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ENVIRONMENTAL MANAGEMENT OF QUALITY OF GROUNDWATER IN AKOT REGION, AKOLA DISTRICT, MAHARASHTRA

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Abstract

The study assesses the extent of change in some hydrological and geomorphologic aspects within the Shahnur river basin of Akot region, Akola District, Maharashtra. Detailed hydro-geological geophysical and hydro-geochemical investigations have been carried out for the Akot region, Akola district, Maharashtra with an aim to understand the hydro-geochemical, geological, geomorphologic and environmental control on the groundwater regime of the region. The study area is characterized by the presence of alluvial tract which is underlined by the horizontal sequence of lava flows which can be divided into simple and compound units based on their field characters, textual parameters and geomorphic expression. In addition, spatial distribution of relative relief and land cover in each l km2 grid were used to map potential soil erosion in the drainage basin. Stream network extent, computed from drainage densities were used to establish the sediment transport capacity for the Shahnur River. Cyclic and non-cyclic visual determination of trends in climatic and hydrologic components was computed by use of various analytical techniques. Time series analysis using regression lines and running averages were computed to examine any cyclic events in the trends. In addition to this, analysis of seasonality patterns was also calculated to establish month to month variability in the trends. Characteristics of extreme low flow events in the downstream direction of River were computed by use of frequency and probability analysis of recurrence intervals. Arc View Geographical Information Systems (GIS) algorithms were used to compute spatial distribution of areas with topographic potential for erosion and directional derivatives of surfaces representing sediment transport routes. Major element chemistry of groundwater samples from dug wells and bore wells from 150 selected sites from the Akot region has been analyzed during pre-monsoon and post-monsoon periods to understand the groundwater quality and its impact on the environment. Detailed geophysical resistivity surveys were carried out to understand the subsurface lithology aquifer parameters. Various thematic maps showing the distribution of various elements and their ratios along with iso-contour maps of physico-chemical parameters have been utilized to understand the water quality management of the region. Geological, hydrogeological, geophysical and water quality studies have thrown light on the water level fluctuations in the region with emphasis on water resource and environmental management. The results of the chemical analysis indicate that in the Deccan Trap regions, both the surface and groundwater are suitable for drinking and irrigation purposes; however, in the alluvial zone brackish water is predominant. The highly fractured, amygdaloidal and weathered basaltic horizons have yielded sufficient amount of water whereas, the compact and massive portions show poor yield in the region. In this study, an attempt has been made to suggest various suitable measures for improving the groundwater recharge potential and salinity problem of the area with due emphasis on water resource management. Detailed environmental analysis was carried out to understand the water level fluctuations and quality of water. In addition, suitable remedial measures were suggested for water resource development and management of the region. Thus the inter stream area has registered higher concentration of various chemical constituents in the groundwater. The groundwater is Mg - Ca - HCO_3 – Cl type as indicated in the hydro-chemical piper plots of groundwater samples in the district. The groundwater quality in the Wilcox diagram shows that most of the samples are under C_2S1 and C3S1 category

Introduction

The area of investigation is characterized by the presence of alluvial zone showing saline tract towards the north and basaltic lava flows showing horizontal nature towards the southern part. The shallow unconfined aquifers, which are tapped by means of dug wells, are the largest producers of groundwater in the region. Reeder et.al. (1972) have concluded that the salinity of the water is largely controlled by litho logy with high salinities regulating from carbonates and evaporates. Miller and Drever (1977) showed various chemical relationships between soil, bedrock lithology and runoff chemistry. They also suggested that water chemistry is dependent on slight alteration of host rock without development of chemical equilibrium involving secondary phases in the soil zone.

Methods of Study

The work done so far in understanding hydrogeological factors controlling the water quality is very limited. In this study, an attempt has been made to analyze the hydrogeological parameters to understand the water quality management of the Akot region, falling in survey of India Toposheet No. 55G/4 (Fig. 1). water levels various from 5-12 bgl and safe yield from open dug wells varies from 35-90m/d. The valley fills indicate depositional landforms developed along the Uma river basin consisting of good groundwater prospectus as the fracture zones are recharged directly by the running streams and also by the lateral inflow from the uplands.

Geology:

The area of investigation is characterized by the presence of 230m thick lava flows belonging to cretaceous Eocene age with thin mantle of recent soil. However, certain portion of the area consists of alluvial zone showing saline nature of groundwater. In general the lava flows can be divided into massive basalts showing limited water resources and vesicular and amygdaloidal basalts with weathered and jointed horizons indicating potential aquifers. The basalts exposed in the study area can be grouped into seven lave flows belonging to Manpur and Mhow formations as per the stratigraphic nomenclature given by Sreenivasa Rao et.al. (1985). The thickness of the lava flows varies from few feet to more than 25 meters showing both simple and compound flows. The compound flows are characterized by the presence of more than two flow units showing pipe amygdales with massive nature at the base and ropy structure dominated by vesicles at the top. The simple flows can be identified by the absence of flow units showing monotonous and uniform nature. The vesicles are generally filled with various secondary minerals like zeolites group, quarts and calcite (Khadri et.al. 1988).

Results and Discussion

Groundwater resource management:

In the study area, the recharge of groundwater is controlled by topography; thickness of weathered zone, and infiltration capacity of soil and subsoil strata within the zone of aeration. The area exposes seven lava flows, which are separated, by these horizons of red boles. Each part of the flow forms a separate unit, which differs from the other, based on variation in porosity and permeability of the flow units. The water bearing capacity of various lava flows depends on the flow nature and geomorphic expression. The massive portions are devoid of any openings due to low porosity and hence unproductive for groundwater. Whereas, the vesicular and amygdaloidal horizons of lava flows show interconnected and uniformly distributed vesicles contributing to their groundwater potential due to high degree of porosity and permeability, which further intensifies due to differential weathering. Occasionally, the closely spaced interconnecting joints present in between the massive horizons may contribute towards the formational porosity can form productive zone. The size and number of vesicles, degree of weathering and jointing pattern mainly control the water productivity and yielding strength of aquifers in basaltic terrain. Hence, highly weathered zones of vesicular and amygdaloidal basalts are good producer of groundwater. The area of investigation is characterized by the presence of multiple aquifer system showing productive and unproductive zones due to the presence of alternating massive and vesicular units with lateral variation. The depth to water level studies indicate four distinct zones which include shallow water level (1 -5m), moderately deep water level (5-8m), deep water level (8-15m) and very deep water level (>15m). Shallow water level is influenced by irrigation methods showing recharge of groundwater table.

