GOVERNMENT OF INDIA

MINISTRY OF JAL SHAKTI

DEPARTMENT OF WATER RESOURCES,

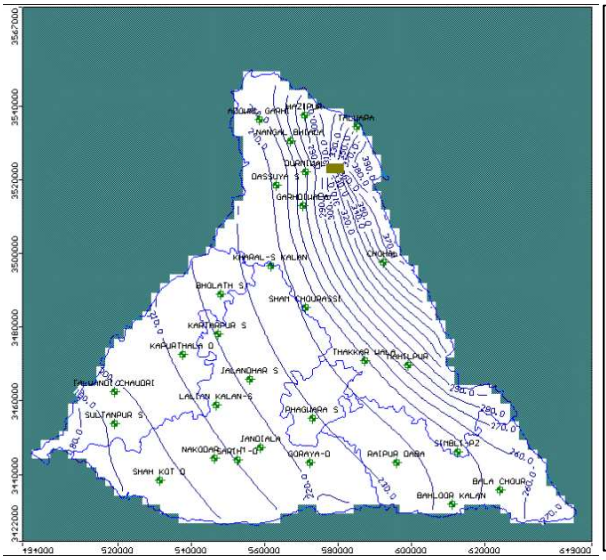
RIVER DEVELOPMENT & GANGA REJUVENATION

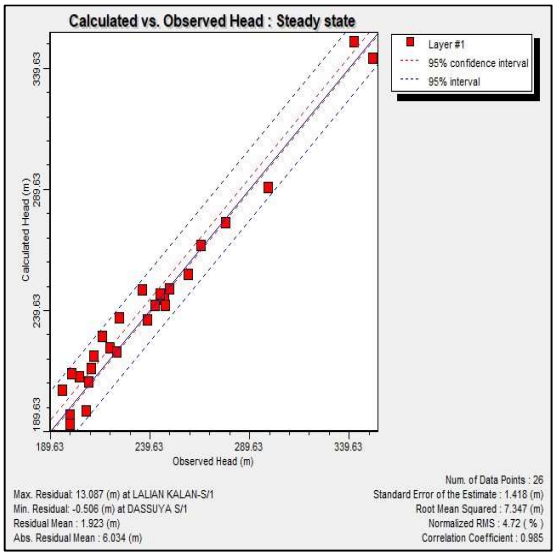
CENTRAL GROUND WATER BOARD

Western Region, JAIPUR

REPORT ON

GROUND WATER FLOW MODELLING STUDY IN BIST DOAB AREA, PUNJAB, (8908 sq km)





SUBMITTED BY

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REPORT ON GROUND WATER FLOW MODELLING STUDY IN BIST DOAB AREA,PUNJAB, (8908 sq km)

Contents

GROUND WATER FLOW MODELLING IN BIST DOAB AREA, PUNJAB, (8908 sq km)

The ground water flow modeling in Bist Doab Area of Punjab has been attempted during the training programme on '4 weeks tailor made short course on ground water flow modelling' at the UNESCO-IHE DELFTS, The Netherlands (14th March to 6th April 2018).

1.0 Introduction

Punjab State is one of the most predominant agricultural region in the country. Ground water is major source of water for Agriculture, drinking/domestic and industrial sectors in Bist Doab Area of Punjab. Due to increasing demand of water for these sectors, the ground water abstraction has increased many folds in last couple of decades. This has resulted in decline in ground water levels. Due to which, out of 30 administrative blocks in the Bist Doab area, 22 blocks have been categorized as Over-exploited (GWRE 2017). For effective management in Bist Doab area it is essential to understand the hydro-geological scenario and water balance of the area. So that the optimal ground water development could be established. Keeping this in view, the ground water flow modeling was attempted.

2.0 Objectives

The objectives of ground water flow modelling techniques cover the ground water dynamics in the Bist Doab Area to formulate the sustainable aquifer management plan.

3.0 Brief about Study Area

Bist Doab Area of Punjab is chosen for the modelling study. The Study area is traingular region covers an area of 8908 sq km spreads over 04 districts namely Hoshiarpur, Jalandhar, Kapurthala & Nawanshahr. The study area covers 30 Nos. of administrative blocks namely Bhunga, Dasua, Garhshankar, Hazipur, Hoshiarpur I & II, Mahilpur, Mukerian, Talwara, Tanda of Hoshiarpur district, Adampur, Bhogpur, Rurka Kalan, Jalandhar East & west Lohian, Nakodar, Nurmahal, Phillaur, Shahkot of Jalandhar district, Nadala, Dhilwan, Kapurthala, Phagwara, Sultanpur Lodhi of

Kapurthala district and Aur, Balachaur, Banga, Nawanshahr, Saroya of Nawanshahr district. Location of the study area is given in figure-1.

It lies between 30°04' and 30°51' N latitude between 74°57' and 76°40' E longitude. It is bounded by Siwaliks all along Eastern boundary and rivers Satluj in the south and Beas in Western Side. Siwalik area is known as Kandi Region. The Kandi area is considered as recharge zone for whole of the Bist Doab Area. The area has a continental type of climate. The area nearest the Siwaliks receive more rainfall than plains that are far away from it. The normal annual rainfall varies from 701 mm to 938 mm.

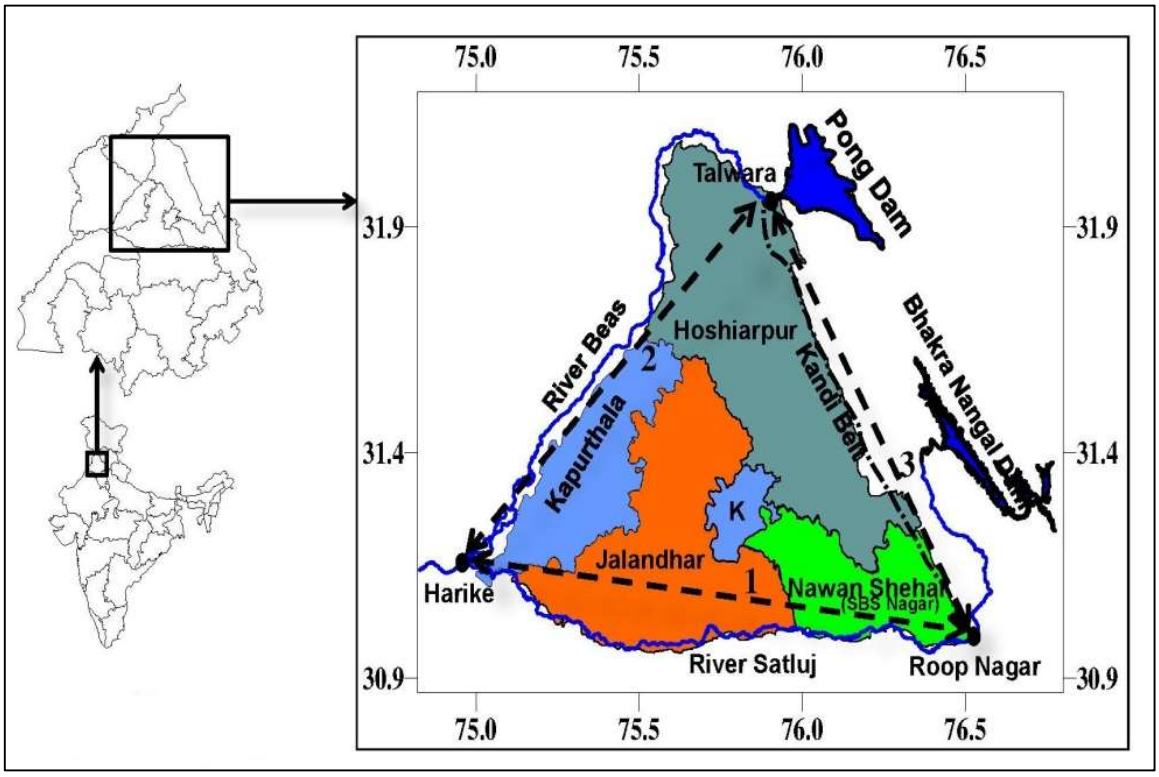


Fig.1- Location of study area

3.1 Hydrogeology

Based on the ground water exploration carried out by CGWB, there exist multilayered aquifer systems. The aquifer geometry is presented in fence diagram (figure-2). The detail of various Aquifer Groups is given below:

Aquifer Group I: The top layer of this aquifer group comprises of coarse sand beds, which is generally thick separated by small thin clay beds, which are regionally not

extensive. This layer varying thickness that ranges from 72 m to 94 m. The average layer is 72 m in Hoshiarpur district, 76 m in Nawanshahr district, 81 m in Jalandhar district and 94 m in Kapurthala district.

Aquifer Group II: This group comprises of alternating sequences of thin layers of sand and clay beds. The aquifer thickness of this group has been worked out upto 250m below the confining layer. This layer varying in thickness that ranges from 81 m to 105 m. The average layer is 81 m in Hoshiarpur district, 85 m in Kapurthala district, 87 m in Jalandhar district and 105 m in Nawanshahr district.

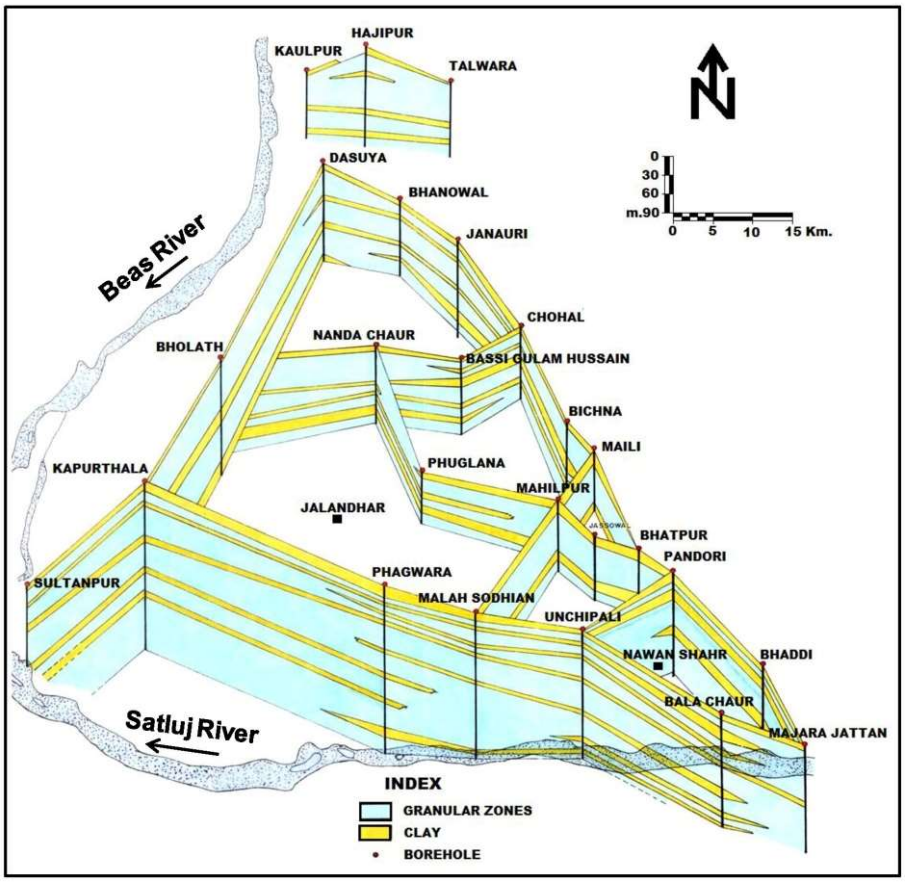


Fig.2- Fence diagram of Bist Doab Area showing Aquifer Groups

3.2 Ground Water Resources

The ground water draft takes place to meet the agriculture, industrial and drinking/domestic demands in the area. The draft in agriculture sector contributes around 93 % of total draft of the area. Thereby, decline in water levels in major parts of the bist doab area has been noticed. The rate of decline varies between

0.07 m/yr and 1.08 m/yr. As per Ground Water Resources Estimation as on 31stMarch 2017, out of 30 blocks in study area, 22 categorized as Over-exploited, 02 Semi-critical & 06 categorized as Safe. The stage of ground water development in overexploited blocks varies from 108 % (Nawanshahr) to 316 % (Jalandhar East) The block-wise details of dynamic ground water resources in Bist Doab area as on 31.03.2017 is given below in table-1.

Table-1: Ground Water Resources of Bist Doab Area (GWRE, 2017)

Assessment Unit	Net Annual Ground Water Availability (Ham)	Existing Gross Ground Water Draft for irrigation (Ham)	Existing Gross Ground Water Draft for domestic and industrial water supply (Ham)	Existing Gross Ground Water Draft for all uses (3+4) (Ham)	Stage of Ground Water Development 5/2*100 (%)	Categorization
1	2	3	4	5	6	7
Hoshaipur District						
Bhunga	8902	5733	504	6237	70	Safe
Dasuya	12186	14305	645	14949	123	Over-Exploited
Garhsahnkar	11935	14299	1327	15626	131	Over-Exploited
Hazipur	8119	5303	308	5611	69	Safe
Hoshiarpur-I	8622	10943	1732	12675	147	Over-Exploited
Hoshiarpur-II	8379	4914	799	5714	68	Safe
Mahilpur	5143	5181	522	5703	70	Safe
Mukerian	8698	6789	687	7476	86	Semi Critical
Talwara	1898	1236	295	1531	81	Semi Critical
Tanda	9048	16187	412	16599	183	Over-Exploited
TOTAL	**82929**	**84890**	**7231**	**92120**	**111**	
Jalandhar District						
Adampur	10889	20289	395	20684	190	Over-Exploited
Bhogpur	9590	26492	288	26780	279	Over-Exploited
RurkaKalan	10258	21263	340	21603	211	Over-Exploited
Jalandhar-East	8087	20719	4848	25567	316	Over-

						Exploited
Jalandhar-West	15790	31949	1617	33566	213	Over-Exploited
Lohian	8312	21840	236	22077	266	Over-Exploited
Nakodar	17004	45854	1231	47085	277	Over-Exploited
NurMahal	13572	29238	321	29560	218	Over-Exploited
Phillaur	16071	31010	2061	33071	206	Over-Exploited
Shahkot	7794	19778	926	20704	266	Over-Exploited
TOTAL	**117367**	**268433**	**12264**	**280697**	**239**	
Kapurthala District						
Nadala	11346	21945	566	22511	198	Over-Exploited
Dhilwan	13409	28485	650	29136	217	Over-Exploited
Kapurthala	14345	26914	1936	28849	201	Over-Exploited
Phagwara	12338	33000	1675	34675	281	Over-Exploited
SultanpurLodhi	18693	41156	592	41748	223	Over-Exploited
TOTAL	**70131**	**151500**	**5419**	**156919**	**224**	
Nawanshahr district						
Aur	13794	24086	337	24424	177	Over-Exploited
Balachaur	15964	9433	590	10023	63	Safe
Banga	9727	14055	495	14550	150	Over-Exploited
NawanShahr	21003	21862	746	22607	108	Over-Exploited
Saroya	2788	1617	234	1851	66	Safe
Total	**63276**	**71053**	**2402**	**73455**	**116**	

3.3 Surface Elevation Contours

The surface elevation contour map is prepared to know the surface gradient in the study area. It is presented in figure-3, it indicates that the surface elevation varies from 218 m to 383 m amsl. The map indicates that the surface gradient is from NE to SW and southern direction. The data on surface elevation of boreholes is given in table-2.

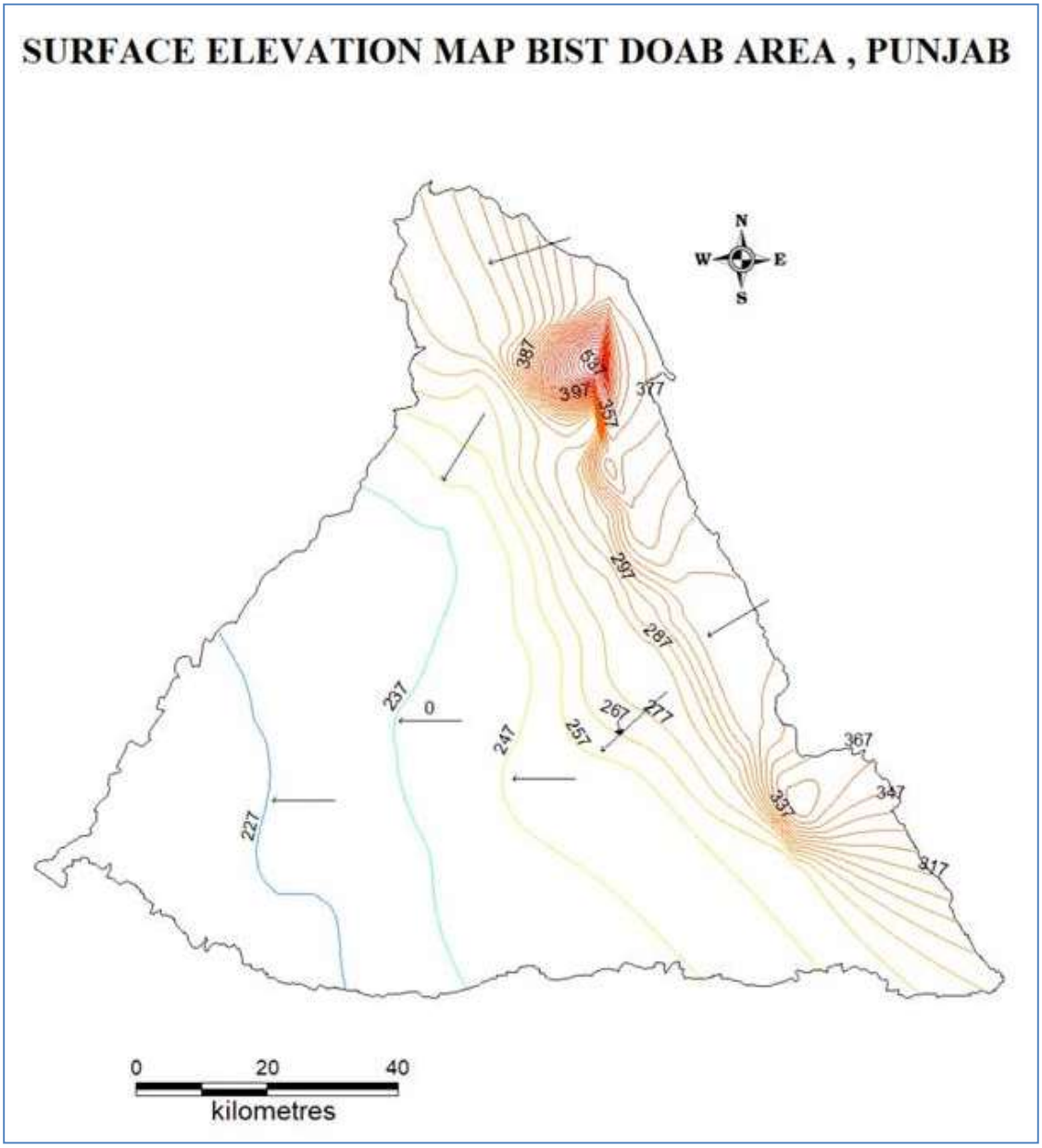


Fig.3- Surface elevation in the study area

Table-2: Location wise data on Surface Elevation (amsl)

Location	Easting	Northing	Surface Elevation
Bhikhowal	582464.9	3498275.43	310
Bhunga	577396.77	3506549.92	301
Dasuya	563107.2	3518461.03	266
FatehgarhNigra	582125.15	3487926.87	282
Hajipur	601545.77	3459954.4	285
Helron	606482.85	3468625.08	336
Janauri	583703.8	3507984.71	390
Kapahat	588435.34	3499556.31	365
Koulpur	565161.00	3526325.5	300
Labbar	581358.86	3521575.91	550
Mehlanwali	596549.41	3485464.24	330
Patti Khas	589622.02	3478012.4	282
Raghowal	581287.43	3513969.73	289
Rampur Colony	589951.51	3485713.09	306
Shahpur	613489.62	3456073.58	383
Simbli	612326.24	3446053.72	262
Talwara	584277.5	3534316.91	380
Adampur	567322.78	3476613.24	244
Jalandhar	556027.8	3465770.7	241
Kartarpur	547382.7	3478043.15	232
KheralKalan	561659.42	3496652.81	240
LallianKalan	546808.71	3458798.35	233
Malsian	534428.9	3443511.29	230
Nakodar	546236.75	3444479.92	231
Sarih	553206.16	3445240	236
Shahkot	532382.36	3438682.55	221
BhatnuraKhurd	555776.26	3493017.17	234
Bholath	547992.31	3488975.77	233
Kapurthala	536343	3472026.12	230
Phagwara	574206.59	3455261.45	249
SultanpurLodhi	519208.14	3453939.78	218

4.0 Model conceptualization and software

The process of groundwater modelling involves a number of different steps. The essential steps are shown in the flow chart diagram given in figure-4.

The purpose of building a conceptual model is to simplify the field problems and organize associated field data so that the system can be analyzed more readily (Anderson and Woessner 2002). The conceptualization includes synthesis and framing up of data pertaining to geology, hydrogeology, hydrology and meteorology. The groundwater model codes: Graphical user interface Visual Modflow was used in the present study.Visual MODLOW is a Graphical User Interface for the USGS MODFLOW. It is popular among the hydro-geologists for its user-friendly features. The software is mainly used for Groundwater flow and contaminant transport models under different conditions. The model was run using "USGS MODFLOW 2000 from SWS" flow engine.

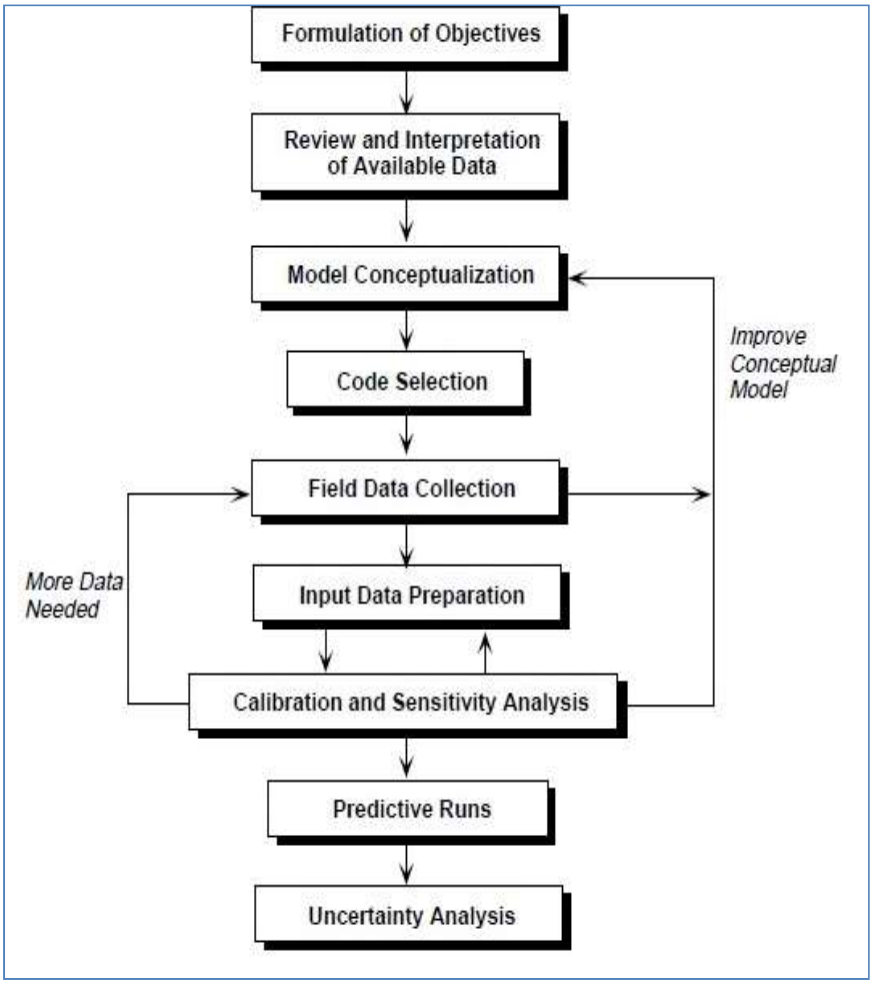


Fig.4-Flow chart of groundwater modeling

4.1 Model Framework

The model domain is bounded by Siwalik ranges all along its eastern boundary and known as Kandi Region, river Beas all along western boundary flowing towards south westerly direction and river Satluj along the southern boundary flowing towards westerly direction. It is shown in figure-5.

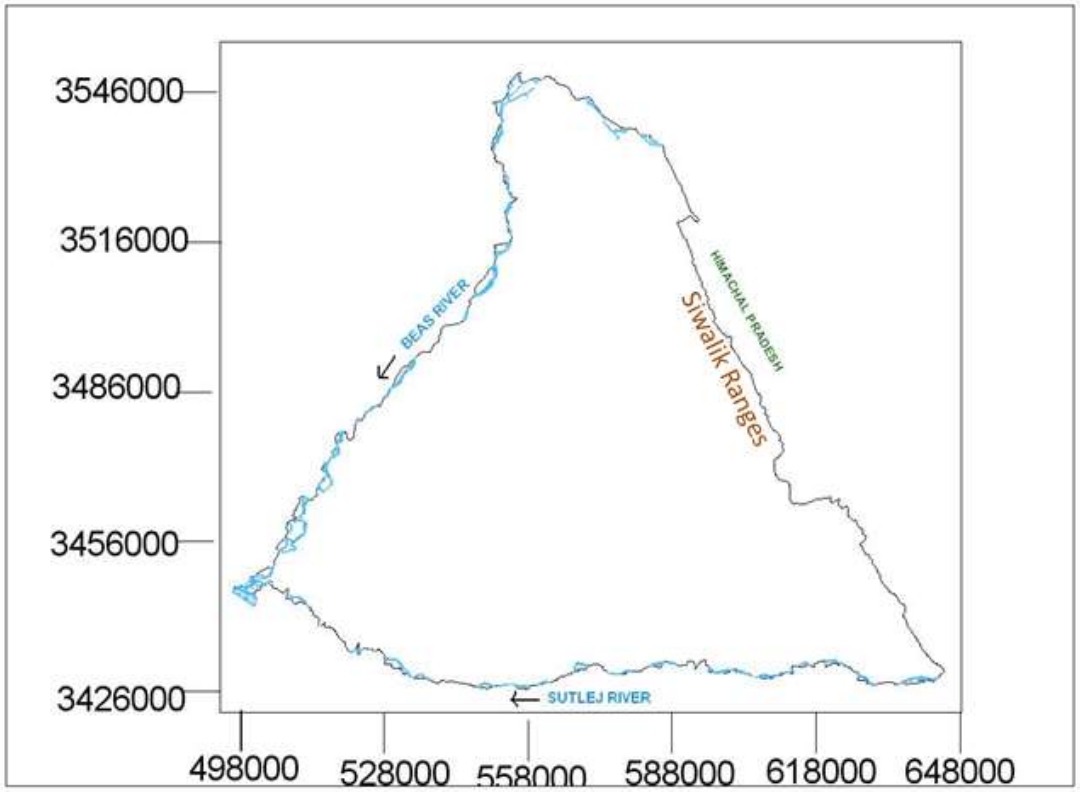


Fig.5-Model Framework

4.2 Model Design (Grid Size Finalization)

The total area of the model is 8908 sq km which is discretized into 58 rows and 62 columns, with the uniform dimension of 2500 x 2500 m grid size. Within the area white colored cell are considered as active cells/domain, which are numbered as 1504. The green colored cells outside the model boundaries are assigned as inactive Cells and are numbered as 2092. It is presented below in table-3 & figure-6.

Table-3: Model Design

Model Area (X1, Y1)	494000, 3422000
Model Area (X2, Y2)	649000, 3567000
Grid Size (m)	2500 X 2500 m
Nos. of Rows	58
Nos. of Columns	62
Layer in Model	Single Layer Model

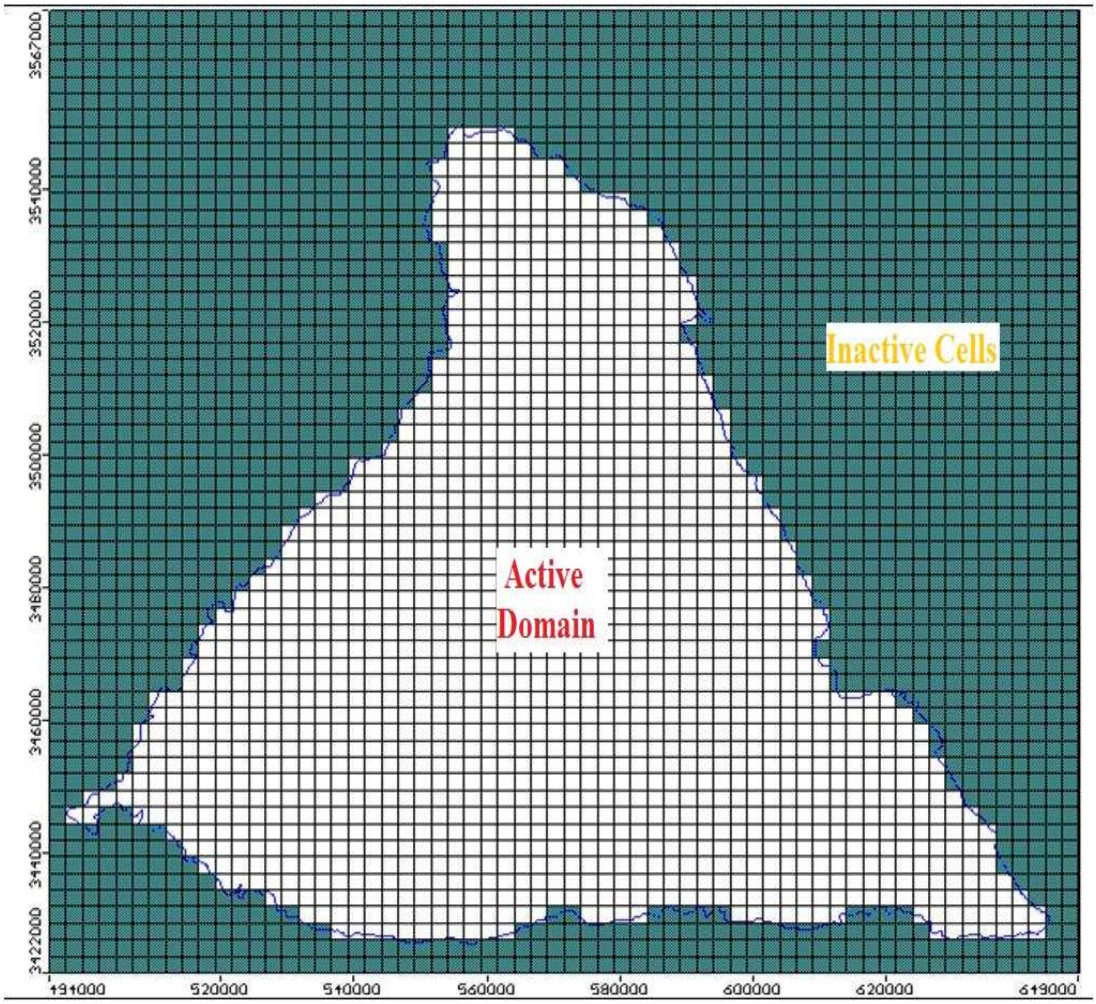


Fig.6- Discretization of grid and assigning Active domain and inactive cells

4.3 Layer

Hydro-geologically, the area is occupied with alluvial deposits consisting of alternate fluvial bands of sand, clay and kankar. The general trend of ground water flow directions of shallow aquifers is from north east to south west and western directions. Based on the interpretation of borehole data, there exist mainly two aquifer groups up to the depth of 250 m separated by the aquitard (clay layer). Lithological data of 34 boreholes were utilized for sketching the horizontal and vertical disposition of aquifers and aquitards in the study area.

The present study was confined to the first group of aquifers down to depth of 150 m only due to insufficient numbers of ground water monitoring wells tapping the second aquifers. It is therefore a numerical groundwater flow model using Visual MODFLOW is developed for the single layer.The top and bottom elevation of the layer is shown below in figure-7 & 8. The location-wise data of top and bottom of layers are given in table-4.

