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SPATIO-TEMPORAL ANALYSIS OF GDROUNDWATER BALANCE IN EASTERN HARYANA

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ABSTRACT - The paper embodies a study of spatio-temporal analysis of groundwater balance in eastern Haryana. At present, 80 per cent of available fresh groundwater is being exploited through more than 5 lakh tubewells. Considering high intensity of groundwater utilization, which is one of the prominent factors leading to groundwater depletion, groundwater balance study is made to estimate available groundwater for future. For this purpose, inflow and outflow of groundwater in the form of recharge and discharge are estimated. Accordingly, it is derived from the study that osverdevelopment of groundwater has taken place in many parts of the study area. Therefore, it is suggested that overdevelopment of groundwater resources must be recognized as a major environmental crisis in the study area.

Groundwater is gaining importance as a source to meet the needs of our ever-increasing population for drinking as well as industry and irrigation. The contribution of groundwater to irrigated agriculture in India is about 50 per cent (Prasad, 1995). Since groundwater structures are generally owned by the cultivators themselves, with the control of water being in their hands, the cultivators have all the incentives to make the investment required for productive agriculture. Groundwater exploitation generally needs smaller capital than that needed for surface water. Groundwater may, thus, rightly be said to be providing the basic infrastructure on which edifice of modern agriculture is being built in India.

Though the groundwater development has taken place all over the country, the maximum development has taken place in the Indo-Gangetic Plain especially in Punjab, Haryana, Gujarat and Uttar Pradesh. However, in areas where the surface water is only available for protective irrigation and the larger part of irrigation is being sustained by the groundwater from tubewells, water has registered continuous lowering resulting in overdevelopment of groundwater (Pant,1987, Singh, 1992, Josi and Tyagi, 1991, Pathak, 1990 and Dhawan, 1995). The resource is deemed to be in a state of overdevelopment when the withdrawal for irrigation and non-irrigation purposes tend to exceed the annual recharge. In case, an imbalance arises, the depth of water table, a critical parameter both in economics of groundwater irrigation as well as groundwater hydrology, is affected. Such a situation of overexploitation is well known in the eastern part of Haryana State. Thus, the main objective in the present study is to find the impact of input and output sources of groundwater balance which affect the groundwater in a specific time and a regional framework. Accordingly, groundwater balance study is made to estimate available groundwater for future development.

STUDY AREA

The study area is the eastern part of Haryana State, forming a part of the Indo-Gangetic Plain. The Yamuna river makes its eastern boundary while average annual water table fluctuations during June 1974 to June 1991 are taken into consideration for the demarcation of western boundary. Blockwise average depth of water below the ground surface during June 1991 is worked out and compared with those of June 1974 to arrive at the total change and also the average annual fluctuations from June 1974 to June 1991. In this way, the zero metre water table depth contour line is fixed to be the western boundary of the study area, where broadly falling water table is an important feature (Fig.1). This study area stretches from Ambala in the north to Mahendragarh in the southwest comprising 55 administrative blocks and 4442 villages. These districts account for 19229 sq. Km of the total State area. Though some districts like, Rewari and Mahendragarh do not fall locationally within the fold of eastern part of the State, yet the entire region is considered to be the eastern part, because they are facing similar kind of problems of groundwater depletion.

The main groundwater basin commences from Shiwaliks southward. The contact of Shiwaliks and the alluvium of Recent to Sub-Recent period is an uncomfortable contact and is overlain by the Bhabhar piedmont formation, which in turn, is interfringed with terai axial deposits, Groundwater reservoir of the plains lying south of Shivaliks, because of its permeability and complex geological structure, effectively separates the plains into two different hydrogeological units of the groundwater reservoir (Chadha, 1983).

Variation in groundwater level is quite large. The average depth of water below ground surface during June 1990 ranged from 5 metre in western part of the Sonepat district to 27.8 metre in the Mahendragarh district. The average groundwater depth varies from northeast to southwest with different bydraulic gradients.

