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GROUND WATER BALANCE BEFORE INTRODUCTION OF IRRIGATION IN THE CANAL COMMAND AREA

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PREFACE

National Institute of Hydrology has taken up comprehensive hydrological studies in the Narmada basin from the year 1994-95. The emphasis in this project of five years duration would be to collect the relevant data, carry out various laboratory and field investigations and analysis of the available data with a view to develop a comprehensive physically-based distributed model or methods encompassing all aspects of water resources in the Narmada basin.

This report entitled "Ground Water Balance before Introduction of Irrigation in the Canal Command Area" is a part of the research activities of 'Ground Water Assessment' division of the Institute. The purpose of this study is to present the ground water availability in the Bargi Left Bank Canal command area located in the Narmada upland alluvial plains. The study has been carried out by Mr. C. P. Kumar, Scientist 'C'.

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ABSTRACT

The earlier practice of planning surface irrigation without much consideration of ground water status has been often resulted in waterlogging and salinity problems in the command areas after a time due to gradual rise of ground water. Even where due to availability of good natural or artificial drainage, waterlogging and salinity problems are not likely to result, the independent planning leads to loss of opportunity for mopping up the losses from surface irrigation for benefit of the command area.

The upland alluvial valley of Narmada river in Madhya Pradesh is one of the most promising area for development of its surface water and ground water resources. Ground water, till recently, was the main source for irrigation and the area recorded a phenomenal rise in the number of tubewells during the last decade. Also, a new fillip has been given to the development of surface water resources. Bargi dam, the longest masonry and earthen dam in Madhya Pradesh, has been constructed across river Narmada with a network of canal system for surface irrigation and power generation. The Left Bank Canal (LBC) is 137.2 Km long and designed to irrigate about 1.57 lakh hectares of land in Jabalpur and Narsinghpur districts of Madhya Pradesh. The command area forms a part of Narmada alluvial valley which is quite rich in its ground water resources. A network of branch canals and distributories are being constructed extending upto river Narmada to achieve the targetted area under surface irrigation. In view of the hydrogeological setup of the area, it is apprehended that with a widespread canal irrigation, problems of waterlogging followed

by salinity hazards may crop up in the area in the long run. The advent of surface irrigation may also have a dampening effect on the present development of ground water resources because of its availability at lower tariffs, thereby indirectly aggravating the waterlogging problem in the area. The impact of surface water development on the existing ground water regime therefore needs to be studied for judicious use of surface water and ground water to derive optimal benefits.

The purpose of this study is to present the ground water availability in the Bargi Left Bank Canal (LBC) command area. Ground water recharge has been estimated for pre-Bargi LBC situation i.e. before introduction of extensive irrigation in the canal command area.

1.0 INTRODUCTION

The earlier practice of planning surface irrigation without much consideration of ground water status has been often resulted in waterlogging and salinity problems in the command areas after a time due to gradual rise of ground water. Even where due to availability of good natural or artificial drainage, waterlogging and salinity problems are not likely to result, the independent planning leads to loss of opportunity for mopping up the losses from surface irrigation for benefit of the command area.

The National Water Policy (1987) recognizes the need for conjunctive use and recommends that the conjunctive use of surface water and ground water should be ensured from project planning stage and should form an essential part of the project. Conjunctive use implies not only the joint use of surface water and ground water resources but also their exploitation through efficient use in techno-economic terms by taking advantage of their interaction and the impact of development of one source on other.

Bargi Multipurpose Project (Rani Avantibai Sagar) is one of the major projects which envisages surface irrigation in an area of 2.03 lakh hectares and generation of 115 MW of electricity. Bargi dam is a composite masonry and earthen dam having maximum height of 69.8 m and a total length of 5.68 km, constructed at a distance of 43.2 km from Jabalpur near village Bijora. The Left Bank Canal (LBC) of the dam has been designed to irrigate 1.57 lakh hectares of land in Jabalpur and Narsinghpur districts. The

LBC takes off from the left bank of Bargi dam and runs for 137.2 km westwards upto village Imaliya in Narsinghpur district. It joins the Amoda distributory which runs upto the confluence of the rivers Shakkar and Narmada. The LBC is provided with a network of distributories and branch canals to irrigate the alluvial area upto Narmada river. A major distributory (Patan branch canal) takes off at 31 km from LBC, crosses over Narmada by an aqueduct and runs towards north to irrigate the area between Hiran and Narmada rivers in Patan tehsil of Jabalpur district.

The command area of Bargi Left Bank Canal in Jabalpur and Narsinghpur districts is covered by alluvial deposits which have aquifers generally with high hydraulic conductivity. At the end of monsoon season, it is not uncommon to find pockets of land waterlogged with depth to water table less than 1 to 2 metre below ground level. With the recession of monsoon and exploitation of ground water through shallow tubewells, deep tubewells and dug wells, the water table recedes fast and during summer season, dugwells become dry in certain pockets. The advent of surface water irrigation by canal network of Bargi LBC is definitely a great help to the area for increasing its agricultural production. However, a judicious use of surface water and ground water is needed for deriving optimal benefits.