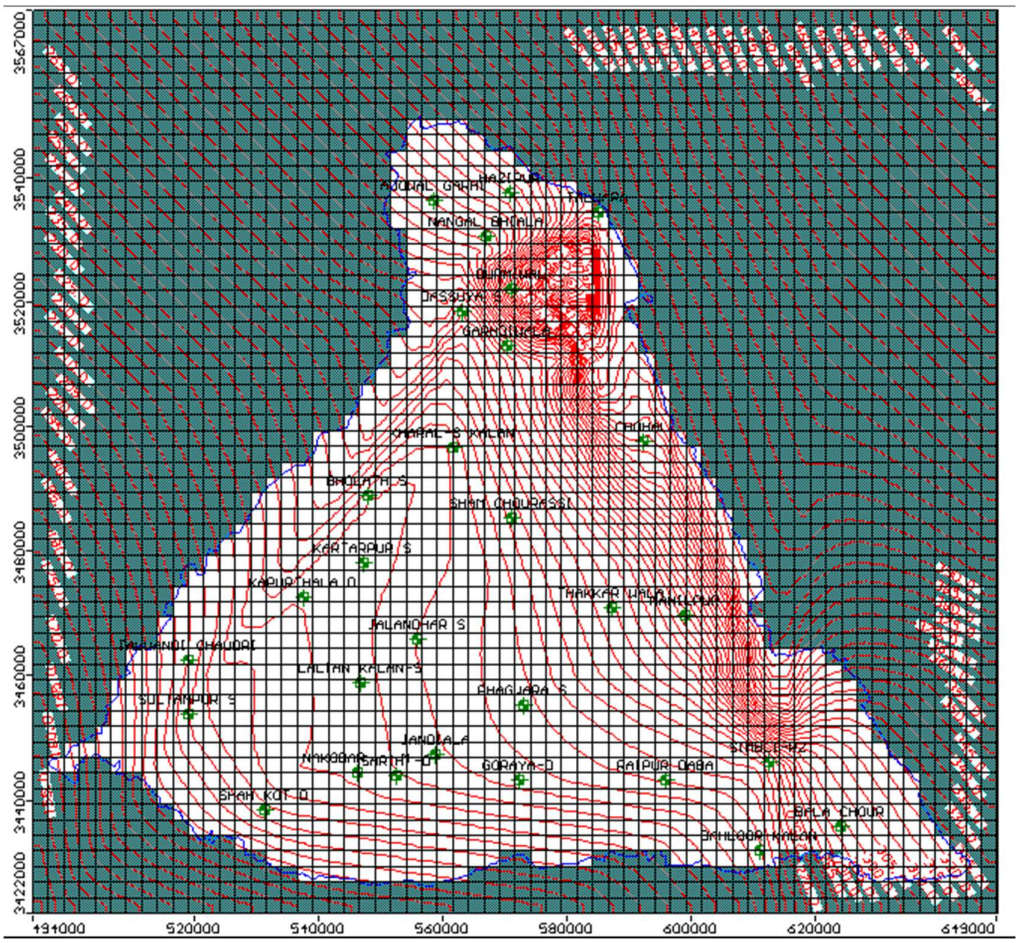


Fig.7-Output of top elevation of layer

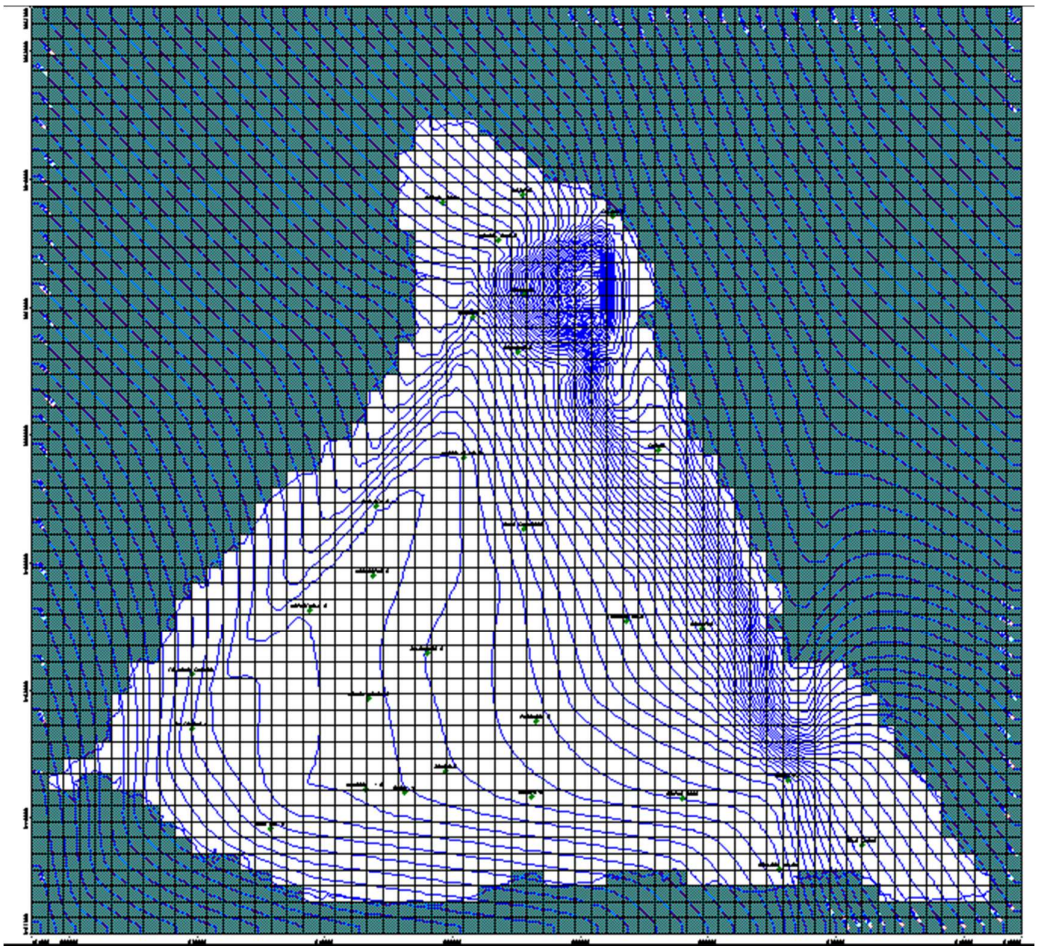


Fig.8-Output of bottom elevation of layer

Table-4: Location wise data of Top and Bottom of Layers (mamsl)

Location	Easting	Northing	Top of Layer	Bottom of Layer
Bhikhowal	582464.9	3498275.43	310	160
Bhunga	577396.77	3506549.92	301	151
Dasuya	563107.2	3518461.03	266	116
FatehgarhNigra	582125.15	3487926.87	282	132
Hajipur	601545.77	3459954.4	285	135
Helron	606482.85	3468625.08	336	186
Janauri	583703.8	3507984.71	390	240
Kapahat	588435.34	3499556.31	365	215
Koulpur	565161.00	3526325.5	300	150
Labbar	581358.86	3521575.91	550	400

Location	Easting	Northing	Top of Layer	Bottom of Layer
Mehlanwali	596549.41	3485464.24	330	180
Patti Khas	589622.02	3478012.4	282	132
Raghowal	581287.43	3513969.73	289	139
Rampur Colony	589951.51	3485713.09	306	156
Shahpur	613489.62	3456073.58	383	233
Simbli	612326.24	3446053.72	262	112
Talwara	584277.5	3534316.91	380	230
Adampur	567322.78	3476613.24	244	94
Jalandhar	556027.8	3465770.7	241	91
Kartarpur	547382.7	3478043.15	232	82
KheralKalan	561659.42	3496652.81	240	90
LallianKalan	546808.71	3458798.35	233	83
Malsian	534428.9	3443511.29	230	80
Nakodar	546236.75	3444479.92	231	81
Sarih	553206.16	3445240	236	86
Shahkot	532382.36	3438682.55	221	71
BhatnuraKhurd	555776.26	3493017.17	234	84
Bholath	547992.31	3488975.77	233	83
Kapurthala	536343	3472026.12	230	80
Phagwara	574206.59	3455261.45	249	99
SultanpurLodhi	519208.14	3453939.78	218	68

4.4 MODEL INPUT

The Input data required for the groundwater flow modeling under Grid are Mesh Size, Layer properties, boundary conditions, Top of layers & Bottom of layers, under parameters is the Time (stressed period), Initial & Prescribed Hydraulic Heads, horizontal & vertical hydraulic conductivity, specific yield& effective porosity and under modflow simulation is Head observations and graphical user interface for ground water recharge (Recharge from rainfall & other sources), ground water draft and assigning of various stress periods. The data was prepared and arranged based on the information available with the office.

4.5 Boundary Conditions

Every model requires an appropriate set of boundary conditions to represent the system's relationship with the surrounding area. The bist doab area is bounded by Siwalik ranges all along its eastern boundary, which is known as Kandi region and considered as continuous recharge sources for the bist doab area, however in the middle stretch it has assigned Constant Flux Boundary and in northern and south eastern stretches are assigned as No Flow Boundary. The western side of the study area is bounded by the river Beas, flows in south western direction, which has been assigned Constant Head Boundary. The southern boundary of the study area is bounded by the river Satluj, flows in westerly direction, which has been assigned Constant Head Boundary. Both these rivers are perennial in nature. Siwalik ranges forms the Kandi area, which is considered as recharge zone for Bist Doab area. The settings up of boundary conditions are shown in figure-9.

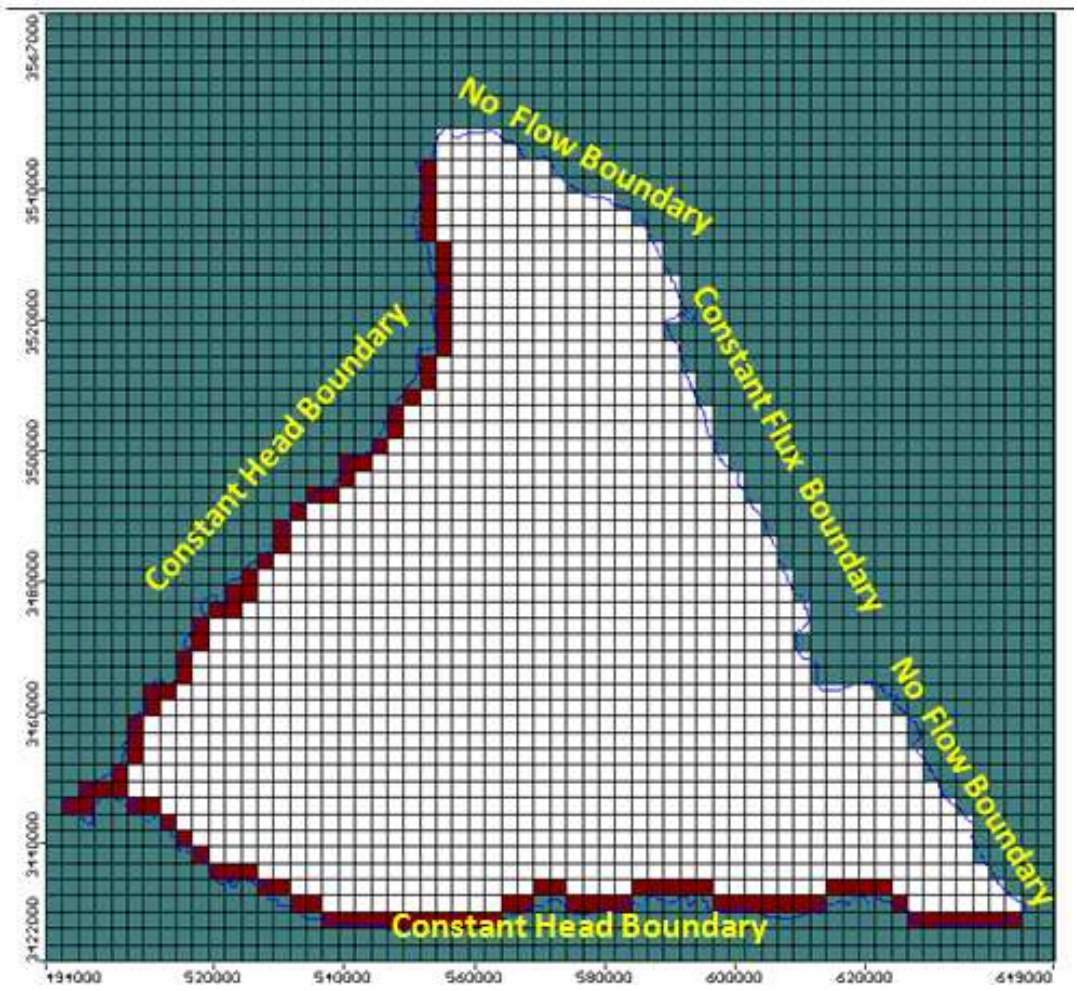


Fig.9-Setting up of boundary conditions of study area

4.6 Time Parameter (Modelling Period)

The time parameter requires period of length and number of steps for simulation. In this parameter, period of length is selected as 1 and number of steps selected as 1. Simulation time unit which is assigned as days and simulation type which is selected as Steady State Flow Simulation as this is the base for Transient State Flow simulation. The simulation period starts from 1st May 2013 and ends 30th April 2018. The simulation has been extended up to post monsoon period 2021 for the prediction and scenario generation. The assigning of time parameters (modeling period) for calibration, validation and prediction are shown in table-5.

Table-5: Time parameters for the Modelling study

Modelling Period	03 Years
Nos. of Stress Period	06 (02 stress period per year)
Calibration Period	03 Years (2013,2014 & 2015)
Validation Period	02 Years (2016 & 2017)
Predicted Simulation Period	04 Years (up to 2021)

4.7 Initial & Prescribed hydraulic Heads

Initial & Prescribed hydraulic Headsare defined by the spatially distributed groundwater levels of the aquifer at the start of the model period. In the present study, initial heads are assigned by interpolating water table elevation data of pre-monsoon 2013. A network of 34 existing ground water observation wells was selected for water level behavior within the study area, which are tapped the first group of aquifers. The water table elevation of pre-monsoon period i.e. May2013 has been taken as initial heads in steady state simulation.Location of ground water monitoring stations are shown in figure -10.

A perusal of water table contour map (pre-monsoon 2013) shows that general ground water flows are from NE to SW and western directions. The elevation of water table ranges from 470.97 m amsl (Bhamnaur) at extreme NE part of the study

area to 196.32 m amsl (Shahkot) at the south western part of the area. The water table elevation contour map is shown in figure-11 and initial heads after interpolating in the software visual modflow is shown in figure-12. The initial heads are given in table-6.

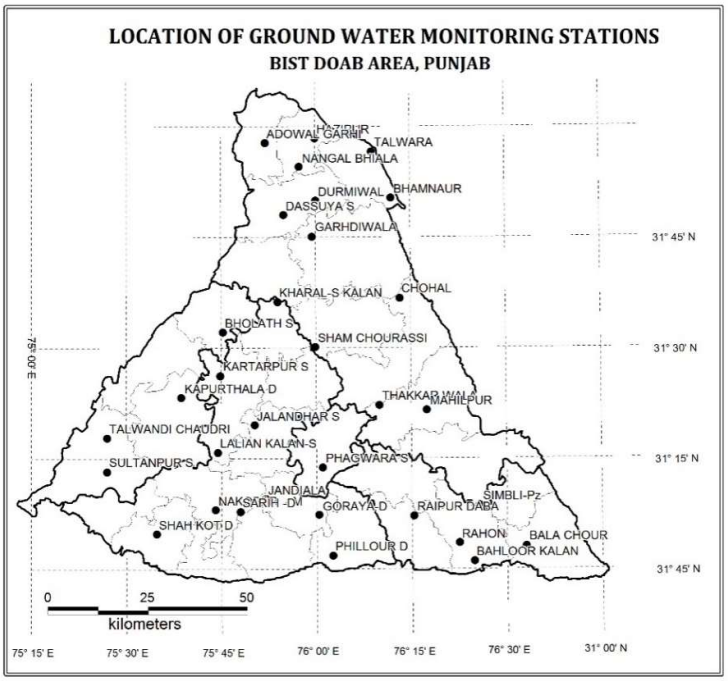


Fig.10- Location of Ground Water Monitoring Stations

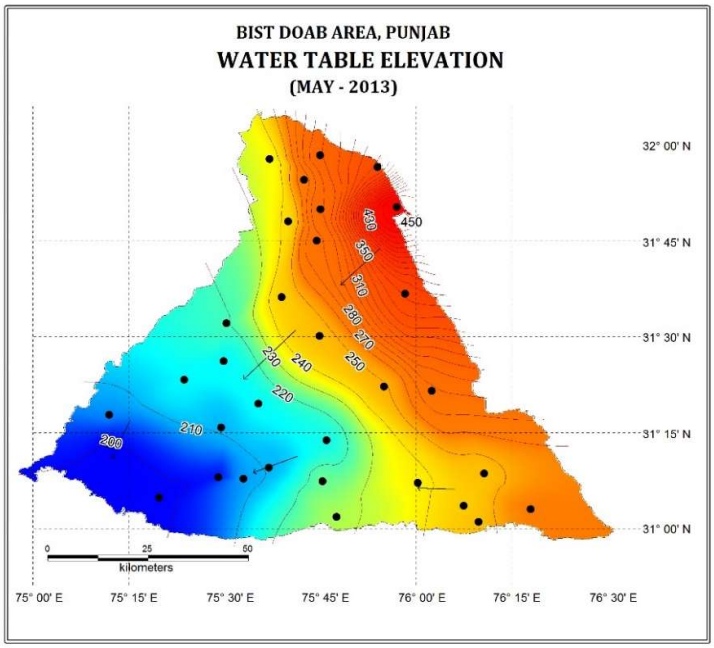


Fig.11-Water Table contour (Pre-monsoon 2013)

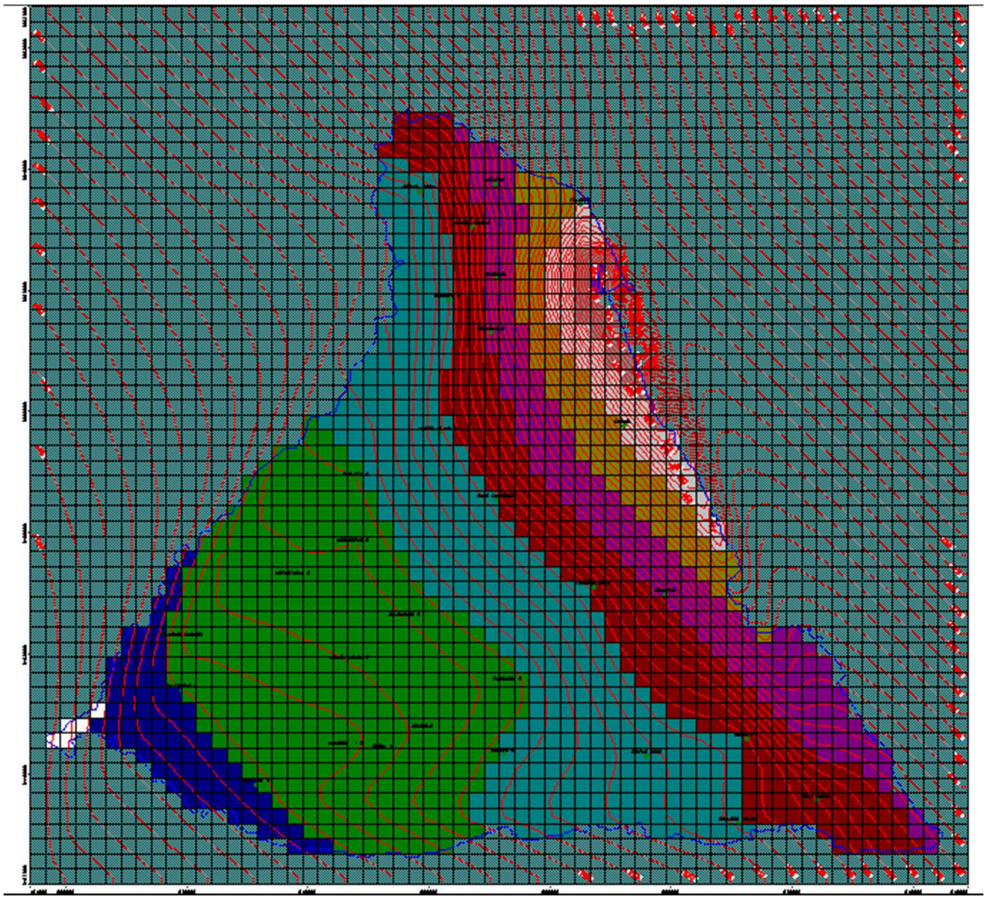


Fig.12- Initial Heads contours

Table-6: Initial Heads assigned for the model area

Village	Easting	Northing	Surface Elevation (m)	WTE May 13 (m)
Hazipur	570863.76	3537602.31	308.37	298.92
NangalBhiala	566973.08	3530494	277.77	265.24
Talwara	585065.14	3534323.43	354.17	342.09
Bhamnaur	589892.32	3522817.17	487.91	470.36
Durmiwal	571102.77	3522054.12	293.20	289.09
Sham Chourassi	571091.21	3485413.27	259.60	247.25
Chohal	592219.06	3497741.72	355.30	351.32
Thakkar Wala	587173.11	3470909.81	259.93	249.37
Dassuya S	563107.2	3518461.03	250.52	242.32
AdowalGarhi	558455.38	3536446.17	251.85	235.91
Garhdiwala	570244.71	3512964.88	289.79	278.09

Mahilpur	599072.57	3469784.03	296.19	277.73
Simbli-Pz	612326.24	3446053.72	260.70	246.60
Kartarpur S	547382.7	3478043.15	233.21	214.52
Jalandhar S	556027.8	3465770.7	235.51	214.45
Shahkot D	531504.25	3438453.25	224.02	199.63
Nakodar- M	546236.75	3444479.92	229.84	201.28
Phillour D	575688.02	3433104.4	244.88	228.68
Goraya-D	572171.12	3443393.75	244.12	223.10
Sarih -D	552435.8	3444047.13	235.61	208.70
KharalKalan-S	561659.78	3496591.3	239.59	244.19
LalianKalan-S	546808.71	3458798.35	231.70	210.26
Jandiala	558773.81	3447313.08	236.35	210.12
Sultanpur S	519049.37	3453939.49	214.88	199.58
Bholath S	547992.31	3488975.77	228.40	219.70
Kapurthala D	537608.86	3472584.77	227.76	213.96
Phagwara S	573042.46	3455253.31	241.46	215.79
TalwandiChaudri	519034.03	3462405.67	217.53	207.48
Rahon	607337.14	3436610.43	262.01	244.31
BalaChour	624046.09	3435869.13	278.21	258.84
Raipur Daba	595879.48	3443212.79	252.90	238.13
BahloorKalan	611096.18	3432030.55	252.59	246.70

4.8 Horizontal Hydraulic Conductivity & Storage Parameter

The hydraulic conductivity data obtained from pumping test were utilized in the preparation of model. Based on the distribution of hydraulic conductivity for available individual well, hydraulic conductivity of the model has been assigned in two zones i.e. along Siwaliks for Kandi Area and for remaining study area. The hydraulic conductivity in Bist Doab area varies from 5m/day to 45 m/day. Accordingly, an average value of 20 m/day has been assigned for selected Siwalik (Kandi) Region and 10 m/day for remaining bist doab area. The Vertical hydraulic conductivity has been taken as 10% of the horizontal hydraulic conductivity. After various model run hydraulic conductivity calibrated as 1.5 m/day and 5.5 m/day for Kandi and Tarai region of study area respectively, thereby it has been found to have good match

between simulated and observed head contours. The study area is sensitive to the hydraulic conductivity.

The storage parameter like specific yield, effective and total porosity were also assigned in similar manner for Kandi Area and Tarai area for same zones. The zoning for assigning the hydraulic conductivity and storage parameter is shown in Figure-13 & presented in table-7.

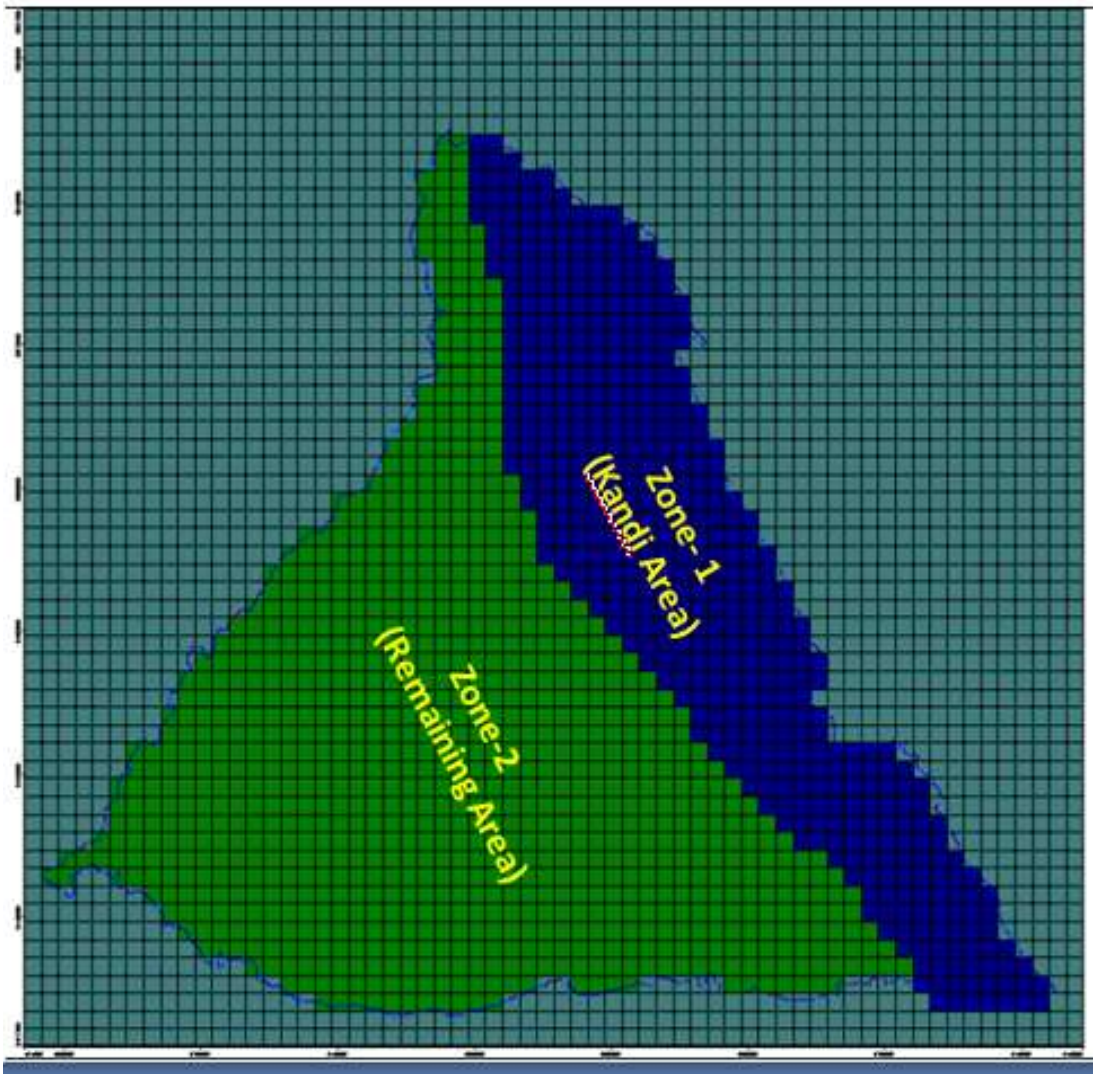


Fig.13-Showing zoning for assigning hydraulic conductivity

Table-7: Assigning Hydraulic Conductivity & Storage

Parameter	Kandi Area	Tarai Area (Remaining Area)
Hydraulic Conductivity		
Hydraulic Conductivity Average Field Values and Initial input to model	20 m/day	10 m/day
Hydraulic Conductivity calibrated as	1.5 m/day	5.5 m/day
Storage (GWRE, 2017)		
Specific Yield	12%	12%
Effective Porosity	15%	15%
Total Porosity	30%	30%

4.9 Recharge Flux

The Kandi belt of Siwalik ranges is predominantly comprised of gravel and bouldery formations with high gradient. These aquifers are well connected with the aquifers of Tarai region. The Kandi zone has been considered as recharge zone for Bist Doab Area, however, to match this well-established field observations with the modeling studies, the model has been assigned Constant Flux Boundary for some specific cells of the region. This is shown in figure-14.

The recharge flux has been assigned based on the annual rainfall in that particular cell. The impact of this has also been seen through scatter plot of steady state conditions for better matching with least RMS. Accordingly, assigned value of recharge has been calibrated and ranged from 0.00015 to 0.0009 m/day.

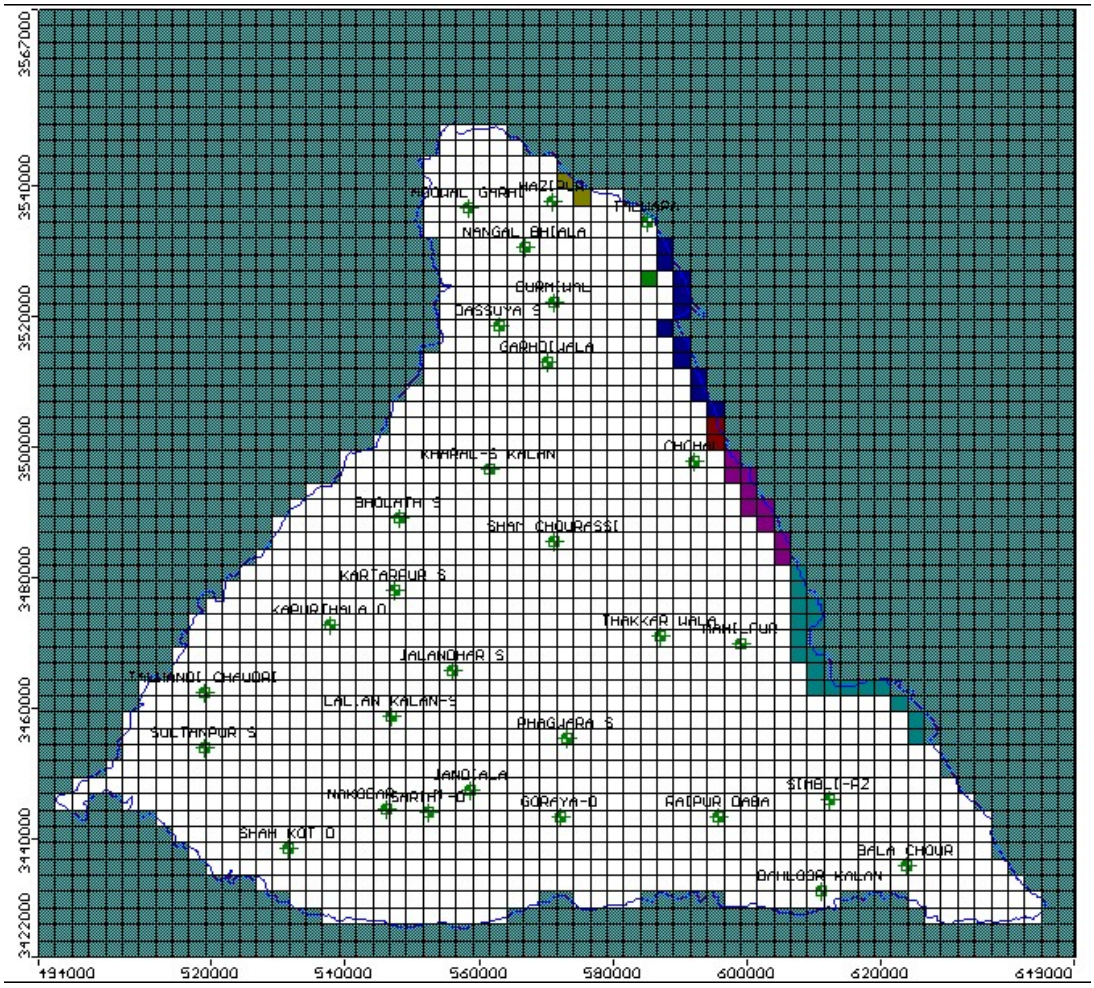


Fig.14-Recharge Flux assigned in Kandi Area

4.10 Head Observations

The data of 33 Nos. of ground water monitoring wells along with surface elevation, screen ID &screen elevation were given in time series for 05 years from pre-monsoon 2013 to Post-monsoon 2017, which is an input for transient model. The time series head observations are given in Annexure-1. The observed and simulated head contours are given in figure-15 &16 respectively.