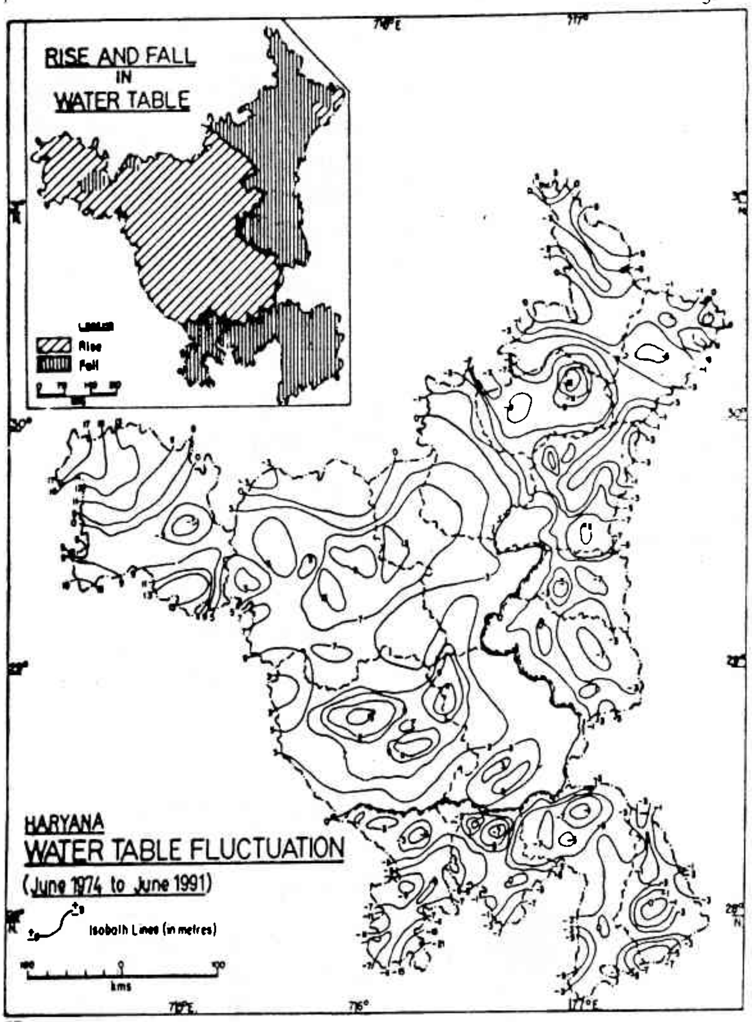
At presesnt, 80 per cent of available fresh groundwater is being exploited through more than 5 lakh tubewells (Handbook of Irrigation, 1993). It is revealed that even with this high intensity of utilization, a substantial amount of additional water resource is, still, required. Considering high intensity of groundwater utilization, which is one of the prominent factors leading to groundwater depletion, groundwater balance study is made to estimate available groundwater for future development.

DATA AND METHODOLOGY

The study is based on secondary data. Data on districtwise rainfall, irrigation (canal and groundwater), number of tubewells engaged in exploiting groundwater and data relating various recharge and discharge parameters collected from groundwater cell of Argiculture Department and Groundwater Directorate located at Karnal.

The objective of goundwater balance is to make an assessment of goundwater available for future development. Such an assessment requires data on large number of hydrological, geohydrological and bydrogeological parameters. In the present study, groundwater balance is estimated at block level taking into account the long-term (i.e., 17 years from 1974 to 1991) annual recharge, return flow from agricultuaral fields, seepage from canals, and groundwater withdrawal by minor irrigation structures.

Fig. 1



Source: Groundwater Directorate, Karnal

Fig. 1 : Haryana - Water Table Fluctuation (June 1974-June1991)

Groundwater discharge from each unit of irrigation is taken according to the norms given by National Bank for Agriculture and Rural Development (NABARD) and adopted by Haryana State Minor Irrigation and Tubewells Corporation. Only a small proportion of the groundwater pumped, is being used for non-irrigation purposes, the