The groundwater level fluctuation mainly depends on the difference in water levels of pre-monsoon and post-monsoon periods, which can be directly linked, to recharge and discharge of groundwater. The results indicate three distinct zones namely low water level fluctuations (1-2m), moderate water level fluctuations (2-3m) and high water level fluctuations (>3m). The low water level fluctuations are more prominent in the region, which is controlled by recharge of groundwater by surface irrigation, and low frequency of dug wells causing less groundwater withdrawal. Whereas, high water level mining of groundwater during non-monsoon seasons for irrigation causes fluctuations.

Groundwater Quality

The chemical characteristics of water samples of the dug wells have demonstrated the quality of groundwater. The physical properties such as pH reveals a range from 6.80 to 8.74, specific conductivity ranges from 248 to 2680mhos/cm at 25^{o}C and chemical properties include calcium (22 to 284mgl), potassium (01 to 40mgl), sodium (16 to 579mgl), magnesium (8 to 283mgl), CO_3^- (0-98mgl), HCO_3^- (113 to 1106mgl) total hardness as Ca Co_3 (110 to 1190mgl), Sulphate (0 to 76mgl), NO_3^{--} (6.30 to 98.07 mgl) and Chloride (53 to 560mgl) (Table 1). Physical and chemical parameters reveal that values vary within range of standard values determined for each constituent of W.H.O.

The suitability of water for irrigation purpose can be classified on the basis of sodium percentage, electrical conductivity and sodium absorption ratio. The values of sodium percentage and electrical conductivity (after Wilcox, 1948) demonstrates that a majority of samples have been classifies as "good to permissible" for irrigation purpose and the remaining samples have been classified as "permissible to doubtful" for irrigation purposes as its sodium absorption ratio is 24 to 58. The isocon maps showing variations of Ec in various alluvial and Deccan Trap regions exposed in the study area indicate the presence of three distinct zones namely good (i) where the electrical conductivity (EC) values range between 250-750, (ii) permissible, where the EC values are between 750-2000 and (iii) doubtful, where the EC values are between 2000-3000 (Fig. 2). The results demonstrate the alluvial zone shows doubtful quality of groundwater, which is not suitable for drinking purposes in the northern most part of the study area with the gradual reduction of EC values towards south. It is interesting to note that none of the samples analysed shows EC values > 3000 which indicates that the rate of salinity is not very high. This proves that salinity of alluvial zone of Shahnur river basin is in lower range which can be removed by employing suitable recharge methods and also by pumping saline water into Purna river during rainy season when most of the water goes as runoff.

The soda-isolines map indicates the lower concentration in the area of investigation indicating the quality of groundwater. (Fig.3). The results of the salinity-sodium hazard index indicate the suitability of groundwater for irrigation. The best quality of groundwater is indicated by C_1S_1 whereas, C_5S_3 denotes worst quality. The presence of saline water in southeastern part of study area is denoted by C_5S_3. (Fig.4).

Based on groundwater hardness, the study area can be divided into six categories namely A_1-A_3 indicating the permanent hardness and B_1-B_3 indicating the temporary hardness. A_2 and A_3 types occur in the southwestern part whereas, the southern part contain the saline belt, which form a part of the Purna Saline tract. (Fig.5). The TDS plots shows fresh water in Akot area with < 1000 TDS whereas, towards the NE and SE parts show brackish water and towards SE extreme, saline zone has been identified. (Fig. 6).

The SAR quality has demonstrated the water quality of the Shahnur river basin, which supports the earlier values of EC. The results indicate the presence of four distinct zones in the study area which are (I) excellent, where the SAR ratio is <10, (ii) good, where it is 10-18, (iii) fair, where it is 18-26 and (iv) poor, where the SAR ratio is >26 (Fig.7). It is interesting to note that alluvial zone belonging to Purna Saline tract shows poor quality of water which is not suitable for drinking and irrigation purpose with small pocket of fair quality zone in between the saline tract. Whereas, the Deccan Trap region show fair to excellent quality of groundwater as indicated by its SAR values. The isochlores map plotted for the study area indicates the lower concentration of the same indicating the quality of groundwater. (Fig.8). The iso-bicarb map for the study area demonstrates the higher concentration (600) towards the south of Akot region indicating the presence of brackish water. (Fig.9).

Resistivity Survey and Pumping test Results:

Detailed resistivity surveys and pumping tests were carried out in the study area to understand the underlying aquifer lithology and groundwater potential of the region (Table 2). The results of the pumping tests demonstrate that in each basin, the transmissivity and permeability values are very similar to one another indicating free movement of groundwater within the basin limits with the presence of permeability barrier towards the high where, the values reduce drastically. These values will also be useful in further defining the boundaries of the basin, which differs with other basins in these parameters. Considering the free movement of groundwater within the limits of a basin, well location can be more accurately identified based on the shapes of the contours. The permeability data is very much useful in determining the optimum dimensions of the wells, safe distance between two wells and their probable safe yields. This will certainly helpful in determining the exploitation limit to which the development can be extended beyond 80% stage which will further lead to locate positive percolating areas where artificial recharge activities can be planned and distinct positive areas for water resources development can be suggested. Jagtap (1984) has indicated that adoption of mini basin as a unit for assessment of groundwater provides a rational solution to problems faced hither to in watershed approach of groundwater development. Pumping test results indicate limited groundwater prospects in the region, which certainly needs careful planning and management of available water resources.

