Ground Water Depletion in the Agricultural Plain between Two Major Rivers in North India

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Abstract

Water is the key to sustainable development and survival of life. The indiscriminate development of surface water of North India's two major rivers- Ganga and Yamuna in Uttar Pradesh (U.P.) has led to ecological and environmental imbalance. The river Ganga, in spite of being fully harnessed through upper, middle and lower Ganga systems, does not fulfill the irrigation needs in tail end regions. Similarly the Yamuna canal system developed in U.P. does not meet the requirement in middle and lower portions. Ground water, which plays an important role in fulfilling the need of water, has been indiscriminately utilised with the advent of green revolution creating adverse impacts. The adverse impacts of mismanaged water resources system are basically on the entire hydrological regime, which has got direct bearing on economics. Also the farmers rely on ground water to meet the irrigation needs. Excessive withdrawal occurs where surface network does not exist. General lowering of water table is observed.

In the present paper the status of water resources development, needs and possible solutions have been studied in lower parts of Ganga-Yamuna Plans falling in lower Ganga canal command. The prevailing hydrogeological conditions and integrated development of water resources have been evaluated.

Key Words

Regional scale ground water depletion, impact of irrigation, imbalanced water resource development, agricultural water mismanagement, Ganga-Yamuna river plains.

1.0 Introduction

Water is vital for sustenance of life. River systems are interwoven with human civilization and river banks have been considered to be the cradle of major civilizations in the world (Khoshoo 1991). With increasing development in various spheres, the need for water grew tremendously. In India where rain water is abundantly available only during three months, a sustainable and economical source for the common man is ground water followed by surface water. The utilization of ground and surface water resources through canals or wells has been common since the Roman period. Agarwal and Narain (1997) have illustrated that rainwater harvesting in water deficit areas of India was well known fact such as the *Tankas* (Tanks) of Rajasthan and artificial recharge to ground water and soil conservation through *Ahar-Pyne* (catchment area) in Bihar during recent past. Energy generation using water was practiced through water mills in many remote parts of country. In a

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nutshell, the common man was well acquainted with the utility and importance of water and had been trying to make best use of it as per his ability.

Since Independence a large irrigation potential has been created in India taking it from 226 000 km^2 in 1951 to 918 000 km^2 in 1996-97 while percentage utilisation of aggregate potential created at the end of 1997 has been 90% (Prasad 2000B). Much of the additional irrigation area comes under ground water and this source is being increasingly exploited in an unsustainable manner. The utilisation potential from major and medium projects together and minor irrigation schemes (towards utilisation) is 35% and 65% respectively at the end of 8th five year Plan (Prasad 2000B). Major irrigation projects are running into serious environmental and social problems. (Swaminathan 2000) The over all impact on environment was a mix of positive and negative. The positive impact was improvement of agrarian economy (Prasad 2000) while the negative impact observed was water logging, soil salanisation (Chitale 2000, Prasad 2000, Prasad and Goel 2000A) and depletion of ground water storage. The positive impact were felt immediately while the negative impacts emerged later.

1.1 Study Area Description

Doab is the name given to the region of fertile plains falling between the two rivers namely Ganga and Yamuna in Uttar Pradesh and Uttaranchal and spreads over 16 districts (Fig 1) encompassing an area of around 65 000 km^2. Doab region has got rich and fertile soil. Based on studies of Central Pollution Control Board (CPCB 2000), it falls in four different agro climatic zones. The northern portions of Doab upto Bulandshahar comes under 'Western Plain'. The middle portion covering Aligarh, Etah, Mathura, Agra, Firozabad and Mainpuri falls under 'South Western Semi Dry Plain'. Further down upto end of Fatehpur district, the region comes under 'Mid Western Plain'. A small portion in south eastern portion falling in Kaushambi district comes under 'Eastern Plain'. As per Department of Agriculture (DOA 2001), the gross cultivated area in Doab region has an agricultural statistic of 71 620 km^2. The average cropping intensity is 155.8%. The Gross irrigated area through different sources is 57 100 km^2. The irrigation intensity is 79.7%. The ground water has got much larger share (73.6%) (SPO 2001) in providing assured irrigation in spite of development of Ganga canal network as well as Yamuna canal sytem. Poor drainage soil salanisation and non availability of sustainable and assured irrigation water are the major constraints in the area.

