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Analytical Study of Groundwater Resources and its Management in Siwan District, Bihar

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Abstract
Rapid population growth and heavy demands of water in agricultural, domestic and industrial sectors have led to deterioration of groundwater resources in the study area, Siwan. The major objectives are to study the groundwater depth zone, water level fluctuations and groundwater balance. This paper is based on secondary data.This data have been collected from PHED, Siwan from 2011 to 2014.76samples of wells have been selected based on stratified random sampling method. The general findings reveal that the maximum blocks of the study area come under shallow depth zone and minimum blocks come under medium depth zone which indicate the variability of groundwater resources. The specific findings and management of groundwater resources have been discussed in detail in this paper.

Keywords: Deterioration, Depth zone, Fluctuations, Groundwater, Groundwater balance.

Introduction

Water existing in the voids of the geological stratum below the surface of the earth is called groundwater and its utilization to fulfil the basic needs is called groundwater resources (Gurjar, 2007). Groundwater, which is 38.5% of the available water resources of country, plays a significant role in irrigation, rural water supply and urban water supply for domestic purposes along with industrial development (Gurjar; 2007).Groundwater has been considered as the purest forms of water available in nature and meets the overall demands of the people(Jonthan,2012). Groundwater meet nearly 85% of rural domestic water requirements, 50% of urban domestic water requirements(Raju2002; CGWB2011).Estimates indicate that more than 80% of total groundwater is utilized for irrigation(IWMI 2000; Rosegrant Cai and Cline; 2003).But now-a-days this resources in several places become contaminated from population pressure,erratic monsoonal activities and unscientific use of water in domestic,agricultural and industrial sectors.So,the requirements of domestic, irrigation and industrial water have been increasing with socio-economic development in a developed as well as developing countries while water availability has been decreasing in the form of groundwater levels. It is occurred due to population pressure, erratic monsoonal activities and unscientific water use in domestic, agricultural and industrial sectors for meeting the needs of water in different sectors of the society. Apart from it, the changes in climatic conditions, geological structure and geomorphological structure leads to the change in groundwater resources.Such situations are before use because of the lack of

groundwater resources in the major parts of the world. From such problems, Siwan district is not free from such problems. Therefore, the management of groundwater is a big problem for the district to fulfil the basic needs in domestic, agricultural and industrial sectors for future generations.

The Study Area

The study area is a part and parcel of Middle Gangetic Plain, which comprises 19 C.D. blocks of Siwan district covering an area of 2220.51 Sq. Km (District Agricultural Office, 2014) and holds population of about 3330464 persons with 1530 villages (Census 2011). This district lies between $25^{0}53^{I}$ and $26^{0}23^{I}$ North latitudes and $84^{0}0^{I}$ and $84^{0}47^{I}$ East longitudes. The major part of study area is formed by newer and older alluvium deposits by the sediments of perennial rivers viz; Ghaghara and Gandak. Geologically, it is underlain by quaternary sediments deposited by Ghaghara and Gandak rivers (Report on Systematic Hydrological Survey in parts of Siwan and Gopalganj District, Bihar). The geological formation of the tract of the study area is of recent (Holocene) period. It is estimated that the district covers the deposits of alluvium more than 5000 feet depth (Siwan district eNotes com. Reference). Geomorphology, the structure of Siwan district is covered with horizontal deposits of alluvium. This region is a part of elongated depression known as the Ganga plain section of Bihar (Ahmad, 1965) The soil of the study area is formed by a thick alluvial mantle of drift deeply interline for most part by Shiwalik and older tertiary rocks on the surface deposits silty loam, silty sand and sandy silt are found near the bank of rivers. Young alluvium calcareous soils are found in the district. Climatologically, this region is in the realm of monsoon type of climate but naturally the climate of the district is sub-tropical to sub-humid. The district experiences severe cold during winter and extreme hot during summer season.