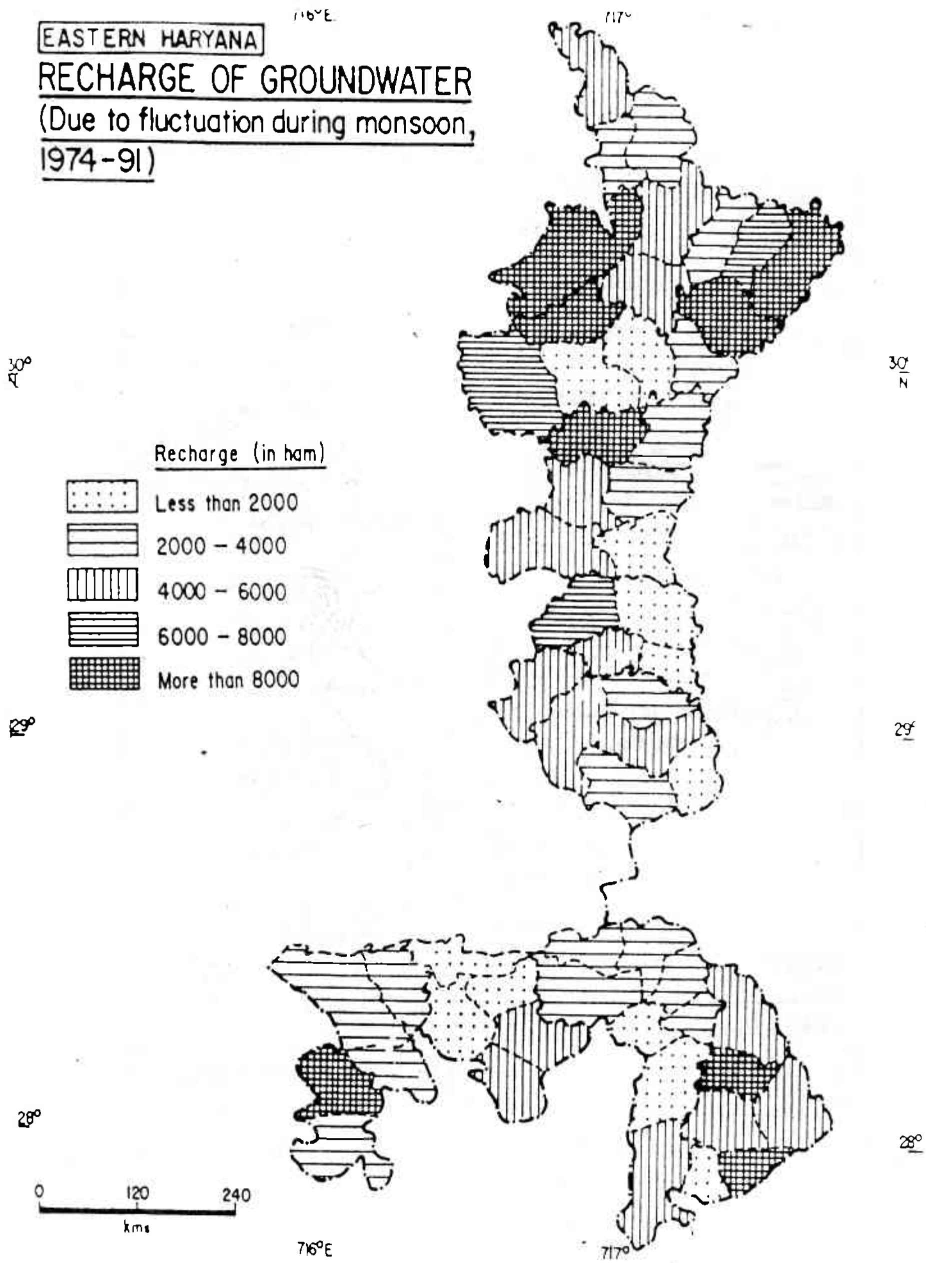


Fig. 2 : Eastern Haryana - Recharge of Groundwater (1974-1991)

total pumpage has been accounted for irrigation. Groundwater recharge in the study area occurs mainly from rainfall during monsoon season and irrigated fields. Therefore, groundwater balance for eastern Haryana is worked using the following relation (Sharma, 1979), with slight modifications.

$\Delta S = I - O$

where, ΔS = change in storage;

I = input to groundwater system (Re_1, Re_2 & Re_3);

O = output from groundwater system (W_1);

where, Re_1 = recharge from precipitation, ($re_a + re_b$) and kharif recharge (re_c);

re_a = corrected fluctuation recharge;

re_b = winter rainfall recharge;

re_c = kharif recharge;

where, Re_2 = recharge due to seepage from canals;

Re_3 = return flow from applied canal irrigation;

W_1 = Quantum of groundwater withdrawal by irrigation structures.

