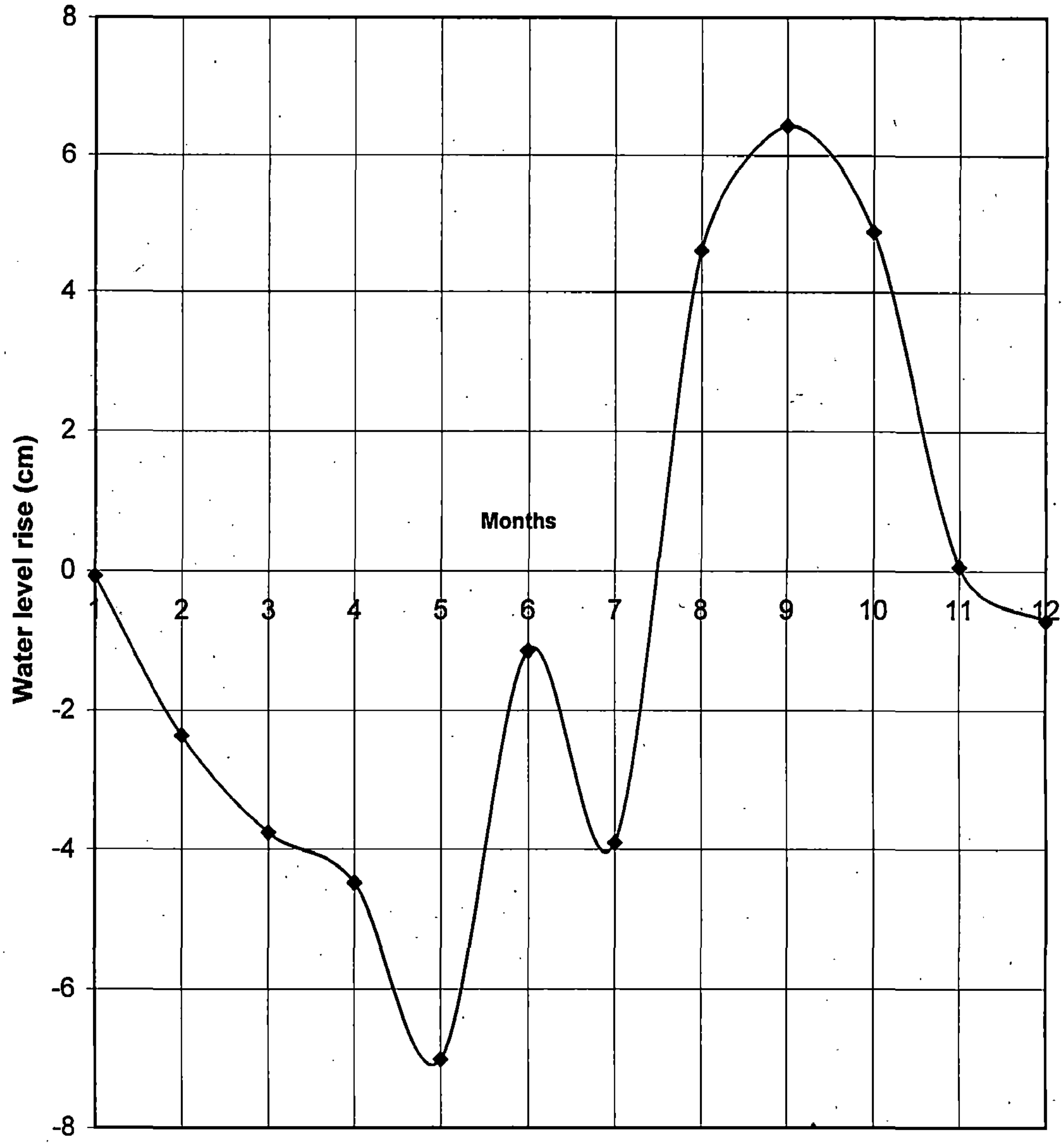


Fig.4.14: Hydrograph of average water level for Case 3:Cropping intensity 170% and rainfall normal

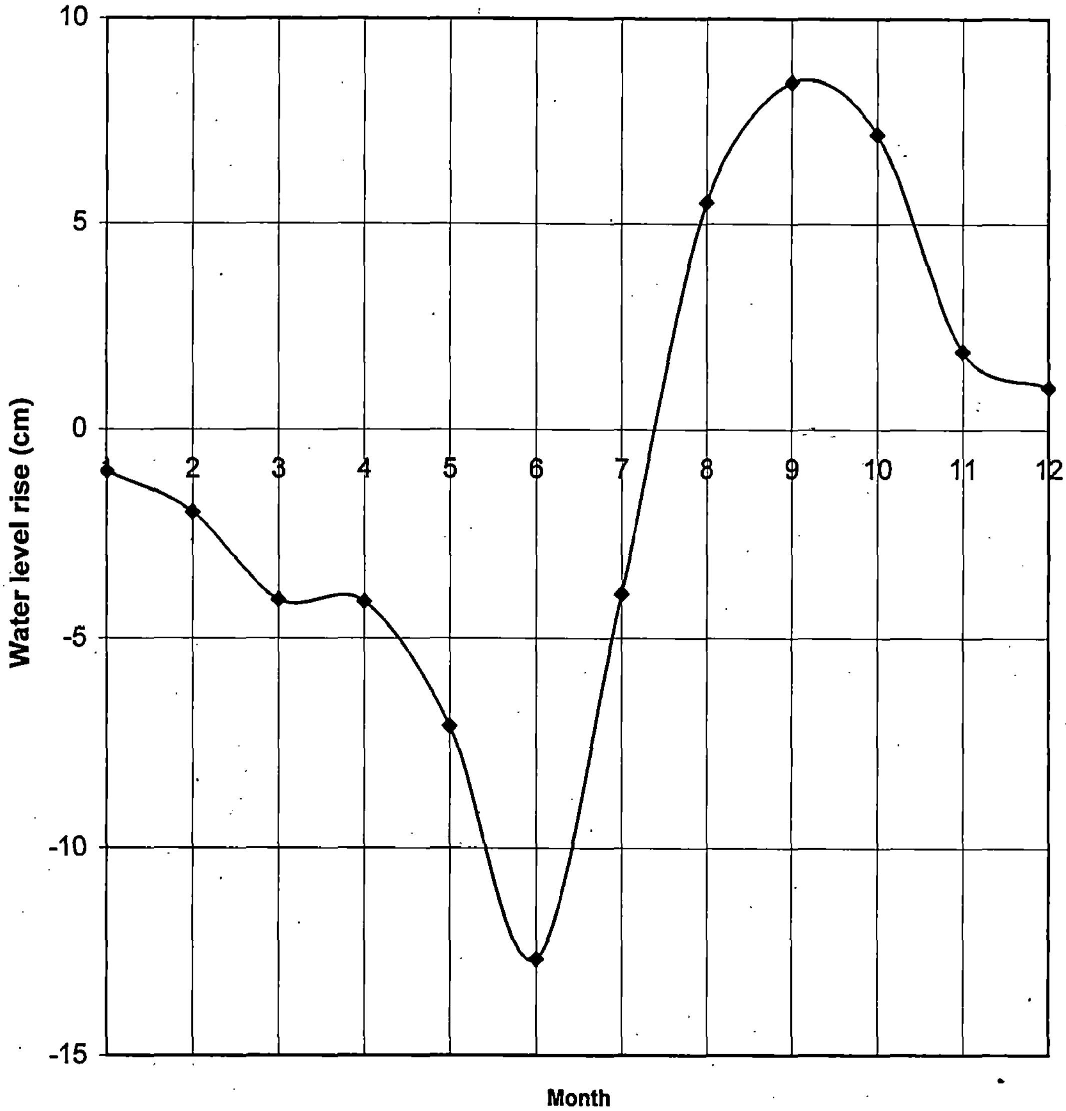


Fig.4.15: hydrograph of average water level`for case 4: Existing cropping intensity 144% and rainfall corresponding to thedrought period of 1987

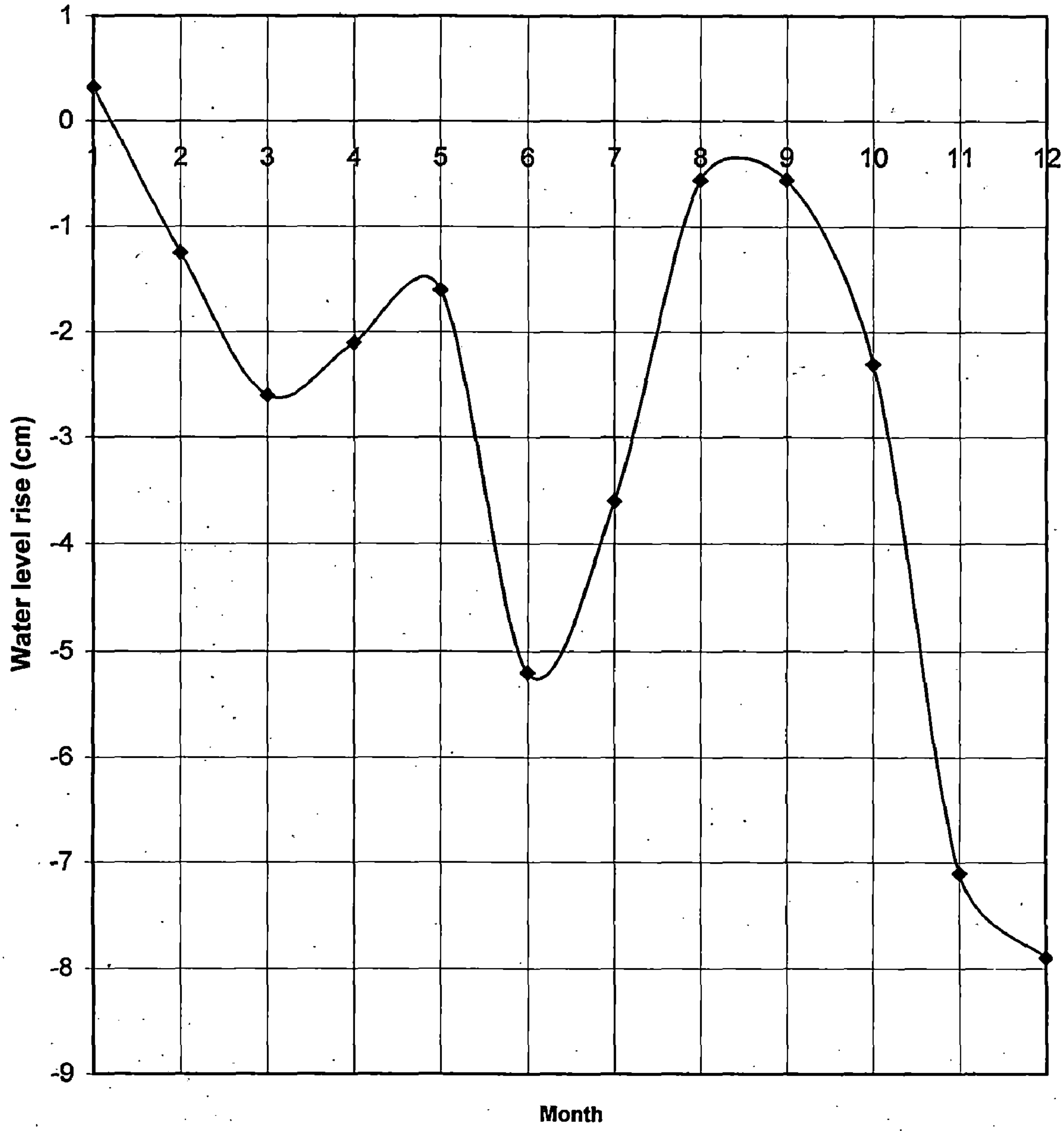


Fig.4.16:Hydrograph of average water level for case 5: Cropping intensity 170% and rainfall corresponding to the drought period of 1987