Figure 1: Identification Map of Siwan Disrict

Objectives

- To assess the groundwater resources in terms of groundwater depth, water level fluctuations and groundwater balance.

- To examine the changes in groundwater balance.
- To examine the positive and negative development in balance of the ground water.
- To suggest in appropriate management techniques for the development of groundwater resources.

Data Base and Methodology

The present study is based on analytical study. The secondary data have been collected from 2011 to 2014 from Public Health Engineering Department, Siwan. 76 samples of wells have been selected for the study based on stratified random sampling method. The selected data are analysed using suitable analytical procedures. Statistical and Cartographical techniques are applied to obtain the better result of the study. Time series analysis has been shown through tables and graphs.

RESULT AND DISCUSSION

Ground Level Depth

Depth of groundwater observation has been made at selected points during the study period which are observed in the month of July, February and November respectively. From agricultural development point of view, the planners have categorized the water table depth zone as under:

- Below 300cm - Critical depth zone
- 300 to 500cm - Shallow depth zone
- 500 to 1000cm - Medium depth zone
- 1000 to 2000cm – Deep depth zone
- Above 2000cm Very depth zone

Table 1

Siwan District: Groundwater Depth Zone, 2011-2014 (In cm)

Depth Zone	2011	2012	2013	2014
Critical Depth Zone (Below 300cm)	No	No	No	Barharia, Maharajganj, Goriakothi, Daraundha, Bhagwanpur, Basantpur, Lakri-Nabiganj.
Shallow Depth Zone (300 to 500 cm)	Barharia, Pachrukhi, Ziradei, Hasanpura, Raghunathpur, Andar, Darauli, Guthani, Nautan, Mairwa, Goriakothi, Daraundha, Bhagwanpur,	Barharia, Pachrukhi, Husanganj, Ziradei, Hasanpura, Raghunathpur, Andar, Darauli, Guthani, Nautan, Mairwa, Maharajganj, Goriakothi,	Barharia, Pachrukhi, Husanganj, Siwan, Ziradei, Hasanpura, Raghunathpur, Andar, Darauli, Guthani, Nautan, Mairwa, Maharajganj, Goriakothi,	Pachrukhi, Husanganj, Siwan, Ziradei, Hasanpura, Raghunathpur, Andar, Darauli, Guthani, Nautan, Mairwa, Siswan

	Basntpur, Lakri-Nabiganj	Daraundha, Siswan, Bhagwanpur, Basantpur, Lakri-Nabiganj	Daraundha, Bhagwanpur, Basantpur, Lakri-Nabiganj	
Medium Depth Zone (500 to1000 cm)	Husanganj, Siwan, Maharajganj, Siswan	Siwan	Siswan	No
Deep Depth Zone (1000 to 2000cm)	No	No	No	No
Very Deep Depth Zone (Above 2000cm)	No	No	No	No

Source: District Public Health Engineering Department, Siwan.

The water table depth zone varies from 300 to 1000cm during the study. Maximum blocks fall under the shallow depth zone ranging from 300 to 500 cm. Maximum blocks are recorded in shallow depth zone in the year of 2012 and 2013while minimum blocks are recorded in 2014.Seven blocks- Barharia, Maharajganj, Goriakothi, Daraundha,Bhagwanpur,Basantpur and Lakri-Nabiganj are under the critical depth zone(below 300cm) in 2014.No any block is recorded under the this depth zone from 2011 to 2013.The blocks under medium depth zone have decreased. The highest blocks are found in 2011 in the same depth zone.Deep depth zone and very deep depth zone are not found during the study. The critical depth zone represents the highest groundwater level and shallow depth zone represents the medium groundwater level. Moreover, medium depth zone represents the lower groundwater level.Lower groundwater level has increased in 2011 with the block of Hussainganj,SiwanMaharajganj and Siswan.The block under lower groundwater has decreased from 2011(see Table-1).