Generally ground water occurs at shallow depths in areas adjacent to Left Bank Canal and hence an uncontrolled surface water irrigation may cause waterlogging in these areas. Incidently, these areas adjacent to the LBC are also poor in their ground water resources and thus need the canal water. The solution to counteract the effects of surface irrigation in this area may lie in the large scale development of ground water resource in the areas all along the Narmada and Hiran rivers. High potential areas, which are rich in ground water resources, exist in the tail reaches of distributories emanating from LBC. Therefore, it becomes imperative to study the impact of surface water development on the existing ground water regime in order to efficiently utilize the water resources without endangering the command area with waterlogging and salinity problems in future.

In the present study, ground water availability in the Bargi Left Bank Canal (LBC) command area has been discussed for pre-Bargi LBC situation and ground water recharge has been estimated before introduction of extensive irrigation in the command area.

2.0 REVIEW

2.1 General

The concept of conjunctive use recognizes the unified nature of water resources as a single natural resource, although the method of exploitation may involve both surface water and ground water structures. The process takes advantage of the interaction between surface water and ground water phases of the hydrological cycle and also the natural movement of ground water, for planning the use of water from the two phases.

Integration of the use of water from the two sources may involve different levels of time and space integration. For example, if one parcel of land is irrigated with surface water and the excess irrigation results in additional ground water recharge which is allowed to flow to adjoining parcel of land where it is extracted as ground water for use, it is one of the ways to meet conjunctive use. Another form would be to use surface water in one season (e.g. wet season) and ground water in other season (e.g. dry season) on the same parcel of land. Yet another form would consist of physical mixing of the water in a common distribution network.

The quantification of water available for conjunctive use may have to be decided by a trial and error procedure. The steps involved are :

1. Establishing a general ground water balance of the command area for "without project" conditions.

2. Deciding the additional recharge that would become available in the command area in "with project" conditions after considering items like seepage losses from main canals and distribution network which find its way to ground water, field losses from surface to ground water due to over irrigation, deep percolation of ponded water etc.

3. Deciding the minimum quantity of ground water extraction which would be necessary to stop a dangerous rise of ground water level which can lead to waterlogging and other problems.

4. Deciding the maximum permissible additional ground water use in the area in order to avoid unplanned mining of ground water which may lead to ecological problems such as drying of wells, impairing the health of deep rooted trees and reduction in low flows of rivers.

5. Deciding the planned quantity of ground water use within the two limits.

6. Deciding the quantum of ground water use available for irrigation conjunctively with surface water after considering the other (non-irrigation) uses of the planned ground water use.

Since the ground water use for irrigation would itself lead to further returning a part of this as field loss to ground water, this would also have to be considered.

2.2 Describing Ground Water Status and Ground Water Balance for the "Without Project" Conditions

The establishment of an accurate ground water balance is a specialized task conducted by geohydrologist in conjunction with surface water hydrologist and hydro-meteorologist etc. Planners of surface irrigation projects are not expected to prepare a final ground water balance without consulting the concerned scientific organisation dealing with ground water. However, using the norms prepared by Ground Water Estimation Committee (1984), a fairly good preliminary ground water balance can be established.

Ground water balance is a type of water balance. Water balance is a common concept in hydrological sciences which in fact is the statement of the principle of conservation of mass used in basic Physics. Considering water equivalent in the liquid state and water density as fairly constant, the mass balance can be expressed as a volume balance. Thus after defining the space boundaries under consideration, water balance for a time interval can be expressed as below :

Volume of water flowing into the space equals the volume of water flowing out of the space plus increase in storage of water in that space.

When establishing ground water balance, generally basin or sub-basin is considered as an area of study. The boundaries of the ground water basin, that is the ground water ridge, can at times be slightly different from the surface water ridge. Also at times, balance of a part of the basin or balance of an area not corresponding to the basin or catchment may have to be considered. For example, sometimes water balance may have to be established for command of a branch or distributory on a ridge. In such cases, the natural movement of ground water may itself constitute inflow or outflow in regard to the space under consideration. Usually inflows into the ground water would consist of the following :

(i) Deep percolation from natural rainfall

This could be as much as 15 to 20 % of the rainfall in alluvial areas and only upto 2 to 3 % for certain massive hard rock areas. The Ground Water Estimation Committee norms and experience based on field observations specific to the region, may allow a better decision in this regard.

(ii) Seepage from canals and tanks, and deep percolation from irrigated fields

Seepage from irrigation tanks is normally considered negligible after first few years of operation. Seepage from surface canals would depend on (a) status of the system whether lined or unlined, (b) order of the system, which reveals how large the distribution network is and how long the water has to travel on land surface before its use and (c) the type of soils. For unlined canal in a major project, seepage losses could be around 50 % of the deliveries at the head. For a medium project, the losses could be nearly 30 % and for minor projects including state tubewells irrigating areas of the order of 100 hectares, this loss could be around 20 %. The corresponding figures for fully lined system could be about half of the figures mentioned for the unlined canals. These are very general indication of seepage losses from canals and site specific information may allow better estimation. Sometimes estimates are based on the wetted perimeter of the canals. Results of experiments on canals at various places in India indicate that seepage loss in m^3/sec/million square metres of wetted perimeter ranges from 2.20 to 20.00 in unlined canals and 0.10 to 2.00 in case of lined canals. The range mentioned above for 'lined' canals is based on the newly lined works, therefore considering the deterioration through cracking etc., the losses under lined condition can perhaps be considered as 50 % of the unlined rates.

