P: ISSN NO.: 2394-0344 RNI No.UPBIL/2016/67980 VOL-4* ISSUE-1* (Part-2) April- 2019
E: ISSN NO.: 2455-0817 *Remarking An Analisation*

Quantification and Management of Groundwater Resources in Transboundary Aquifer across International Boundary of Jammu District J&K State

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Abstract

Water is one of the most vital of all the resources for human survival and thriving, it is an inherently shared resource that does not know human boundaries between persons, communities, states and nations. The natural subsurface groundwater flow, intersected by an international boundary which transfer from one side of the boundary to the other side and utilized by more than one country. Transboundary resource of the study area has been estimated through good observations and measurements of selected hydraulic parameters like transmissivity, hydraulic gradient, specific yield, thickness of the aquifer zone and length of cross section of area. The quantification and management of groundwater resources of the transboundary aquifers have been carried out by analytical method such as storage ground water resources and quantification by groundwater flow rate. The storage ground water resources for confined and unconfined aquifer condition is measured by using average areal extent of the unconfined aquifer with average specific yield of the area with average thickness of the granular zone. The total storage ground water resources of the study area has been estimated as 38310.94 mcm. The quantity of groundwater flow passing an international boundary measured directly from hydraulic parameters of the study area by using Darcy's law. The quantity of ground water flow calculated by using transmissivity of the area, hydraulic gradient and the length of cross section of area. The total quantity of groundwater flow, passing an international boundary from different parts study area has been calculated as 4031638.5 m^3/d.

Keywords: Quantification And Management; Groundwater Resources; Transboundary Aquifer; International Boundary.

Introduction

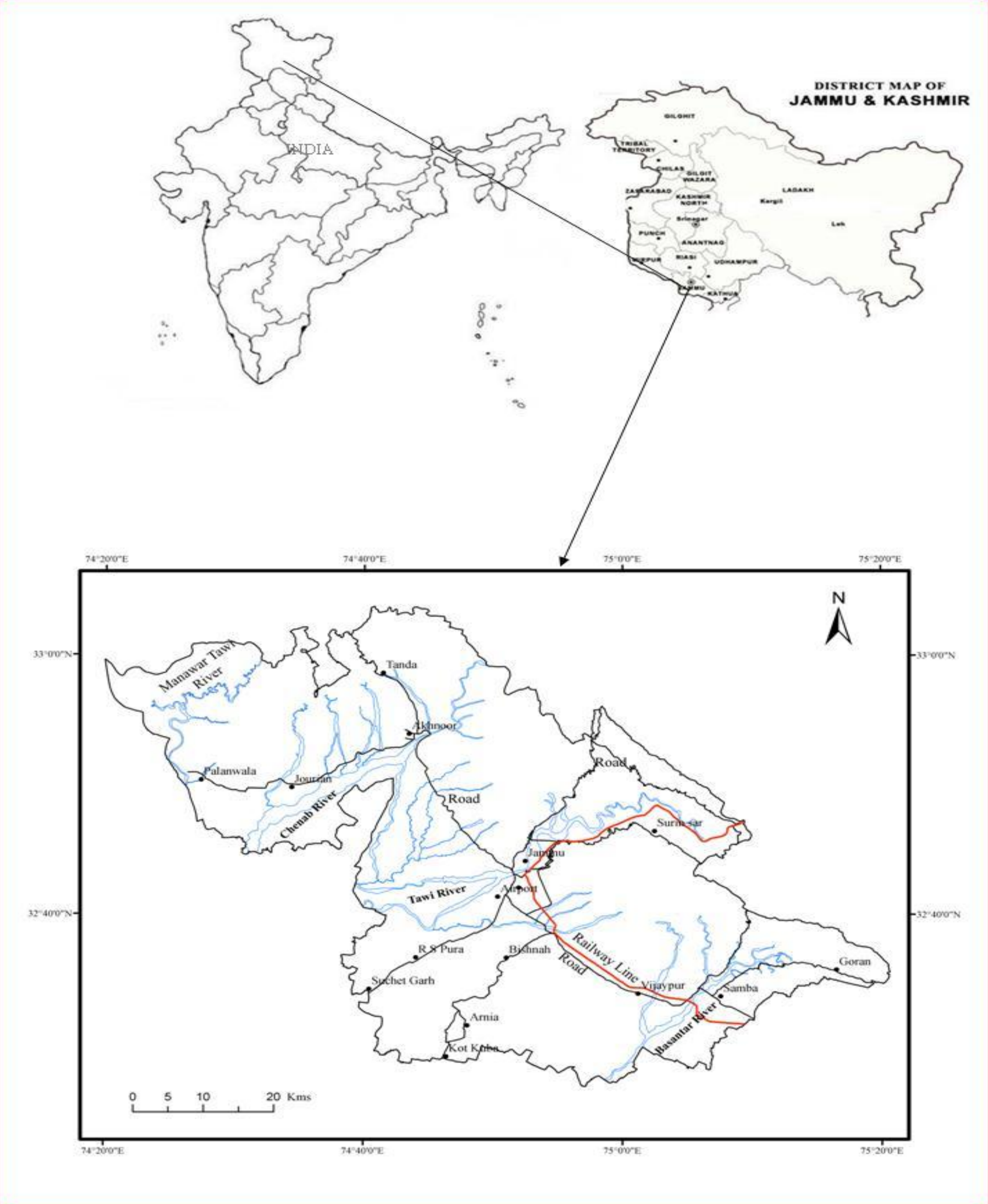
The term transboundary aquifer means an aquifer that extends across the boundary between two or more states/countries and shares the national or international boundaries. As far as the shared groundwater is concerned, it is necessary to investigate the relevant transboundary aquifers to understand the hydrogeological characteristics of these aquifers. The key features of transboundary aquifers include a natural subsurface path of groundwater flow intersected by an international boundary and transfer from one side of the boundary to the other side. Like surface water groundwater has no political boundary and is usually a part of the greater hydrologic system. The aquifers underlying them may not reflect the true transfer of groundwater which flows from one side to another and the groundwater resources can cross them unhindered and the correct identification of groundwater flow/movement is followed by its quantification. When it is confirmed that a particular aquifer is in fact of a transboundary in nature and shared groundwater resources are utilized by more than one country. It is extremely important to take pre-emptive, appropriate measures to avoid possible future conflicts that may arise due to the depletion, unsustainable exploitation or pollution of the aquifers.These measures can be agreed to manage these aquifers for obtaining the maximum benefits. For fair share, quantification and good management of ground water resources, scientists must estimate the ground water resources that cross the boundaries. In hydrogeological terms, these transboundary resources can only be estimated through good observations and measurements of selected hydraulic parameters like transmissivity, hydraulic gradient, specific yield, thickness of the aquifer zone and length of cross section of area. The detailed aquifer parameters and subsurface geological information which were studied by various scientists, needed to improve the results over the period of time. The numerous studies concentrated on movement of groundwater through various hydrologic units using application of Remote Sensing and GIS techniques (Raj and Sinha., 1989, Baldev et al., 1991, Gustafson, 1993, Krishnamurthy and Srinivas, 1995; Saraf and Jain, 1996, Jasrotia and Kumar 2014; Jasrotia et al., 2016). Moreover, groundwater is likely to be the least expensive water resource, to improve the water supply coverage in many areas but nevertheless inexhaustible resource that could be exploited without due consideration of its sustainability. However just like surface water groundwater is finite, it must be recharged (Sarafand Choudhury,1998). For this moderately high resolution remotely sensed data and GIS technique is very useful for identifying the recharge and discharge areas. Anbazhagan and Ramasamy (2005) identify the suitable recharge sites of groundwater based on geological, geomorphological, sub-surface geological and water level fluctuation data. The utilization of groundwater has a huge socio-economic advantage which contributes to food security and human health. Therefore, the development of groundwater should be carefully managed to utilize its sustainable potential.

