केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण मंत्रालय

भारत सरकार

Central Ground Water Board

Ministry of Water Resources, River Development and Ganga Rejuvenation

Government of India

Report

on

AQUIFER MAPPING AND MANAGEMENT PLAN

Faridkot District, Punjab

उत्तरी पश्चिम क्षेत्र, चंडीगढ़

North Western Region, Chandigarh

AQUIFER MAPPING & MANAGEMENT PLAN OF FARIDKOT DISTRICT, PUNJAB

Central Ground Water Board
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Ministry of Water Resources, River Development and Ganga Rejuvenation
Government of India
2017

AQUIFER MAPPING AND MANAGEMENT PLAN
FARIDKOT DISTRICT
(1418.60 Sq Km)

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1.0 INTRODUCTION

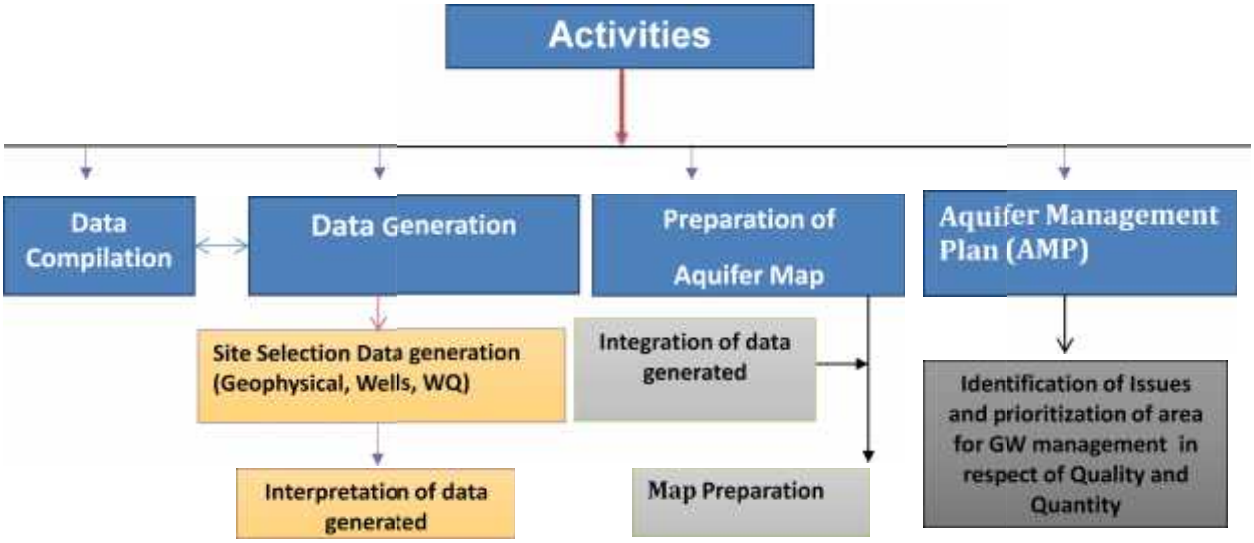
The primary objective of the Aquifer Mapping can be summed up as "Know your Aquifer, Manage your Aquifer". Demystification of Science and thereby involvement of stake holders is the essence of the entire project. The involvement and participation of the community will infuse a sense of ownership amongst the stakeholders. This is an activity where the Government and the Community work in tandem. Greater the harmony between the two, greater will be the chances of successful implementation and achievement of the goals of the Project. As per the Report of the Working Group on Sustainable Ground Water Management, "It is imperative to design an aquifer mapping programme with a clear-cut groundwater management purpose. This will ensure that aquifer mapping does not remain an academic exercise and that it will seamlessly flow into a participatory groundwater management programme. The aquifer mapping approach can help integrate ground water availability with ground water accessibility and quality aspects.

1.2 Scope of the study:

Systematic mapping of an aquifer encompasses a host of activities such as collection and compilation of available information on aquifer systems, demarcation of their extents and their characterization, analysis of data gaps, generation of additional data for filling the identified data gaps and finally, preparation of aquifer maps at the desired scale. This manual attempts to evolve uniform protocols for these activities to facilitate their easy integration for the district as whole.

1.3 Approach and Methodology:

National Aquifer Mapping Programme basically aims at characterizing the geometry, parameters, behaviour of ground water levels and status of ground water development in various aquifer systems to facilitate planning of their sustainable management. The major activities involved in this process include compilation of existing data, identification of data gaps, and generation of data for filling data gaps and preparation of aquifer maps. The overall activities of aquifer mapping are presented in the flow chart below.



1.4 Location and Geographical Units

Faridkot is located in South- Western part of Punjab State. The area lies between 30°21'59" to 30°49'52" North latitude and 74°28'12" to 75°03'22" East longitude and falls in the Survey of India Toposheet Nos. 44J/6, 9, 10, 11, 13, 14, 15 and 44N/3 covering an area of 1418.60 sq km (Fig.1). It shares common boundaries with Moga district in east, Ferozepur district in North & West and Muktsar and Bathinda districts in South. The highest elevation 213.3 m above m.s.l is near Jiwanwala in the eastern part whereas the minimum of 190m at Pind Balochan in the western part with a gentle gradient of 0.45m/km to the SSW.

Faridkot district is the smallest district of Punjab State and has two Sub divisions/ Tehsils namely Faridkot and Jaito and two Sub Tehsils namely Kotkapura and Sadiq comprising 190 Gram Panchayats and 171 villages. Faridkot District has two administrative development blocks i.e., Faridkot and Kot Kapura.

Total Population of the district, as per the 2011 Census, is 6,18,008 out of which 3,27,121 are males and 2,90,887 are females. The total rural population in the district is 2,17,514 and the urban population is 4,00,494. The population density is 424 persons/ sq km against the state average of 550 persons/sq km.

1.5 Climatic Conditions: Rainfall and Climate

The climate of the district is classified as sub-topical steppe, semi-arid and hot which is mainly dry except in rainy months and characterized by intensely hot summer and cold winter.

The Normal Annual Rainfall is 449 mm in 24 days which is unevenly distributed over the district. Normal Monsoon Rainfall is 349 mm. The southwest monsoon sets in last week of June and withdraws towards end of September and contributes about 78% of annual rainfall. July and August are the wettest months. The remaining 22% of the annual rainfall occurs during non-monsoon months of the year in the form of thunder storm and western disturbances. Rainfall in the district increases from southwest to northeast.

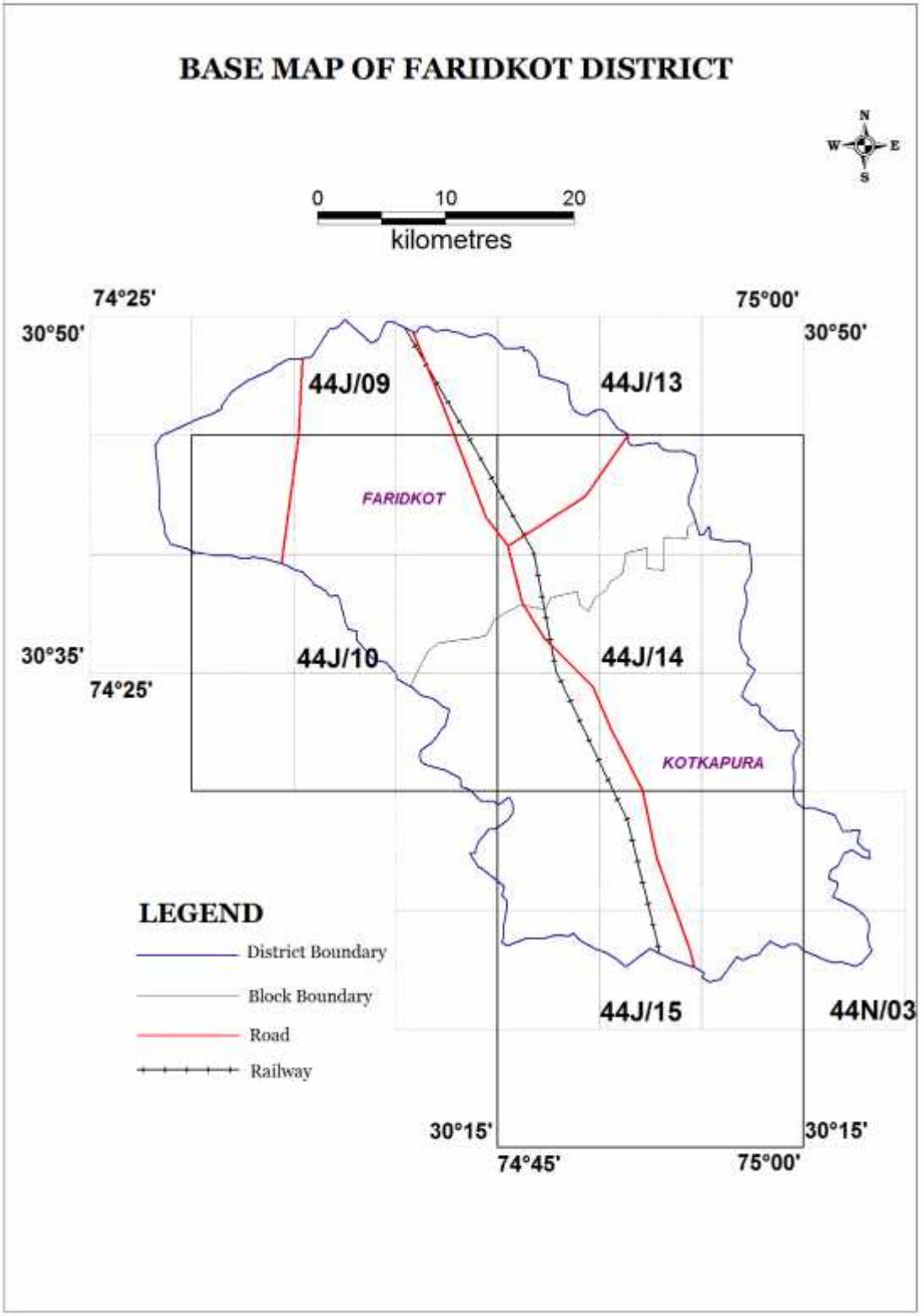
1.6 Geomorphology & Soil Type

The study area forms a part of the Sutlej Basin and exhibits gradational landforms, mainly fluvial, formed by sediments. On the whole it exhibits a low-lying flat topography generally sloping towards southwest, except few linear depression occupied by palaeo-bluff and palaeo channel near Pakka and southeast of Kamiyana Villages and by sand dunes, which are concentrated in northwestern and southern part of the study area. Because of the exceptionally flat topography there is not much development drainage system.

The Study area forms a part of Punjab Plain and is sub-divided into the following three regions on the basis of soil, topography, climate and natural vegetation.

a. *Faridkot Hathar- Sadiq- Sandy Plain*: This part extends over Sadiq town part of the district commonly known as Hathar area. This part of the district has a large numbers of sand dunes and wind blown sand has its own effect on the fertility of soil.

Fig.1: Base map of Faridkot District



b. *Faridkot Uttar- Dhudhi- sandy-loamy*: This part of Faridkot district extends over Dhudhi, Kot Sukhia, Tehna and is known as Uttar area. The soil is sandy loam. Due to extension of agriculture and irrigation there is apparent disappearance of sand dunes to a great extent which have been leveled up generally.
c. *Jaitu Area- Sandy Loam to Loam*: This region extends over and around Jaitu tehsil. The texture of the soil is sandy loam to loam. This area is known for the best staple of cotton. Most of the area is covered under sandy soil followed by clayey soil except some patches where there is appreciable thickness of top clay layer varying from 6.7 to 16.7m.

The study area is developed by Indo Gangetic Alluvium; main landforms are Alluvial Plain, Sand sheets, Sand dunes and Palaeo Channels. Alluvial plain forms the major part of the area followed by Sand Sheets and Sand dunes as patches. Palaeo channel is occurred in central part of the study area.

The soils classes are mainly loams, loamy sand, sandy to fine sandy loams and silty loams. Loamy sand is covered in major part of the study area.

The combined studies on fluvial geomorphology and Remote sensing studies in north western region are carried out by IITs and Delhi University. It has been observed that the huge flood depositions by River Ghaggar, Saraswati and other minor rivers at different time interval and channel migrations in different ages and also Aeolian depositions caused sand dunes in different time interval leads to difficulty in aquifer grouping. The studies are also conformed through sedimentological, core sampling analysis during the project. The observations are understood by regional geomorphology and channels migrations which shown in the below Fig.2.

Fig.2: Fluvial Geomorphological Studies carried out to understand the Subsurface Aquifer System in North Western Regions.

1.7 Land Use/ Land Cover

Based on the visual interpretation of satellite data and topographical data, land use/land classes have been identified. The main classes are Built Up land, Agricultural land, forestland, Land under non agriculture use, current fallows and water bodies. The Land use patterns are given in below table.

Land use pattern of Faridkot district, Punjab (www.agripb.gov.in)

Type of Land use	Area (ha)
1. Total Geographical area	141900
2. Forest	2004
3. Land put to non-agricultural use	16719 (11%)
4. Current Fallows	2239
5. Net area sown	126678 (89%)
6. Gross cropped area	252989
7. Cropping intensity	200%

1.8 River System and Water Resources

No river is flowing through the area, but there are some drains which flow during heavy rains and serve as natural drainage. The main drains are Tarobri Drain, Mari Drain, Samadh Bhai Drain and Chand Bhan Drain (Fig.3). There is a good network of canals and these passes through the area. The main canals are Bikaner Canal, Sirhind Feeder, Rajasthan Feeder, Abohar and Bathinda branches of Sirhind Canal. Bikaner Canal and Bathinda Branch of Sirhind Canal passes through northwestern and southeastern margins of the district and Sirhind Feeder, Rajasthan Feeder, Abohar Branch of Sirhind Canal run through the entire length of district in north-south and northeast-southwest directions respectively (Fig.4). Sirhind canal system has been serving the district for irrigation since long time. There are large water bodies near Khara, Panjgrain, Jaito Mandi, Wara daraka and in Faridkot Town. These water bodies generally dry in summer.

1.9 Agriculture & Irrigation

Faridkot is mainly an agricultural district and 70% of the population resided in the rural areas depends up on agriculture. The two main crop seasons in a year are Kharif and Rabi which is locally known as ‘Sauni’(Summer Harvest Season) and ‘Harrhi’ (Winter Harvest Season). The principle Kharif crops are Paddy, Maize, Bajra, Cotton, Moong, Mash, Moth, Arhar, Sugarcane, etc., while important Rabi crops are Wheat, Barley, Gram, Sarson, Taramera and Toria, etc.

Irrigation is carried out by surface water and ground water. As major parts of the area are underlain by saline water, so canal water is major source of irrigation. In some parts where ground water is available as fresh water lenses, than irrigation is covered by skimming wells known as multiple well point system. Kharif and Rabi is cultivated in study area under two types of soil i.e. loamy sand and sandy loam and the sources of irrigation are canal as well as tubewells. Conjunctive use of canal water and ground water for irrigation is being carried out efficiently in this area.

a. Canal Water Irrigation

Major source of irrigation is canal where water from Sirhind canal is utilized for irrigation. The other important distributaries are Abohar Branch, Dhulkot distributary system, Mari distributary system, Faridkot distributary, Kotkapura distributary, Jaitu distributary, Rupana and Doda distributary system. The total length of above distributaries which serve in Faridkot district is 228.44 km, out of which 206.49 km is lined and 21.85 km is unlined. Gross irrigated areas of all the channels are 90253.39 ha and cultural command area is 80266.56 ha with 294 no. of outlets. Intensity of irrigation is 140%.

b. Ground Water Irrigation

With the advent of multiple well point systems, ground water irrigation is also playing an important role in development of agriculture economy of the study area. This is not only release the pressure mounted on the canal water supply but also creates the maximum storage in the unconfined aquifer for fresh ground water through return flow and canal seepage.

1.10 Industries

There are no major industries in the area except rice mills in Deviwala village and few poultry farms in the district.

1.11 Mineral Resources

Since the entire area is occupied by Quaternary sediments, no minerals of significant industrial use are found.Alkaline soils contain saltpetre called *Kalmi Shora* in local language, which has application in chemical, oxide, glass, soap industry and leather tanning are found in this area. It is being extracted at Sirsari and Kot Sukhia villages. It occurs as thin slightly yellowish to dark brown encrustation on the ground surface and is found mostly over the old habitation sites 'Thehs' or over barren/ kallar lands and cattle sheds.

Saltpetre is an important source of Niter (KNO_3), which is used in cracker industry, matchbox manufacture and as a fertilizer.

1.12 Water Conservation and Artificial recharge:

The north and eastern part of the area where water level is declining, artificial recharge structures may help in arresting the decline. Recharge Trench with injection well structure is the suitable for artificial recharge. Water conservation methods like change in cropping pattern, change in Irrigation policy, lining of unlined channels, timely plantation of paddy, promotion of sprinkler and drip irrigation etc. may be adopted to overcome the ground water decline in the area.

Fig.3: Drainage and Water Bodies of Faridkot District

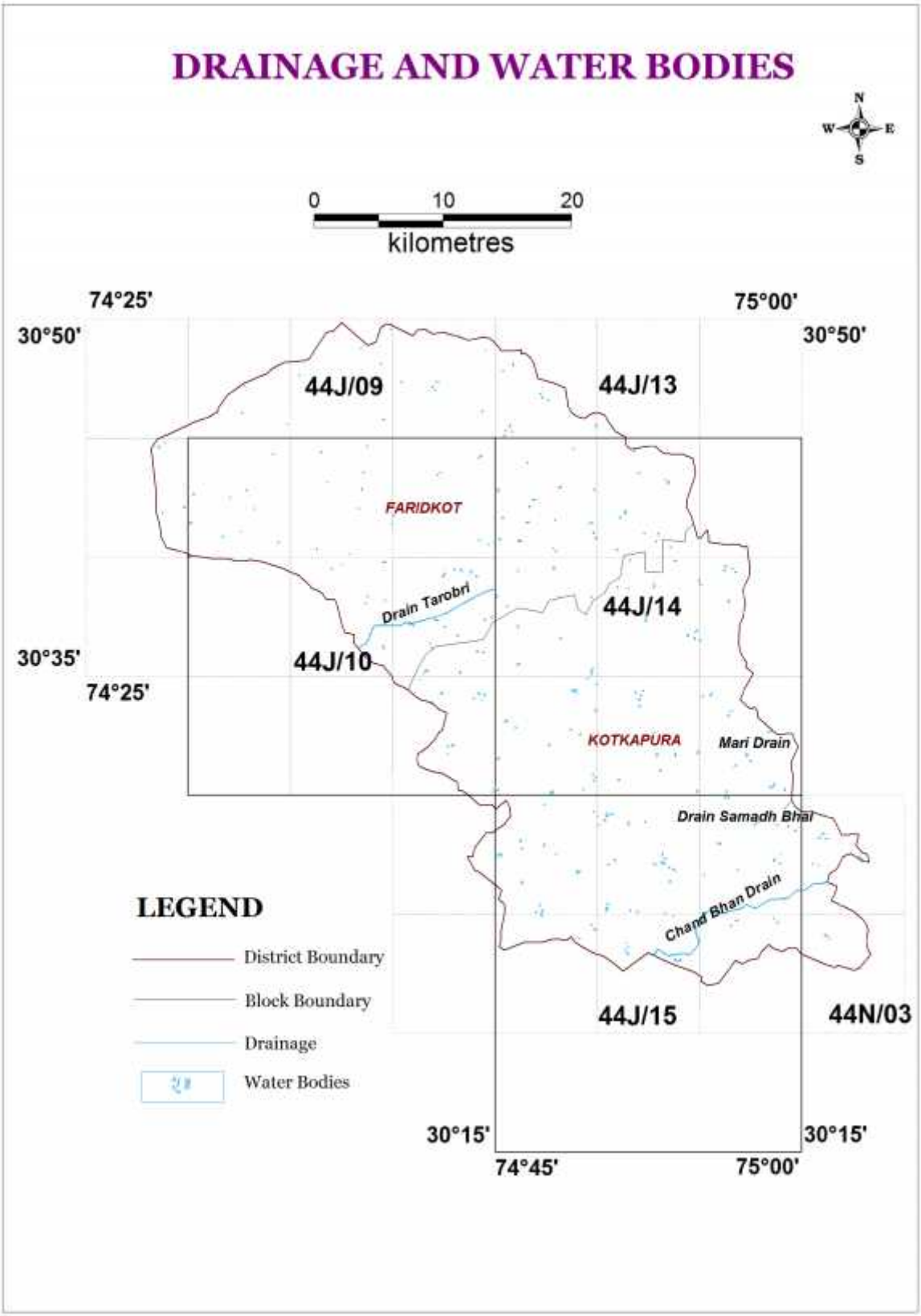
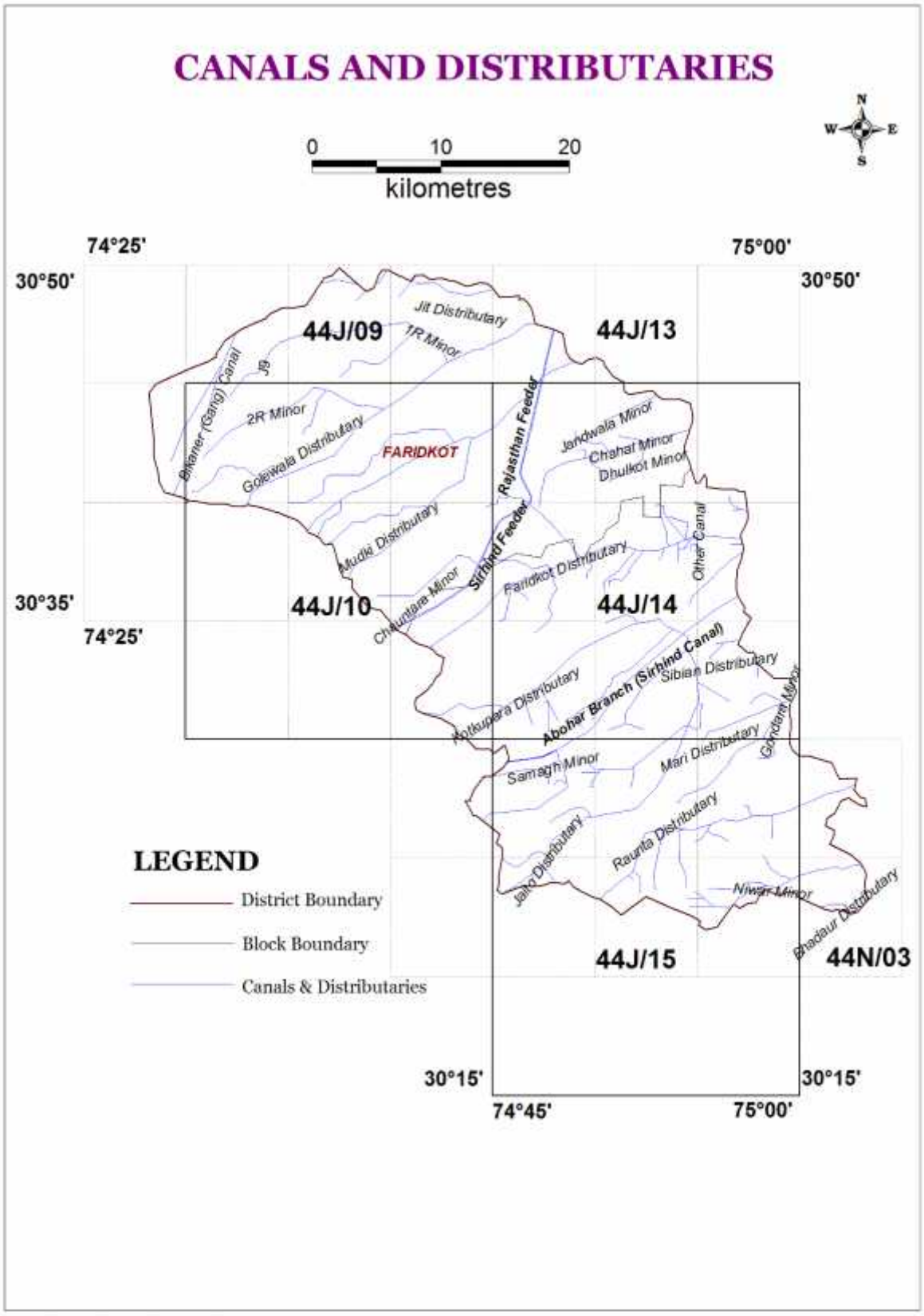


Fig.4: Canal and Distributaries of Faridkot District



2.0 DATA COLLECTION AND GENERATION

2.1 Geology and Hydrogeological data:

The area lies in the central part of Satluj basin of Indo-Gangetic Alluvial plain. Geologically, the area is occupied by a thick sequence of Quaternary deposits of Mid-Pleistocene to Recent age. These comprise alternate sequence of fluvial and arid phases. The exposed Quaternary Sediments can be broadly classifies as- (i) Older Alluvium of Middle to Upper Pleistocene age overlain by (ii) Aeolian deposits of Holocene age. The provenance of Older Alluvium deposited by rivers originated from Himalayas and Aeolian deposits have been laid down by wind action from Thar Desert of Rajasthan in the southwest part of the area. The generalized stratigraphic sequence of the area are given below,

Generalized Stratigraphy, Faridkot District (After Garg & Singh, 1993)

Age	***Lithological Unit***	***Lithological Characteristics***
Holocene	*Aeolian Flat*	Unconsolidated thin veneer of Aeolian sand.
	Newer Dunes	Unconsolidated orange brown sand and silt.
	Semi consolidated dunes	Semi consolidated light to dark brown sand.
	Older dune	Dark brown, Aeolian sand and silt with some vegetal matter.
Mid to Upper Pleistocene	*Older Alluvium*	Multi-cyclic light grey to brown fine to medium grained mixture of clay, silt and sand with Kankar. Light grey to pink sticky clay, grayish mica sand with kankar.