Field losses consist of seepage from field channels and deep percolation from the field. Field channels are normally unlined in the major part. Seepage from field channels can be considered as about 10 to 15 % of the deliveries at the chak. Deep percolation losses result from a tendency of applying slightly more irrigation than is actually required for wetting the root zone soil. Unexpected rainfall occurring after irrigation can also lead to higher percolation. For all dry crops it is customary to take deep percolation losses as about 10 to 15 % of the water supplied to the field. Where water management is poor and very heavy irrigation are given by the head reach farmers, deep percolation losses can be considered greater. For ponded crops, particularly paddy, deep percolation almost throughout the growth season is unavoidable. The percolation rate would depend on (a) type of soil, (b) whether sufficient time is elapsed after introducing irrigation to allow hard pan formation below the roots of the paddy and (c) whether crop rotations require the hard pan to be ploughed through for the next crop. The minimum customary rate for percolation through paddy is 3 mm per day but in light soils it would be around 6 mm per day. Much higher initial rates normally stabilize to a lower figure after hard pan formation and therefore need not be considered in a long term water balance.

(iii) Inflow from other areas

Inflow from other areas into the space under consideration through ground water movement is normally insignificant if the hydrologic unit like a basin, sub-basin or catchment is considered. Where the area under consideration is a 'doab', forming the command of a ridge branch, bounded by main canal at the upper boundary and two or three rivers/streams as other boundaries, ground water movement from adjoining areas becomes more important. However, if the ground water table is generally higher than the stream and the streams are effluent (i.e. receiving supplies from ground water), ground water movement across the streams can often be neglected.

Outflows from ground water normally consist of

(a) Base flows or return flows into the surface stream network,
(b) Direct evapotranspiration through capillary rise or from swampy low lying areas where ground water comes to surface,
(c) Evapotranspiration from deep rooted trees touching ground water.

Artificial withdrawal of ground water also constitutes an important withdrawal. While volumetric measurement of such withdrawals may be possible under a few cases of planned withdrawals for water supply etc., they are difficult to measure in case of numerous irrigation withdrawals. Approximate estimates can be made on the basis of number of water structures for each type (state tubewells, private tubewells, bore wells, open wells with pumps, open wells with persian wheels, other open wells etc.), norms of area irrigated per structure and delta used. Generally, in the northern alluvial tracts, deep state tubewells support an irrigated area of about 70 ha each and private shallow tubewells irrigate about 3 ha each. Bore wells in hard rock areas irrigate about 1 ha each. Open wells with pumps or persian wheels irrigate about 3 ha each. An annual delta of around 0.6 m is a reasonable assumption. More site specific information based on sample survey should however be used, whenever possible.

Out of the total canal losses, a small part may enter the rivers through surface drains, another small part may cause waterlogging along canals and a major part would however reach the ground water. Perhaps around 70 % of the canal losses can be taken as entering to the ground water. For direct evapotranspiration from ground water due to various causes, a fair estimate can be around 10 % of the total outflow. In arid or semi-arid areas where ground water is deep, this loss may be insignificant, whereas in wet and swampy areas it can be substantial.

2.3 Additional Ground Water Recharge in the "With Project" Conditions

While the "without project" water balance can be a preliminary one as described in the earlier section, the additional ground water recharge available in "with project" conditions has to be worked out relatively accurately. The various methods given in Section 2.2 aided with location specific information would allow such estimation.

2.3.1 Deciding the 'minimum necessary' and 'maximum permissible' extraction to avoid sustainability problems

In the "with project" conditions, inputs to the ground water balance of the command area could be substantially higher.

If the outputs could be held stationary, the resulting change in ground water storage would lead to increase in ground water levels. In practice, the increased water levels would lead to increased outflows in the form of greater base/return flows into the stream network and greater evapotranspiration through swampy lands etc. Thus a new ground water regime would be established. However, depending on the quantum of additional inflow, earlier regime status, soil moisture characteristics, specific yield etc. this new regime may involve unacceptably higher ground water levels leading to waterlogging, salinization etc. Thus in order to have a new regime within the acceptable range, artificial increase in the outflow through increased withdrawal would become necessary in many cases.

The quantity of the increased withdrawal is linked to

(i) the additional ground water recharge as added in the 'with project' conditions and

(ii) the trend shown by the previous ground water status.

The estimates of the 'minimum necessary' and the 'maximum permissible' additional withdrawals have been suggested by Central Water Commission in the "Draft Guidelines for Planning of Conjunctive Use in Irrigation Projects" (1993). The minimum necessary withdrawal is in order to avoid large imbalance leading to large rise in ground water. Small rise in ground water table leading to increased base flows in stream network may in many cases be very desirable. The maximum permissible withdrawals are intended for maintaining ecology and not allowing ground water to deplete unless such depletion is likely to be beneficial due to the very high ground water table or rising tendency even in the 'without project' conditions. The suggested guidelines are given in table 1.