The above relation, when elaborated using different components, forms the model as follows:

$$\Delta S = [\{A.Sy.cf\} + \{RK\} + \{A.Wr.If\} + \{cl.wr.cr.Rt\} + \{Qr.Rf\}] - [\{ad + Nk\}\ nd]$$

where, A = total geographical area of a block;

Sy = specific yield;

cf = seasonal fluctuations (corrected);

Rk = kharif recharge (45 per cent of total kharif recharge);

Wr = winter rainfall;

If = infiltration factor;

Cl = total length of canal in the block;

Cw = wetted perimeter of the canal;

Cr = canal running days;

Rt = seepage factor;

Qr = total quantity of water released;

Rf = return flow factor;

Ad = average draft during monsoon;

Nk = net kharif draft

nd = net kharif draft (85 per cent of Ad + Nk)

The groundwater draft in the investigated area is estimated using data on a number of irrigation structures employed for different purposes and their average draft. Draft has been estimated taking into account the norms approved by National Bank for Agriculture and Rural Development. Computation of draft by minor irrigation structures is explained here:

Number of minor irrigation structures in a block x annual draft (ham)

Open well, pumping and shallow tubewells, Direct Irrigation Tubewells and Augmentation Tubewells are considered as minor irrigation structure for the present study.

RESULT AND DISCUSSION

Input (Re_1, Re_2, Re_3)

Monsoon rainfall is the main source of groundwater infiltration and recharge in the area and it contributes nearly 38 per cent of the gross recharge during 1974-91 (Table 1). The main source of rainfall in the area is the southwest monsoon which generally encompasses the entire region from the third week of June to middle of July. However, it is highly seasonal in character and widely varying in distribution over the area. More that 80 per cent of total rainfall is received during four months period, which is from June to September. Maximum groundwater recharge takes place during this period in the form of re_a and groundwater contours are usually at their highest level immediately after this period. Figure 2 reveals that recharge due to fluctuation during monsoon varies from less than 2000 ham to more than 8000 ham in the entire study area. In the northern part of the region fluctuation recharge is comparatively higher and is more than 6000 ham especially in Ambala block of the Ambala district, Bilaspur, Chhachhrauli and Jagadhari blocks of the Yamunagar district, Shahabad, Pehowa blocks in the Kurukshetra district and Nilokheri block in the Karnal district. Groundwater extraction also takes place owing to kharif season which influences the water table fluctuations. As such, the net kharif recharge which is 85 per cent of aveage draft during monsoon is counted as kharif recharges (re_c) which is almost 36.5 per cent of gross recharge (Table-1). Rice is the main kharif crop of eastern Haryana, which requires an ample amount of water. Farmers are very much dependent on tubewells irrigation for the rice cultivation. Therefore, groundwater draft during kharif season also contributes to groundwater recharge. Figure 3 presents an interesting picture of recharge through net kharif draft in the study area. Recharge through the net kharif draft is apparently directly related to the paddy cultivation and tubewell irrigation. It is more than 8,000 ham in the block of Shahabad, Pehowa and Thanesar in the Kurukshsetra district; Jagadhari in the Yamunanagar district; and Indri, Nising, Karnal and Gharaunda in the Karnal distric. Tubewell irrigation is at its peak and is the main source of irrigation in all these blocks. In the extreme north in the Piedmont Plain and the Shiwalik regions, boulder fromation prevented developed agriculture, especially rice cultivation and recharge through net kharif draft is less than 2,000 ham in the blocks namely, Pinjore, Naraingarh, Bilaspur and Chhachhrauli. Elsewhere, in the remaining districts, existence of aquifers at greater depth and impairment of the groundwater either by impregnation of undesirable salts or deep thin strata having brackish water did not encourage tubewell irrigation. Therefore, recharge through net kharif draft is less than 4000 ham. Winter rainfall (re_b) also plays significant role in the

Table 1:

Eastern Haryana: Groundwater Recharge During Monsoon and Non-Monsoon: 1974-1991

Sr. No.	Monsoon Recharge	Amount of recharge (ham)	Per cent of total monsoon/non monsoon recharge	Per cent of gross recharge
1.	Corrected fluctuation recharge	231416.9	50.9	38.00
2.	Kharif recharge	222500.3	49.1	36.50
	Total Monsoon Recharge	453917.2	100.0	74.50
	Non-Monsoon Recharge			
3.	Recharge due to seepage	56738.0	36.0	9.31
4.	Recharge due to return flow	21339.0	13.7	3.50
5.	Recharge due to winter rainfall	76924.6	49.6	12.60
	Total Non-Monsoon Recharge	155001.6	100.0	25.50
	Gross Recharge	608917.9		100.00

