Aquifer characterization of Quaternary alluvium sequence of Northwest Himalayas

B Abhishek*, Vidya Nand Negi, Sidhanta Kumar Sahu, Vikrant Singh, Rayees Ahmad Pir

Abstract

For sustainable development of the Kashmir valley, it is essential to understand the nature of water resources. Groundwater forms a substantial part in sufficing the drinking and domestic use of the local population. Groundwater is stored in the aquifer, a rock unit acting as a conduit for water storage; however, the quantum of water released from it is highly dependent on the transmissivity of the aquifers. The transmissivity variation in quaternary alluvium deposits of the Kashmir valley in the Northwestern Himalayas was analyzed to correlate the aquifer homogeneity and continuity. The transmissivity analysis and its spatial relationship were carried out using Jiri Krasny's (1990) transmissivity classification system based on transmissivity magnitude and variation. Negative, positive, extremely positive, and negative anomalies were obtained for the transmissivity values of the aquifers. Based on the studies, it was observed that the aquifer was considerably heterogeneous within the same district and even within a single aquifer system, and large-scale mapping (1:10000) is required to obtain the aquifer continuity. The places with extreme positive and positive anomalies are suited for large water supply schemes, whereas the extreme negative areas are suitable for forming the waste treatment plant.

Keywords – Alluvium, Aquifer, Groundwater, Karewas, Magnitude, Statistical testing, Transmissivity.

1. Introduction

In recent decades the dependency on groundwater for domestic, agricultural, and irrigation purposes has increased manifold due to which in-depth idea of the nature of the available resources, their behavior to stress conditions has become extremely important for the sustainable development of the resources. The occurrence and movement of groundwater within an area are primarily controlled by the aquifer rock type, topography, and drainage. Aquifer Geometry is mostly determined directly by drilling and indirectly by geophysical studies. From pumping test behavior of the aquifer in different stress conditions is deciphered. Aquifer parameters like transmissivity helps in determining the rate of groundwater flow and act as an effective parameter for groundwater evaluation and assessment. The Kashmir valley lies in the northern part of India within the Union-Territory of Jammu and Kashmir. The shape of the valley is bowl-shaped covering one-fourth to half of the total area of all the ten districts within the Kashmir region of UT of J&K. The valley is drained by Jhelum and its tributaries like Rembiara, Vishva, Zali, Romush, Shanganga, Lidder, Sind, Lolab, Pohru. The Kashmir valley is composed of the Pliocene to Pleistocene alluvial sequence of Karewas, overlain by Pleistocene-Holocene sediments consisting of alluvium moraines, hillwash, and scree deposited by Jhelum River and its tributaries in a fluvio-lacustrine depositional environment.

The stage of groundwater development is 21 % in Jammu & Kashmir (Report on Dynamic resource estimation 2020), representing that there is further scope for groundwater development. Transmissivity is a very important parameter determining the behavior of the aquifer, and it can be classified according to magnitude and variation. (Krasnys,1993). The elements of rock heterogeneity and the extent of researched areas substantially influence the statistical distribution and current value of permeability and transmissivity (Rats, 1967). The lack of information on the behavior of aquifer and lithological variation along the valley has led to uncertainty in predicting the economics of the water well and increased costing and failure of tube wells due to improper well development methodologies. Whereas improper selection of sites for waste fills, will lead to contamination of the groundwater.

On the other hand, increasing stress on the aquifer due to increased groundwater abstraction has made it mandatory to ascertain the recharge zones within the area to achieve managed aquifer