-----Basement not exposed----

The Principle Aquifer in the study area is Alluvium and the Major Aquifers are Older Alluvium and Aeolian Alluvium (Fig.5). The Ground water occurs in unconfined (water table) and confined conditions.

2.1.1 Water Level Behavior

Twenty three monitoring stations of Central Ground Water Board (CGWB) (7 Piezometers and 16 Dugwells) and Eighteen monitoring stations (18 Piezometers) of State Government represent the first aquifer. Second and third aquifer is represented by one monitoring station of CGWB. Depth to water level in the area ranges from 1.45 to 18.19 m bgl during pre-monsoon period (Fig.6) and 1.20 to 20.15 m bgl during post monsoon period (Fig.7). In eastern part water levels are in the range of 10 to 20 m, in central part the water levels are in the range of 5 to 10 m bgl and in western part the water levels are shallower in the range of 2 to 5 m. Seasonal water level fluctuation shows a rise and fall in the range of 1.10 to (-) 2.00 m in western and eastern part of the districts respectively during year 2015.

Hydrograph of Different Observation Wells

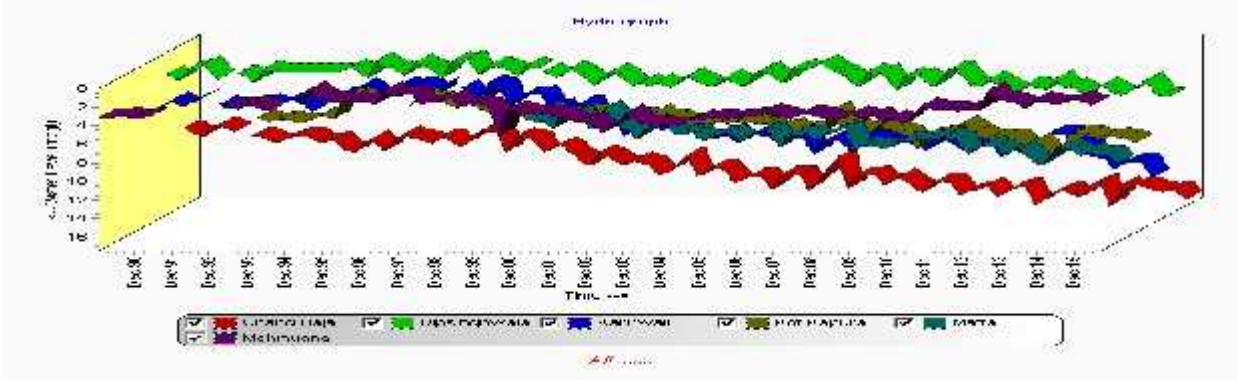


Fig.5: Major Aquifers

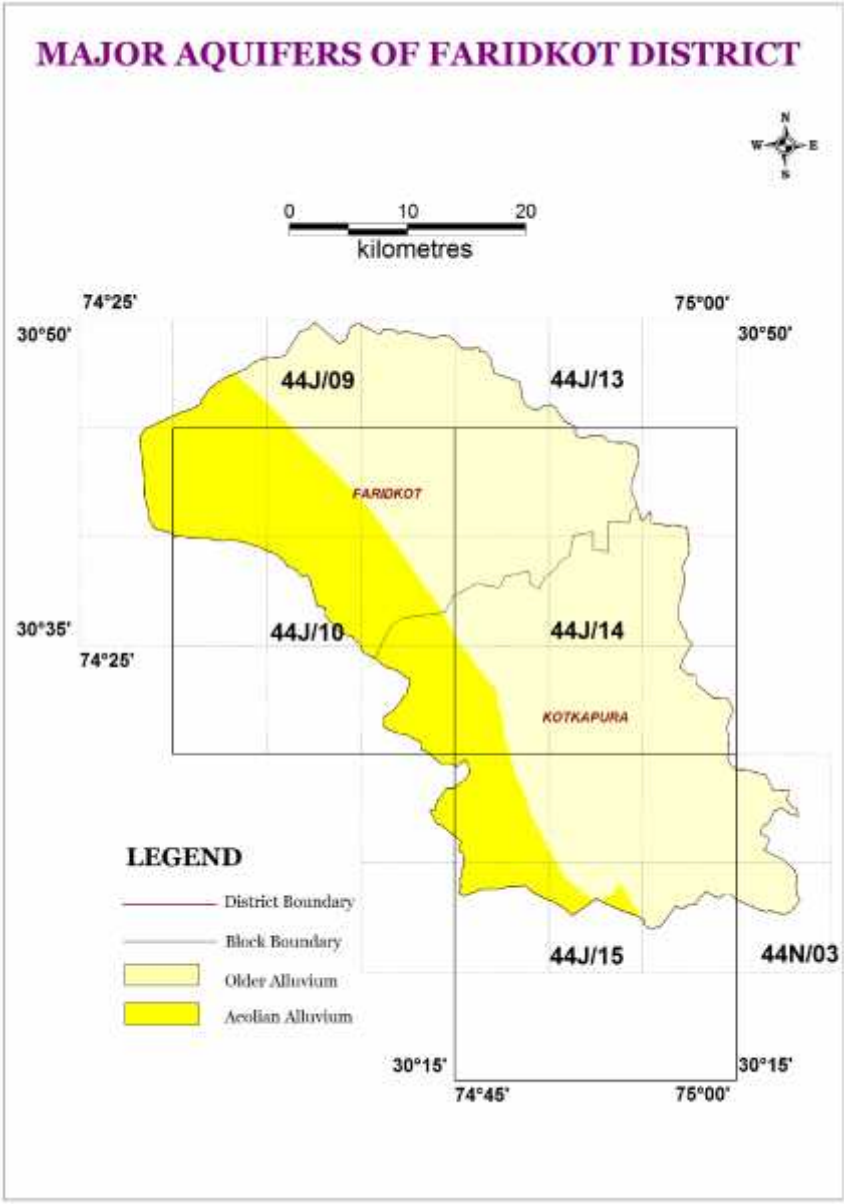


Fig.6: Depth to Water level Pre Monsoon, 2015

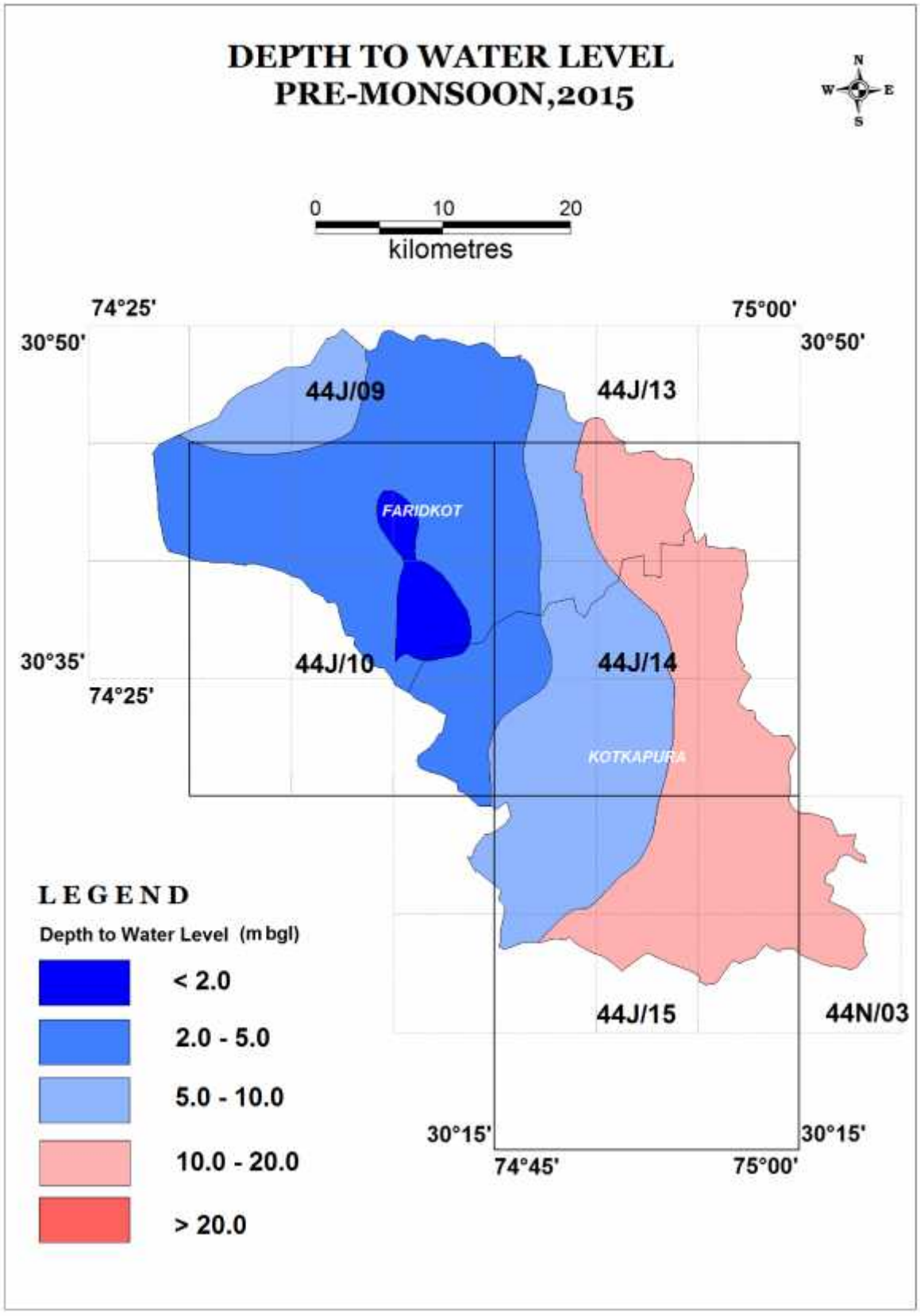
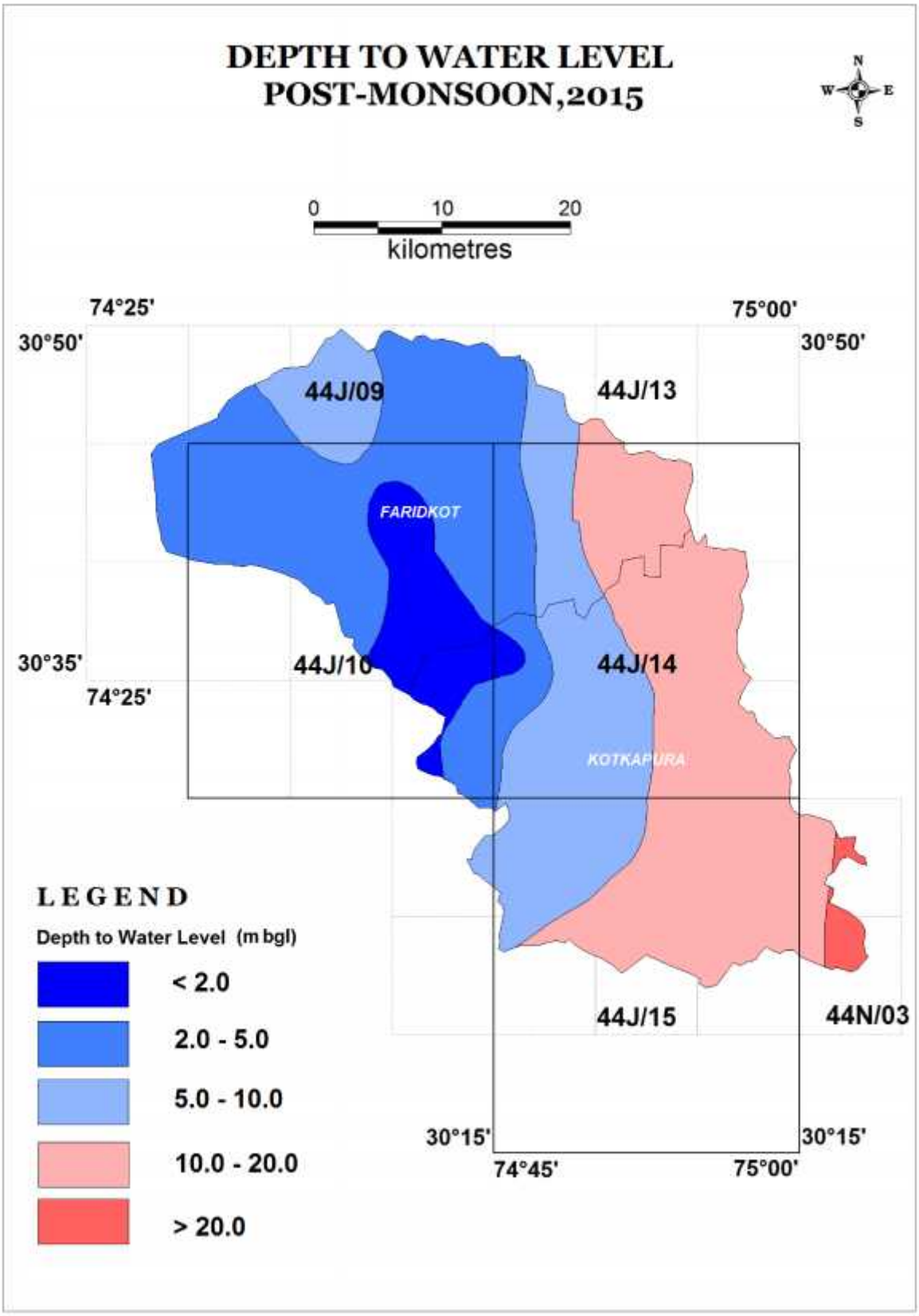


Fig.7: Depth to Water level Post Monsoon, 2015

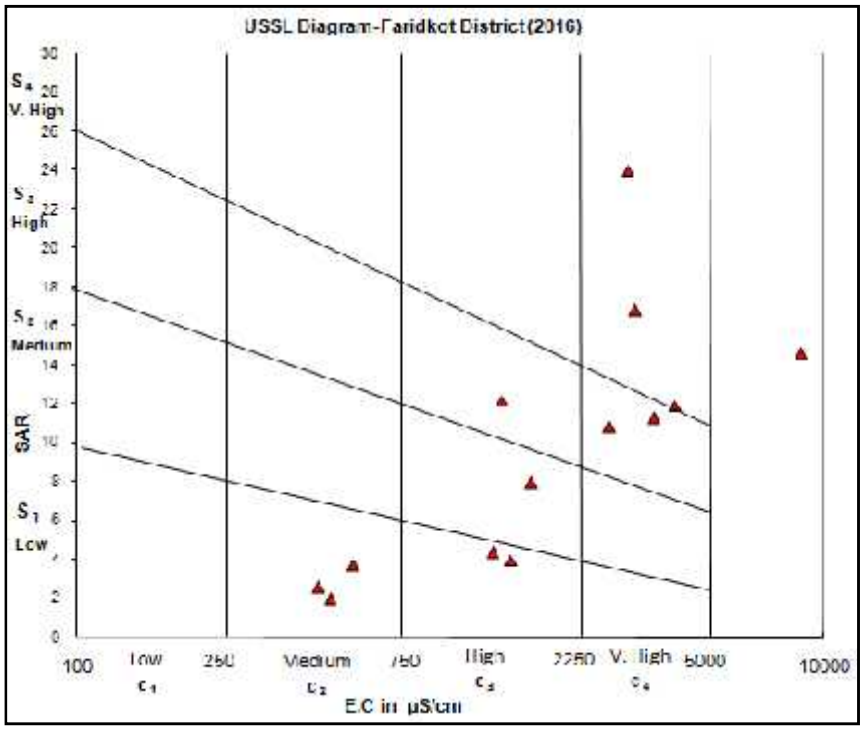


2.2 Water Quality Data:

Ground water quality of shallow aquifer (Aquifer-I) is assessed on the basis of chemical data of National Hydrograph Network stations i.e. NHNS monitored during Pre monsoon period. Twenty four groundwater samples are collected during NHNS, 2015 and chemical analysis is given in Annexure-I. The chemical quality of deeper aquifers has to be assessed during ongoing groundwater exploration programme under NAQUIM.

Chemical data of shallow aquifer indicates that ground water is alkaline in nature. The Electrical Conductivity (EC) values ranges from 444 to 8653 µS/cm at 25^{o}C indicating fresh to moderately saline. The EC values less than 1000 µS/cm at 25^{o}C have observed at four locations i.e. Jand Sahib (444), Devi wala (476), Mehmuana (550) and Arianwala (700) respectively. The EC values more than 3000 µS/cm at 25^{o}C have observed at six locations i.e; Tehna (8653), Baja Khana, (3988), Nangal (3487), Kot Kapura (3299), Mumara (3212) and Sukhanwala (3126). The ground water occurring in the central and south-eastern parts are marginally to highly saline and not suitable for drinking purposes.

The chloride concentration in ground water varies broadly between 28 mg/l at Ariyanwala and also 1544 mg/l at Tehna. Ground water with fluoride above 1.5 mg/L are found mainly in Nathuwala (6.03), Killi (4.29), Kot Kapura (3.33), Dhilwan kalan (2.85), Moharewala (1.95) and Bir Sikhanwala (1.84) and Nitrate concentration in groundwater above permissible limit 1.5 mg/l are found in ,Kot kapura (144), Killi (140), Dal Singhwala (136),Tehna (118), Nangal (104), Bir Sikhan wala (89), Nathuwala (79), Chand baja (79), Wara Daraka (66) ,Sher singhwala (65) and Sukhanwala(46). The USSL diagrams used for classification of irrigation water based on EC and SAR, shown below observed that ground water occurring in Faridkot district falls under C_4S_3, C_2S_1, C_4S_4, C_3S_1, C_3S_3 and C_3S_2 classes of irrigation classification.



Such waters when used continuously for irrigation, they are likely to cause salinity hazards and lead to reduction in crop yields. Plot of USSL diagram indicates that ground waters fall under C_2S_1 and C_3S_1 classes of irrigation rating.

Analysing mechanism and equipments used for chemical analysis are given in table-1.

Table-1: Analytical methods and equipments used for chemical analysis.

S. No.	Parameters	Analytical Methods
A.	***Physico-chemical analysis***	
	pH	Electrometric method
	Conductivity (EC)	Electrical conductivity method
	Carbonate & bicarbonate (CO_3,HCO_3)	Titrimetric method
	Chloride (Cl)	Argenotometric method
	Sulphate (SO_4)	Nephloturbidity method
	Nitrate (NO_3)	Spectro-photometric method
	Fluoride (F)	Ion metric method
	Total hardness (T.H)	EDTA-Titri metric method
	Calcium (Ca)	EDTA-Titri metric method
	Magnesium (Mg)	By difference
	Sodium (Na)	Flame photometric method
	Potassium (K)	Flame photometric method
	Total Dissolved Solids (TDS)	Gravimetric
B.	***Trace elements/Heavy metals***	
	Copper (Cu) Cadmium (Cd) Chromium (Cr) Lead (Pb) Manganese (Mn) Nickel (Ni) Cyanide (Cn)	Digestion followed by Atomic Absorption Spectrophotometer (AAS)
	Iron (Fe)	Spectrophotometer method

Fig.8: Hill-Piper diagram for Groundwater Quality of Shallow Aquifer of Faridkot District

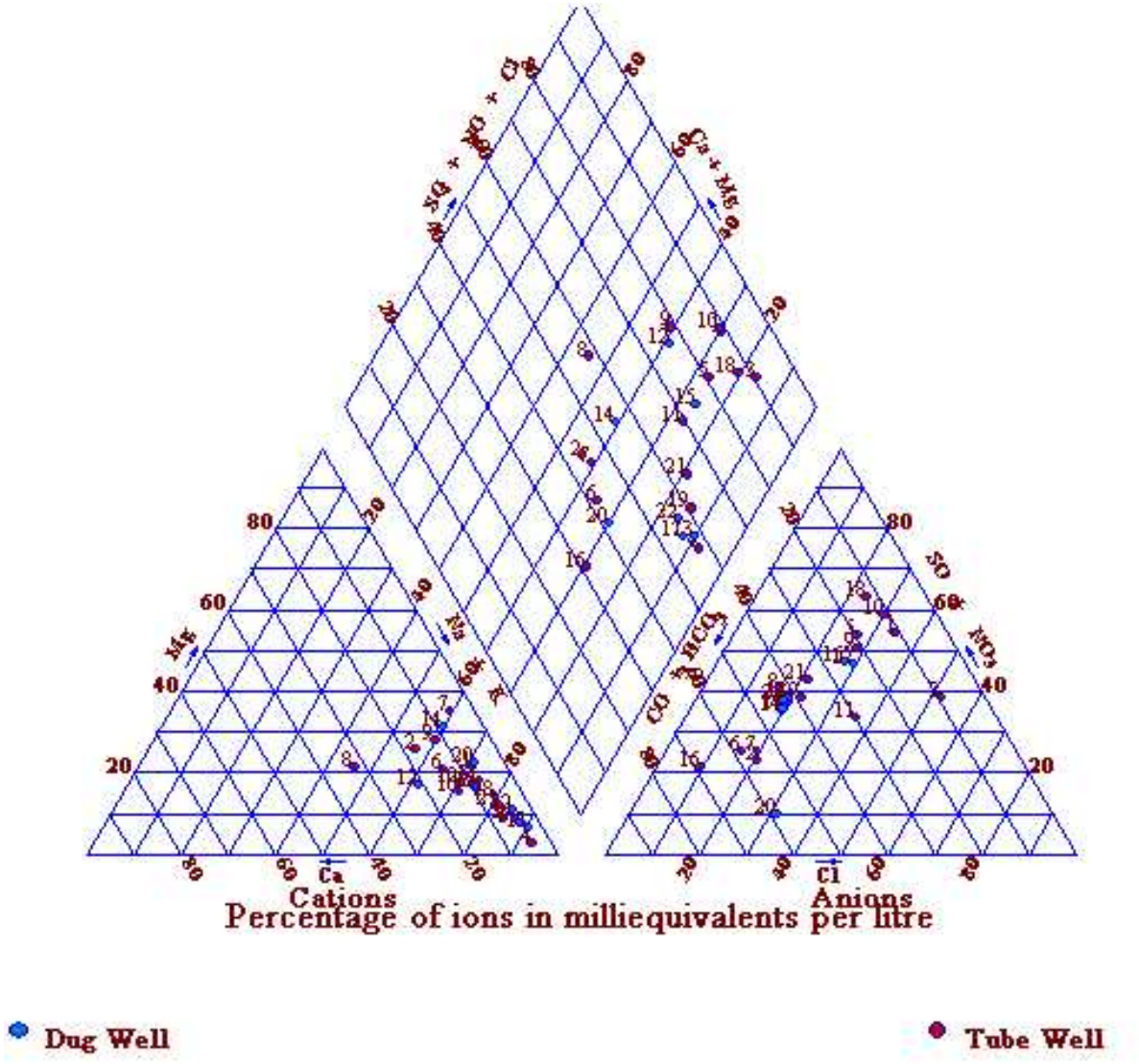
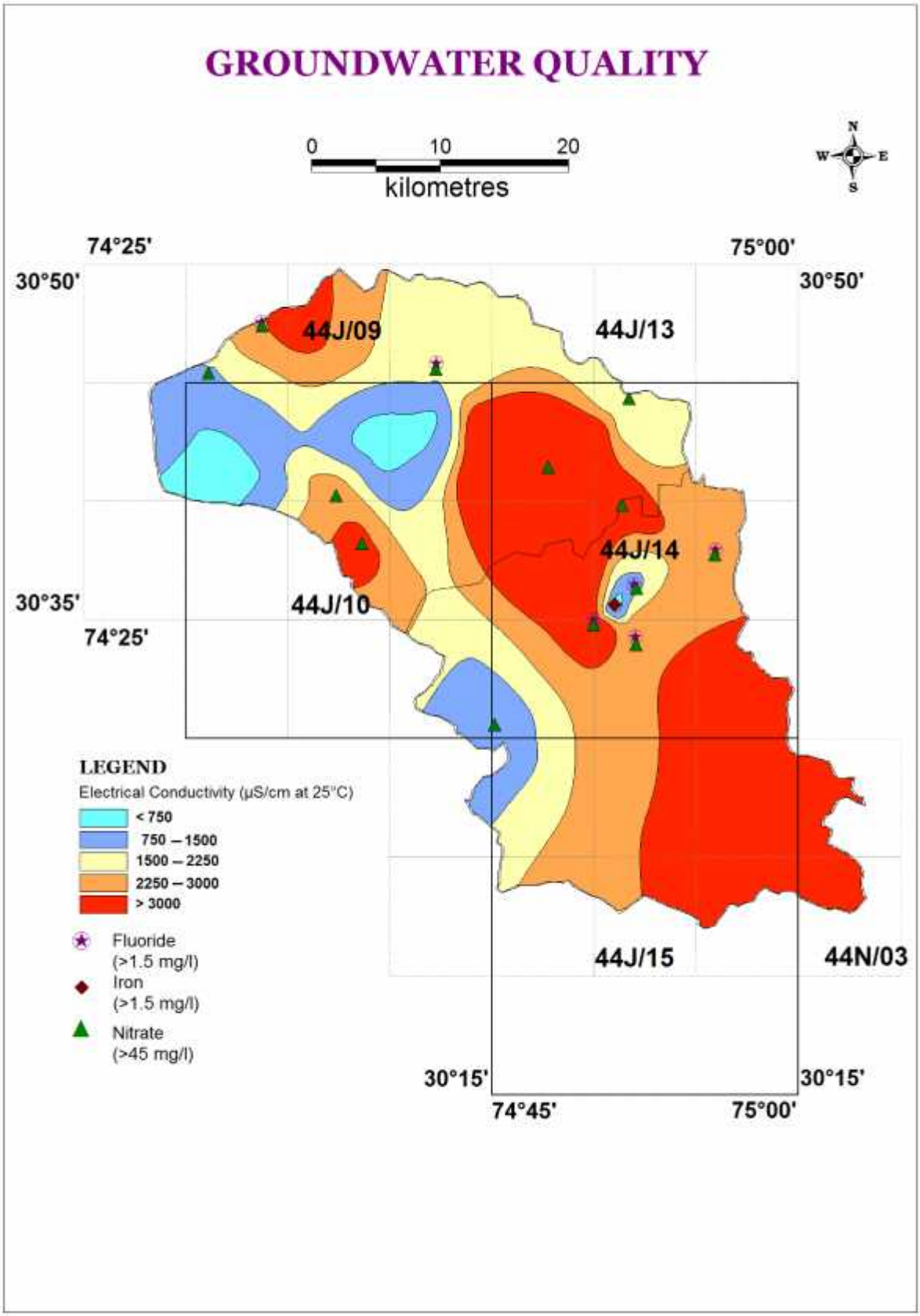