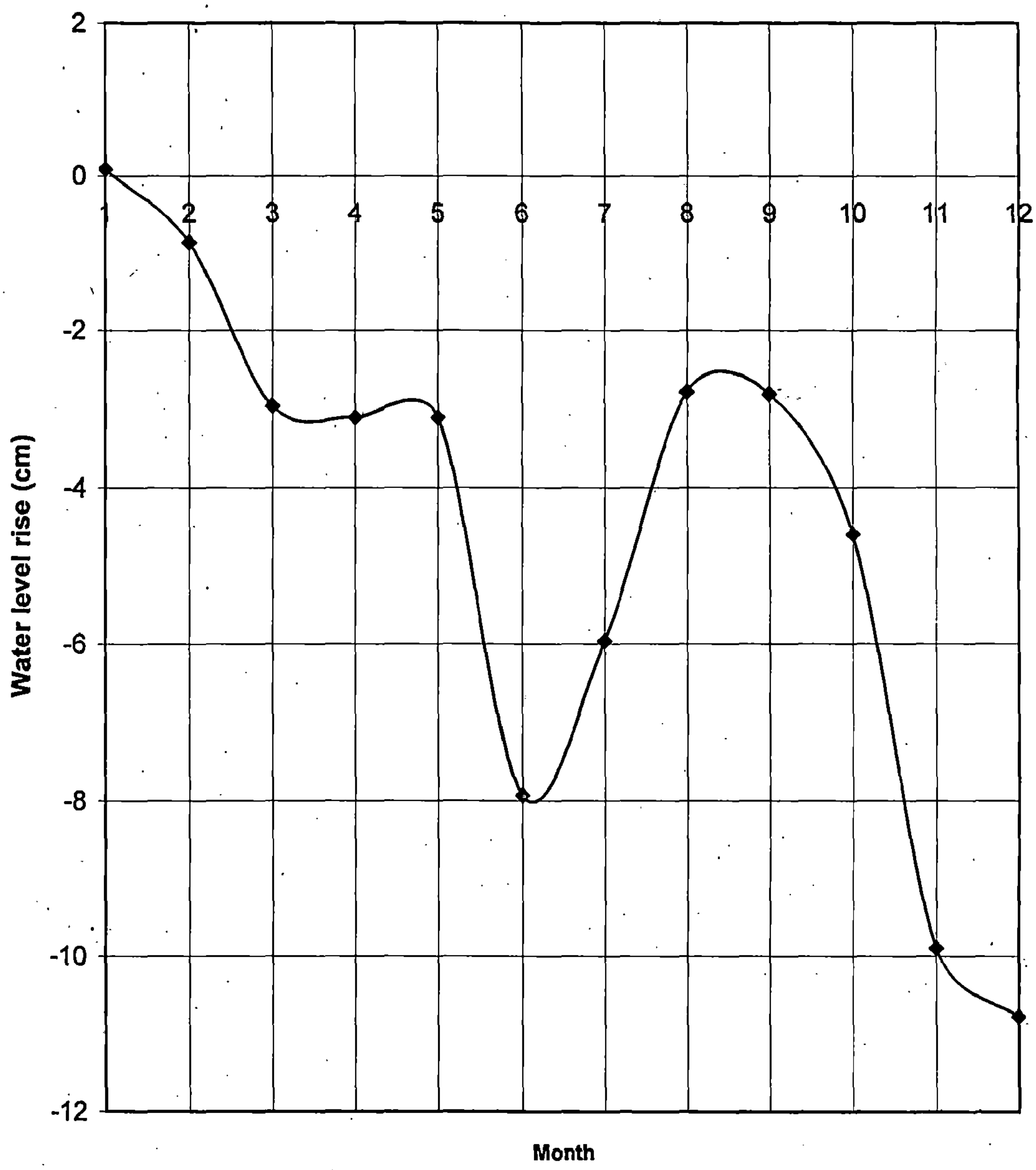


TABLE:4.2

Monthly rainfall data in mm

Name of observatory station:Roorkee

S. N.	Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
1	1994	38	105	0	30	46	18	463	407	6	0	0	0	1113
2	1995	70	55	3	8	0	135	418	626	165	0	0	0	1480
3	1996	33	124	10	0	5	61	184	499	355	63	0	0	1334
4	1997	23	0	4	70	15	39	350	279	82	67	37	101	1067
5	1998	0	20	112	89	36	82	257	472	214	157	0	0	1439
Average of 5		32.8	60.8	25.8	39.4	20.4	67	334	457	164	57.4	7.4	20.2	1286.6

Source:ground water depar

TABLE 4.3

GROUND WATER BALLANCE(I ham)

case1: Existig cropping intensity 144% and normal rainfall

S. N	Particulars	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
1	Inflow:												
a	Rainfall recharge	0	225.7	0	38.5	0	280	2620	3689	1132	196	0	0
b	Irrigation return flow	281.7	596.3	387.7	462.3	982.1	1817	745.9	112	204.1	744.9	888.4	347.9
c	Canal seepage	92.68	102.4	98.38	194	191.1	218.7	269.6	249.3	249.2	136	97.98	109.9
d	Subsurface inflow	27.64	25.33	27.64	64.49	69.09	69.09	66.79	43.76	50.67	52.97	32.24	29.94
e	total inflow(a+d)	402.02	949.7	513.72	759.29	1242.29	2384.79	3702.29	4096.06	1635.97	1129.87	1018.62	487.74
2	Outflow:												
f	Ground water withdrawl	184.1	1070	5231	0	1686	3545	0	0	0	1071	2353	262.9
g	Basin outflow towards river	248	224	248	240	248	240	248	248	240	248	240	248
h	Outflow towards main Ganga canal	124	112	124	120	124	120	124	124	120	124	120	124
I	Outflow at bottom	150.9	136.3	150.9	146	150.9	146	150.9	150.9	146	150.9	146	150.9
j	total out flow(f+I)	707	1542	1046	506	2208.9	4051	522.9	522.9	506	1593.9	2859	785.8
3	change in storage(e-j)	-304.98	-592.6	-532.28	253.29	-966.61	-1666.21	3179.39	3571.16	1129.97	-464.03	-1840.38	-298.06
4	Ground water potential	-304.98	-897.6	-1429.8	-1176.5	-2143.15	-3809.36	-629.97	2941.19	4071.16	3607.13	1766.75	1468.69
5	Water level rise (cm)	-0.8	-2.3	-3.7	-3.1	-5.6	-10	-1.6	7.7	10.7	9.5	4.6	3.8
6	Annual water level rise (cm)	24.1											

TABLE 4.4

GROUND WATER BALAN(ham)

Case 2: Excess surface water is not supplied more than crop water requirement and normal

S. N.	Particulars	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
1	Inflow:												
	a Rainfall recharge	0	226	0	38.5	0	280	2620	3689	1132	196	0	0
	b Irrigation return flow	281.7	596	387.7	462.3	982.1	1817	745.9	112	204.1	744.9	888.4	347.9
	c Canal seepage	92.68	102	98.38	138.2	191.1	218.7	178.7	26.42	51.84	126.6	97.98	109.9
	d Subsurface inflow	27.64	25.3	27.64	46.06	69.09	69.09	48.36	20.73	23.03	52.97	32.24	29.94
	e Total inflow (A+D)	402.02	950	513.72	685.06	1242	2384.8	3593	3848.2	1411	1120.5	1018.62	487.74
2	Outflow:												
	f Ground water withdrawl	184.1	1070	523.1	452.9	1686	3545	217.8	85.57	212.3	1182	2353	262.9
	g Basin outflow towards river	248	224	248	240	248	240	248	248	240	248	240	248
	h Outflow towards main Ganga canal	124	112	124	120	124	120	124	124	120	124	120	124
	i Outflow at bottom	150.9	136	150.9	146	150.9	146	150.9	150.9	146	150.9	146	150.9
	j Total outflow (F+I)	707	1542	1046	958.9	2209	4051	740.7	608.47	718.3	1704.9	2859	785.8
3	Change in storage(E-J)	-304.89	-593	-532.3	-273.84	-966.6	-1666	2852	3239.7	692.7	-584.4	-1840.38	-298.06
4	Ground water potential	-304.98	-898	-1430	-1703.7	-2670	-4336	-1484	1755.5	2448	1863.7	23.31	274.75
5	Water level rise (cm)	-0.8	-2.36	-3.76	-4.48	-7.01	-1.14	-3.9	4.61	6.43	4.89	0.06	-0.72
6	Annual water level rise (cm)	-4.5											

TABLE:4.5

GROUND WATER BALANCE (ham)

Case3: Normal rainfall and proposed cropping intensity 170%

S. N,	Description	Jan	Feb	Mar	Apr	MAY	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Inflow												
a	Rainfall recharge	0	225.7	0	38.5	0	280	2620	3689	1132	196	0	0
b	Irrigation return flow	280.1	465.9	402.7	453.3	841.3	2068	1090	134.9	191.6	718.9	872	324.8
c	Canal seepage	92.68	102.4	98.38	194	191.1	218.7	269.6	249.3	249.2	136	97.98	109.9
d	subsurface inflow	27.64	25.33	27.64	64.49	69.09	69.09	66.79	43.76	50.67	52.97	32.24	29.94
e	Total inflow(A+B)	400.42	819.3	528.72	750.29	1101.49	2635.8	4046.39	4116.96	1623.47	1103.87	1002.22	464.64
2	Outflow												
f	Ground water withdrawl	272.7	706.9	799.9	264.1	1713	4248	198.5	0	0	1060	2511	276.9
g	Basin outflow towards river	248	224	248	240	248	240	248	248	240	248	240	248
h	Basin outflow towards main canal	124	112	124	120	124	120	124	124	120	124	120	124
I	Outflow at bottom	150.9	136.3	150.9	146	150.9	146	150.9	150.9	146	150.9	146	150.9
j	Total outflow (F+I)	795.6	1179	1322.8	770.1	2235.9	4754	721.4	522.9	506	1582	3017	799.8
3	Change in storage (E-J)	-395.2	-396	-794.1	-19.81	-1134.4	-2118.2	3324.99	3594.06	117.47	-479.03	-2014.8	-335.16
4	Ground water potential	-395.2	-755	-1549	-1569	-2703.4	-4821.6	-1496.6	2097.49	3214.96	2735.93	721.15	385.99
5	Water level rise in(cm)	-1	-1.98	-4.07	-4.12	-7.1	-12.67	-3.93	5.51	8.45	7.19	1.89	1.01
6	Annual water level rise in cm	6.3											

TABLE 4.6
GROUND WATER BALANCE(ham)

Case4: Cropping intensity is 144%(existing) and rainfall corresponding to the drought year 1987.