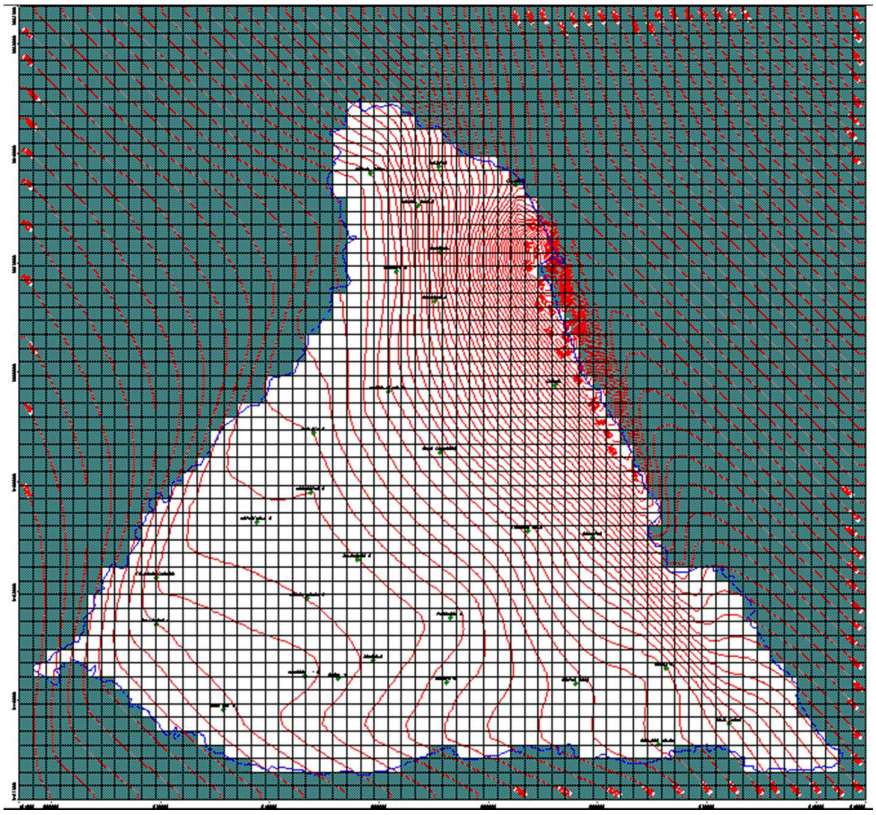


Fig.15-Steady State Simulation- Observed Heads Equipotential Lines

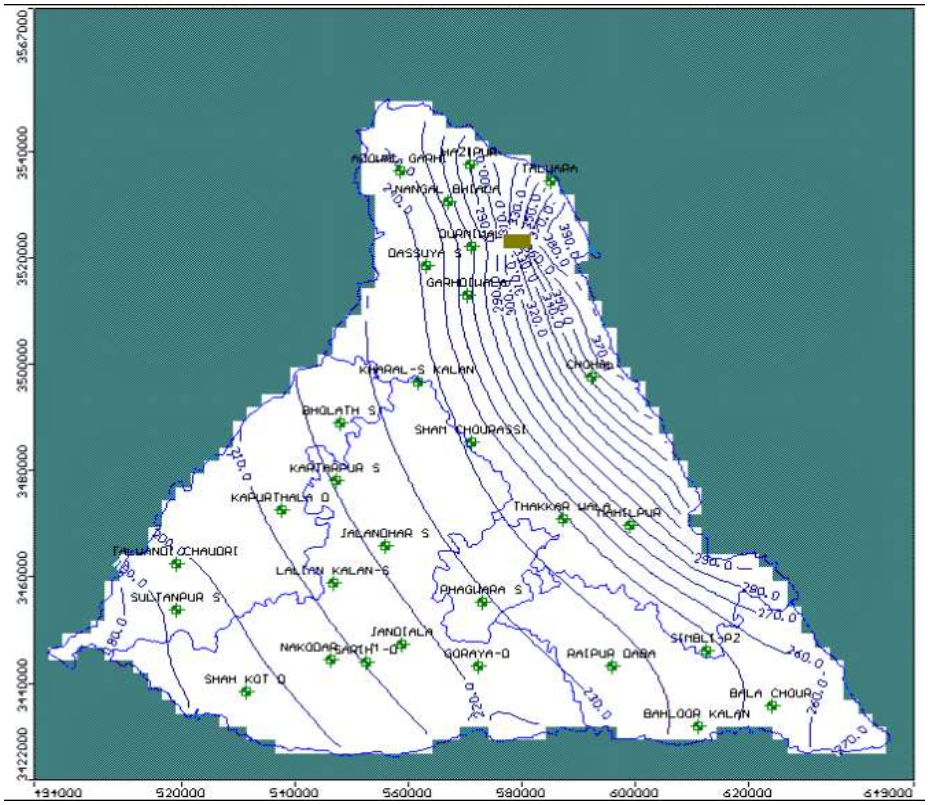


Fig.16-Steady State Simulation- Calculated Heads Equipotential Lines

4.11 Assigning Recharge and Ground Water Draft

Besides, the head observations, recharge and ground water draft with stress period are the main input for transient simulation. The net recharge, which is a difference of recharge and draft has been assigned to the model. The model domain is divided into 05 zones. These zones are following district boundary of four districts vizHoshiarpur, Kapurthala, Jalandhar &Nawanshahr and Phagwara block boundary of Kapurthala district. The time variant recharge and groundwater draft have been assigned to each of the zones. The details of recharge and ground water draft are given below:

Recharge

In the study area, main recharge is from annual precipitation. Besides, recharge also takes place from other sources like seepage from canal network, return flow from Surface water and ground water irrigation and recharge from constructing water conservation structures. The recharge for monsoon and non-monsoon periods have been taken from Ground Water Resources Assessment carried out as on 2011, 2013 and 2017.

Draft/Discharge

In the study area, main draft/discharge input is the groundwater pumping from tubewells to meet out the demand of various sectors. The ground water draft for monsoon and non-monsoon seasons have been used from Ground Water Resources Assessment as on 2011, 2013 and 2017. The ground water resources assessment data indicates that ground water draft in study area is very high during monsoon season, which may vanish the impact of recharge and further contribute towards decline in water levels.The recharge & draft for Assessment year Vis-à-vis tenure used in the modeling study is given in tablebelow:

Table-8: Assigning the Ground Water Draft & Recharge in Model

Item	GWRE Assessment Year	Tenure in Modelling
Ground Water Draft& recharge Data	2011	For the Year 2013
	Average of 2011 & 2013	For the Year 2014
	2013	For the Year 2015
	Average of 2011 & 2013	For the Year 2016
	2017	For the Year 2017

The district/block wise data on net recharge assigned are given in table-9 & data on ground water draft and recharge are given in Annexure-2.

Table-9: District wise data on Net Recharge Assigned

District/Block	Area (ha)	Net Recharge {Recharge- Draft} (m/day)	Start Time (Days)
Hoshiarpur	278690		0
Hoshiarpur	278690	0.000324	120
Hoshiarpur	278690	0.000009	365
Hoshiarpur	278690	0.000362	485
Hoshiarpur	278690	0.000015	730
Hoshiarpur	278690	0.000399	850
Hoshiarpur	278690	0.000021	1095
Hoshiarpur	278690	0.000286	1215
Hoshiarpur	278690	0.000018	1460
Hoshiarpur	278690	0.000172	1580
Hoshiarpur	278690	0.000015	1825
Jalandhar	263350	0	0
Jalandhar	263350	-0.002084	120
Jalandhar	263350	-0.001100	365
Jalandhar	263350	-0.001878	485
Jalandhar	263350	-0.001068	730
Jalandhar	263350	-0.001672	850
Jalandhar	263350	-0.001035	1095
Jalandhar	263350	-0.001880	1215
Jalandhar	263350	-0.001076	1460
Jalandhar	263350	-0.002088	1580
Jalandhar	263350	-0.001116	1825
Kapurthala	131770	0	0
Kapurthala	131770	-0.002348	120
Kapurthala	131770	-0.000545	365
Kapurthala	131770	-0.002188	485
Kapurthala	131770	-0.000528	730
Kapurthala	131770	-0.002028	850
Kapurthala	131770	-0.000510	1095

District/Block	Area (ha)	Net Recharge {Recharge- Draft} (m/day)	Start Time (Days)
Kapurthala	131770	-0.002184	1215
Kapurthala	131770	-0.000523	1460
Kapurthala	131770	-0.002339	1580
Kapurthala	131770	-0.000536	1825
Phagwara	30040	0	0
Phagwara	30040	-0.003306	120
Phagwara	30040	-0.001439	365
Phagwara	30040	-0.002820	485
Phagwara	30040	-0.001337	730
Phagwara	30040	-0.002335	850
Phagwara	30040	-0.001234	1095
Phagwara	30040	-0.002526	1215
Phagwara	30040	-0.001262	1460
Phagwara	30040	-0.002717	1580
Phagwara	30040	-0.001290	1825
Nawanshahr	129415	0	0
Nawanshahr	129415	0.000171	120
Nawanshahr	129415	-0.000116	365
Nawanshahr	129415	0.000327	485
Nawanshahr	129415	-0.000106	730
Nawanshahr	129415	0.000483	850
Nawanshahr	129415	-0.000095	1095
Nawanshahr	129415	0.000356	1215
Nawanshahr	129415	-0.000115	1460
Nawanshahr	129415	0.000229	1580
Nawanshahr	129415	-0.000136	1825

5.0 Model calibration& Validations

The purpose of model calibration is to establish that the model can reproduce field measured/calculated heads and flows. Calibration is carried out by trial and error adjustment of parameters or by using an automated parameter estimation code. In the present study trial and error adjustment has been used.

5.1 Steady State Simulation/Calibration

Steady state conditions are usually taken to be historic conditions that existed in the aquifer before significant development has occurred (i.e., inflow are equal to outflows and there is no change in aquifer storage). Steady state simulation of the model was carried out using the finite-difference approximation of three-dimensional partial differential equation of groundwater flow in the aquifer using specified/initial hydraulic heads of pre-monsoon (May) 2013 for a network of 34 observation wells. Overall, water table elevation data from May 2013 to May 2017 were considered for Steady Model calibration.

Calibration involved making adjustments to the various input parameters of inflow and outflow like hydraulic conductivity, specific yield, constant head and assigning recharge flux keeping in view the expected recharge takes place in Kandi belt of the area until steady state model calibrated to a reasonable satisfaction in terms of least value of Root Mean Square (RMS) error.

By trial and error calibration, the inflow and outflow parameters were changed during many sequential run to match the observed and simulated/calculated heads (water table contours). The water table elevation contour made from observed data and model simulated output show a similar contour pattern and flow direction. It suggests the acceptability of the model. It has also been observed that Calculated Vs Observed values of head were found to be comparatively matching with RMS error of 7.34 m & normalized RMS as 4.72%. The steady state calibration is a base for transient state simulation.

The calculated Vs observed Heads contours for steady state simulation are shown in figure-17 and Heads are shown in Scatter plot (figure-18). The differences of calculated and observed heads are shown in table-10.

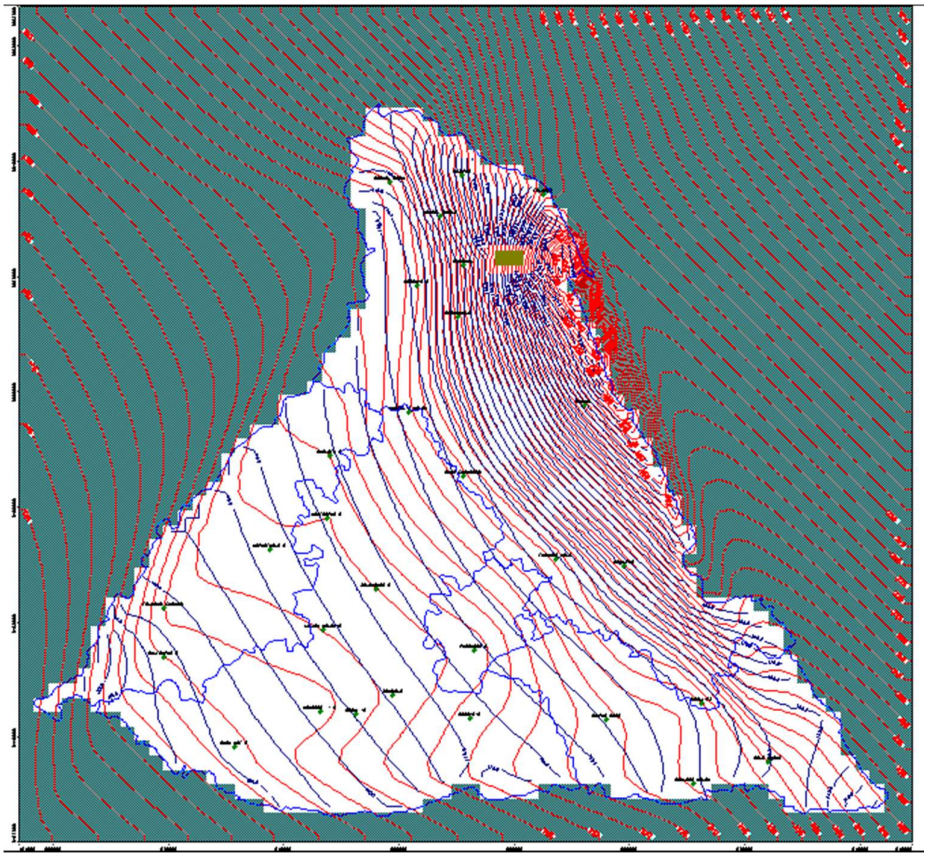


Fig.17-Steady State Simulation-Calculated Vs Observed Heads Contours

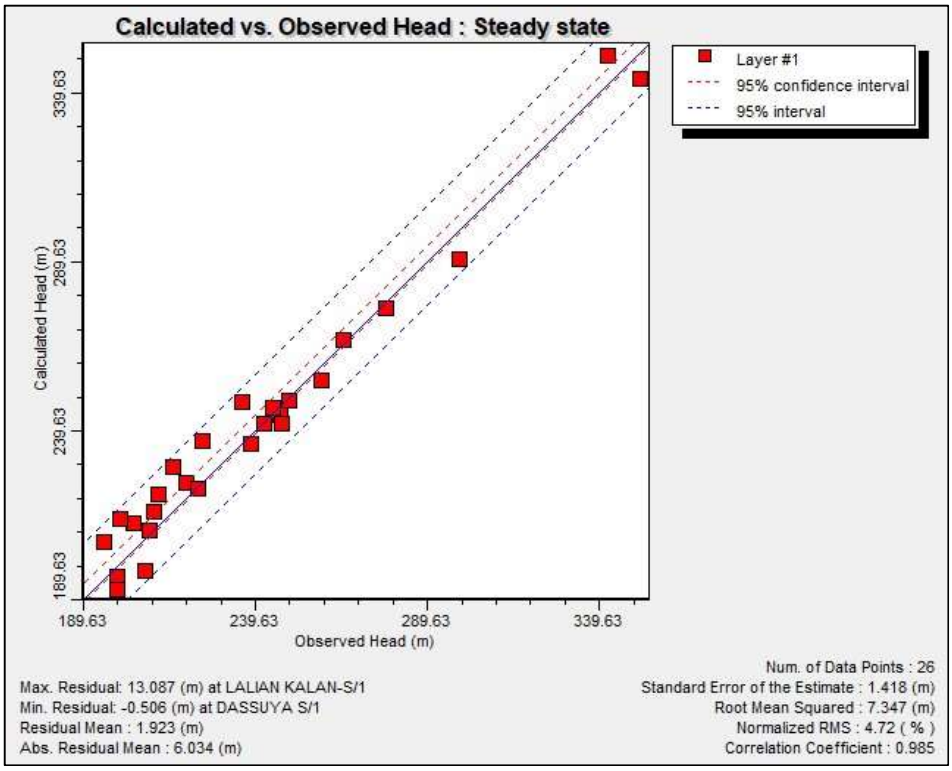


Fig.18-Steady State Simulation-Scatter Plot

Table-10: Difference in Observed and Calculated heads of Calibrated Data for 2013

Locations	X-Model	Y-Model	X-World	Y-World	Observed	Calculated	Calc.-Obs.
AdowalGarhi	558455.4	3536446	558455.4	3536446	235.91	248.30	12.39
BahloorKalan	611096.2	3432031	611096.2	3432031	246.70	244.34	-2.36
BalaChour	624046.1	3435869	624046.1	3435869	258.84	254.72	-4.12
Bholath S	547992.3	3488976	547992.3	3488976	219.70	224.33	4.63
Chohal	592219.1	3497742	592219.1	3497742	351.32	343.75	-7.57
Dassuya S	563107.2	3518461	563107.2	3518461	242.32	241.81	-0.51
Goraya-D	572171.1	3443394	572171.1	3443394	223.10	222.38	-0.72
Hazipur	570863.8	3537602	570863.8	3537602	298.92	290.56	-8.36
Jandiala	558773.8	3447313	558773.8	3447313	210.12	215.86	5.74
Kapurthala D	537608.9	3472585	537608.9	3472585	203.96	212.41	8.45
Kartarpur S	547382.7	3478043	547382.7	3478043	211.31	220.79	9.48
Kharal-S Kalan	561659.8	3496591	561659.8	3496591	224.19	236.68	12.49
LalianKalan-S	546808.7	3458798	546808.7	3458798	200.26	213.35	13.09
Mahilpur	599072.6	3469784	599072.6	3469784	277.73	275.92	-1.81
Nakodar - M	546236.8	3444480	546236.8	3444480	195.66	206.83	11.17
NangalBhiala	566973.1	3530494	566973.1	3530494	265.24	266.34	1.10
Phagwara S	573042.5	3455253	573042.5	3455253	215.79	228.76	12.97
Raipur Daba	595879.5	3443213	595879.5	3443213	238.13	235.62	-2.51
Sarih -D	552435.8	3444047	552435.8	3444047	208.70	210.33	1.63
Shah Kot D	531504.3	3438453	531504.3	3438453	199.63	196.40	-3.23
Sham Chourassi	571091.2	3485413	571091.2	3485413	247.25	241.71	-5.54
Simbli-Pz	612326.2	3446054	612326.2	3446054	244.60	246.39	1.79
Sultanpur S	519049.4	3453939	519049.4	3453939	199.58	192.80	-6.78
TalwandiChaudri	519034	3462406	519034	3462406	207.48	198.17	-9.31
Talwara	585065.1	3534323	585065.1	3534323	342.09	350.62	8.53
Thakkar Wala	587173.1	3470910	587173.1	3470910	249.37	248.73	-0.64

5.2 Transient State Calibration

The aquifer may attain steady state conditions at more than one time period as at any time period if the flows get balanced and the water levels do not change over that period, the system remains in the steady state conditions. If the model calibrated under steady state for the chosen/assigned period the calibrated hydraulic conductivity distribution obtained which is a base for the model calibration in transient state. In Transient state, head changes with time thus it is also called time dependent, unsteady, non-equilibrium, or non-steady state conditions of aquifers.

The transient Calibration begins with the setting up of USGS Modflow 2000 from SWS engine and by selecting transient flow conditions.

Besides the calibrated hydraulic conductivity values & storage parameters (Specific yield, porosity etc), the calculated heads of steady state were taken as initial heads in transient state.

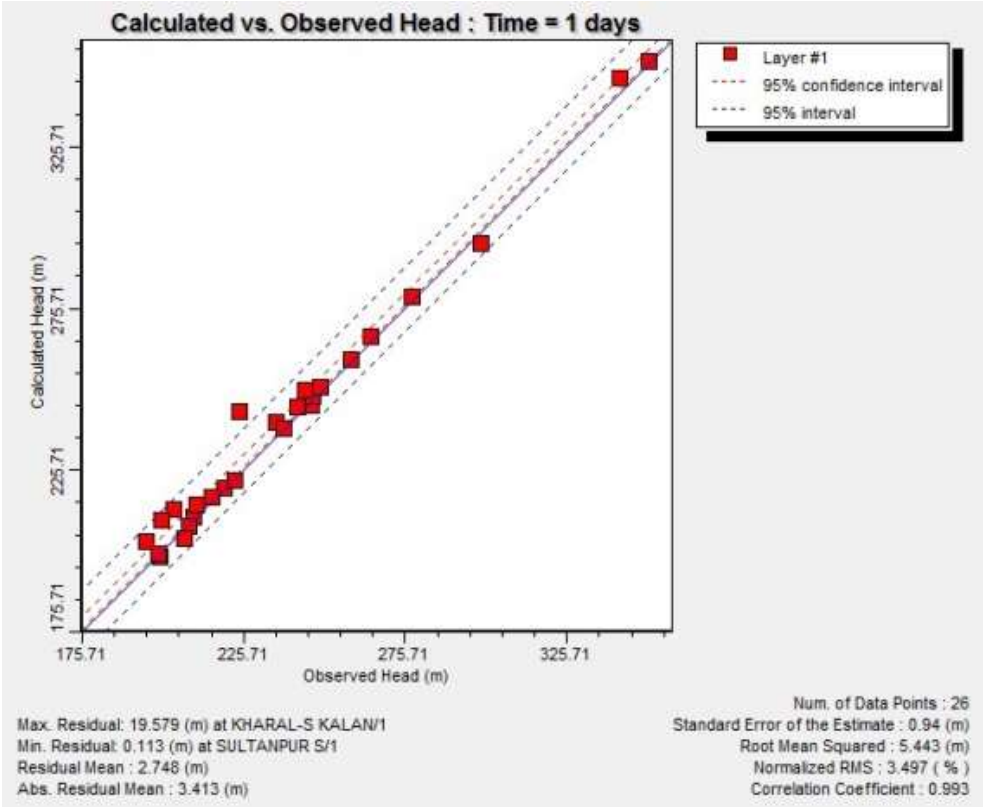
Transient state simulation was carried out for a period of 5 years from May 2013 to May 2017 with 10 nos. of stress period at the rate of 02 stress period (monsoon/non-monsoon) in a year.

The ground water recharge and draft has been assigned to the Transient State Model calibration. The ground water draft and recharge through rainfall & various other sources were taken from the Ground Water Resources Assessment carried out jointly by the CGWB & State Agencies for the Punjab State. As the ground water draft and recharge are assessed at the block & district level, hence, these were assigned in the zones matching with the district boundary.

The calibration of transient model was achieved by several trials until a good match between computed and observed heads was obtained over space and time by slight modification of the input and output parameters for every run.

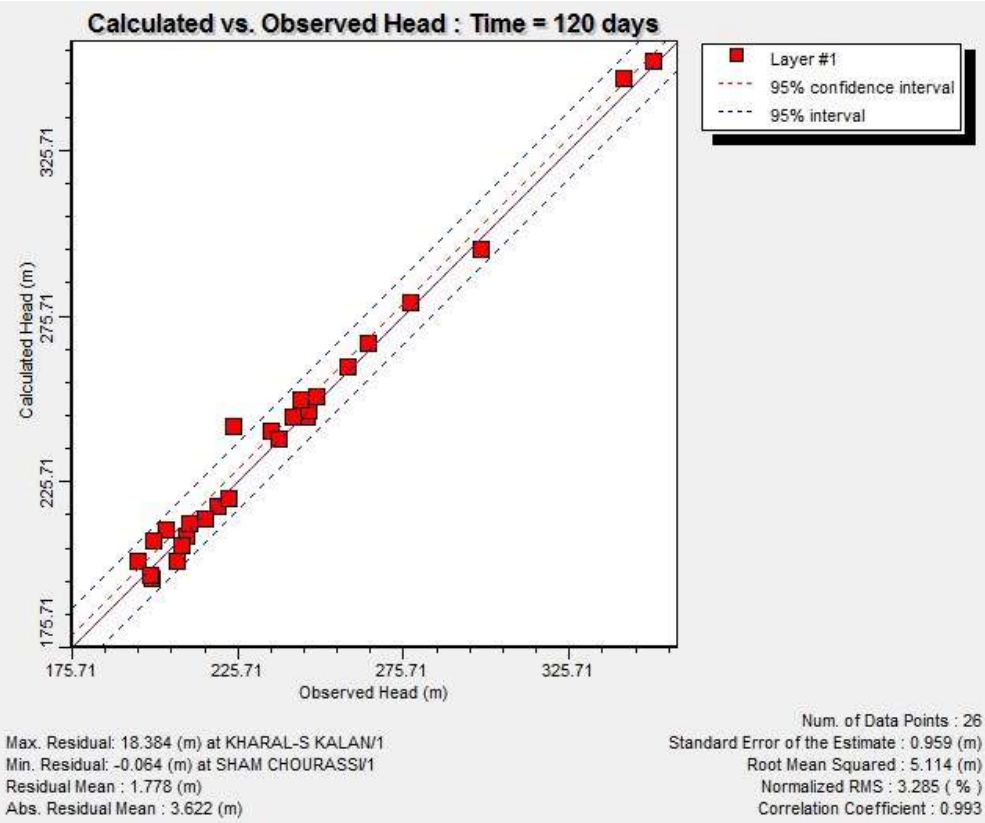
It has been observed that Calculated Vs Observed values of head were gone up to RMS error of 7.54 m with normalized RMS as 4.78%.

The calculated Vs observed Heads are shown in Scatter plot (figure-19) and head equipotential lines for transient state simulation are shown in figure-20. The differences of calculated and observed heads for various stress period of calibration are shown in Annexure-3.



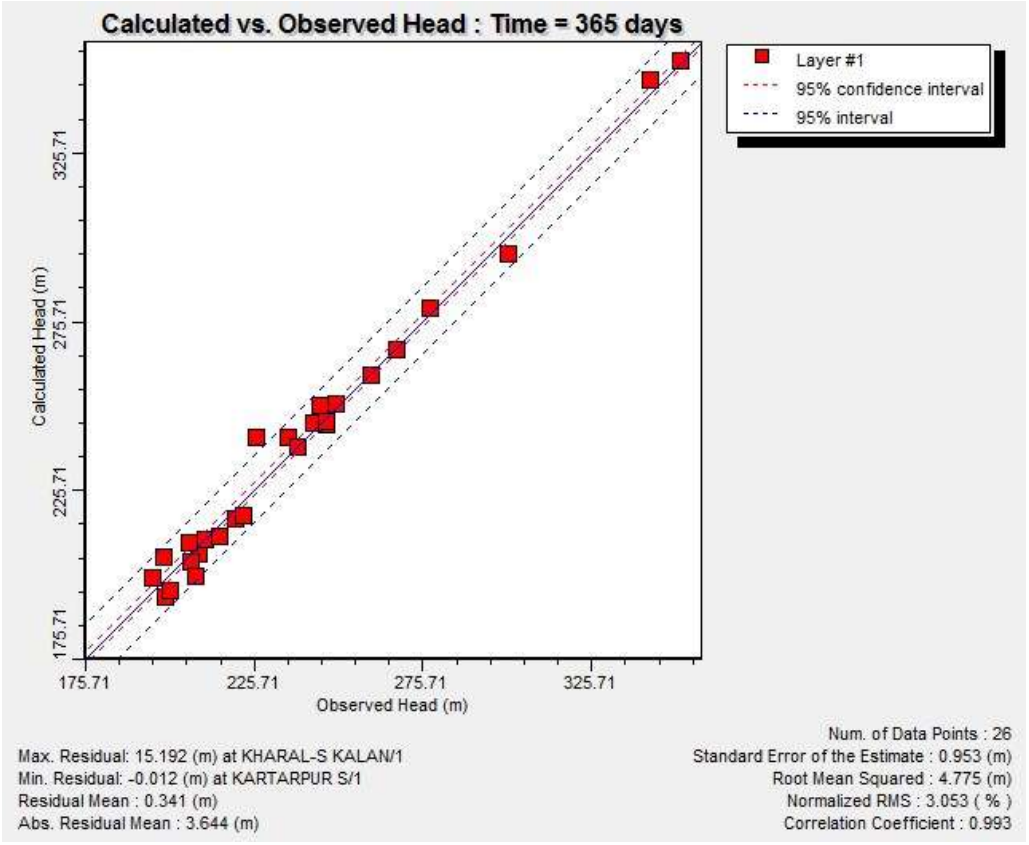
Max. Residual: 19.579 (m) at KHARAL-S KALAN/1
Min. Residual: 0.113 (m) at SULTANPUR S/1
Residual Mean : 2.748 (m)
Abs. Residual Mean : 3.413 (m)

Num. of Data Points : 26
Standard Error of the Estimate : 0.94 (m)
Root Mean Squared : 5.443 (m)
Normalized RMS : 3.497 (%)
Correlation Coefficient : 0.993



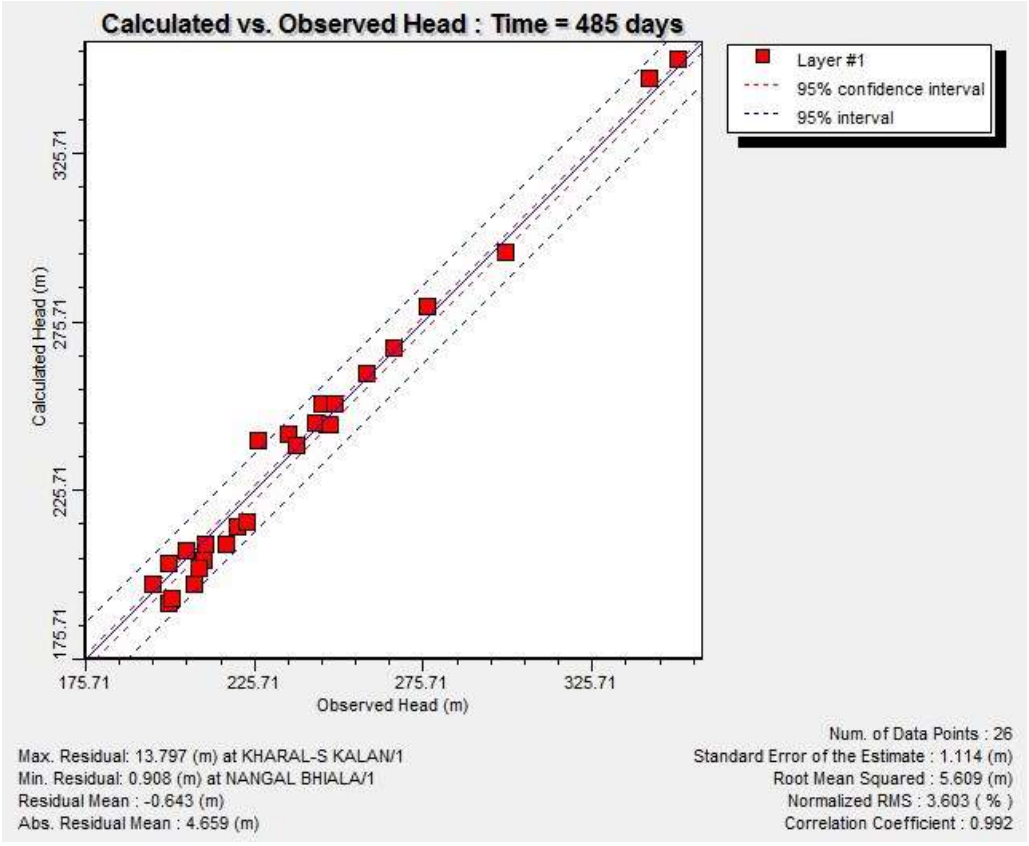
Max. Residual: 18.384 (m) at KHARAL-S KALAN/1
Min. Residual: -0.064 (m) at SHAM CHOURASSI/1
Residual Mean : 1.778 (m)
Abs. Residual Mean : 3.622 (m)

Num. of Data Points : 26
Standard Error of the Estimate : 0.959 (m)
Root Mean Squared : 5.114 (m)
Normalized RMS : 3.285 (%)
Correlation Coefficient : 0.993



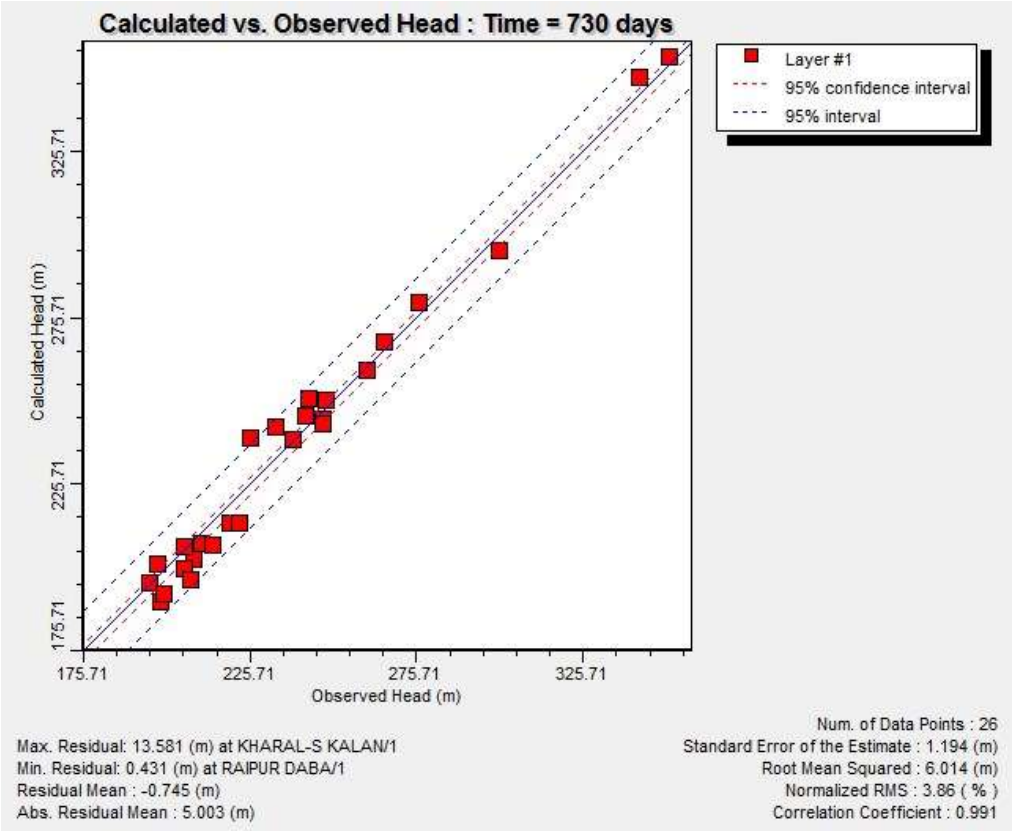
Max. Residual: 15.192 (m) at KHARAL-S KALAN/1
Min. Residual: -0.012 (m) at KARTARPUR S/1
Residual Mean : 0.341 (m)
Abs. Residual Mean : 3.644 (m)

Num. of Data Points : 26
Standard Error of the Estimate : 0.953 (m)
Root Mean Squared : 4.775 (m)
Normalized RMS : 3.053 (%)
Correlation Coefficient : 0.993



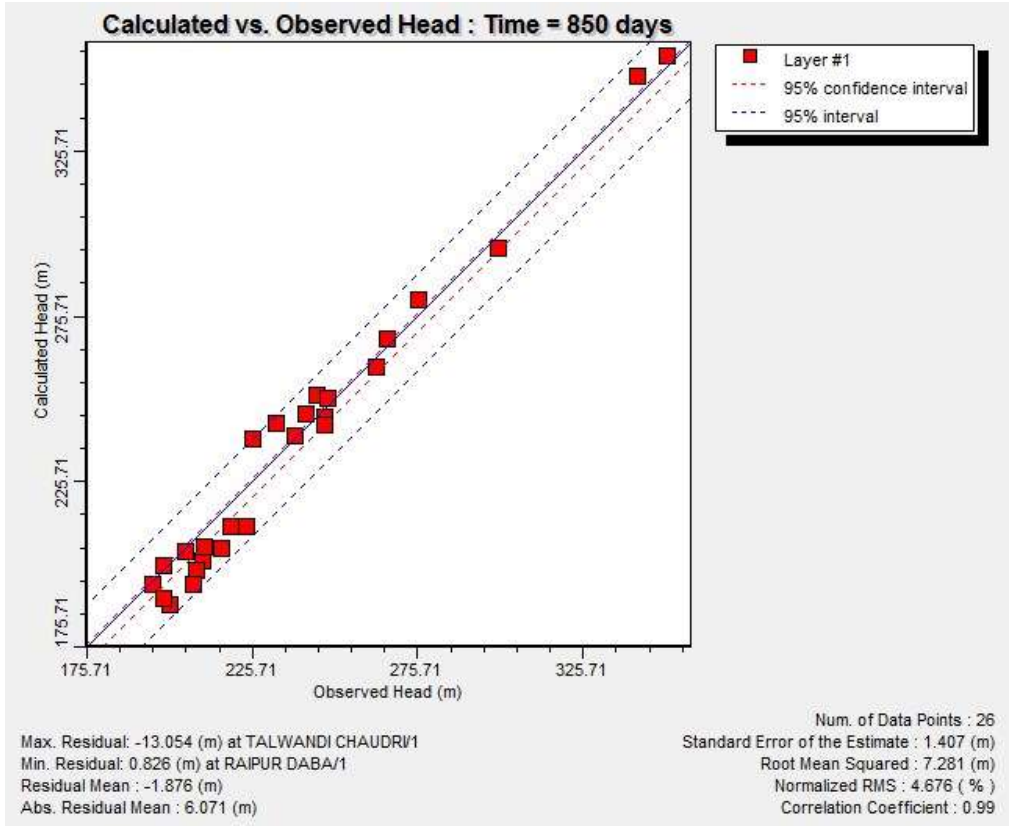
Max. Residual: 13.797 (m) at KHARAL-S KALAN/1
Min. Residual: 0.908 (m) at NANGAL BHIALA/1
Residual Mean : -0.643 (m)
Abs. Residual Mean : 4.659 (m)