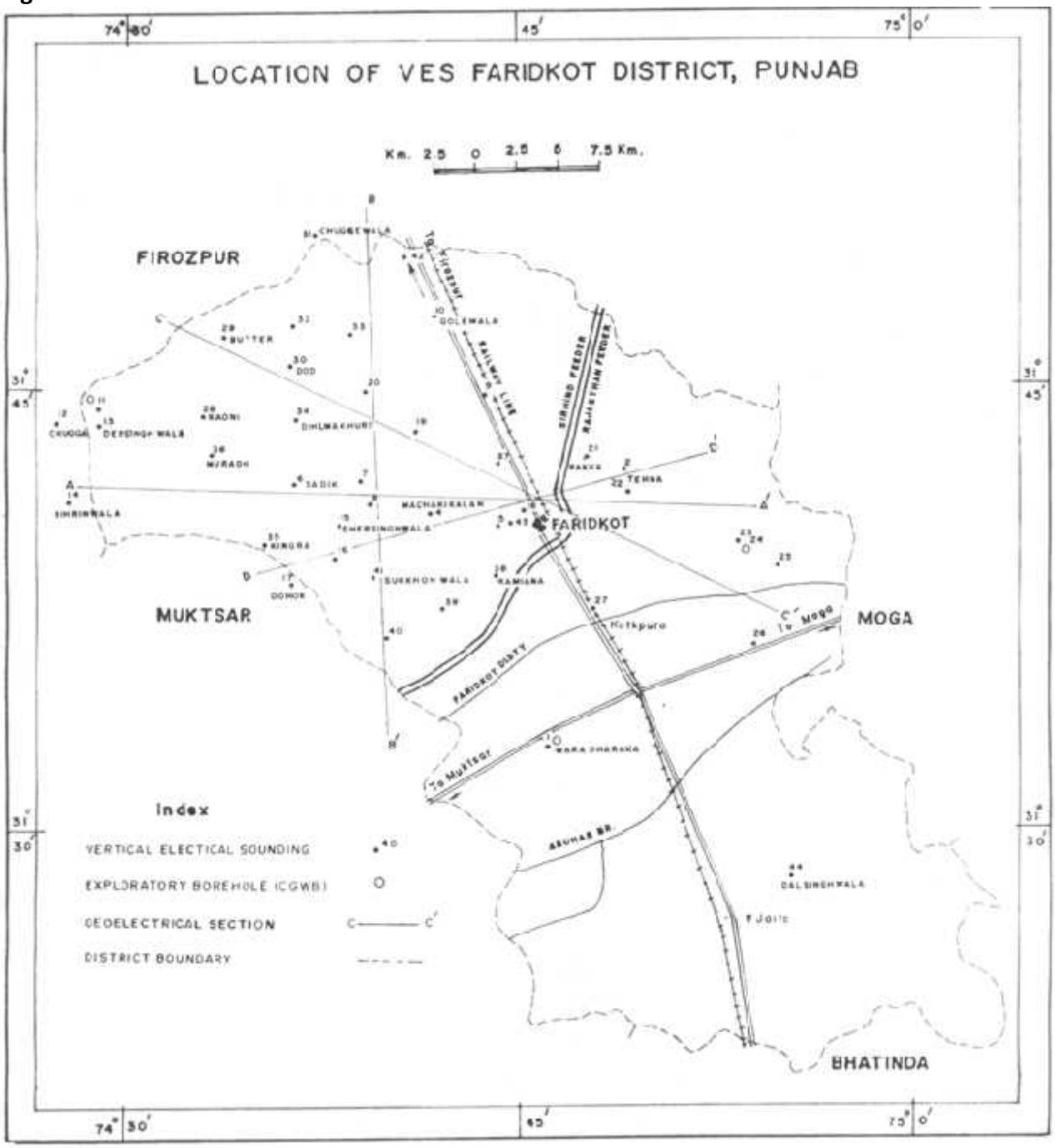
Fig.8: Groundwater Quality, 2015



2.3 Geophysical data:

To delineate fresh water - saline water interface laterally as well as vertically, surface geophysical investigations have been carried out in alluvial tracts over parts of the study area. Under surface geophysical investigations, total 44 VES (Fig.9) in an area of 1800 sq km were conducted with current electrical separation of 600 to 1000 m.

Fig.9: VES Locations in Faridkot District



Subsurface geophysical investigations include borehole logging. The ground water quality data pertaining to the CGWB exploratory boreholes indicate vertical and lateral variation in EC values. Shallow ground water quality data shows clearly the existence of salinity at shallow depth in the many parts of study area such as Pakka, Mahmuana, Shirinwala, Shersinghwala, Dohak, Kamiyana, Kingra and many other places. Electrical conductivity (EC) of ground water is more than 2000 µS /cm in major part of the area except at few places. Slight improvement in quality of ground water at deeper depth as compared to shallow depth, has been observed at few places. These places are Chuggewala, Golewalla, Nangal, Deepsinghwala where EC of ground water was found to be within 2000 µS /cm within the depth range of 80 to 120 m.

2.4 Exploratory drilling State - Data Availability:

The Lithologs of Exploratory Well/ Observation well/ Piezometer/ productive wells of CGWB, Punjab State Tubewell Corporation (PSTC) now as Punjab Water Resources Development and Management (PWRDM) , WRED (Water Resources and Environment Directorate), Water Supply and Sanitation (WSS) and Private Wells have been collected and those supported electrical logs have been validated for aquifer map preparation. The details are shown in Table-1.

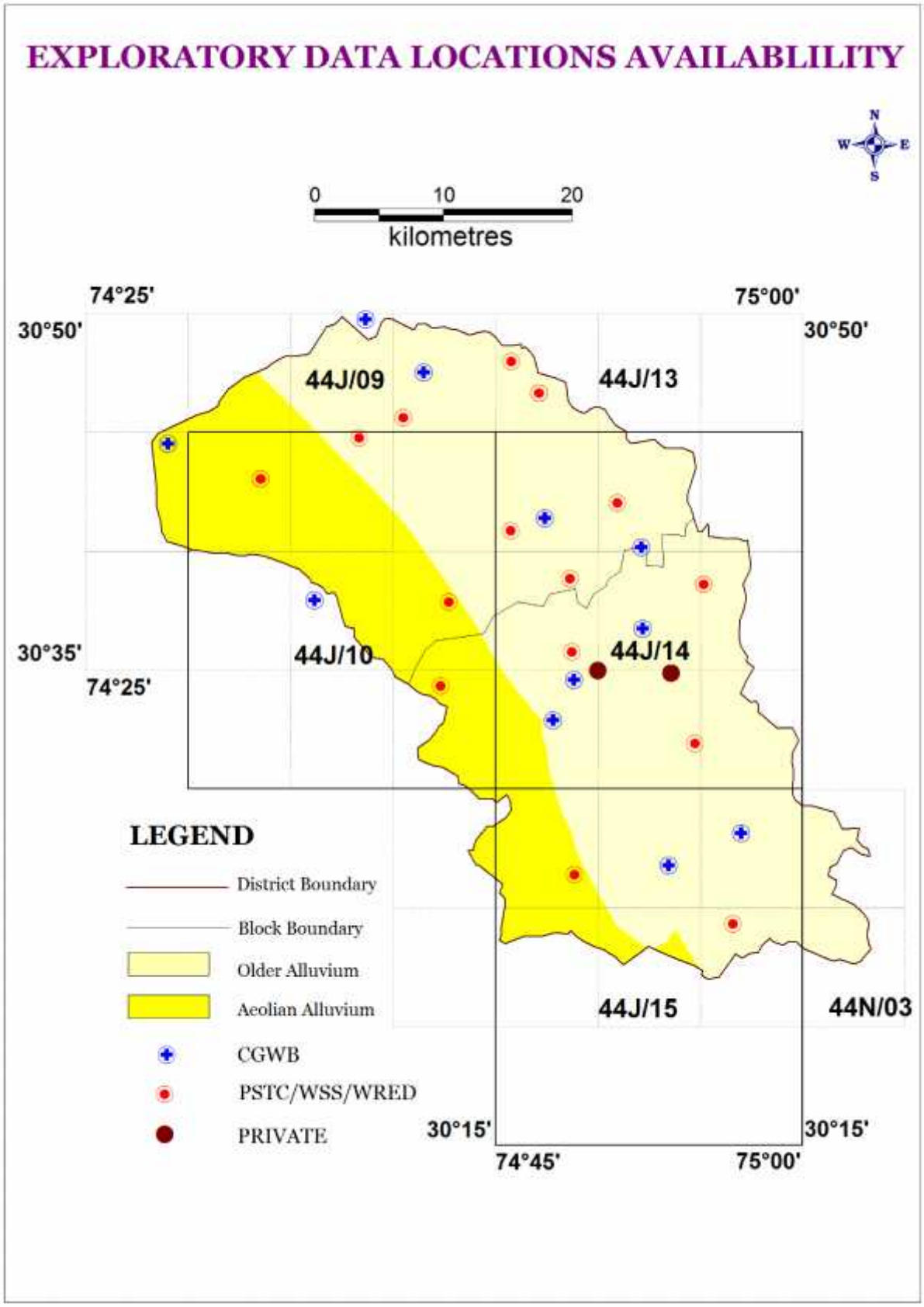
Table-1: Data Availability of Exploration Wells of Faridkot district

Sl.No	*Source of data*	*Depth Range (m)*				***Total***
		< 100	*100-200*	*200-300*	*>300*	
1	CGWB	2	1	1	8	**12**
2	WRED/PSTC/WSS	15	1	0	3	**19**
3	PRIVATE WELLS	1	0	1	0	**2**
Total		**18**	**2**	**2**	**11**	**33**

2.5 Spatial Data Distribution

The actual data of all the wells in the area are plotted on the map of 1:50000 scale with 5'X5'grid (9 x 9) km (Fig. 10). Perusal of table shows that majority of tube wells falls in the shallow aquifer having depth less than 100m and deeper aquifer having depth more than 300m. The grids/ formations devoid of groundwater exploration are identified as data gaps and these are to be filled by data generation. The Physical record of the availability of exploration data are given in Annexure-II.

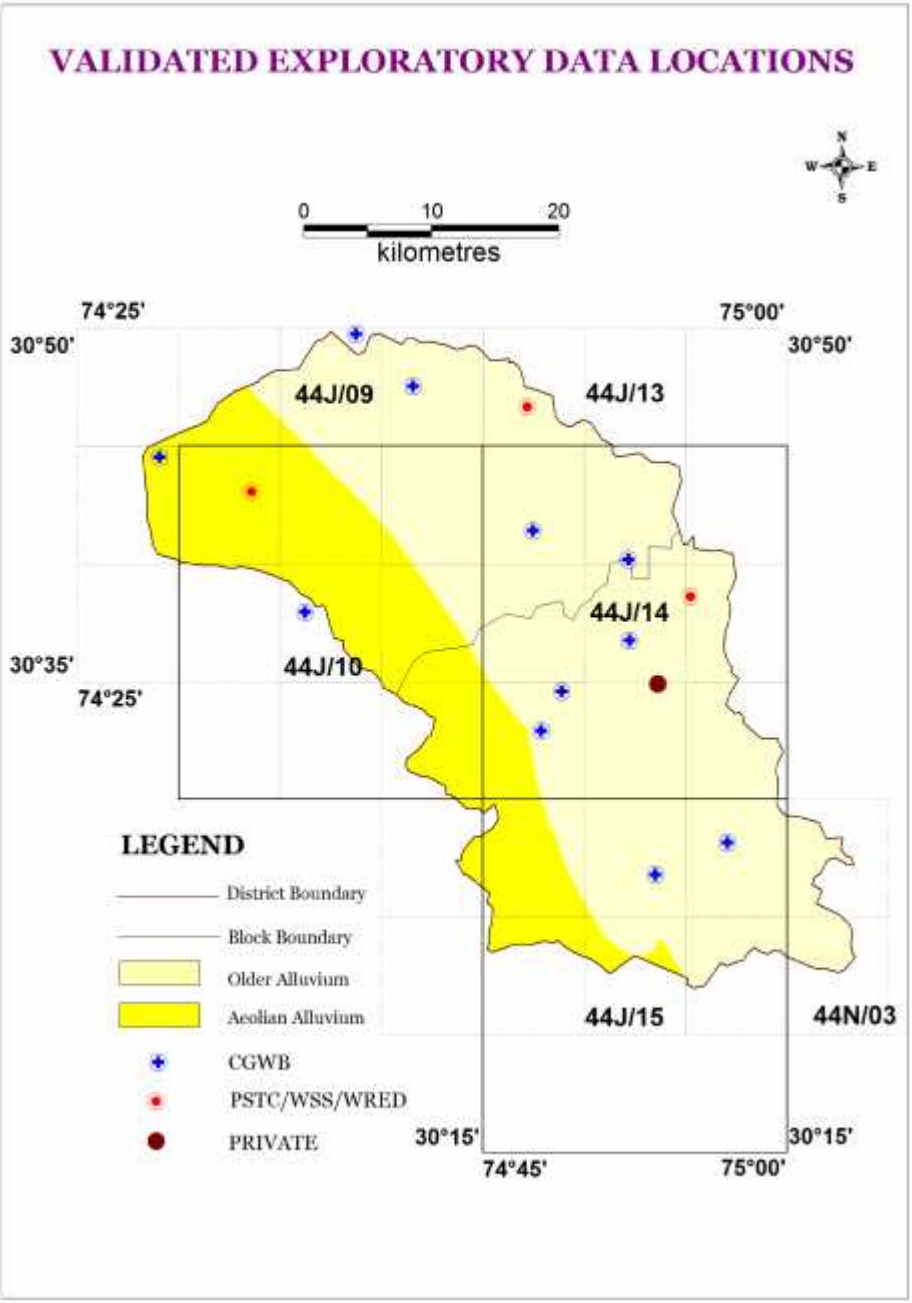
Fig.10: Locations of Exploration Data Availability



3.0 DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

All the available data have been validated to generate aquifer map. The deepest well in each quadrant is selected and plotted on the map of 1.50000 scale with 5'X5'grid (9 x 9) km (Fig.11).

Fig.11: Locations of validated exploration data



The optimized wells of CGWB, PWRDM, WRED, WSS and Private Wells have been used to prepare the elevation or collar elevation map to identify the topographic variations on ground surface so that it can give the synoptic picture of gradient variations in the water levels.

The topographic elevation values have been plotted to prepare the elevation contour map (Fig.12). The locations of validated wells in quadrant and toposheet wise distributions in respective blocks are given in Table-2. Locations of validated exploratory wells with litholog are shown in Fig.13.

Fig.12: Elevation contour map

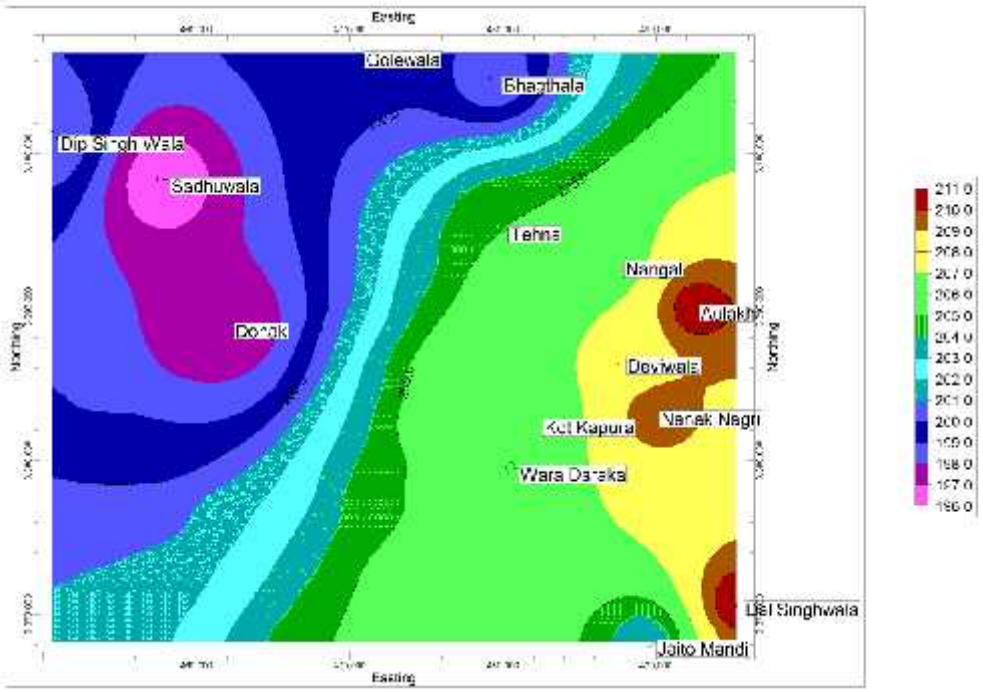


Fig.13: Locations of validated exploratory wells with Litholog

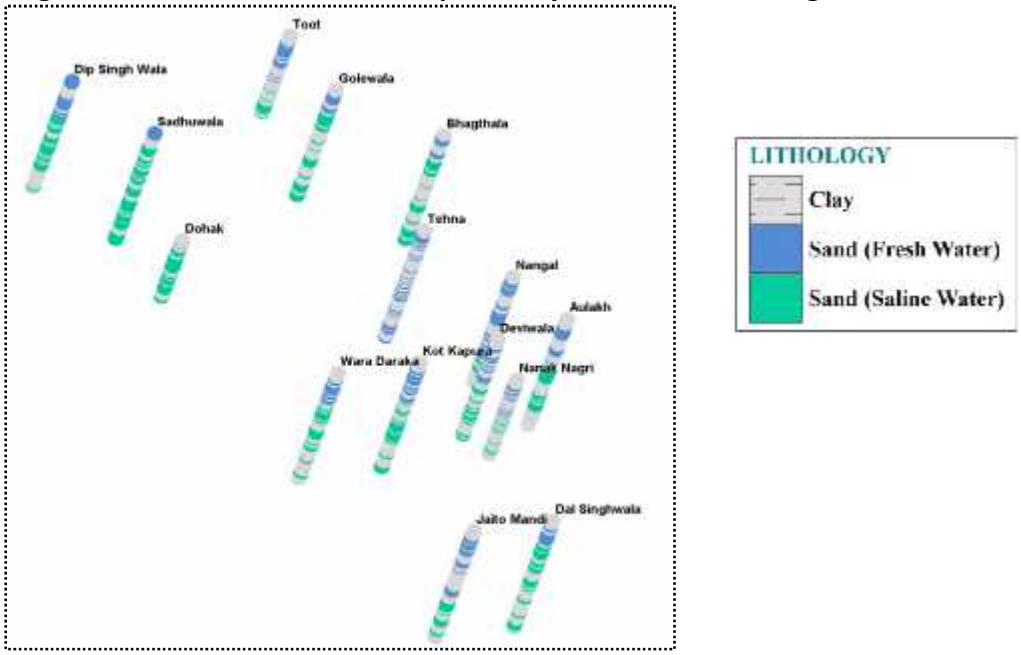


Table -2: Summary of optimized exploration wells

Block	Toposheet/Quadrant	Depth Range (m)					Elevation (m amsl)	Source of data
		Location	< 100	100-200	200-300	>300		
Faridkot	1A 44J/06	Dip Singh Wala	-	-	-	350	201	CGWB
Faridkot	3C 44J/09	Golewala	-	-	-	343.78	199.5	CGWB
Faridkot	1A 44J/14	Tehna	-	-	-	300	205	CGWB
Faridkot	3A 44J/14	Bhagthala	-	-	-	371.95	198	PSTC
Faridkot	1A 44J/10	Sadhuwala	-	-	-	359.70	196	PSTC
Kot Kapura	1C 44J/15	Dal Singhwala	-	-	-	300	211	CGWB
Kot Kapura	1B 44J/15	Jaito Mandi	-	-	-	419.20	203	CGWB
Kot Kapura	2A 44J/14	Kot Kapura	-	-	-	421.90	206	CGWB
Kot Kapura	3B 44J/14	Nanak Nagri	-	-	213.4	-	210	PRIVATE
Kot Kapura	1B 44J/14	Nangal	-	-	-	300	206	CGWB
Kot Kapura	3A 44J/14	Wara Daraka	-	-	-	300	205	CGWB
Kot Kapura	2C 44J/14	Aulakh	-	-	-	384.14	211	PSTC
Kot Kapura	2B 44J/14	Deviwala	-	-	269	-	207	CGWB
Muktsar	*2B 44J/10*	*Dohak*	-	*163*	-	-	*197*	*CGWB*
Ghal khurd	*3B 44J/09*	*Toot*	-	-	*217*	-	*196*	*CGWB*

Two exploratory wells from adjacent districts i.e: Dohak from Muktsar district and Toot from Ferozpur district have been incorporated for the preparation of lithological fence and cross sections.

3.1 Sub Surface Disposition

3.1.1 Previous Work:

To delineate and determine the potential aquifer zones, evaluation of aquifer characteristics etc. Exploratory drilling was conducted by CGWB at 6 locations in the district includes 05 exploratory wells and 1 slim hole between 1975 to 2008 through in-house activities and 02 exploratory wells and 2 piezometers through outsourced by M/s WAPCOS Ltd. between 2011 to 2015 (Fig.10);. The drilling has been carried out to a maximum depth of about 408 m (Kot Kapura) and revealed the presence of 6 to 12 prominent permeable granular zones with aggregate thickness varying from 28 to 283 m. The granular zone consists of fine to medium sand. The slim hole at Golewala and exploratory well at Kot Kapura have abandoned due to poor quality of formation water upto depth of 350m bgl.