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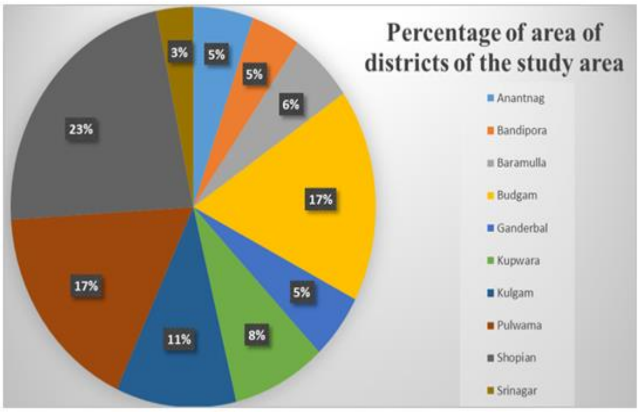
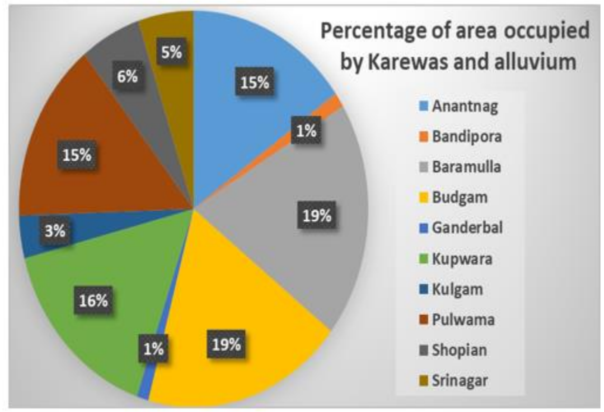
recharge. In this study, aquifer characterization is achieved by pumping test, and its spatial relationship is ascertained through ArcGIS. Aquifer type and their vertical extent is determined through borewell logs and water levels in dug wells, and groundwater potential of the Kashmir valley is ascertained through aquifer parameter analysis which will aid to provide information of the productive areas.

Figure 1 statistical data of the study area.





2. Study area

The study area lies between 33.516921˚ N to 34.640389˚ N latitude and 74.028665˚ E to 75.293739˚ E, covering a total area of 5096 Km^2. From a groundwater recharge point of view, only areas with a slope of less than 20% were used to delineate the study area's boundary. The Kashmir valley lies in North-west Himalayas in the UT of Jammu & Kashmir and is surrounded on all sides by Pir-Panjal ranges which also underlies the Karewas and recent alluvium deposits. The total area of the valley distributed along with all the ten districts of summarized in table-1 and Figure-1

Table 1 Proportion of areas covered under the study

District	Total Geographical Area in SqKm	Study area in SqKm	Percentage of district	Percentage of Valley area
Anantnag	3574	628	17.6	15.1
Bandipora	354	51	14.4	1.2
Baramulla	4243	799	18.8	19.2
Budgam	1361	773	56.8	18.6
Ganderbal	259	45	17.4	1.1
Kupwara	2379	653	27.4	15.7
Kulgam	410	144	35.1	3.5
Pulwama	1086	614	56.5	14.8
Shopian	312	234	75.0	5.6
Srinagar	1979	213	10.8	5.1
Total	**15957**	**4154**		