Groundwater Level Fluctuation

The fluctuations in the water table represent the net effect of both recharge and draft of groundwater during a year (Neeraj and Bittu, 2014).The water level fluctuations occur due to seasonal variations in rainfall and groundwater utilizations. The groundwater fluctuated from 2011 to 2013 and 2011 to 2014. The positive fluctuation represents the increase in water level while the negative fluctuation represents the decrease in water level in the particular blocks of the district. Six blocks hold the negative fluctuation from 2011 to 2013.These blocks are Goriakothi, Maharajganj, Guthani, Zeradei, Siwan and Hussainganj. Thirteen blocks hold the positive fluctuation in water level. These blocks are Barharia, Pachrukhi, Hasanpura, Raghunathpur, Andar, Darauli, Nautan, Mairwa, Daraundha, Siswan, Bhagwanpur, Basantpur and LakriNabiganj. The highest positive fluctuation is observed in Maharajganj block while lowest positive fluctuation is observed in Ziradei anddecreasing trend is found in Darauli block while lowest decreasing trend is found in both Hasanpura and Bhagwanpur block. The area of six blocks has increased in

water level. These blocks are Hussainganj, Siwan, Ziradei, Guthani, Maharajganj and Goriakothi. The highest increasing trend of water level is recorded in Maharajganj block while lowest is recorded in Ziradei block. During 2011 to 2014,Only Darauli block has experienced as negative fluctuation in water level (-7.62cm) which indicates the decrease in water level. Remaining blocks provide the positive fluctuation in water level. Annual water level is fluctuated from 2.54 to 130.39 cm. The negative annual water fluctuation is found in the block of Darauliwhich shows the annual decreasing trends of water level and remaining blocks highlight the increasing trends of groundwater level. The highest annual fluctuation is found in Maharajganj block while lowest annual fluctuation is found in Guthani block.

Table-2

Siwan District : Block wise Average depth to Water Table and Fluctuations of Water Level from July 2011-2012 and Feb.2013-Nov.2014 (In Centimetres)

Block/Year	Depth of Water Level				Water Level Fluctuations		Average Annual Water Level Fluctuation
	2011	2012	2013	2014	2011-2013	2011-2014	
Barharia	320.04	365.76	347.98	281.94	-27.94	38.1	12.7
Pachrukhi	365.76	441.96	421.64	304.8	-55.88	60.96	20.32
Hussainganj	548.64	411.48	403.86	304.8	144.78	243.84	81.28
Siwan	563.88	541.02	419.1	365.76	144.78	198.12	66.04
Ziradei	406.4	396.24	403.86	304.8	2.54	101.6	33.86
Hasanpura	426.72	426.72	431.8	350.52	-5.08	76.2	25.4
Raghunathpur	415.64	426.72	431.8	350.52	-16.16	65.12	21.71
Andar	426.72	439.42	464.82	401.32	-38.1	25.4	8.47
Darauli	426.72	459.74	487.68	434.34	-60.96	-7.62	-2.54
Guthani	411.48	436.88	401.32	403.86	10.16	7.62	2.54
Nautan	426.72	444.5	469.9	401.32	-43.18	25.4	8.47
Mairwa	426.72	457.2	474.98	403.86	-48.26	22.86	7.62
Maharajganj	673.1	365.76	406.4	281.94	266.7	391.16	130.39
Goriakothi	439.42	396.24	431.8	274.32	7.62	165.1	55.03
Daraundha	327.66	340.36	378.46	231.14	-50.8	96.52	31.17
Siswan	510.54	495.3	530.86	378.46	-20.32	132.08	44.03
Bhagwanpur	396.24	370.84	401.32	259.08	-5.08	137.16	45.72
Basantpur	434.34	381	441.96	259.08	-7.62	175.26	58.42
LakriNabiganj	381	360.68	401.32	241.3	-20.32	139.7	46.57

Source: District PHED, Siwan, 2015.