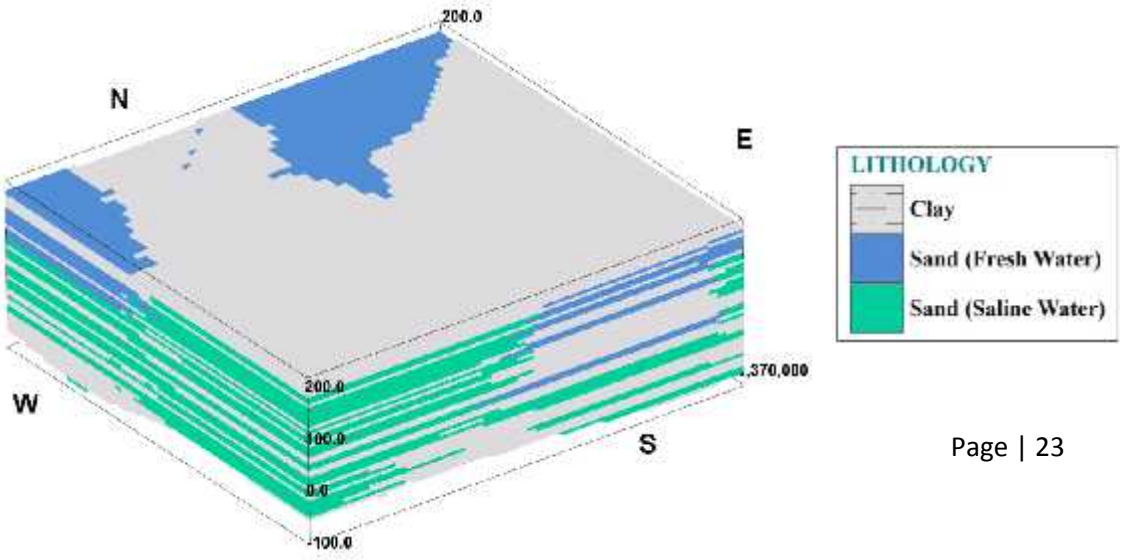
Further, the study of exploratory boreholes drilled in the district revealed the presence of multiple aquifer groups up to the maximum drilled depth of 408 m. The first aquifer group forms very shallow water table aquifer (IA) and occurs down to 57 m. Below that clay layer starts getting thickened to about 8-10m separating Aquifer IB down to 120 m. The below multi aquifers behaves as semi-confined to confined and consisting of thin sand layers alternating with thicker clay layers. Overall flow of ground water is towards south-west direction. Further, the study of exploratory boreholes drilled in the area revealed that the area is considered as a single aquifer system up to the maximum depth of 300 m.

3.1.2 Present NAQUIM Study:

To understand the sub surface disposition in the study area, geological sections and fence diagram have been prepared by synthesizing the various sub-surface sections on the basis of study of the lithological logs and electrical logs of boreholes drilled by CGWB, WRED, PSTC and Private Agencies using the RockWorks15 software and a 3D lithological model has been prepared (Fig.14). The 2D lithology sections and 3D lithological fence diagram has been prepared using lithology model and are shown in Fig.15a, b & 16 respectively. The aquifers are composed of fine to medium sand with clay intercalations. The granular zones are extensive. The aquifer occurring below 252m depth are composed of very fine to medium sand with silt.

Based on geophysical borehole logging and use of resistivity profiling followed by the depth soundings at few selected places, fresh-saline water zones are demarcated. This analysis is extremely important for the present study and will be referred from time to time as it is obviously the higher resistivity beds represents freshwater zone in contrast in low resistive beds indicating saline groundwater zone.

Fig.14: 3-Dimension Lithological Model



The major aquifer system of the area is Quaternary alluvial deposits having Older and Aeolian alluvium which mainly comprises of sand, silt and clay. The top surface layer is mainly silty clay. The lithology along W-E direction shows the variation in lithological thickness i.e. thin clay layers inter bedded with sand except at Nangal where thick clay layers were identified at 55 m bgl. There is inter-layering of sand and clay with thick clay at Golewala and Bhagthala towards western side at a depth between 150m to 210m bgl. There is thick a inter-layering of sand and clay towards all lithologs except Nanak Nagri shows thin sequence of sand and clay towards SW Lithological data of wells are given in Annexure-III.

Fig.15a,b: 2-Dimension Lithological Sections

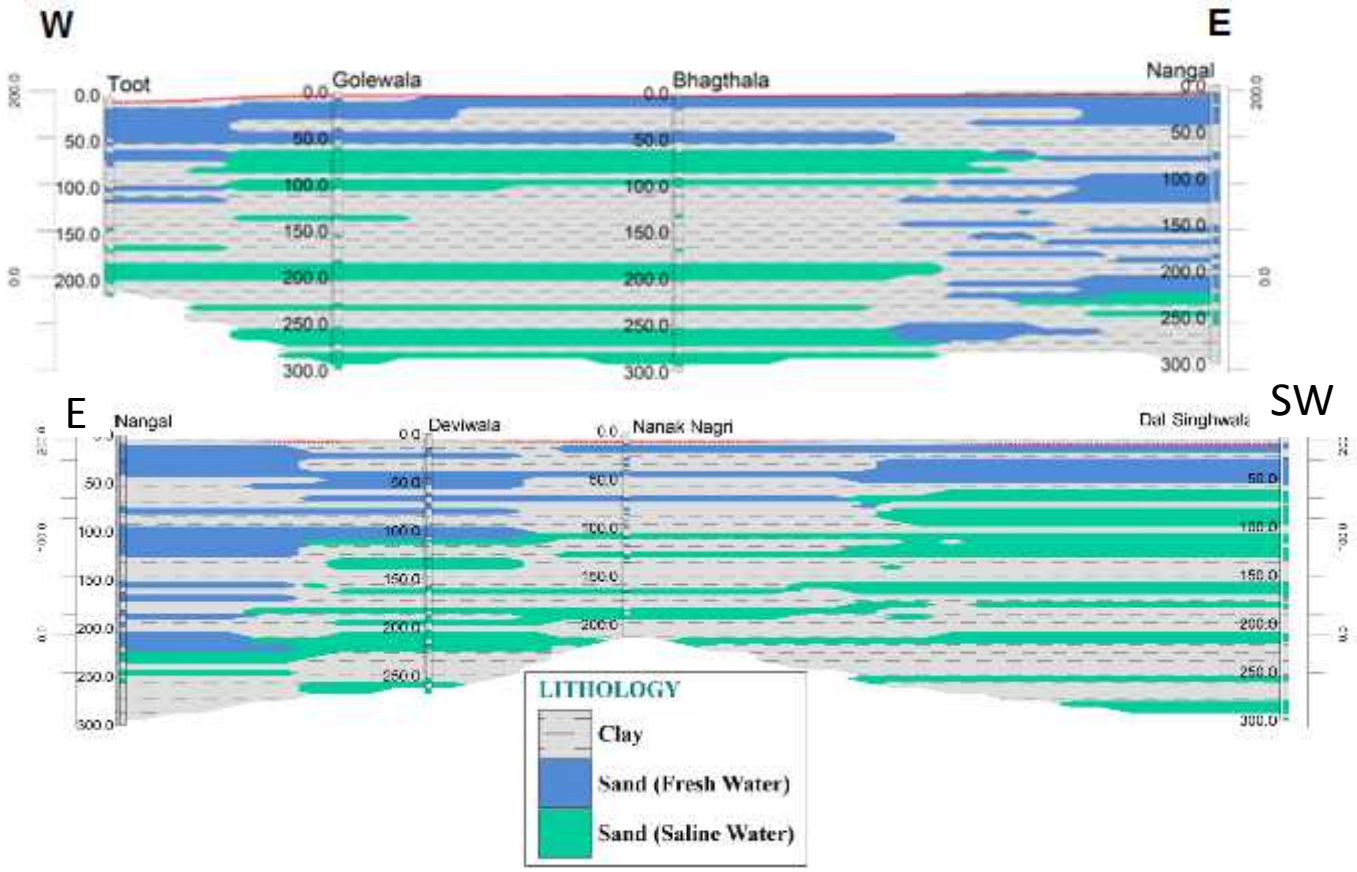
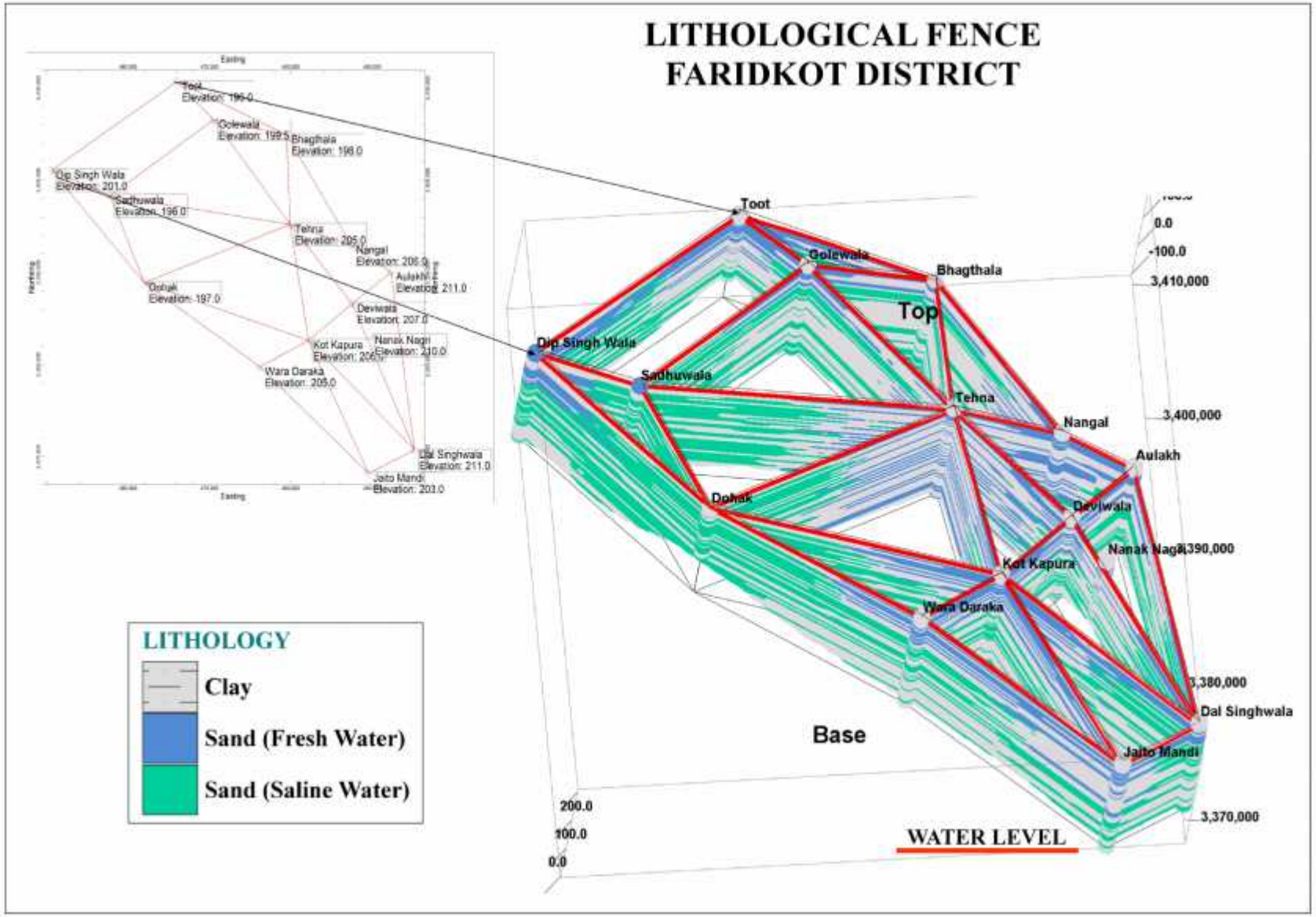


Fig.16: 3-Dimension Lithological Fence



3.2 Aquifer Geometry:

The aquifer group embodies a number of granular layers alternating with clay lenses. A few clay layers intervening these aquifer groups pinch out against the sand zones at few places. The marker horizons are traced all over the area by connecting their tops and bottoms. Sandy clay layer occurs at the surface covering the unconfined aquifer which is in turn underlain by prominent clay zone. It is composed of mainly of medium sand with thin beds of fine sand.

Aquifer IA (Very Shallow Aquifer) extends maximum upto 70 m of depth and below that clay layer starts getting thickened about 10-12m separating Aquifer IB to a maximum depth of 123 m. Multi layer aquifers are existing in the area each aquifer is separated by thick clay zones of 25 to 40 m upto 300m depth (Annexure IV). Based on the same criteria, to know the broad picture of the aquifer disposition, inter-relationship of granular zones, nature, geometry and extension of aquifers in the study area, the aquifer grouping has been carried out using the sub-surface lithology and a 3-Dimensional aquifer model (Fig.17) and aquifer disposition 3D fence diagram has also been prepared using the aquifer model (Fig.18). Various groups identified in the area are given in Table-3. It is very difficult to differentiate the aquifer groups after Aquifer Group I, so the whole lithology is considered to be a single aquifer group system. The first aquifer is water table aquifer and extends all over the area. The aquifer is mainly composed of fine to coarse grained sand.

Table-3: Aquifer Grouping in Faridkot District

Aquifer Group	Range		Thickness	
	From	To	Min	Max
Aquifer IA	4	70	29	50
Aquifer IB	64	123	21	52
Multiple Aquifers	133	300	21	85

Fig.17: 3D Aquifer Disposition Model

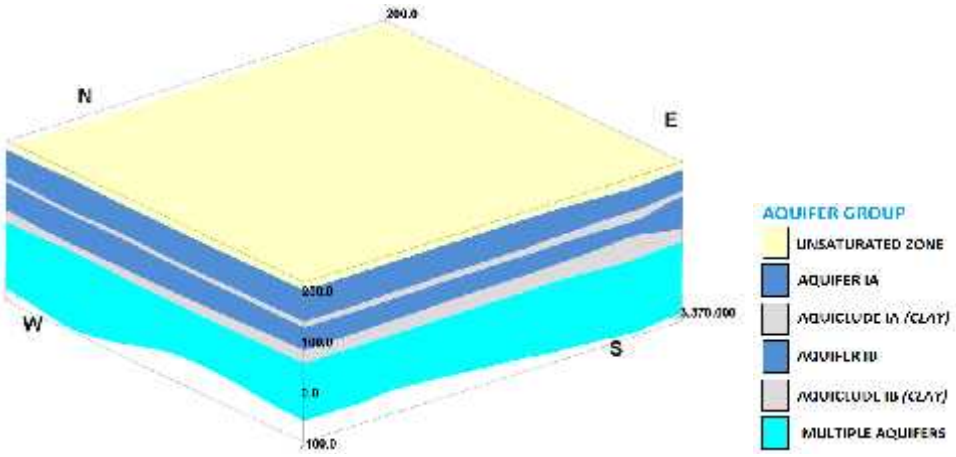
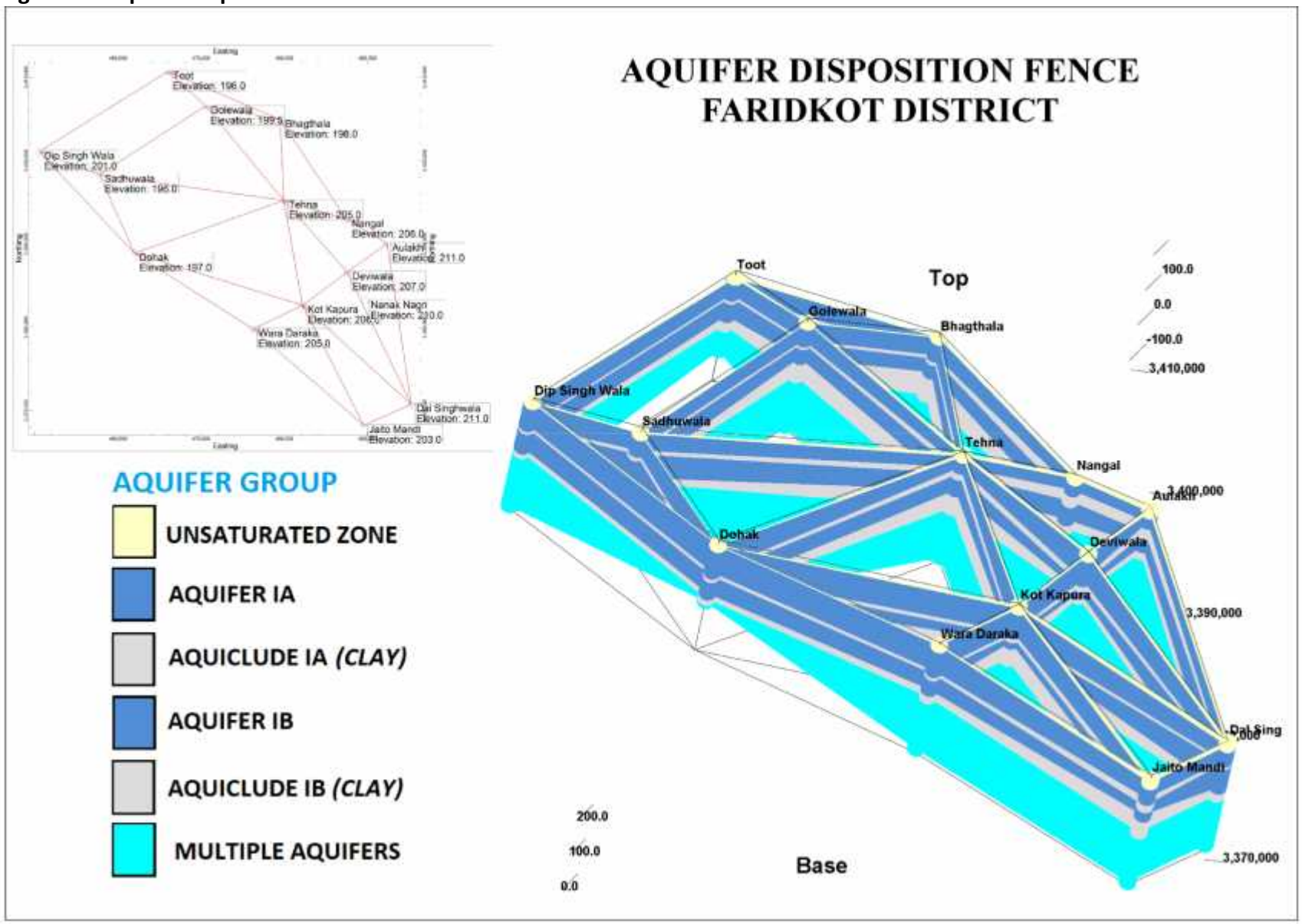


Fig.18: 3D Aquifer Disposition Fence



4.0 GROUND WATER RESOURCES

Ground water resource estimation of the area have been carried out by taking Dynamic and In-storage resources of unconfined aquifer and confined aquifer present upto 300m depth. The assessment of dynamic ground water Resources of the study area have been carried out jointly by CGWB and Water Resources and Environment Directorate (WRED), Department of Irrigation, Punjab on the basis of Ground Water Estimation Committee (1997) methodology.

The occurrence of potential aquifers (productive granular zones) upto 300 m depth has been demarcated on basis of aquifer wise subsurface mapping. The total saturated thickness of granular zones was derived from the exploratory borehole data of a particular block. The granular zones occurring below the zone of water level fluctuation up to the first confining layer has been considered as static unconfined zone. The specific yield value for the unconfined aquifer has been taken as 60% of 0.12 which comes as 0.072 whereas for the confined aquifer, the storativity value has been considered. Since the specific yield is likely to reduce with increase in depth due to compaction of overlying sediments.

Hence, the major data elements considered in this estimation are thickness of granular zones, specific yield/storativity, and area of both fresh water and saline/brackish water. It has been observed that in some of the blocks sufficient data on probable occurrence of granular zones was not available. In those cases, the existing exploratory data of adjoining block/district has been either extrapolated or interpolated to derive such parameters required for estimation. This assessment of total groundwater resources has been computed based on the available data with CGWB & WRED, Department of Irrigation, and Punjab.

4.1 Groundwater Resources up to depth of 300m

a. Dynamic Resources:

Block-wise ground water resource potential of the district has been assessed as per GEC-97 as on 31st March 2013. The primary source of recharge in the area is the rainfall. The ground water development in all the blocks has exceeded the available recharge, thus all the blocks have been categorized as over exploited. The overall stage of ground water development in the Faridkot district has been assessed to be 160%. The block wise details are given in below Table-4.

Table 4: Dynamic Ground Water Resource & Development Potential (31.03.2013) in mcm

Assessment Unit/ Block	*Net Annual Ground Water Availability*	*Existing Gross Ground Water Draft for irrigation*	*Existing Gross Ground Water Draft for domestic and industrial water supply*	*Existing Gross Ground Water Draft for All uses (11+12)*	*Provision for domestic, and industrial requirement supply to 2025*	*Net Ground Water Availability for future irrigation development (10-11-14)*	*Stage of Ground Water Development {(13/10) * 100} (%)*	*Category*
Faridkot	346.32	528.61	19.11	547.71	22.19	-204.48	158	Over Exploited
Kot Kapura	268.21	420.20	14.02	434.21	15.11	-167.09	162	Over Exploited
TOTAL	**614.53**	**948.80**	**33.13**	**981.93**	**37.30**	**-371.57**	**160**	**Over Exploited**

b. In-storage Ground Water Resources

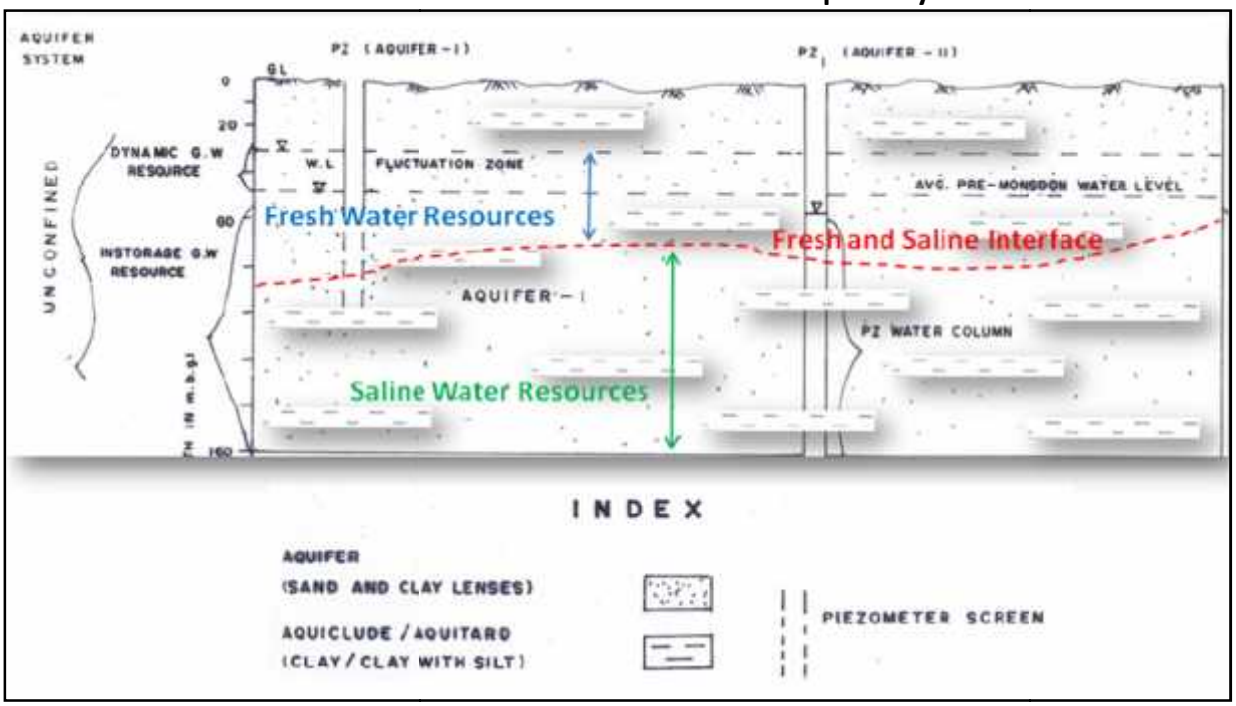
As per revised guidelines recommended by the Central Level Expert Group on groundwater resources assessment, the resources are separately considered as dynamic and in-storage unconfined. In case of alluvial area, in-storage resources of unconfined aquifer have been computed on the basis of specific yield of aquifer as detailed below.

In-storage Ground Water resources (Unconfined Aquifer)	=	**Thickness of the aquifer (granular/productive zone) below the zone of water level fluctuation down to the bottom layer of unconfined aquifer**	x	**Sp. Yield of the aquifer**	x	**Areal extent of the aquifer**

The dynamic and in-storage ground water resource estimations have been calculated for single aquifer group upto 300m of each block of Faridkot district. In-storage ground water resources are estimated for fresh water and saline water resources based on the geophysical interpretations of depth to fresh and saline water interface for each block. The fresh and saline calculations are made on the basis of the assumptions on aquifer that is considered as unconfined aquifer so that the specific yield concept is used for resources estimations (Fig.19). The detailed resources estimations are calculated in detailed table for fresh and saline water resources in the below Table-5, 6& 7.

Total Availability of Ground Water Resources = Dynamic Resources + In-storage Resources.

Fig.19: Conceptual figure to understand the fresh and saline water resources in the aquifer up to 300 m for Resource Estimation in Unconfined and Confined Aquifer System.