1.2 Climate and Rainfall in Study Area

The area experiences variable climate from North to South. The northern portion of the area experiences tropical and sub humid climate. The southern parts have semi arid condition. The mean annual rainfall varies between 600 – 1000 mm (IMD 1999). Large parts of north western districts of the Doab have got mean annual rainfall less than 800 mm. Rainfall in the region all along right bank of the river Ganga and in south eastern portion of the Doab is above 800 mm annually. Nearly 85% of the annual rainfall occurs through south western monsoonic wind during the period late June to mid October every year.

1.3 Geology of Study Area

The generalized geological sequence of formations present in the Doab region is as under :

GENERAL STRATIGRAPHIC SUCCESSION

Time Unit	Rock Units	Time-Rock Unit
Recent Holocene	Sand-Clay Sand-Clay-Pebbles	Quaternary Alluvium
-------------------------------	Discontinuity	-------------------------------
Pleistocene to Lower Miocene	Argillaceous sediment	Middle to lower Siwalik
------------------------------------	Unconfirmity	------------------------------
Precambrian	Sandstone/shale/Limestone	Vindhyan
Archaen	Granite	Bundelkhand Granite

1.4 Hydrogeology of Study Area

The entire Doab region is underlain by thick fluvial sediments brought down by Ganga river sediments and overlies Precambrain formation. These fluvial sediments are of variegated nature from north to south and generally comprise sands of different grade, silts and clays. The presence of Kankar pan is common in central portions of the Doab region. The thickness of alluvial sediments gradually decreases southward and exposure of Aravali group of rocks and Vidhyan formations are observed in central portions of Doab region. Along the river Yamuna nature of fluvial sediment varies greatly than those present in northern portions, due to change in provinence of deposits. The drainage originating from southern plateau region brings a different type of fluvial sediment than the one coming from the Himalayan region in the North. Consequently the sedimentation pattern and its nature change in the southern parts of Doab, specially in near vicinity of Yamuna river.

The study of bore holes data of Central Ground Water Board (CGWB 1999, CGWB 2000) at Allahabad (CGWB 1999, pp 7) indicate presence of two aquifer groups down to a depth of 200 m below ground. The first unconfined aquifer lies at a depth between 20-90 m below ground and the second lies between 110 to 140 m below ground.

Proceeding to north western direction, at Kanpur (CGWB 1999, pp 85), the formation become finer and more silty in nature. The prominent aquifer lies at a depth between 175 to 250 m below ground and the ground water occurs in confined state in this aquifer. The shallow aquifer down upto 175 m depth from ground does not show great potential and generally contains brakish water. The phreaetic aquifer down to 60 m depth contains fresh ground water and is silty in nature. The alluvial sediments over lie Vidhyan limestone at Allahabad and Bundelkhand granites at Kanpur.

Further north west ward in Mathura district (CGWB 1999, pp 100) presence of three aquifers have been observed. The top unconfined aquifer lies between 30-80 m depth, second between 135 to 180 m below ground and third below the depth of 200 m from the ground. The aquifers are discontinuous, pinching out at short distance. The deeper aquifers in Mathura district contain brakish to saline water.

Further northwards in Bulandshahar district (CGWB 1999, pp 45) three aquifer groups have been observed. The first aquifer lies within 80 m depth from the ground, the second between 120-150 m depth below ground and the third between 200 to 300 m depth. Further north in Meerut (CGWB 1999, pp 105) several aquifers are present down to explored depth of 740 m below the ground. The first aquifer lies between 30 to 80 m depth, the second between 130-180 m depth, the third between 200 to 300 m depth, and the fourth group occurs below 350 m depth.

In short it appears that the Doab region represents two different hydrological regimes separated by sub surface ridge in central parts. The thickness of fluvial sediment in northern block is above 700 m while it gradually decreases in south eastern direction. Further it was observed that the quality of ground water present in aquifer between the depths of 125-175 m below ground is invariabley brakish in southern portions of the Doab region.