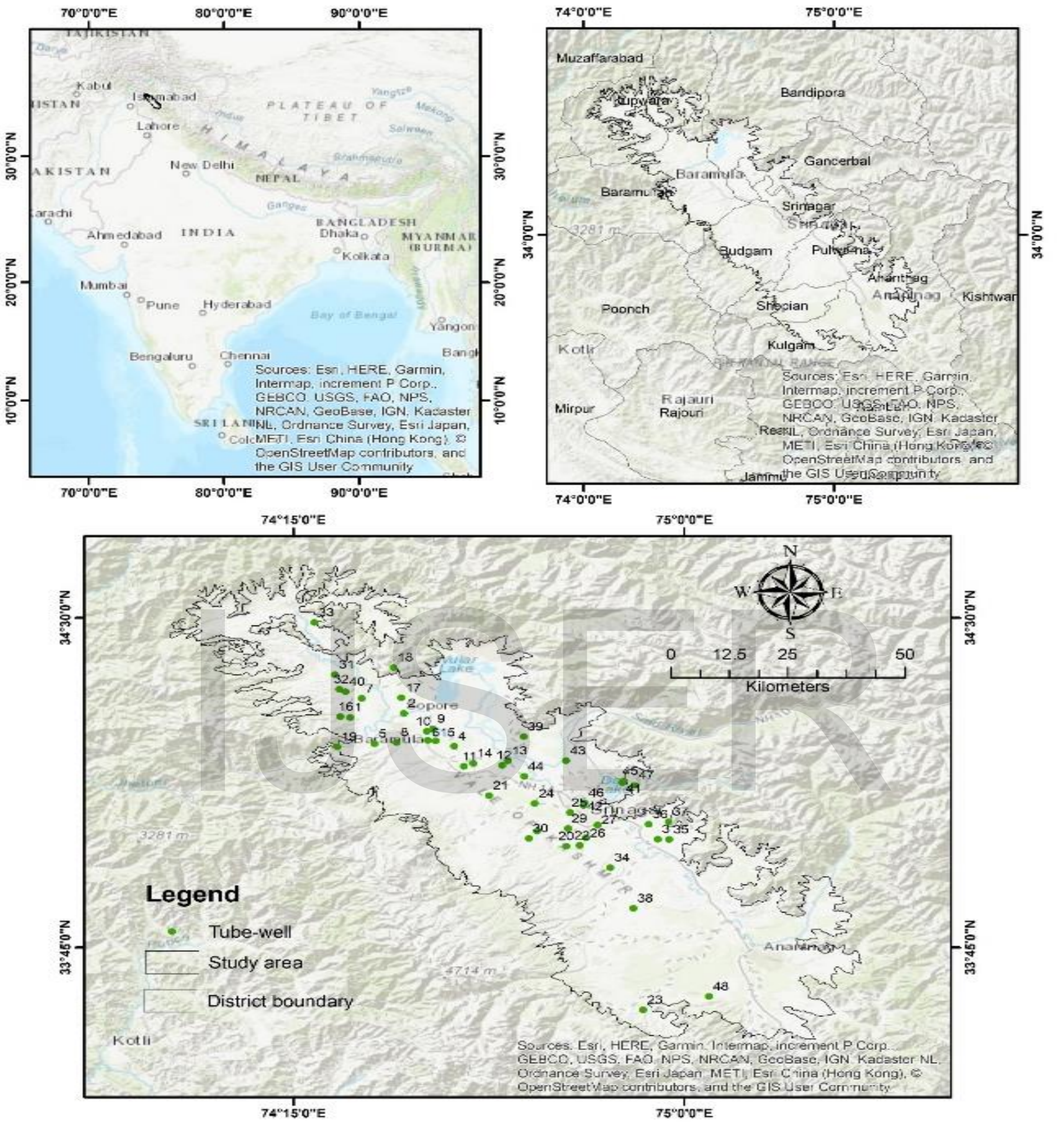


Figure 2 Location map of the study area

2.1 Geology-

The intermountain valley of Kashmir consists of rock formations ranging from Archean to Recent times (Figure-3). Two major geological formations overlie the Archean Salkhala formation: the Panjal Volcanic Complex and the Triassic Limestone. Tectono-geomorphic reveals the presence of paleolake known as the Karewa lake in which the sediments were deposited during the uplift of the Karewas. The sediments of the Karewa Group are fluvial, glacial-fluvial, and lacustrine in nature ranging in age from the Pliocene to Pleistocene and constitute an unconsolidated to semi–consolidated sand-clay-conglomerate sequence. The thickness of the Karewa sediments varies between 1300 and 1800 m (Kotlia,1985a; Bronger et al., 1987; Kotlia and Koenigswald, 1992; Basavaiah et al., 2010; Dar et al., 2014) and has been extensively studied by various workers from time to time over the past few decades (Bhatt,1976; Kotlia et al., 1982, 1998; Burbank, and Johnson, 1983; Agrawal et al., 1985, 1989; Kotlia, 1985a,b,1990, 1992, 2013; Sahni and Kotlia,1985; Kusumgar et al., 1986; Kotlia and Mathur, 1992). The Kashmir valley consists of an alluvial rock sequence of Karewas and quaternary alluvium. The detailed stratigraphic succession of the Kashmir valley is illustrated in Table-2. The lower Karewa sediments comprise bluish, grey clay, silt, and sand greyish, interspersed with gravel. The Dilpur formation is separated from the Nagum formation by conformable contact. The Nagum formation consists of fine to coarse greenish and purplish and grey and ochre sandy clay, ochre and cream-colored marl and gravel. The Dilpur formation comprises of loam deposits.

Table 2 Scheme of Sub-divison of Karewa sequence (after Bhatt, 1989)

AGE		LITHOSTRATIGRAPHY		KASHMIR VALLEY		
				SOUTHWESTERN PART	NORTHEASTERN PART	
RECENT		ALLUVIUM		ALLUVIUM		
PLEISTOCENE	Upper	KAREWA GROUP	DILPUR FORMATION	DILPUR FORMATION		
	Middle		NAGUM FORMATION	Shupian Member	Pampur Member	Krungus Member
	Lower		HIRPUR FORMATION	Methawoin Member	Sporadically exposed	
PLIOCENE	Upper			Rembiara Member		
	Lower			Dubjan member		
		PRE-KAREWA		MOSTLY PALEOZOIC AND TRIASSIC BASEMENT		