+ = Increase, - = Decrease

Groundwater Balance

Table 3 shows the variations in groundwater balance with the influence of net recharge and net graft of groundwater in a particular year. The annual net recharge was 7474.3 cubic meter in 2004. The annual net recharge of water has decreased 484.2 cubic metres during the study. Moreover, annual net draft of water has decreased 1614.4 cubic metres from 2004 to 2009.The analysis of groundwater balance highlights that five block support the negative balance. The highest positive balance is found in the block of Mairwa along with highest negative balance is found in Siswan during 2004.

Table-3

Variations in Groundwater Balance, 2004-2009 (in Cubic Metre)

Block	Net Recharge		Change	Net Draft		Change	Ground water Balance		Change
Year	2004	2009	2004-09	2004	2009	2004-09	2004	2009	
Siwan	563.88	365.76	-198.1	419.1	363.76	-55.34	144.78	2	-142.78
Barharia	320.04	441.96	121.92	347.98	281.94	-66.04	-27.94	160.02	187.96
Pachrukhi	365.76	411.48	45.72	421.64	304.8	-116.84	-55.88	106.68	162.56
Husainganj	548.64	396.24	-152.4	403.86	304.8	-99.06	144.78	91.44	-53.34
Ziradei	406.4	426.72	20.32	431.8	304.8	-127	-25.4	121.92	147.32
Raghunathpur	426.72	439.42	12.7	431.8	350.52	-81.28	-5.08	88.9	93.98
Andar	415.64	459.74	44.1	464.82	350.52	-114.3	-49.18	109.22	158.4
Darauli	426.72	436.88	10.16	487.68	401.32	-86.36	-60.96	35.56	96.52
Guthani	411.48	444.5	33.02	401.32	434.34	33.02	10.16	10.16	0
Nautan	426.72	457.2	30.48	469.9	403.86	-66.04	-43.18	53.34	96.52
Mairwa	673.1	365.76	-307.3	474.98	401.32	-73.66	198.12	-35.56	-233.68
Maharajganj	439.42	396.24	-43.18	406.4	403.86	-2.54	33.02	-7.62	-40.64
Goriakothi	327.66	340.36	12.7	431.8	281.94	-149.86	-104.14	58.42	162.56
Daraundha	510.54	495.3	-15.24	378.46	274.32	-104.14	132.08	220.98	88.9
Siswan	396.24	370.84	-25.4	530.86	231.14	-299.72	-134.62	139.7	274.32
Bhagwanpur	434.34	381	-53.34	401.32	378.96	-22.36	33.02	2.04	-30.98
LakriNabiganj	381	360.68	-20.32	441.96	259.08	-182.88	-60.96	101.6	162.56
Total	**7474.3**	**6990.08**	**-484.2**	**7345.68**	**5731.28**	**-1614.4**	**128.62**	**1258.8**	**1130.18**

Source: Central Groundwater Board, Patna India.

During the period of 2009, maximum blocks of the district are in form of such blocks are fifteen. Only one block comes under the negative balance of water. These blocks are Maharajganj and Mairwa. The highest positive development in groundwater balance is in the block of Daraundha while lowest is found in the block of Siwan in 2009.

Table 2 also exhibits that groundwater balance has changed from one place to another. The groundwater balance has increased in the maximum blocks of the district. It is occurred in the blocks of Barharia, Pachrukhi, Ziradei,

Raghunathpur,Andar, Nautan, Goriakothi, Siswan, Lakari-Nabiganj and remaining blocks of the district have decreased from 2004 to 2009. Five blocks cover the negative groundwater balance in the study area. These blocks are Siwan,Hussainganj,Mairwa,Maharajganj and Bhagwanpur while twelve blocks are recorded as positive groundwater balance. These blocks are Barharia, Pachrukhi, Ziradei, Raghunathpur, Andar, Darauli, Guthani,Nautan, Goriakothi,Daraundha,Siswan,Lakri Nabiganj from 2004 to 2009.