S. N,	Description	Jan	Feb	Mar	Apr	MAY	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Inflow												
a	Rainfall recharge	428.7	218.7	0	0	1134	568.7	43.75	1304	0	0	0	0
b	Irrigation return flow	281.7	596.3	387.7	462.3	982.1	1817	745.9	112	204.1	744.9	888.4	347.9
c	Canal seepage	92.68	102.4	98.38	194	191.1	218.7	269.6	249.3	249.2	136	97.98	109.9
d	subsurface inflow	27.64	25.33	27.64	64.49	69.09	69.09	66.79	43.76	50.67	52.97	32.24	29.94
e	Total inflow(a+d)	830.72	942.73	513.72	720.79	2376.29	2673.49	1126.04	1709.06	503.97	933.87	1018.62	487.74
2	Outflow												
f	Ground water withdrawl	184.1	1070	523.1	0	1686	3545	0	0	0	1071	2353	262.9
g	Basin outflow towards river	248	224	248	240	248	240	248	248	240	248	240	248
h	Basin outflow towards main canal	124	112	124	120	124	120	124	124	120	124	120	124
I	Outflow at bottom	150.9	136.3	150.9	146	150.9	146	150.9	150.9	146	150.9	146	150.9
j	Total outflow (f+I)	707	1542.3	1046	506	2208.9	4051	522.9	522.9	506	1593.9	2859	785.8
3	Change in storage (e-j)	123.72	-599.57	-532.28	214.79	167.39	-1377.51	603.14	1186.16	-2.03	-660.03	-1840.38	-298.06
4	Ground water potential	123.72	-475.85	-1008.13	-793.34	-625.95	-2003.46	-1400.32	-214.16	-216.19	-876.22	-2716.6	-3014.66
5	Water level rise in(cm)	0.32	-1.25	-2.6	-21	-1.6	-5.2	-3.6	-0.56	-0.56	-2.3	-7.1	-7.9
6	Annual water level rise in cm	-49.5											

TABLE:4.7
GROUND WATER BALANCE(ham)

Case:5 Cropping intensity of 170%(propesed) and rainfall corresponding to the drought year 1987

S. N,	Description	Jan	Feb	Mar	Apr	MAY	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Inflow												
a	Rainfall recharge	428.7	218.7	0	0	1134	568.7	43.75	1304	0	0	0	0
b	Irrigation return flow	280.1	465.9	402.7	453.3	841.3	2068	1090	134.9	191.6	718.9	872	324.8
c	Canal seepage	92.68	102.4	98.38	194	191.1	218.7	269.6	249.3	249.2	136	97.98	109.9
d	subsurface inflow	27.64	25.33	27.64	64.49	69.09	69.09	66.79	43.76	50.67	52.97	32.24	29.94
e	Total inflow(a+d)	829.12	812.33	528.72	711.79	2235.49	2924.49	1470.14	1731.96	491.47	907.87	1002.22	464.64
2	Outflow												
f	Ground water withdrawl	272.7	706.9	799.9	264.1	1713	4248	198.5	0	0	1060	2511	276.9
g	Basin outflow towards river	248	224	248	240	248	240	248	248	240	248	240	248
h	Basin outflow towards main canal	124	112	124	120	124	120	124	124	120	124	120	124
I	Outflow at bottom	150.9	136.3	150.9	146	150.9	146	150.9	150.9	146	150.9	146	150.9
j	Total outflow (f+I)	795.6	1179.2	1322.8	770.1	2235.9	4754	721.4	522.9	506	1582.9	3017	799.8
3	Change in storage (e-j)	33.52	-366.87	-794.08	-58.31	-0.68	-1829.51	748.74	1209.06	-14.53	-675.03	-2014.78	-335.16
4	Ground water potential	33.52	-333.35	-1127	-1185.31	-1186	-3015.51	-2267	-1058	-1073	-1747	-3762	-4097
5	Water level rise in(cm)	0.09	-0.87	-2.96	-3.11	-3.11	-7.93	-5.96	-2.78	-2.81	-4.59	-9.89	-10.77
6	Annual water level rise in cm	-67.3											

CHAPTER – 5

DISCUSSION

U.G.C. is one of the oldest canal systems in India, which was designed earlier to provide protective irrigation in Ganga – Yamuna Basin in U.P. Now due to increased cropping intensity and high yielding varieties of crop, canal water is not sufficient to meet the crop water requirement of area commanded. The general operations problem and constraints are discussed in Chapter – 2. In view of of the above, the operational problems and constraints of right main distributary have also been observed as narrated below.

The right main distributary is supplied with water according to rotational program of channels framed by the irrigation department and published and sent to all concerned district officers and public representatives. During Kharif the normal pattern of flow is two weeks flow and one week closure alternatively. During Rabi, the pattern of flow is one week flow and two weeks closure alternatively except that during January and February the closure period is three weeks. Varabandi has been implemented on all the outlets in the system.

There are no canal telegraph or telephone line within the command of right main distributary. The canal telepgraph offices nearest to the head of right main distributary are at Asafnagar and Roorkee which is situated at approx. 8 and 14 km respectively from the command area.

There is no any meter flumes for discharge measurement and supply into canal are estimated by guague discharge method which is normally not updated. There is general problem of distribution of equitable supplies and this problem is quite serious specially on some tail reach channels such as the lower part of Bhaisani distributary.

The irrigation water does not appear to be used economically. It could be observed that during some periods the canal supplies are not available when required. There are practically no control structure for distribution of required supplies.

The difference between gross irrigation requirement and canal supply at head is calculated monthwise which is given in Table 3.12 of Chapter – 3. The gross irrigation requirement is 5613.86 ha.m. and supply is 1678.86 ha.m.

Thus surface water meets only 70% of crop water requirement and 30% of requirement is met by ground water. For computating the sustainable yield of ground water, a lumped ground water balance model has been developed.

The following distributaries and minors convey the irrigation water in the study area :

1. Gaddarjudda minor
2. Right main distributary
3. Sidhauli distributary
4. Majhol minor
5. Saloni minor
6. Tansipur right distributary
7. Right Mohamadpur distributary

The length and perimeter of each distributary and minor have been calculated grid wise for computing seepage loss.

For discharge calculation of distributary and minor, the average discharge of five years has been taken into consideration.

Ground water balance has been carried out for five specific cases. These are :

There are five cases and each cases has separate results.

Case – 1 : Existing cropping intensity of 144% is continued under normal rainfall occurrence. In this case the annual water level rise is 24.1 cm. It is observed that here is exces supply of canal water during the month of April, July, August and September part of these exces supplies is recharged to groundwater due to canal seepage. The minimum ground water potential is in the month of June. The maximum ground water potential is in the month of September after monsoon.

Case – 2 : Excess surface water is not supplied more than crop water requirement and rainfall is normal. Under these conditions the annual ground water level falls by 4.5 cm. Thus there will be a nominal ground water mining. Maximum ground water potential is in the month of September. The potential is minimum in the month of June. Maximum groundwater is withdrawn in the month of June.

Case – 3 : Cropping intensity is 170% and rainfall is normal. In this case the annual water level rise in the command is 6.3 cm. This is due to the recharge from the exces supply of canal water in the month of August and September. The minimum and maximum ground water potential occur in the month of June and September respectively.

Case – 4 : Cropping intensity is 144%(existing) and rainfall is equal to the rainfall that occurred during drought period of year 1987. It is assumed that in April, July, August and September, excess surface water was supplied more than the crop water requirement. The annual water level falls by 49.5 cm causing ground water mining.

Case - 5 : Cropping intensity of 170% (proposed) and rainfall corresponding to the drought period of 1987. For increased cropping intensity under drought condition the annual water level falls by 67.3 cm . Minimum ground water potential is in the month of December and maximum in the month of January.

Because there is rising trend of ground water level with existing irrigation cropping intensity and normal rainfall. The deficit in surface water supply in the command area of right main distributary can be met by ground water successfully. Water balance study The model result shows that there is also rise in water level after introducing proposed increased cropping intensity. Therefore cropping intensity can safely be increased upto 200% through conjunctive use of ground water and surface water.

A ground water balance model has been prepared which can be used for conjunctive use of surface and groundwater.

CHAPTER – 6

CONCLUSIONS AND SUGGESTIONS

6.1 FINDINGS

The surface water is not sufficient to meet the crop water requirement at present. It only protects the crops in Rabi, but for more production adequate water is to be required. The study area has good aquifer and sufficient ground water potential. A software has been written for monthly ground water balance. The result of water balance shows that there is an average increasing tendency of ground water level. In normal rainfall and existing cropping intensity 144%, the annual water level rises by 24 cm. For proposed increased cropping intensity of 170%, the annual water level rise is 6.3 cm indicating a definite trend of surplus groundwater.

Thus, there is ample scope of ground water use to meet the irrigation requirements.

1. The water balance study indicates that seepage loss from channel ranges between 8.86 to 9.5% of head discharge.
2. The study area has good fertile land. The sugarcane is the principal crop, which is extensively grown at head reach of canal by farmers. In head reaches, they use more water than the share allotted to them.
3. The actual discharges in some distributaries and minors are more than the design discharges.
4. The operation and regulation system of distributary and minor is not functioning efficiently. There is lot of water wastage due to mismanagement and poor operating system of canal.

5. From the water balance study, it is ascertained that the cropping intensity can be increased upto 170% and there is sufficient groundwater available to support this increased cropping intensity.

6. The excess water more than crop water requirement supplied causes recharge to groundwater. If this water is not conveyed in the canal a groundwater mining of 4.5 cm occurs even for 144% cropping intensity. If the excess water is conveyed cropping intensity can be increased from 144 to 170% without causing ground water mining.

6.2 SUGGESTIONS

The study has been conducted with available data from the various department of the state. In absence of the required full data several assumptions have been made on the basis of studies conducted in this area and other similar areas and experiences. With improved data, it would be possible to improve the results further.

It is necessary to improve the data in following aspects :

1. It is suggested to install additional observation well to observe water table levels near canals.

2. It is also suggested to carry out pumping tests at various selected sites to evaluate the value of specific yield and transmissivity.

3. Experiments should be carried out to evaluate return flow of irrigation, canal seepage at different places of all distributaries and minors.

4. Deficit of water between crop water requirement and available surface water is supplemented by 100% ground water withdrawal assumption in the absence of data.

5. From the contour map, it is observed that ground water level is rising in the area where canal water is being used, where as ground water table is lowered in areas,

where ground water is mainly used for irrigation. Hence, proper planning is necessary to use the supply of water as well as selection of cropping pattern to check the situation.

6. For measuring surfaces water delivered to irrigation channels and different outlets, proper measuring devices need to be introduced in the system for correct assessment of supplies delivered and to control wasteful use of water.