Application of Hotspot Geoinformatics in Shahnur River basin

Geoinformatics surveillance for spatial and temporal hotspot detection and prioritization is a critical need for the 21st century Digital Government. A hotspot can mean an unusual phenomenon, anomaly, aberration, outbreak, elevated cluster, or critical area. The declared need may be for monitoring, etiology, management, or early warning. The responsible factors may be natural, accidental or intentional, with relevance to both infrastructure and homeland security. This involves critical societal issues, such as carbon budgets, water resources, ecosystem health, public health, drinking water distribution system, persistent poverty, environmental justice, crop pathogens, invasive species, bio-security, bio-surveillance, remote sensor networks, early warning and homeland security. The geo-surveillance provides an excellent opportunity, challenge, and vehicle for synergistic collaboration of computational, technical, and social scientists.

This initiative describes a multi-disciplinary research program based on novel methods and tools for hotspot detection and prioritization, driven by a wide variety of case studies of direct interest to several government agencies. These case studies deal with critical societal issues. Our methodology involves an innovation of the popular circle-based spatial scan statistic methodology. In particular, it employs the notion of an upper level set and is accordingly called the upper level set scan statistic, pointing to the next generation of a sophisticated analytical and computational system, effective for the detection of arbitrarily shaped hotspots along spatio-temporal dimensions. We also propose a novel prioritization scheme based on multiple indicator and stakeholder criteria without having to integrate indicators into an index, using revealing Hasse diagrams and partially ordered sets. Responding to the Government's role and need, we propose a cross-disciplinary collaboration among federal agencies and academic researchers to design and build the prototype system for surveillance infrastructure of hotspot detection and prioritization. The methodological toolbox and the software toolkit developed will support and leverage core missions of federal agencies as well as their interactive counterparts in the society. The research advances in the allied sciences and technologies necessary to make such a system work are the thrust of this initiative. A multi-disciplinary, multi-institution research team will address the issues in an integrated manner, a crucial element of success. The team comprises several leading researchers with track records from research universities. Information technologies promise to make Govt. more efficient and responsive. The purpose of this initiative is to help that happen.

Application of Sensor Networking in Watershed management

The availability of a variety of inexpensive micro-sensors with embedded wireless communications have enabled real-time monitoring of natural phenomena that span temporal and spatial scales. This enables in-situ information fusion for comprehension and scientific prediction of spatial-temporal events, which in turn supports scientific decision models that adapt to predicted events. For example, autonomous networks of unmanned undersea vehicles with embedded sensor systems have been designed to formulate high fidelity new casts and forecasts of the ocean through time-space coordinated sampling to support collaborative undersea mine-hunting missions (Phoha et. al. 2006, Phoha et.al.1999). The National Ecological Observatory Network (NEON) is another national effort of the US National Science Foundation to create a national observing system for ecological measurements and monitoring to support research (Schimel 2007). In this section we present recent research on sensor networking architectures that enable in-situ scientific decision making with the goal of exploring possible value added enhancements to current plans of watershed management of the Uma river basin, India. This research will enable the project to establish the appropriate regional infrastructure for utilizing the transformational power of information to support situation aware adaptive control of natural resources, such as optimal water conservation. Other possible uses of such a network are delineated by the NEON project in areas of land use and agriculture, spatial patterns of climate-change that affect eco-hydrology and bio-geo-chemistry, and bio-diversity (Schimel 2007). The important characteristics of the decision-support sensor network architecture are its quality of fusion support, low total cost of ownership, scalability, portability of nodes, and system dependability. The architectural design of the infrastructure for an adaptive sensor network has generated a lot of research interest and experimentation. The following subsections discuss some of the design issues for a cost effective, flexible and reconfigurable sensor network. The major new research addressed here is the fusion driven dynamic adaptation of the decision support network. The paper presents innovative analytical models to support regional decision-making. The methodology is extendible and has the potential of influencing the design of a national scale environment-monitoring network such as the INDOFLUX (Srinivasan et.al. 2007).

Real-time data interactions are necessary. Some local nodes are remote data logging devices that store information for later retrieval. The network physical layer may use long-range 802.11 and/or cell phone connections. The data portal provides a grid-computing environment. Data signatures certify the sensor hardware that produced the original data and provide assurance that the data is not tampered with. The exact processing history of all derived data can be verified using cryptographic primitives. Sensors interact with their environment and degrade over time, leading to loss of precision and/or accuracy. With minimal knowledge of degradation modes, it is possible to detect and compensate for calibration problems.

The network design space is reconfigured to adapt to the information space in a manner that preserves the statistical characteristics (predictability) of the ensemble of original sensor data at each level of fusion. Network-centric sensor information is organized as a discrete-event dynamic system of interacting probabilistic automata, where sensor nodes may change their internal states through interactions with other nodes or the environment. Sensor nodes generate multivariate asynchronous data streams that interact over the network. Based on these interactions, some sensors may form collaborative clusters. The symbolization and filtering processes (fusion levels 0 and 1) for a multivariate stream of asynchronous sensor data are said to be effective to the extent that they preserve the statistics of the original data. The goal here is to design flexible network topologies for sufficiently fine -grained adaptive sensing that can detect changes in the statistics of the information space in emerging hotspots. Statistical invariance, simultaneously in space and time, is used to reduce the order of the nonlinear dynamic systems and its computational complexity, without loss of predictability. We have defined a formal quantitative language measure (Ray et.al. 2005), which is used to quantify statistical changes in the information space as we vary the operational setting of the network design space. We thus formulate theoretical foundations for solving the forward and backward problems of network adaptation by analytically associating a measure of the effect of changes in the network's topological structure to forecasts of system evolution. The actuation of network reconfiguration for large sensor networks is achieved through adaptive sampling at individual sensors, sensor mobility, turning existing sensors on or off, bandwidth reallocation, protocol modification, or through redeployment of resources.