In the present study, large numbers of aquifers in the study area have been identified as transboundary in nature and none of them have been studied jointly by the countries sharing these aquifers. The eventual advantage of such studies would be immense potential that future conflicts can be avoided through proper resource management. Hynes et al., (2008). The recognition of transboundary aquifers should lead to mutual international acceptance of an effective and equitable management of shared groundwater resources.

Study Area

The study area lies between latitude 32^{0} $33^{/}$ $07^{//}$ - 33^{0} $07^{/}$ $30^{//}$ N andlongitude$74^{0}27^{/}00^{//}$ -$77^{/}21^{/}00^{//}$ E and geographical coverage of the area of 3092.52 km^{2} (Fig.1) out of which 1457.60 sq. km is covered by hilly terrain and 1634.92 sq. km. is covered by outer plains, which comprises of Siwalik, Kandi and Sirowal belts and comes under the urban as well as rural developing areas. The area enjoys subtropical to moist temperate climate with an average temperature of 2 -20^{0}C in winter and 30- 47^{0}C in summer the average annual rainfall is about 1116 mm, of which monsoon rainfall is about 800mm. Hence the south-west monsoon passes through the study area. Physiographically, the northern part of the study area is hilly, comprising low to moderately high ridges with moderate to steep slope. Geologically the area covers the formations from Recent to Sub Recent and Miocene in age, such as Siwalik formation, Kandi formation and Sirowal formation. Among these the Kandi region of Jammu district faces acute shortage of drinking water around the year and comprises of fan deposits constituted by boulders, pebbles, cobbles and coarse sand associated with clay and bordering the Siwalik Hills in the EW part of the study area. However, on the basis of lithology the study area has been divided into lower, middle and upper Siwalik subgroups exposed in uplifted thrust sheets that record Middle Miocene to Pleistocene synorogenic foreland basin sedimentation and alluvium Formation of recent to upper Pleistocene (Ranga Rao et al 1988; Jasrotia et al., 2019).