REFERENCES

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2. Doorenbos, J. and W.O. Pruitt (1977), "Guidelines for Predicting Crop Water Requirements", F.A.O., Irrigation and Drainage Paper, 33.
3. Khan, I.A., (1980), "Determining Impact of Irrigation on Groundwater", Journal of Irrigation and Drainage, ASCE, IR-4, pp. 335.
4. U.P.I.R.I. (1995), "Status Report on Estimation of Unlined and Lined Channels by Different Techniques", T.M. No. 65, RR (G-9) I.R.I., Roorkee.

```
$Debug
C       IN THIS PROGRAMME LUMPED WATER BALANCE HAS BEEN CARRIED OUT.
C       DIMENSION HINI(25,25),HFIN(25,25)
        CHARACTER*12 CROPNAME(15)
        DIMENSION CANALL(25,25),CANALP(25,25),NCTYPE(25,25),NELEMENT(25)
        DIMENSION CANALRD(0:10,12),UCOMMAND(25,25)
C       DIMENSION TRANS(25,25),SYIELD(25,25)
        DIMENSION DELX(25),DELY(25),JINI(25),JFIN(25)
        DIMENSION SEEPLOSS(25,25,12),RECHRAIN(12),PUMPREQM(12),
     1           RETURNF(9,12),WRQM(12),RFLOWM(12),SEEPM(12),DSEEP(0:10),
     2               NUMDAYSM(12) ,DAILYD(10), SWATERSM(12), QPUMPPUA(12),
     3             GWPOTEN(12),TWRQM(12), SWAVAILF(12),CGWPOTEN(12),
     4           EXCESSSW(12),DEFICSW(12),HYDROGRAPH(12),
     5           BOUTFR(12),BOUTFL(12),BOUTFB(12),BINFT(12)
C       BASIC DATA

        DIMENSION USELAND(9),CROPKC(9,12),  ETCROP(9,12)
        DIMENSION EFFRAIN(9,12),EXTRAW(9,12),WREQCROP(9,12),
     1             RFACTOR(9)
        DIMENSION RAIN(12),EVAP(12)
c       DIMENSION RDEOBAND(12),RGJUDDA(12),RRMAIND(12),RSIDHDIST(12),
c       1             RMAJH(12),RSALONI(12),RTANSID(12),RRMOHD(12),
c       2             RBASERAD(12),RGANGAM(12)
C       CROP1=PADDY
C       CROP2=MAIZE
C       CROP3=SORGHUM
C       CROP4=COTTON
C       CROP5=WHEAT
C       CROP6=BERSEEM
C       CROP7=MUSTARD
C       CROP8=MUNG
C       CROP9=SUGARCANE

        OPEN(1, FILE= 'C:\FOR1\GEOMETRY.DAT', STATUS= 'OLD')
        OPEN(2, FILE= 'C:\FOR1\BSURESH.OUT', STATUS='UNKNOWN')
        OPEN(3, FILE= 'C:\FOR1\TIMEVAR.DAT', STATUS= 'OLD')

        READ(1,*) IMAX,JMAX
        WRITE(2,*)'         I    JINI(I)    JFIN(I)'

        READ(1,*)  (JINI(I),JFIN(I),I=1,IMAX)
        WRITE(2,50) (I,JINI(I),JFIN(I),I=1,IMAX)
50      FORMAT(5X,I5,5X,I5,5X,I5)

C       DO I=1,IMAX
C       READ(1,*)(HINI(I,J),J=JINI(I),JFIN(I))
C       END DO
C
C       WRITE(2,*)'INITIAL HEAD IN DIFFERENT GRIDS'
C       DO I=1,IMAX
C       WRITE(2,54)(HINI(I,J),J=JINI(I),JFIN(I))
C       END DO
C
C       DO I=1,IMAX
C       READ(1,*)(HFIN(I,J),J=JINI(I),JFIN(I))
C       END DO
C
```

```
C       WRITE(2,*)'FINAL HEAD IN DIFFERENT GRIDS'
C       DO I=1,IMAX
C       WRITE(2,54)(HFIN(I,J),J=JINI(I),JFIN(I))
C       END DO


        DO I=1,IMAX
        DELY(I)=1052.
        END DO

        DO J=1,JMAX
        DELX(J)=800.
        END DO

        AREA=0.
        DO I=1,IMAX
        DO J=JINI(I),JFIN(I)
        AREA=AREA+DELY(I)*DELX(J)
        END DO
        END DO

        WRITE(2,*)'STUDY AREA=',AREA
C
C       DO I=1,IMAX
C       READ(1,*)    (SYIELD(I,J),J=JINI(I),JFIN(I))
C       WRITE(2,54)(SYIELD(I,J),J=JINI(I),JFIN(I))
C       END DO
C
C       DO I=1,IMAX
C       READ(1,*)    (TRANS(I,J),J=JINI(I),JFIN(I))
C       WRITE(2,54)(TRANS(I,J),J=JINI(I),JFIN(I))
C       END DO

        DO I=1,IMAX
        DO J=JINI(I),JFIN(I)
C       SYIELD(I,J)=0.16
C       TRANS(I,J)=1521.
        CANALL(I,J)=0.
        CANALP(I,J)=0.
        NCTYPE(I,J)=0
        END DO
        END DO


        READ(1,*)RIVERL,GANGACL,PERIMG,RIVGRAD
        READ(1,*)DBANDHL,DBANDHP
        READ(1,*)SEPFM,SEPFB,SEPFD,SEPFMR
        FCTR=60.*60.*24./10**6
        DSEPM=SEPFM*FCTR
        DSEPB=SEPFB*FCTR
        DSEPD=SEPFD*FCTR
        DSEPMR=SEPFMR*FCTR
        DSEEP(1)=DSEPB
        DSEEP(2)=DSEPMR
        DSEEP(3)=DSEPD
        DSEEP(4)=DSEPD
        DSEEP(5)=DSEPMR
```

```
      DSEEP(6)=DSEPMR
      DSEEP(7)=DSEPD
      DSEEP(8)=DSEPD
      DSEEP(9)=DSEPD
      DSEEP(10)=DSEPM
      DO I=1,IMAX
      READ(1,*)INDEXDUMY,NELEMENT(I)
      DO N=1,NELEMENT(I)
      READ(1,*)J,CANALL(I,J),CANALP(I,J),NCTYPE(I,J)
      END DO
      END DO

      READ(1,*)   (RFACTOR(I),I=1,9)
      WRITE(2,*)'RETURN FLOW FACTOR FOR EACH CROP'
      WRITE(2,54)(RFACTOR(I),I=1,9)

      DO I=1,IMAX
      READ(1,*)(UCOMMAND(I,J),J=JINI(I),JFIN(I))
      END DO
      SCOMMAND=0.
      DO I=1,IMAX
      DO J=JINI(I),JFIN(I)
      SCOMMAND=SCOMMAND+UCOMMAND(I,J)
      END DO
      END DO
      SCOMMAND=SCOMMAND*800.*1052.

      READ(3,57)(CROPNAME(I),I=1,9)
57    FORMAT(A15)
      READ(3,*)NTIME
      READ(3,*)(USELAND(I),I=1,9)
      READ (3,*)(RAIN(K),K=1,NTIME)
      WRITE(2,*)'MONTHLY RAINFALL IN MM'
      WRITE(2,54)(RAIN(K),K=1,NTIME)

      READ(3,*)(NUMDAYSM(K),K=1,NTIME)

      READ (3,*)  (EVAP(K),K=1,NTIME)
      DO K=1,NTIME
      EVAP(K)=EVAP(K)*NUMDAYSM(K)
      END DO
      WRITE(2,*)'MONTHLY EVAPORATION IN MM'
      WRITE(2,54)(EVAP(K),K=1,NTIME)

      DO I=1,9
      READ (3,*)(EFFRAIN(I,K),K=1,NTIME)
      END DO

      WRITE(2,*)'MONTHLY EFFECTIVE RAINFALL IN MM'
      DO I=1,9
      WRITE(2,*)'CROP ---', CROPNAME(I)
      WRITE(2,54)(EFFRAIN(I,K),K=1,NTIME)
      END DO

      DO I=1,9
      READ(3,*)(EXTRAW(I,K),K=1,NTIME)
      END DO
```

```
      WRITE(2,*)'MONTHLY WATER APLICATION FOR LAND PREPARATION  IN MM'
      DO I=1,9
      WRITE(2,*)'CROP ---', CROPNAME(I)
      WRITE(2,54)(EXTRAW(I,K),K=1,NTIME)
      END DO


      DO I=1,9
      READ(3,*)(CROPKC(I,K),K=1,NTIME)
      END DO

      WRITE(2,*)'CROP COEFFICIENT '
      DO I=1,9
      WRITE(2,*)'CROP ---', CROPNAME(I)
      WRITE(2,54)(CROPKC(I,K),K=1,NTIME)
      END DO

C     RUNNING DAYS OF CANAL BEING READ
      DO I=1,10
      READ(3,*)(CANALRD(I,K),K=1,NTIME)
      END DO

      WRITE(2,*)'RUNNING DAYS OF DEOBAND BRANCH AND GANGA CANAL SYSTEM'
        WRITE(2,*)'RDEOBAND BRANCH CANAL'
        WRITE(2,54)(CANALRD(1,K),K=1,NTIME)
      WRITE(2,*)'RGJUDDA MINOR'
      WRITE(2,54)(CANALRD(2,K),K=1,NTIME)
      WRITE(2,*)'RRMAIN DISTRIBUTARY'
      WRITE(2,54)(CANALRD(3,K),K=1,NTIME)
      WRITE(2,*)'RSINDHAULI DISTRIBUTARY'
      WRITE(2,54)(CANALRD(4,K),K=1,NTIME)
      WRITE(2,*)'RMAJHOL MINOR'
        WRITE(2,54)(CANALRD(5,K),K=1,NTIME)
      WRITE(2,*)'RSALONI MINOR'
      WRITE(2,54)(CANALRD(6,K),K=1,NTIME)
      WRITE(2,*)'RTANSIPUR DISTRIBUTARY'
        WRITE(2,54)(CANALRD(7,K),K=1,NTIME)
      WRITE(2,*)'RMOHD DISTRIBUTARY'
        WRITE(2,54)(CANALRD(8,K),K=1,NTIME)
      WRITE(2,*)'RMAIN BASERA DISTRIBUTARY'
        WRITE(2,54)(CANALRD(9,K),K=1,NTIME)
      WRITE(2,*)'MAIN GANGA CANAL'
      WRITE(2,54)(CANALRD(10,K),K=1,NTIME)

      READ(3,*)(DAILYD(I),I=1,10)
C
C     COMPUTATION OF WATER REQUIREMENT OF CROP IN A MONTH
C
      DO I=1,9
      DO K=1,NTIME
      ETCROP(I,K)=CROPKC(I,K)*EVAP(K)
      END DO
      END DO
C
C
C     NET IRRIGATION REQUIREMENT=ETCRROP+ EXCEESIRRIGATION-EFFECTIVE RAIN
```

```
C     WHICH HAS BEEN COMPUTED PER UNIT AREA; IN UNIT AREA LAND
C     OCCUPIED BY EACH CROP HAS BEEN CONSIDERED
      DO I=1,9
      DO K=1,NTIME
      WREQCROP(I,K)=(ETCROP(I,K)+EXTRAW(I,K)-EFFRAIN(I,K))
     1  *USELAND(I)
      IF(WREQCROP(I,K).LT.0.)WREQCROP(I,K)=0.
      RETURNF(I,K)=WREQCROP(I,K)*RFACTOR(I)
      END DO
      END DO
C
      WRITE(2,*)'MONTHLY WATER REQUIREMENT OF EACH CROP IN MM PER UNIT
     1  AREA'
      DO I=1,9
      WRITE(2,*)'CROP ---',CROPNAME(I)
      WRITE(2,54)(WREQCROP(I,K),K=1,NTIME)
      END DO
C
      WRITE(2,*)'MONTHLY IRRIGATION RETURN FLOW FROM EACH CROP IN MM'
      DO I=1,9
      WRITE(2,*)'CROP ---',CROPNAME(I)
      WRITE(2,54)(RETURNF(I,K),K=1,NTIME)
      END DO
C
      DO K=1,NTIME
      SUM1=0.
      SUM2=0.
      DO I=1,9
      SUM1=SUM1+WREQCROP(I,K)
      SUM2=SUM2+RETURNF(I,K)
      END DO
      WRQM(K)=SUM1
      TWRQM(K)=SUM1*AREA/1000.
      RFLOWM(K)=SUM2
      END DO

      WRITE(2,*) 'MONTHLY WATER REQUIREMENT IN MM FOR UNIT AREA'
      WRITE(2,54)(WRQM(K),K=1,NTIME)

      WRITE(2,*) 'MONTHLY RETURN FLOW IN MM FROM UNIT AREA'
      WRITE(2,54)(RFLOWM(K),K=1,NTIME)

      DO K=1,NTIME
      RFLOWM(K)=RFLOWM(K)*AREA/1000.
      END DO
C
C     RECHARGE RATES ARE BEING COMPUTED
C
C

      WRITE(2,*)'MONTHLY RECHARGE FROM RAIN  IN MM PER UNIT AREA'
      DO K=1,NTIME
      RECHRAIN(K)=(RAIN(K)-35.)*0.23
      IF(RECHRAIN(K).LE.0.) RECHRAIN(K)=0.
      END DO

      SUM1=0.
```

```
      SUM2=0.
      DO K=1,12
      SUM1=SUM1+RAIN(K)
      SUM2=SUM2+RECHRAIN(K)
      END DO
      TRECH1=3.47*(SUM1/10.-38.)**(2./5.)/100.
      TRECH2=SUM2/1000.
      WRITE(2,*)'TRECH1',TRECH1,'TRECH2', TRECH2

      WRITE(2,54) (RECHRAIN(K),K=1,NTIME)
      DO K=1,NTIME
      RECHRAIN(K)=RECHRAIN(K)*AREA/1000.
      END DO
C
C     COMPUTATION OF MONTHLY SEEPAGE LOSS IN A GRID
C
      DO K=1,NTIME
      DO I=1,IMAX
      DO J=JINI(I),JFIN(I)
      SEEPLOSS(I,J,K)=CANALL(I,J)*CANALP(I,J)*
     1      CANALRD( NCTYPE(I,J), K ) * DSEEP(NCTYPE(I,J))
      END DO
      END DO
      END DO
C     COMPUTATION OF MONTHLY SEEPAGE FROM THE ENTIRE SYSTEM
C     EXCLUDING BOUNDARY SEEPAGE IN EACH MONTH
      DO K=1,NTIME
      SEEPM(K)=0.
      DO I=1,IMAX
      DO J=JINI(I),JFIN(I)
      SEEPM(K)=SEEPM(K)+SEEPLOSS(I,J,K)
      END DO
      END DO
      END DO
C     OUTFLOW TOWARDS KALI

      DO K=1,NTIME
      BOUTFL(K)=RIVERL*RIVGRAD*1521.*NUMDAYSM(K)
      END DO


C     OUTFLOW TOWARDS GANGA CANAL
      DO K=1,NTIME
C     BOUTFR(K)=-0.5*GANGACL*PERIMG*DSEPM*CANALRD(10,K)
      BOUTFR(K)=GANGACL*0.5*RIVGRAD*1521.*NUMDAYSM(K)
      END DO


C     INFLOW FROM TOP

      DO K=1,NTIME
      BINFT(K)=0.5*DBANDHL*DBANDHP*DSEEP(1)*CANALRD(1,K)
      END DO

C     MONTHLY OUTFLOW  AT BOTTOM

      INDEX=0
```

```
      DO J=JINI(IMAX),JFIN(IMAX)
      INDEX=INDEX+1
      END DO
      BOTTOML=INDEX*800.
      DO K=1,NTIME
      BOUTFB(K)=BOTTOML*RIVGRAD*1521.*NUMDAYSM(K)
      END DO

C     COMPUTATION OF SURFACE WATER SUPPLY TO THE STUDY AREA
      DO K=1,NTIME
      SWSUPPLY=0.
      DO I=2,9
      SWSUPPLY=SWSUPPLY+CANALRD(I,K)*DAILYD(I)*60.*60.*24
      END DO
        SWATERSM(K)=SWSUPPLY
      END DO

      WRITE(2,*)'MONTHLY WATER SUPPLY THROUGH CANALS'
      WRITE(2,55)(SWATERSM(K),K=1,NTIME)

C     CANAL WATER SUPPLY AT HEAD- SEEPAGE LOSS=WATER APPLIED AT FIELD

      DO K=1,NTIME
      SWAVAILF(K)=SWATERSM(K)-SEEPM(K)
      END DO

      WRITE(2,*)'MONTHLY SURFACE WATER AVAILABLE AT FIELD'
      WRITE(2,55)(SWAVAILF(K),K=1,NTIME)

      WRITE(2,*) 'MONTHLY WATER REQUIREMENT IN METRE CUBE FOR THE AREA'
      WRITE(2,55)(TWRQM(K),K=1,NTIME)

      WRITE(2,*)'EXCESS SURFACE WATER SUPPLIED MORE THAN REQUIRED'
      DO K=1,NTIME
      EXCESSSW(K)=0.
      DEFICSW(K)=0.
      TERM=SWAVAILF(K)-TWRQM(K)
      IF(TERM.GE.0.)EXCESSSW(K)=TERM
      IF(TERM.LT.0.)DEFICSW(K)=ABS(TERM)
      END DO
      WRITE(2,55)(EXCESSSW(K),K=1,NTIME)
      WRITE(2,*)'DEFICIT IN  SURFACE WATER  SUPPLY'
      WRITE(2,55)(DEFICSW(K),K=1,NTIME)
      WRITE(2,*)'PUMPING REQUIREMENT PER MONTH'

      DO K=1,NTIME
      PUMPREQM(K)= AREA*WRQM(K)/1000.-(SWATERSM(K)-SEEPM(K))
      IF(PUMPREQM(K).LE.0.)PUMPREQM(K)=0.
      QPUMPPUA(K)=PUMPREQM(K)/SCOMMAND
        END DO
      WRITE(2,55)(PUMPREQM(K),K=1,NTIME)
      WRITE(2,*)'PUMPING REQUIREMENT PER UNIT AREA PER MONTH'
      WRITE(2,55)(QPUMPPUA(K),K=1,NTIME)

      DO K=1,NTIME
```

```
      GWPOTEN(K)=SEEPM(K)+BINFT(K)+RFLOWM(K)+RECHRAIN(K)
     1       -BOUTFR(K)-BOUTFL(K)-BOUTFB(K)-PUMPREQM(K)
      END DO

      WRITE(2,*)'MONTHLY RECHARGE FROM RAIN'
      WRITE(2,55)(RECHRAIN(K),K=1,NTIME)

      WRITE(2,*)'MONHLY IRRIGATION RETURNFLOW'
      WRITE(2,55)(RFLOWM(K),K=1,NTIME)

      WRITE(2,*)'MONTHLY SEEPAGE LOSS FROM CANAL IN METRE CUBE'
      WRITE(2,55)(SEEPM(K),K=1,NTIME)

      WRITE(2,*)'MONTHLY INFLOW FROM TOP IN METER CUBE'
      WRITE(2,55)(BINFT(K),K=1,NTIME)


      WRITE(2,*)'MONTHLY BASIN OUTFLOW TOWARDS GANGA CANAL'
      WRITE(2,55)(BOUTFR(K),K=1,NTIME)

      WRITE(2,*)' MONTHLY BASIN OUTFLOW TOWARDS RIVER KALI'
      WRITE(2,55)(BOUTFL(K),K=1,NTIME)

      WRITE(2,*)'MONTHLY OUTFLOW AT BOTTOM'
      WRITE(2,55)(BOUTFB(K),K=1,NTIME)


      WRITE(2,*)'GROUNDWATER WITHDRAWAL AS PER CROPWATEWR REQUIREMENT'
      WRITE(2,55)(PUMPREQM(K),K=1,NTIME)

      WRITE(2,*)'MONTHLY GROUND WATER CHANGE IN METRE CUBE '
      WRITE(2,55)(GWPOTEN(K),K=1,NTIME)


      DO K=1,NTIME
      CGWPOTEN(K)=0.

      DO INDEX=1,K
      CGWPOTEN(K)=CGWPOTEN(K)+GWPOTEN(INDEX)
      END DO
      HYDROGRAPH(K)=CGWPOTEN(K)/AREA
      END DO
      WRITE(2,*)'GROUND WATER POTENTIAL IN EACH MONTH'
      WRITE(2,55)(CGWPOTEN(K),K=1,NTIME)

C      DO K=1,5
C     SUM=CGWPOTEN(12)
C     DO INDEX=1,K
C     SUM=SUM+GWPOTEN(INDEX)
C     END DO
C     CGWPOTEN(K)= SUM
C     END DO
C     WRITE(2,*)'GROUND WATER POTENTIAL IN EACH MONTH'
C     WRITE(2,55)(CGWPOTEN(K),K=1,5)

      WRITE(2,*)'GROUND WATER RISE'
      WRITE(2,55)(HYDROGRAPH(K),K=1,NTIME)
```