Table 1 : Minimum Necessary and Maximum Permissible Additional Withdrawals in the 'With Project' Conditions

Present Ground Water Status		Minimum Necessary Additional Withdrawal as Percentage of the Additional Recharge caused by the Project	Maximum Permissible Additional Withdrawal as Percentage of the Additional Recharge caused by the Project
Depth of Ground Water	Trend		
< 2 m	Rising	70 %	100 %
	Steady	50 %	80 %
	Falling	30 %	60 %
2m to 6m	Rising	60 %	90 %
	Steady	40 %	70 %
	Falling	20 %	60 %
> 6 m	Rising	50 %	80 %
	Steady	30 %	60 %
	Falling	0 %	40 %

Note : For the purpose of this table, a general long term rise or fall of more than 0.2m/year in case of alluvial condition and more than 0.5m/year in case of hard rock areas would qualify for classifying the trend as 'rising' or 'falling'.

These general guidelines would require the command area to be divided into zones depending upon the present ground water status and to plan conjunctive use separately for these zones. If conditions over the command area are homogeneous, zones can be large whereas if the ground water status is too variable, zones can be small. In general, it is envisaged that the zone size may vary from a minimum of around 3000 ha to a maximum of around 30,000 ha for the purpose of planning conjunctive use.

2.3.2 Modifications of estimates for special areas

The general guidelines given above (table 1) would require modifications under certain conditions as follows :

(i) Coastal areas : For coastal areas say within 50 km of the sea, all values may be reduced by 20 % to avoid the possibility of saline ingress due to heavy conjunctive use.

(ii) Saline and shallow ground water : Where ground water is saline (conductivity > 4 m mhos/cm) and at shallow depth, say less than 6 metres deep (and particularly less than 3 metres deep), the area should normally be considered unfit for either surface irrigation or ground water use.

(iii) Saline, deep-seated ground water : Where ground water is saline but deep-seated (that is more than 6 metres deep), the area is problematic but irrigation alongwith conjunctive use of surface water and ground water can be planned after careful studies. The general strategy in such areas could be :

(a) Plan for reduction of additional recharge into the command area because any such additional recharge leading to increase in ground water levels may create irreversible sustainability problems. This can be done by lining the canals, not planning the paddy crop and applying irrigation in frequent short doses in order to avoid deep percolation.

(b) Conjunctive use may be planned to mop up the unavoidable additional deep percolation and canal losses. However, attempts should be made to mop up this deep percolation at comparatively shallow depths through shallow open wells, horizontal sub-surface drainage etc. before it reaches the main saline water table.

(c) While quantifying the minimum necessary and maximum permissible ground water use, the norms as stated earlier (table 1) may be increased by 20 % of the additional recharge.

(d) If conjunctive use involves pumping of saline ground water, this may have to be mixed with good quality fresh water so that the quantity of the irrigation water is acceptable.

(iv) Areas with soil salinity : Where ground water is deep-seated and not saline but the command area soils have salinity, the following precautions may be necessary in planning irrigation through conjunctive use :

(a) Leaching doses, which leach out the soil salinity to deeper layers, may have to be planned.

(b) Quantities of ground water withdrawal, both minimum necessary and maximum permissible, can be considered as lower than those indicated in the general guidelines.

(c) Where the problems are more serious, sub-surface drainage may have to be planned. Depending on the quality of effluent in the drainage system, it can either be directly used for irrigation or after mixing it with better quality surface water otherwise carted away as wastage elsewhere.

3.0 STUDY AREA

3.1 Bargi Multipurpose Project

Bargi Multipurpose Project on the Narmada river envisages construction of a major dam, power houses and canal systems on both banks. The main benefits from the Bargi Project are irrigation and power generation with a small portion of water being reserved for urban water supply and industrial uses. The dam site is situated around 43 km from Jabalpur (latitude $22^{o}56'30''$ N, longitude $79^{o}55'30''$ E). It has a catchment area of 14,556 sq km with a gross storage of 3294 Mm^3. The dam is of composite type with masonry central portion and earthen on either flank. The maximum height of dam above the deepest foundation level is 69.80 m. The full reservoir level is at RL 422.76 m (above mean sea level). The sill level of the Left Bank Canal (LBC) is RL 399.50 m and that of Right Bank Canal (RBC) is RL 405.98 m.

3.2 Bargi Left Bank Canal Project

The Left Bank Canal will be 137.2 km long. The design capacity of canal is 124.65 m^3/s. The total volume of water to be utilized annually for irrigation is 1740 Mm^3. The Left Bank Canal will irrigate 0.157 million ha area which comprises 62,000 ha in Jabalpur and 95,000 ha in Narsinghpur district. A special feature of Bargi LBC project is that it would irrigate around 55,000 ha area through Patan branch on the right bank. The Bargi LBC is proposed to irrigate parts of Bargi, Panagar, Patan and Shahpura blocks of Jabalpur district and Gotegaon, Narsinghpur, Kareli, Chawarpatha, Chichli and Sainkheda blocks of Narsinghpur district. The Left Bank Canal is already under construction since 1978 and expected to be completed fully lined by the year 2000.

Besides providing irrigation, the Bargi LBC also envisages generation of hydropower by installing 2 units of 7.5 MW capacity. In addition, it is proposed to supply annually 54 Mm^3 water to Jabalpur town for municipal uses from Patan branch canal and 47 Mm^3 of water for meeting municipal and industrial requirements in rural and urban areas from Bargi LBC system.