(The clay lenses are more dominant in the aquifer and sometimes huge thickness of clay deposits are also observed in the litholog)

Table-5: Block wise In-Storage Ground Water Resources of Fresh Water Aquifer

GENERAL DESCRIPTION OF THE GROUND WATER ASSESSMENT UNIT OF DISTRICT FARIDKOT, PUNJAB STATE (2013)												
Type of Ground Water Assessment Unit (Block): Faridkot Blocks												
Sr. No	Name of Assessment Unit	Type of formation	Areal extent (sq km)		Average Pre-monsoon Water Level (m bgl)	Depth to bottom of Aquifer based on Geophysical Interface & Borehole logging (m bgl)	Total Thickness of formation below Pre-monsoon Water Level (m) (7-6)	Total thickness of the Granular Zones up to the depth of Fresh Water Zones (m)	Thickness of the unsaturated granular Zones up to Pre-monsoon WL (m)	Thickness of the saturated granular Zones up to the depth of Fresh water aquifer below (m) (9-10)	Average Specific Yield	In-Storage Ground Water Resources up to the depth of Fresh Water Aquifer (ham) 5*11*12
			Total Geographical Area	Assessment Area: Fresh Water								
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	Faridkot	Alluvium	75210	36710	4.50	152	147.5	72	2	69	0.072	182375
2	Kot Kapura	Alluvium	66650	61650	10.69	106	95.31	51	3	48	0.072	213062
Dist. Total (ham)			**141860**	**228406**								**395438**
Dist. Total (mcm)												**3954**

ham : hectare metre

mcm: million cubic metre

Table-6: Block Wise In-Storage Ground Water Resources of Saline Aquifers upto 300 m Depth

GENERAL DESCRIPTION OF THE GROUND WATER ASSESSMENT UNIT OF DISTRICT FARIDKOT, PUNJAB STATE (2013)										
Type of Ground Water Assessment Unit (Block): Faridkot Blocks										
Sr. No.	Name of Assessment Unit	Type of formation	Areal extent (ha)		Depth to bottom of Aquifer based on Geophysical Interface & Borehole logging (m bgl)	Depth to bottom of Saline Water Aquifer based on Geophysical Interface & Borelogging (m bgl)	Total thickness of the Saline Water up to the max depth (m)	Total thickness of the Granular Zones up to the depth of Saline Water Zones (m)	Average Specific Yield	In-Storage Ground Water Resources up to the depth of Saline Water Aquifer (ham) 5*10*11
			Total Geographical Area	Assessment Area Saline Water						
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	Faridkot	Alluvium	75210	38500	152	300	148	103	0.072	285516
2	Kot Kapura	Alluvium	66650	5000	106	300	194	76	0.072	27360
Dist. Total (ham)			**141860**	**228406**						**312876**
Dist. Total (mcm)										**3129**

ham : hectare metre

mcm: million cubic metre

Table-7: Block Wise Total Availability of Fresh and Saline Groundwater Resources upto 300 m Depth and Volume of unsaturated granular zone after 3m upto water level.

BLOCK WISE AVAILABILITY OF TOTAL GROUNDWATER RESOURCES IN FARIDKOT DISTRICT								
Sl.No	**BLOCK**	*Volume of Unsaturated Granular Zone up to Pre-monsoon WL*	*Dynamic Groundwater Resources (2013) AQUIFER-I*	*In-storage Groundwater Resources UPTO FRESHWATER*	**Total Fresh Groundwater Resources [(4)+(5)] (HAM)**	**Total Saline Groundwater Resources[(3)+(4)] (HAM)**	**Total Availability of Groundwater Resources [(6)+(7)]**	
							ham	**mcm**
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
1	Faridkot	10830	34632	182375	217007	285516	**502523**	**5025**
2	Kot Kapura	14396	26821	213062	239883	27360	**267243**	**2672**
Dist.Total (ham)		**25227**	**61453**	**395438**	**456891**	**312876**	**769767**	**7698**
Dist.Total (mcm)		**252**	**615**	**3954**	**4569**	**3129**		

ham : hectare metre

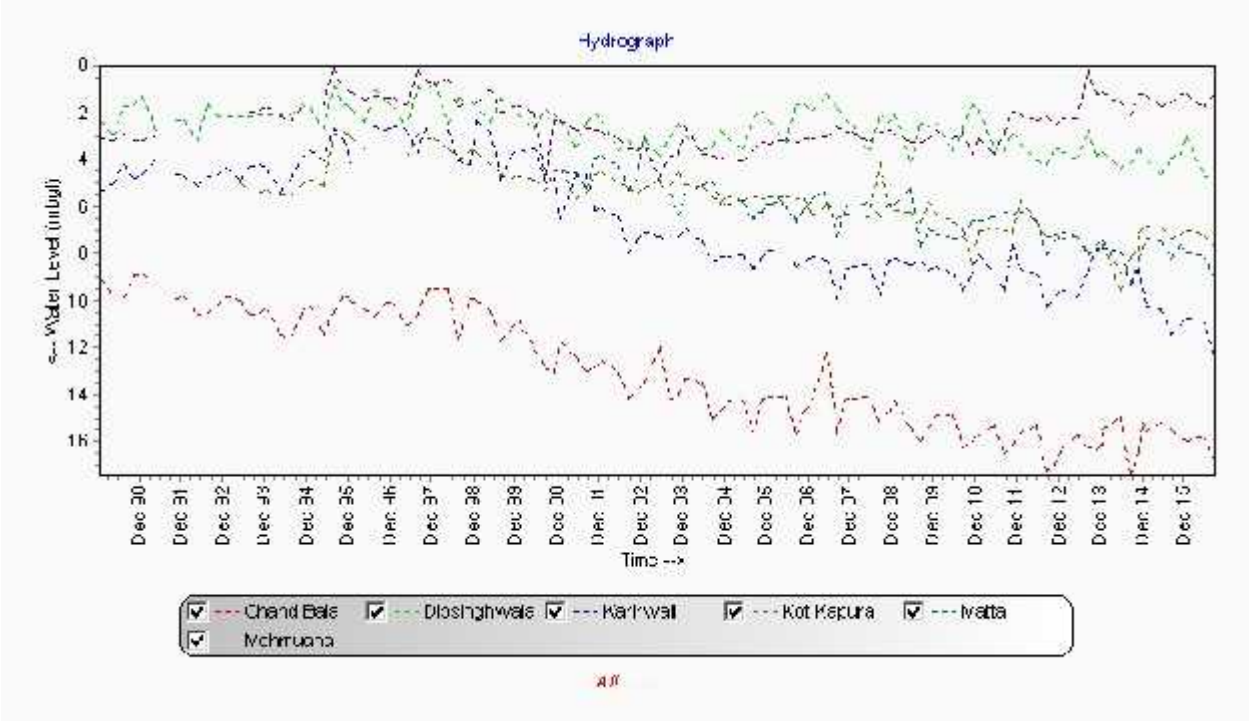
mcm: million cubic metre

5.0 GROUND WATER ISSUES

5.1 Ground Water Depletion

The Study area is famous for its paddy and non paddy cultivation. The quality of ground water in the area is suitable for irrigation and drinking purposes, therefore, the ground water is constantly being pumped for the irrigation due to its easy access through tube wells at shallow depths and they are the main source of irrigation. This will lead to its deepening of ground water levels in blocks of Faridkot and Kot Kapura of Faridkot district as the recharge of the groundwater through rainfall and other sources are less than the overall extraction. The hydrographs also shows the declining water level trend over the years in the district (Fig.20) and is categorized as over-exploited. This declining water table trend, if not checked, would assume an alarming situation in the near future affecting agricultural production and thus economy. Ground Water Recharge and Conservation may be carried out in these areas to overcome the depletion. Other than the groundwater depletion, quality and rising water table are the other issues.

Fig.20: Long term ground water table variation



5.2 Rising Water table

In western parts of the area water table is rising due to less withdrawal of ground water because of brackish / saline quality coupled with easy availability of canal water for domestic and irrigation purposes. As such, these areas are likely to get water logged in near future. There is an urgent need to arrest the rising water trend in western part and implement anti-water logging schemes.

5.3 Ground Water Quality

The ground water of the study area is alkaline in nature. Ground water in the area is generally fresh to marginally saline with fluoride concentration above permissible limit (1.5 mg/L) are found mainly in Nathuwala (6.03), Killi (4.29), Kot Kapura (3.33), Dhilwan Kalan(2.85) and Bir Sikhanwala (1.84) , Nitrate concentration above permissible limit (45mg/l) are found in Sukhanwala (46), Sher singhwala (65), Wara Daraka (66), Dhilwan Kalan (72),Nathuwala (79), Chand Bhaja (79), Bir Sikhanwala (89), Nangal (104), Tehna (118), Dal Singhwala(136), Killi (140), and KotKapura (144) and iron concentration above permissible limit (1.5 mg/L)are observed in Deviwala (1.77) There is growing concern on deterioration of ground water quality due to geogenic and anthropogenic activities.

5.4 Ground Water Irrigation Scenario

As per the data available from minor irrigation census 2005-06, the detailed number of shallow, deep, tube wells, lined, unlined water distribution system, land holdings of wells are given in Table-8,9 &10 .

Table-8: Distribution of Tube wells According to Well Owner's land holding Size

Type of Tube well (TW)	***Marginal (0-1 ha)***	***Small (1-2 ha)***	***Semi-Medium (2-4 ha)***	***Medium (4-10ha)***	***Big (>10ha)***	***Total***
Shallow TW	1100	4029	10069	14576	5314	**35088**
Deep TW	29	197	596	1188	468	**2478**
Total	**1129**	**4226**	**10665**	**15764**	**5782**	**37566**

Table-9: Distribution of Tube wells According to Depth

Depth of Tubewells in metres								**Total depth Range 0-150m**
Depth range	0-20 m	20-40 m	40-60 m	60-70 m	70-90m	90-150m	>150 m	
Tubewells	3507	9947	9998	11636	543	1744	191	**37566**
Tubewells (%)	9	26	27	31	1	5	1	

Table-10: System of Ground water distribution device

Open Water Channels			
Lined/pucca	*Unlined/kutcha*	*Others*	*Total*
2093	35455	18	**37566**

6.0 MANAGEMENT STRATEGIES AND AQUIFER MANAGEMENT PLAN

Aquifer mapping is leads to groundwater management plans to be implemented by including demand side-management and Ground Water Use Efficiency.

An outline of the Aquifer Management Plan for each block is given in Part-II. This includes details regarding population, rainfall, average annual rainfall, agriculture and irrigation, water bodies, ground water resource availability, ground water extraction and water level behavior. Aquifer disposition and various cross sections have also been given. Ground water resources, extraction and other issues including ground water resource enhancement and demand side innervations have been given.

Artificial recharge plan is less feasible in the Faridkot District due to very low availability of volume of surplus water (9.59 mcm). Another focus has been given to minimize the gross draft by enhancing ground water use efficiency in irrigation system after replacing the water distribution system from unlined/kutcha channel to Under Ground Pipeline System (UGPS) in over exploited blocks of the district.

6.1 Scope of Implementation

This plan is focusing on the technical aspects of the ground water recharge through various means so that various implementing agencies may get the appropriate technical guidelines. The existing/ongoing schemes of the central or state govt. like MANERGA, IWSP, PMKSY (Prime Minister Krishi Sinchai Yojna), NABARD funded schemes, Urban Development schemes, departmentally funded projects etc. may be benefitted from the recharge plan by incorporating the input in the operational guidelines/ design and for locating the specific sites.

Agriculture University, engineering Collages, Academic and Research Institution, NGO may also take up the pilot or demonstrative projects in the blocks suitable to them to plan at local level as per local conditions.

6.2 Potential of Enhancing the Ground Water Use Efficiency

The micro level transformation in the ground water management have vast impact potential to counter extensive ground water depletion faced in the state of Punjab, particularly in overexploited blocks.

There are around 35455 (out of 37566) tube wells (94.38 %) operated by farmers for irrigation through unlined/Kutcha open channel system in study area (Table-10) where water from the tube well is discharge to the agricultural field. In this process, huge (around 25 %) (RKVY, 2015) quantity of ground water is wasted in soil moisture and evaporation losses.

Around 95 % of the tube wells are of shallow depth (20 to 70m) and remaining wells are deeper depth (70 to >150 m) existed in the area (Table-9). Thus, majority of wells are tapping shallow aquifer which is under stress.

Dynamic ground water resources (2013) indicate that Gross ground water draft for irrigation in the district is estimated at 948.80 mcm. It is expected that around 25 % of over draft can be brought down by switching over to underground/surface pipeline based

distribution from the prevailing unlined open channels. Thereby gross draft will be reduced to 224 mcm (Table-11a) assuming that there is no crop diversification by the farmers.

The benefit will lead to saving of precious ground water resources in overexploited blocks. The measure if implemented will bring down the ground water overdraft from 160 % to 123%. The category of the blocks will also improve resulting in boosting of agriculture and industrial development otherwise not sustainable in over-exploited blocks (Table-11b).

The tube wells also consume enormous electricity which is subsidized and government incur significant revenue on this account. The measures therefore will result in saving of energy and money. Pollution impact will be reduced whenever diesel engines are used by the farmers. The environmental and ecological condition in the irrigated land will improve. Unwanted weed growth will also be controlled inside the farm land. It is expected to save 1% of the agricultural land occupied by open channels which can be utilized for cultivation purpose. Heavy ground water overdraft can be reduced by these efforts. This will ensure ***more crops per drop.***

6.3 Water saving Potential from Crop Diversification-Change Paddy to Maize/Soya-bean:

As the requirement of water for paddy is much high therefore by changing paddy to maize/soya-bean will help in saving of water. For estimating the water saving by crop diversification it is assumed that ***one mcm*** of water will be saved in case of maize or soyabean planted in ***one sq km*** of land. In case of pulses even higher amount of ground water can be saved.

The block wise saving of water in mcm by applying various management strategies such as crop diversification, Under Ground Pipe lines (UGPL) in individual land and artificial recharge methods are given in tables 11.a, b.

Table-11a: Scope of Quantitative Impact on Stage of Development after applying various management strategies in mcm

Block	*Net Ground Water Availability (mcm)*	*Total Irrigation Draft (mcm)*	*Present Stage of draft (SOD) (%) (As per 2013)*	*Reduction in draft by different water saving method*				*SOD afterwards (%)*	*Change of paddy cultivation area (% of existing)*
				Replace water courses by UG Pipes (mcm)	*Adopt Artificial recharge (mcm)*	*Change Paddy to Maize (mcm)*	*Total (mcm) (2+3+4)*		
			1	2	3	4	5		
Faridkot	346.32	528.61	158	124.72	4.84	72.45	202.01	99.69	-
Kot Kapura	268.21	420.20	162	99.15	4.75	62.64	166.54	99.86	-
Total	**614.53**	**948.80**	**160**	**223.87**	**9.59**	**135.67**	**369.13**	**99.48**	

Table-11b: Impact on Stage of Development (SOD) after applying various management strategies in Faridkot District

Block	*Present SOD (%) as on 2013*	*Reduction in SOD (%) after unlined channel (%)*	*Resultant SOD (%) Col.(2 - 3)*	*Reduction in Stage of development after crop diversification by Maize/Soyabean (%)*	*Resultant SOD (%) Col.(2 - 5)*	*Reduction in Stage of development after Artificial recharge (%)*	*Resultant SOD (%) Col.(2 - 7)*
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Faridkot	158	36.01	121.99	20.90	137.10	1.40	156.60
Kot Kapura	162	36.97	125.03	23.40	138.60	1.77	160.23
Total	**160**	**36.64**	**123.36**	**22.10**	**137.90**	**1.78**	**158.22**

By adopting all the management strategies resulting in total reduction in stage of groundwater development is 60.52%. Hence overall stage of development afterwards is 99.48 % and is given in Table.12.

Table-12: Overall Stage of Development (SOD) after reduction in Faridkot

Block	*Present Stage of development (%) as on 2013*	*Reduction in stage of development after unlined channel (%)*	*Reduction in Stage of development after crop diversification by Maize/Soyabean (%)*	*Reduction in Stage of development after Artificial recharge (%)*	*Total Reduction in Stage of development (%) (3 +4+5)*	*Stage of development afterwards (%) (2-6)*
1	**2**	**3**	**4**	**5**	**6**	**7**
Faridkot	158	36.01	20.90	1.40	58.31	99.69
Kot Kapura	162	36.97	23.40	1.77	62.14	99.86
Total	**160**	**36.64**	**22.10**	**1.78**	**60.52**	**99.48**

7.0 CONCLUSIONS

1. The area lies in the central part of Satluj basin of Indo-Gangetic Alluvial plain. Geologically, the area is occupied by a thick sequence of Quaternary deposits of Mid-Pleistocene to Recent age.
2. The Principle Aquifer system in the study area is Alluvium and the Major Aquifers are Older Alluvium and Aeolian Alluvium.
3. Lithological characteristics of the area are Multi-cyclic light grey to brown fine to medium grained mixture of clay, silt and sand with Kankar.
4. Thick layering of clay with sand at many places can be observed towards south of the district at deeper depths. The Ground water occurs in unconfined (water table) and confined conditions.
5. Chemical data of ground water from shallow aquifer indicates that ground water is alkaline and fresh to moderately saline.
6. To delineate fresh water - saline water interface laterally as well as vertically, surface geophysical investigations have been carried out in alluvial tracts.
7. To understand the sub surface disposition, geological sections and fence diagram have been prepared by synthesizing the various sub-surface sections on the basis of study of the lithological logs and electrical logs of boreholes drilled by CGWB, WRED, PSTC and Private Agencies using the RockWorks15 software.
8. Aquifer IA (Very Shallow Aquifer) extends maximum upto 70 m of depth and below that clay layer starts getting thickened about 10-12m separating Aquifer IB to a maximum depth of 123 m. Multi layer aquifers are existing in the area each aquifer is separated by thick clay zones of 25 to 40 m upto 300m depth. It is very difficult to differentiate the aquifer groups after Aquifer Group I, so the whole lithology is considered to be a single aquifer group system.
9. Stage of Ground Water Development of the district is 160% on the basis of Dynamic ground water resources, 2013. In- storage ground water resources has also been calculated up to a depth of 300 meters.
10. The fresh water resources are inadequate in aquifer upto maximum depth of 106m, whereas saline water is dominant resources below 106 m depth upto 300 m. In the north of the district towards Faridkot block fresh water is available upto 152m depth.
11. Dynamic ground water resources of the study area are 614.53 mcm, whereas In-storage ground water resources up to fresh water zones are 3954 mcm. Thus, total fresh ground water resources up to maximum depth of 152 m are 4569 mcm. Total saline water resources up to depth of 300 m are 3129 mcm.
12. Main groundwater issues in the area are groundwater depletion, quality and rising water table.
13. Considering the high ground water abstraction for irrigation (948.80 mcm) and overdraft (371.57 mcm), it is suggested that proposed artificial recharge measures (9.59 mcm), crop diversification measures (135.67 mcm) and conserving ground water through laying of underground pipe line (223.87 mcm) will be useful.
14. Other techniques of water saving and modern irrigation technology to be enforced to maximize per drop of water use in the district and also to think about the hidden saline water resources and for its utilizations.

BLOCK WISE

AQUIFER MAPS

AND

MANAGEMENT PLAN

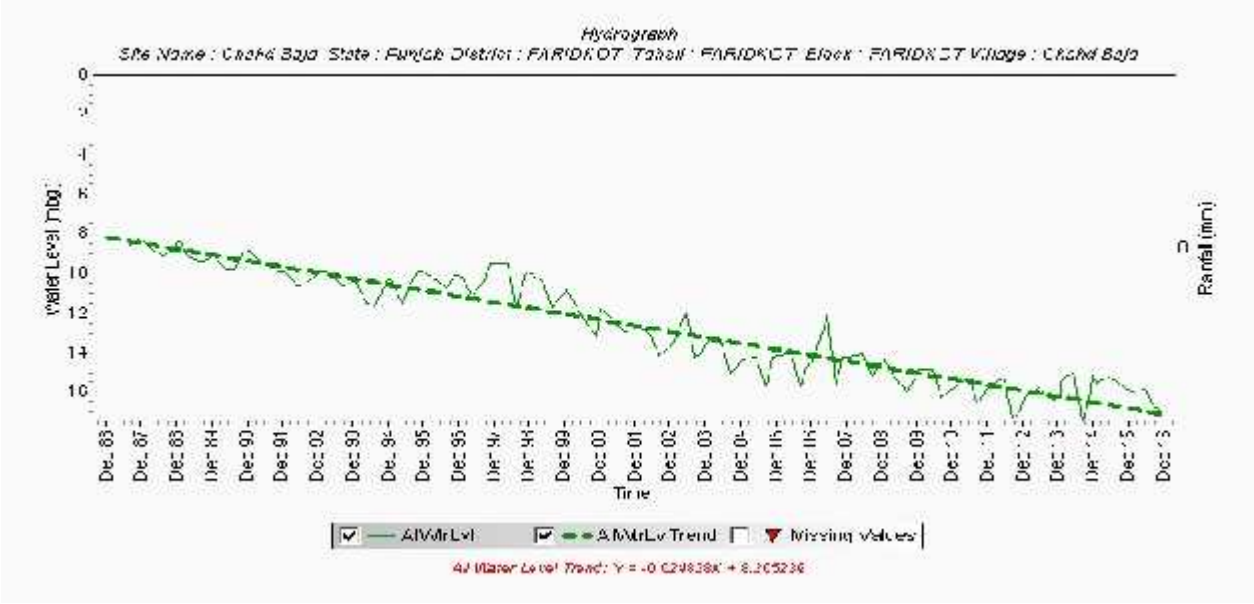
(PART-II)

I .Salient Information of Faridkot Block

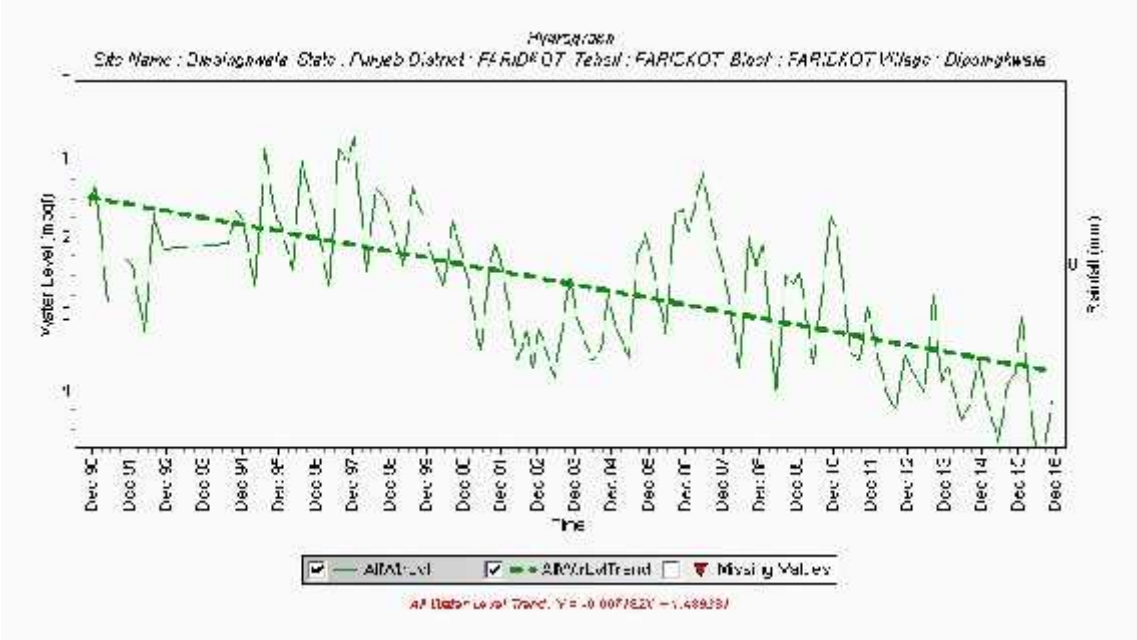
Block Area (in Km^2)	**752.10 sq km**
District/ State	Faridkot, Punjab
Population	Urban Population: 2260 Rural Population: 179432 Total population: 181692
Rainfall	Normal Monsoon: 335 mm Non-monsoon Rainfall : 35 mm Annual Average Rainfall: 349 mm
Agriculture and Irrigation	Principal crops: Wheat, Cotton and Paddy Gross cropped area: 1195.62 sq km Net sown area: 591.80 sq km Irrigation practices: Canal and Tube well Irrigation Cropping intensity: 202% *Area under* Ground water Irrigation: 61.59 sq km Surface water irrigation: 511.43 sq km Number and types of abstraction structures: 20927, Tubewells
Ground Water Resource Availability and Extraction	**Ground water Resources Availability** Total Ground Water Resources available is 5025 mcm (fresh and saline water) up to the depth of 300m. The fresh water resources are estimated up to the depth of 152 m on the basis of geophysical interpretations. The potential granular zones available for fresh water are calculated as 72 m. Saline water resources are estimated on the basis of available well depth (up to 300 m) and the granular zones are counted after depth of 152 m and available zones are 103 m. Block is categorized as Over-Exploited as per Dynamic Groundwater Resources, 2013 assessment. **Ground water Resources Extraction** Deeper aquifers are marginal to highly saline and not suitable for irrigation purpose as such all users are tapping shallow aquifers. Drinking water supply wells of State Government tapping shallow aquifers Therefore, the ground water draft could not be assessed for deeper aquifer.