Fig 1: Location Map of Study Area



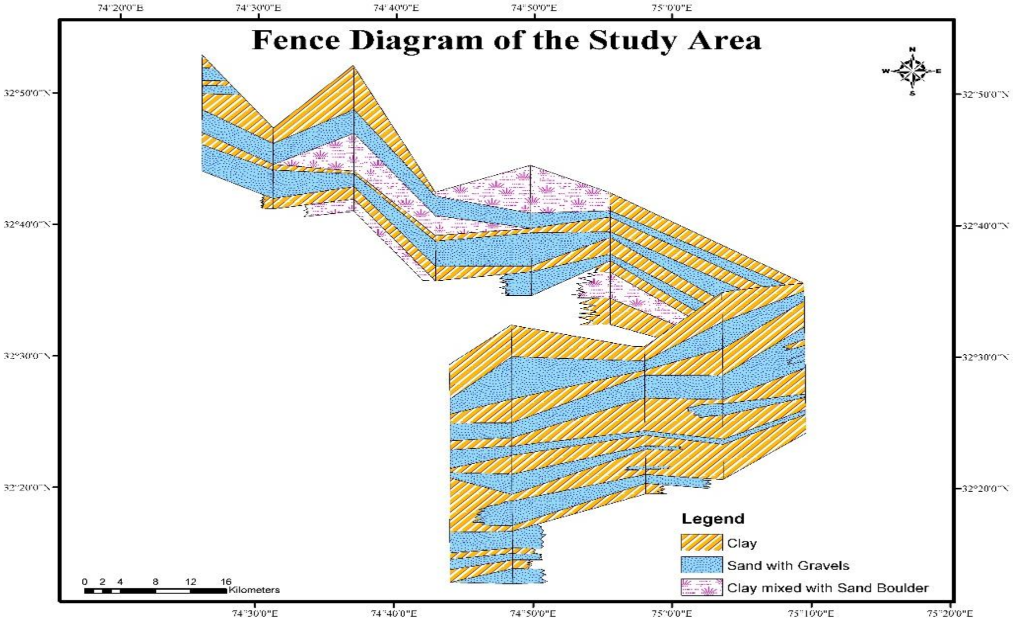
Data Set and Methodology

Survey of India (SoI) topographic map on scale (1:50,000) and field collection (pumping test & water level) data was used to prepare the transmissivity, hydraulic conductivity, water level and water table map of shallow, medium and deep aquifers respectively. For quantification of ground water flow (TIL-method used) all the wells are classified into three different zones (i.e. Shallow aquifer, medium aquifer and deep aquifer). Using ERDAS IMAGINE 10 and Arc GIS 10.5, for preparing the water table map from reduced to mean sea level (msl) of shallow, medium and deep aquifers are prepared to calculate the hydraulic gradient of the study area. From the litholog data, the fence diagram and different subsurface geological cross-sections were prepared, which gives the sub-surface geological information and used to calculate the thickness of the aquifer zone tapped as well as area covered by the aquifers. All these values of shallow, medium and deep aquifers i.e. the specific yield values, thickness of the zone tapped and area covered by the aquifers are used to calculate the storage ground water resources.

Result and Discussion

The fence diagram of the study area has been prepared (Fig.2) by using the available litholog data of various tube wells to understand the nature and extension of aquifers of the study area. The regional picture of subsurface geology (up to the depth of 300m.) shows that there are three distinct regional permeable granular zones (aquifer zone-I, II and III) separated by three impermeable horizons, spread from west to east part of the study area. Each aquifer zone embodies a granular layer alternating with thick or thin clay lenses having almost similar log characteristics indicating hydraulic continuity between them. A perusal of fence diagram reveals that the aquifer zones extends all over the study area, the lateral and vertical disposition of aquifer, aquiclude and aquatard down to the depth of 300m below ground level with varying thickness which comes under unconfined to confined aquifer conditions. The aquifer zone–Ist is composed generally of coarse sediments as compare to the other zones with average thickness of 32.77m which is underlain by an extensive impermeable layer varying in thickness from 8m to 18m thick. The sediments of aquifer zone-II and zone-III are compact and finer in size as compare to the aquifer zone-Ist. The average depth of aquifer zone-II and zone-III is 30.33m and 13.6m respectively which are separated from each other by impervious layer of 7 to 10m thick.