Source: Based on the Records of Groundwater Directorate, Haryana

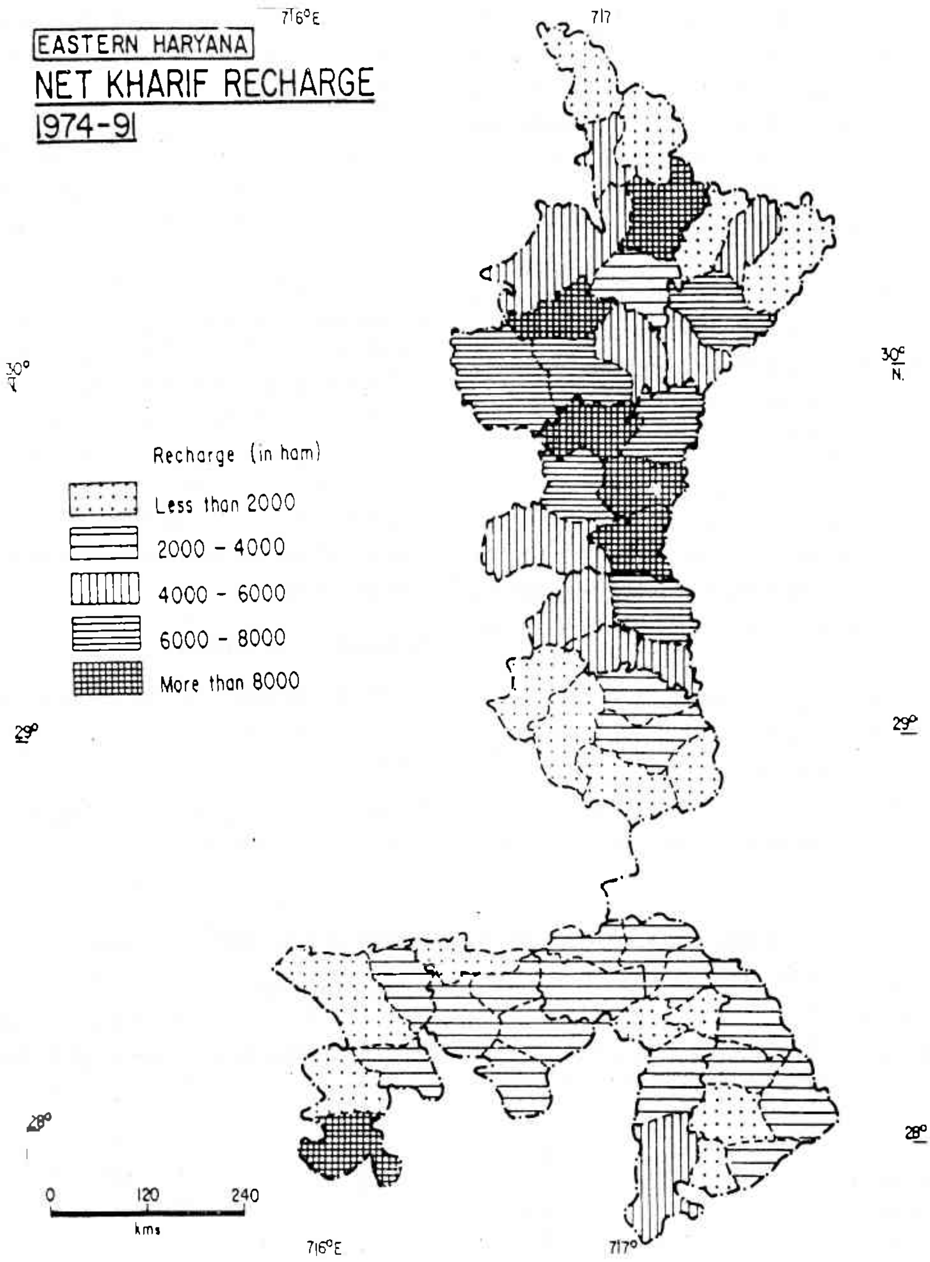


Fig. 3 : Eastern Haryana - Net Kharif Recharge (1974-1991)

recharging of groundwater reservoir but sometimes it only replenishes the soil moisture deficiency (Sharma, 1974).