Existing and future water demands	*Existing Gross Ground water Draft as on 2013* Irrigation: 528.61 mcm Domestic and industrial water supply: 19.11 mcm *Future water demands* Irrigation development potential : (-)20.45 mcm Domestic and industrial water supply up to 2025 years : 22.19 mcm
Water level behavior	*Aquifer wise water level* **Aquifer-I** Pre Monsoon: 1.45 – 15.22 m bgl Post Monsoon: 1.20 – 13.10 m bgl Mean (10 yrs) : 1.00 – (-)1.01 m/yr *Trends* Pre Monsoon: 0.18 – (-)0.22 m/yr Post Monsoon: 0.24 – (-)0.30 m/yr **Aquifer-II:** No Monitoring stations **Aquifer-III** No Monitoring stations

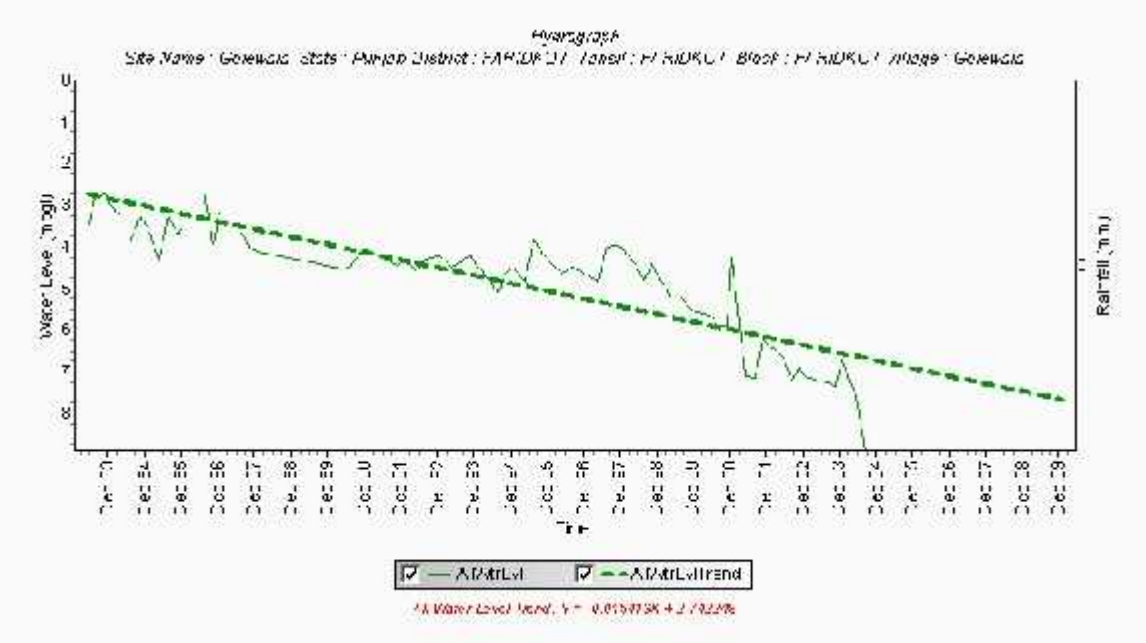
HYDROGRAPH SHOWING DECLINING WATER TABLE



HYDROGRAPH SHOWING DECLINING WATER TABLE



HYDROGRAPH SHOWING DECLINING WATER TABLE



Monitoring well Golewala dried after 2004.

Aquifer Disposition

Number of aquifers	1
Principal aquifer	Alluvium
Major Aquifer	Older Alluvium, Aeolian Alluvium

Exploratory Data Availability

Source of Data	*No. of exploration wells as per depth range (m)*				*Total*
	<100	*100-200*	*200-300*	*>300*	
CGWB	1	0	0	4	**5**
WRED/PSTC/WSS	6	1	0	2	**9**
PRIVATE	0	0	0	0	**0**
TOTAL	**7**	**1**	**0**	**6**	**14**

Aquifer wise Characteristics (CGWB, 2012)

Aquifer Group *	*Geology*	*Type of Aquifer*	*Thickness of Granular zones (m)*	*Transmissivity (m^2/day)*	*Yield/ Discharge (m^3/day)*	*Specific Yield*	*Storativity*
Single Aquifer System	Quarter-nary Alluvial deposits	Unconfined to confined	175	474 - 2660	939 - 5594.4	12 *% (0.072)*	17.5×10^{-3} - 1.8×10^{-3}

* Well field proposed in adjacent block

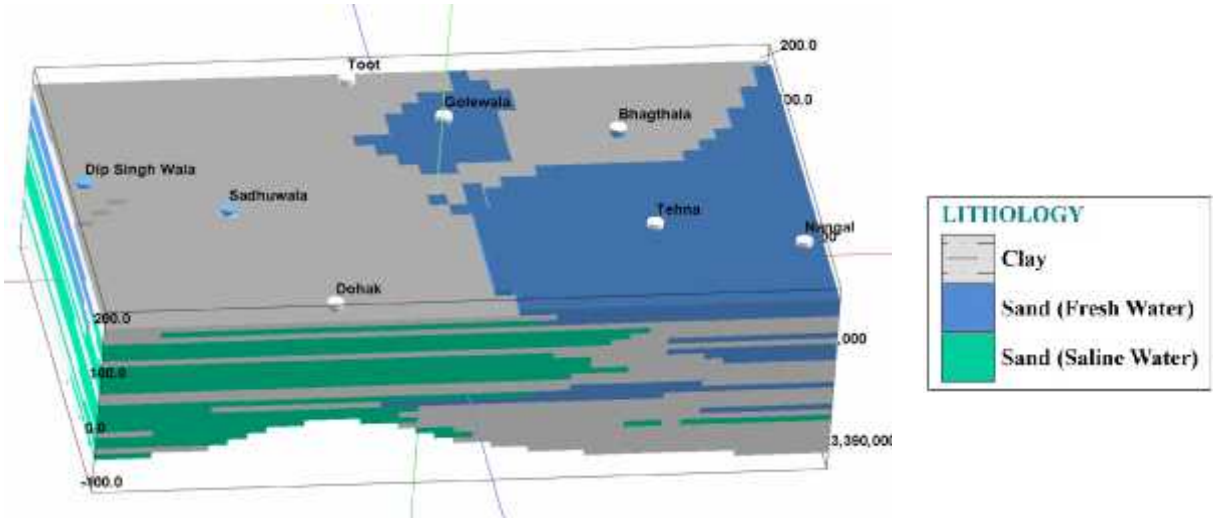
The Aquifer comprises of fresh and saline water and the major aquifer material is sand. The aquiclude and aquitard comprises of clay, clay with silt.

Exploratory Data Validated

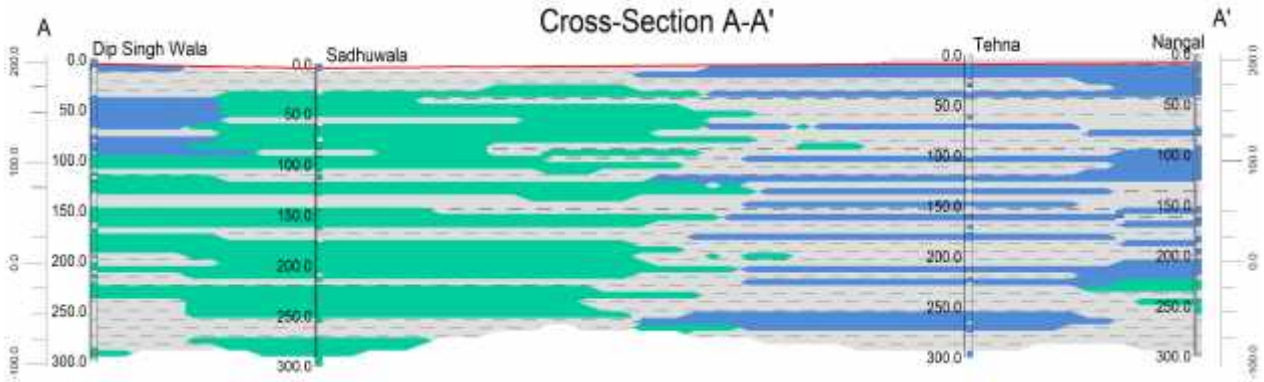
Source of Data	*No. of exploration wells as per depth range (m)*				*Total*
	<100	*100-200*	*200-300*	*>300*	
CGWB	0	0	0	4	**4**
WRED/PSTC/WSS	0	0	0	2	**2**
PRIVATE	0	0	0	0	**0**
TOTAL	**0**	**0**	**0**	**6**	**6**

The data is validated by selecting the deepest well in each quadrant and used for preparation of 3-D Litho models, 2-D Geological Cross Sections, Fence Diagrams and Aquifer Maps.

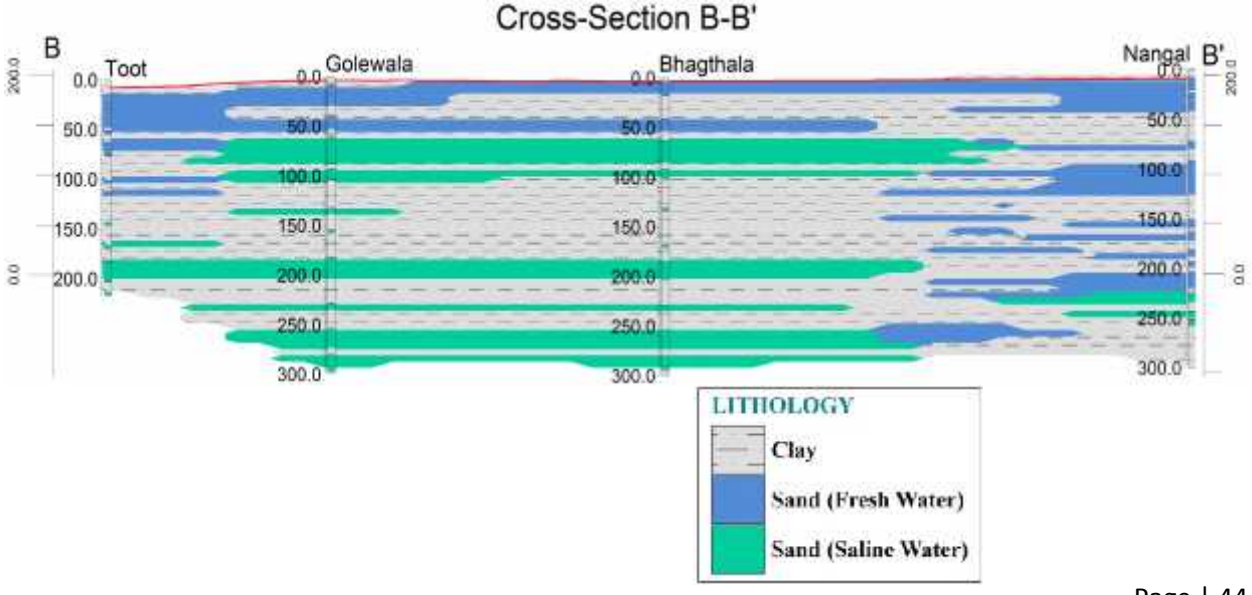
3-D Lithological Model of Faridkot Block



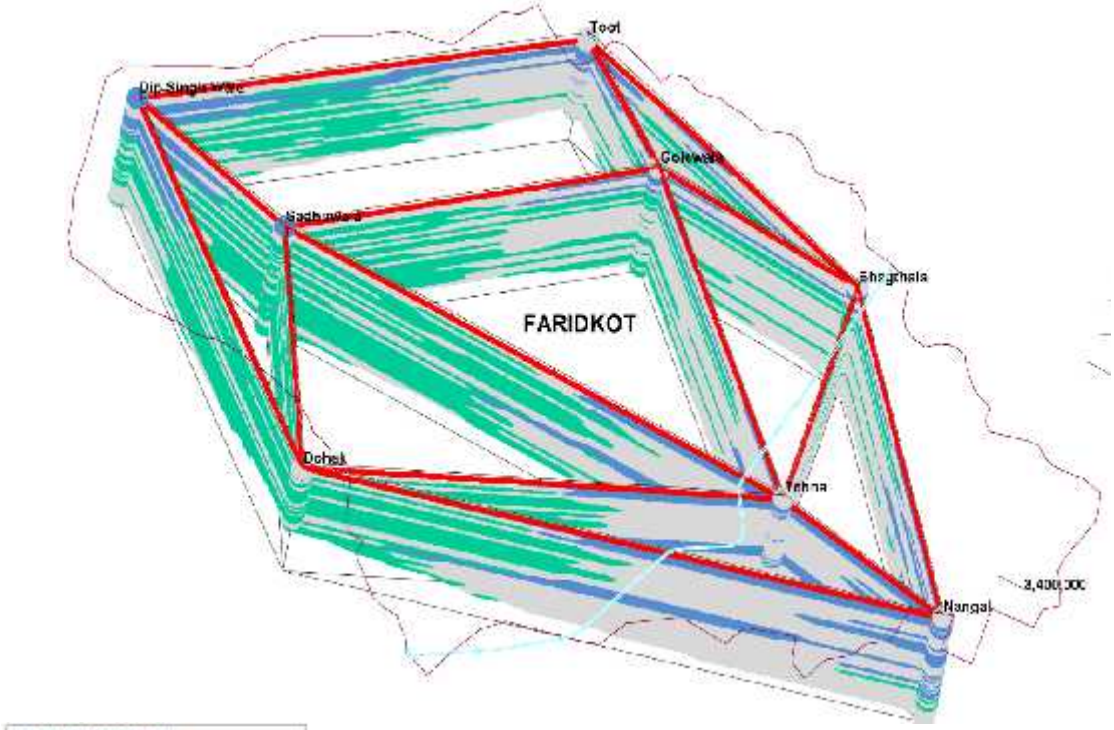
Lithological Cross Section from Dip Singh Wala to Nangal



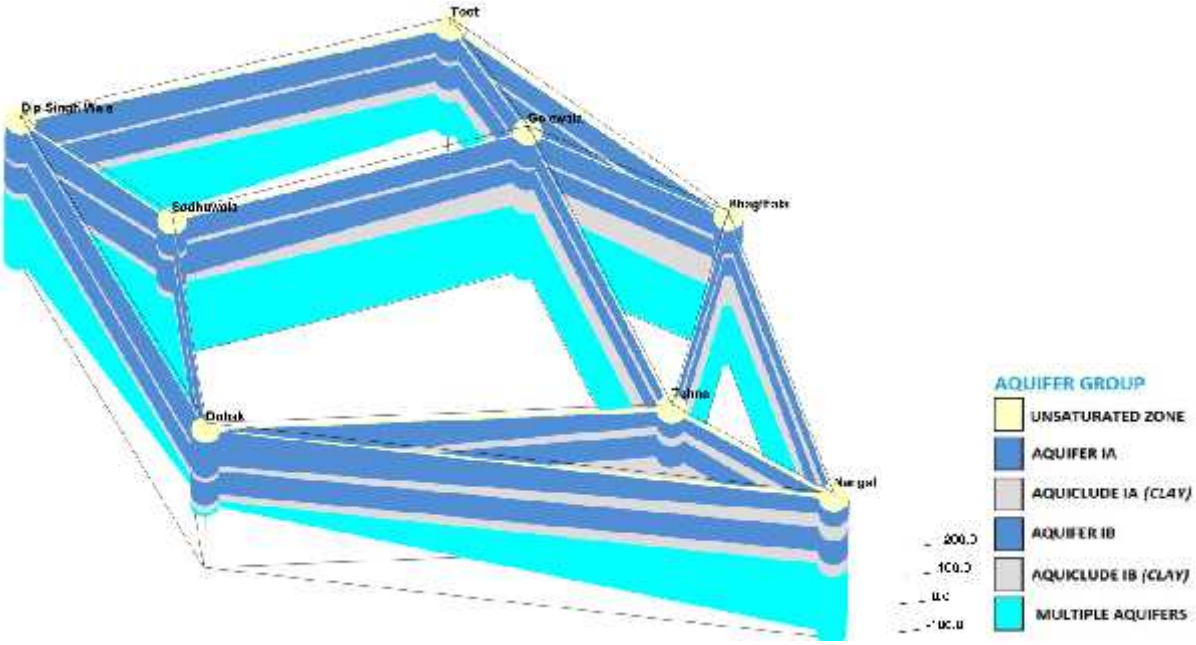
Lithological Cross Section from Toot to Nangal



3-D Lithological Fence Diagram



3-D Aquifer Disposition Fence Diagram



Ground water Resource, Extraction, Contamination and other issues in Faridkot Block

Ground Water Resources upto the depth of 300m	Dynamic Fresh water resources	346.32 mcm
	In-storage Fresh water resources	1823.75 mcm
	In-storage Saline water resources	2855.16 mcm
	Total	5025.23 mcm
Ground Water Extraction (as per 2013)	Irrigation	528.61 mcm
	Domestic & Industrial	19.11 mcm
Future Demand for domestic & Industrial sector (2025) (as per 2013)		22.19 mcm
Stage of Groundwater Development		158 %
Chemical Quality of ground water		Ground water in the area is alkaline and pH ranges between 7.94 to 9.17. Ground water in the area is fresh to marginal saline. EC value of ground water show wide variations and ranges from 444 μS/cm to 8653μS/cm at 25^0C. RSC values vary from (–) 7.3 to 11.3 meq/L area is fit for irrigation.
Ground water Contamination Issues		*Fluoride (mg/l):* Nathuwala (6.03), Killi(4.29) *Nitrate (mg/l):* Sukhanwala (46), Sher Singhwala (65), Nathuwala (79), Chand Baja (79), Nangal (104), Tehna (118), Killi (140) *Iron (mg/):* Devi wala (1.77)
Other issues		Water level decline has been observed in major parts of the block due to in discriminate development of ground water resources. In shallow water level area, less development of ground water resource couple with recharge from canal irrigation is causing water logging and inland salinity problems.

Ground water Resource Enhancement Potential

Aquifer wise space available for recharge and proposed interventions (Supply Side Measures)

Aquifer-I:

Volumes of unsaturated zone after 3m upto a desirable depth: 108.30 mcm
Source water requirement/availability for recharge: *Rain, Canal, Irrigation return flow*
Types and number of structures: NA
Other interventions proposed*: Artificial Recharge, Roof top Rainwater harvesting will conserve 4.84 mcm volume of water*

Demand side interventions

Advanced Irrigation Practices
Area proposed to be covered: Entire Block Faridkot (752.10 sq km)
Volume of Water expected to be conserved under advanced irrigation practices such as lining of underground pipelines (Kutcha channel): 124.72 mcm

Required Change in cropping pattern

Proposed change in cropping pattern: *Paddy to Maize/ Soyabean. The overexploitation can be managed at sustainable level (100%) by changing the Paddy crop.*
Area coverage: *15 % of the total paddy area needs to change i.e.*72.45 sq km
Anticipated volume of water to be saved: 72.45 mcm

Net Annual Ground Water Availability 2013 (mcm)	*Total Irrigation Draft (present) (mcm)*	*Gross Draft all uses (present) (mcm)*	*Paddy area (Sq km)*	*Required Area to be Change from Paddy to Maize/ soya bean (Sq km)*	*Amount of Water Saved (mcm)*	*Gross draft after saving of water (mcm)*	*Present Stage of development (%)*	*Reduction in Stage of development after Maize/ soya bean (%)*	*Crop Diversified area (%)*
346.32	528.61	547.71	483.00	72.45	72.45	456.16	158	20.9	15

Alternate Water sources
Surface water sources: *Tanks, Ponds*
Location, details and availability from such sources outside the area: Not Available
Regulation and Control:
Punjab Subsoil Act for delay in paddy plantation should continue in the area.

Other interventions proposed, if any

Modern Irrigation Practices be adopted for Rabi crops. Some of the techniques are given in the table below (PAU, Ludhiana).

Sl.No	Techniques	Water Saving (%)	Crops
1	Mulching	17	Wheat
2	Bed Planting	18-25	Wheat
3	Use of Sprinkler and drip Irrigation	70-90	Sugarcane, Cotton, Sunflower, Maize

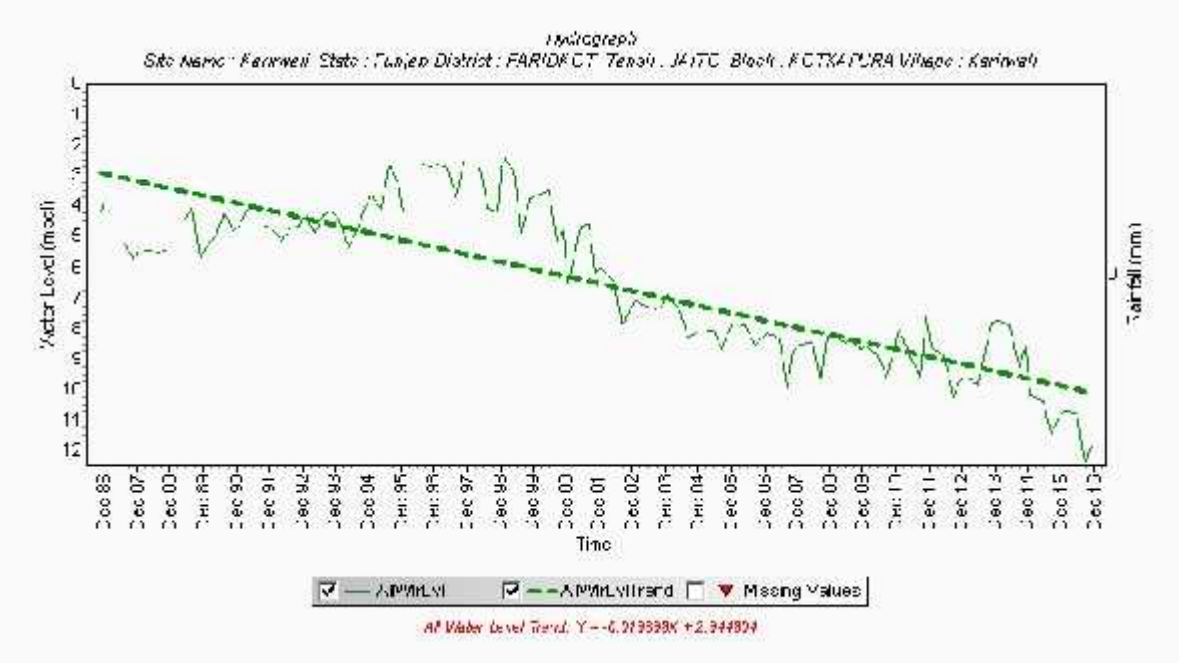
Other than that by 15 days ponding followed by 2 days of drying can lead to 25% saving of water in paddy crop.