Num. of Data Points : 26
Standard Error of the Estimate : 1.114 (m)
Root Mean Squared : 5.609 (m)
Normalized RMS : 3.603 (%)
Correlation Coefficient : 0.992



Max. Residual: 13.581 (m) at KHARAL-S KALAN/1
Min. Residual: 0.431 (m) at RAIPUR DABA/1
Residual Mean : -0.745 (m)
Abs. Residual Mean : 5.003 (m)

Num. of Data Points : 26
Standard Error of the Estimate : 1.194 (m)
Root Mean Squared : 6.014 (m)
Normalized RMS : 3.86 (%)
Correlation Coefficient : 0.991



Max. Residual: -13.054 (m) at TALWANDI CHAUDRI/1
Min. Residual: 0.826 (m) at RAIPUR DABA/1
Residual Mean : -1.876 (m)
Abs. Residual Mean : 6.071 (m)

Num. of Data Points : 26
Standard Error of the Estimate : 1.407 (m)
Root Mean Squared : 7.281 (m)
Normalized RMS : 4.676 (%)
Correlation Coefficient : 0.99

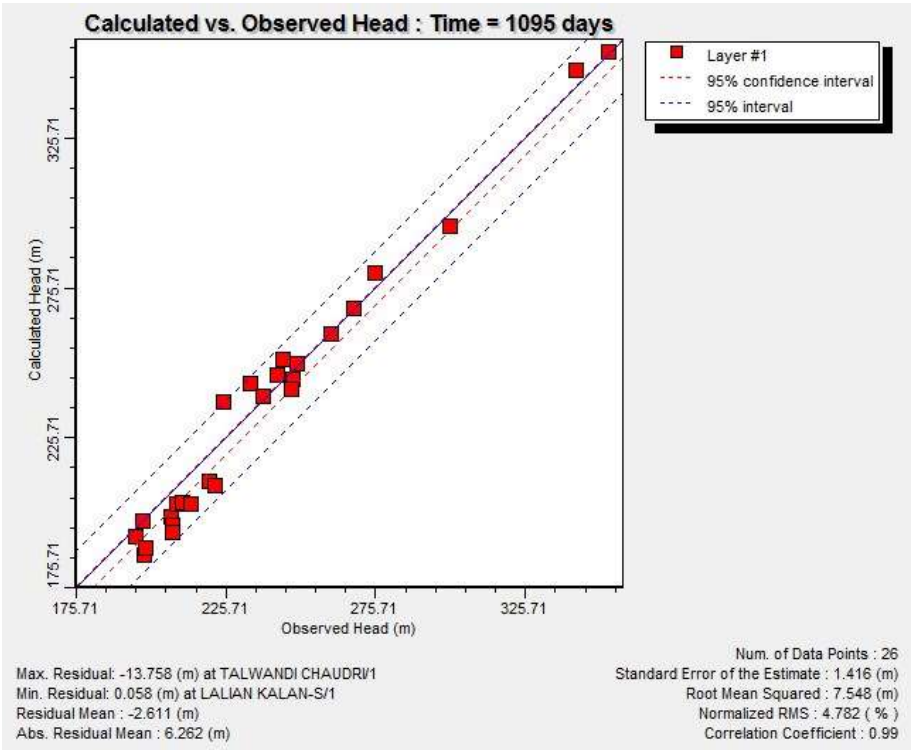
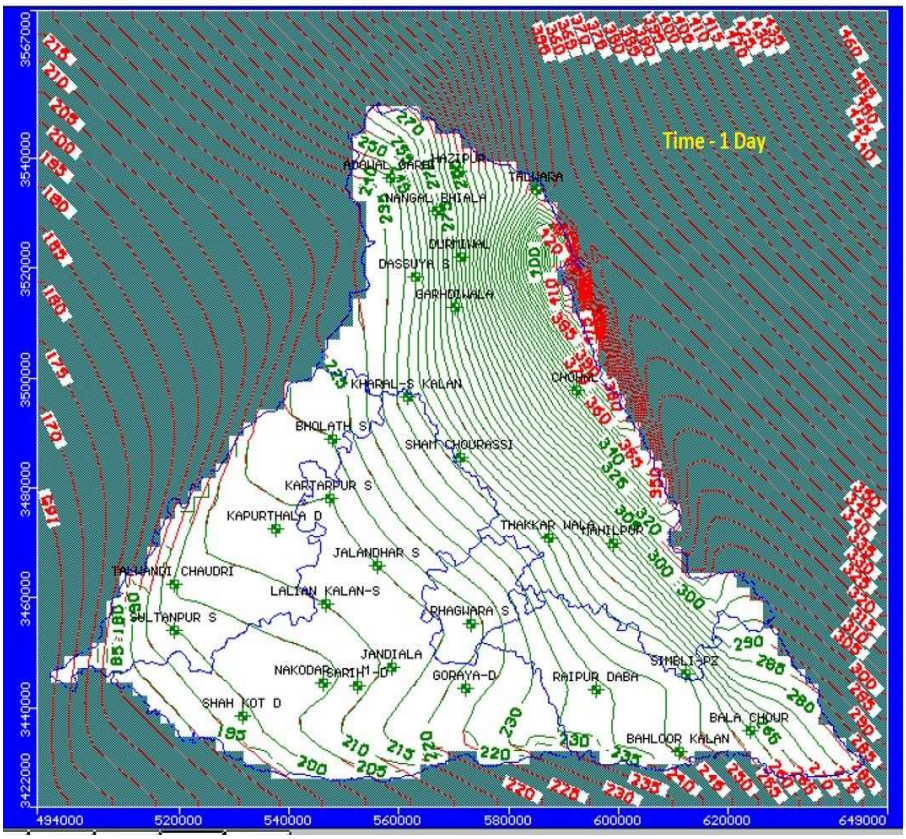
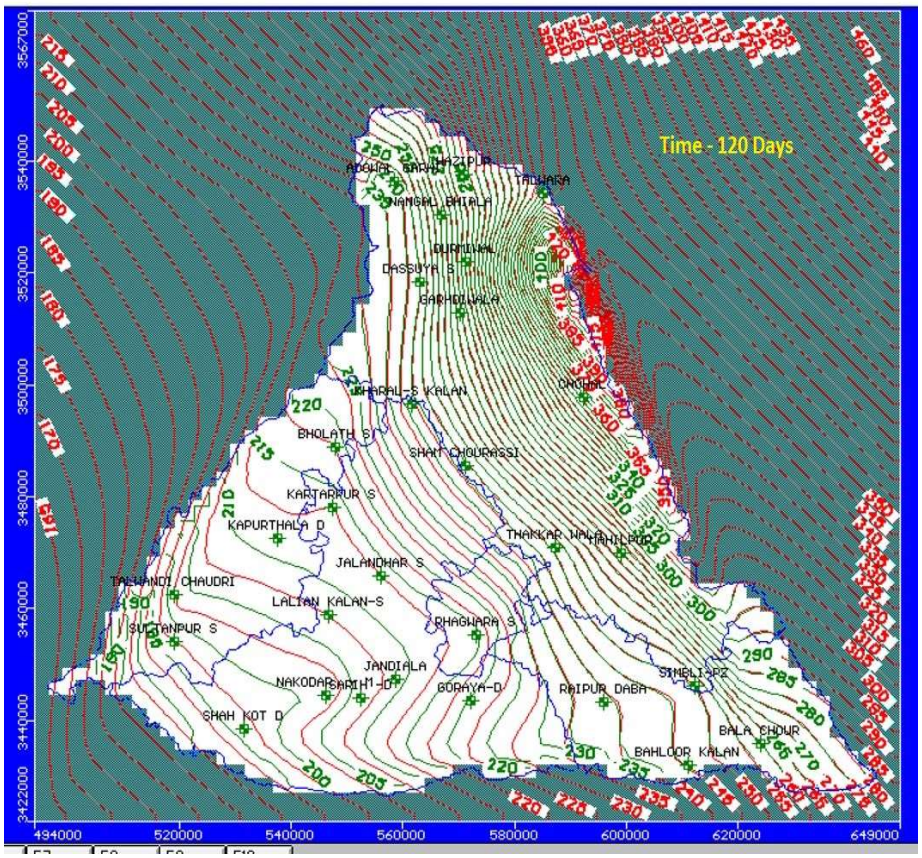


Fig.19-Head Scatter Plots of Various Stress Period of Transient Calibration




Time - 120 Days
ADDITIONAL GARAH
HAZIPUR
TALWARA
NANGAL BHALA
DURMILWAL
DASSUYA S
GARHDIWALA
KHARAL-S KALAN
BHOLATH S
SHAM CHOURASSI
KARTARPUR S
KAPURTHALA D
THAKKAR WALA
TAHLI PDA
JALANDHAR S
TALWANDI CHAUDRI
LALIAN KALAN-S
SULTANPUR S
RHAGHARA S
JANDIALA
NAKODAR
GORAYA-D
RAIPUR DABA
SIMELI-PZ
SHAH KOT D
BALA CHOUR
BAHLOOR KALAN
494000
520000
540000
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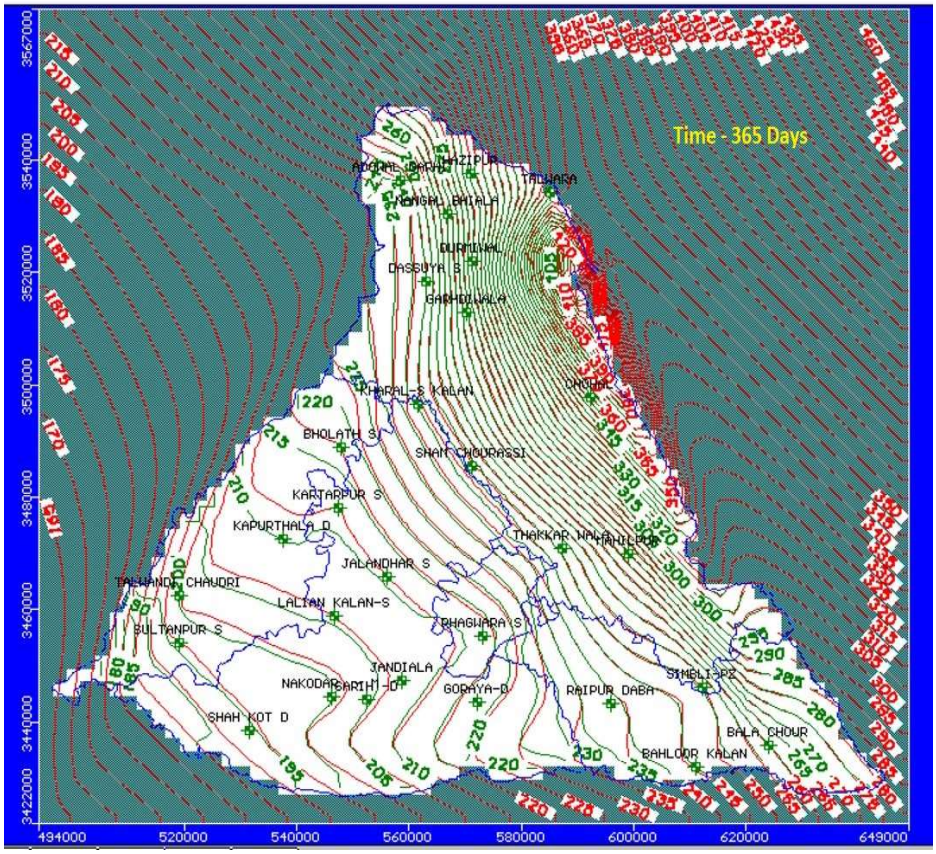
3460000
3480000
3500000
3520000
3540000
3567000


Time - 365 Days
ADDITIONAL GARAH
HAZIPUR
TALWARA
NANGAL BHALA
DURMILWAL
DASSUYA S
GARHDIWALA
KHARAL-S KALAN
BHOLATH S
SHAM CHOURASSI
KARTARPUR S
KAPURTHALA D
THAKKAR WALA
TAHLI PDA
JALANDHAR S
TALWANDI CHAUDRI
LALIAN KALAN-S
SULTANPUR S
RHAGHARA S
JANDIALA
NAKODAR
GORAYA-D
RAIPUR DABA
SIMELI-PZ
SHAH KOT D
BALA CHOUR
BAHLOOR KALAN
494000
520000
540000
560000
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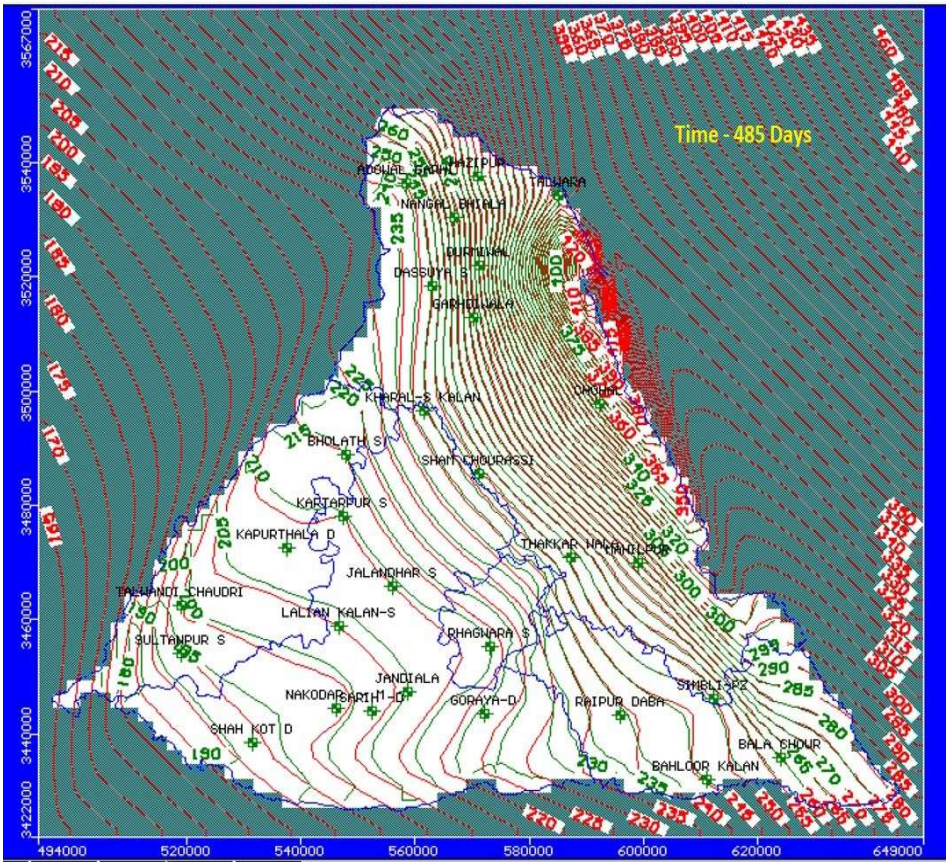
3520000
3540000
3567000


Time - 485 Days
ADDIWAL BADHU
NANGAL BHALA
DURMIWAL
DASSUYA S
GARHDIWALA
KHARAL-S KALAN
BHOLATH S
SHAM CHOURASSI
KARTARPUR S
KAPURTHALA D
JALANDHAR S
TALWANDI CHAUDRI
LALIAN KALAN-S
SULTANPUR S
JANDIALA
NAKODAR-SARIN-D
GORAYA-D
SHAH KOT D
RHAGWARA S
THAKKAR WALA
RAIPUR DABA
SIHBLI-PZ
BALA CHOUR
BAHLOOR KALAN
3567000
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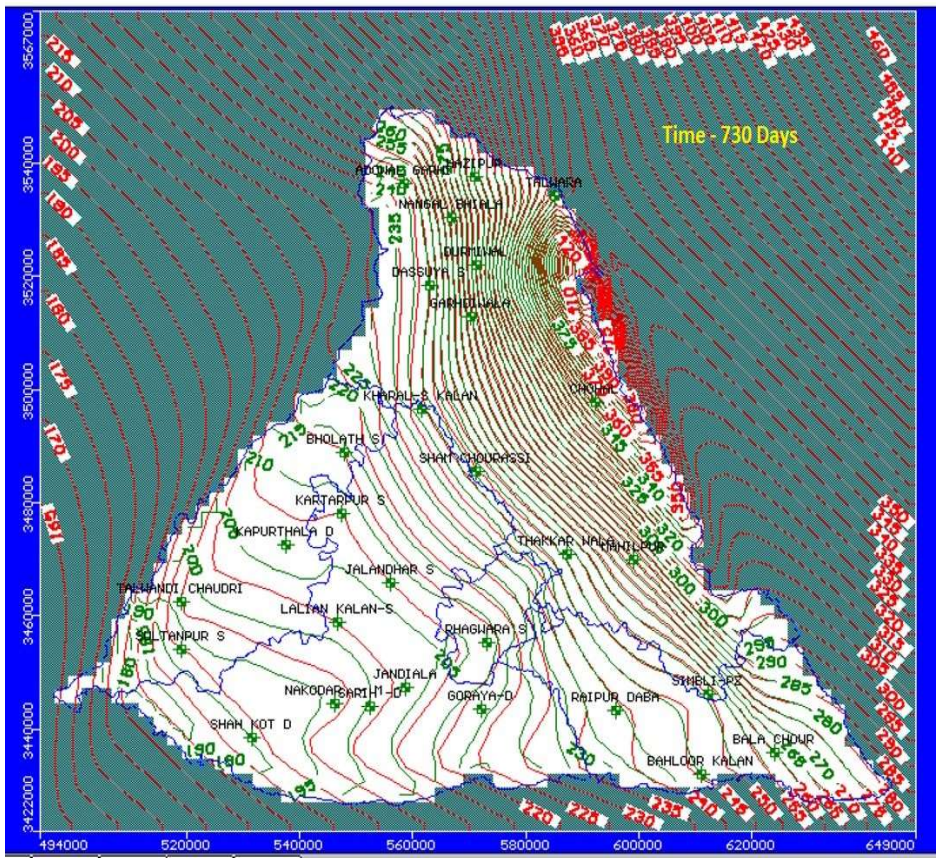
494000
520000
540000
560000
580000
600000
620000
649000


Time - 730 Days
ADDIWAL BADHU
NANGAL BHALA
DURMIWAL
DASSUYA S
GARHDIWALA
KHARAL-S KALAN
BHOLATH S
SHAM CHOURASSI
KARTARPUR S
KAPURTHALA D
JALANDHAR S
TALWANDI CHAUDRI
LALIAN KALAN-S
SULTANPUR S
JANDIALA
NAKODAR-SARIN-D
GORAYA-D
SHAH KOT D
RHAGWARA S
THAKKAR WALA
RAIPUR DABA
SIHBLI-PZ
BALA CHOUR
BAHLOOR KALAN
3567000
3540000
3520000
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3480000
3460000
3440000
3422000
494000
520000
540000
560000
580000
600000
620000
649000

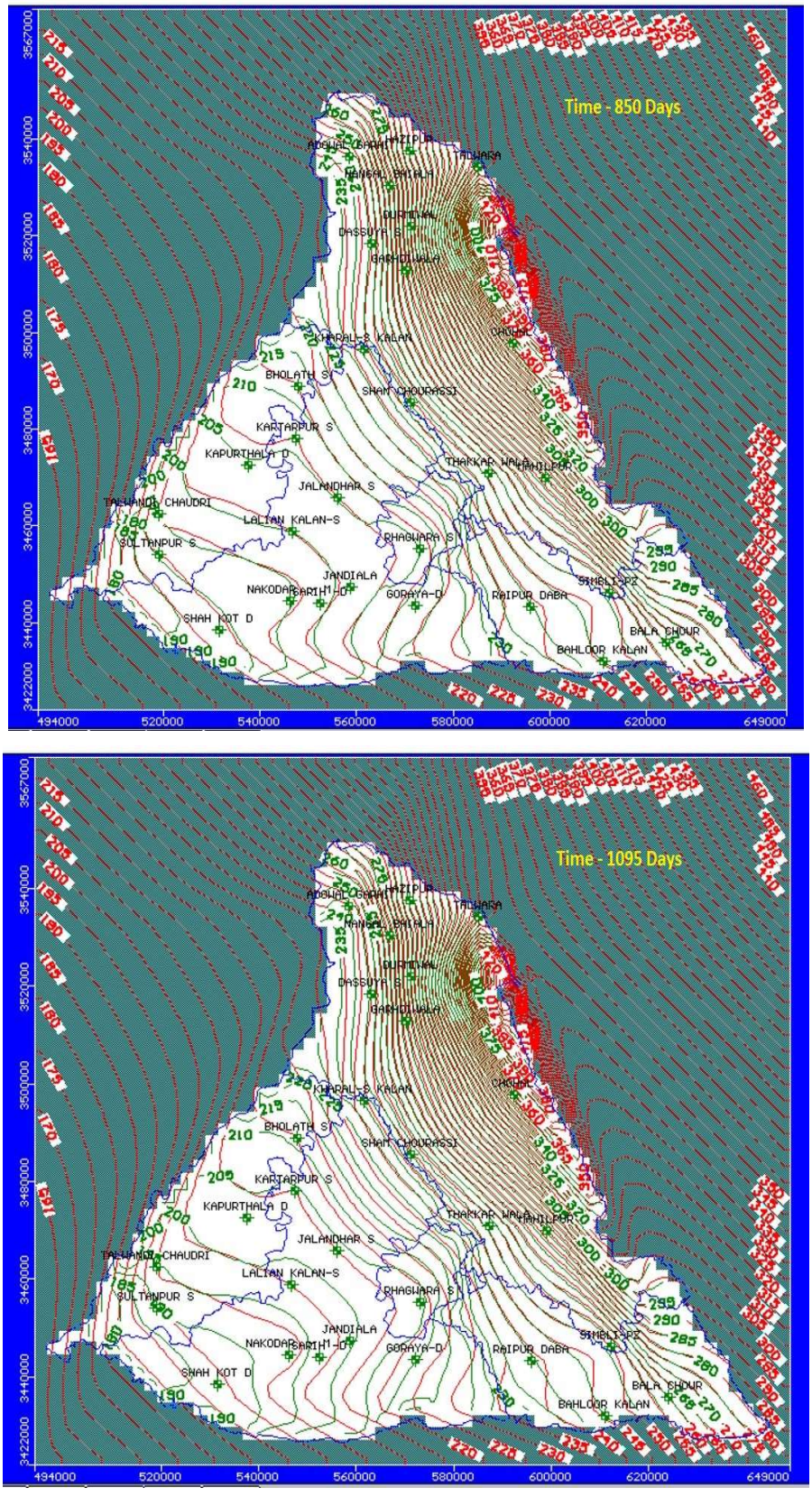


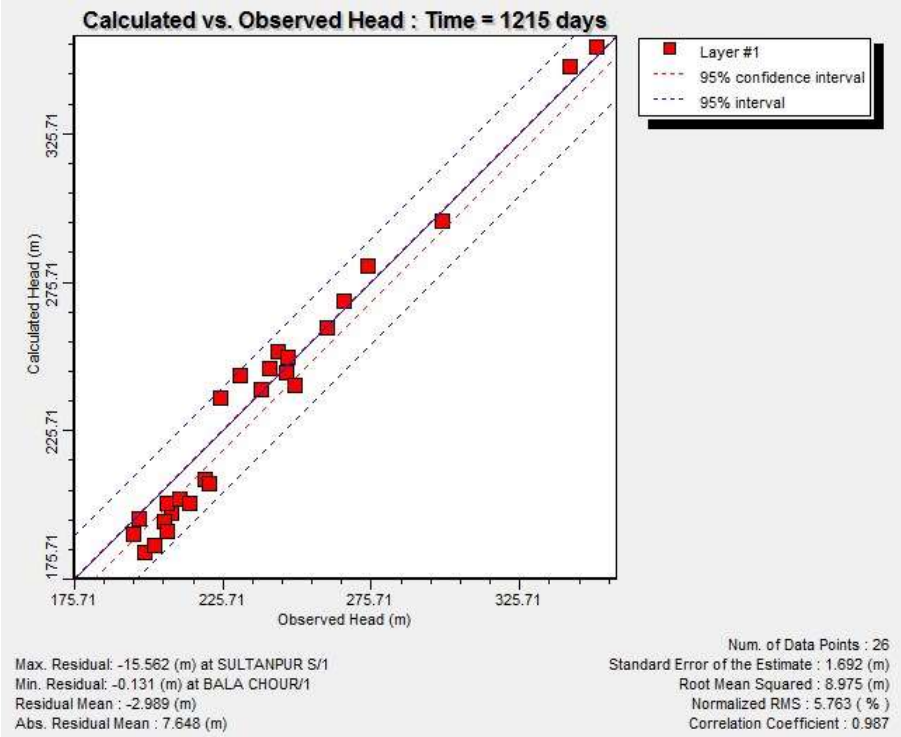
Fig.20-Calculated Head Contours of Various Stress Period of Transient Calibration

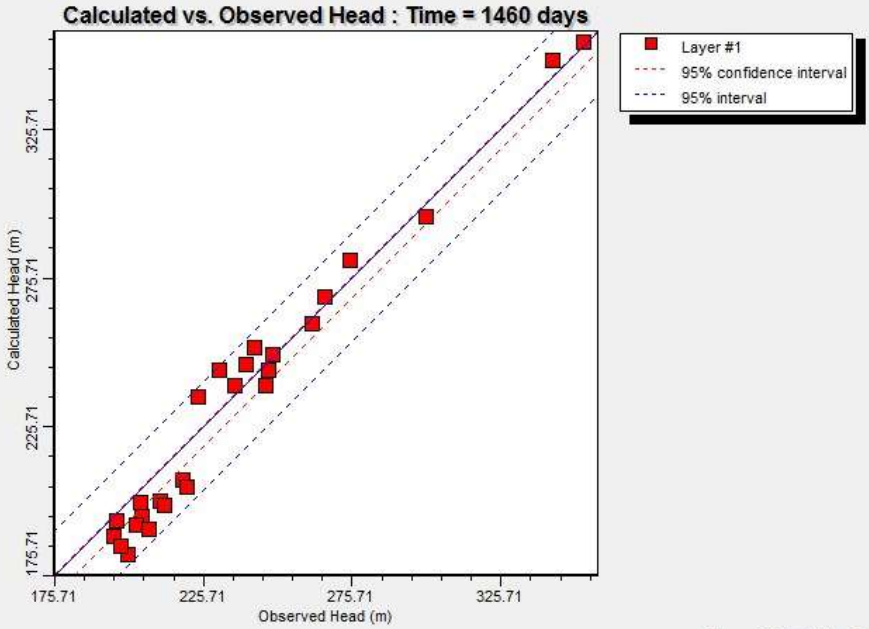
5.3 Model Validation

The ground water flow model in transient conditions was calibrated for validation period of 02 years viz. May 2016 and May 2017. The results indicates that calculated/computed & observed values of head were found to be comparatively matching with RMS error of 9.26 m to 11.79 m and normalized RMS as 5.87 % to 7.54 % for validated period 2016 and 2017 respectively.

The calculated Vs observed Heads are shown in Head Scatter graph (figure-21) and simulated head equipotential lines for transient state simulation for validation period are shown in figure-22. The differences of calculated and observed heads for various stress period of calibration& validation period are shown in Annexure-4.

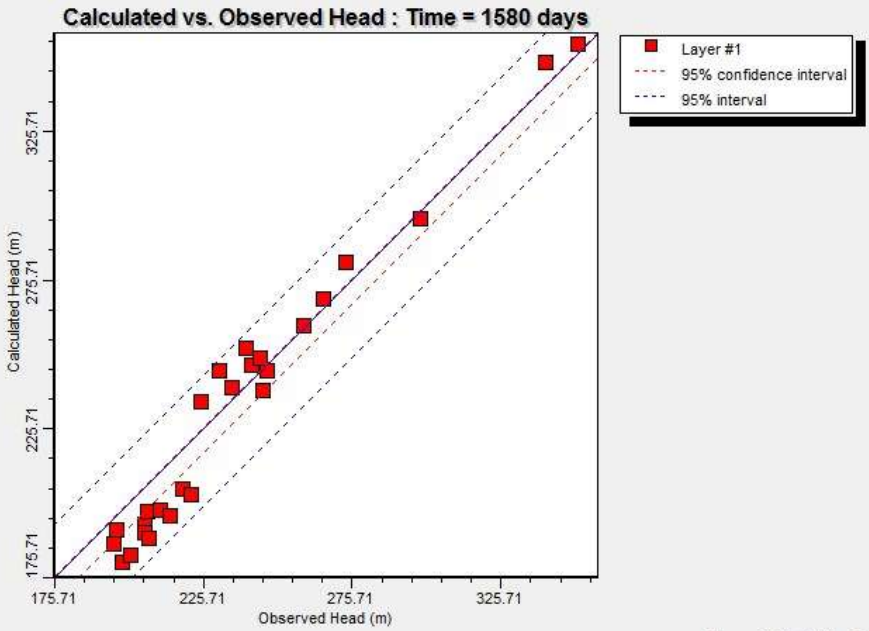
The time series hydrograph of some of the selected observation wells for transient state calibration and validation period are shown in figure-23.