Seepage recharge (Re_2) or groundwater flow is generally defined as the movement of water between the groundwater aquifers and the surface sources. It is worked out that recharge due to seepage was almost 56738 ham during 1974-91,which nearly makes 36.6 per cent of non-monsoon recharge and 9.6 per cent of the gross recharge (Table 1). Figure 3 reveals that seepage recharge varied from nil to more than 3000 ham during this period. It is evident that seepage recharge is very low in the study area. The reason is the modernization of canals. The modernization work under World Bank assistance was taken up in 1978 by lining the main canals and branches. This has resulted in saving water; improvement in water conveyance efficiency; reduction in waterlogging; reduction in cuts and branches. Therefore, seepage loss in canal s and branches has also been reduced to a large extent.

Table 1 highlights that recharge due to return flow (Re_3) in the study area is quite low in comparison to other recharging components, this recharge was only 3.50 per cent of the gross recharge and 13.7 per cent of the non-monsoon recharge. Table 2 reveals that in most of the blocks, return flow recharge is almost nil owing to low intensity of canal irrigation. 21 such blocks registered where return flow recharge is nil. In case of recharge through applied canals, farmers are mainly responsible for that by oveirrigating their fields.

Output (W_1)

The region has made impressive development of groundwater resource through tubewells in and outside canal commands. The groundwater by minor irrigation units has increased many fold during 1971-91. The total annual groundwater draft was 367,633 ham in 1971 which increased to 537,579 ham in 1981 and 919008 ham in 1991. It has been worked out that in 1991, shallow tubewells extracted 81.5 per cent of total groundwater draft followed by augmentation tubewells, i.e., 10.5 per cent, pumping sets, i.e., 4.9 per cent, direct irrigation tubewells, i.e. 2.5 per cent and open wells, i.e., 0.39 per cent.

Groundwater Balance

From the foregoing estimation of groundwater balance is made with the help of following balance equation.

Recharge – Discharge = ± Balance
608918 – 919008.1 = – 310090.1 ham

Table 2

Eastern Haryana: Recharge of Groundwater by Different Sources

Amount of Recharge (ham)	Number of Blocks					
	Rainfall Monsoon	Rainfall Winter	Due to seepage	Due to return flow	Total monsoon	Total non-monsoon
	1	2	3	4	5	6
<1000	4	39	18	21	2	15
1000-2000	8	8	7	3	Nil	20
2000-3000	8	3	3	2	3	9
3000-4000	11	Nil	3	Nil	5	2
4000-5000	7	Nil	4	Nil	8	1
5000-6000	8	1	4	Nil	7	3
6000-7000	1	Nil	1	Nil	4	1
7000-8000	1	2	2	Nil	4	1
8000-9000	2	Nil	Nil	Nil	5	Nil
9000-10000	2	1	Nil	Nil	1	2
>10,000	3	1	Nil	Nil	16	3

Source: Based on the Records of Groundwater Directorate, Haryana

Table 3

Blockwise Groundwater Draft by Minor Irrigation Structures during 1971, 1981 and 1991

	District/Block	1971	1981	1991
	AMBALA			
1	Ambala	8613.9	17454.1	27238.7
2	Brara	328.77	15795.6	1745.81
3	Barwala	DNA	DNA	DNA
4	Morni	DNA	DNA	DNA
5	Naraingarh	3939.4	9713.1	14948.1
6	Pinjore	293.8	480.5	877.0
7	Raipur Rani	5416.5	4800.3	7078.05
	Total	21551.3	48243.6	67599.9
	YAMUNANAGAR			
8	Bilaspur	3951.2	7008.5	9712.5
9	Chhachhrauli	5033.0	9732.5	11945.0
10	Jagadhari	19008.0	17327.5	22157.0
11	Radur	13380.5	20053.9	22080.9
12	Saroura	DNA	DNA	3845.0
	Total	41372.7	54122.4	69740.4
	KURUKSHETRA			
13	Ladwa	11768.8	12059.2	16294.5
14	Pehowa	10039.8	17277.1	30312.2
15	Sahabad	18070.7	28513.9	33355.8
16	Thanesar	22600.1	30746.4	16771.2
	Total	62478.4	88596.6	96733.4
	KARNAL			
17	Ghraunda	9227.1	28949.4	39774.6
18	Indri	14213.6	18750.0	34028.4
19	Karnal	36994.5	27030.7	38728.7
20	Nilokheri	27318.1	17575.5	51774.7
21	Nisingh	14576.3	20236.5	30188.3
	Total	102329.6	112542.1	194494.7
	PANIPAT			
22	Assandh	10733.9	13697.2	24549.7
23	Israna	DNA	DNA	13902.5
24	Madlauda	8049.7	15.579	18133.1
25	Pasnipat	16334.8	25266.3	25382.3
26	Samblkha	9447.3	15394.2	19301.7
	Total	44565.7	69936.7	101269.2
	SONEPAT			
27	Ganaur	4224.8	7860.8	9809.8
28	Gohna	DNA	DNA	189129.6