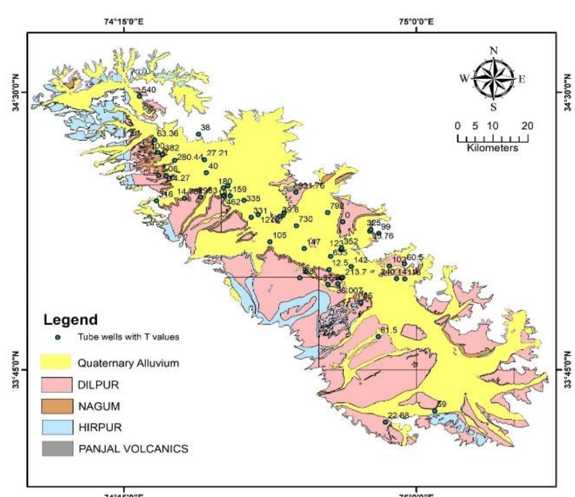


Figure 3 Geological map of the study area

2.2 Hydrogeology –

The synclinal basin of Kashmir valley consists of a thick deposit of sediments of glacial and interglacial origin. The Jhelum River and its tributaries deposited sediments ranging from coarse sand, gravel, and pebble, forming massive flood plains. The alluvial deposits of the recent period and the Middle Karewas form the major aquifer system. The groundwater level in the alluvial formation ranges from ground level to 3 mbgl and is mostly unconfined.

The Karewa group has been subdivided into Hirpur, Nagum, and Dilpur formations. The Hirpur formation is exposed along the southwestern flanks of the Kashmir valley overlying the Panjal Traps. The groundwater occurence in this region is along with the fractured basaltic and andesitic traps of Pir Panjal. In the central part of the valley, the aquifer comprises sediments of middle and lower Karewas. The lower Karewas forms the most prominent aquifer with numerous water-bearing zones. The piezometric surface is two to ten meters above ground level. The granular region forming the aquifer in Kashmir valley is irregular in disposition. The transmissivity of the aquifer in the Kashmir valley ranges between 3.06 m^2/day to 931.76 m^2/day. Most of the aquifer zones are encountered as small patches upto a depth of 400 meters in the center part of the basin. However, they are restricted to 100 meters on the eastern and western flanks. The piezometric surface is above ground level, and most of the well are artesian wells. Few patches of the perched aquifer are encountered along the Dilpur formation.

3. Materials and Methodology

Data Acquisition

The data of Pumping tests conducted by Central Ground Water Board in forty-nine tube wells throughout the Kashmir valley area was used to access aquifer properties. The lithology of the wells were made onsite. Constant rate pumping test method with a single well was used. The method involved data acquisition in three phases. In the first phase Preliminary Yield test was conducted for 100 minutes for identifying the maximum discharge of the wells. In the second phase Step Drawdown test was conducted 60 to 100 minutes in three to five steps to know the well efficiency and in the third phase Aquifer Performance test was the duration of which varied from 300 minutes to 1000 minutes which consisted of pumping phase and recovery phase. Water level was measured using steel tape using Cut and hold method.

Data Interpretation

The Aquifer properties like Hydraulic conductivity, Transmissivity (T), and Specific capacity (Sc) were determined using Cooper and Jacob solution method and Theis recovery method. The data of the Aquifer Performance test was analyzed using a Semi-log format. The time was plotted in X-axis, and drawdown and residual drawdown were plotted in the Y axis. The transmissivity of the confined aquifer is obtained by Jacob straight lines method, which can be determined by the equation-

$$\boldsymbol{T} = \frac{2.3Q}{2\pi\Delta S} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where,
T = Transmissivity in meter square per day.
Q = discharge in meter cube per day.
ΔS = Change in drawdown over one logarithmic cycle.
Sc = Specific capacity

In the Theis recovery method t/t' is plotted in X axis and residual drawdown is plotted in Y axis The transmissivity and Specific capacity were determined by Theis recovery method using the equation-

$$\boldsymbol{T} = \frac{2{\cdot}30Q}{4\pi\Delta S} \text{ or } 0\cdot 183\left(\frac{Q}{\Delta s}\right) \ldots\ldots\ldots \quad (2)$$

$$\boldsymbol{Sc} = \frac{Q}{\Delta s} \quad \ldots\ldots\ldots\ldots \quad (3)$$