Max. Residual: -17.472 (m) at SHAH KOT D/1
Min. Residual: 0.833 (m) at THAKKAR WALA/1
Residual Mean : -3.137 (m)
Abs. Residual Mean : 7.919 (m)

Num. of Data Points : 26
Standard Error of the Estimate : 1.743 (m)
Root Mean Squared : 9.261 (m)
Normalized RMS : 5.87 (%)
Correlation Coefficient : 0.986



Max. Residual: -18.366 (m) at TALWANDI CHAUDRI/1
Min. Residual: 0.896 (m) at BALA CHOUR/1
Residual Mean : -3.896 (m)
Abs. Residual Mean : 9.687 (m)

Num. of Data Points : 26
Standard Error of the Estimate : 2.088 (m)
Root Mean Squared : 11.143 (m)
Normalized RMS : 7.155 (%)
Correlation Coefficient : 0.983

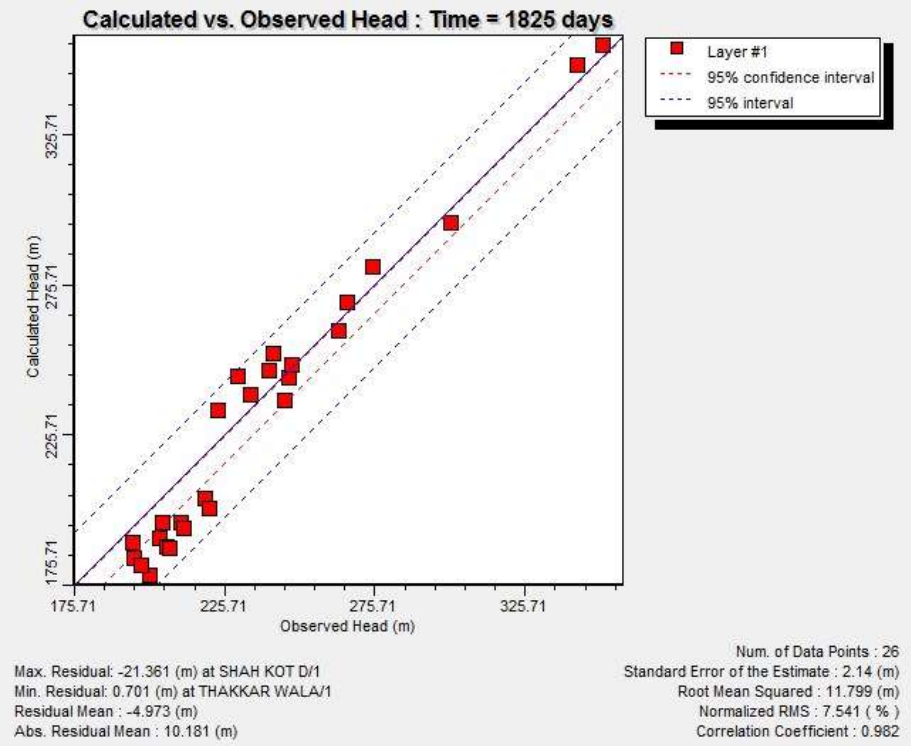
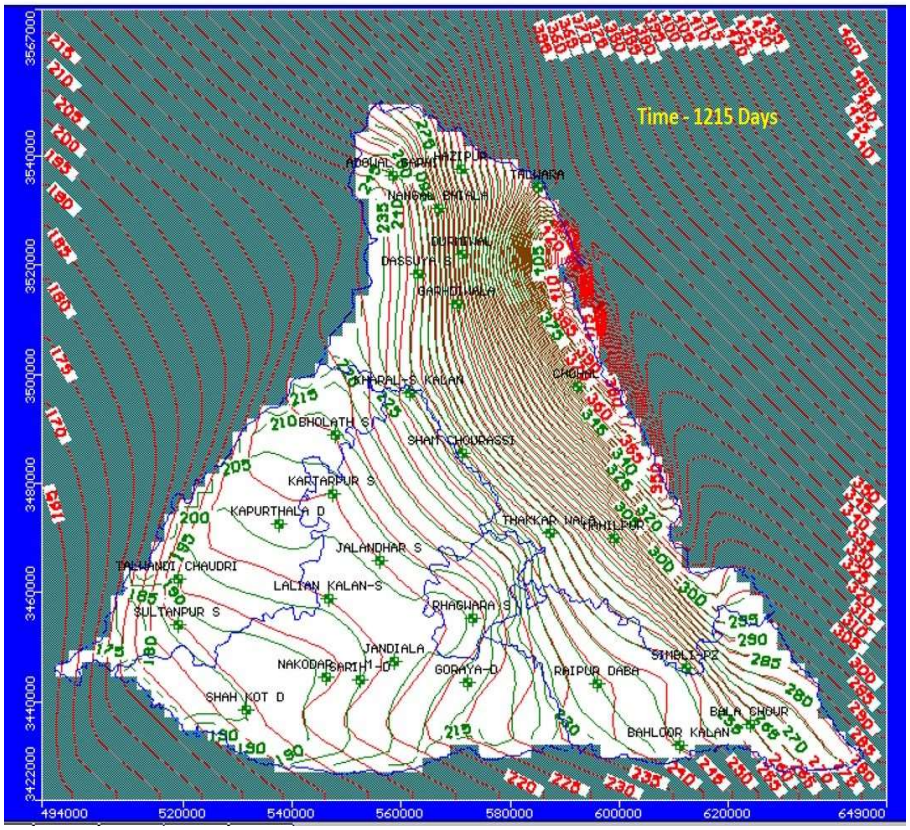
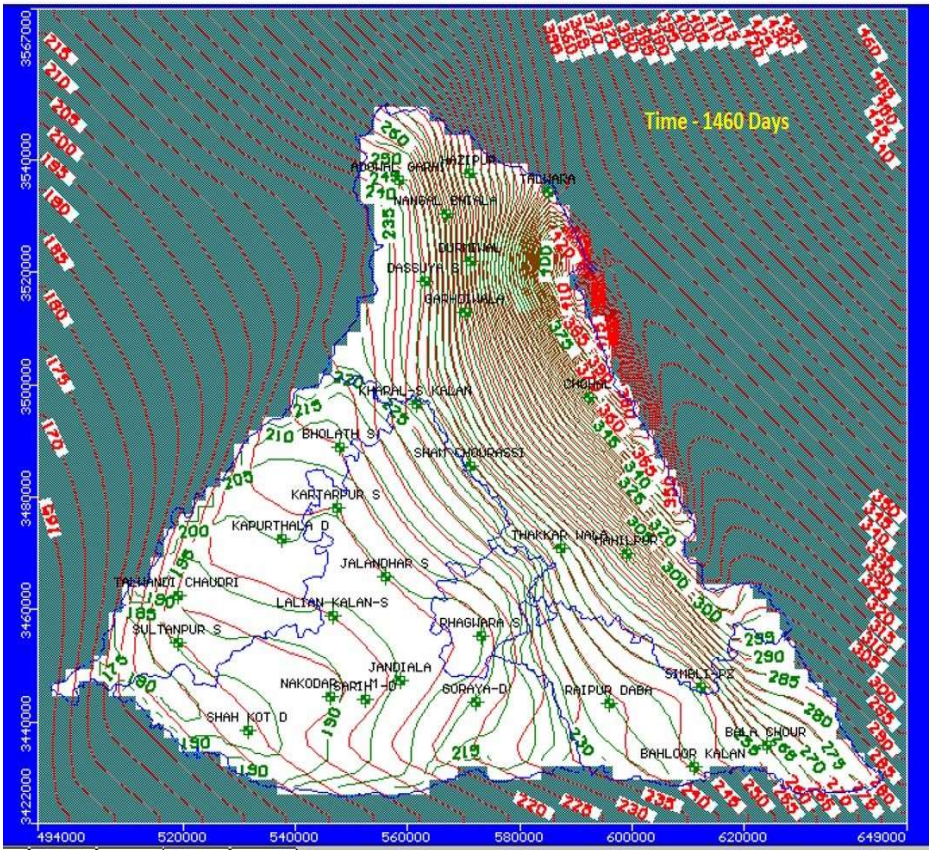
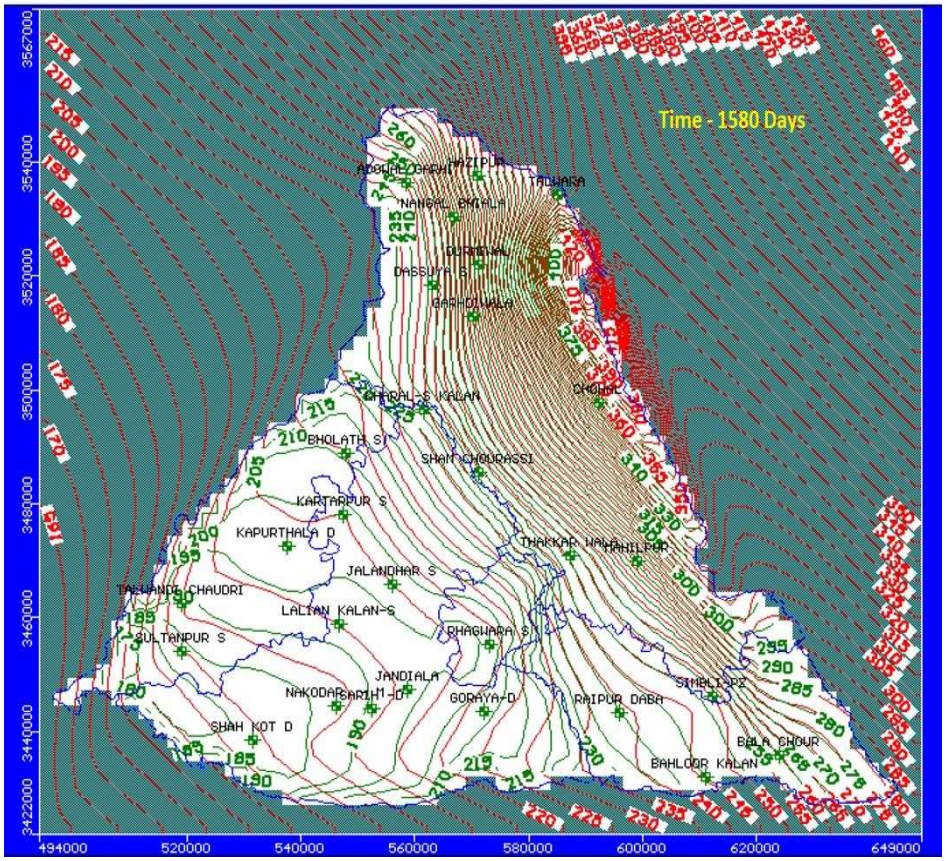


Fig.21-Head Scatter Graph for Validation Periods 2016 &2017




Time - 1460 Days
TALWARA
NANGAL BHALA
DASSUYA S
BARHOLIWALA
KHARAL-S KALAN
BHOLATH S
SHAM CHOURASSI
KARTARPUR S
KAPURTHALA D
JALANDHAR S
TALWANDI CHAUDRI
LALIAN KALAN-S
SULTANPUR S
RHAGWARA S
JANDIALA
NAKODAR
SARIH-D
GORAYA-D
RAIPUR DABA
SIMBLI-PZ
SHAH KOT D
BAHLOOR KALAN
494000
520000
540000
560000
580000
600000
620000
649000


Time - 1580 Days
TALWARA
NANGAL BHALA
DASSUYA S
BARHOLIWALA
KHARAL-S KALAN
BHOLATH S
SHAM CHOURASSI
KARTARPUR S
KAPURTHALA D
JALANDHAR S
TALWANDI CHAUDRI
LALIAN KALAN-S
SULTANPUR S
RHAGWARA S
JANDIALA
NAKODAR
SARIH-D
GORAYA-D
RAIPUR DABA
SIMBLI-PZ
SHAH KOT D
BAHLOOR KALAN
494000
520000
540000
560000
580000
600000
620000
649000

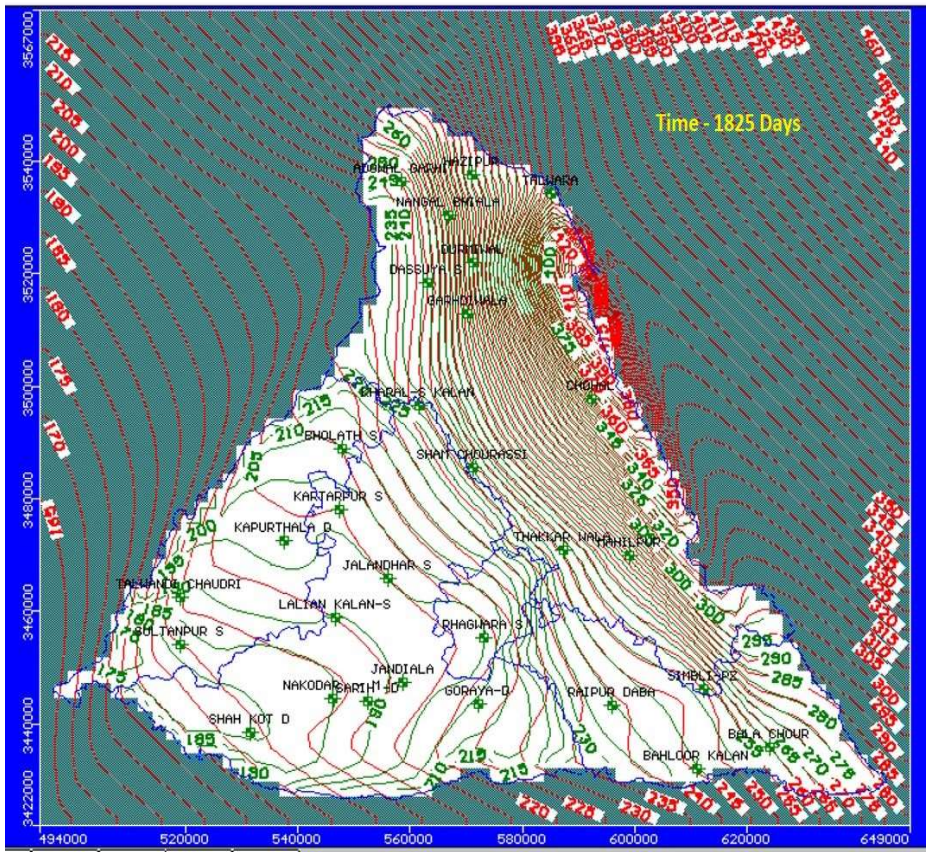


Fig.22-Calculated Head Contours for Validation Periods 2016 &2017

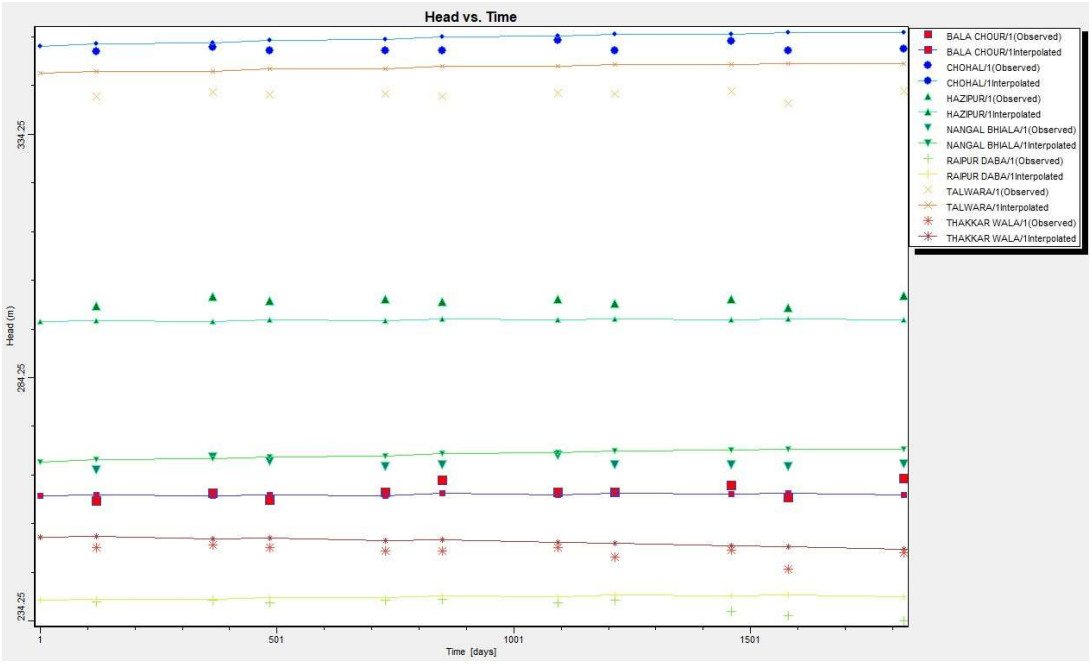


Fig.23-Hydrograph of some selected OWs for transient state calibration

6.0 Cumulative Budget-Transient Simulation

Zone wise budget of infow and out flow in the model area along with Mass balance are obtained, which are elaborated below:

6.1 Zone Budget

As an output of transient state simulation, ground water budget in the model area were also carried out. The model domain is divided into 05 zones. The ground water budgets were computed zone wise, which matches with the district boundary. Five budget zones were assigned throughout the model to determine the overall hydraulic budget for the area for different stress periods. The zone budget indicates the amount of inflow, outflow and flow between the hydro-geological units viz., Storage, Constant Heads, Recharge etc in the identified zones.

The district wise zones assigned for ground water budgeting are shown in figure-24. The zone budget determined for assigned zones in various stress period are given in table-11(A) to (E) and shown in figure-25.

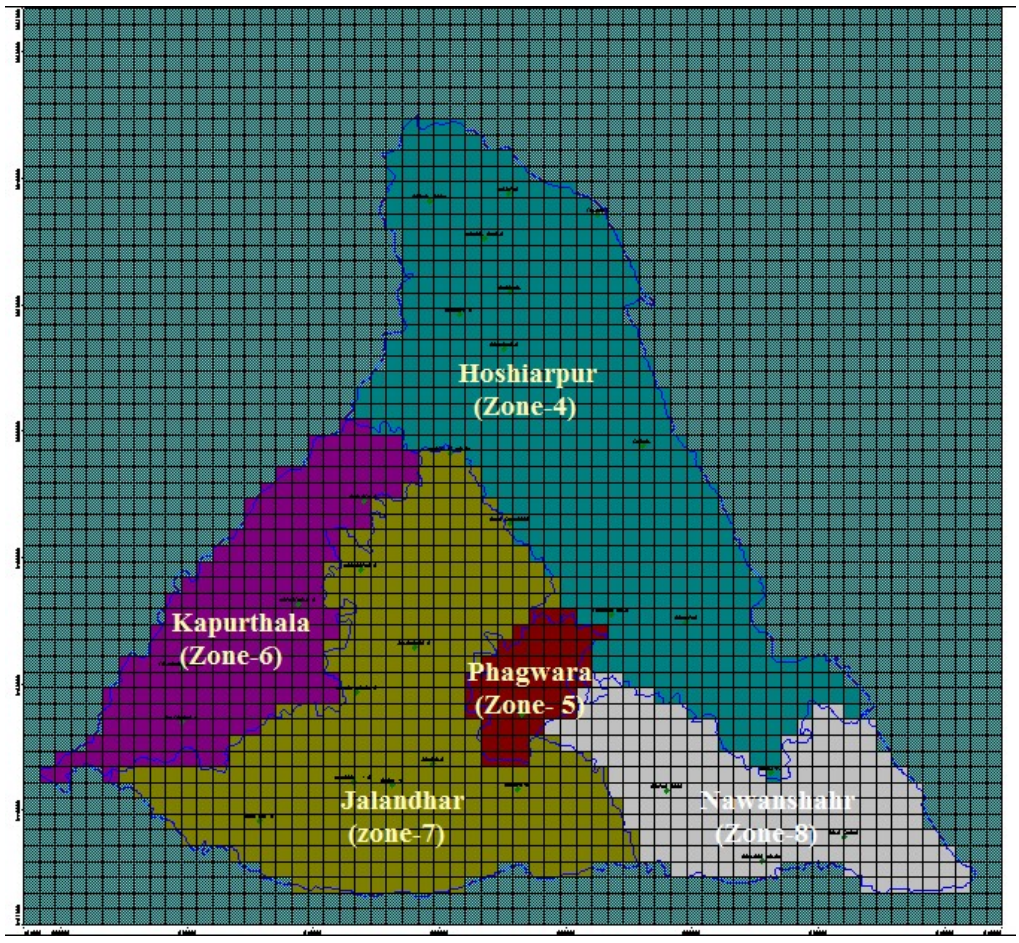


Fig.24- Map showing 05 zones of model domain for Zone Budget

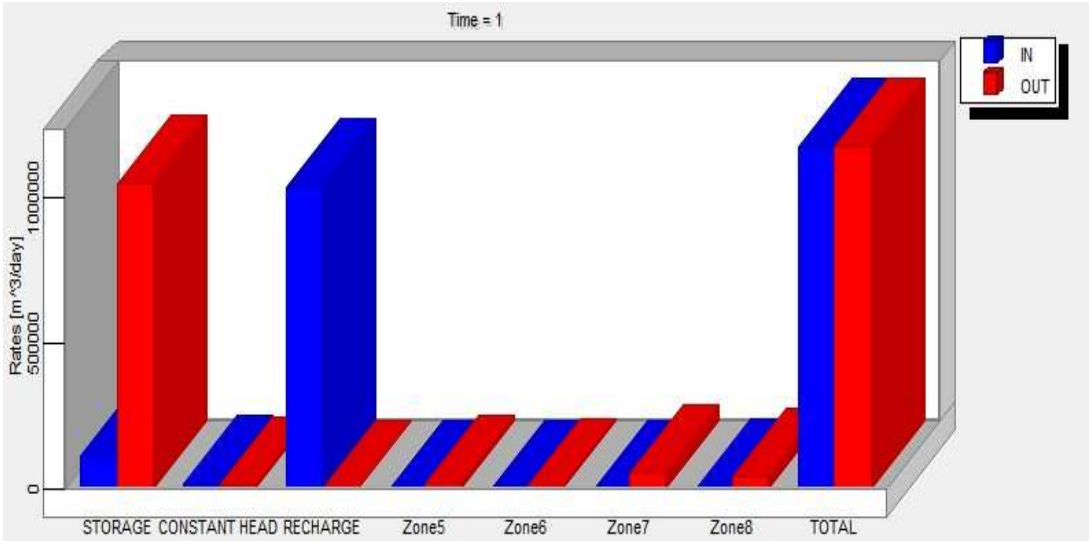
Table-11 (A): ZONE BUDGET IN HOSHIARPUR DISTRICT (Zone-4) (m3/day)											
Stress Period: Time (days)	**1**	**120**	**365**	**485**	**730**	**850**	**1095**	**1215**	**1460**	**1580**	**1825**
Input											
Storage	114020	100320	284940	79509	277770	62338	266200	89392	272070	141840	280600
Constant Head	17268	15926	13723	12547	11005	10280	9052.9	8859.6	7880.6	8034.4	7207.9
Recharge	1036800	1036800	28800	1158400	48000	1276800	67200	915200	57600	550400	48000
Zone 5 to 4	1374.7	0	0	0	0	0	0	0	0	0	0
Zone 6 to 4	195.04	0	0	0	0	0	0	0	0	0	0
Zone 7 to 4	180.54	0	0	0	0	0	0	0	0	0	0
Zone 8 to 4	6543.4	6401.9	6141.6	6106.1	5879.1	5939.9	5725.5	5776.8	5549.5	5589.9	5359.2
Total IN	**1176400**	**1159500**	**333610**	**1256600**	**342650**	**1355400**	**348170**	**1019200**	**343100**	**705870**	**341170**
Output											
Storage	1051600	985430	147790	1039300	125800	1115400	112750	761390	90729	432120	73791
Constant Head	15088	18057	19445	22552	23643	27167	27755	30223	30432	31813	31830
Zone 4 to 5	16895	29895	33795	42224	41769	47216	45384	50814	48720	54072	51722
Zone 4 to 6	4549.6	12158	12322	18238	16792	21725	19657	24486	22115	26878	24286
Zone 4 to 7	51514	74936	82015	97064	97462	108610	106790	118070	115640	126950	123920
Zone 4 to 8	39300	38976	38238	37187	37185	35210	35844	34252	35470	34033	35621
Total OUT	**1178900**	**1159500**	**333610**	**1256600**	**342660**	**1355400**	**348170**	**1019200**	**343100**	**705870**	**341170**
Difference:											
IN - OUT	**-2553.8**	**0.1921**	**0.57433**	**1.7521**	**-0.52814**	**-0.16114**	**-0.014815**	**-3.8301**	**-0.30383**	**0.36474**	**-0.14081**
Percent Discrepancy	**-0.22%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**

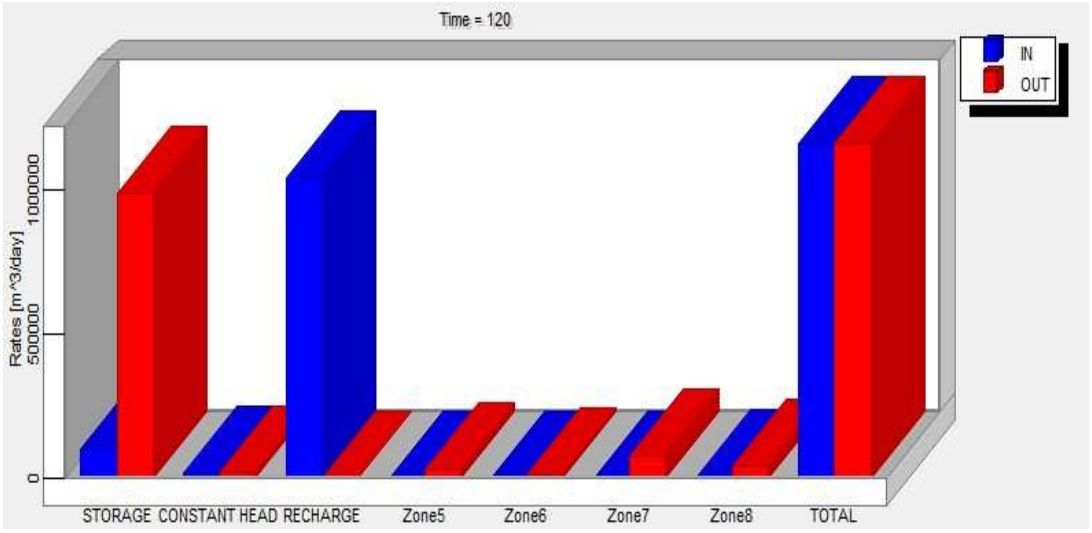
Table-11(B): ZONE BUDGET FOR PHAGWARA BLOCK (ZONE-5), KAPURTHALA DISTRICT (m3/day)											
Stress Period: Time (Days)	**1**	**120**	**365**	**485**	**730**	**850**	**1095**	**1215**	**1460**	**1580**	**1825**
Inflow											
Storage	1085000	1045000	406220	848680	350890	673110	307970	729700	310090	787330	313270
Constant Head	0	0	0	0	0	0	0	0	0	0	0
Recharge	0	0	0	0	0	0	0	0	0	0	0
Zone 4 to 5	16895	29895	33795	42224	41769	47216	45384	50814	48720	54072	51722
Zone 7 to 5	17873	25492	26470	32162	30718	33718	31399	34447	32147	35064	32762
Zone 8 to 5	10087	19908	23046	30610	30183	35571	33802	39023	36873	41945	39490
Total IN	**1129900**	**1120300**	**489530**	**953680**	**453560**	**789620**	**418550**	**853980**	**427830**	**918410**	**437240**
Outflow											
Storage	0	0	0	0	0	0	0	0	0	0	0
Constant Head	0	0	0	0	0	0	0	0	0	0	0
Recharge	1115800	1115800	485660	951750	451240	788060	416470	852520	425920	916990	435380
Zone 5 to 4	1374.7	0	0	0	0	0	0	0	0	0	0
Zone 5 to 7	11049	4556.4	3864.4	1931.1	2320.3	1554.9	2078.5	1458.6	1902.3	1423.9	1867.1
Zone 5 to 8	2067.5	0	0	0	0	0	0	0	0	0	0
Total OUT	**1130300**	**1120300**	**489530**	**953680**	**453560**	**789620**	**418550**	**853980**	**427830**	**918410**	**437240**
Difference:											
IN - OUT	**-396.7**	**-0.38278**	**0.075188**	**-0.26751**	**-0.05104**	**0.2127**	**-0.05115**	**-0.22453**	**0.039592**	**0.073311**	**0.22784**
Percent Discrepancy	-0.04%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

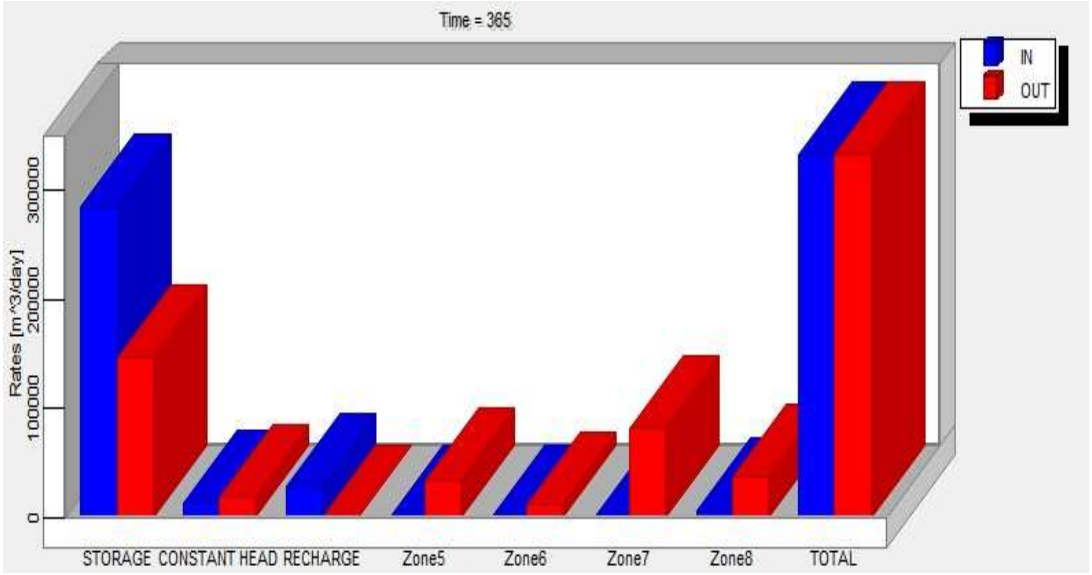
Table-11(C): ZONE BUDGET FOR KAPURTHALA DISTRICT (Zone-6) (m3/day)											
Stress Period: Time (days)	1	120	365	485	730	850	1095	1215	1460	1580	1825
Input											
Storage	2683700	2612900	618630	2379900	545660	2159200	488860	2295300	473610	2433300	462760
Constant Head	27656	44559	44730	72889	73437	102490	100540	134390	129390	166730	158920
Recharge	0	0	0	0	0	0	0	0	0	0	0
Zone 4 to 6	4549.6	12158	12322	18238	16792	21725	19657	24486	22115	26878	24286
Zone 7 to 6	19356	22779	13677	18491	13522	18459	14901	19123	16046	19783	17021
Total IN	**2735300**	**2692400**	**689360**	**2489500**	**649410**	**2301800**	**623950**	**2473300**	**641160**	**2646700**	**662980**
Output											
Storage	0	0	12662	0	7203.5	0	8536.7	0	13573	0	20702
Constant Head	89802	51207	39631	22335	19827	10973	11018	5501.1	5777.2	2288.9	2771
Recharge	2626800	2626800	609720	2447800	590700	2268800	570560	2443400	585110	2616800	599650
Zone 6 to 4	195.04	0	0	0	0	0	0	0	0	0	0
Zone 6 to 7	18944	14371	27348	19382	31676	22029	33834	24489	36708	27680	39860
Total OUT	**2735800**	**2692400**	**689360**	**2489500**	**649410**	**2301800**	**623950**	**2473300**	**641160**	**2646700**	**662980**
Difference:											
IN - OUT	**-484.85**	**0.045448**	**-0.18531**	**-0.11719**	**-0.13162**	**-0.29729**	**-0.04169**	**-0.16971**	**-0.00858**	**0.74681**	**0.31461**
Percent Discrepancy	**-0.02%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**

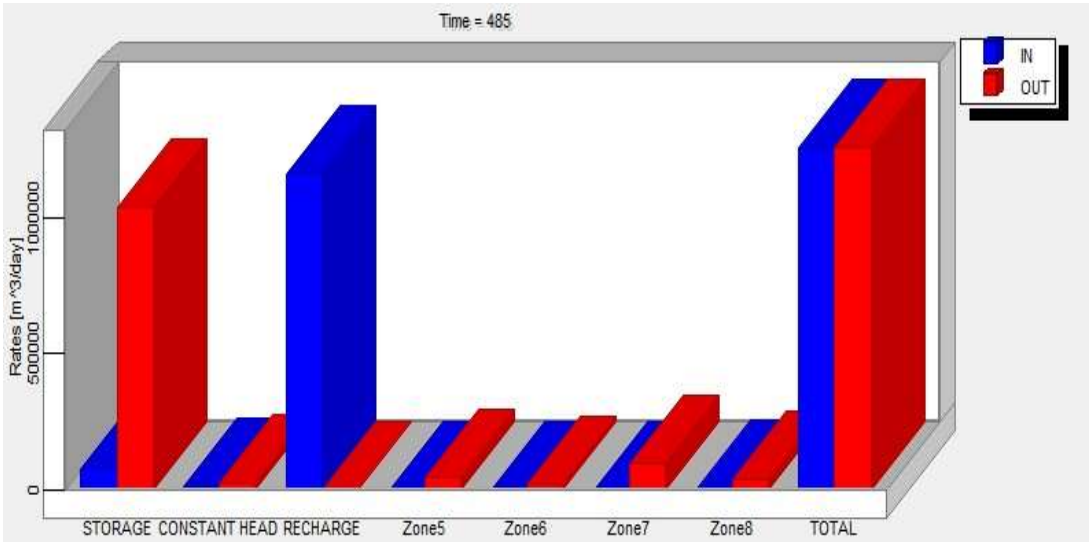
Table-11(D): ZONE BUDGET FOR JALANDHAR DISTRICT (Zone-7) (m3/day)											
Stress Period: Time (Days)	1	120	365	485	730	850	1095	1215	1460	1580	1825
Input											
Storage	5241700	5140300	2622700	4468700	2420100	3860500	2255600	4284800	2279100	4715000	2304700
Constant Head	0	3327.8	15449	45393	75733	107460	134800	172550	195490	235750	253380
Recharge	0	0	0	0	0	0	0	0	0	0	0
Zone 4 to 7	51514	74936	82015	97064	97462	108610	106790	118070	115640	126950	123920
Zone 5 to 7	11049	4556.4	3864.4	1931.1	2320.3	1554.9	2078.5	1458.6	1902.3	1423.9	1867.1
Zone 6 to 7	18944	14371	27348	19382	31676	22029	33834	24489	36708	27680	39860
Zone 8 to 7	10879	26272	32062	42749	43120	51703	49933	58222	55537	63669	60289
Total IN	**5334000**	**5263700**	**2783400**	**4675300**	**2670400**	**4151800**	**2583000**	**4659600**	**2684400**	**5170400**	**2784000**
Output											
Storage	0	0	0	0	0	0	0	0	0	0	0
Constant Head	190450	109640	48284	23504	9586.2	3263.6	937.97	0	0	0	0
Recharge	5105800	5105800	2695000	4601100	2616600	4096400	2535700	4606000	2636200	5115600	2734200
Zone 7 to 4	180.54	0	0	0	0	0	0	0	0	0	0
Zone 7 to 5	17873	25492	26470	32162	30718	33718	31399	34447	32147	35064	32762
Zone 7 to 6	19356	22779	13677	18491	13522	18459	14901	19123	16046	19783	17021
Zone 7 to 8	671.06	0	0	0	0	0	0	0	0	0	0
Total OUT	**5334300**	**5263700**	**2783400**	**4675300**	**2670400**	**4151800**	**2583000**	**4659600**	**2684400**	**5170400**	**2784000**
Difference:											
IN - OUT	-284.7	1.5048	-0.13207	0.31012	1.0913	-1.0764	-0.38197	0.5571	0.17203	0.05505	0.55666
Percent Discrepancy	-0.01%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