3.3 Location

Bargi dam across the Narmada river is located near Bijora village about 43 km from Jabalpur in Madhya Pradesh. The Bargi Left Bank Canal takes off from the left flank of Bargi dam and runs upto the Shakkar river covering a distance of 137.2 km. The command area under Bargi LBC lies in Jabalpur and Narsinghpur districts between the latitudes 22°52' N to 23°26' N and longitudes 78°45' E to 79°54' E. In the west, extent of the command is upto the confluence of Shakkar and Narmada rivers. In the north, Hiran river limits the boundary in Patan tehsil of Jabalpur district and Narmada river limits the boundary in Narsinghpur district. The proposed LBC forms the boundary in the south. The command extends upto Patan branch canal in the east. The command area of Bargi Left Bank Canal is shown in figure 1.

3.4 Canal System

The Bargi LBC takes off from the left flank of Bargi reservoir. The full supply level of LBC is 404.07 m and it is

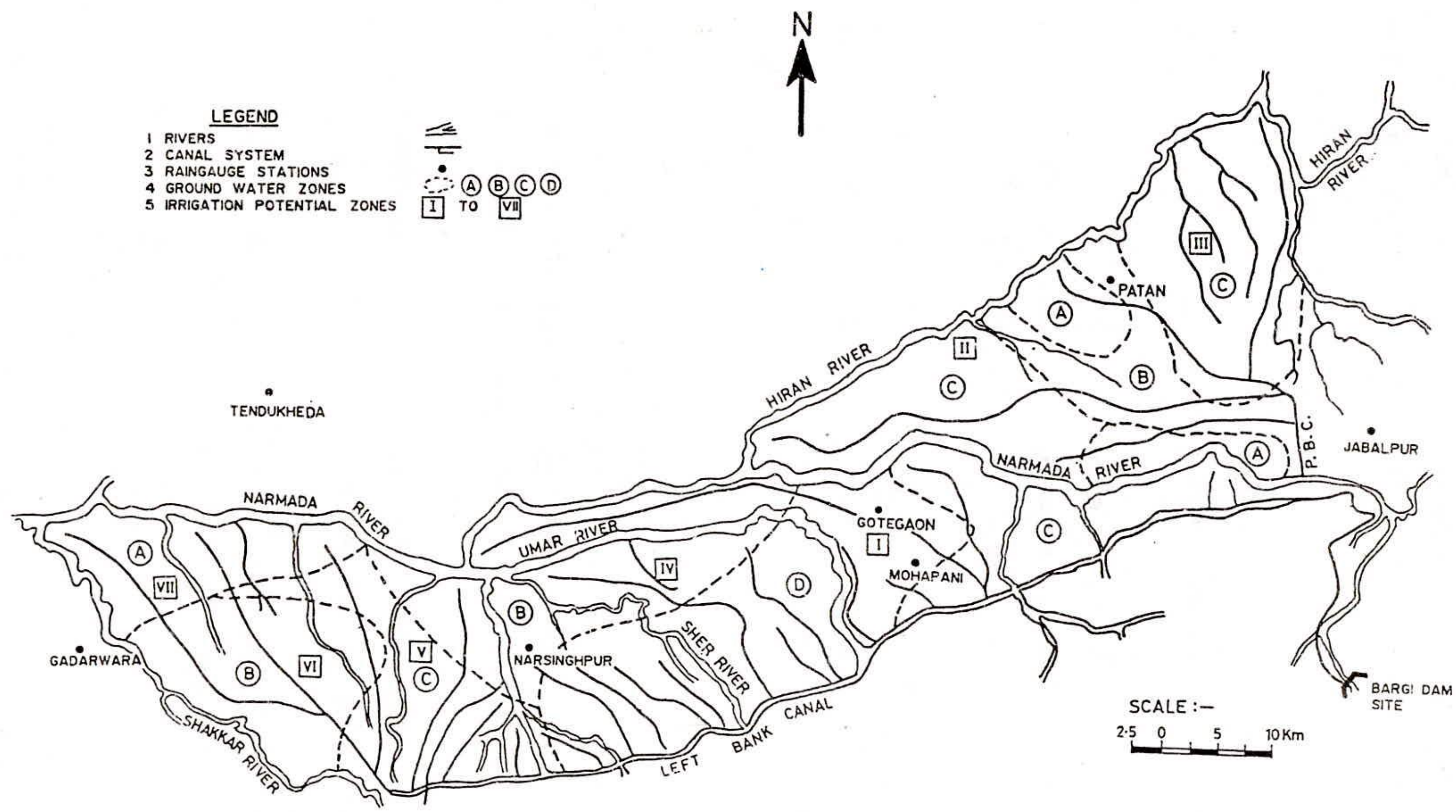

FIG. 1- INDEX MAP OF BARGI LEFT BANK CANAL COMMAND AREA

137.2 km long. There are 4 branch canals, 11 distributories, 16 minors and 4 sub-minors serving the complete command. The details are as follows :

Branch canals (discharge 5 to 50 cumecs) -

Patan, Hareri, Bhadgawan and Sadhumar

Distributories (discharge 1 to 5 cumecs) -

Kareli, Deori, Seoni, Matanpur-Barkheda, Andia, Kandeli, Surgi, Rehli, Renuka, Lalpur and (1 unnamed)