Fig.2. Map showing the fence diagram of the study area



Hydrogeology and Aquifer Characteristics

There are several boreholes lies within different zones of shallow, medium and deep aquifer conditions drilled in the lithostratigraphical successions should be correlated and extrapolated within and adjoining areas across the boundary. The static water level and borehole lithological logs have been recorded from all the boreholes drilled within the aquifer. These data have been analyzed to determine the approximate depth to the aquifer, nature of the aquifer material, thickness of the aquifer zone tapped and piezometric levels of the aquifer. The pumping test data (pumping and recovery) of the boreholes has been analyzed to assume the information of water level, discharge, drawdown, transmissivity, hydraulic conductivity, storage coefficient and specific capacity of the area. The nature of aquifer in the study area is confined in some parts and semi-confined to unconfined in other areas and the aquifer material comprises of sand, sand gravel and sandy clay. Whereas the aquatard comprised of clay, clay sand and boulder clay which are lacking in the area. The tests to be performed in separate boreholes penetrating exclusively in the different aquifers and quantification of groundwater reserve would then be carried out.

Quantification and Management of Transboundary Aquifers

To study the quantification and management of the transboundary aquifer, all the existing tube wells taping the different aquifers and lies in the study area are classified into different zones (on the basis of depth of penetration and thickness of the zone tapped) into three different zones i.e. shallow aquifer condition, medium aquifer condition and deep aquifer condition as shown below (Fig. 3, 4 & 5) and the aquifer parameters of these corresponding wells are calculated and the results are shown in (Table-1, 2 & 3).

Fig.3 Map showing the location of shallow aquifer tube wells

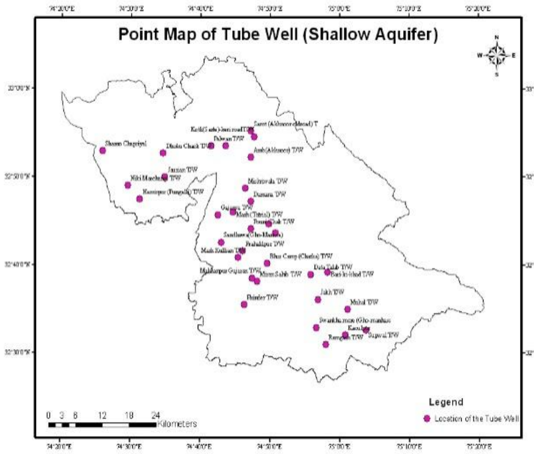


Fig..4 Map showing the location of medium aquifer tube wells

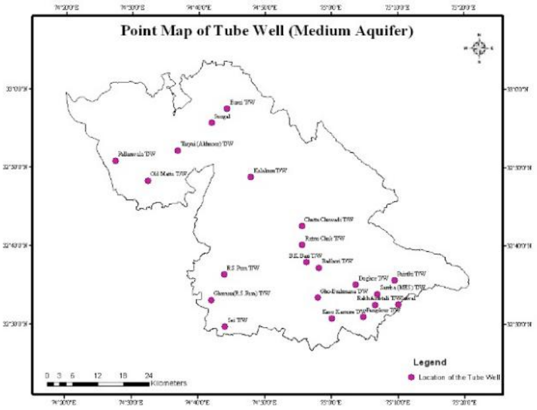


Fig.5 Map showing the location of deep aquifer tube wells.