DATA INPUT

```
25      22
7       20
5       20
3       20
1       19
1       19
2       19
4       19
5       20
5       20
6       20
5       20
4       20
3       20
3       21
3       21
3       21
3       21
3       21
3       21
3       22
3       22
3       22
3       22
3       22
3       22

26300.      26300.      71.0  0.002
16000.      17.
1.5    1.96  1.21    1.21
1      5
17     1204. 3.25  2
15     1214. 7.5   3
11     824.  6.4   4
19     950.  6.9   7
6      380.  3.4   5
2      7
17     1140. 2.89  2
15     1277. 7.5   3
11     982.  6.4   4
19     1076. 6.9   7
12     150.  2.24  4
6      1120. 3.4   5
17     1140. 2.89  2
3      8
15     1128. 7.5   3
11     820.  6.4   4
10     1010. 6.4   4
19     1014. 6.9   7
12     1100. 2.24  4
6      1050. 3.3   5
5      190.  3.2   5
16     1030. 1.68  2
4      8
15     380.  7.5   3
16     317.  7.5   3
```

9	1080.	6.3	4
18	1080.	6.9	7
12	1050.	2.24	4
5	1130.	3.2	5
2	823.	3.0	6
3	880.	3.0	6
5	7		
16	950.	7.5	3
9	1060.	6.3	4
12	1076.	2.2	4
6	1120.	2.8	5
3	320.	2.5	6
4	810.	2.5	6
18	1425.	6.8	7
6	8		
15	1277.	7.0	3
9	2165.	6.3	4
11	1108.	2.20	4
6	1090.	2.4	5
4	1078.	1.8	6
17	570.	5.3	7
18	1050.	6.8	7
19	640.	5.4	7
7	8		
15	1280.	7.0	3
8	1204.	2.19	4
10	820.	6.2	4
6	1050.	2.4	5
4	127.	1.8	6
16	1050.	5.2	7
17	580.	5.3	7
18	1080.	6.6	7
8	5		
14	1203.	7.0	3
7	310.	2.19	4
9	1330.	6.2	4
15	1300.	5.2	7
18	1204.	6.6	7
9	4		
14	1214.	6.6	3
8	1320.	6.0	4
18	1013.	6.0	7
20	824.	10.2	8
10	9		
13	1245.	6.6	3
7	605.	5.8	4
8	610.	6.0	4
17	450.	5.0	7
18	887.	5.0	7
19	695.	6.0	7
20	254.	5.8	7
19	1869.	10.1	8
20	1045.	7.8	9
11	8		
13	1275.	6.6	3
7	1455.	5.8	4
8	890.	2.18	4