Summary and Conclusions

The results demonstrate the role of chemical weathering causing water chemistry to remain unchanged in trappean areas whereas, the alluvial zone show definite change in chemistry due to salinity problem. The variation of pH and total dissolved solids (TDS) is controlled by litho logy and climate. Bhatt and Saklani (1996) have indicated that high velocity of river water may lead to excessive mass transport over rock weathering which influences the quality. Chemical weathering plays major role in controlling water chemistry in the downstream temperate areas. The results demonstrate the presence of poor water quality in the northern saline tract of the alluvial zone which is not suitable for either drinking and irrigation purposes whereas, the trappean regions show fair to excellent quality for groundwater which is suitable for the drinking and irrigation purposes.

The water quality of the area can be improved by adopting artificial recharging methods and also by pumping the saline water into the Purna River during rainy seasons. In the study area the highly fractured, weathered and jointed horizons of Deccan Traps have yielded large amount of water, which shows good quality whereas, the massive basalts have shown poor yield. In general, the study area has great potential for large-scale groundwater resource development due to the presence of groundwater in unconfined, semi confined and confined conditions in deep fractured regions. In order to achieve planned and sustainable scientific development of ground water resource, it is suggested that priority be given for dug wells due be surplus availability of groundwater in shallow aquifers down to a depth of 20m bgl. The existing shallow dug wells may be depended to a maximum depth of 20m bgl so as to tap the vesicular unit of underlying flow. Dug wells ending in the vesicular zones may be further depending so as to tap its full thickness. Suitable measures are taken to construct water conservation and artificial recharge structures like rooftop drainage recharge, percolation, trenches / tanks and under-ground bandhara. Detailed hydro-geological and geophysical investigation is carried out to tap the deeper aquifer below the depth of 150-200m. Surplus groundwater potential indicated in the study area may be utilized by the construction of additional groundwater structures (Ramaiah, 1996). In addition to the above, reappraisal hydrogeological surveys be carried out for further groundwater development of the region.

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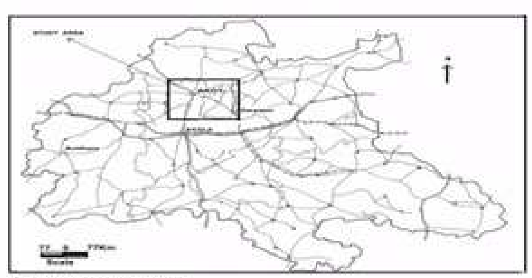