	District/Block	1971	1981	1991
29	Kharkhoda	2207.9	2390.6	6024.1
30	Mudlana	DNA	DNA	12749.3
31	Rai	2222.2	5240.9	10275.7
32	Sonepal	3361.8	6562.5	14162.1
	Total	12016.7	22054.8	71949.8
	GURGAON			
33	Firojpur	638.8	1389.6	3581.4
34	Gurgaon	50.35.5	11764.6	9883.1
35	Nagina	426.0	7008.1	1720.2
36	Nuh	1444.8	4128.6	4173.7
37	Pataudi	6456.2	2140.2	12690.7
38	Sohna	7000.1	13524.6	12699.3
39	Taoru	796.8	19611.0	5808.2
40	Punhana	1068.0	2124.6	4225.1
41	Farukhnagar	DNA	DNA	11644.9
	Total	22866.2	59779.3	66456.5
	FARIDABAD			
42	Basllabgarh	5843.9	8100.1	1112.3
43	Faridabad	9137.2	10578.4	12387.9
44	Hathin	3954.2	2781.6	4533.0
45	Hodel	2807.7	7841.6	8541.1
46	Palwal	4255.8	8012.1	10860.1
	Total	25998.8	37313.8	37434.4
	REWARI			
47	Bawal	9668.8	5745.5	7753.1
48	Jatusana	3227.6	7102.5	10996.7
49	Khol	2799.7	4917.6	8775.8
50	Nahar	DNA	DNA	7505.4
51	Rewari	3981.9	4479.1	8577.6
	Total	19678.0	22244.7	43608.6
	MAHENDRAGARH			
52	Ateli Nangal	2633.8	5354.6	11840.0
53	Kanina	5361.7	4194.3	10382.6
54	Mahendragarh	24218	4000.1	10070.7
55	Nangal	1257.7	4808.2	126503.0
56	Narnaul	2500.6	4388.4	10925.6
	Total	14175.6	22745.6	169721.9
	Total in Eastern Haryana	367633	537579.6	919008.9
	DNA-Data Not Available			

Source: Groundwater Cell of Agriculture Department, Haryana.

It is found out that during 1991, groundwater potential is not available for future development. Therefore, overdraft from the groundwater reservoir has taken place in almost all the block owing to more discharge by minor irrigation structures than the natural and artificial recharge. Entire area inducted an overdraft of -310090.1 ham during 1991.

CONCLUSION

Groundwater recharge in the study area occurs mainly from rainfall during monsoon season and irrigated fields. The scope for natural recharging of groundwater reservoir during non-monsoon through seepage by canals is being reduced due to modernization of surface conveyance and distribution system, that is due to lining of main canals and other distributories in irrigation projects. Consequently, overdevelopment of groundwater has taken place in many parts of the study area. Overdevelopment of groundwater leading to permanent lowering of water table has been created by shallow tubewells. High consumption crops like sugarcane and paddy are grown in this area, which require huge quantity of water, even then farmers have strong preference for them. Therefore, groundwater draft is more than the groundwater recharge, hence over-exploitation of groundwater continues unabated.

Above results of the investigation give an idea that overdevelopment of groundwater resources must be recognized as a major environmental crisis is eastern Haryana. The above conditions necesritate the groundwater depletion studies which are necessay to avoid harmful economic, social and ecological consequences.

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