16	507.	4.3	7
17	823.	4.6	7
18	1045.	10.1	8
19	1050.	3.6	8
20	1331.	7.8	9
12	10		
13	1214.	6.6	3
6	1530.	5.6	4
7	506.	5.6	4
8	633.	2.16	4
9	538.	2.16	4
15	317.	4.3	7
16	950.	4.3	7
17	1204.	10.0	8
19	1055.	3.4	8
20	2010.	7.8	9
13	9		
13	1290.	5.9	3
5	760.	2.08	4
6	1362.	5.6	4
7	1077.	2.08	4
14	380.	4.0	7
15	950.	4.0	7
16	1080.	10.0	8
19	127.	3.4	8
20	2142.	6.8	9
14	6		
13	1080.	5.9	3
5	1035.	5.2	4
14	570.	3.8	7
15	950.	9.8	8
16	1300.	5.6	8
20	2155.	6.0	9
15	7		
12	1052.	5.9	3
12	640.	6.3	3
5	1175.	5.2	4
14	887.	9.8	8
15	380.	9.8	8
16	1080.	4.0	8
20	2130.	6.2	9
16	10		
10	570.	6.2	3
11	950.	6.2	3
12	1076.	5.9	3
4	1109.	5.0	4
5	1140.	5.2	4
13	850.	9.6	8
14	385.	9.8	8
16	1120.	4.0	8
19	950.	4.5	9
20	1014.	7.6	9
17	11		
10	1140.	5.42	3
12	1050.	2.3	3
4	825.	5.0	4
12	570.	9.6	8

13	1000.	8.0	8
14	315.	5.3	8
15	130.	3.8	8
16	890.	3.8	8
18	350.	4.2	9
19	1370.	6.0	9
20	380.	7.6	9
18	6		
9	1204.	5.36	3
11	1530.	2.28	3
12	1140.	9.5	8
14	1140.	5.3	8
18	300.	4.0	9
19	1045.	7.6	9
19	8		
5	1280.	2.33	3
6	860.	2.35	3
7	920.	2.38	3
8	320.	5.34	3
9	800.	2.25	3
12	1077.	9.5	8
14	1080.	4.9	8
19	140.	7.6	9
20	8		
4	860.	2.3	3
7	1214.	5.3	3
9	1245.	2.2	3
12	1200.	9.2	8
14	1090.	4.9	8
18	1014.	6.4	9
19	1875.	6.4	9
20	1014.	5.8	9
21	7		
8	1480.	5.3	3
9	890.	2.15	3
12	1140.	9.2	8
13	1080.	4.6	8
17	1160.	6.2	9
19	950.	7.4	9
21	960.	5.6	9
22	9		
6	570.	5.28	3
7	475.	5.28	3
8	860.	2.1	3
11	1200.	9.2	8
12	380.	4.0	8
13	570.	4.6	8
16	320.	6.2	9
18	1076.	7.4	9
21	1115.	5.6	9
23	8		
4	1080.	2.4	3
5	1500.	4.0	3
6	1214.	5.26	3
10	730.	8.0	8
11	316.	8.7	8
15	1250.	6.2	9

18	1267.	7.4	9
21	1077.	5.6	9
24	9		
4	1700.	5.24	3
6	1420.	3.0	3
9	190.	7.4	8
10	950.	7.4	8
14	580.	6.0	9
15	570.	6.0	9
17	760.	7.5	9
18	440.	7.5	9
21	1045	5.4	9
25	7		
3	640.	5.22	3
5	300.	2.6	3
6	325.	2.9	3
9	1014.	7.4	8
14	1014.	5.9	9
17	1014.	7.4	9
21	1050.	5.2	9

.40 0.15 0.15 0.15 0.25 0.15 0.15 0.15 0.30

1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 0 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 0 1 1 1 1 1
0 1 1 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1
1 1 1 1 1 1 1 1 0 0 1 1 1 1 1 1
1 1 1 1 1 1 0 0 1 1 1 1 1 1 1 1
0 0 1 1 1 0 0 1 1 1 1 1 1 1 1 1
1 1 1 1 0 0 1 1 1 1 1 1 1 1 1
1 1 1 1 0 0 0 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 0 0 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 0 0 1 1 1 1 1 1 0 1 1 1
1 1 1 1 1 1 0 0 0 0 1 0 1 1 0 0 1 1 1
1 1 1 1 1 0 0 0 1 1 1 1 1 1 0 0 1 1 1
1 1 1 1 0 0 0 0 1 1 1 1 1 1 0 1 1 1 1
1 1 1 0 0 0 0 1 1 1 1 1 1 1 0 1 1 1 1
1 0 0 0 1 1 1 1 1 1 1 1 1 0 0 1 1 1 1
0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 1 1 1 1
0 1 1 1 1 1 1 1 1 1 1 1 0 0 1 1 1 1 1 1
0 0 0 1 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1
0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
0 1 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1
0 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1
0 1 1 1 1 1 1 1 0 0 1 1 1 1 1 1 1 1 1 1

```
DATA INPUT TIME VAR.
    PADDY
    MAIZE
    SORGHUM
    COTTON
    WHEAT
    BERSEEM
    MUSTARD
    MUNG
    SUGARCANE
    12
 0.2  0.07  0.08  0.05  0.32  0.04  0.04  0.04  0.6
    32.8     60.8  25.8  39.4  20.4  67.0
    334.4    456.6 164.4 57.4  7.4   20.2

31  28       31  30       31  30       31  31       30  31       30  31

1.7   2.4   3.7   5.3   6.7   6.6
4.7   4.2   4.1   3.5   2.3   1.7

0.00  0.00  0.00  0.00  0.00  25.65
155.48      123.03      121.16      52.13 0.00  0.00

0.00  0.00  0.00  0.00  0.00  42.52
97.62 130.00      46.00 0.00  0.00  0.00

0.00  0.00  0.00  0.00  0.00  30.00
69.00 120.00      118.00      32.00 0.00  0.00

0.00  0.00  0.00  26.00 0.00  58.96
134.28      120.00      102.25      36.00 0.00  0.00

21.00 40.00 12.00 0.00  0.00  0.00
0.00  0.00  0.00  0.00  0.00  0.00

21.28 41.00 20.20 30.00 19.00 0.00
0.00  0.00  0.00  30.00 0.00  13.00

21.80 21.12 0.00  0.00  0.00  0.00
0.00  0.00  0.00  0.00  0.00  13.40

0.00  0.00  16.65 34.00 20.32 0.00
0.00  0.00  0.00  0.00  0.00  0.00

21.00 26.93 17.00 28.00 16.40 51.88
133.00      127.00      108.00      38.00 0.00  14.30

0.00  0.00  0.00  0.00  0.00  100.00
225.00      0.00  0.00  0.00  0.00  0.00

0.00  0.00  0.00  0.00  0.00  75.00
0.00  0.00  0.00  0.00  0.00  0.00

0.00  0.00  0.00  0.00  0.00  75.00
0.00  0.00  0.00  0.00  0.00  0.00

0.00  0.00  0.00  75.00 0.00  0.00
```

0.00 0.00 0.00 0.00 0.00 0.00

0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.0 0.00 0.00 100.00 0.00

0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 75.00 0.00 0.00

0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 75.00 0.00

0.00 0.00 75.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00

0.00 75.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00

0.00 0.00 0.00 0.00 0.00 1.10
1.10 1.10 1.10 1.06 0.00 0.00

0.00 0.00 0.00 0.00 0.00 0.30
0.67 1.08 0.81 0.00 0.00 0.00

0.00 0.00 0.00 0.00 0.00 0.34
0.53 0.99 0.98 0.60 0.00 0.00

0.00 0.00 0.00 0.40 0.70 1.06
1.06 0.99 0.89 0.80 0.00 0.00

1.09 0.99 0.44 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.39 0.71

1.10 1.13 0.95 0.70 0.60 0.00
0.00 0.00 0.00 0.35 0.50 0.70

0.97 0.55 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.30 1.00

0.00 0.00 0.30 1.24 1.10 0.00
0.00 0.00 0.00 0.00 0.00 0.00

0.83 0.38 0.44 0.52 0.69 0.85
0.95 1.02 1.04 1.03 1.00 0.88

12 11 12 20 30 30 21 9 10 23 14 13
6 7 7 10 14 7 12 2 5 14 7 1
8 11 11 11 21 21 15 2 5 7 7 8
7 7 8 10 17 16 10 3 4 7 7 7
7 7 3 11 17 16 12 3 4 7 7 7
7 7 8 10 17 16 10 2 5 5 7 7
7 7 7 15 14 27 16 3 4 24 11 7
7 11 10 16 20 20 21 2 5 17 11 14
14 11 10 14 17 23 21 3 6 10 11 14
31 28 31 30 31 30 31 13 14 20 21 31
19.13 0.28 3.4 2.83 0.42 0.2 1.98 2.83 1.84 255.10

RESULTS FOR CROPPING INTENSITY 144% AND NORMAL RAINFALL

I	JINI(I)	JFIN(I)
1	7	20
2	5	20
3	3	20
4	1	19
5	1	19
6	2	19
7	4	19
8	5	20
9	5	20
10	6	20
11	5	20
12	4	20
13	3	20
14	3	21
15	3	21
16	3	21
17	3	21
18	3	21
19	3	21
20	3	22
21	3	22
22	3	22
23	3	22
24	3	22
25	3	22

STUDY AREA= 3.804032E+08

RETURN FLOW FACTOR FOR EACH CROP

.400	.150	.150	.150	.250	.150
.150	.150	.300			

MONTHLY RAINFALL IN MM

32.800	60.800	25.800	39.400	20.400	67.000
334.400	456.600	164.400	57.400	7.400	20.200

MONTHLY EVAPORATION IN MM

52.700	67.200	114.700	159.000	207.700	198.000
145.700	130.200	123.000	108.500	69.000	52.700

MONTHLY EFFECTIVE RAINFALL IN MM

CROP --- PADDY

.000	.000	.000	.000	.000	25.650
155.480	123.030	121.160	52.130	.000	.000

CROP --- MAIZE

.000	.000	.000	.000	.000	42.520
97.620	130.000	46.000	.000	.000	.000

CROP --- SORGHUM

.000	.000	.000	.000	.000	30.000
69.000	120.000	118.000	32.000	.000	.000

CROP --- COTTON

.000	.000	.000	26.000	.000	58.960
134.280	120.000	102.250	36.000	.000	.000

CROP --- WHEAT

21.000	40.000	12.000	.000	.000	.000
.000	.000	.000	.000	.000	.000

CROP --- BERSEEM

21.280	41.000	20.200	30.000	19.000	.000
.000	.000	.000	30.000	.000	13.000

CROP --- MUSTARD

```
     21.800      21.120        .000        .000        .000        .000
       .000        .000        .000        .000        .000      13.400
CROP --- MUNG
       .000        .000      16.650      34.000      20.320        .000
       .000        .000        .000        .000        .000        .000
CROP --- SUGARCANE
     21.000      26.930      17.000      28.000      16.400      51.880
    133.000     127.000     108.000      38.000        .000      14.300
MONTHLY WATER APLICATION FOR LAND PREPARATION  IN MM
CROP --- PADDY
       .000        .000        .000        .000        .000     100.000
    225.000        .000        .000        .000        .000        .000
CROP --- MAIZE
       .000        .000        .000        .000        .000      75.000
       .000        .000        .000        .000        .000        .000
CROP --- SORGHUM
       .000        .000        .000        .000        .000      75.000
       .000        .000        .000        .000        .000        .000
CROP --- COTTON
       .000        .000        .000      75.000        .000        .000
       .000        .000        .000        .000        .000        .000
CROP --- WHEAT
       .000        .000        .000        .000        .000        .000
       .000        .000        .000        .000     100.000        .000
CROP --- BERSEEM
       .000        .000        .000        .000        .000        .000
       .000        .000        .000      75.000        .000        .000
CROP --- MUSTARD
       .000        .000        .000        .000        .000        .000
       .000        .000        .000        .000      75.000        .000
CROP --- MUNG
       .000        .000      75.000        .000        .000        .000
       .000        .000        .000        .000        .000        .000
CROP --- SUGARCANE
       .000      75.000        .000        .000        .000        .000
       .000        .000        .000        .000        .000        .000
CROP COEFFICIENT
CROP --- PADDY
       .000        .000        .000        .000        .000       1.100
      1.100       1.100       1.100       1.060        .000        .000
CROP --- MAIZE
       .000        .000        .000        .000        .000        .300
       .670       1.080        .810        .000        .000        .000
CROP --- SORGHUM
       .000        .000        .000        .000        .000        .340
       .530        .990        .980        .600        .000        .000
CROP --- COTTON
       .000        .000        .000        .400        .700       1.060
      1.060        .990        .890        .800        .000        .000
CROP --- WHEAT
      1.090        .990        .440        .000        .000        .000
       .000        .000        .000        .000        .390        .710
CROP --- BERSEEM
      1.100       1.130        .950        .700        .600        .000
       .000        .000        .000        .350        .500        .700
CROP --- MUSTARD
       .970        .550        .000        .000        .000        .000
```