Management of Groundwater Resources

The management of groundwater resources is essential in the district of Siwan. The demands and availability has changed with the development in domestic, agricultural and industrial sectors. The management of groundwater mainly depends upon the suitable locations and conditions, net recharge, net draft of water resources. The net recharge of water is 7474.3 cum in 2004. It has declined 6.48% in the year 2009. About 21.98% net draft has declined from 2004 to 2009. So, the groundwater balance has diversified. Thus, the groundwater management techniques should be adopted for the effective management of groundwater resources:

- The effective monitoring in discharge and demands of groundwater in the block Siwan, Hussainganj, Mairwa, Maharajganj, Bhagwanpur should be done to maintain the groundwater development.
- Government need to create awareness among the people on the importance of groundwater resources and their conservation to improve the decreasing level of groundwater.
- Maximum water requirement crops should be reduced for the cultivation especially in the period scanty rainfall in the district.
- Excess use of water through hand pump should be avoided in the area where low level of groundwater is available.
- District Water Resource Department (DWRD) should be regularly reviewing the progress of water resources.
- DWRD should be categorized into very high, high, medium, low and very low groundwater level to plan the sustainable use of groundwater resources in the blocks of the district, Siwan.
- Prime Minister Irrigation Programme (PMIP) should be practiced under the medium depth zone blocks of the district.
- Water Policy-2012 may be applied for effective management of groundwater resources in the blocks of the district, Siwan..Rainwater harvesting techniques should be practiced in the block of Hussainganj,Siwan,Maharajganjand Siswan to enhance the groundwater level.
- Modern Irrigation Method should be practiced in the block of negative water fluctuated area.
- The traditional wells should be repaired to store the water which participates to increase the groundwater level.
- Traditional Groundwater Development System (TGDS) should be applied for eco-friendly development of groundwater.

Major Findings

1. From 2011 to 2013, the depth zone of groundwater in the study area was in critical and deplorable situation but during 2014 a marked change was visible

in critical depth zone of groundwater in the block of Barharia, Maharajganj, Goriakothi, Daraundha ,Bhagwanpur, Basantpur and Lakri-Nabiganj.

2. It is to be noted here that groundwater of shallow depth zone could not delight us as shallow depth zone had decreased in 2014.

3. The medium depth zone of groundwater in the study area remained satisfactory from 2011 depth zone.

4. The deep depth zone and very deep depth zone disappointed a lot because of having no result in rising of groundwater level from 2011 to 2014.

5. The highest annual water level fluctuation is found in Maharajganj block while lowest is found in Guthani block.

6. Negative annual water level fluctuation is found in Darauliblock (-254cm) during the study

7. The net recharge of water has decrease from 7474.3 to 6990.08 cubic metres during the study.

8. Net draft of water for industrial, agricultural and domestic uses has decreased from 7345.68 to 5731.28 cubic metres.

9. The groundwater balance has decreased in Pachrukhi, Barharia, Ziradei, Raghunathpur, Andar, Darauli, Goriakothi, Siswan and Lakri-Nabiganj which indicate the over uses of water than available for various purposes in 2014.

10. Only two blocks like Mairwa and Maharajganj have decreased in ground water balance which show the over uses of water than the availability in 2009.

11. Maharajganj block can be cited as critical depth zone which indicates the highest increasing trend of groundwater level.

12. The positive fluctuation in water level highlights the minimum use of water and the negative fluctuation in water level highlights the maximum use of water in the district.

Conclusion

The study is focused on the groundwater resources and its management in Siwan district, Bihar in terms of groundwater depth zone, groundwater fluctuation and groundwater balance. The groundwater depth zone has shifted in favour of shallow depth zone and medium depth zone. The groundwater level is rich in the major parts of the district observed based on groundwater depth zone. The analysis of groundwater resources highlights the problems, availability and utilisation of water resources through the groundwater level. These features pay attention on the people of the district, plannersand scientists for the better management of groundwater resources. In short it can be concluded that the groundwater level can be improved by adopting the groundwater management techniques for the sustainable use of water resources in the district.

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