2.0 Objective of the Study

In an agriculture based economy such as that of India, water becomes the key environmental parameter for economic growth. Intensive development of surface water canals in fertile plains of Ganga-Yamuna have taken place during the last few decades. One of the aims of the surface water irrigation schemes is to augment the water table. A case study of the fertile plains of Ganga-Yamuna Doab has been taken up to evaluate the changes in the status of ground water over a period of one and a half decade and the impact of surface water irrigation schemes. The exercise is all the more important as no environmental impact assessment (EIA) study was undertaken prior to execution of irrigation projects in the study area.

3.0 Methodology

To decipher the sub surface condition and configuration of aquifer, the borehole data available for the area with various agencies and reports of Central Ground Water Board (CGWB), Ministry of Water Resources have been referred. The long term water level data have been analyzed to evaluate mean depth of water table over the period 1985-2002. This has been done based on CGWB's Ground water Yearbooks from 1985-86 to 2001-2002. The water level measurements were done during the months of January, May, August and November every year at 454 observation wells in the 16 districts under analysis by Central Ground Water Board officials. Based on the collected data, water level trend for pre monsoon and post monsoon season have been analyzed using statistical tools. The status of ground water resources and utilization in the study area have been sourced from CGWB reports. The agricultural statistical records of the State were referred to find out the status of cultivation and irrigation. The logistic conclusions were drawn from the factual conditions prevailing. Over the 17 years study period, the administrative areas of some of the districts have been divided into two districts and some have been renamed. However, for the purpose of this study, the administrative boundaries of 1985 have been followed with single nomenclature.

4.0 Result

4.1 Water Level

The water table slopes south easterly with an average gradient of 25 cm km^{-1} (Fig 1). Mean water table depth over the Doab region varies greatly. Using long term water levels mean depth to water table for four seasons of the year has been worked out based on CGWB's Ground Water Yearbooks of Uttar Pradesh from 1985-86 to 2001-02 for the districts falling in Doab region and are given in Table 1.

The average annual depth to water table is 7.77 m below ground having deepest level in Agra district and shallowest in Mainpuri. The average pre monsoon level (May) is 8.62 m and post monsoon level (November) 7.42 m. The deepest level is found in Agra and shallowest in Mainpuri during both the seasons. The mean annual fluctuation of water table is 1.20 m for the Doab region.

The mean seasonal fluctuation of water table ranges between 0.23 m (Agra) to 2.08 m (Kaushambi). The level of fluctuation appears to be high in central parts of the Doab. The water level trend analysis of long term water level data shows that the water table is declining fast (Table 2).

The review of table 2 indicates predominance of decline in pre monsoon water table at the rate of 2.6 cm/year excluding Aligarh, Bulandshahar, Dehradun and Ghaziabad districts which falls in upper reaches of Doab and are being irrigated through upper Ganga & Yamuna canal system. The water level trend in Kaushambhi district shows a rising trend. The district comes under lower Ganga canal command.

4.2 Ground Water Resources Utilisation

The estimated annual replenishable ground water resources of the Doab region is 20 008 million m^3 and the present annual utilization is 11 531 million m^3 (CGWB 2000A). The district wise break up is given in Table 3.

The review of ground water resource utilization figures indicate that though average level of ground water development is 59.23% over the Doab, but it varies between 32.78 to 85.06%. In general the level of ground water use is around 60% over larger parts with exception in Agra, Aligarh, Etah, Farukhabad and Mainpuri districts where it is in the vicinity of 70%.

4.3 Status of irrigation

There are three seasonal crops grown in the Doab zone. The season wise status of cultivation and irrigation is given in Table 4.

The above table indicates rainfed cultivation during Kharif season to certain extent and further scope of enhancing the irrigation facility. If we take the lower Ganga canal command spread over 8 districts in the lower reaches of Doab (Mainpuri, Etah, Farukhabad, Etawah, Kanpur Dehat and Kanpur Nagar, Fatehpur and Kaushambi) the status of irrigation is given in Table 5.

It is evident that lower parts of Doab has got very poor irrigation facility compared to the average of the entire Doab (Table 5 vs. Table 4). The break up of irrigation source (DOA, 2001) indicates that 65.89% of gross irrigation is through ground water and remaining through lower Ganga canal network. This implies that improvement in or additional irrigation facilities are required, in this part of Doab to meet the irrigation demand.