II. Salient Information of Kot Kapura Block

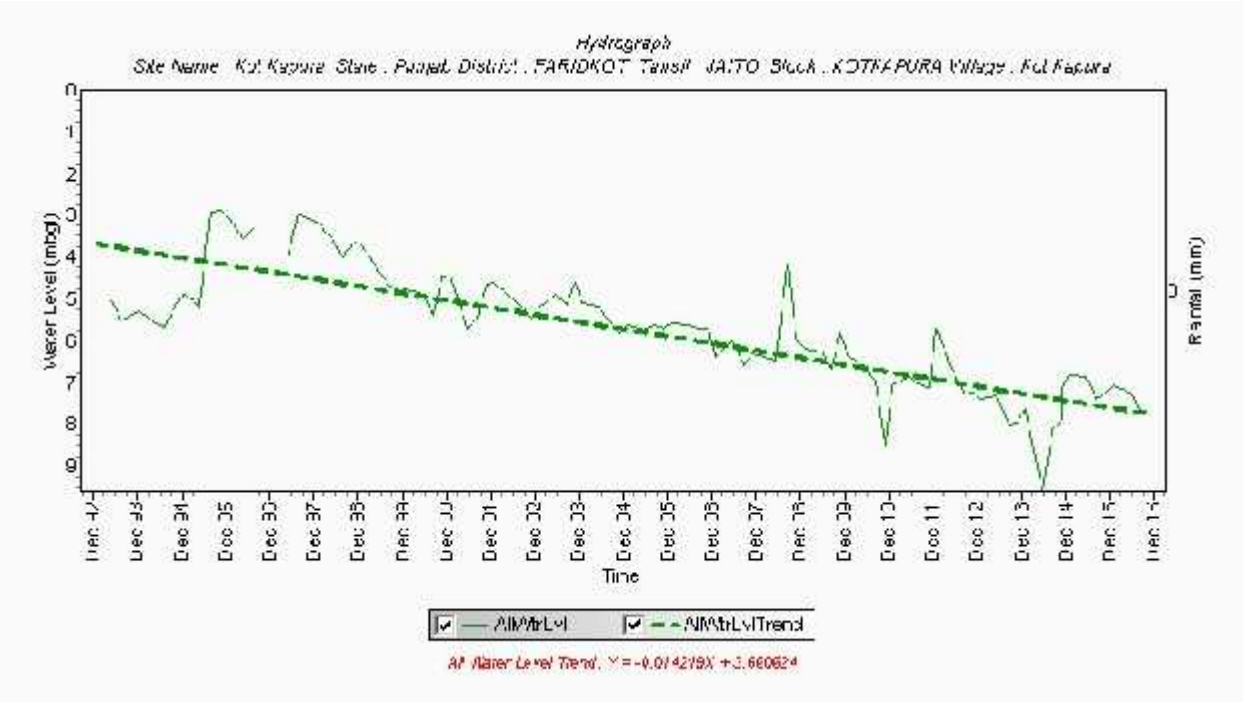
Block Area (in Km^2)	**666.50 sq km**
District/ State	Faridkot, Punjab
Population	Urban Population: 373 Rural Population: 221025 Total population: 221398
Rainfall	Normal Monsoon: 328 mm Non-monsoon Rainfall : 61 mm Annual Average Rainfall: 370 mm
Agriculture and Irrigation	Principal crops: Wheat, Cotton and Paddy Gross cropped area: 1334.27 sq km Net sown area: 674.98 sq km Irrigation practices: Canal and Tube well Irrigation Cropping intensity: 198% *Area under* Ground water Irrigation: 42.78 sq km Surface water irrigation: 628.99 sq km Number and types of abstraction structures: 16639, Tubewells
Ground Water Resource Availability and Extraction	**Ground water Resources Availability** Total Ground Water Resources available is 2672 mcm (fresh and saline water) up to the depth of 300 m. The fresh water resources are estimated up to the depth of 106 m on the basis of geophysical interpretations. The potential granular zones available for fresh water are 51 m. Saline water resources are estimated on the basis of well (up to 300 m) and the granular zones are counted after depth of 106 m and available zones are 76 m. Block is categorized as Over-Exploited as per Dynamic Groundwater Resources, 2013 assessment. **Ground water Resources Extraction** Deeper aquifers are marginal to highly saline and not suitable for irrigation purpose as such all users are tapping shallow aquifers. Drinking water supply wells of State Government tapping shallow aquifers Therefore, the ground water draft could not be assessed for deeper aquifer.

Existing and future water demands	*Existing Gross Ground water Draft as on 2013* Irrigation: 420.20 mcm Domestic and industrial water supply: 14.02 mcm *Future water demands* Irrigation development potential : (-)16.709 mcm Domestic and industrial water supply up to 2025 years : 15.11 mcm
Water level behavior	*Aquifer wise water level* **Aquifer-I** Pre Monsoon: 2.35 – 16.00 m bgl Post Monsoon: 1.55 – 18.20 m bgl Mean (10 yrs) : 1.58 – (-)0.86 m/yr *Trends* Pre Monsoon: 0.16 – (-)0.26 m/yr Post Monsoon: 0.15 – (-)0.29 m/yr **Aquifer-II (156m)** Pre Monsoon: 7.72 m bgl Post Monsoon: 8.05 m bgl **Aquifer-III (269m)** Pre Monsoon: NA Post Monsoon: 8.20 m bgl

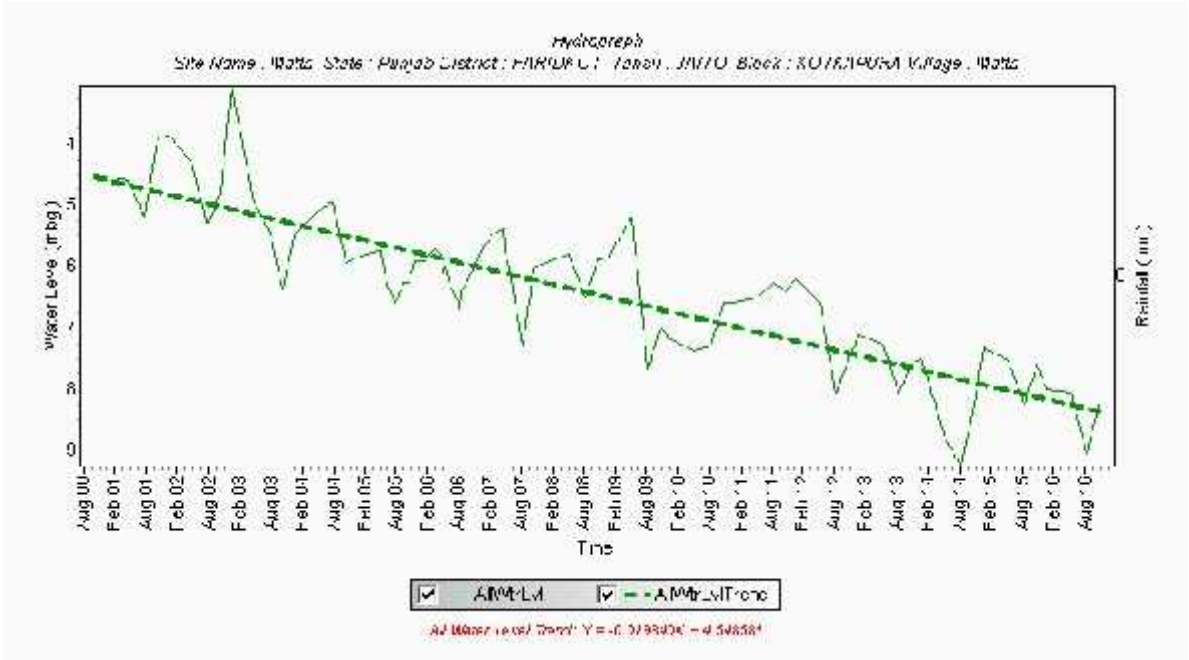
HYDROGRAPH SHOWING DECLINING WATER TABLE



HYDROGRAPH SHOWING DECLINING WATER TABLE



HYDROGRAPH SHOWING DECLINING WATER TABLE



Aquifer Disposition

Number of aquifers	1
Principal aquifer	Alluvium
Major Aquifer	Older Alluvium, Aeolian Alluvium

Exploratory Data Availability

Source of Data	*No. of exploration wells as per depth range (m)*				*Total*
	<100	*100-200*	*200-300*	*>300*	
CGWB	2	1	1	4	**8**
WRED/PSTC/WSS	8	0	0	1	**9**
PRIVATE	1	0	1	0	**2**
TOTAL	**11**	**1**	**2**	**5**	**19**

Aquifer wise Characteristics (CGWB,2015)

Aquifer Group *	*Geology*	*Type of Aquifer*	*Thickness of Granular zones (m)*	*Transmi-ssivity (m^2/day)*	*Yield (m^3/day)*	*Specific Yield*	*Storativity*
Single Aquifer System	Quatern ary Alluvial deposits	Unconfined to confined	127	547 - 2990	3668	12 % *(0.072)*	$7.2x10^{-4}$

* Well field proposed in this block (Site Location: Deviwala)

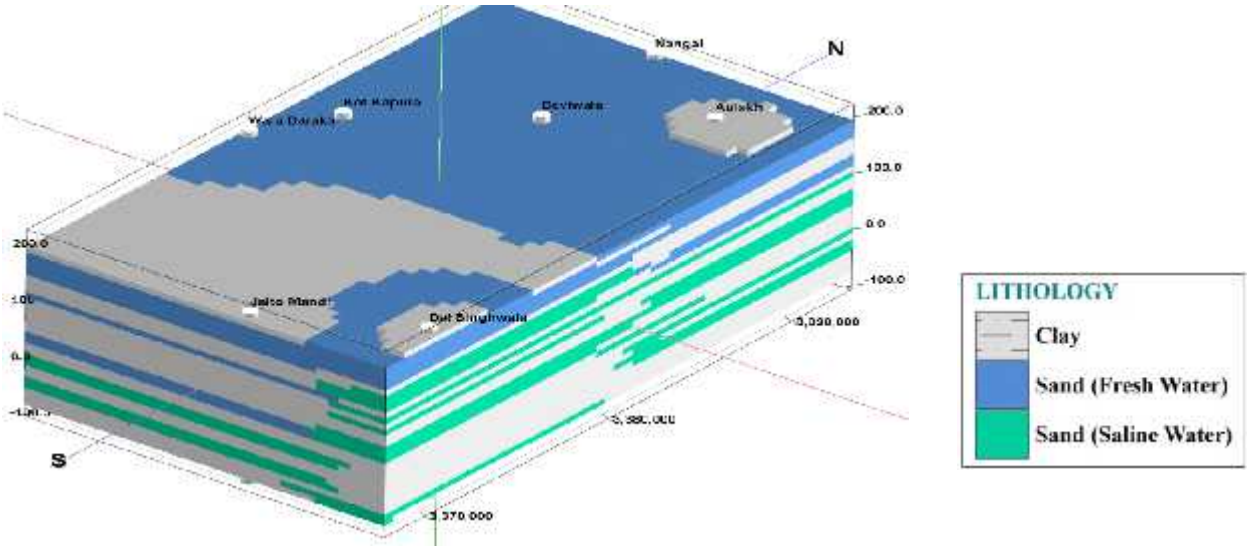
The Aquifer comprises of fresh and saline water and the major aquifer material is sand. The aquiclude and aquitard comprises of clay, clay with silt.

Exploratory Data Validated

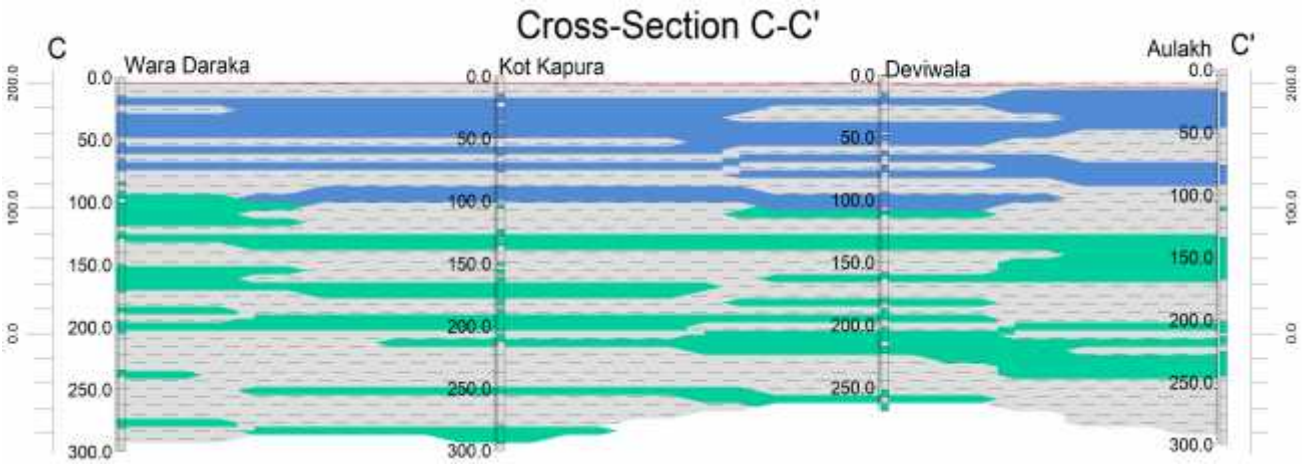
Source of Data	*No. of exploration wells as per depth range (m)*				*Total*
	<100	*100-200*	*200-300*	*>300*	
CGWB	0	0	1	4	**5**
WRED/PSTC/WSS	0	0	0	1	**1**
PRIVATE	0	0	1	0	**1**
TOTAL	**0**	**0**	**2**	**5**	**7**

The data is validated by selecting the deepest well in each quadrant and used for preparation of 3-D Litho models, 2-D Geological Cross Sections, Fence Diagrams and Aquifer Maps.

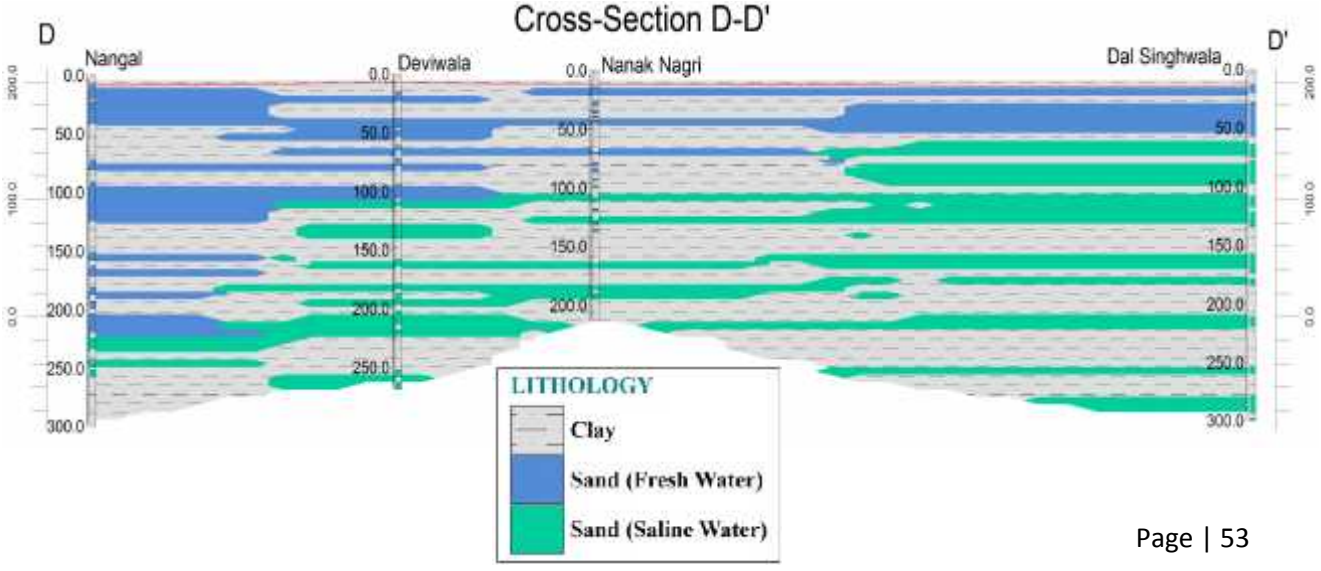
3-D Lithological model of Kot Kapura Block



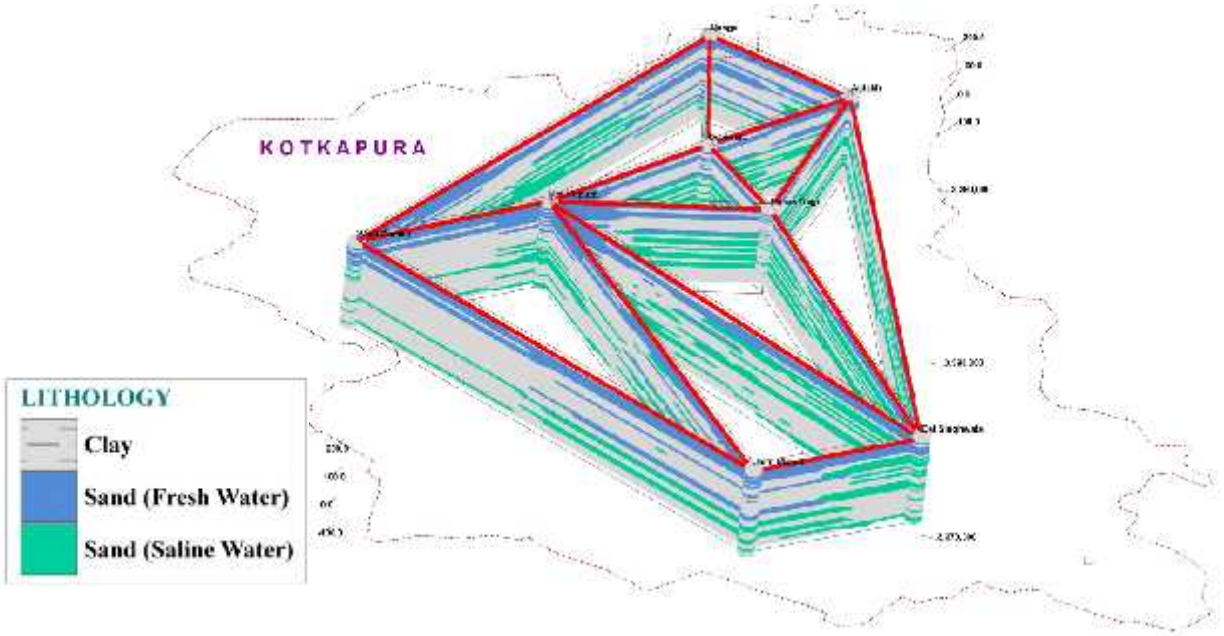
Lithological Cross section from Wara Daraka to Aulakh



Lithological Cross section from Nangal to Dal Singhwala

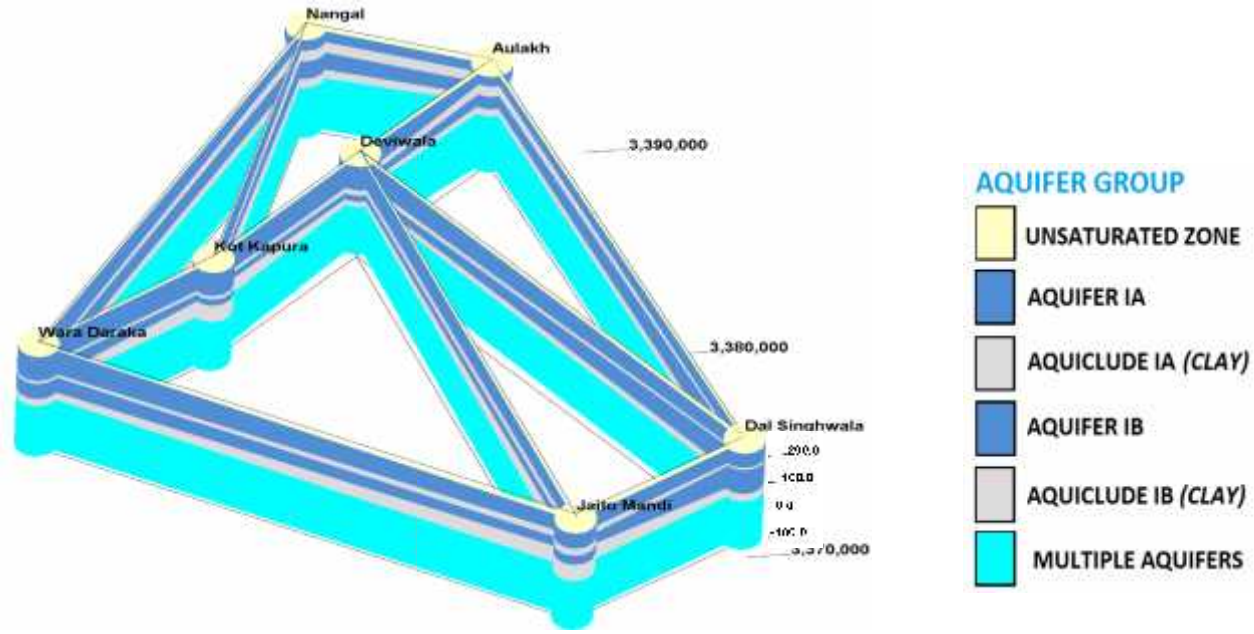


3-D Lithological Fence Diagram



WATER LEVEL

3-D Aquifer Disposition Fence Diagram



Ground water Resource, Extraction, Contamination and other issues in Kot Kapura Block

Ground Water Resources upto the depth of 300m	Dynamic Fresh water resources	268.21 mcm
	In-storage Fresh water resources	2130.62 mcm
	In-storage Saline water resources	273.60 mcm
	Total	2672.43 mcm
Ground Water Extraction (as per 2013)	Irrigation	420.20 mcm
	Domestic & Industrial	14.02 mcm
Future Demand for domestic & Industrial sector (2025) (as per 2013)		15.11 mcm
Stage of Groundwater Development		162 %
Chemical Quality of ground water		Ground water in the area is alkaline and pH ranges between 8.20 to 8.93. Ground water in the area is slightly fresh to marginal saline. EC value of the ground water show wide variations and ranges from 1154 µS/cm to 3988 µS/cm at 25^0C. RSC values are varies from -0.03 to 11.00 meq/L and the area is fit for irrigation.
Ground water Contamination Issues		***Fluoride (mg/l):*** Kot Kapura (3.33) , Dhilwan kalan (2.85), Moharewala (1.95) Bir Sikhanwala (1.84) ***Nitrate (mg/l):*** Wara Daraka (66), Dhilwan Kalan (72), Moharewala (78), Bir sikhan wala (89), KotKapura (144),
Other issues		Water level decline has been observed in major parts of the block due to in discriminate development of ground water resources. In shallow water level area, less development of ground water resource couple with recharge from canal irrigation is causing water logging and inland salinity problems.

Ground water Resource Enhancement Potential

Aquifer wise space available for recharge and proposed interventions (Supply Side Measures)

Aquifer-I:

Volume of unsaturated zone after 3m upto a desirable depth: 143.96 mcm
Source water requirement/availability for recharge: *Rain, Canal, Irrigation return flow*
Types and number of structures: NA
Other interventions proposed*: Artificial Recharge, Roof top Rainwater harvesting will conserve 4.75 mcm volume of water*

Demand side interventions

Advanced Irrigation Practices

Area proposed to be covered: Entire Kot Kapura Block (666.50 sq km)
Volume of Water expected to be conserved under advanced irrigation practices such as lining of underground pipelines (Kutcha channel) etc.: 99.15 mcm

Required Change in cropping pattern

Proposed change in cropping pattern: *Rice to Maize, Soyabean .The overexploitation can be managed at sustainable level (100%) by changing the Paddy crop*
Area coverage: *12 % of the total rice area needs to change i.e.* 62.64 sq km
Anticipated volume of water to be saved: 62.64 mcm

Net Annual Ground Water Availability 2013 (mcm)	*Total Irrigation Draft (present) (mcm)*	*Gross Draft all uses (present) (mcm)*	*Paddy area (Sq km)*	*Required Area to be Change from Paddy to Maize/ soya bean (Sq km)*	*Amount of Water Saved (mcm)*	*Gross draft after saving of water (mcm)*	*Present Stage of development (%)*	*Reduction in Stage of development after Maize/ soya bean (%)*	*Crop Diversified area (%)*
268.21	420.20	434.21	522.00	62.64	62.64	357.56	162	23.4	12

Alternate Water sources
Surface water sources: *Tanks, Ponds*
Location, details and availability from such sources outside the area: Not Available
Regulation and Control:

Punjab Subsoil Act for delay in paddy plantation should continue in the area.

Other interventions proposed, if any

Modern Irrigation Practices be adopted for Rabi crops. Some of the techniques are given in the table below (PAU, Ludhiana).

Sl.No	Techniques	Water Saving (%)	Crops
1	Mulching	17	Wheat
2	Bed Planting	18-25	Wheat
3	Use of Sprinkler and drip Irrigation	70-90	Sugarcane, Cotton, Sunflower, Maize

Other than that by 15 days ponding followed by 2 days of drying can lead to 25% saving of water in paddy crop.