Where,
Sc = Specific capacity

From the Step Drawdown Test data, well efficiency, formation loss and well loss was calculated graphically using specific discharge in X axis and Specific drawdown in Y axis. From the Drawdown vs. Time graph corrected drawdown was calculated as shown in figure-4. And a comparison of drawdown and recovery curve is illustrated by figure-5

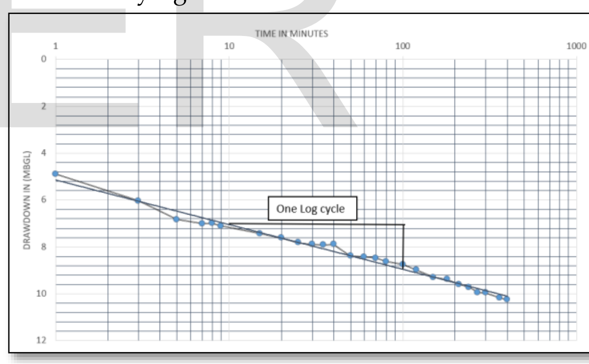


Figure 4 time vs drawdown plot – Procedure to estimate transmissivity value through Jacob straight line method

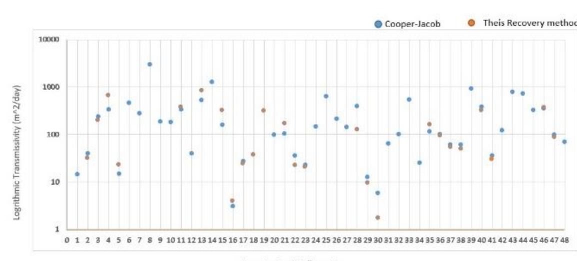
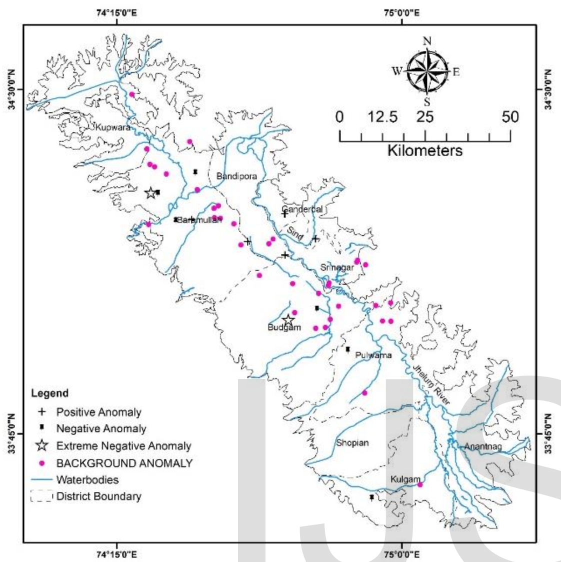


Figure 5 Comarison of Theis and copper Jacob method.

4. Result and Discussion

4.1 Spatial Variation in Transmissivity

Figure 2 denotes the spatial distribution of transmissivity values along the valley floor, which shows some relationship to the geology of the area. The low transmissivity aquifers are lower along upper Karewas, while the high transmissivity aquifer is found along the center of the valley, with transmissivity ranging from 14.7 to 1276 m^2/day. The high transmissivity is apparently due to recharge from the Jhelum river and its tributaries. Numerous discontinuous zones of Aquifers are present all along the valley floor. In the southern part of the valley, most of the tube wells were dry, and no prominent zones were encountered and also the presence of numerous springs also shows light on the nature of the underlying beds, which are essentially impervious limestones and Panjal volcanic. The southern and the western region of the Kashmir valley is chacterized by very low transmissivity shallow zones with extreme negative anomalies.