5.0 Conclusion and Discussion

The need of the day is integrated development incorporating conjunctive use of various water resources simultaneously coupled with conservation and management (Prasad and Goel 2000A, Sharma 2000). Optimal use of water resources safeguarding against indiscriminate exploitation causing adverse impact on environment has to be assured. Depending upon sustainable availability of all water resources, cropping pattern needs to be decided and suitable irrigation method to be devised.

It is evident from the aforesaid data that ground water plays a primary role in providing assured irrigation in the Doab region, in spite of dense network of surface irrigation system. The average irrigation efficiency of surface irrigation system is 57% on account of non availability of sufficient water in tail end reaches. Consequently the farmers rely on ground water. As the entire Doab region has rich fertile soil and the economy is basically agriculture base, hence, to meet the irrigation needs excessive withdrawal of ground water takes place. **The water level trend clearly indicates a general lowering of water table, indicating thereby heavy stress on ground water storage.**

The poor performance of surface irrigation system appears to be a serious matter. The management of water resources is not upto the mark as the ground water development is quite low in certain districts such as Etawah, Dehradun and Kaushambi which may possibly be due to sufficient availability of surface water. Unequitable distribution of water is the root cause for environmental disturbances. There is no large deviation in agricultural practices, cropping pattern and soil character. It is the ease with which the farmer gets water that controls the water use. Induction of people's participation may yield better results. But the foremost need is to carry out an in-depth EIA study before implementing any further surface water development schemes which are State controlled. A precise evaluation of water need, availability (all sources) is required to be worked out before planning to develop any of the water resources.

From the foregoing study following is evident:

1. Surface irrigation network is not efficient enough.
2. Heavy withdrawal of ground water has lead to depletion of storage.
3. Excessive surface water application has created rise of water table in pocket causing soil salinity

Possibly these problems could have been tackled had an EIA study been made prior to implementing surface irrigation scheme which could have been suitably modified to yield better result on the basis of this study. However, it is not too late. Management measures that are successfully being followed and implemented in other parts of the country can be replicated in this region and should be urgently implemented. They are as follows:

- To harvest and conserve rain water by reviving traditional water harvesting structures as done in South India for Tanks (Agarwal and Narain, 1997) and construct new water harvesting structures in both rural (check dams, sub surface dykes, recharge through abandoned well, infiltration basins (Bouwer 1989)) and urban areas (recharge basins, parks and playgrounds, infiltration trench and porous pavement (Karanth 1987)).
- promote conjunctive use of water sources such as river, rain, ground water in appropriate combinations (Sharma, 2000; Karanth, 1987)
- Prevent unsustainable exploitation of aquifers. The Government of India took a revolutionary step in forcing this issue in New Delhi by banning any access to ground water unless specific permission is sought for the same with effect from August 2000
- Ensure efficiency, economy and equity in water use through cooperative management of watersheds and command areas. Prasad 2000B has highlighted the success of watershed management in parts of Haryana, Punjab and Uttar Pradesh and on western Yamuna Canal system.
- Introduce proactive measures to avoid water conflicts (Swaminathan, 2000)

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TABLE 1

DISTRICT WISE MEAN WATER LEVELS (1985 TO 2002) (IN METRES)

District	January	May	August	November	Average	Seasonal Fluctuation
1. Agra	13.17	13.63	13.27	13.40	13.37	0.23
2. Aligarh	7.15	7.90	6.88	6.91	7.21	0.99
3. Bulandshahar	7.80	8.37	7.47	7.54	7.80	0.83
4. Dehradun	9.13	12.31	5.70	7.96	8.78	4.35
5. Etah	5.52	6.28	5.20	5.33	5.58	0.95
6. Etawah	8.06	9.39	8.24	7.90	8.40	1.49
7. Farukhabad	8.56	9.55	8.51	8.13	8.69	1.42
8. Fatehpur	8.28	9.76	7.90	8.05	8.50	1.71
9. Ghaziabad	7.21	7.96	6.76	6.80	7.18	1.16
10. Kanpur Nagar & Kanpur Dehat	7.77	9.21	7.56	7.31	7.96	1.90
11. Kaushambi	7.78	9.16	6.92	7.08	7.74	2.08
12. Mainpuri	4.02	4.96	3.56	3.72	4.06	1.24
13. Mathura	7.01	7.75	6.81	6.87	7.11	0.88
14. Meerut	8.07	8.98	7.93	8.34	8.33	0.54
15. Muzaffar Nagar	6.22	6.81	5.90	6.09	6.25	0.72
16. Saharanpur & Haridwar	7.72	8.70	7.09	7.24	7.69	1.46
Average	**7.67**	**8.62**	**7.37**	**7.42**	**7.77**	**1.20**