Minors (discharge 0.2 to 1.0 cumecs) -

Rosara, Dharwari, Gotegaon, Belkhedi, Niwari and (11 unnamed)

Sub-minors - 4 (unnamed)

Bargi LBC will irrigate 54,626 ha on the right bank of Narmada through Patan branch canal which takes off at RD 31 km of LBC. This branch canal crosses the Narmada river through an aqueduct to irrigate Bargi, Panagar, Patan and Shahpura blocks of Jabalpur district. The important distributories and minors of the Patan branch canal are as follows :

Distributories - Patan, Belkhedi and Shahpura

Minors - Bheraghat, Tewar and Nagna

3.5 Climate

The command area of Bargi Left Bank Canal is covered by tropical type of climate having considerable variations in rainfall, temperature and humidity. The changes in behaviour of climate are the direct results of changes in pressure and movement of air currents from the Indian Ocean across the Bay of Bengal and the Arabian Sea. The year has three distinct seasons - the wet season (mid-June to October), the winter season (November to February) and the hot season (March to mid-June).

3.5.1 Rainfall

The rainy season in the command area extends from mid-June to October under influence of the south-west monsoon. The command area also receives some rainfall during January and February from the north-east monsoon. July and August are the heaviest rainy months. Normally, the rainfall ceases by the end of September. However, sometimes October also receives a good rainfall. The rainfall data reveals that there is considerable variation in rainfall from year to year as well as month to month in a year.

Jabalpur and Patan are the only raingauge stations in the command area in Jabalpur district. In Narsinghpur district, the raingauges are located at Narsinghpur, Gotegaon and Mohapani. In addition, there are two raingauge stations namely Gadarwara and Tendu Kheda which lie outside the command area but very close to it. The locations of these raingauge stations are shown in figure 1. The average annual rainfall at Jabalpur raingauge station for the 31 year period (1948-78) is 1345 mm. The annual rainfall, however, varied from 888 mm to 2043 mm during the period. The average annual rainfall at Narsinghpur raingauge station for the same period is 1246 mm. The annual rainfall varied from 623 mm to 1993 mm. From the rainfall records, it is observed that Jabalpur raingauge receives about 92 percent of the annual rainfall in monsoon season whereas it is 95 percent for Narsinghpur raingauge. The mean annual and monsoon rainfalls in the command area are 1290 mm and 1200 mm respectively.

3.5.2 Temperature and Humidity

The command area lies in the hot region of the country. The temperature begins to rise rapidly from March till May which is generally the hottest month. With the onset of monsoon in the second week of June, there is appreciable drop in the day temperature. From mid-November onwards, both day and night temperatures decrease rapidly. December and January are the coldest months of year. The average annual temperature (1948-78) in the command area (Jabalpur site) is 25.7^{o}C. The mean maximum temperature ranges between 42.2^{o}C and 25.8^{o}C and the mean minimum between 26.7^{o}C and 9.2^{o}C.

As the command area lies in the hot zone, the variation in humidity is quite large. The mean monthly relative humidity varies between a maximum of about 87.8 percent in July/August and a minimum of 18.1 percent in February/March.

3.6 Topography and Soils

Bargi Left Bank Canal command area forms a part of Narmada alluvial valley. The alluvial soils cover almost the entire command area, deep and medium black clays are predominant. The general topography of the area appears to be flat except in the vicinity of rivers where deep gullies and ravines have been formed. The top soils have been washed away in the region and resulted in undulating and rolling topography. As such, the entire area is a broad plain of low relief and local difference in elevation is due to adoption of 'Haveli' system of cultivation which has checked the erosion.

The elevation above mean sea level of the command area varies from 365 m to 397 m in Jabalpur district and from 313 m to 380 m in Narsinghpur district. In the plain area, the slope ranges from 0 to 3 percent. The steeper slopes upto 15 percent are observed in the area where topography is undulating and rolling. The land slopes in the command area have been categorized into four classes by Madhya Pradesh Irrigation Department. The percentage of command area coming under each slope range is given below.

Land Slope	Percentage Area
0 - 1 %	55
1 - 2 %	20
2 - 3 %	15
3 % and above	10

The soils are deep, imperfectly to moderately drained, having self-mulching characteristics and high degree of swelling and shrinkage resulting in profound cracking during the dry spell. Sub-soil drainage may have to be provided in deep heavy soils having flat slopes and high ground water table. The surface texture in majority of flat areas vary from clay to clay loam with limited area under sandy loam. The surface texture in undulating areas is coarser with gravel and kankar due to exposure of sub-surface horizons by erosion. As per land irrigability classification, around 93 percent of the command area is considered suitable for irrigation.

Madhya Pradesh Irrigation Department has identified 7 zones considering soils and topographical situation within the Bargi Left Bank Canal command area for phase-wise irrigation development. These zones are depicted in figure 1.