Annexure-I

Results of chemical analysis of water samples from NHS in Faridkot (2015)

S. No	Block	Location	Latitude	Longitude	pH	EC in µS/cm at 25°C	CO_3	HCO_3	Cl	SO_4	NO_3	F	PO_4	Ca	Mg	Na	K	SiO_2	T.H as $CaCO_3$	Arsenic (As)	Iron (Fe)	RSC
							(----------mg/l----------)															
1	Faridkot	Chand Baja	30.739	74.862	8.52	1645	36	229	218	208	**79**	0.26	0.01	25	38	270	28	15	217	BDL	BDL	0.5
2	Faridkot	Dalsinghwal	30.757	74.519	8.65	1451	18	157	155	270	**136**	0.24	0.01	37	53	162	85	18	309	0.005	BDL	-3.1
3	Faridkot	Devi Wala	30.594	74.850	8.09	476	nil	145	35	106	6.9	0.11	0.02	37	15	57	5.3	9.3	155	0.001	**1.77**	-0.7
4	Faridkot	Dipsinghwa	30.739	74.479	9.08	1293	71	253	84	130	24	1.21	0.01	12	52	157	13	16	247	0.003	0.28	1.6
5	Faridkot	Mehmuana	30.708	74.656	8.88	550	59	85	35	68	3.8	1.22	0.01	16	15	86	4.3	15	103	0.002	BDL	1.3
6	Faridkot	Sher Singh V	30.671	74.623	8.37	2657	36	254	274	690	**65**	0.89	BDL	54	58	482	16	12	371	BDL	0.17	-2.2
7	Faridkot	Sukhanwala	30.637	74.644	8.69	**3126**	24	121	597	560	**46**	1.13	BDL	45	35	618	10	15	258	0.013	1.19	-2.4
8	Faridkot	Jand Sahib	30.690	74.527	8.71	444	24	109	35	50	3.8	0.28	BDL	16	15	60	1.8	16	103	0.003	0.23	0.5
9	Faridkot	Nangal	30.664	74.856	8.36	**3487**	36	181	484	950	**104**	0.70	BDL	58	103	617	49	22	567	0.001	BDL	-7.3
10	Faridkot	Tehna	30.691	74.796	7.94	**8653**	nil	278	1544	3100	**118**	1.41	BDL	371	328	1603	48	22	2276	0.007	BDL	-41.3
11	Faridkot	Sadiq	30.707	74.584	8.56	1438	59	423	175	70	7.6	0.28	0.01	20	43	184	117	5.5	227	0.001	BDL	4.3
12	Faridkot	Nathuwala	30.721	74.977	8.9	1683	59	290	140	260	**79**	**6.03**	0.01	16	20	349	7	9.9	124	BDL	BDL	4.3
13	Faridkot	Mumara	30.793	74.589	8.61	**3212**	47	157	295	1036	6.7	0.27	BDL	41	60	626	6	15	350	BDL	0.17	-2.9
14	Faridkot	Arianwala	30.726	74.702	8.74	700	36	254	28	68	19	1.06	0.02	21	15	128	4.8	14	114	BDL	0.15	3.1
15	Faridkot	Kilanau	30.647	74.691	8.25	1759	nil	254	190	390	26	0.58	BDL	78	38	256	7	13	350	0.001	0.12	-2.9
16	Faridkot	Killi	30.841	74.483	9.17	2978	131	567	237	480	**140**	**4.29**	0.04	25	13	594	194	4	114	0.004	BDL	11.3
17	Kotkapura	Baja Khana	30.454	74.983	8.2	**3988**	nil	278	456	1200	29	0.91	BDL	103	93	692	10	24	639	0.001	BDL	-8.3
18	Kotkapura	Beed Sikhan	30.608	74.866	8.93	1367	59	362	63	194	**89**	**1.84**	0.02	16	18	299	5	5.9	114	0.001	BDL	5.6
19	Kotkapura	Dhilwan Kal	30.571	74.867	8.54	2872	71	664	211	520	**72**	**2.85**	0.03	25	42	608	12	4.7	237	BDL	BDL	8.5
20	Kotkapura	Karirwali	30.406	74.828	8.43	2680	59	507	225	576	32	1.1	0.03	37	43	542	8	4.7	266	0.001	0.12	4.8
21	Kotkapura	Kot Kapura	30.583	74.833	8.69	**3299**	59	809	253	486	**144**	**3.33**	0.05	29	33	603	186	1.4	206	0.001	0.11	11.0
22	Kotkapura	Matta	30.481	74.838	8.69	2447	47	290	246	580	2.6	0.5	BDL	45	52	435	11	13	330	BDL	0.03	-0.3
23	Kotkapura	Wara Dhara	30.510	74.752	8.59	1154	36	242	84	148	**66**	0.72	0.01	21	45	125	63	20	237	BDL	1.13	0.4
24	Kotkapura	Moharewal	30.645	75.071	8.92	2777	83	580	211	488	**78**	**1.95**	0.03	16	25	617	10	20	144	0.005	BDL	9.4

Nd: Not Determined, BDL: Below Detection Limit

Annexure-II

Data Availability of Exploration Wells of Faridkot district

Sl.No	LOCATION	LONGITUDE	LATITUDE	DEPTH	ELEVATION	BLOCK	DEPARTMENT
1	Dal Singhwala	74.950	30.469	300	211	Kot Kapura	CGWB
2	Dip Singh Wala	74.483	30.742	300	201	Faridkot	CGWB
3	Golewala	74.692	30.792	300	199.5	Faridkot	CGWB
4	Jaito Mandi	74.891	30.446	300	203	Kot Kapura	CGWB
5	Kot Kapura	74.814	30.576	300	206	Kot Kapura	CGWB
6	Nanak Nagri	74.893	30.581	200	210	Kot Kapura	PRIVATE
7	Nangal	74.869	30.669	300	206	Faridkot	CGWB
8	Tehna	74.790	30.690	300	205	Faridkot	CGWB
9	Wara Daraka	74.797	30.548	300	205	Kot Kapura	CGWB
10	Aulakh	74.920	30.643	300	211	Kot Kapura	PSTC
11	Bhagthala	74.786	30.777	300	198	Faridkot	PSTC
12	Sadhuwala	74.559	30.717	300	196	Faridkot	PSTC
13	Deviwala	74.870	30.612	269	207	Kot Kapura	CGWB
14	Deviwala-I	74.870	30.612	156	207	Kot Kapura	CGWB
15	Kouni	74.675	30.760	60	194	Faridkot	WSS
16	Ghugiana	74.639	30.746	60	198	Faridkot	WSS
17	Pahluwala	74.763	30.799	60	203	Faridkot	WSS
18	Faridkot	74.763	30.681	60	203	Faridkot	WSS
19	Doda Bhundar	75.016	30.470	121	212	Kot Kapura	WRED
20	Dhudi	74.849	30.700	60	207	Faridkot	WSS
21	Ratti Rori	74.811	30.647	60	208	Faridkot	WSS
22	Chak Kalyan	74.705	30.572	60	203	Kot Kapura	WSS
23	Kot Kapura	74.812	30.596	60	208	Kot Kapura	WSS
24	Behbal Kalan	74.913	30.531	60	210	Kot Kapura	WSS
25	Rorian Kapura	74.815	30.439	60	207	Kot Kapura	WSS
26	Panjgrain	74.914	30.608	70	211	Kot Kapura	PRIVATE
27	Fatehgarh	74.943	30.405	60	208	Kot Kapura	WSS
28	Bhurj Jawar Singh	74.987	30.535	60	211	Kot Kapura	WRED
29	Dewarana	74.766	30.593	30	206	Kot Kapura	WRED
30	Sher Singhwala	74.628	30.665	65	195	Faridkot	CGWB
31	Bir Sikhan wala	74.849	30.627	65	207	Kot Kapura	CGWB
32	*Dohak*	*74.603*	*30.632*	*163*	*197*	*Muktsar*	*CGWB*
33	*Toot*	*74.645*	*30.829*	*217*	*196*	*Ghal khurd*	*CGWB*

Two exploratory wells from adjacent districts i.e: Dohak from Muktsar district and Toot from Ferozpur district have been incorporated for the preparation of lithological fence and cross sections.

Annexure-III

LITHOLOGICAL DATA OF WELLS IN FARIDKOT DISTRICT				
Well Location	***Depth from***	***Depth to***	***Lithology***	***Thickness***
Dal Singhwala	0	13	Clay	13
	13	20	Fresh Sand	7
	20	28	Clay	8
	28	57	Fresh Sand	29
	57	64	Clay	7
	64	75	Saline Sand	11
	75	78	Clay	3
	78	97	Saline Sand	19
	97	108	Clay	11
	108	117	Saline Sand	9
	117	122	Clay	5
	122	134	Saline Sand	12
	134	157	Clay	23
	157	173	Saline Sand	16
	173	179	Clay	6
	179	184	Saline Sand	5
	184	211	Clay	27
	211	219	Saline Sand	8
	219	253	Clay	34
	253	259	Saline Sand	6
	259	278	Clay	19
	278	293	Saline Sand	15
	293	298	Clay	5
	298	300	Saline Sand	2
Dip Singh Wala	0	8	Fresh Sand	8
	8	36	Clay	28
	36	68	Fresh Sand	32
	68	75.5	Clay	7.5
	75.5	80.5	Fresh Sand	5
	80.5	83	Clay	2.5
	83	92	Fresh Sand	9
	92	93	Clay	1
	93	109	Saline Sand	16
	109	113	Clay	4
	113	116	Saline Sand	3
	116	120	Clay	4
	120	132	Saline Sand	12

Dip Singh Wala	132	146	Clay	14
	146	162	Saline Sand	16
	162	168	Clay	6
	168	192	Saline Sand	24
	192	195	Clay	3
	195	197	Saline Sand	2
	197	201.5	Clay	4.5
	201.5	209	Saline Sand	7.5
	209	213.5	Clay	4.5
	213.5	217.5	Saline Sand	4
	217.5	221	Clay	3.5
	221	237	Saline Sand	16
	237	286.5	Clay	49.5
	286.5	289.5	Saline Sand	3
	289.5	293	Clay	3.5
	293	296	Saline Sand	3
	296	300	Clay	4
Golewala	0	7.5	Clay	7.5
	7.5	28.85	Fresh Sand	21.35
	28.85	40	Clay	11.15
	40	52.5	Fresh Sand	12.5
	52.5	60	Clay	7.5
	60	88	Saline Sand	28
	88	93	Clay	5
	93	103	Saline Sand	10
	103	132.5	Clay	29.5
	132.5	137.5	Saline Sand	5
	137.5	155	Clay	17.5
	155	157.5	Saline Sand	2.5
	157.5	182	Clay	24.5
	182	203.5	Saline Sand	21.5
	203.5	228.5	Clay	25
	228.5	234	Saline Sand	5.5
	234	253	Clay	19
	253	272.5	Saline Sand	19.5
	272.5	280	Clay	7.5
	280	297.5	Saline Sand	17.5
	297.5	300	Clay	2.5
Jaito Mandi	0	15	Clay	15
	15	25	Fresh Sand	10
	25	28	Clay	3

Jaito Mandi	28	42	Fresh Sand	14
	42	46	Clay	4
	46	59	Fresh Sand	13
	59	80	Clay	21
	80	91.5	Fresh Sand	11.5
	91.5	103	Clay	11.5
	103	107	Fresh Sand	4
	107	155.5	Clay	48.5
	155.5	171.5	Fresh Sand	16
	171.5	191	Clay	19.5
	191	213	Saline Sand	22
	213	220	Clay	7
	220	223	Saline Sand	3
	223	238	Clay	15
	238	255	Saline Sand	17
	255	273	Clay	18
	273	278.5	Saline Sand	5.5
	278.5	280.5	Clay	2
	280.5	283	Saline Sand	2.5
	283	298.5	Clay	15.5
	298.5	300	Saline Sand	1.5
Kot Kapura	0	14	Clay	14
	14	21	Fresh Sand	7
	21	25	Clay	4
	25	35.5	Fresh Sand	10.5
	35.5	37	Clay	1.5
	37	50	Fresh Sand	13
	50	57	Clay	7
	57	64	Fresh Sand	7
	64	69	Clay	5
	69	77	Fresh Sand	8
	77	88	Clay	11
	88	99	Fresh Sand	11
	99	103	Clay	4
	103	106	Saline Sand	3
	106	123	Clay	17
	123	128.6	Saline Sand	5.6
	128.6	130	Clay	1.4
	130	132.6	Saline Sand	2.6
	132.6	134	Clay	1.4
	134	135.5	Saline Sand	1.5

Kot Kapura	135.5	149.2	Clay	13.7
	149.2	151.8	Saline Sand	2.6
	151.8	155	Clay	3.2
	155	158.4	Saline Sand	3.4
	158.4	161	Clay	2.6
	161	179.6	Saline Sand	18.6
	179.6	181.2	Clay	1.6
	181.2	183.8	Saline Sand	2.6
	183.8	186.5	Clay	2.7
	186.5	204.5	Saline Sand	18
	204.5	207	Clay	2.5
	207	212.5	Saline Sand	5.5
	212.5	249	Clay	36.5
	249	254.5	Saline Sand	5.5
	254.5	280	Clay	25.5
	280	294.4	Saline Sand	14.4
	294.4	300	Clay	5.6
Nanak Nagri	0	13.6	Clay	13.6
	13.6	20.8	Fresh Sand	7.2
	20.8	26.5	Clay	5.7
	26.5	30.5	Fresh Sand	4
	30.5	34	Clay	3.5
	34	36.8	Fresh Sand	2.8
	36.8	38.8	Clay	2
	38.8	40	Fresh Sand	1.2
	40	42.8	Clay	2.8
	42.8	46	Fresh Sand	3.2
	46	69.5	Clay	23.5
	69.5	71.2	Fresh Sand	1.7
	71.2	78.5	Clay	7.3
	78.5	81.5	Fresh Sand	3
	81.5	84	Clay	2.5
	84	87	Fresh Sand	3
	87	92	Clay	5
	92	93.6	Saline Sand	1.6
	93.6	98.8	Clay	5.2
	98.8	100	Saline Sand	1.2
	100	108.5	Clay	8.5
	108.5	111.5	Saline Sand	3
	111.5	118	Clay	6.5
	118	120	Saline Sand	2

Nanak Nagri	120	128	Clay	8
	128	129.6	Saline Sand	1.6
	129.6	130	Clay	0.4
	130	131.6	Saline Sand	1.6
	131.6	135	Clay	3.4
	135	136.8	Saline Sand	1.8
	136.8	165	Clay	28.2
	165	167.6	Saline Sand	2.6
	167.6	184	Clay	16.4
	184	186.8	Saline Sand	2.8
	186.8	190.5	Clay	3.7
	190.5	194.8	Saline Sand	4.3
	194.8	213.4	Clay	18.6
Nangal	0	8	Clay	8
	8	20	Fresh Sand	12
	20	23	Clay	3
	23	28	Fresh Sand	5
	28	29	Clay	1
	29	41	Fresh Sand	12
	41	72	Clay	31
	72	80	Fresh Sand	8
	80	91	Clay	11
	91	124	Fresh Sand	33
	124	151	Clay	27
	151	158	Fresh Sand	7
	158	163	Clay	5
	163	171	Fresh Sand	8
	171	181	Clay	10
	181	187	Fresh Sand	6
	187	193	Clay	6
	193	199	Fresh Sand	6
	199	203	Clay	4
	203	219	Fresh Sand	16
	219	224	Clay	5
	224	233	Saline Sand	9
	233	243	Clay	10
	243	249	Saline Sand	6
	249	251	Clay	2
	251	257	Saline Sand	6
	257	300	Clay	43
Tehna	0	8	Clay	8

Tehna	8	23	Fresh Sand	15
	23	28	Clay	5
	28	32	Fresh Sand	4
	32	37	Clay	5
	37	41	Fresh Sand	4
	41	59	Clay	18
	59	63	Fresh Sand	4
	63	69	Clay	6
	69	72	Fresh Sand	3
	72	102	Clay	30
	102	106	Fresh Sand	4
	106	120	Clay	14
	120	123	Fresh Sand	3
	123	133	Clay	10
	133	136	Fresh Sand	3
	136	145	Clay	9
	145	150	Fresh Sand	5
	150	158	Clay	8
	158	163	Fresh Sand	5
	163	168	Clay	5
	168	172	Fresh Sand	4
	172	176	Clay	4
	176	184	Fresh Sand	8
	184	210	Clay	26
	210	215	Fresh Sand	5
	215	221	Clay	6
	221	225	Fresh Sand	4
	225	254	Clay	29
	254	264	Fresh Sand	10
	264	267	Clay	3
	267	275	Fresh Sand	8
	275	294	Clay	19
	294	300	Fresh Sand	6
Wara Daraka	0	15	Clay	15
	15	22	Fresh Sand	7
	22	28	Clay	6
	28	48	Fresh Sand	20
	48	52	Clay	4
	52	61	Fresh Sand	9
	61	65	Clay	4
	65	75	Fresh Sand	10

Wara Daraka	75	84	Clay	9
	84	86	Saline Sand	2
	86	91	Clay	5
	91	97	Saline Sand	6
	97	101	Clay	4
	101	119	Saline Sand	18
	119	124	Clay	5
	124	129	Saline Sand	5
	129	150	Clay	21
	150	172	Saline Sand	22
	172	184	Clay	12
	184	188	Saline Sand	4
	188	196	Clay	8
	196	205	Saline Sand	9
	205	234	Clay	29
	234	239	Saline Sand	5
	239	274	Clay	35
	274	281	Saline Sand	7
	281	300	Clay	19
Aulakh	0	18.29	Clay	18.29
	18.29	45.73	Fresh Sand	27.44
	45.73	76.21	Clay	30.48
	76.21	91.46	Fresh Sand	15.25
	91.46	109.75	Clay	18.29
	109.75	112.8	Saline Sand	3.05
	112.8	134.14	Clay	21.34
	134.14	167.68	Saline Sand	33.54
	167.68	201.12	Clay	33.44
	201.12	210.36	Saline Sand	9.24
	210.36	213.41	Clay	3.05
	213.41	219.51	Saline Sand	6.1
	219.51	225.6	Clay	6.09
	225.6	245	Saline Sand	19.4
	245	300	Clay	55
Bhagthala	0	3.5	Clay	3.5
	3.5	18.29	Fresh Sand	14.79
	18.29	41	Clay	22.71
	41	53	Fresh Sand	12
	53	63	Clay	10
	63	85.37	Saline Sand	22.37
	85.37	92	Clay	6.63

	92	102	Saline Sand	10
	102	131.1	Clay	29.1
	131.1	134.15	Saline Sand	3.05
	134.15	167.68	Clay	33.53
	167.68	170.73	Saline Sand	3.05
	170.73	185	Clay	14.27
	185	203	Saline Sand	18
	203	228.66	Clay	25.66
	228.66	234.76	Saline Sand	6.1
	234.76	253	Clay	18.24
	253	273	Saline Sand	20
	273	280	Clay	7
	280	294	Saline Sand	14
	294	300	Clay	6
Sadhuwala	0	6.1	Fresh Sand	6.1
	6.1	30.49	Clay	24.39
	30.49	52	Saline Sand	21.51
	52	62.5	Clay	10.5
	62.5	72.5	Saline Sand	10
	72.5	77	Clay	4.5
	77	84	Saline Sand	7
	84	91	Clay	7
	91	107	Saline Sand	16
	107	110	Clay	3
	110	114	Saline Sand	4
	114	118	Clay	4
	118	130	Saline Sand	12
	130	143.39	Clay	13.39
	143.39	164.63	Saline Sand	21.24
	164.63	176.83	Clay	12.2
	176.83	207	Saline Sand	30.17
	207	211.5	Clay	4.5
	211.5	215.5	Saline Sand	4
	215.5	219	Clay	3.5
	219	235	Saline Sand	16
	235	237	Clay	2
	237	256.24	Saline Sand	19.24
	256.24	271.34	Clay	15.1
	271.34	300	Saline Sand	28.66
Deviwala	0	15	Clay	15
	15	23	Fresh Sand	8

Deviwala	23	38	Clay	15
	38	46	Fresh Sand	8
	46	48	Clay	2
	48	53	Fresh Sand	5
	53	61	Clay	8
	61	65	Fresh Sand	4
	65	72	Clay	7
	72	78	Fresh Sand	6
	78	94	Clay	16
	94	106	Fresh Sand	12
	106	109	Clay	3
	109	112	Saline Sand	3
	112	128	Clay	16
	128	140	Saline Sand	12
	140	158	Clay	18
	158	163	Saline Sand	5
	163	179	Clay	16
	179	183	Saline Sand	4
	183	187	Clay	4
	187	196	Saline Sand	9
	196	202	Clay	6
	202	213	Saline Sand	11
	213	218	Clay	5
	218	223	Saline Sand	5
	223	252	Clay	29
	252	258	Saline Sand	6
	258	263	Clay	5
	263	269	Saline Sand	6
Dohak	0	8	Clay	8
	8	10	Fresh Sand	2
	10	21	Clay	11
	21	33	Saline Sand	12
	33	41	Clay	8
	41	79	Saline Sand	38
	79	89	Clay	10
	89	95	Saline Sand	6
	95	99	Clay	4
	99	112	Saline Sand	13
	112	116	Clay	4
	116	139	Saline Sand	23
	139	154	Clay	15

	154	163	Saline Sand	9
Toot	0	15	Clay	15
	15	19.8	Fresh Sand	4.8
	19.8	21	Clay	1.2
	21	47.4	Fresh Sand	26.4
	47.4	51	Clay	3.6
	51	55.2	Fresh Sand	4.2
	55.2	62.6	Clay	7.4
	62.6	76.6	Fresh Sand	14
	76.6	101	Clay	24.4
	101	104	Fresh Sand	3
	104	113	Clay	9
	113	116	Fresh Sand	3
	116	143	Clay	27
	143	146	Saline Sand	3
	146	167	Clay	21
	167	170	Saline Sand	3
	170	182	Clay	12
	182	204	Saline Sand	22
	204	214	Clay	10
	214	217	Saline Sand	3

Annexure-IV

AQUIFER GROUPING OF WELL LOCATIONS IN FARIDKOT DISTRICT

Well location	*Depth from*	*Depth to*	*Aquifer*	*Thickness*	*Fresh Granular Zones*	*Saline Granular Zones*
Dal Singhwala	0	15	Unsaturated Zone	15	2	
	15	57	Aquifer Group-IA	42	34	
	57	64	Aquiclude-IA	7		
	64	134	Aquifer Group-IB	70		51
	134	157	Aquiclude-IB	23		
	157	300	Multiple Aquifers	143		52
Dip Singh Wala	0	5	Unsaturated Zone	5	5	
	5	68	Aquifer Group-IA	63	35	
	68	75.5	Aquiclude-IA	7.5		
	75.5	132	Aquifer Group-IB	56.5	14	31
	132	146	Aquiclude-IB	14		
	146	300	Multiple Aquifers	154		75.5
Golewala	0	4	Unsaturated Zone	4	1	
	4	52.5	Aquifer Group-IA	48.5	33	
	52.5	60	Aquiclude-IA	7.5		
	60	103	Aquifer Group-IB	43		38
	103	155	Aquiclude-IB	52		
	155	300	Multiple Aquifers	145		66.5
Jaito Mandi	0	14	Unsaturated Zone	14	1	
	14	59	Aquifer Group-IA	45	37	
	59	80	Aquiclude-IA	21		
	80	107	Aquifer Group-IB	27	15.5	
	107	155.5	Aquiclude-IB	48.5		
	155.5	300	Multiple Aquifers	144.5	16	51.5
Kot Kapura	0	9	Unsaturated Zone	9	2	
	9	77	Aquifer Group-IA	68	45.5	
	77	88	Aquiclude-IA	11		
	88	106	Aquifer Group-IB	18	11	3
	106	155	Aquiclude-IB	49		
	155	300	Multiple Aquifers	145		68
Nanak Nagri	0	12	Unsaturated Zone	12	1	
	12	46	Aquifer Group-IA	34	18.4	
	46	69	Aquiclude-IA	23		
	69	131	Aquifer Group-IB	62	7.7	11
	131	165	Aquiclude-IB	34		
	165	213.4	Multiple Aquifers	48.4		9.7
Nangal	0	9	Unsaturated Zone	9	1	

Nangal	9	41	Aquifer Group-IA	32	29	
	41	72	Aquiclude-IA	31		
	72	124	Aquifer Group-IB	52	41	
	124	151	Aquiclude-IB	27		
	151	300	Multiple Aquifers	149	43	21
Tehna	0	10	Unsaturated Zone	10	2	
	10	41	Aquifer Group-IA	31	187	
	41	59	Aquiclude-IA	18		
	59	106	Aquifer Group-IB	47	33	
	106	158	Aquiclude-IB	52		
	158	300	Multiple Aquifers	142	50	
Wara Daraka	0	4	Unsaturated Zone	4	0	
	4	75	Aquifer Group-IA	71	46	
	75	84	Aquiclude-IA	9		
	84	129	Aquifer Group-IB	45		31
	129	150	Aquiclude-IB	21		
	150	300	Multiple Aquifers	150		47
Aulakh	0	17	Unsaturated Zone	17	2	
	17	46	Aquifer Group-IA	29	26	
	46	76	Aquiclude-IA	30		
	76	113	Aquifer Group-IB	37	15.25	3.05
	113	134	Aquiclude-IB	21		
	134	300	Multiple Aquifers	166		68.28
Bhagthala	0	4	Unsaturated Zone	4	1	
	4	53	Aquifer Group-IA	49	24	
	53	63	Aquiclude-IA	10		
	63	102	Aquifer Group-IB	39		32.37
	102	168	Aquiclude-IB	66		
	168	300	Multiple Aquifers	132		61.15
Sadhuwala	0	5	Unsaturated Zone	5	5	
	5	52	Aquifer Group-IA	47		21.51
	52	63	Aquiclude-IA	11		
	63	130	Aquifer Group-IB	67		49
	130	144	Aquiclude-IB	14		
	144	300	Multiple Aquifers	156		119.31
Deviwala	0	8	Unsaturated Zone	8	2	
	8	78	Aquifer Group-IA	70	31	
	78	94	Aquiclude-IA	16		
	94	112	Aquifer Group-IB	18	12	3
	112	128	Aquiclude-IB	16		
	128	269	Multiple Aquifers	141		58

Dohak	0	3	Unsaturated Zone	3	0	
	3	79	Aquifer Group-IA	76	2	50
	79	89	Aquiclude-IA	10		
	89	139	Aquifer Group-IB	50		42
	139	154	Aquiclude-IB	15		
	154	163	Multiple Aquifers	9		9
Toot	0	9	Unsaturated Zone	9	1	
	9	55	Aquifer Group-IA	46	35.4	
	55	63	Aquiclude-IA	8		
	63	116	Aquifer Group-IB	53	25	
	116	143	Aquiclude-IB	27		
	143	217	Multiple Aquifers	74		31