TABLE 2

DISTRICT WISE TREND OF GROUND WATER LEVEL (M YEAR^{-1})

PERIOD : 01-JAN-85 TO 31-DEC-02

District	Premonsoon	Postmonsoon
1. Agra	-0.129	-0.161
2. Aligarh	0.000	0.017
3. Bulandshahar	0.141	0.170
4. Dehradun	0.161	-0.092
5. Etah	-0.056	-0.093
6. Etawah	-0.062	-0.061
7. Farukhabad	-0.195	-0.211
8. Fatehpur	-0.066	-0.033
9. Ghaziabad	0.062	0.003
10. Kanpur Nagar & Kanpur Dehat	-0.130	-0.067
11. Kaushambhi	+0.055	+0.156
12. Mainpuri	-0.032	-0.069
13. Mathura	-0.017	-0.127
14. Meerut	-0.074	-0.004
15. Muzaffar nagar	-0.056	-0.032
16. Saharanpur & Haridwar	-0.014	0.035
AVERAGE	**-0.026**	**-0.035**

TABLE 3
DISTRICTWISE GROUND WATER RESOURCE POTENTIAL OF GANGA YAMUNA DOAB UTTAR PRADESH AS ON 01/04/2004

District	Ground water Availability ('000 m^3)	Ground water draft (all) ('000 m^3)	Level of development (%)
1. Agra	1830323.7	1323512.1	72.31
2. Aligarh	1705992.6	1237137.0	72.52
3. Bulandshahar	1596083.9	1025229.8	64.23
4. Dehradun	422161.1	36872.4	8.73
5. Etah	1327618.2	1013445.2	76.34
6. Etawah	1520252.2	538618.6	35.43
7. Farukhabad	770537.5	530205.6	68.81
8. Fatehpur	1556059.2	642406.4	41.28
9. Ghaziabad	946116.8	531780.9	56.21
10. Kanpur Nagar & Kanpur Dehat	3593600.6	1988434.0	55.33
11. Kaushambi	602863.7	200281.2	33.22
12. Mainpuri	981396.4	662016.6	67.46
13. Mathura	990413.0	622588.6	62.86
14. Meerut	1876870.7	1144552.5	60.98
15. Muzaffar Nagar	1917638.1	1162453.4	60.62
16. Saharanpur & Haridwar	2345269.0	1032367.7	44.02
Total/ average	**23983196.7**	**13691902.0**	**55.02**

TABLE 4
STATUS OF IRRIGATION IN GANGA-YAMUNA DOAB (U.P.)

Season	Period (Lokeshwar 1997)	Cultivated Area ('000 km^2)	Irrigated Area ('000 km^2)	Irrigation Intensity (%) (SPO, 2001)
Rabi (winter)	Oct-March	36.5	33.4	91.5
Kharif (monsoon)	July-Oct	31.8	20.5	64.4
Zaid (Summer)	March-June	3.3	3.2	96.9
Total		**71.6**	**57.1**	**79.7**

TABLE 5
STATUS OF IRRIGATION IN LOWER GANGA CANAL COMMAND

Season	Period (Lokeshwar 1997)	Cultivated Area ('000 km^2)	Irrigated Area ('000 km^2)	Irrigation Intensity (%) (NWDA, 1994)
Rabi (winter)	Oct-March	25.97	13.63	52.48
Kharif (monsoon)	July-Oct	13.63	5.19	38.08
Zaid (Summer)	March-June	0.65	0.65	100.00
Total		**40.25**	**19.47**	**48.37**