.000 .000 .000 .000 .300 1.000
CROP --- MUNG
.000 .000 .300 1.240 1.100 .000
.000 .000 .000 .000 .000 .000
CROP --- SUGARCANE
.830 .380 .440 .520 .690 .850
.950 1.020 1.040 1.030 1.000 .880
RUNNING DAYS OF DEOBAND BRANCH AND GANGA CANAL SYSTEM
RDEOBAND BRANCH CANAL
12.000 11.000 12.000 28.000 30.000 30.000
29.000 19.000 22.000 23.000 14.000 13.000
RGJUDDA MINOR
6.000 7.000 7.000 15.000 14.000 7.000
16.000 17.000 16.000 14.000 7.000 1.000
RRMAIN DISTRIBUTARY
8.000 11.000 11.000 14.000 21.000 21.000
21.000 13.000 13.000 11.000 7.000 8.000
RSINDHAULI DISTRIBUTARY
7.000 7.000 8.000 14.000 17.000 16.000
15.000 14.000 14.000 7.000 7.000 7.000
RMAJHOL MINOR
7.000 7.000 3.000 16.000 17.000 16.000
15.000 14.000 14.000 7.000 7.000 7.000
RSALONI MINOR
7.000 7.000 8.000 14.000 17.000 16.000
15.000 14.000 14.000 7.000 7.000 7.000
RTANSIPUR DISTRIBUTARY
7.000 7.000 7.000 22.000 14.000 27.000
31.000 31.000 31.000 24.000 11.000 7.000
RMOHD DISTRIBUTARY
7.000 11.000 10.000 22.000 20.000 20.000
31.000 31.000 31.000 17.000 11.000 14.000
RMAIN BASERA DISTRIBUTARY
14.000 11.000 10.000 21.000 17.000 23.000
31.000 31.000 31.000 10.000 11.000 14.000
MAIN GANGA CANAL
31.000 28.000 31.000 30.000 31.000 30.000
31.000 31.000 30.000 20.000 21.000 31.000
MONTHLY WATER REQUIREMENT OF EACH CROP IN MM PER UNIT AREA
CROP --- PADDY
.000 .000 .000 .000 .000 58.430
45.958 4.038 2.828 12.576 .000 .000
CROP --- MAIZE
.000 .000 .000 .000 .000 6.432
.000 .743 3.754 .000 .000 .000
CROP --- SORGHUM
.000 .000 .000 .000 .000 8.986
.658 .712 .203 2.648 .000 .000
CROP --- COTTON
.000 .000 .000 5.630 7.270 7.546
1.008 .445 .361 2.540 .000 .000
CROP --- WHEAT
11.662 8.489 12.310 .000 .000 .000
.000 .000 .000 .000 40.611 11.973
CROP --- BERSEEM
1.468 1.397 3.551 3.252 4.225 .000
.000 .000 .000 3.319 1.380 .956

```
CROP --- MUSTARD
      1.173        .634        .000        .000        .000        .000
       .000        .000        .000        .000       3.828       1.572
CROP --- MUNG
       .000        .000       3.710       6.526       8.326        .000
       .000        .000        .000        .000        .000        .000
CROP --- SUGARCANE
     13.645      44.164      20.081      32.808      76.148      69.852
      3.249       3.482      11.952      44.253      41.400      19.246
MONTHLY IRRIGATION RETURN FLOW FROM EACH CROP IN MM
CROP --- PADDY
       .000        .000        .000        .000        .000      23.372
     18.383       1.615       1.131       5.030        .000        .000
CROP --- MAIZE
       .000        .000        .000        .000        .000        .965
       .000        .111        .563        .000        .000        .000
CROP --- SORGHUM
       .000        .000        .000        .000        .000       1.348
       .099        .107        .030        .397        .000        .000
CROP --- COTTON
       .000        .000        .000        .845       1.090       1.132
       .151        .067        .054        .381        .000        .000
CROP --- WHEAT
      2.915       2.122       3.077        .000        .000        .000
       .000        .000        .000        .000      10.153       2.993
CROP --- BERSEEM
       .220        .210        .533        .488        .634        .000
       .000        .000        .000        .498        .207        .143
CROP --- MUSTARD
       .176        .095        .000        .000        .000        .000
       .000        .000        .000        .000        .574        .236
CROP --- MUNG
       .000        .000        .557        .979       1.249        .000
       .000        .000        .000        .000        .000        .000
CROP --- SUGARCANE
      4.093      13.249       6.024       9.842      22.844      20.956
       .975       1.045       3.586      13.276      12.420       5.774
MONTHLY WATER REQUIREMENT IN MM FOR UNIT AREA
     27.947      54.684      39.652      48.216      95.968     151.245
     50.873       9.420      19.098      65.336      87.219      33.747
MONTHLY RETURN FLOW IN MM FROM UNIT AREA
      7.405      15.676      10.191      12.154      25.817      47.772
     19.608       2.945       5.365      19.582      23.354       9.146
MONTHLY RECHARGE FROM RAIN  IN MM PER UNIT AREA
TRECH1    2.105212E-01TRECH2   2.150500E-01
       .000       5.934        .000       1.012        .000       7.360
     68.862      96.968      29.762       5.152        .000        .000
MONTHLY WATER SUPPLY THROUGH CANALS
  .9717E+07   .1112E+08   .1084E+08   .2120E+08   .2156E+08   .2427E+08
  .2884E+08   .2621E+08   .2619E+08   .1551E+08   .1063E+08   .1131E+08
MONTHLY SURFACE WATER AVAILABLE AT FIELD
  .8790E+07   .1010E+08   .9852E+07   .1926E+08   .1965E+08   .2209E+08
  .2614E+08   .2372E+08   .2370E+08   .1415E+08   .9653E+07   .1021E+08
MONTHLY WATER REQUIREMENT IN METRE CUBE FOR THE AREA
  .1063E+08   .2080E+08   .1508E+08   .1834E+08   .3651E+08   .5753E+08
  .1935E+08   .3583E+07   .7265E+07   .2485E+08   .3318E+08   .1284E+08
EXCESS SURFACE WATER SUPPLIED MORE THAN REQUIRED
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  .0000E+00   .0000E+00   .0000E+00   .9205E+06   .0000E+00   .0000E+00
  .6791E+07   .2014E+08   .1643E+08   .0000E+00   .0000E+00   .0000E+00
DEFICIT IN  SURFACE WATER  SUPPLY
  .1841E+07   .1070E+08   .5231E+07   .0000E+00   .1686E+08   .3545E+08
  .0000E+00   .0000E+00   .0000E+00   .1071E+08   .2353E+08   .2629E+07
PUMPING REQUIREMENT PER MONTH
  .1841E+07   .1070E+08   .5231E+07   .0000E+00   .1686E+08   .3545E+08
  .0000E+00   .0000E+00   .0000E+00   .1071E+08   .2353E+08   .2629E+07
PUMPING REQUIREMENT PER UNIT AREA PER MONTH
  .5712E-02   .3321E-01   .1623E-01   .0000E+00   .5229E-01   .1100E+00
  .0000E+00   .0000E+00   .0000E+00   .3321E-01   .7299E-01   .8155E-02
MONTHLY RECHARGE FROM RAIN
  .0000E+00   .2257E+07   .0000E+00   .3850E+06   .0000E+00   .2800E+07
  .2620E+08   .3689E+08   .1132E+08   .1960E+07   .0000E+00   .0000E+00
MONHLY IRRIGATION RETURNFLOW
  .2817E+07   .5963E+07   .3877E+07   .4623E+07   .9821E+07   .1817E+08
  .7459E+07   .1120E+07   .2041E+07   .7449E+07   .8884E+07   .3479E+07
MONTHLY SEEPAGE LOSS FROM CANAL IN METRE CUBE
  .9268E+06   .1024E+07   .9838E+06   .1940E+07   .1911E+07   .2187E+07
  .2696E+07   .2493E+07   .2492E+07   .1360E+07   .9798E+06   .1099E+07
MONTHLY INFLOW FROM TOP IN METER CUBE
  .2764E+06   .2533E+06   .2764E+06   .6449E+06   .6909E+06   .6909E+06
  .6679E+06   .4376E+06   .5067E+06   .5297E+06   .3224E+06   .2994E+06
MONTHLY BASIN OUTFLOW TOWARDS GANGA CANAL
  .1240E+07   .1120E+07   .1240E+07   .1200E+07   .1240E+07   .1200E+07
  .1240E+07   .1240E+07   .1200E+07   .1240E+07   .1200E+07   .1240E+07
 MONTHLY BASIN OUTFLOW TOWARDS RIVER KALI
  .2480E+07   .2240E+07   .2480E+07   .2400E+07   .2480E+07   .2400E+07
  .2480E+07   .2480E+07   .2400E+07   .2480E+07   .2400E+07   .2480E+07
MONTHLY OUTFLOW AT BOTTOM
  .1509E+07   .1363E+07   .1509E+07   .1460E+07   .1509E+07   .1460E+07
  .1509E+07   .1509E+07   .1460E+07   .1509E+07   .1460E+07   .1509E+07
GROUNDWATER WITHDRAWAL AS PER CROPWATEWR REQUIREMENT
  .1841E+07   .1070E+08   .5231E+07   .0000E+00   .1686E+08   .3545E+08
  .0000E+00   .0000E+00   .0000E+00   .1071E+08   .2353E+08   .2629E+07
MONTHLY GROUND WATER CHANGE IN METRE CUBE
 -.3050E+07  -.5928E+07  -.5323E+07   .2533E+07  -.9661E+07  -.1666E+08
  .3179E+08   .3571E+08   .1130E+08  -.4636E+07  -.1840E+08  -.2981E+07
GROUND WATER POTENTIAL IN EACH MONTH
 -.3050E+07  -.8978E+07  -.1430E+08  -.1177E+08  -.2143E+08  -.3809E+08
 -.6298E+07   .2941E+08   .4071E+08   .3608E+08   .1768E+08   .1470E+08
GROUND WATER RISE
 -.8019E-02  -.2360E-01  -.3760E-01  -.3094E-01  -.5633E-01  -.1001E+00
 -.1656E-01   .7731E-01   .1070E+00   .9484E-01   .4647E-01   .3863E-01
WATER LEVEL RISE
       .241
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STANDING ORDER NO.6708-W-1/80 DATED AUGUST 5, 1980

FOR SHARING OF GANGA WATER DURING RABI

RABI 1990

STANDING ORDER ON INTER-CIRCLE REGULATION OF SUPPLIES OF UPPER GANGA CANAL, LOWER GANGA CANAL AND AGRA CANAL FOR RABI SEASON.

1. The available supplies in U.G.C., L.G.C. and Agra Canal remain short of actual requirement for considerabl period during Rabi season. There is, thus, a need for working out a share of each system, whenever the total supplies available during entire rabi irrigation period are loss than the requirement of three systems.

2. The total supply (T) available for distribution will be arrived at by the formula

   T = S+N+F-J

Where

S	=	Discharge of Upper Ganga Canal at Dhanauri
N	=	Discharge of Lower Ganga Canal at narora mile 2 including the supplies recovered there by relaease from Ramganga Reservoir.
F	=	Discharge of Agra Canal at Faridabad.
J	=	Discharge of Jani Escape.

3. The standing order on inter-circle regulation of supplies on U.G.C.,L.G.C. and Agra Canal was last issued in 1974-75 when Ramganga reservoir was filled for the first time. Although Ramganga Dam has partial fillings since last six years but till now the proposed irrigation on L.G.C. during Rabi has not been achieved. It has, therefore, beon decided now to work out the distribution of water for ansuing Rabi season on the basis of post Ramganga areas provided in the Ramganga project.

4. In the standing order for Rabi irrigation the shares have been worked out in proportion of the Kor period requirement of water at distributary head for total

rabi area and 1/3 sugarcane area plus the system and main line losses on each system.

5. The rabi and 1/3 sugarcane areas proposed under post Ramganga Project on these systems are as follows:

Sl. No.	**Name of System**	**Rabi lac acres**	**Sugarcane in lac acres**	**R+S/3 lac acreas**
1.	U.G.C.	9.14	3,91	10.44
2.	L.G.C.	10.69	1.49	11.19
3.	Agra Canal	3.14	0.78	3.40

6. The number of cusec days required on this basis at distributary head for the canal systems during the Kor period works out as follows:

Sl. No.	**Name of System**	**R+S/3 lac Acres**	***Cusec days required at distributary head @ 24 acreas per cusec week.***
1.	U.G.C.	10.44	3,04,500
2.	L.G.C.	11.19	3,26,375
3.	Agra Canal	3.40	99,167

7. The main line losses have been adopted as follows :

(i)	U.G.C. System	Cuses days
1.	Main U.G.C. (1000-100 cusecs for Harduaganj Power Station) 9 weeks.	69,300
2.	Deoband Branch 60x6 cusec weeks	2,520
3.	Anupshahr Branch (200+80)x6”	11,760
4.	Supply channel 41x8 weeks	2,296
5.	Mat Branch System 300x8 weeks	16,800
	Total	**1,02,676**
	Say	**1,02,700**

(ii) Agra Canal 300x9 cusec weeks 18,900

(iii) L.G.C.System

1.	Main Lower Ganga Canal 850x9 cusec weeks.	54,000
2.	Farukhabad Branch (100x4) + (50x4) cusec weeks.	4,200
3.	Bewar Branch 100x4 cusec week	2,800
4.	Kanpur Branch (150+150) cusec week	18,900
5.	Etawah Branch (30+100+50) cusec week	10,080
6.	Ghatampur Dy. 60x8 cusec week	3,360
7.	Fatehpur Branch + Feeder 180x8 cusec week	10,080
8.	Bhognipur Branch (80+120)x4 cusec week	5,600
9.	West Allahabad Branch 380x6 cusec week	16,000
10.	Kanpur Stump 50x6 cusec week	2,100
11.	Misc. Bulk supplies at Kanpur 100x9 cusec week	6,300
	Total :	**1,33,420**
	Say :	**1,33,400**

The main line losses adopted on L.G.C. and Agra Canal systems are the same as those provided in standing order of 1974-75. The losses in U.G.C. have however, been increased by 1000 cusecs only for the consumptive use in Harduaganj Power Station.

8. On the basis of the above areas and losses the shares of the three systems work out as below:

Sl. No.	**Name of system**	**Requirement at Dy.head cusecs days.**	**Main line losses cu.days.**	**Total requirement cu. Days**	**Percent tage.**
1.	U.G.C.	304500	102700	407200	41.5%
2.	L.G.C.	326375	133400	459775	46.5%
3.	Agra Canal	99167	18900	118067	12%
			Total	**985042**	

9. Before working out shares of L.G.C. on U.G.C. it will be imperative to decide the operation of Ramganga reservoir each season. This will be done jointly by the two Superintending Engineers viz of Ist Circle, I.W. Meerut and IInd Circle, I.W. Kanpur.

10. If reservoir is filled upto some level lower than F.R.L. preference will be given for the irrigation as per project requirements and the operation of reservoir decided accordingly.

11. The allocation of water for operation of Ganga Canal, Lower Ganga Canal, Agra Canal at head and for releases from Ramganga reservoir (for irrigation purpose only) during Rabi shall be done by S.E.I Circle, Irrigation Works, Meerut.

12. The Inter-Circle Regulation on Upper Ganga Canal will be done by S.E.I. Circle, Meerut and on Lower Ganga Canal by S.E.II Circle, Kanpur. These S.E's can hand ovler the inter-circle regulation to Executive Engineer, meerut Division Ganga Canal/Kanpur Division Lower Ganga Canal during period of slack demands when the available supplies are more than the demand.

13. At the time of preparing the allotment for the ensuing week the Superintending Engineer will have worked out the shares of the total available supply received by each canal system to end of the previous week, the estimated supplies expected to be received by each during the current week and the deficit or excess expected to be received by each canal to end of the week. Such deficit or excess will be made up in the allotment for the ensuing week.

14. If at any time during the Kor period the supplies available in Agra Canal at Faridabad are in excess of proportionate share of the Agra Canal this excess cannot be utilized by other canals to which it is due and must therefore be utilised by the Agra Canal. The excess supply so utilised will be adjusted later during the fasal when the supply available at Okhla falls below the Agra Canal share.

15. The supply available at Dhanauri, Narora and Agra Canal at Faridabad during the ensuing week will be estimated by the allotting officer and the allotment made thereon on the following basis :

(i) No supply should be passed through Jani Escape for Agra Canal as long as the supply available at Okhla is more than 1875 cusecs nor until the Kor supply received to end of the week is less than 12% of the total supply available computed as laid down in paragraph 5 to 8. Thereafter, sufficient water should be passed from the Ganga Canal to Agra Canal to make up the total supply received by the Agra Canal to 12% of the total supply available.

(ii) The balance left after fixing the discharge to be passed into Jani Escape for Agra Canal will be distributed between Upper Ganga and Lower Ganga in the ratio of 41.50 and 46.50.

16. The S.Es I, II and III will work out the shares of different constituents of U.G.C., L.G.C., Agra Canal and Mat Brach on the basis of principles laid down in paras 5 and 6 above.

17. Inter adjustment in weekly allotments of supply will be permissible by mutual agreement to avoid running of distributaries with much less than full supply discharge or to meet variations in demands.

18. Kor account will be submitted by each Divisional Officer in the prescribed from to the Superientending Engineer as well as to the Chief Engineer Ganga and Ramganga. These should be submitted promptly and without delay to enable the system of distribution to be adjusted in time due to fluctuations in the rate of irrigation and demand for water.

19. Immediately on receipt of the Kor account from the Divisions, the Superientending Engineer will send consolidated Kor account for his circle to the

other Superintending Engineers and the Additional Chief Engineer (Ganga) and (Ramganga) by name.

20. In order to utilise to the best advantage the indadequate supplies available for irrigation and to enable the largest possible area to secure benefits of irrigation, it is essential to see that water is equitably distributed in accordance with requirements and is neither wasted nor too lavishly used anywhere during the period of keen demand. It will, therefore, be necessary during the progress of irrigation to keep a constant watch in the depth of watering attained by each Division or Cirele and to adjust the shares suitably by diverting water from areas showing abnormally high depth to those where water is being most usefully utilised. To enable such adjustment to be correctly made the need for fairly accurate estimating of the areas irrigated and recorded as well as for the prompt and timely submission of the Kor account should be impressed upon the Executive Engineer.

Approved

Sd/hari Mohan
Engineer-in-Chief
Irrigation Department,
U.P., Lucknow.

Sd/(J.P. Agarwal)
Addl. Chief Engineer (Ganga)

Annexure.2

Engineer-in-Chief's Office,

(Works-1-Section)

Irrigation Department, U.P.

No.670-W-1/80 Dated: Lucknow August 5,80

Copy forwarded for information and necessary action :

1. Addl. Chief Engineer (Ramganga), Kalagarh.
2. Superintending Engineer, Ist Circle, I.W., Meerut.
3. Superintending Engineer, Irrigation Construction Circle, Roorkee
4. Superintending Engineer, IIIrd Circle, I.W. Agra.
5. Superintending Engineer, Drainage Circle, Aligarh.
6. Superintending Engineer, Irrigation Construction Circle, Okhla.
7. Superintending Engineer, Iind Circle, I.W., kanpur.
8. Superintending Engineer, Irrigation Works Circle, Aligarh.
9. Superintending Engineer, Ramganga Channel Construction Circle, Fatehpur.
10. Personal Assistant (Ramganga), Kalagarh.
11. Personal Assistant (Flood) to E.W.C., Lucknow.

Sd/ (S.K. Kumar) 4.8.80
Executive Engineer &
Personal Assistant (West)
For Engineer-in-Chief, I.D.

STANDING: ORDER NO. 3662/W-1 DATED AUGUST 7, 1979 FOR SHARING OF GANGA WATER DURING HOT WEATHER

Office memorandum

No.3662-W-1/79/44B/IW/71 Dated: Lucknow August 7,1979

The distribution of supplies on Upper Gnga Canal System for Kharif required reconsideration since long due to changed pattern and intensity of irrigation during Kharif after completion of Ramganga Project. Superintending Engineer, I Circle, Irrigation Works, Meerut has therefore been asked to work out fresh distribution based on the mean of the following areas for sugarcane, rice and other Kharif pertaining to different systems:

(a) Average Irrigation of last 10 years.

(b) Proposed post Ramganga Irrigation.

The distribution table prepared by Superintending Engineer, I Circle, Meerut on the above basis and sent to concerned Superintending Engineers vide his D.O. Letter No. 7525-I/W-39, dated 25.6.79, is hereby approved for regulation of supplies on Upper Ganga Canal during Kharif with immediate effect till further orders.

J.P. Agrawal

Addl. Chief Engineer (Ganga)

No. 3662(I)-W-1/79 of date 7.8.79

Copy forwarded to the following Superintending Engineers for information and necessary action with reference to Superintending Engineer Ist Circle, Irrigation Works, Meerut under mentioned above :

1. Addl. Chief Engineer (Ramganga) Kalagarh District.
2. Superintending Engineer, First Circle, I.W. Meerut.
3. Superintending Engineer, Irrigation Construction Circle, Roorkee.
4. Superintending Engineer, Irrigation Works Circle, Aligarh.
5. Superintending Engineer, Drainage Circle, Aligarh.
6. Superintending Engineer, Drainage Circle, Aligarh.
7. Superintending Engineer, Irrigation Construction Circle, Okhla, New Delhi-25.

Ss/(S.K. Kumar)
Executive Engineer &
Personal Assistant (West)
For Chief Engineer, I.D.