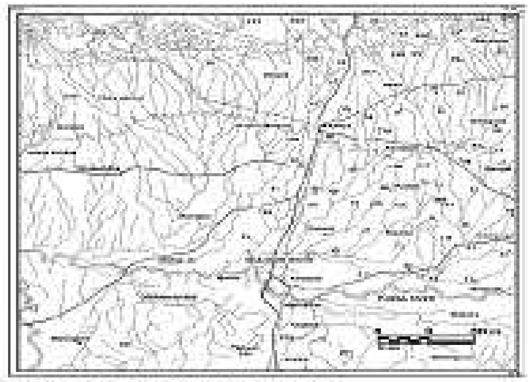

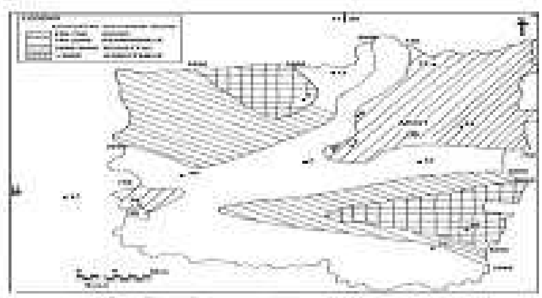

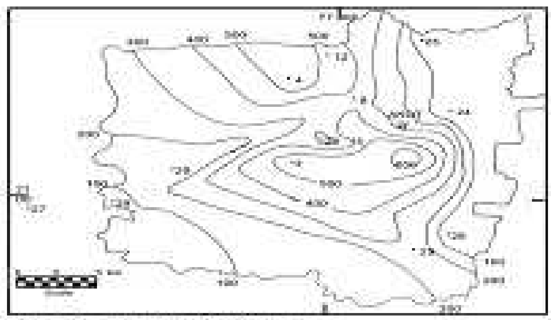

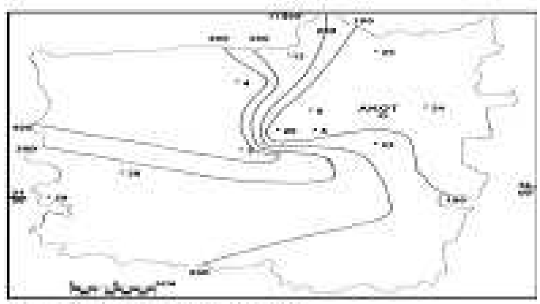

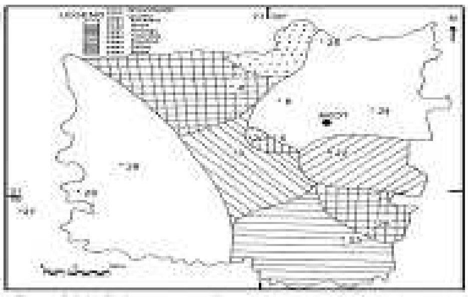

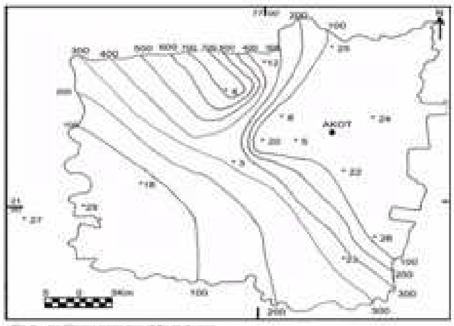

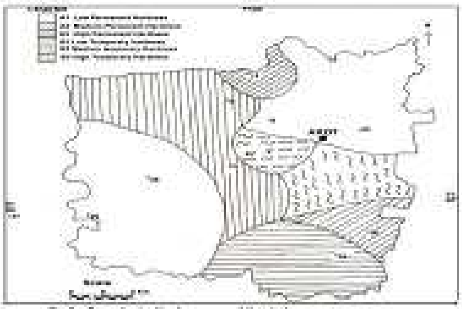

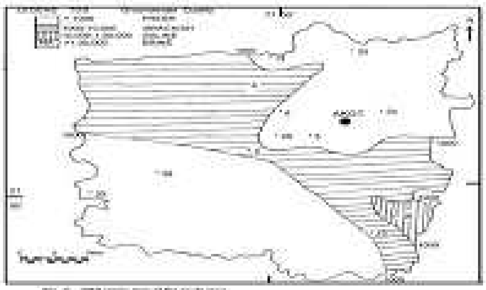

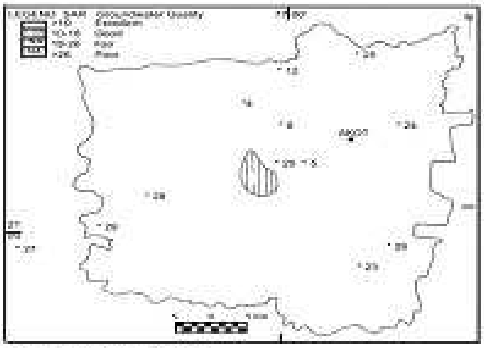

Table 1 Physico-chemical characteristics of Shahnur river basin (TH: Hardness; A: Acidity)

S No	Well no	Geomorphic unit	well Type	Physical parameters T		pH	Chemical parameters Ca	HCO3	Cl	Mg	TH	A
				T	C	pH	Ca	HCO_3	Cl	Mg		
1	A-1	H D P (B)	B.W.	28.2	0.36	6.5	35.2	22.72	12.6	400	140	8
2	A-2	H D P (A)	B.W.	25.7	0.44	6.1	88.1	25.56	0.1	520	220	20
3	A-3	H D P (A)	D.W.	28.3	0.92	5.8	128.	53.96	30.2	116	444	80
4	A-4	M D P (B)	D.W.	26.3	0.46	6.4	46.4	22.72	8.77	560	152	20
5	A-5	H D P (B)	D.W.	24.2	0.38	5.7	83.3	17.04	3.89	500	224	20
6	C-6	P.T.	D.W.	22.3	0.26	6	88.1	22.72	12.6	200	132	12
7	C-7	P.T.	D.C.	20.5	0.40	6.4	96.1	48.28	16.9	500	220	12
8	C-8	P.T.	D.W.	20.1	0.56	5.7	88.1	31.24	24.3	800	320	80
9	C-9	P.T.	D.W.	18.8	0.35	6.8	80.1	14.2	16.5	600	268	16
10	C-10	P.T.	D.W.	22.3	0.38	5.0	72.1	45.44	7.79	320	212	36
11	C-11	P.T.	D.W.	24.3	0.3	6.5	48.0	19.88	1.95	320	128	12
12	C-12	M D P (B)	D.W.	22	0.31	6.4	48.0	14.2	18.5	400	196	16
13	C-13	M D P (B)	D.W.	26.5	0.20	6.5	32.0	19.88	3.89	140	96	10
14	C-14	M D P (B)	D.W.	24.6	0.38	6.6	212.	14.2	6.32	500	160	12
15	C-15	H D P (A)	D.W.	28.7	0.22	5.7	51.3	14.2	1.94	340	136	52
16	C-16	H D P (A)	D.W.	25.2	0.27	6	54.5	11.36	9.74	440	176	20
17	C-17	H D P (B)	D.W.	24.6	0.32	6	152.	19.88	9.42	500	192	12
18	C-18	H D P (B)	D.W.	29.3	0.36	7.8	56.1	28.4	17.5	340	212	32
19	C-19	H D P (B)	D.W.	24	0.23	6.3	76.9	14.2	2.92	360	152	12
20	C-20	H D P (B)	D.W.	25.2	0.30	7.4	104.	17.04	2.41	380	204	16
21	C-20	H D P (B)	D.W.	28.2	0.30	7.0	83.3	19.88	0.1	420	212	12
22	C-22	M D P (A)	D.C.	27.7	0.55	6.3	56.1	22.72	36.0	720	288	14
23	C-23	M D P (A)	D.W.	26.4	0.53	6.3	120.	17.04	6.43	100	236	24
24	C-24	M D P (B)	D.W.	27.5	0.68	7.5	152.	34.08	9.02	920	376	4
25	C-25	M D P (B)	B.W.	30.1	0.32	5.5	72.1	28.4	19.4	780	260	16
26	C-26	M D P (A)	D.C	27.9	0.50	6.6	96.1	19.88	11.6	880	288	28
27	C-27	M D P (A)	D.C.	26.0	0.32	7.2	128.	14.2	7.54	760	268	44
28	C-28	M D P (A)	D.W.	27.2	0.56	8.1	120.	31.24	2.9	800	312	20
29	C-29	H D P (A)	D.W.	26.7	0.28	6.5	101.	19.88	6.82	420	172	20
30	C-30	M D P (A)	D.W.	27.2	0.33	7.8	96.1	14.2	8.25	580	208	32
31	C-31	M D P (A)	D.W.	26.9	0.46	7.8	212.	34.08	5.12	560	308	20
32	C-32	M D P (A)	D.W.	27.1	0.35	8.8	68.9	17.04	6.82	580	200	20
33	C-33	M D P (A)	D.W.	26	0.43	6.4	96.1	25.56	6.41	640	256	28
34	C-34	M D P (A)	D.W.	26.2	0.40	6.7	123.	56.8	8.04	640	240	24
35	C-35	M D P (B)	D.W.	26.9	0.66	8.0	160.	53.96	6.89	110	380	28
36	C-36	M D P (A)	D.W.	27.5	0.57	8.4	152.	25.56	1.54	100	332	24
37	C-37	M D P (A)	D.W.	27	0.38	8.6	115	17.04	3.21	180	228	32
38	C-38	M D P (A)	B.W.	26.9	0.20	7.8	80.2	22.72	7.56	400	60	28
39	C-39	M D P (B)	D.W.	26.5	0.56	7.5	152.	71	9.32	640	280	8