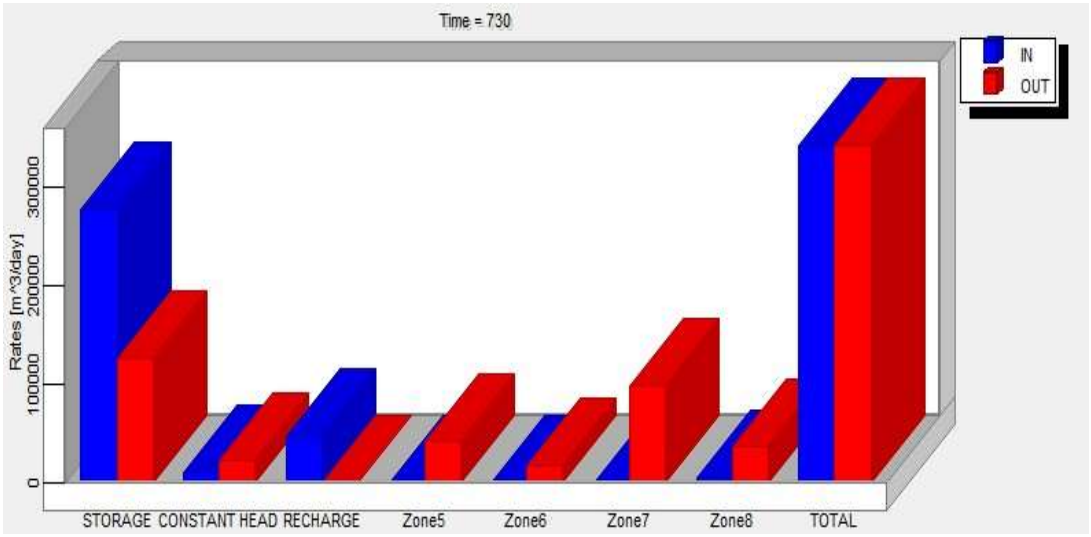
Table-11(E): ZONE BUDGET FOR NAWANSHAHR DISTRICT (ZONE-8) (m3/day)											
Stress Period:Time (Days)	1	120	365	485	730	850	1095	1215	1460	1580	1825
Input:											
Storage	46852	44976	205470	23803	202690	10457	197530	20975	224270	36364	250770
Constant Head	178.79	332.59	795.96	701.77	1008.8	769.96	1030.7	858.8	1107.3	997.59	1228.2
Recharge	193440	193440	0	369920	0	546390	0	402720	0	259060	0
Zone 4 to 8	39300	38976	38238	37187	37185	35210	35844	34252	35470	34033	35621
Zone 5 to 8	2067.5	0	0	0	0	0	0	0	0	0	0
Zone 7 to 8	671.06	0	0	0	0	0	0	0	0	0	0
Total IN	**282510**	**277730**	**244500**	**431610**	**240880**	**592830**	**234400**	**458810**	**260850**	**330450**	**287620**
Output:											
Storage	188860	164100	3687.4	304080	2052.8	456930	1196.6	317350	100.29	185330	0
Constant Head	66694	61042	48338	48059	39734	42688	36275	38440	32693	33912	28627
Recharge	0	0	131230	0	119910	0	107470	0	130090	0	153850
Zone 8 to 4	6543.4	6401.9	6141.6	6106.1	5879.1	5939.9	5725.5	5776.8	5549.5	5589.9	5359.2
Zone 8 to 5	10087	19908	23046	30610	30183	35571	33802	39023	36873	41945	39490
Zone 8 to 7	10879	26272	32062	42749	43120	51703	49933	58222	55537	63669	60289
Total OUT	**283070**	**277730**	**244500**	**431610**	**240880**	**592830**	**234400**	**458810**	**260850**	**330450**	**287620**
Difference:											
IN - OUT	-552.78	0.0719	0.28852	0.63537	-0.17896	-0.59984	0.032572	-2.1383	-0.59195	1.8688	0.43096
Percent Discrepancy	-0.20%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

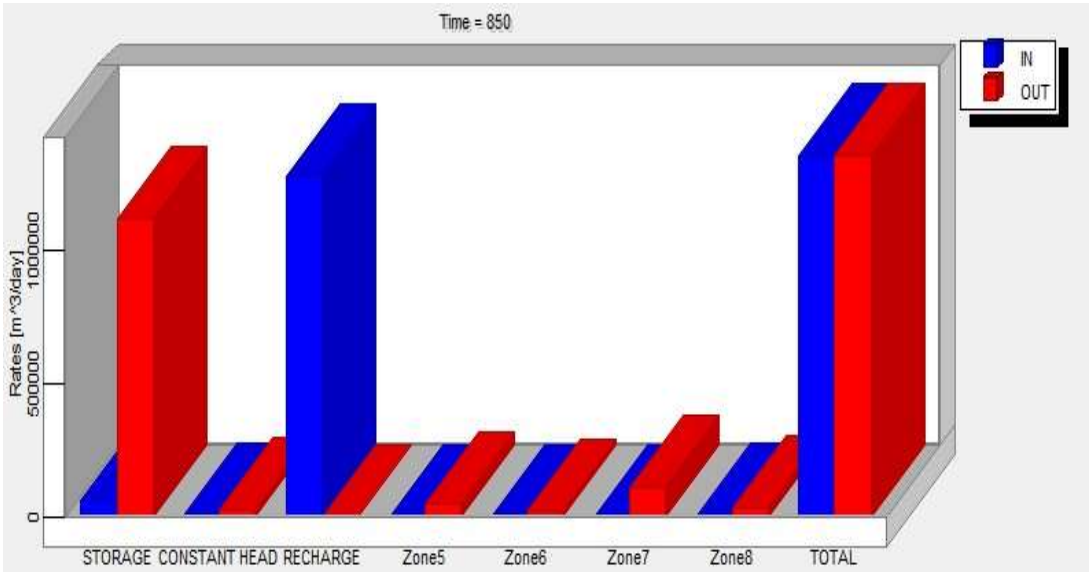

Time = 1
IN
OUT
Rates [m^3/day]
0
500000
1000000
STORAGE
CONSTANT HEAD
RECHARGE
Zone5
Zone6
Zone7
Zone8
TOTAL


Time = 120
IN
OUT
Rates [m^3/day]
0
500000
1000000
STORAGE
CONSTANT HEAD
RECHARGE
Zone5
Zone6
Zone7
Zone8
TOTAL


Time = 365
IN
OUT
Rates [m^3/day]
0
100000
200000
300000
STORAGE
CONSTANT HEAD
RECHARGE
Zone5
Zone6
Zone7
Zone8
TOTAL


Time = 485
IN
OUT
Rates [m^3/day]
0
500000
1000000
STORAGE
CONSTANT HEAD
RECHARGE
Zone5
Zone6
Zone7
Zone8
TOTAL


Time = 730
IN
OUT
Rates [m^3/day]
0
100000
200000
300000
STORAGE
CONSTANT HEAD
RECHARGE
Zone5
Zone6
Zone7
Zone8
TOTAL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IN
OUT
Rates [m^3/day]
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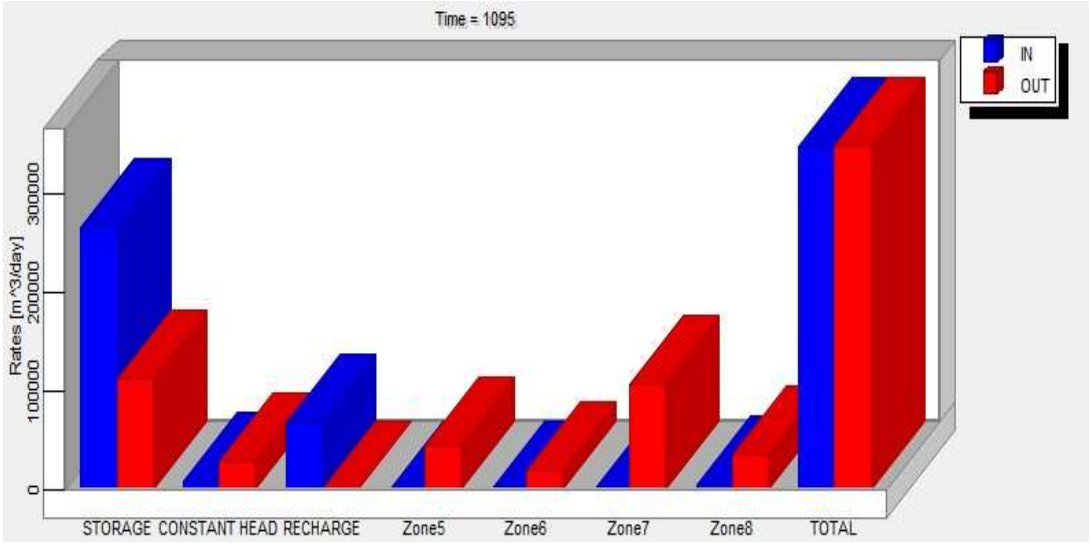
500000
1000000
STORAGE
CONSTANT HEAD
RECHARGE
Zone5
Zone6
Zone7
Zone8
TOTAL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OUT
Rates [m^3/day]
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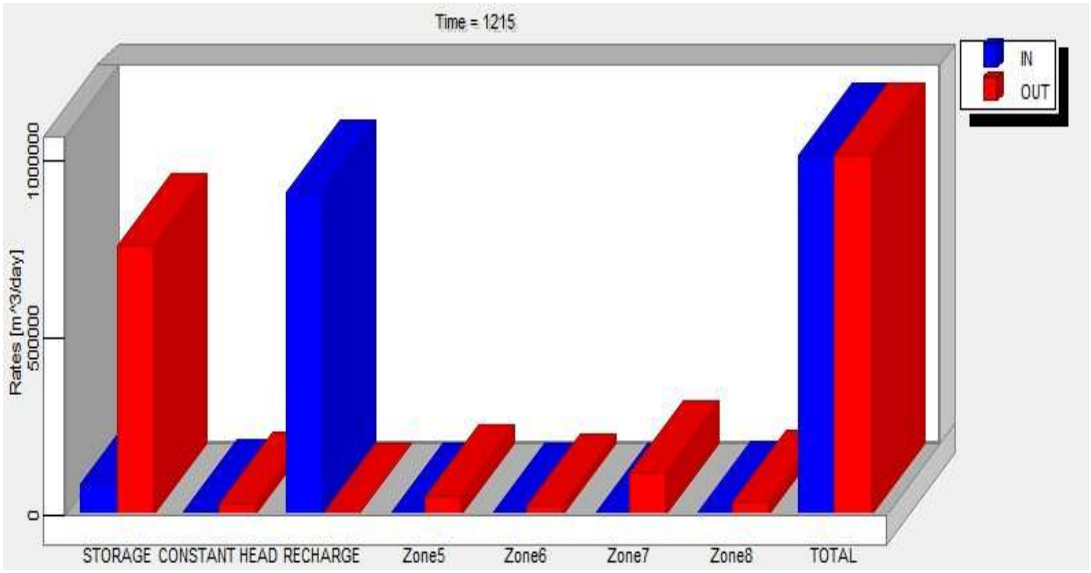
100000
200000
300000
STORAGE
CONSTANT HEAD
RECHARGE
Zone5
Zone6
Zone7
Zone8
TOTAL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OUT
Rates [m^3/day]
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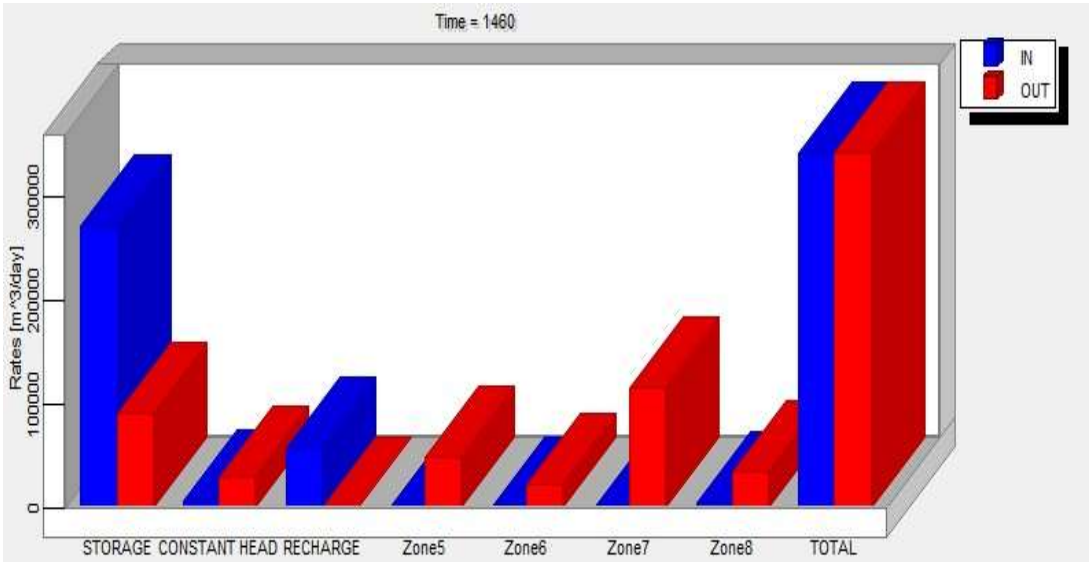
STORAGE
CONSTANT HEAD
RECHARGE
Zone5
Zone6
Zone7
Zone8
TOTAL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OUT
Rates [m^3/day]
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100000
200000
300000
STORAGE
CONSTANT HEAD
RECHARGE
Zone5
Zone6
Zone7
Zone8
TOTAL

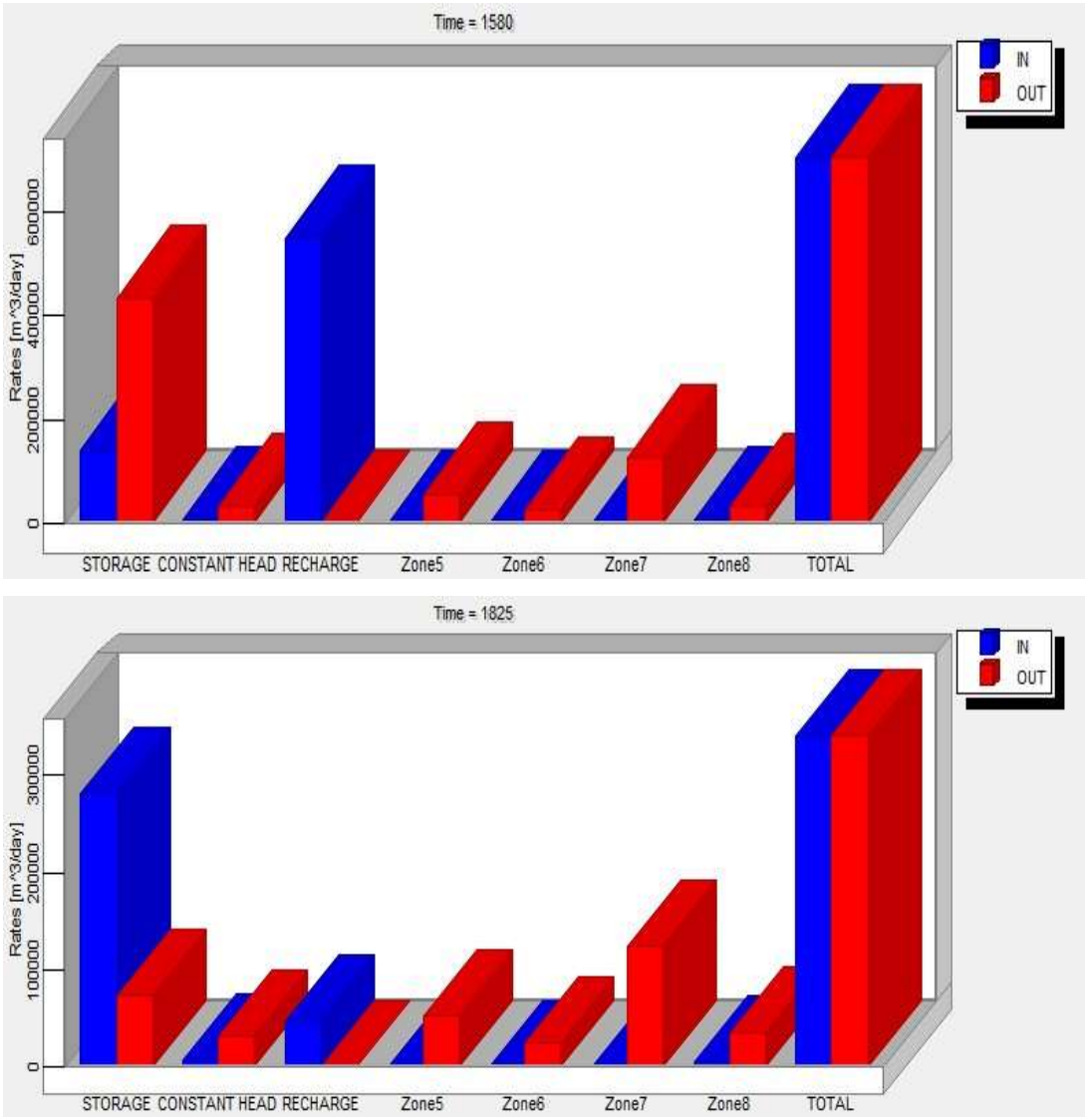


Fig.25-Graphical representation of Zone Budgets for various stress period

6.2 MASS BALANCE

Mass balance is one of the key indicators of a successful simulation of a ground water flow model. The mass balance showing cumulative inflows and outflow and percent discrepancy in each time step provides the detailed information about the entire model domain. If the mass balance error for a simulation is less than 2% the results of the simulation may be considered to be acceptable provided model is also calibrated.

The Mass balance of the simulated model for different time steps in cube meter is given in table-12.

The rate of ground water inflow and outflow from the system in different time steps in cube meter per day along with the total inflow or outflow & discrepancy is given in table-13.

Table-12: Mass Balance of Validated Model

CUMULATIVE VOLUME REPORT [m3)											
Stress Period: Time (Days)	**1**	**120**	**365**	**485**	**730**	**850**	**1095**	**1215**	**1460**	**1580**	**1825**
IN:											
Storage	9171261	1073446912	2087244288	3023323136	3953616896	4765481984	5626927104	6517348864	7389342208	8363003904	9247959040
Constant Head	45102.4336	7678363.5	25979096	41762816	81252776	107772856	167900720	205900384	287699264	337080864	440161216
Recharge	1230243.75	147629248	154685248	338083520	349843520	568626752	585090752	743241728	757353728	854488448	866248448
Total IN	**10446607**	**1228754432**	**2267908608**	**3403169536**	**4384713216**	**5441881600**	**6379918336**	**7466490880**	**8434395136**	**9554573312**	**1055436902**
OUT:											
Storage	1240448	138034704	178249152	339454784	372544608	561227776	591235648	720684160	746262912	820357696	843508480
Constant Head	362031.906	28915984	67061972	81035920	103769512	113860456	132477048	141376736	158257536	166419152	181910144
Recharge	8848400	1061808000	2022601472	2982682624	3908402944	4766797312	5656209920	6604434944	7529879552	8567800832	9528953856
Total OUT	**10450880**	**1228758656**	**2267912704**	**3403173376**	**4384716800**	**5441885696**	**6379922432**	**7466496000**	**8434400256**	**9554577408**	**1055437209 6**
IN - OUT	**-4273**	**-4224**	**-4096**	**-3840**	**-3584**	**-4096**	**-4096**	**-5120**	**-5120**	**-4096**	**-3072**
Discrepancy	**-0.04%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**

Table-13: Rate of Ground Water Inflow and Outflow in Validated Model for various stress period

RATES FOR TIME STEP REPORT [m3/day]											
Stress Period: Time (Days)	**1**	**120**	**365**	**485**	**730**	**850**	**1095**	**1215**	**1460**	**1580**	**1825**
IN:											
Storage	9171261	8943493	4137948.5	7800657.5	3797117.5	6765542.5	3516102.75	7420182	3559155.75	8113848	3612061.75
Constant Head	45102.4336	64145.0508	74696.8672	131531.0156	161183.5156	221000.6875	245419.875	316663.9375	333872.938	411513.25	420736.125
Recharge	1230243.75	1230243.75	28800.002	1528318.75	47999.9961	1823193.75	67200	1317925	57600.0039	809456.25	47999.9961
Total IN	**10446607**	**10237882**	**4241445.5**	**9460507**	**4006301**	**8809737**	**3828722.5**	**9054771**	**3950628.75**	**9334817**	**4080798**
OUT:											
Storage	1240448	1149531.5	164140.6406	1343380.375	135060.5	1572359.75	122481.0625	1078737.5	104403.094	617456.375	94492.8828
Constant Head	362031.906	239949.1719	155697.9062	116449.5703	92790.1797	84091.1719	75986.0859	74164.0391	68901.2344	68013.4922	63228.543
Recharge	8848400	8848400	3921606.25	8000675	3778450	7153288	3630256	7901875	3777325	8649344	3923075
Total OUT	**10450880**	**10237881**	**4241445**	**9460505**	**4006300.75**	**8809739**	**3828723.25**	**9054776**	**3950629.25**	**9334814**	**4080796.5**
IN - OUT	**-4273**	**1**	**0.5**	**2**	**0.25**	**-2**	**-0.75**	**-5**	**-0.5**	**3**	**1.5**
Discrepancy	**-0.04%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**

7.0 Predictive Simulations

"National Aquifer Mapping and Management Programme (NAQUIM)", broadly aims at characterizing the geometry, parameters, behavior of ground water regime and status of ground water development/extraction in aquifer system to facilitate planning of their sustainable management. The NAQUIM reports of the study area have been suggested toimplement demand side and supply side interventions for better management of the aquifer system.

The demand side interventions include the reduction of ground water draft through replacing existing kutcha/open irrigation channels by laying of network of underground pipeline and crop diversification through replacing paddy crops by encouraging maize/pulses cultivation.

The supply side interventions include the enhancement of the ground water recharge by adopting artificial recharge techniques.

The proposed interventions as per NAQUIM reports of four numbers of the districts viz Hoshiarpur, Jalandhar, Kapurthala which falls in the study area are used for the predictive simulation. The district wise details of water saving by applying various management strategies such as crop diversification, laying of Under Ground Pipe lines (UGPL) in individual land and adopting artificial recharge techniques are given in Annexure-4-.

Accordingly, the following scenarios have been attempted for the period from 2018 to 2021:

Scenario-1: Extending the present data set of ground water draft and recharge.

Scenario-2: Reduction in groundwater draft due to the replacing existing open irrigation channels by network of the underground pipeline and crop diversification shifting from paddy to maize/pulses and ground water recharge remained unchanged.

Scenario-3: Enhancement in ground water recharge due to adopting artificial recharge techniques and ground water draft remained unchanged.

Scenario-4: Incorporation of both the reduction in ground water draft and enhancement in ground water recharge as elaborated above in Scenario-2 and Scenario-3.

The model output for the above cited predictive scenario has been assessed on the aspects of: (i) simulated heads (ii) Drawdown contours and (iii) hydrographs.

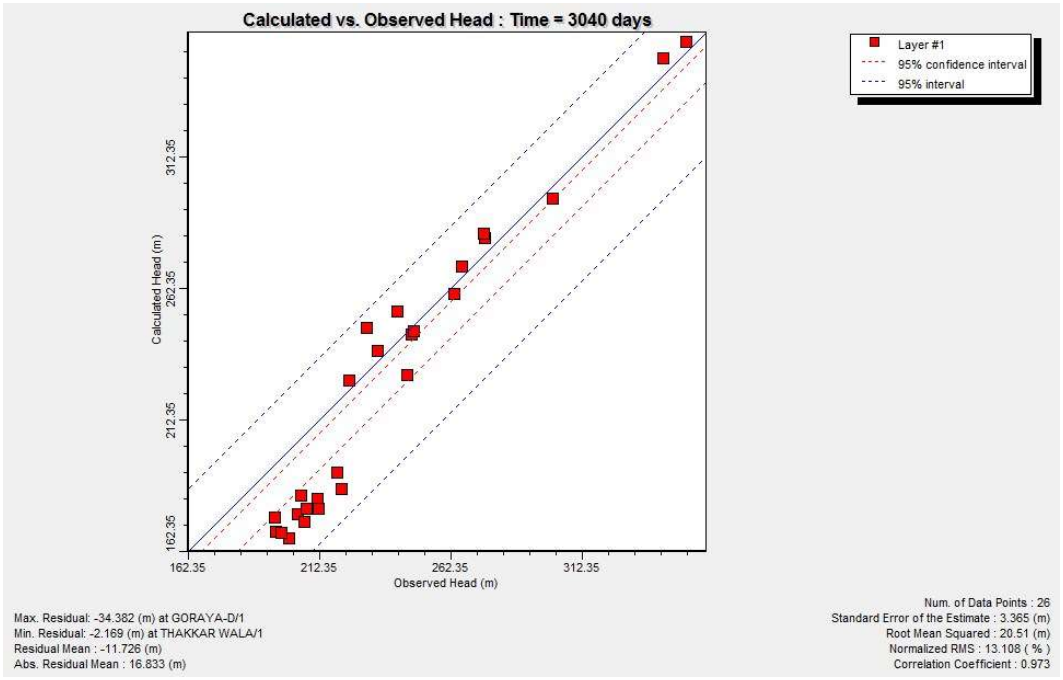
7.1 Prediction Scenario-1

In this scenario, ground water draft & recharge conditions for the assessment year 2017 at the end of simulation/validation period were allowed to continued from pre-monsoon period 2018 to post monsoon period 2021.

The model generated heads at different stress period for 1945 days (May 2018), 2190 days (Nov.2018), 2310 days (May 2019), 2555 days (Nov. 2019), 2675 days (May 2020), 2920 days (Nov. 2020), 3040 days (May 2021) & 3285 days (Nov. 2021) are shown in figure-26, head contours in figure-27& draw down contours are shown in figure-28. Hydrograph showing continuous decline with steady pace are shown in figure-29.

When comparison of head contours for the time stress 1580 days (pre-monsoon 2017) with 3040 days (pre-monsoon 2021) and time stress 1825 days (post-monsoon 2017) with 3285 days (post-monsoon 2021) was made, it indicates both rise and fall in water levels in observation wells of Hoshiarpur district whereas decline in water levels at all the observation wells in Jalandhar and Kapurthala district and decline at majority of observation wells in Nawanshahr district with average water levels decline to the tune of 13.50 m in highly exploitable area of Jalandhar & Kapurthala district. The average water levels decline in Nawanshahr to the tune of 0.75 m, which is probably due to the influent nature of river Satluj in the tract of Nawanshahr district. The rise in water levels in some part of the Hoshiarpur district is due to continuous recharge flux assigned.

The overall behavior of contours indicates the persistence of decline in water levelsconsistently. The same has also been corroborated in draw down contour maps and data set of simulated heads. The comparison of simulated heads for various stress periods for pre-monsoon and post-monsoon period are given in Annexure-5(A) & (B).



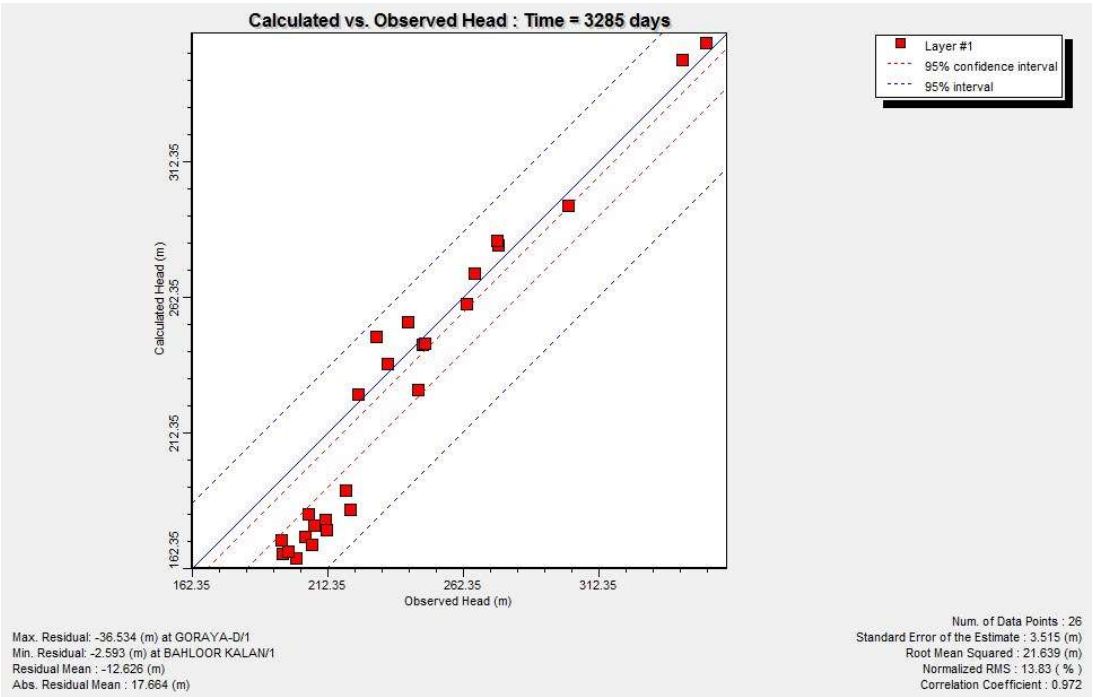
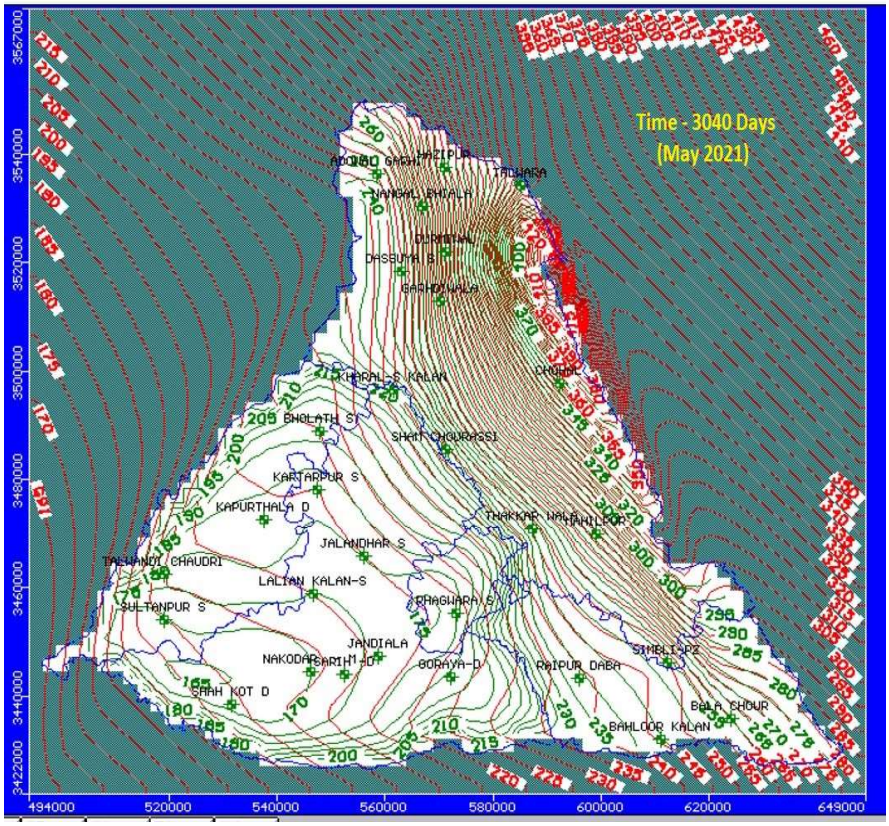


Fig.26-Head Scatter Plots for Various Stress Period (Prediction-1)



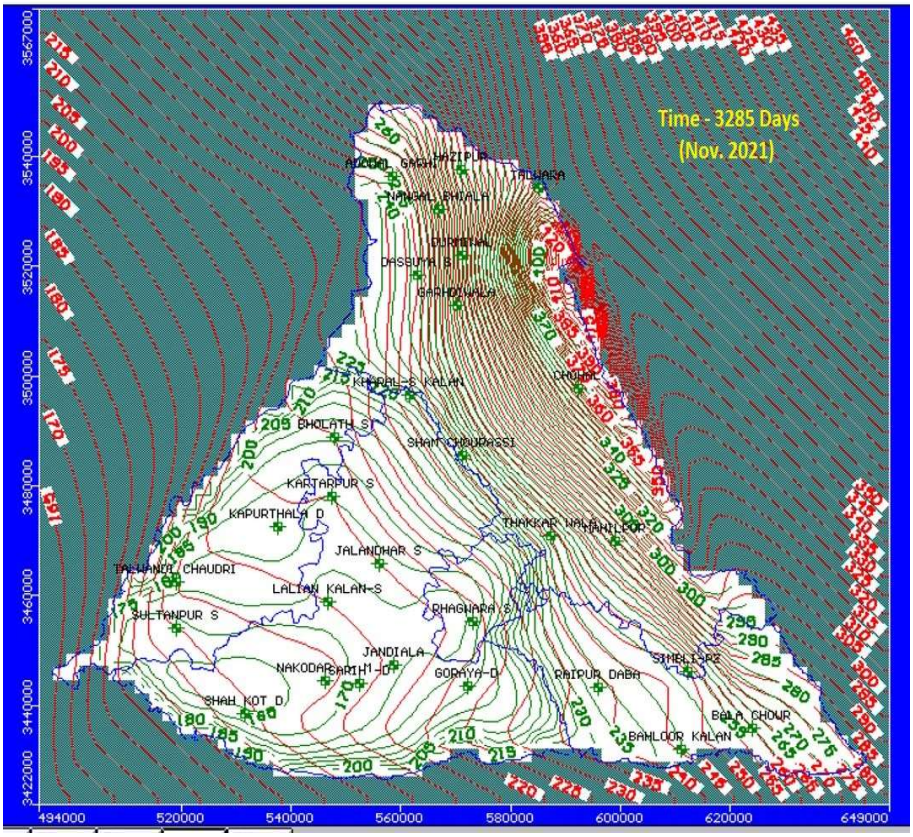
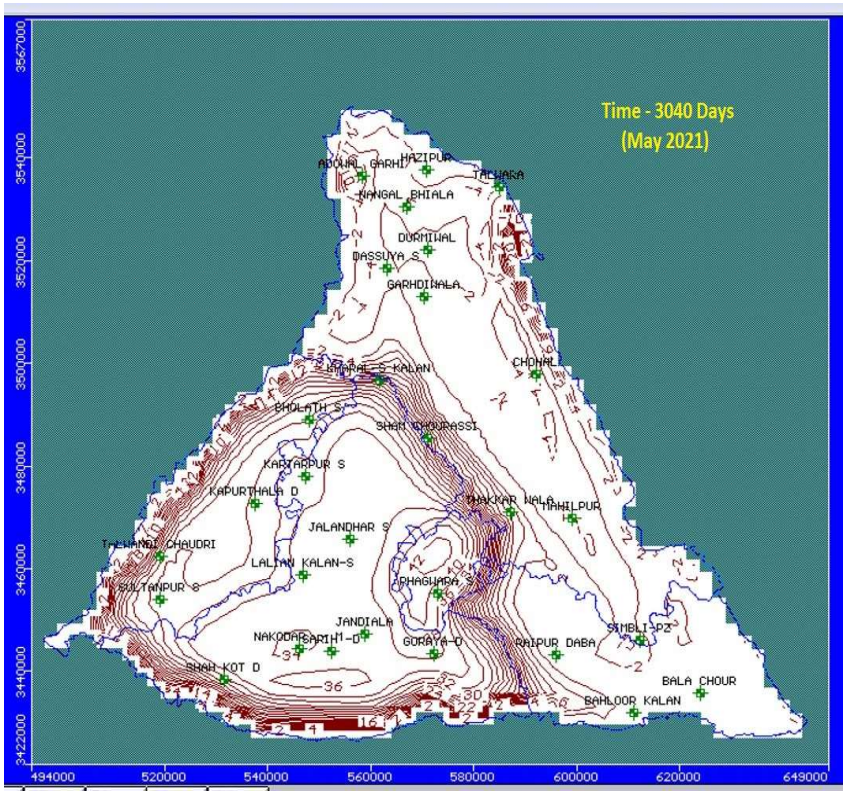