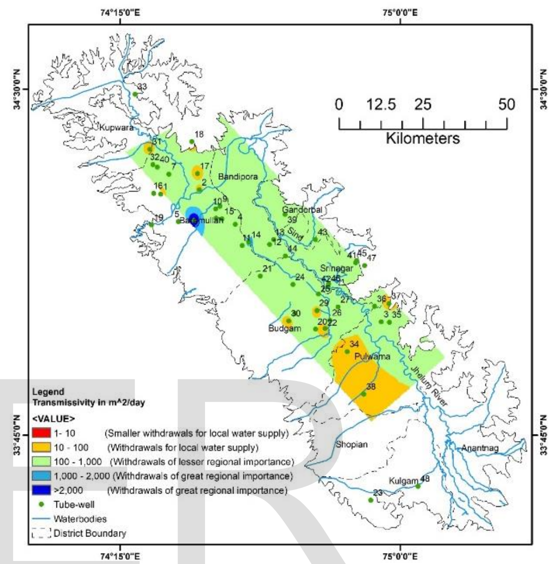


Figure 7 Transmissivity variation in the study area

Figure 6 Transmissivity anomalies within the study area

4.2 Transmissivity Analysis

The two primary methods for carrying out transmissivity analysis are Statistical testing and Krasny's classification. The statistical testing involves identifying background transmissivity and anomalies, and the other method is based on the classification scheme introduced by Krasny in 1993. Statistical Testing

In this approach all the transmissivity values collected are pooled in a particular region using Transmissivity index 'Y'. The relationship between transmissivity (T) and logarithmic Transmissivity index (Y);

$T\ (m^2/day) = 10^{Y-8.96} \times 86400$ ………(1)

The above relationship was found by Jetal and Krasny in 1968, is used to calculate the logarithmic Transmissivity index (Y) from transmissivity (T) values. Equation 1 can be modified as;

$$Y = log\left(\frac{T}{86400}\right) + 8.96 \quad \text{………….(2)}$$

Where,

T = Transmissivity in m^2/day

The interval between (mean – standard deviation) and (mean + standard deviation) of the logarithmic transmissivity index values represent the background transmissivity. The values outside the interval are considered positive or negative anomalies. The positive anomalies represent prospective zones for groundwater exploration, while less favorable zones are represented by the negative anomaly. Extreme anomalies can be found outside the intervals [mean ± (2 × standard deviation)]. The classification is tabulated in table 3. The logarithmic transmissivity index (Y) values are calculated using the modified equation, and the calculation are tabulated in Table 2. The mean value of the transmissivity index is obtained as 6.11 and the standard deviation of the transmissivity index is 0.63. The classification is summarized in table 4.

Table 3 Transmissivity analysis based on Transmissivity index Y Classification

Classification	Description	Range of Y of the studied area
Negative extreme anomalies	Less than [mean – (2 * standard deviation]	<4.86
Negative Anomalies	Between (mean – standard deviation) and [mean – (2 * standard deviation]	5.49 - 4.86
Background Anomalies	Between (mean – standard deviation) and (mean + standard deviation)	5.49 - 6.74
Positive Anomalies	Between (mean + standard deviation) and [mean + (2 * standard deviation]	6.74 - 7.37
Positive extreme anomalies	Greater than [mean + (2 * standard deviation]	>4.86

4.3 Krasny's Classification

Jiri Krasny (1990) proposed a transmissivity classification system based on transmissivity magnitude and variation based on transmissivity and transmissivity index values. The classification method for transmissivity magnitude and variation is tabulated in table 4, 5 and 6 and presented in figure 6 and 7.

Table 4 Krasny's Classification of Transmissivity Magnitude

Coefficient of Transmissivity (m2/day)	Class of Transmissivity magnitude	Designation of Transmissivity Magnitude	Groundwater Supply Potential
>1000	I	Very High	Withdrawals of great regional importance
1000 - 100	II	High	Withdrawals of lesser regional importance
100 – 10	III	Intermediate	Withdrawals for local water supply (small communities and plants)
10 – 1	IV	Low	Smaller withdrawals for local water supply (private consumption)
1 – 0.1	V	Very Low	withdrawals for local water supply with limited consumption.
<0.1	VI	Imperceptible	Sources for local water supply are difficult

Table 5 Krasny's classification of Transmissivity Variation

The standard deviation of Transmissivity Index (Y)	Class of Transmissivity variation	Designation of Transmissivity Variation	Hydrogeological Environment
< 0.2	A	Insignificant	Homogenous
0.2 – 0.4	B	Samll	Slightly Heterogenous
0.4 – 0.6	C	Moderate	Fairly Heterogenous
0.6 – 0.8	D	Large	Considerably Heterogenous
0.8 – 1.0	E	Very Large	Very Heterogenous
> 1.0	F	Extremely Large	Extremely Heterogenous

Table 6 Transmissivity classification for data collected in Kashmir valley

S.No	Location	T-Jacob	Transmissivity index Y	Classification	Designation of Transmissivity variation	Designation of Transmissivity variation
1.	Rihoma	14.27	5.18	Negative anomalies	Intermediate	Large