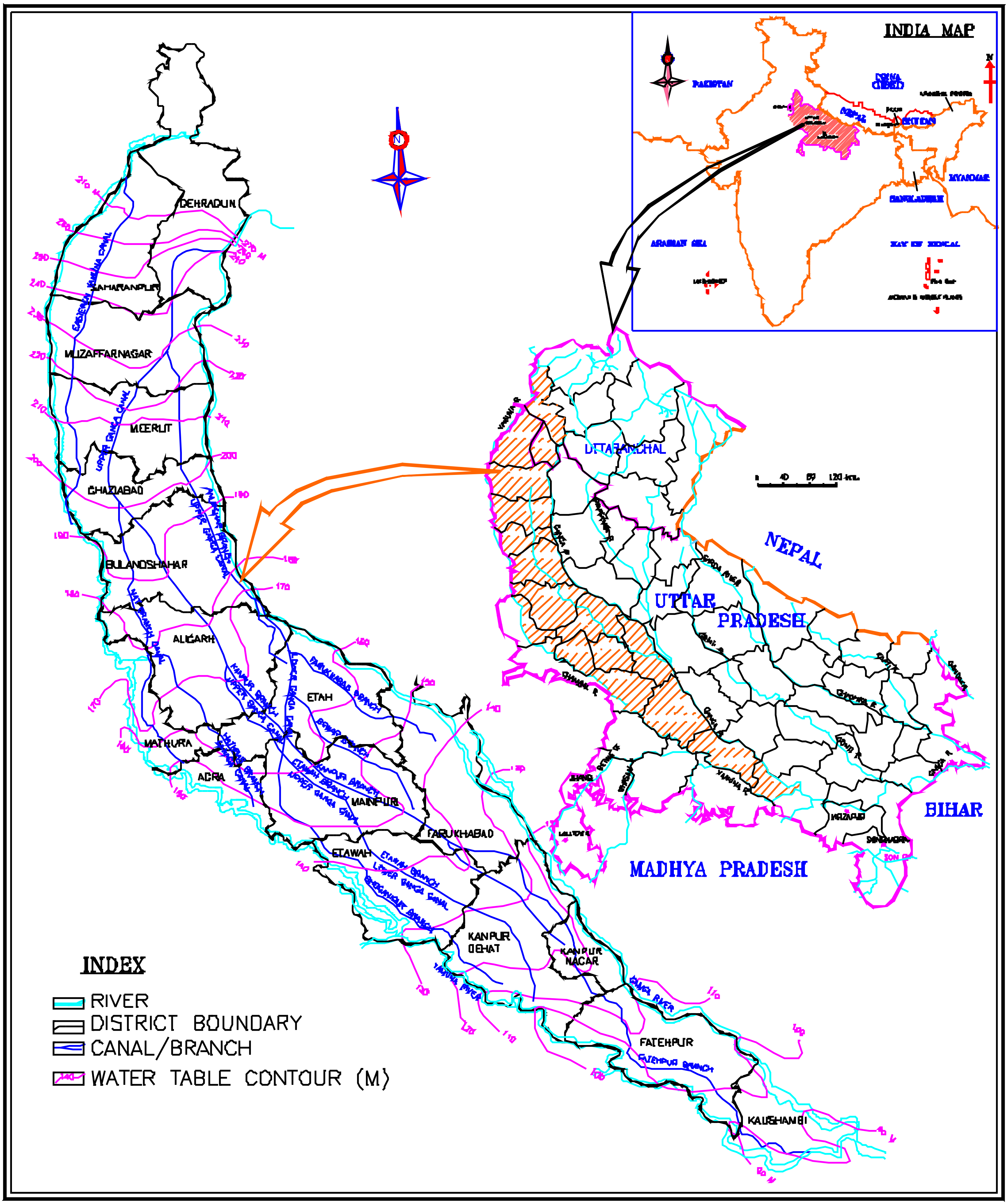

Fig.1. MAP SHOWING GANGA-YAMUNA DOAB (U.P.)
Source: Fig.-9, State Report on Hydrogeology & Ground water Resource, U.P. (CGWB 2000), pp 66-67