3.7 Cropping Pattern

The cropping patterns in the command area (pre-Bargi situation) are Rabi oriented as around 50 and 55 percent of the cultivated areas are under Rabi crops and only 18 and 27 percent areas are under Kharif crops in Jabalpur and Narsinghpur districts respectively. This is probably due to high clay content of the soils and adoption of 'Haveli' system for Rabi crops. Because of the high percentage of clay, surface layers shrink and heavy cracks develop during the period April to June when the temperatures are high and solar radiation is maximum. During the rainy season, when the soils are wet, the fine textured part of clayey soils swells and becomes problematic for the cultivators in preparation of lands. Broadly speaking, 'Haveli' system is the storage of precipitation within the earthen bunds raised by farmers along the periphery of their holdings. The 'Haveli' system not only serves as a small storage reservoir for penetration of rain water in the soil but also checks the soil erosion during monsoonic torrential rainfall. The earthen bunds vary in height from 0.3 m to 1.0 m according to location of the field and topography of the area. The rain water soaked in the soil serves as a source of water supply for the Rabi crops. The late onset of monsoon or its early recession has very little adverse effect on the 'Haveli' system. Early recession of monsoon allows the farmers to sow oilseeds and gram whereas the late recession permits them to go in for wheat etc. but in any case one crop is assured in a year. The most important fact is that the soil fertility and top soil are preserved even during the torrential monsoonic rainfall.

The total area irrigated by all sources in the command (pre-Bargi situation) is 15,750 ha representing 10 percent of the net CCA of 1,57,000 ha. The gross cultivated area in the command is mostly rainfed as only around 6 and 9 percent of the cultivated areas in Jabalpur and Narsinghpur districts respectively are irrigated by tanks, tubewells, open wells and other sources. The command area lands have the potential and farmers have gained experience in irrigated agriculture in the problematic clayey soils. The assured irrigation supplies through canal network will increase the agricultural production, create job potential for the landless labourers and promote agricultural based cottage industries.

3.8 Present Status of Ground Water Development

At present, ground water is being utilized both for irrigation and drinking water. Irrigation by ground water resources is more than irrigation by surface water. Currently (pre-Bargi situation) 11,603 ha area is irrigated by ground water as against 4,147 ha by surface water. The annual drafts from ground water in the command area for irrigation and domestic uses are presented in table 2.

Table 2 : Annual Draft in the Command Area

S.No.	Type of Well	Number	Annual Draft per Well (ham)	Total Volume (ham)
1.	Domestic wells	-	-	294
2.	Irrigation wells with			
	(a) Pump sets	3137	1.2	3764
	(b) Rahats	337	0.5	168
3.	Shallow tubewells	494	10.0	4940
4.	Deep tubewells	22	30.0	660
			Total	9826

4.0 ASSESSMENT OF GROUND WATER AVAILABILITY

4.1 Hydrogeology

The command area of Bargi Left Bank Canal covers a geographical area of 2.60 lakh hectares and culturable area of 1.99 lakh hectares. The area on southern parts of Narmada river falls mostly in the sub-basins of Piria, Sher and Saner rivers which are tributories of Narmada. The thickness of the alluvium in these sub-basins ranges from 14 m to 49 m at the southern fringes and shows a progressive increase towards the north-central parts attaining thickness of 104 m to 176 m. Further north, it decreases to the range 62 m to 81 m near Narmada river. The alluvium overlies the Gondwana formations in the southern part and the Pre-Cambrians towards Narmada. The LBC command on the northern part of Narmada river falls under Hiran sub-basin. The average thickness of alluvium in this sub-basin ranges from 75 m to 100 m. The basement generally comprises of Pre-Cambrian and Cambrian rocks.

Most of the area in Bargi Left Bank Canal command is covered by alluvium of Quaternary age. A few exposures of Metamorphics, Gondwanas and Deccan traps are seen in southern and south-eastern parts. The general flow of ground water in phreatic zone is towards the Narmada river and its tributory Hiran.

Exploratory drilling in the area between 1971 and 1978 revealed occurrence of good aquifers. In the Piria, Sher and Saner sub-basins, the alluvial aquifers can be broadly grouped into a single major aquifer system comprising generally 3 to 4 granular zones separated by clay lenses. The topmost zone is generally under phreatic conditions varying in thickness from 3 m to 5 m within a depth range of 4 m to 40 m below ground level and generally tapped by dug wells. The deeper aquifers are under locally confined conditions and merge towards the recharge area in the south. The principal confined aquifer, composed of sand and gravels, occurs within a depth range of 15 m to 90 m below ground level. It is tapped by both shallow and deep tubewells. The underlying Gondwana aquifers occur within a depth range of 50 m to 120 m below ground level and have ground water under confined conditions. Generally, the Gondwana aquifers are poor as compared to the alluvial aquifers. In the Hiran sub-basin, there is only one confined aquifer in addition to the phreatic aquifer. The phreatic aquifer mostly consists of fine sand mixed with clay, silt and kankar occurring within a depth range of 16 m to 27 m below ground level with thickness varying from 5 m to 23 m. It is tapped by dug wells which yield from 19 m^3/hr to 76 m^3/hr. The confined aquifer tapped by tubewells commences at depth between 20 m and 50 m below ground level with its thickness ranging from 9 m to 57 m. It comprises of mostly sand, gravel and kankar intercalated occasionally with silt and clay lenses.

The Central Ground Water Board has divided the command area into four ground water zones, as shown in figure 1. The area under each zone, average well discharge and its suitability for ground water development are shown in table 3.