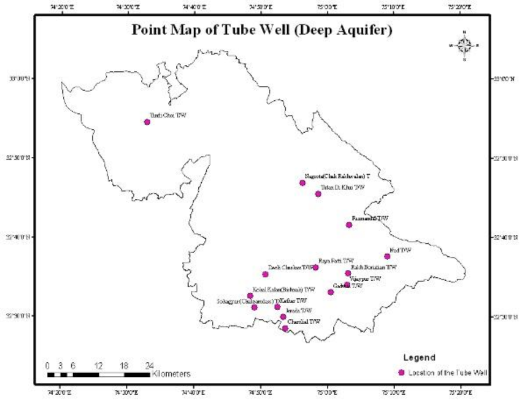


Table.1 Showing The Distribution of Shallow Aquifer Tube Wells

S. No	Name of the Well	Hydraulic Conductivity (m/day)	Trans missivity (m2/day)	SWL (mts)	Thickness of zone tapped (mts)	Depth of the well (mts)	Specific Capacity (lpm/m)	Elevation (mts)
1	AmbAkhnoor	9.3	120.7	44.5	13.0	84.7	93.62	387
2	Bari-ki-khad	4.9	79.9	43.8	16.0	100.0	65.12	410
3	Bhur Camp	1.0	32.7	1.5	30.0	66.4	672.0	287
4	Domana	3.2	65.8	32.3	20.5	85.4	88.0	315
5	Data Talab	10.9	196.7	25.3	18.0	96.0	97.76	355
6	Dhokuchack	17.9	179.7	47.3	10.0	75.0	122.02	380
7	Gajansoo	16.4	370.4	3.1	22.6	71.6	278.0	275
8	Hamirpur	52.8	667.1	5.0	12.6	55.8	182.0	272
9	HC Akhnoor	114.6	2292.6	17.6	20.0	70.5	2804.6	316
10	Jakh	10.1	131.9	18.7	13.0	96.0	50.5	320
11	Jaurian	9.5	177.6	8.2	18.7	70.1	183.0	270
12	Kaoulpur	25.0	600.0	4.3	24.0	82.2	269.4	324
13	Kotli Sarte	5.0	75.7	50.3	15.0	86.9	37.2	360
14	Makhanpur	15.0	585.9	7.5	39.0	85.0	114.3	280
15	Marh Tatrial	130.8	1785.5	1.9	13.6	51.8	810.0	274
16	Marh Kullian	59.1	650.3	0.8	11.0	76.0	202.8	270
17	Miran Sahib.	11.3	599.9	7.3	53.0	71.4	224.3	284
18	Mishriwala	21.5	387.0	12.0	18.0	57.9	455.0	312
19	Mohinder Nagar	27.6	888.7	13.2	32.2	58.0	561.7	300
20	Mohal	62.6	970.4	38.8	15.5	100.0	219.0	370
21	Niki Marchangi	13.2	186.1	3.2	14.1	62.0	146.0	270
22	Ploura	17.2	765.0	21.9	44.5	92.0	645.2	310
23	Palwan	48.6	485.8	42.9	10.0	83.5	179.7	535
24	Phinder	99.7	1197.0	5.3	12.0	92.0	446.8	270
25	Pouni Chak	9.5	209.9	4.4	22.0	70.7	144.0	282
26	Prahaldpur	57.8	1156.0	1.3	20.0	94.5	297.0	270
27	Ramgarh	1.9	57.3	1.5	30.5	103.9	27.0	300
28	Sandhawa	3.9	105.4	3.0	27.0	60.9	53.9	265
29	Sarot Akhnoor	23.1	231.0	48.3	10.0	86.0	115.1	360
30	Shamo Chapriyal	22.0	175.0	26.8	7.9	81.0	37.5	280
31	Swankha Morh	27.3	463.3	11.4	17.0	93.0	71.5	339
32	Supwal	13.7	367.5	5.3	26.7	123.0	88.0	330

Table.2 Showing the Distribution of Medium Aquifer Tube Wells

S. No	Name of the Well	Hydraulic Conductivity (m/day)	Trans missivity (m^2/day)	SWL (m)	Thickness of zone tapped (m)	Depth of the well (m)	Specific Capacity. (lpm/m)	Elevation (m)
1	B.K.Bari	54.7	600.0	20.5	10.9	207.9	329.9	330
2	Badhori	8.3	266.6	26.8	32.0	142.4	225.7	358
3	Barui	4.8	233.3	66.2	49.0	110.2	129.5	260
4	ChataChowdhi	13.1	65.6	25.2	5.0	125.0	59.0	580
5	Dughor	8.98	602.0	22.9	67.0	131.4	380.0	390
6	Gharana	34.83	975.4	6.4	28.0	109.0	295.6	255
7	GhoBrahmna	19.54	606	11.0	31.0	272.0	192.3	320
8	Jatwal	20.0	650	71.3	32.5	145.0	288.5	450
9	KalaKam	13.88	333.3	60.0	24.0	125.0	264.9	358
10	Keso Kamore	11.44	588	3.3	51.38	203.6	308.2	290
11	Old Mattu	93.8	1500.8	5.7	16.0	112.0	277.0	275
12	Painthi	51.07	638.4	2.9	12.5	105.0	453.1	370
13	Pallanwala	28.68	774.4	6.0	27.0	191.0	217.6	265
14	Pangdor	52.26	1052	15.1	20.1	130.0	196.9	340
15	R S Pura	26.08	547.8	5.7	21.0	105.0	219.8	256
16	Rakh Ambtali	107.25	3106	35.2	28.9	131.4	557.6	380
17	Ratnu Chak	7.53	338.9	23.5	45.0	127.0	165.0	330
18	Samba	14.59	281.4	60.0	19.3	137.8	209.7	360
19	Sei	14.91	775.5	5.9	52.0	153.9	237.0	260
20	Sungal	6.87	192.3	61.8	28.0	114.9	194.5	440
21	Taryai Akhnor	37.01	555.2	33.9	15.0	102.0	117.9	490