Fig.27-Head Contours for Various Stress Period (Prediction-1)



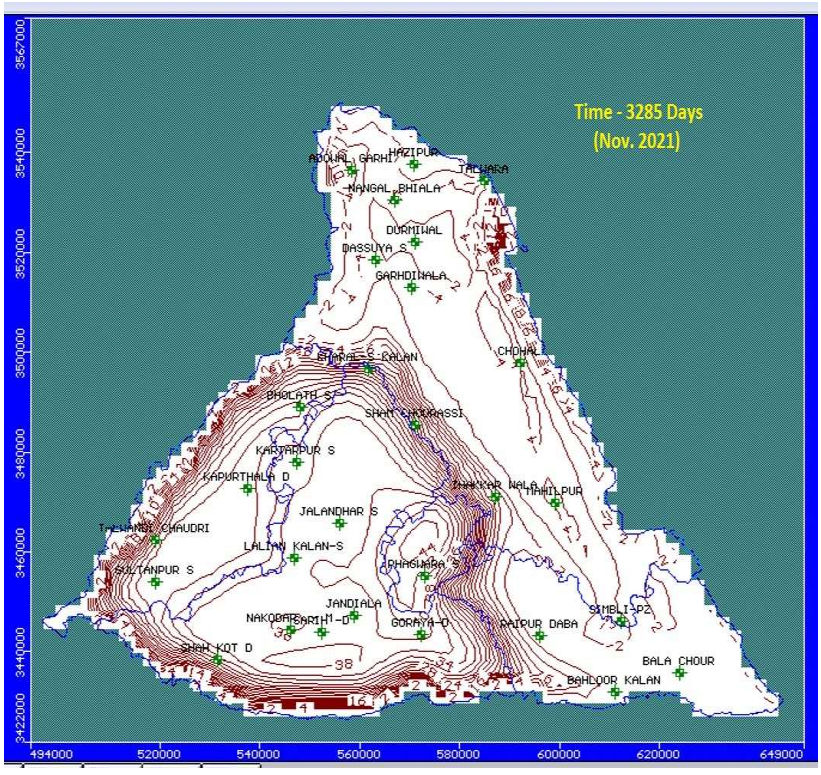


Fig.28-Drawdown Contours for Various Stress Period (Prediction-1)

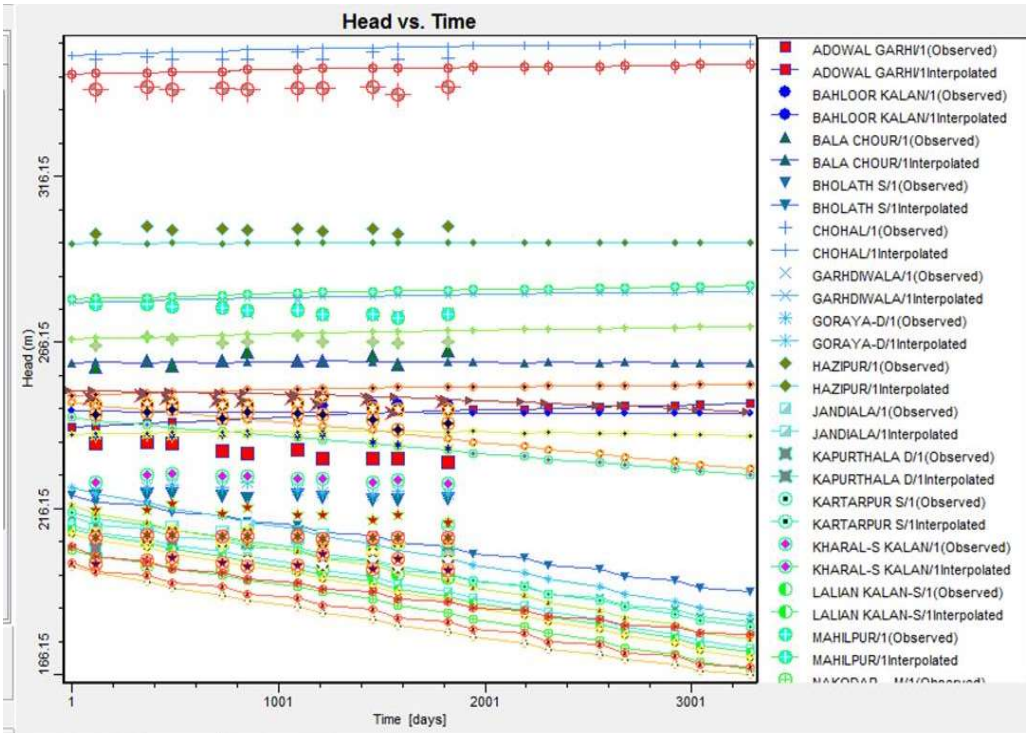


Fig.29-Hydrograph (Pridiction-1)

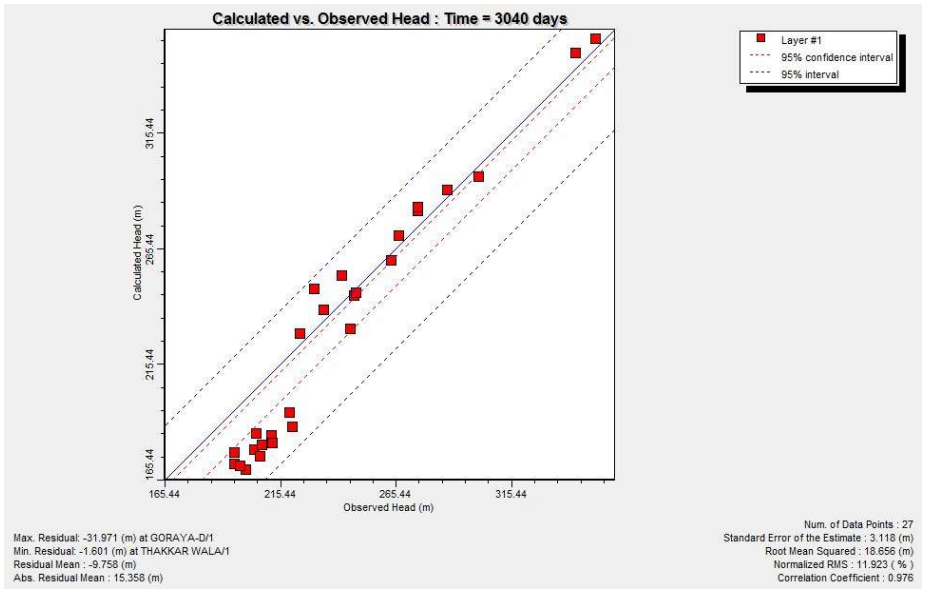
7.2 Prediction Scenario-2

In this scenario, reduction in ground water draft due to laying down of underground pipeline for improved irrigation system and shifting from paddy to maize/pulses have been assigned together with no change in ground water recharge data. This has been assigned for pre-monsoon and post monsoon period of 2021.

When comparison of head contours for the time stress 1580 days (pre-monsoon 2017) with 3040 days (pre-monsoon 2021) and time stress 1825 days (post-monsoon 2017) with 3285 days (post-monsoon 2021) was made, it indicates rise in water levels at all the observation wells of Hoshiarpur, Jalandhar, Kapurthala and Nawanshahr districts during pre-monsoon and post-monsoon period. The rise in water levels is predominant in highly exploitable area of Jalandhar & Kapurthala district with average rise of 2.90 m as compared to Hoshiarpur and Nawanshahr districts where average rise of 0.75 m has been observed during pre and post periods.

The behavior of contours indicatesbetterment in the highly declined region of the study area. The same has also been corroborated in draw down contour maps and data set of simulated heads. The comparison of simulated heads for various stress periods for pre-monsoon and post-monsoon period are given in Annexure-5 (A) & (B).

The model generated heads at stress period 3040 days (May 2021) and 3285 days (Nov. 2021) are shown in figure-30, head contours & draw down contours for same stress period are shown in figure-31 & 32 respectively.



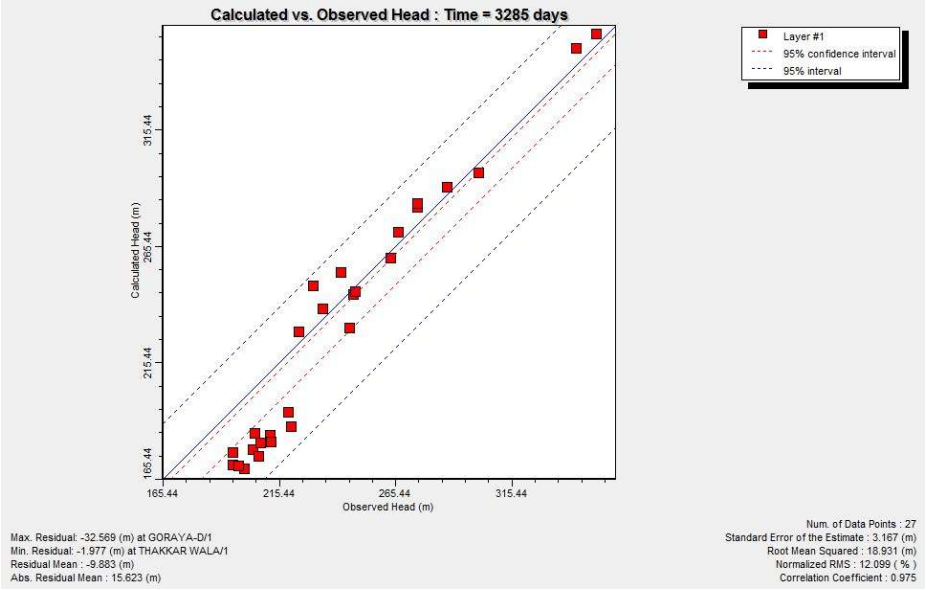
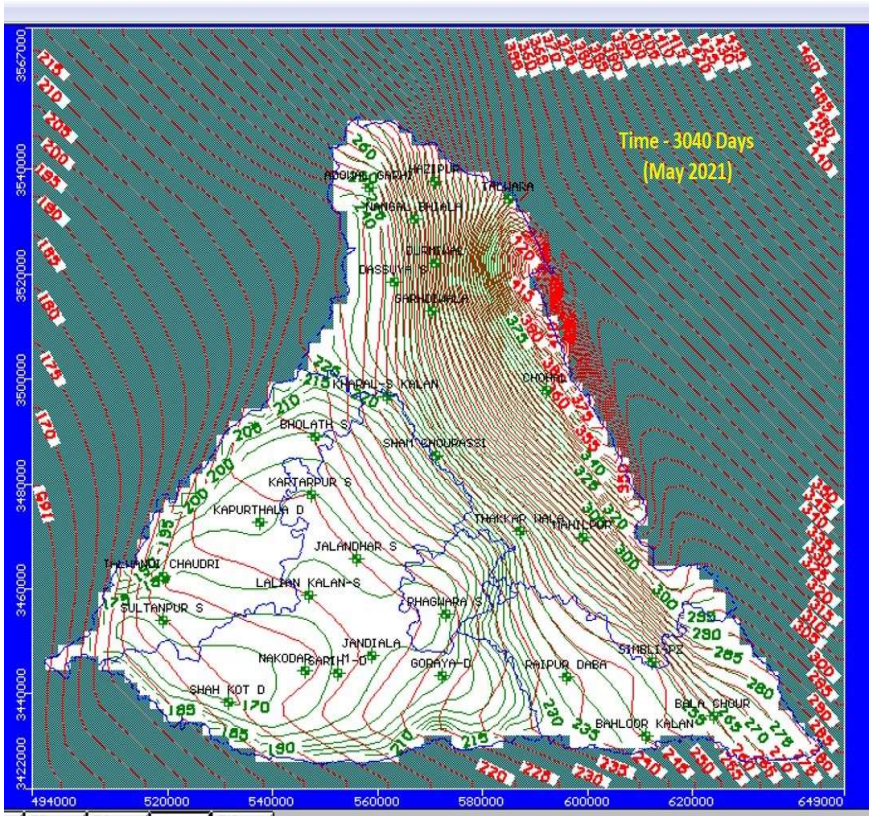


Fig.30-Head Scatter Plot for various stress period (Prediction-2)



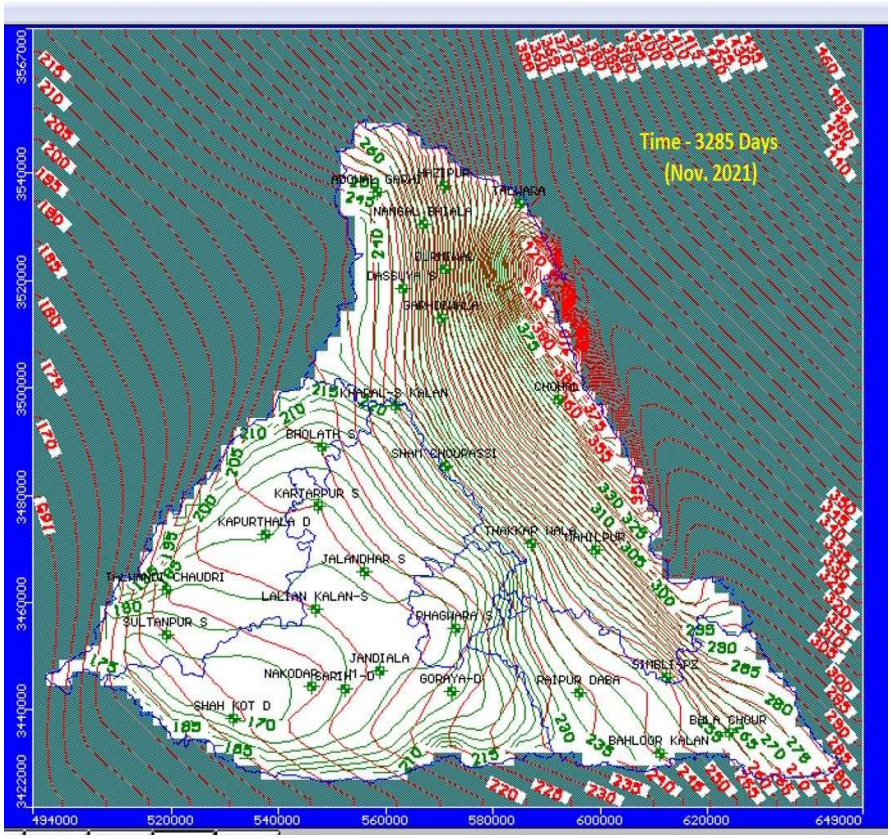
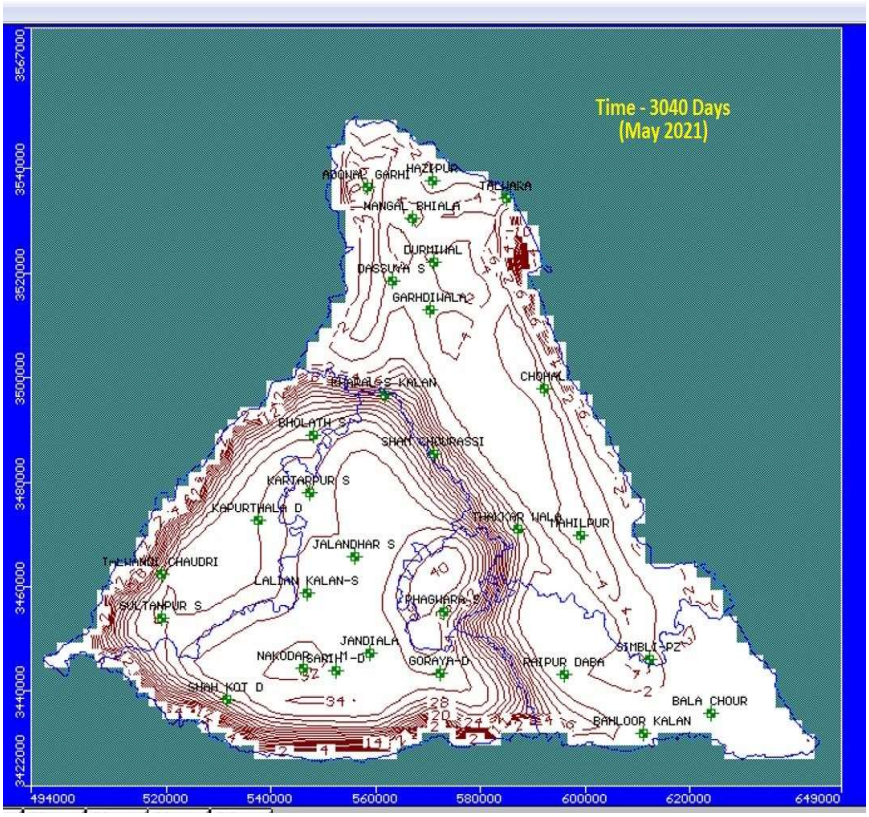


Fig.31-Head Contours for Various Stress Period (Prediction-2)



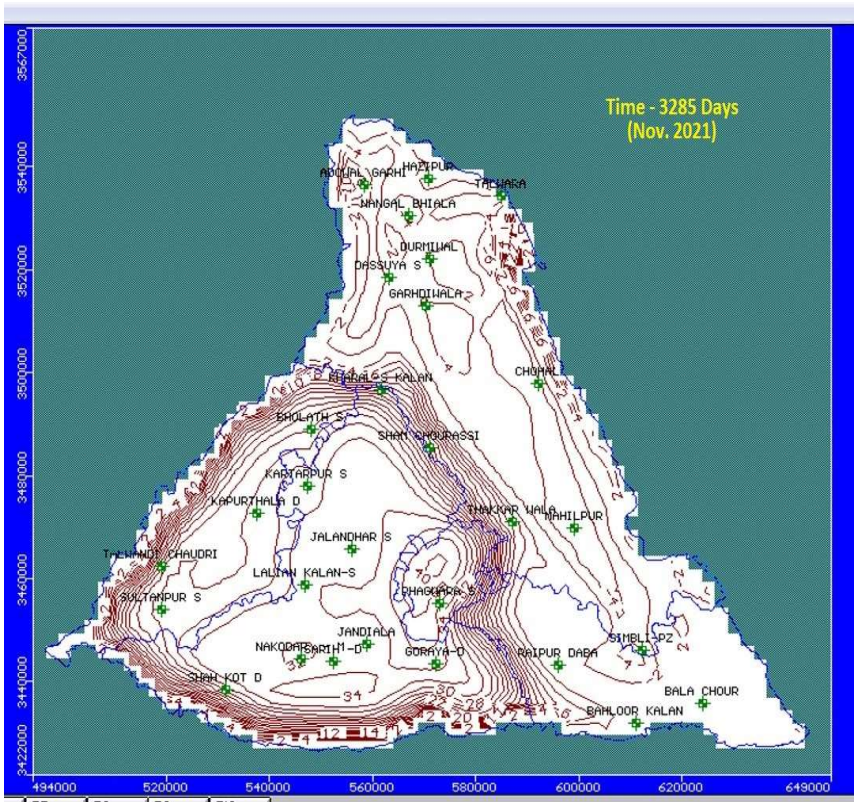


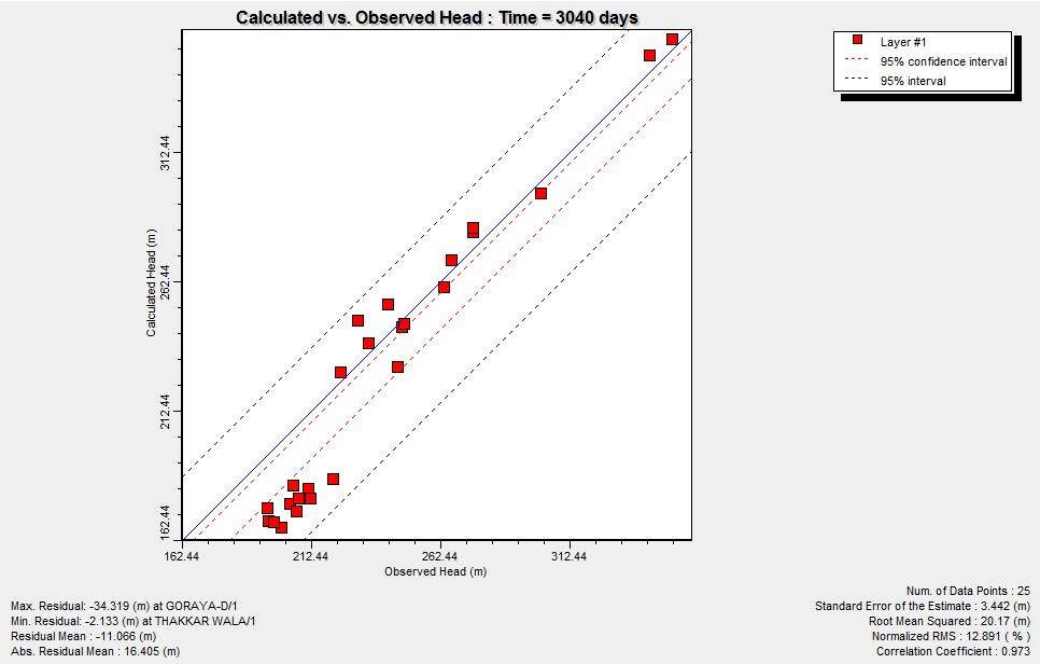
Fig.32-Drawdown Contours for Various Stress Period (Prediction-2)

7.3 Prediction Scenario-3

In this scenarioassigned data of enhancement of ground water recharge due to adopting artificial recharge techniques together with no change in ground water draft for pre-monsoon and post monsoon period of 2021.

When comparison of head contours for the time stress 1580 days (pre-monsoon 2017) with 3040 days (pre-monsoon 2021) and time stress 1825 days (post-monsoon 2017) with 3285 days (post-monsoon 2021) was made, it indicates rise in water levels at all the observation wells of Hoshiarpur, Jalandhar, Kapurthala and Nawanshahr districts during pre-monsoon and post-monsoon period. Though rise in water levels are observed at all the observation wells in all the four district, but the rise are not so prominent. The rise in water levels has been observed during pre and post periods with average value of 0.06 m, 0.08 m, 0.05 & 0.03 for Jalandhar, Kapurthala, Hoshiarpur and Nawanshahr districts respectively. It further indicates that the implementation of enhancement of recharge only are not going to improve the ground water regime much.

The model generated heads at stress period 3040 days (May 2021) and 3285 days (Nov. 2021) are shown in figure-33, head contours & draw down contours for same stress period are shown in figure-34&35 respectively. The comparison of simulated heads for various stress periods for pre-monsoon and post-monsoon period are given in Annexure-5 (A) & (B).



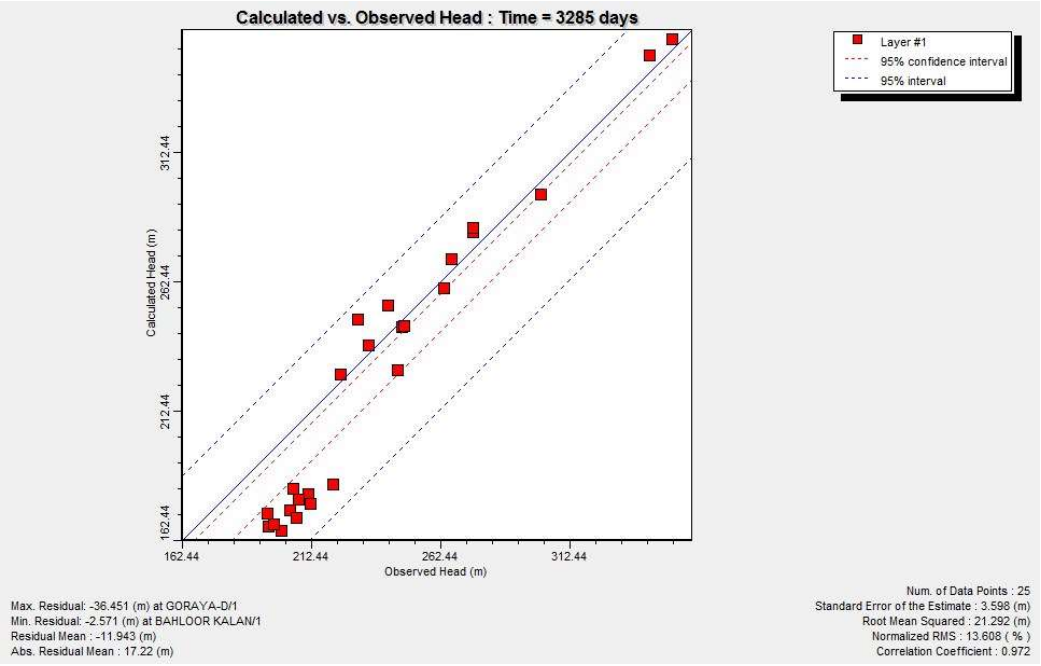
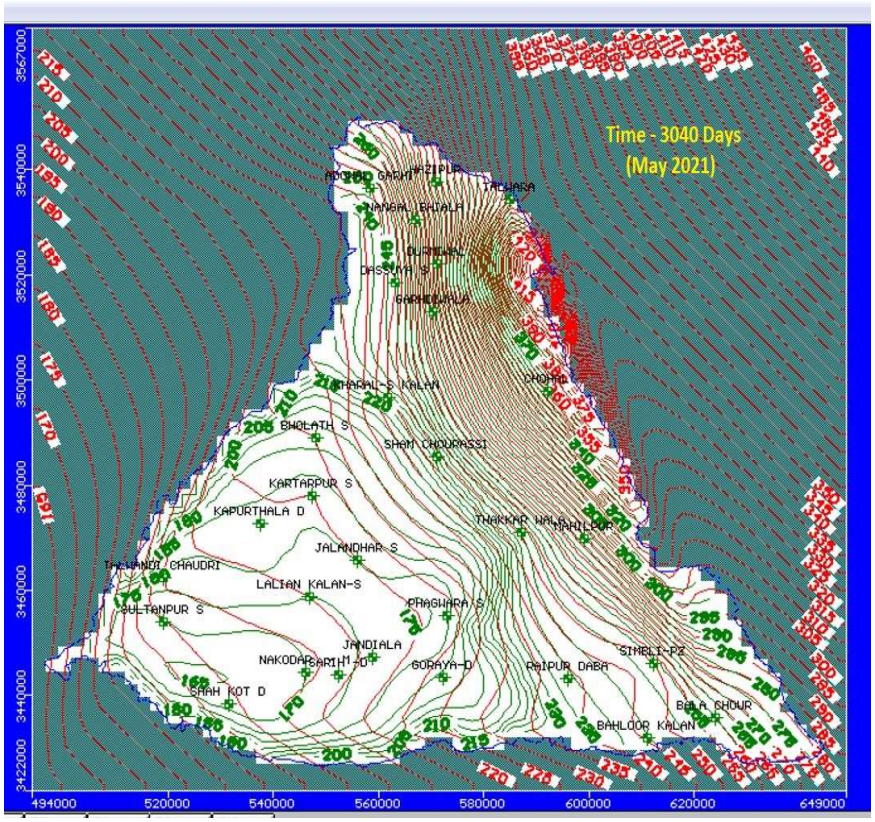


Fig.33-Head Contours for Various Stress Period (Prediction-3)



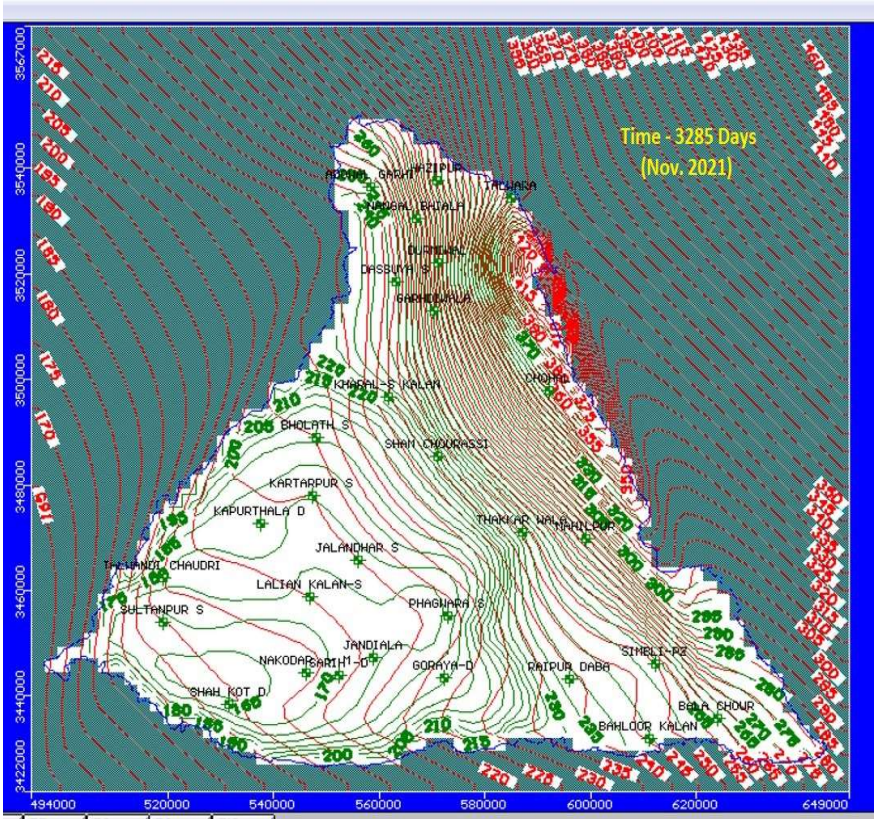
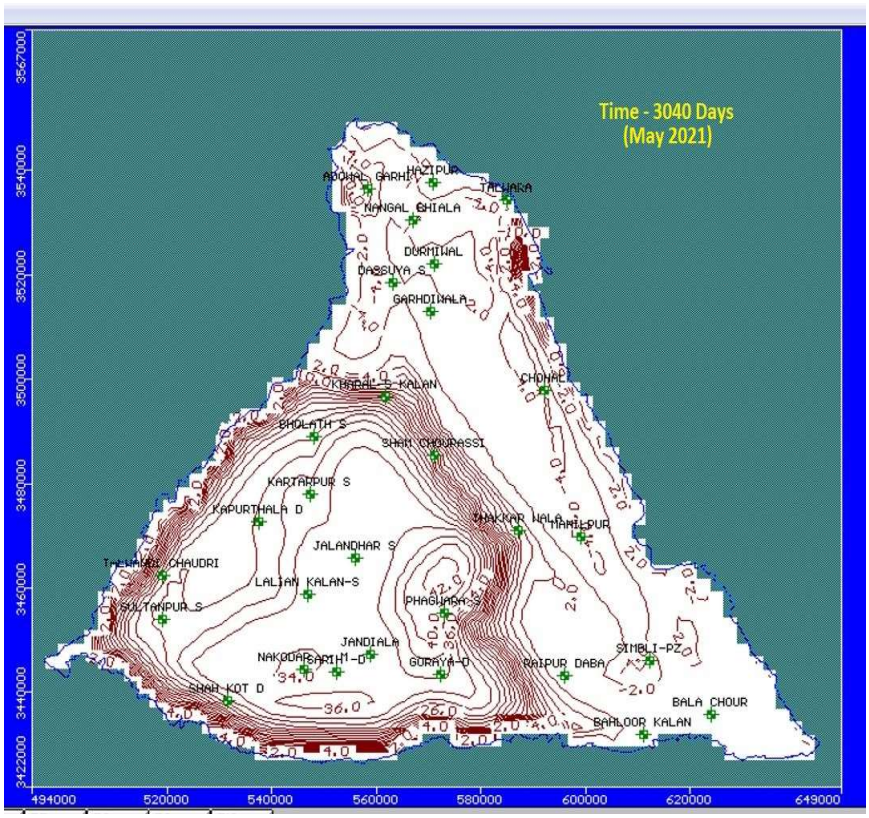


Fig.34-Head Contours for Various Stress Period (Prediction-3)



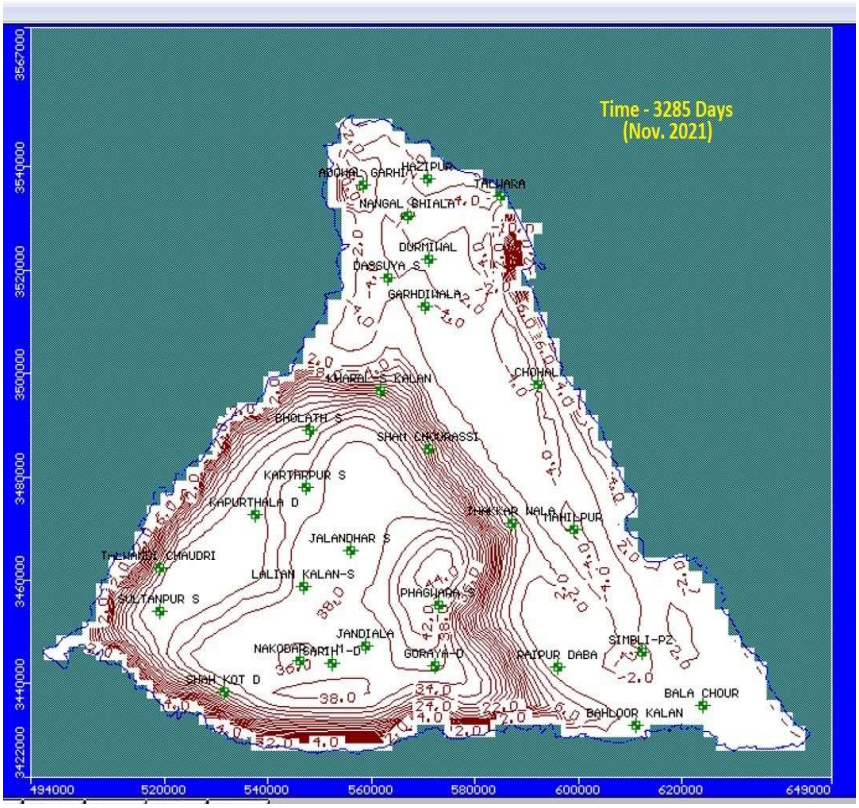


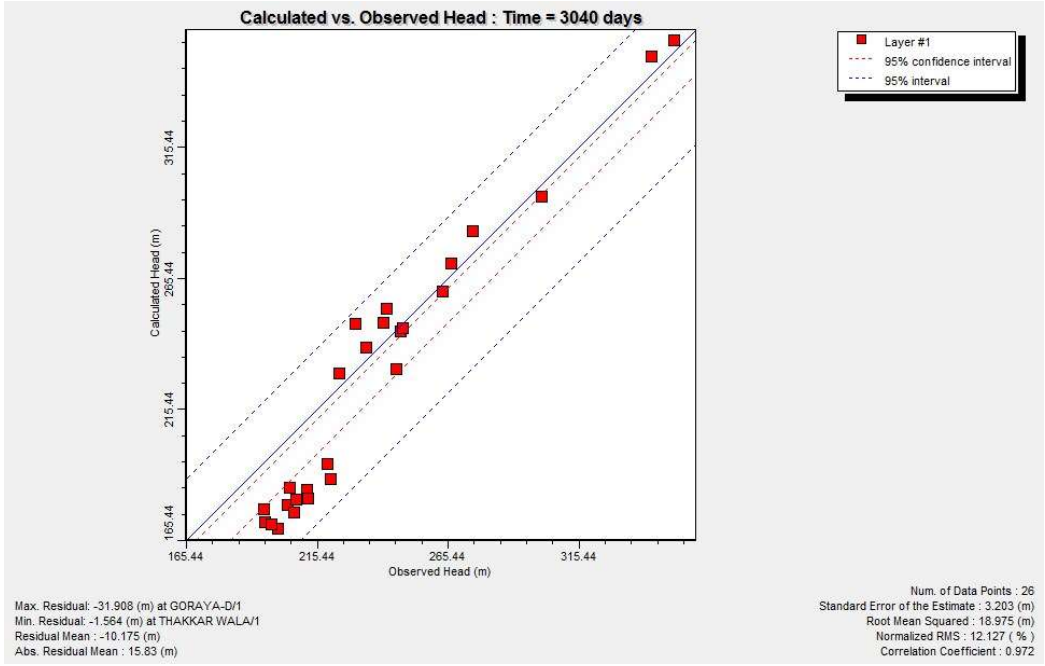
Fig.35-Draw Down Contours for Various Stress Period (Prediction-3)

7.4 Prediction Scenario-4

This scenario is a combination of scenario 2 and 3 wherein district wise data on reduction of ground water draft and enhancement of ground water recharge has been considered for pre-monsoon and post monsoon period of 2021.