40	C-40	M D P (A)	D.W.	26.8	0.48	6.7	112.	14.2	4.12	780	292	8
41	C-41	M D P (B)	D.W.	27.5	0.43	6.5	107.	17.04	5.87	700	248	28
42	C-42	M D P (A)	D.W.	27.2	0.41	7.6	123.	19.88	9.32	680	260	4
43	C-43	M D P (A)	D.W.	25.9	0.47	6.4	113.	19.88	6.43	740	280	16
44	C-44	M D P (A)	D.W.	27.5	0.53	7.5	131.	14.2	6.41	900	340	12
45	C-45	M D P (A)	D.W.	26.1	0.54	6.6	142.	25.56	10.4	900	308	20
46	C-46	M D P (A)	D.W.	27.5	0.52	6.4	112.	19.88	5.12	830	336	20
47	C-47	M D P (A)	D.W.	26.4	0.52	8.4	115.	22.72	8.77	880	324	16
48	C-48	M D P (B)	D.W.	27.1	0.50	6.8	160.	19.88	6.98	740	340	24
49	C-49	A. P.	D.W.	26.2	0.54	6.7	107.	28.4	15.5	800	332	24
50	C-50	H D P (B)	B.W.	28.2	0.36	6.5	35.2	22.72	12.6	400	140	8
51	C-51	H D P (A)	B.W.	25.7	0.44	6.1	88.1	25.56	0.1	520	220	20
52	C-52	H D P (A)	D.W.	28.3	0.92	5.8	128.	53.96	30.2	116	444	80
53	C-53	M D P (B)	D.W	26.3	0.46	6.4	46.4	22.72	8.77	560	152	20
54	C-54	H D P (B)	D.W.	24.2	0.38	5.7	83.3	17.04	3.89	500	224	20
55	C-55	P.T.	D.W.	22.3	0.26	6	88.1	22.72	12.6	200	132	12
56	C-56	P.T.	D.C	20.5	0.40	6.4	96.1	48.28	16.9	500	220	12
57	C-57	P.T.	D.W.	20.1	0.56	5.7	88.1	31.24	24.3	800	320	80
58	C-58	M D P (B)	B.W.	30.1	0.32	5.5	72.1	28.4	19.4	780	260	16
59	C-59	M D P (A)	D.C.	27.9	0.50	6.6	96.1	19.88	11.6	880	288	28
60	C-60	M D P (A)	D.C.	26.0	0.32	7.2	128.	14.2	9.76	760	268	44
61	C-61	M D P (A)	D.W.	27.2	0.56	8.1	120.	31.24	2.9	800	312	20
62	C-62	M D P (B)	D.W.	26.5	0.20	6.5	32.0	19.88	3.89	140	96	0
63	C-63	M D P (B)	D.W.	24.6	0.38	6.6	212.	14.2	5.32	500	160	12
64	C-64	H D P (A)	D.W.	28.7	0.22	5.7	51.3	14.2	1.94	340	136	52
65	C-65	H D P (B)	B.W.	28.2	0.36	6.5	35.2	22.72	12.6	400	140	8
66	C-66	H D P (A)	B.W.	25.7	0.44	6.1	88.1	25.56	0.1	520	220	20
67	C-67	H D P (A)	D.W.	28.3	0.92	5.8	128.	53.96	30.2	116	234	80
68	C-68	M D P (B)	D.W	26.3	0.46	6.4	46.4	22.72	8.77	560	152	20
69	C-69	H D P (B)	D.W.	24.2	0.38	5.7	83.3	17.04	3.89	500	224	20
70	C-70	P.T.	D.W.	22.3	0.26	6	88.1	22.72	12.6	200	132	12
71	C-71	P.T.	D.C	20.5	0.40	6.4	96.	48.28	16.9	500	220	12
72	C-72	M D P (B)	B.W.	30.1	0.32	5.5	72.	28.4	19.4	780	260	16
73	C-73	M D P (A)	D.C	27.9	0.50	6.6	96.1	19.88	11.6	880	288	28
74	C-74	M D P (A)	D.C	26.0	0.32	7.2	128.	14.2	7.98	760	268	44
75	C-75	M D P (A)	D.W.	27.2	0.56	8.1	120.	31.24	2.9	800	312	20
76	C-76	M D P (B)	D.W.	22	0.31	6.4	48.0	14.2	18.5	400	196	16
77	C-77	M D P (B)	D.W.	26.5	0.20	6.5	32.0	19.88	3.89	140	96	0
78	C-78	M D P (B)	D.W.	24.6	0.38	6.6	212.	14.2	4.56	500	160	12
79	C-79	H D P (A)	D.W.	28.7	0.22	5.7	51.3	14.2	1.94	340	136	52
80	C-80	H D P (B)	B.W.	28.2	0.36	6.5	35.2	22.72	12.6	400	140	8
81	C-81	H D P (A)	B.W.	25.7	0.44	6.1	88.1	25.56	0.1	520	220	20
82	C-82	H D P (A)	D.W.	28.3	0.92	5.8	128.	53.96	30.2	116	114	80
83	C-83	M D P (B)	D.W	26.3	0.46	6.4	46.4	22.72	8.77	560	152	20
84	C-84	H D P (B)	D.W.	24.2	0.38	5.7	83.3	17.04	3.89	500	224	20
85	C-85	P.T.	D.W.	22.3	0.26	6	88.1	22.72	12.6	200	132	12
86	C-86	P.T.	D.C	20.5	0.40	6.4	96.1	48.28	16.9	500	220	12
87	C-87	P.T.	D.W.	20.1	0.56	5.7	88.1	31.24	24.3	800	320	80
88	C-88	P.T.	D.W.	18.8	0.35	6.8	80.1	14.2	16.5	600	268	16
89	C-89	P.T.	D.W.	22.3	0.38	5.0	72.1	45.44	7.79	320	212	36
90	C-90	P.T.	D.W.	24.3	0.3	6.5	48.0	19.88	1.95	320	128	12
91	C-91	M D P (B)	D.W.	22	0.31	6.4	48.0	14.2	18.5	400	196	16
92	C-92	M D P (B)	D.W.	26.5	0.20	6.5	32.0	19.88	3.89	140	96	0
93	C-93	M D P (B)	D.W.	24.6	0.38	6.6	212.	14.2	4.98	500	160	12
94	C-94	H D P (A)	D.W.	28.7	0.22	5.7	51.3	14.2	1.94	340	136	52
95	C-95	H D P (B)	B.W.	28.2	0.36	6.5	35.2	22.72	12.6	400	140	8
96	C-96	H D P (A)	B.W.	25.7	0.44	6.1	88.1	25.56	0.1	520	220	20
97	C-97	H D P (A)	D.W.	28.3	0.92	5.8	128.	53.96	30.2	154	444	80
98	C-98	M D P (B)	D.W	26.3	0.46	6.4	46.4	22.72	8.77	560	152	20
99	C-99	H D P (B)	D.W.	24.2	0.38	5.7	83.3	17.04	3.89	500	224	20
100	C100	H D P (A)	B.W.	25.7	0.44	6.1	88.1	25.56	0.1	520	220	20
101	C101	H D P (A)	D.W.	28.3	0.92	5.8	128.	53.96	30.2	116	444	80
102	C102	M D P (B)	D.W	26.3	0.46	6.4	46.4	22.72	8.77	560	152	20
103	C103	P.T.	D.W.	18.8	0.35	6.8	80.1	14.2	16.5	600	268	16
104	C104	P.T.	D.W.	22.3	0.38	5.0	72.1	45.44	7.79	320	212	36
105	C105	P.T.	D.W.	24.3	0.3	6.5	48.0	19.88	1.95	320	128	12