2.	Sopore	40	5.62	Background Anomalies	Intermediate	Large
3.	Deva Karanchoo	240.14	6.40	Background Anomalies	High	Large
4.	Ghoshbug	335	6.55	Background Anomalies	High	Large
5.	Chandsuma	14.78	5.19	Negative anomalies	Intermediate	Large
6.	Ranji	462	6.69	Background Anomalies	High	Large
7.	Watergam	280.44	6.47	Background Anomalies	High	Large
8.	Naugam	2983	7.50	Positive anomaly	Very-high	Large
9.	Haigam Trumb Gund	187	6.30	Background Anomalies	High	Large
10	Haigam	180	6.28	Background Anomalies	High	Large
11	Devar Yakmanpura	331	6.54	Background Anomalies	High	Large
12	Yakmanpura	39.6	5.62	Background Anomalies	Intermediate	Large
13	Trigam Shadipora	526.9	6.75	Background Anomalies	High	Large
14	Trikulbal	1276	7.13	Positive Anomaly	Very-high	Large
15	Hamray-Ranji	159	6.22	Background Anomalies	High	Large
16	Naugam Tragpora	3.06	4.51	Negative extreme anomaly	Low	Large
17	Saidpora-Zaingar	27.21	5.46	Negative anomalies	Intermediate	Large
18	Latishot	38	5.60	Background Anomalies	Intermediate	Large
19	Khanpora	316	6.52	Background Anomalies	High	Large
20	Satsukalan	97.83	6.01	Background Anomalies	Intermediate	Large
21	shibpur	105	6.04	Background Anomalies	High	Large
22	Cith	36.007	5.58	Background Anomalies	Intermediate	Large
23	Dhamal Hanjipora	22.88	5.38	Negative anomalies	Intermediate	Large
24	Suibug	147	6.19	Background Anomalies	High	Large
25	Bemina (P.stn)	635	6.83	Background Anomalies	High	Large
26	Karalpura	213.7	6.35	Background Anomalies	High	Large

27	Naugam	142	6.18	Background Anomalies	High	Large
28	District police line	396	6.62	Background Anomalies	High	Large
29	Humhama	12.5	5.12	Negative anomalies	Intermediate	Large
30	Mamat	5.8	4.79	Negative extreme anomaly	Intermediate	Large
31	Pandipura	63.36	5.83	Background Anomalies	Intermediate	Large
32	Rawalpura	100	6.02	Background Anomalies	High	Large
33	Drugmulla	540	6.76	Background Anomalies	High	Large
34	Hayatpura	25	5.42	Negative anomalies	Intermediate	Large
35	Dussoo	116	6.09	Background Anomalies	High	Large
36	Bafina	102	6.03	Background Anomalies	High	Large
37	Green colony Wayun	60.5	5.81	Background Anomalies	Intermediate	Large
38	Badrivan	61.5	5.81	Background Anomalies	Intermediate	Large
39	Badampur	931.76	6.99	Positive anomaly	High	Large
40	Badrahpayeen	382	6.61	Background Anomalies	High	Large
41	Upper Ishber	35.76	5.58	Background Anomalies	Intermediate	Large
42	Karannagar	123	6.11	Background Anomalies	High	Large
43	Gadurah	792	6.92	Positive anomaly	High	Large
44	Tokenwaripura	730	6.89	Positive anomaly	High	Large
45	Panthachowk	325	6.54	Background Anomalies	High	Large
46	Iqbal Park	352	6.57	Background Anomalies	High	Large
47	Tulip Gardens	99	6.02	Background Anomalies	Intermediate	Large
48	Kuchipura	69	5.86	Background Anomalies	Intermediate	Large

Conclusion:

The central axis of the valley floor consists of high to very high transmissivity aquifers. The large transmissivity variation along the valley indicates that the hydrogeological environment is considerably heterogeneous. The periphery of the valleys is at high altitudes and consists of steep topography usually associated with extreme negative and negative anomalies. Whereas in the central part, the potential of the aquifer is very high, showing positive and background anomalies; these aquifers are well suited for local as well as regional water supplies. The places like Mamat and Nagum Tragpora showed Negative extreme anomalies and are wells suited for waste treatment plants, however despite of the low transmissivity of the aquifer these areas shouldnot be used for dumping landfills as these hilly areas form the catchment area of Jhelum and its tributaries.

ACKNOWLEDGEMENT

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