Table.3 Showing the Distribution Of Deep Aquifer Tube Wells

S. No	Name of the Well	Hydraulic Conductivity (m/day)	Trans missivity (m^2/day)	SWL (m)	Thickness of zone tapped (m)	Depth of the well (m)	Specific Capacity. (lpm/m)	Elevation (m)
1	Chamliyal	15.9	848.0	6.0	53.5	350.0	236.1	290
2	Deoli Chak	3.3	271.8	7.6	81.5	305.5	72.9	287
3	Gadwal	27.5	659.0	5.1	24.0	271.0	82.2	330
4	Jerada Vijaypur	5.5	271.8	8.3	49.0	305.0	23.0	280
5	Kathar	9.0	203.0	7.7	22.5	200.4	76.6	284
6	Kohal Kalan	46.0	783.0	3.7	17.0	204.1	203.2	272
7	Nagrota	2.0	61.5	6.8	31.0	271.0	36.5	350
8	Nud	7.5	376.8	8.8	49.9	229.5	15.4	373
9	Purmandal	0.2	6.0	8.8	30.0	209.0	5.8	460
10	Rakh Boriatian	11.2	191.0	13.2	17.0	301.0	71.6	375
11	Raya Patti	0.9	9.3	26.4	106.9	302.7	253.3	339
12	Sohagpur	30.1	1054.8	6.2	35.0	302.7	307.0	280
13	Thandi Choi	0.2	5.6	1.2	33.0	305.0	4.3	373
14	Tutan-Ki-Khui	0.8	23.5	9.4	29.0	300.0	21.3	400
15	Vijaypur	22.8	571.0	13.2	25.0	270.0	262.3	360

Assessment of Groundwater Potential of Aquifers

The groundwater flow dynamics in confined aquifer is different from that of unconfined aquifer. Because the main source of recharge to any aquifer is rainfall and in case of unconfined aquifer, the recharge is both through vertical infiltration and lateral inflow while in case of confined aquifer; the recharge is through lateral inflow and vertical exchange from top as well as bottom of the aquifers. The recharge zone in the case of confined aquifer is located far apart and there is a dynamic equilibrium between recharge and discharge or outflow from an aquifer because the groundwater is under pressure and the total volume of groundwater storage remains relatively constant. The confined aquifer systems are more sensitive to development than unconfined systems because of their hydraulic properties. In the wells taping the confined aquifers, initially the water level is released from the well storage and subsequently from the compressibility of the fluid and compaction of aquifer material which is controlled by elastic properties of aquifer material. However, in case of unconfined aquifer the mechanism of release of water is mainly because of desaturation of aquifer. The quantity of groundwater involved in storage change in confined aquifers is usually several orders of magnitude smaller than that involved in phreatic aquifers (Karanth, 1963). Assessment of development potential (CGWB Report, 2009) of confined aquifers assumes crucial importance, since the over exploitation of these aquifers may leads to far more detrimental consequences than those of shallow unconfined aquifers. If the piezometric surface of the confined aquifer is lowered below the upper confining layer so that desaturation of the aquifer occurs, the coefficient of storage is no longer related to the elasticity of the aquifer but to the specific yield. The most widely analytical techniques used for assessment of groundwater potential of aquifers are-

a) Storage ground water resources concept.
b) Quantification by groundwater flow rate concept

Storage Ground Water Resources Concept

The abstraction on one side of the boundary may alter the flow through the boundary and the groundwater flow passing through an international boundary cannot be measured directly. It is estimated from hydraulic parameters and calculated through mathematical models. The storage ground water resources for confined and unconfined aquifer conditions can be calculated as under. The storage ground water resources for unconfined aquifer condition.

The storage ground water resources for unconfined aquifer condition can be calculated by multiplying average areal extent of the unconfined aquifer in Km^2 with average specific yield of the area by average thickness of the granular zone in meters. The total storage ground water resources of unconfined aquifer is measured in million cubic meter (mcm) and is defined as

Qu = (A.* Sy.* Tz) mcm

Where,

Qu = Storage ground water resources of unconfined aquifer (mcm)
A = Areal extent of the unconfined aquifer (Km^2)
Sy = Average specific yield of the area (percentage).
Tz. = Average thickness of the granular zone (m.)

In the study area the storage ground water resources for unconfined aquifer condition is Qu

The Areal extent of the unconfined aquifer (A)= 1634.92 Km^2

The average specific yield (Sy) = 18 percent

The average thickness of the granular zone (Tz.) = 32.77 m.

(Qu) = 18 %*32.77*(1634.92)
= 0.18*32.77*1634.92
= 9643.74 mcm

The storage ground water resources for confined aquifer condition

The co-efficient of storage or storativity of an aquifer is defined as the volume of water it releases or takes into storage per unit surface area of the aquifer per unit change in head. Hence the quantity of water added to or released from the entire aquifer can be calculated by using Storativity method.

The storage ground water resources for Confined aquifer condition of the study area

The area of the confined aquifer (A) = 1547 Km^2

The average Storativity (S) = 9.24*10^{-4}

The Average granular thickness in confined aquifer = 171m.

The Average Pre-monsoon water level. = 17 m.

The Average depth of bottom of first confining layer = 85 m.