Table2. Results of pumping tests and resistivity surveys carried out in Shahnur river basin

(I) Pumping Test Results

Well No.	Safe Yield (Qs)	Specific Capacity (C)	Transmissivity (T	Storage Coeff. (S)
01	1,12,370 Lts/day	47.59 Lts/min/mt.of D/	48.82 sq.mt./day	0.527
02	34,240 Lts/day	59.04 Lts./min/mt.of D/	69.49 Sq.mt./day	0.032
03	71,400 Lts./day	18.46 Lts./min/mt.of D/	58 Sq.mt./day	0.80
04	4,47,000Lts./day	104 Lts./min/mt.of D/D	58Sq.mt./day	0.052
05	18,720 Lts./day	18 Lts./min/mt.of D/D	218 Sq.mt./day	1.33
06	1,31,414 Lts./day	39 Lts./min/mt.ofD/D	274 Sq.mt./day	0.219
07	71,400 Lts./day	25.44 Lts./min/mt.of D/	49 Sq.mt./day	0.82
08	4,47,000Lts./day	104 Lts./min/mt.of D/D	51 Sq.mt./day	0.053
09	18,720 Lts./day	15 Lts./min/mt.of D/D	215 Sq.mt./day	1.01
10	63,360 Lts./day	44 Lts./min/mt.ofD/D	105 Sq.mt./day	0.196
11	1,31,414 Lts./day	39 Lts./min/mt.ofD/D	274 Sq.mt./day	0.239
12	13,351 Lts./day	18 Lts./min/mt.of D/D	330 Sq.mt./day	0.134
13	4,47,000Lts./day	104 Lts./min/mt.of D/D	53 Sq.mt./day	0.159
14	57,960 Lts./day	25Lts./min.mt.ofD/D	62 Sq.mt./day	0.112
15	71,400 Lts./day	18.46 Lts./min/mt.of D/	52 Sq.mt./day	0.83
16	4,47,000Lts./day	104 Lts./min/mt.of D/D	58 Sq.mt./day	0.050
17	18,720 Lts./day	12 Lts./min/mt.of D/D	211 Sq.mt./day	1.98
18	29,952 Lts./day	16 Lts./min/mt.ofD/D	181 Sq.mt./day	0.66
19	79,200 Lts./day	44Lts./min/mt.ofD/D	459 Sq.mt./day*	2.42*
20	4,47,000Lts./day	104 Lts./min/mt.of D/D	56 Sq.mt./day	0.051
21	18,720 Lts./day	17 Lts./min/mt.of D/D	218 Sq.mt./day	1.32
22	71,400 Lts./day	18.46 Lts./min/mt.of D/	56 Sq.mt./day	0.86
23	4,47,000Lts./day	104 Lts./min/mt.of D/D	54Sq.mt./day	0.089
24	18,720 Lts./day	15 Lts./min/mt.of D/D	208 Sq.mt./day	1.31
25	71,400 Lts./day	18.46 Lts./min/mt.of D/	59 Sq.mt./day	0.89
26	4,47,000Lts./day	104 Lts./min/mt.of D/D	51 Sq.mt./day	0.059
27	18,720 Lts./day	15 Lts./min/mt.of D/D	210 Sq.mt./day	1.38
28	71,400 Lts./day	18.46 Lts./min/mt.of D/	57 Sq.mt./day	0.89
29	4,47,000Lts./day	104 Lts./min/mt.of D/D	51 Sq.mt./day	0.039
30	18,720 Lts./day	15 Lts./min/mt.of D/D	213 Sq.mt./day	1.32

* Fracture zone encountered in a well attributes high transmissivity value

Please see location map for the actual location of the wells

Recommendations:

Well No.	Recommendations
01	Deepening of well by 2mts.can increase the well yield by 25%-30%
02	Further development not required
03	Further development not required
04	Further development not required
05	Further development not required
06	Further development not required
07	Poor recuperation, Not potential
08	Not potential
09	Further development not required
10	Potential well for further development(Recommended Diameter 6mts.x Depth 10 may give the Safe Yield 80,000 - 1,00,000 Lts./day intermittently.
11	Potential well for further development(Recommended Diameter 6mts.x Depth 10

	may give the Safe Yield 60,000 - 85,000 Lts./day intermittently.
12	Poor recuperation, Not potential
13	Potential well for further development(Recommended Diameter 6mts.x Depth 10 may give the Safe Yield 60,000 - 1,00,000 Lts./day intermittently.
14	Further development not required
15	Further development not required
16	Potential well for further development(Recommended Diameter 6mts.x Depth 10 may give the Safe Yield 40,000 - 70,000 Lts./day intermittently.
17	Further development not required
18	Not potential as the rate of recuperation is slow.
19	Highly potential well for further development (Recommended Diameter 6mts. mts which may give the Safe Yield 1,00,000 - 1,25,000 Lts./day.
20	Further development not required
21	Further development not required
22	Potential well for further development(Recommended Diameter 6mts.x Depth 10 may give the Safe Yield 45,000 - 75,000 Lts./day intermittently.
23	Further development not required
24	Potential well for further development(Recommended Diameter 6mts.x Depth 10 may give the Safe Yield 50,000 - 60,000 Lts./day intermittently.
25	Further development not required
26	Poor recuperation, Not potential
27	Potential well for further development(Recommended Diameter 6mts.x Depth 10 may give the Safe Yield 70,000 - 85,000 Lts./day intermittently.
28	Further development not required
29	Potential well for further development(Recommended Diameter 6mts.x Depth 10 may give the Safe Yield 45,000 - 65,000 Lts./day intermittently.
30	Further development not required

(II) Resistivity Survey Results:

Location*	0—5—10—15—20—25—30—35—40—45—50—55—60—65
31	W.B | C.B | V.B
32	WB | C.B. (HFr | V.B.
33	WB | CB | VB | CB
34	WB | CB | VB
35	WB | CB | VB
36	WB | CB (HFr | VB
37	WB | CB
38	WB | CB | VB
39	WB | CB | VB | CB
40	WB | CB(HFr) | VB
41	CB | VB | CB
42	WB | CB | VB
43	WB | CB | VB(HFr | CB
44	WB | CB | VB
45	WB | CB | VB
46	WB | C.B. | V.B.
47	WB | CB | VB | CB
48	WB | CB | VB | CB
49	WB | CB | VB
50	WB | CB (HFr | VB
51	WB | C.B. | V.B.
52	WB | CB | VB | CB
53	WB | CB | VB | CB
54	WB | CB (HFr | VB
55	WB | CB | VB
56	WB | C.B. (HFr | V.B.
57	WB | CB | VB | CB
58	WB | CB | VB | CB
59	WB | CB | VB
60	WB | CB (HFr | VB

* Please see location map for details

Key words:-

WB = Weathered Basalt CB = Compact, Massive Basalt
HFr = Highly fractured Basalt VB = Vesicular Basalt (beginning with red tuffaceous laye

Recommendations:

Location	Recommendations
31	Fractured and Weathered zone encountered upto the depth of 25 mts.b.g.l.
32	Fractured and Weathered zone encountered upto the depth of 32 mts.b.g.l.
33	Fractured and Weathered zone encountered upto the depth of 15 mts.b.g.l.
34	Fractured and Weathered zone encountered upto the depth of 10 mts.b.g.l.
35	Weathered zone not extending below 15mts.
36	Weathered zone not extending below 12mts
37	Weathered zone not extending below 25mts
38	Feasible for Bore well of depth 250ft. Saturated zone may struck below 45 mts.
39	Not feasible
40	Feasible for Open well of depth 15mts.and also for Bore well of depth of 200 m
41	Not feasible
43	Fractured and Weathered zone encountered upto the depth of 45 mts.b.g.l.
44	Fractured and Weathered zone encountered upto the depth of 20mts.b.g.l.
45	Fractured and Weathered zone encountered upto the depth of 35 mts.b.g.l.
46	Weathered zone not extending below 15mts.
47	Weathered zone not extending below 10mts
48	Weathered zone not extending below 5mts.
49	Feasible for Bore well of depth 150ft. Saturated zone may struck below 55 mts.
50	Fractured and Weathered zone encountered upto the depth of 15 mts.b.g.l.
51	Fractured and Weathered zone encountered upto the depth of 10 mts.b.g.l.
52	Fractured and Weathered zone encountered upto the depth of 25 mts.b.g.l.
53	Weathered zone not extending below 15mts.
54	Weathered zone not extending below 25mts
55	Weathered zone not extending below 5mts
56	Feasible for Bore well of depth 250ft. Saturated zone may struck below 65 mts.
57	Fractured and Weathered zone encountered upto the depth of 25 mts.b.g.l.
58	Fractured and Weathered zone encountered upto the depth of 30 mts.b.g.l.
59	Fractured and Weathered zone encountered upto the depth of 14 mts.b.g.l.
60	Weathered zone not extending below 5mts.

Table. 3 Results the pilot study demonstration of the Pumping test showing the Change in the water quality after consisting pumping at Akot and Daryapur Tube Wells

Akot region				Daryapur region			
Well	Date of sampling	Chlorides (mg/L)	Period of pumping (PP)	Well	Date of sampling	Chlorides (mg/L)	**Period of pumping**
1	12.4.2009 30.7. 2010 15.10.2010 10.4.2011	4016 2150 1580 1240	@ 1.3 years 1.5 years 2 years	3	13.4.2009 31.7. 2010 16.10.2010 11.4.2011	5268 3040 2150 1420	**@ 1.3 years 1.5 years 2 years**
2	**12.4.2009 30.7. 2010 15.10.2010 10.4.2011**	**3521 2150 1060 560**	**@ 1.3 years 1.5 years 2 years**	**4**	**13.4.2009 31.7. 2010 16.10.2010 11.4.2011**	**4826 2680 1790 1420**	**@ 1.3 years 1.5 years 2 years**

@ Reference point for estimate of PP