In general, the area all along the Left Bank Canal is poor in its ground water resources with yield ranging from 4 m^3/hr to 13 m^3/hr for 6 m drawdown. In the central and northern parts of the command area, good aquifers occur with a few pockets adjacent to Narmada and Hiran rivers recording yield upto 360 m^3/hr at 6 m drawdown. The transmissivity of aquifers averages about 70 m^2/day in the southern fringes and ranges upto 1200 m^2/day in pockets adjacent to Narmada and Hiran rivers.

Table 3 : Ground Water Zones in the Command Area

Ground Water Zone	Area (ha)	Average Discharge with 6 m Drawdown (m^3/hr)	Remarks
A	27,000	more than 150	Very promising for ground water development
B	72,000	75 to 150	Very promising for ground water development
C	107,000	less than 75	Suitable in patches only
D	54,000	-	Not suitable

4.2 Ground Water Levels and Fluctuations

There are nearly 40 permanent observation wells in and around the command area where the water level fluctuations are recorded by the State Ground Water Organisation. The average depth to water table below ground surface at the beginning of monsoon season varies from 2 m to 22 m. In the rainy season, the water table rises appreciably and remains between 1 m and 20 m below the ground surface. The average water level fluctuation between pre-monsoon and post-monsoon season ranges from 1 m to 6.4 m.

In general, the water table is deep adjacent to Narmada and Hiran rivers. Pockets of shallow water table are generally concentrated along the Left Bank Canal. The depth to water table during August in some pockets adjacent to Left Bank Canal and Patan block of Jabalpur is recorded less than 1 m below ground surface and remains less than 5 m upto the month of January. In other parts, due to excessive use of ground water, a general declining trend is observed. In some wells in Narsinghpur district, decline of 1 m to 4 m has been observed between 1985 and 1993. In areas where water table occurs upto 2 m below the ground surface, waterlogging status may get worsened after the introduction of extensive irrigation.

4.3 Ground Water Recharge : Pre-Bargi LBC Situation

The ground water currently available (pre-Bargi LBC situation) is due to percolation of rain water. There is very little irrigation and recharge due to seepage of irrigation water may be neglected for the assessment of ground water availability before large scale irrigation is introduced through Bargi LBC system.

The Ground Water Estimation Committee (set up by Ministry of Irrigation) in its report of March 1984, gave recommendations for ground water estimation methodology. According to these recommendations, the ground water recharge should be estimated by ground water level fluctuation and specific yield approach in preference to rainfall infiltration method. The recommended value of specific yield for silty/clayey alluvial area (Bargi LBC command belongs to this type of soil) ranges between 5 and 12 percent. Madhya Pradesh Irrigation Department has adopted the specific yield values of 5 percent for irrigation zones II and III, 8 percent for zones I, IV and V and 10 percent for zones VI and VII. These values tally with the recommendations (5 to 12 percent) of Ground Water Estimation Committee for the type of soil in Bargi LBC command. The specific yield values as recommended by Madhya Pradesh Irrigation Department were adopted for the assessment of annual ground water recharge by water table fluctuation method, as shown in table 4. The net annual utilizable recharge is taken as 70 percent of the gross recharge.

Table 4 : Annual Ground Water Recharge in the Command Area

Irrigation Zone	Annual Water Table Fluctu- ation (m)	Gross Area (ha)	Specific Yield (%)	Gross Annual Recharge (Mm^3)	Net Annual Recharge (Mm^3) (70 % of gross)
I	2.1	47,000	8	78.96	55.27
II	2.6	46,000	5	59.80	41.86
III	3.3	43,000	5	70.95	49.66
IV	2.8	52,000	8	116.48	81.54
V	2.6	33,000	8	68.64	48.05
VI	2.5	29,000	10	72.50	50.75
VII	2.0	10,000	10	20.00	14.00
Total		260,000		487.33	341.13

The net annual utilizable ground water recharge may be taken as 341.13 Mm^3 which is considered to be contributed by rainfall.

4.4 Concluding Remarks

The development of ground water resources in the central and northern parts of Bargi LBC command (where already good aquifers exist) would result not only in proper utilization of available water resources but also the pumpage from ground water storage will provide a sub-surface drainage to the areas which are likely to be waterlogged. The large scale ground water development in the area adjacent to Narmada river would steepen the sub-surface gradient of ground water flow and prevent any waterlogging in the southern areas where surface water irrigation is being done from the main Left Bank Canal. Thus, conjunctive use of surface water and ground water would help irrigation in large areas without any adverse effect of the uncontrolled surface water irrigation.

5.0 CONCLUSION

The Bargi Left Bank Canal command is wholly located in the Narmada upland alluvial plains and requires special attention to study the impact of surface water development on the existing ground water regime. A rational approach is imperative to develop the water resources of the Bargi Left Bank Canal command area in such a manner that the adverse effects of uncontrolled surface water irrigation can be avoided. Proper conjunctive use of surface water and ground water is necessary to efficiently utilize the water resources without endangering the command area with waterlogging and salinity problems in future.

The availability of ground water in the Bargi Left Bank Canal (LBC) command area has been presented. Annual ground water recharge for pre-Bargi LBC situation i.e. before introduction of extensive irrigation in the canal command area has been estimated as 487.33 Mm^3.

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