The pumping water level (h_0) = 85 m.
Pre-monsoon water level (h_1)= 17 m.
$\Delta h = (h_0 - h_1) = 68$ m.

The storage ground water resources for confined aquifer (Q_p) condition of the study area can be calculated by multiplying the average area of the confined aquifer with average Storativity of the study area by Δh (difference between pumping water level and pre-monsoon water level) the ground water resources under confined aquifer condition (Q_p) is measured in million cubic meter (mcm) and is calculated as

(Q_p)= A*S*Δh
= 1547*9.24*10-4*68
= 1547*0.000924*68
= 97.20 mcm

Where,

Q_p = Quantity of water under pressure (m^3)
S = Average Storativity
Δh =Difference between pumping water level and pre-monsoon water level.

During the continuous pumping the water level decreases respectively, when the water level touches the first confining layer. The confined aquifer starts behaving as unconfined aquifer (Fig. 6) under such circumstances the ground water resources of this aquifer are estimated and the total Storage ground water resources of this aquifer is measured in million cubic meter (mcm) and is defined as

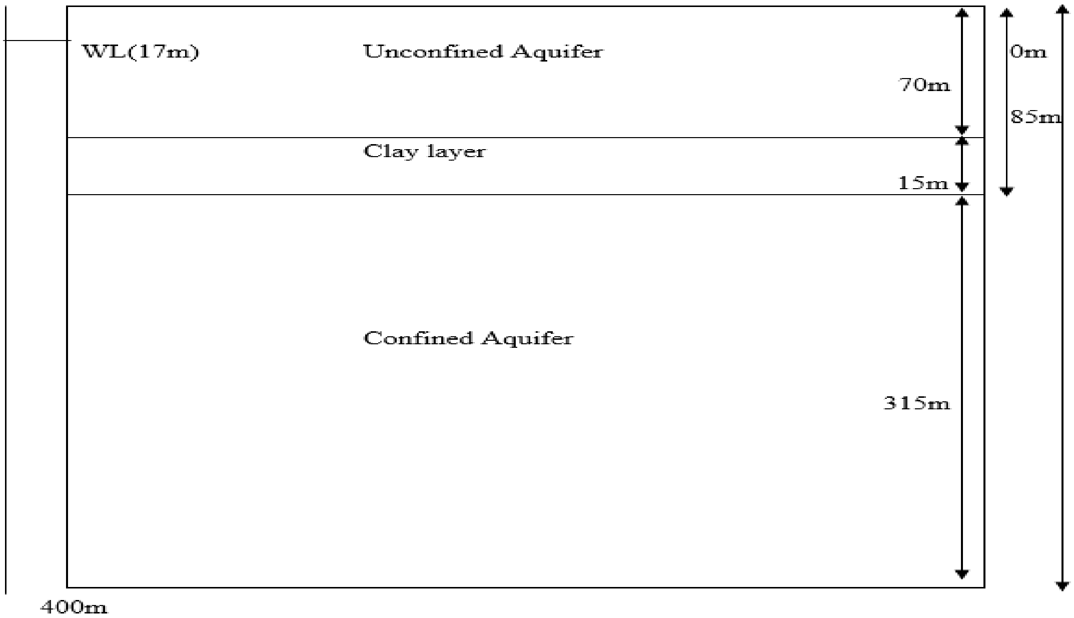
Q_{p2} = (A.* Sy.* Tz) mcm

= 1547*(0.108)*171
= 28570mcm

Hence, the total storage ground water resources, for both confined aquifer and unconfined aquifer condition ‘Q’ is

$Q = Q_u + Q_p + Q_{p2}$
$= 9643.73 + 97.20 + 28570$
$= 38310.94$ mcm

Fig.6. Showing the behavior of the aquifer in different conditions



Determination of Flow Direction and Recharge Characteristics of The Groundwater

To determine the flow direction, the groundwater contours were prepared using different boreholes data of piezometric heads in the study area. The piezometric head contours are more or less parallel to the topographic contours. The contours are plotted from the values of static water table of different wells lies at shallow, medium and deep aquifer conditions when the aquifer is not subjected to pumping. The water table contour maps of shallow, medium and deep aquifer are used to calculate the hydraulic gradient of the study area (Fig. 7, 8 & 9). It is estimated that the groundwater flow direction is generally towards the south-west direction which is usually in the opposite direction of the increasing hydraulic gradient. These contour maps of groundwater table will show the flow trend from one contiguous country to another which gives the essential information for management of the shared groundwater water resources.

Fig.7. Map showing Water Table (Reduced to MSL) of Shallow Aquifer Tube Wells

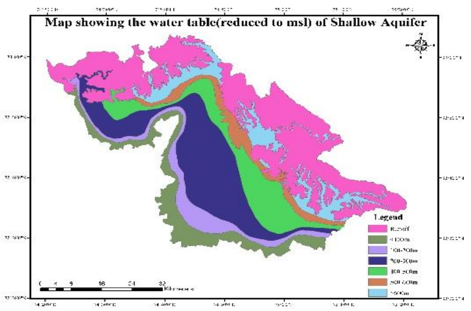


Fig.8. Map showing Water Table (Reduced To Msl) of Medium Aquifer Tube Wells

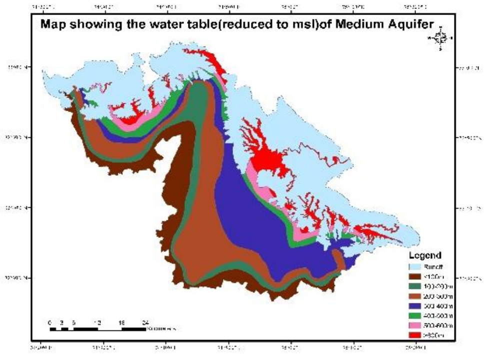
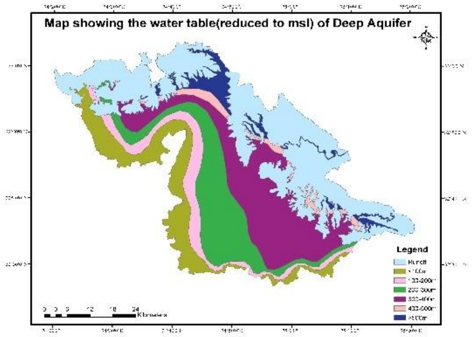


Figure.9 Map showing water table (reduced to msl) of deep aquifer tube wel



Quantification by Groundwater Flow Rate Concept

The quantity of groundwater flow, passing an international boundary cannot be measured directly. It is estimated from hydraulic parameters. The ground water available in a confined aquifer equals the rate of flow of water through this aquifer. The rate of ground water flow available for development in a confined aquifer in the area can be estimated by using Darcy's law. In this method the quantity of water flow 'Q' (of shallow, medium and deep aquifer condition in m^3/day) has been calculated by multiplying Transmissivity of the area, Hydraulic gradient and the Length of cross section of area and defined as.

$Q = TIL$

Where,

Q = Rate of flow through a cross- section of aquifer in m^3/day.

T = Transmissivity in m^2/d

i = Hydraulic gradient ratio.

L = Length of cross section of area

The quantity of water (Q_1) flows (along different parts) across the transboundary in shallow aquifer condition of the study area is calculated as.

$$
\begin{aligned}
Q_1 &= Til \\
&= 422.47 * 0.022 * 122118.02 \\
&= 1135006.4 \ m^3/d.
\end{aligned}
$$

The Quantity of water (Q_2) flows (along different parts) across the transboundary in medium aquifer condition of the study area is

$$
\begin{aligned}
Q_2 &= Til \\
&= 728.47 * 0.027 * 122118.02 \\
&= 2401901.48 \ m^3/d.
\end{aligned}
$$

The Quantity of water (Q_3) flows (along different parts) across the transboundary in deep aquifer condition of the study area is

$$
\begin{aligned}
Q_3 &= Til \\
&= 162.05 * 0.025 * 122118.02 \\
&= 494730.63 \ m^3/d
\end{aligned}
$$

The total quantity of water (Q) flows across the transboundary in shallow, medium and deep aquifer conditions of the study area is.

$$
\begin{aligned}
Q &= Q_1 + Q_2 + Q_3 \\
&= 1135006.4 + 2401901.48 + 494730.63 \\
&= 4031638.5 \ m^3/d
\end{aligned}
$$

Hence the total quantity of groundwater which flows and passing an international boundary from different parts in Jammu district is estimated from hydraulic parameters and calculated through mathematical models by using Darcy's law in shallow, medium and deep aquifer condition is 4031638.5 m^3/d.

Conclusion

To quantify the storage ground water resources and management of groundwater flow passing an international boundary across the transboundary aquifer of the study area.All the existing tube wells lies in the study area are classified into three different zones i.e. shallow, medium and deep aquifer conditions. The different thematic layers are prepared by the field collection data such as transmissivity map water level map, Water table map (from reduced to msl) of shallow, medium and deep aquifer respectively. The storage ground water resources for unconfined aquifer condition has been calculated from the average areal extent of the unconfined aquifer in square kilometer with average specific yield of the area by average thickness of the granular zone and the total storage ground water resources of this aquifer is 38310.94 mcm. The total quantity of groundwater flow passing an international boundary from different parts in Jammu district is estimated from hydraulic parameters and calculated through mathematical models by using Darcy's law in shallow aquifer condition is 4031638.5 m^3/d. In this regard it is suggested that groundwater flows passing an international boundary can be managed using the artificial recharge techniques.

Acknowledgement

The authors are thankful to unanimous persons those providing the support for the completing of this task.

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