When comparison of head contours for the time stress 1580 days (pre-monsoon 2017) with 3040 days (pre-monsoon 2021) and time stress 1825 days (post-monsoon 2017) with 3285 days (post-monsoon 2021) was made, it indicates rise in water levels at all the observation wells of Hoshiarpur, Jalandhar, Kapurthala and Nawanshahr districts during pre-monsoon and post-monsoon period. The rise in water levels are more during post monsoon as compared to pre-monsoon period. The output result shows the improvement in ground water levels in major part of the area. The data set of simulated heads indicates rise in water levels observed by an average of 0.30 in Jalandhar and Kapurthala district, which is highly exploitable area of model and 0.85 m in other region of model. The scenario further indicates that there need to implement the demand side intervention over supply side intervention to a large extent and in efficient manner so that the improvement in ground water regime could be achieved for sustainability of the aquifer system.

The model generated heads at stress period 3040 days (May 2021) and 3285 days (Nov. 2021) are shown in figure-36, head contours & draw down contours for same stress period are shown in figure-37 & 38 respectively. The graphical representation of clear cut rise in water levels are shown through hydrograph and given in figure-39. The comparison of simulated heads for various stress periods for pre-monsoon and post-monsoon period are given in Annexure-5 (A) & (B).



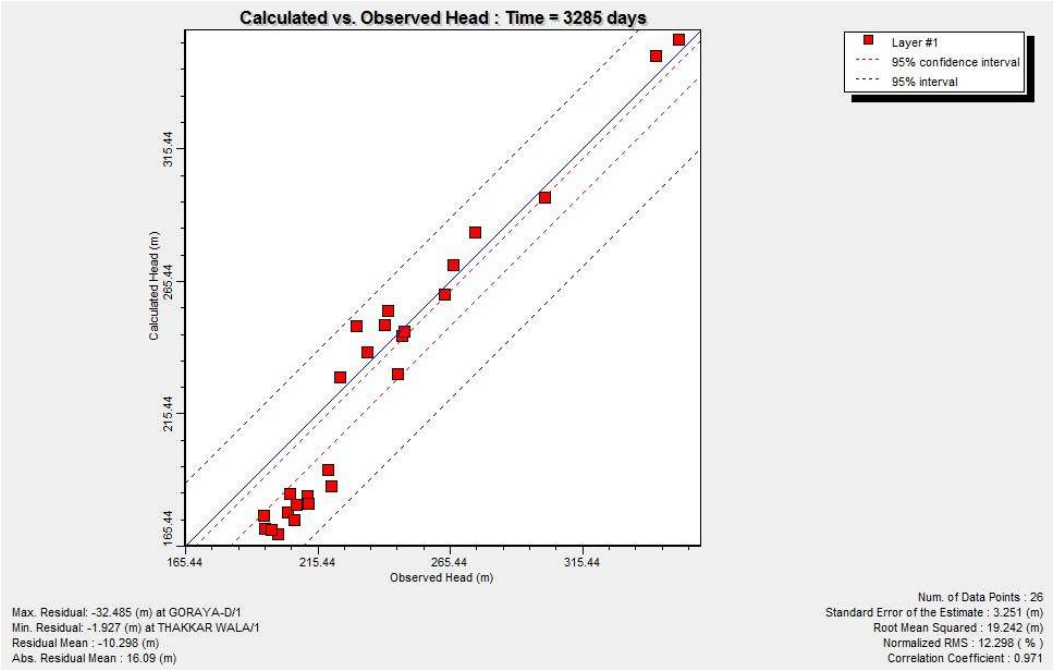
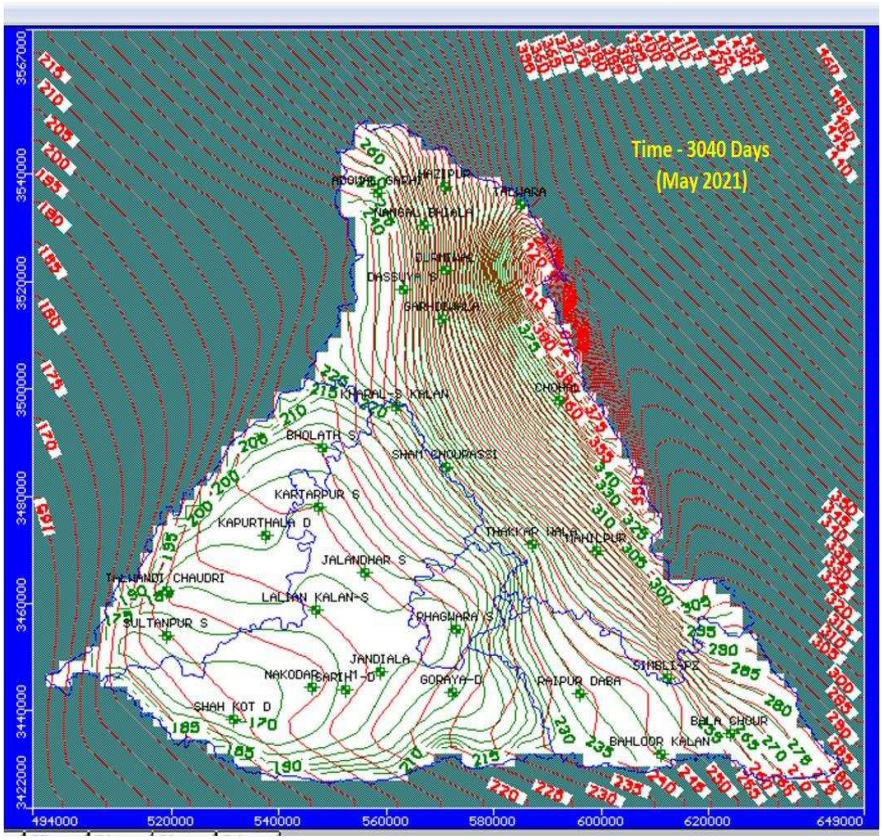


Fig.36-Head Contours for Various Stress Period (Prediction-4)



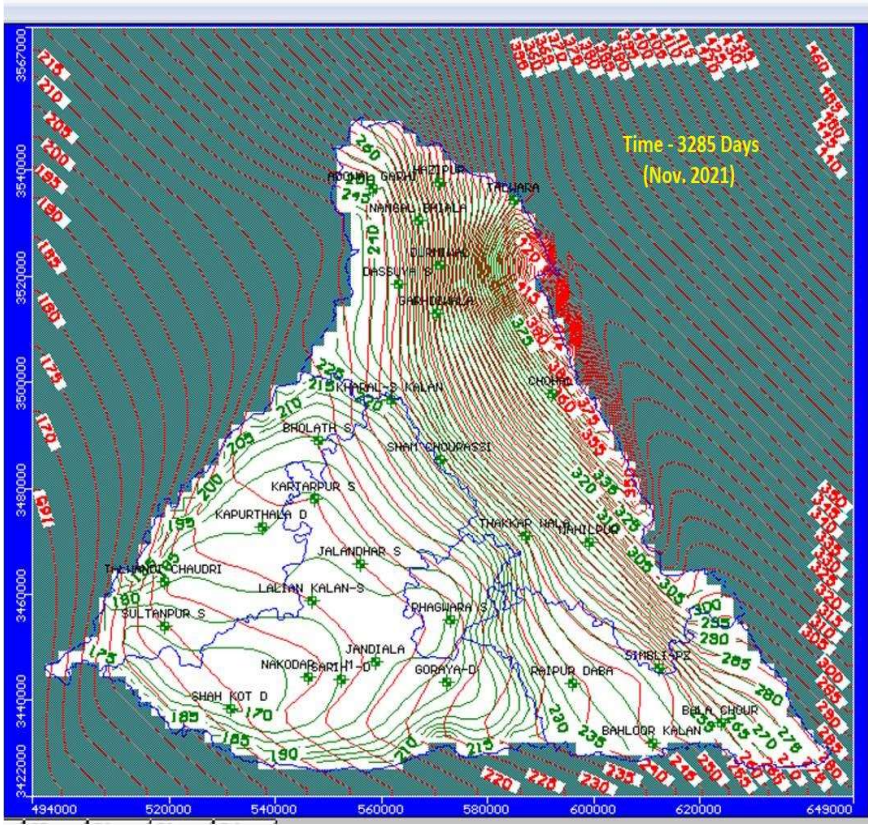


Fig.37-Head Contours for Various Stress Period (Prediction-4)

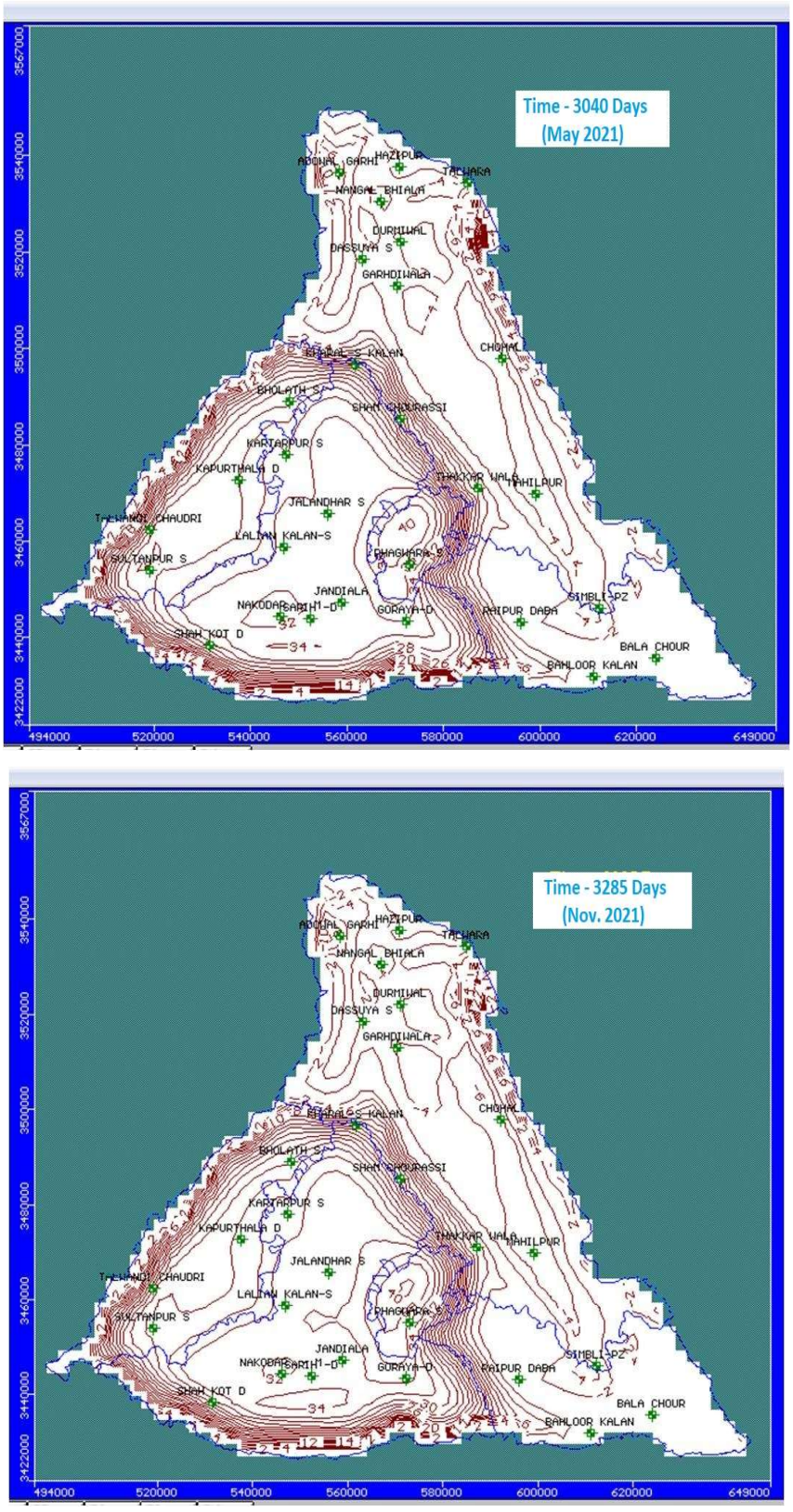
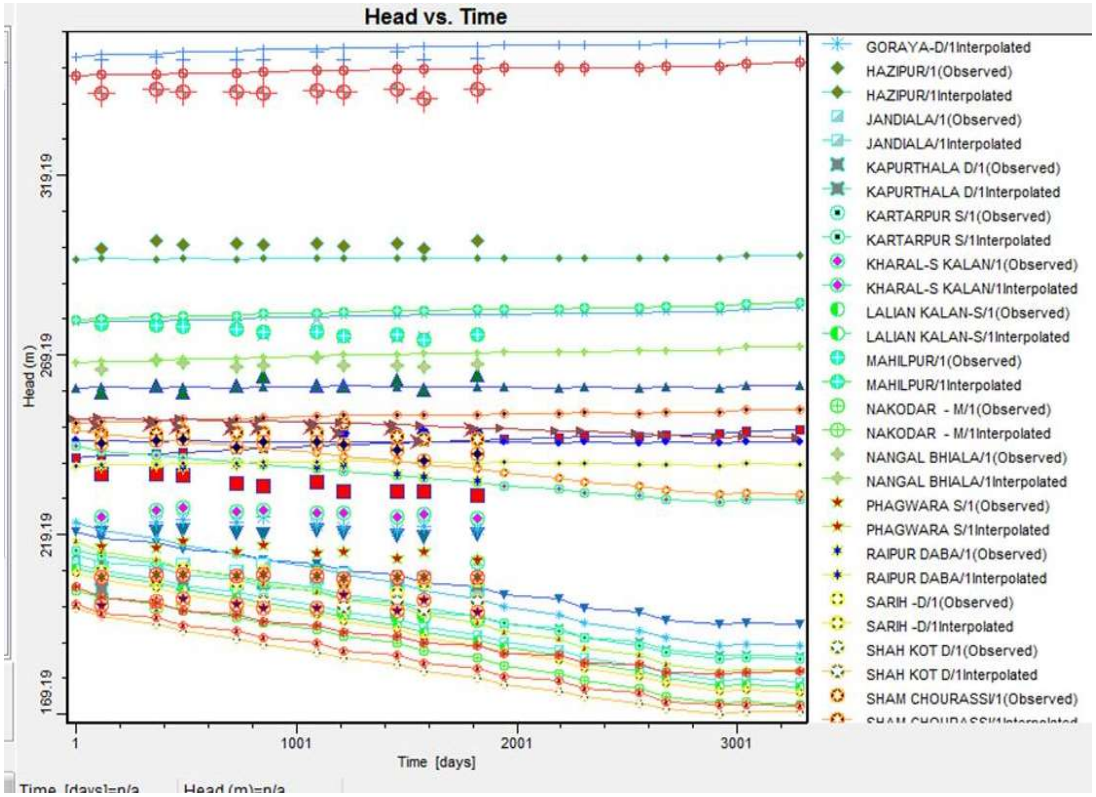


Fig.38-Drawdown Contours for Various Stress Period (Prediction-4)



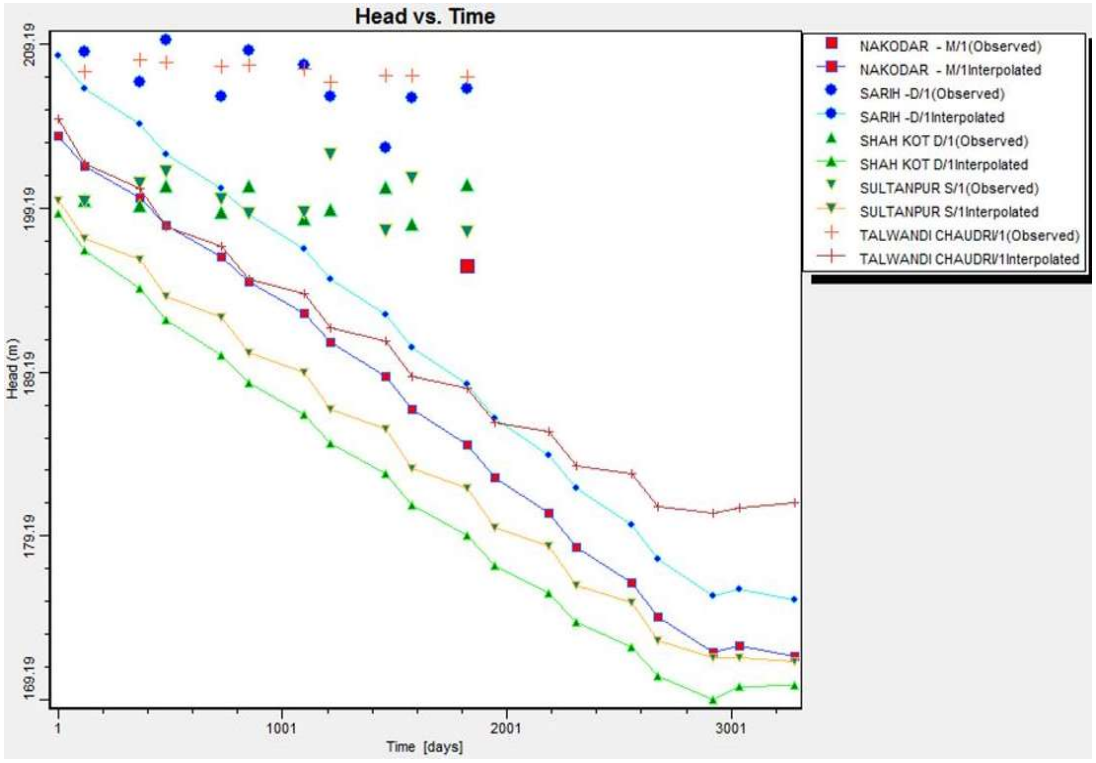


Fig.39-Hydrograph (Prediction-4)

8.0 Conclusion & Way Forward

The study area i.e. Bist Doab Area is covered under 30 administrative blocks of 04 districts viz. Hoshiarpur, Jalandhar, Kapurthala and Nawanshahr districts. Out of 30 blocks, 22 blocks are categorized as over-exploited with stage of ground water development varies from 147 % to 316 % (GWRE 2017), which indicates that aquifers are under tremendous stress to meet the requirement of agriculture, industrial & domestic sectors of the area.

To investigate the response of implementation of proposed demand side and supply side interventions on ground water regime, predictive simulation was done for various scenario/model.The output of scenario for implementation of either demand or supply side interventions or both, in terms of simulated head, draw down contours and hydrograph indicates improvement in the water levels. The predictive scenario no, 4 in which reduction in ground water draft together with enhancement in recharge applied, it seems to be more promising and indicate improvements in water levels in most of the parts of the model area and rise in water levels varies from 0.32 m to 2.57 m during pre-monsoon and 0.60 m to 3.86 m during post monsoon period.

It further indicates that implementation of NAQUIM report will be helpful not only for suggesting the optimal water utilizing strategies by generating additional future scenarios but also in lowering down the stage of ground water development with considerable amount.

Way Forward

- Block-wise impact of proposed NAQUIM interventions may be attempted separately being voluminous data with various outputs.
- Ground water flow modeling can be attempted for multiple layered aquifer systems to study the response of deeper aquifers and transitional region of Kandi and Tarai due to ground water draft and recharge components.
- Assigning ground water draft based on land use pattern may also be attempted for better picture and insight the response of aquifers.
- There is also a need to synergize data of canal net work and two major drainage (black bein& white bein) prevailing in the area to look at their further impact on ground water regime.

References

1. Anderson M P and Woessner W W 2002, Book on Applied Ground Water Modelling-Simulation of Flow and Advective Transport.
2. Ahmed Izrar and Ummar Rashid 2009, Ground Water Flow Modelling of Yamuna-KrishniInterstream, a Part of Central Ganga Plan, Uttar Pradesh.
3. CGWB, NWR, Chandigarh, 2016, Ground Water Year Book of Punjab and Chandigarh Year 2015-16.
4. CGWB, NWR, Chandigarh, 2016, Report on Dynamic Ground Water Resources of Punjab as on 31.03.2013.
5. CGWB, NWR, Chandigarh, Report on Dynamic Ground Water Resources of Punjab as on 31.03.2017.
6. CGWB, NWR, Chandigarh, 2017, Ground Water Year Book of Punjab and Chandigarh Year 2016-17.
7. Ground water Dynamics of Bist Doab Region Using Isotopes, 2014, National Institute of Hydrology, Roorkee.
8. KrishanGopal, Rao, M.S., Purushothaman P, Rawat, Y.S., Kumar C.P, Gupta S., Bhatia A.K., Marwah S., Kaushik Y.B., Angurala M.P. and Singh G.P. 2014, Ground Water Resources in Bist Doab Regio, Punjab, India-An over View.
9. Kumar Vijay, Anandhakumar K.J., Goel M.K. and Das P., 2009, Ground water flow modeling in a canal command of Haryana State, India.
10. Sharma Manishi, Rao M.S., Rathore D.S, KrishanGopal, 2014, An integrated approach to augment the depleting ground water resources in bist-doab, region of Punjab, India.
11. Statistical Abstract of Punjab, 2016, Economic & Statistical Organization, Government of Punjab.
12. Zhou Yangxiao, Li Wenpeng, 2011, A review of regional ground water flow modeling.
13. Zhou Yangxiao, Herath H.M.P.S.D, 2017, Evaluation of alternative conceptual models for ground water modeling.

Annexure-1

Stress period wise Head Observations

Village	Easting	Northing	Surface Elevation	Screen ID	Screen Elevation	Head Observation	Time	Date
HAZIPUR	570863.76	3537602.31	308.37	1	301.10	298.92	120	6/1/2013
HAZIPUR	570863.76	3537602.31	308.37	1	301.10	300.95	365	10/1/2013
HAZIPUR	570863.76	3537602.31	308.37	1	301.10	299.99	485	6/1/2014
HAZIPUR	570863.76	3537602.31	308.37	1	301.10	300.35	730	10/1/2014
HAZIPUR	570863.76	3537602.31	308.37	1	301.10	299.90	850	6/1/2015
HAZIPUR	570863.76	3537602.31	308.37	1	301.10	300.36	1095	10/1/2015
HAZIPUR	570863.76	3537602.31	308.37	1	301.10	299.50	1215	6/1/2016
HAZIPUR	570863.76	3537602.31	308.37	1	301.10	300.40	1460	10/10/2016
HAZIPUR	570863.76	3537602.31	308.37	1	301.10	298.64	1580	6/1/2017
HAZIPUR	570863.76	3537602.31	308.37	1	301.10	301.10	1825	10/1/2017
NANGAL BHIALA	566973.08	3530494	277.77	1	268.35	265.24	120	6/1/2013
NANGAL BHIALA	566973.08	3530494	277.77	1	268.35	267.89	365	10/1/2013
NANGAL BHIALA	566973.08	3530494	277.77	1	268.35	267.08	485	6/1/2014
NANGAL BHIALA	566973.08	3530494	277.77	1	268.35	265.97	730	10/1/2014
NANGAL BHIALA	566973.08	3530494	277.77	1	268.35	266.29	850	6/1/2015
NANGAL BHIALA	566973.08	3530494	277.77	1	268.35	268.35	1095	10/1/2015
NANGAL BHIALA	566973.08	3530494	277.77	1	268.35	266.39	1215	6/1/2016
NANGAL BHIALA	566973.08	3530494	277.77	1	268.35	266.31	1460	10/10/2016
NANGAL BHIALA	566973.08	3530494	277.77	1	268.35	265.97	1580	6/1/2017
NANGAL BHIALA	566973.08	3530494	277.77	1	268.35	266.49	1825	10/1/2017
TALWARA	585065.14	3534323.43	354.17	1	343.10	342.09	120	6/1/2013
TALWARA	585065.14	3534323.43	354.17	1	343.10	343.00	365	10/1/2013

Village	Easting	Northing	Surface Elevation	Screen ID	Screen Elevation	Head Observation	Time	Date
TALWARA	585065.14	3534323.43	354.17	1	343.10	342.41	485	6/1/2014
TALWARA	585065.14	3534323.43	354.17	1	343.10	342.55	730	10/1/2014
TALWARA	585065.14	3534323.43	354.17	1	343.10	342.10	850	6/1/2015
TALWARA	585065.14	3534323.43	354.17	1	343.10	342.72	1095	10/1/2015
TALWARA	585065.14	3534323.43	354.17	1	343.10	342.53	1215	6/1/2016
TALWARA	585065.14	3534323.43	354.17	1	343.10	343.02	1460	10/10/2016
TALWARA	585065.14	3534323.43	354.17	1	343.10	340.56	1580	6/1/2017
TALWARA	585065.14	3534323.43	354.17	1	343.10	343.10	1825	10/1/2017
BHAMNAUR	589892.32	3522817.17	487.91	1	473	470.36	120	6/1/2013
BHAMNAUR	589892.32	3522817.17	487.91	1	473	475.48	365	10/1/2013
BHAMNAUR	589892.32	3522817.17	487.91	1	473	472.79	485	6/1/2014
BHAMNAUR	589892.32	3522817.17	487.91	1	473	472.64	730	10/1/2014
BHAMNAUR	589892.32	3522817.17	487.91	1	473	470.97	850	6/1/2015
BHAMNAUR	589892.32	3522817.17	487.91	1	473	473.71	1095	10/1/2015
BHAMNAUR	589892.32	3522817.17	487.91	1	473	473.06	1215	6/1/2016
BHAMNAUR	589892.32	3522817.17	487.91	1	473	472.16	1460	10/10/2016
BHAMNAUR	589892.32	3522817.17	487.91	1	473	472.94	1580	6/1/2017
BHAMNAUR	589892.32	3522817.17	487.91	1	473	472.16	1825	10/1/2017
DURMIWAL	571102.77	3522054.12	293.20	1	290.11	289.09	120	6/1/2013
DURMIWAL	571102.77	3522054.12	293.20	1	290.11	290.11	365	10/1/2013
DURMIWAL	571102.77	3522054.12	293.20	1	290.11	289.48	485	6/1/2014
DURMIWAL	571102.77	3522054.12	293.20	1	290.11	289.32	730	10/1/2014
DURMIWAL	571102.77	3522054.12	293.20	1	290.11	288.66	850	6/1/2015
DURMIWAL	571102.77	3522054.12	293.20	1	290.11	289.05	1095	10/1/2015

Village	Easting	Northing	Surface Elevation	Screen ID	Screen Elevation	Head Observation	Time	Date
DURMIWAL	571102.77	3522054.12	293.20	1	290.11	287.83	1215	6/1/2016
DURMIWAL	571102.77	3522054.12	293.20	1	290.11	288.31	1460	10/10/2016
DURMIWAL	571102.77	3522054.12	293.20	1	290.11	287.10	1580	6/1/2017
DURMIWAL	571102.77	3522054.12	293.20	1	290.11	287.40	1825	10/1/2017
SHAM CHOURASSI	571091.21	3485413.27	259.60	1	250.14	247.25	120	6/1/2013
SHAM CHOURASSI	571091.21	3485413.27	259.60	1	250.14	247.32	365	10/1/2013
SHAM CHOURASSI	571091.21	3485413.27	259.60	1	250.14	247.84	485	6/1/2014
SHAM CHOURASSI	571091.21	3485413.27	259.60	1	250.14	247.53	730	10/1/2014
SHAM CHOURASSI	571091.21	3485413.27	259.60	1	250.14	247.55	850	6/1/2015
SHAM CHOURASSI	571091.21	3485413.27	259.60	1	250.14	247.80	1095	10/1/2015
SHAM CHOURASSI	571091.21	3485413.27	259.60	1	250.14	250.14	1215	6/1/2016
SHAM CHOURASSI	571091.21	3485413.27	259.60	1	250.14	246.44	1460	10/10/2016
SHAM CHOURASSI	571091.21	3485413.27	259.60	1	250.14	245.84	1580	6/1/2017
SHAM CHOURASSI	571091.21	3485413.27	259.60	1	250.14	245.80	1825	10/1/2017
CHOHAL	592219.06	3497741.72	355.30	1	353.5	351.32	120	6/1/2013
CHOHAL	592219.06	3497741.72	355.30	1	353.5	352.05	365	10/1/2013
CHOHAL	592219.06	3497741.72	355.30	1	353.5	351.36	485	6/1/2014
CHOHAL	592219.06	3497741.72	355.30	1	353.5	351.45	730	10/1/2014
CHOHAL	592219.06	3497741.72	355.30	1	353.5	351.35	850	6/1/2015
CHOHAL	592219.06	3497741.72	355.30	1	353.5	353.5	1095	10/1/2015
CHOHAL	592219.06	3497741.72	355.30	1	353.5	351.38	1215	6/1/2016
CHOHAL	592219.06	3497741.72	355.30	1	353.5	353.43	1460	10/10/2016
CHOHAL	592219.06	3497741.72	355.30	1	353.5	351.4	1580	6/1/2017
CHOHAL	592219.06	3497741.72	355.30	1	353.5	351.73	1825	10/1/2017

Village	Easting	Northing	Surface Elevation	Screen ID	Screen Elevation	Head Observation	Time	Date
THAKKAR WALA	587173.11	3470909.81	259.93	1	249.9	249.37	120	6/1/2013
THAKKAR WALA	587173.11	3470909.81	259.93	1	249.9	249.9	365	10/1/2013
THAKKAR WALA	587173.11	3470909.81	259.93	1	249.9	249.26	485	6/1/2014
THAKKAR WALA	587173.11	3470909.81	259.93	1	249.9	248.67	730	10/1/2014
THAKKAR WALA	587173.11	3470909.81	259.93	1	249.9	248.67	850	6/1/2015
THAKKAR WALA	587173.11	3470909.81	259.93	1	249.9	249.27	1095	10/1/2015
THAKKAR WALA	587173.11	3470909.81	259.93	1	249.9	247.39	1215	6/1/2016
THAKKAR WALA	587173.11	3470909.81	259.93	1	249.9	248.88	1460	10/10/2016
THAKKAR WALA	587173.11	3470909.81	259.93	1	249.9	244.89	1580	6/1/2017
THAKKAR WALA	587173.11	3470909.81	259.93	1	249.9	248.22	1825	10/1/2017
DASSUYA S	563107.2	3518461.03	250.52	1	243.62	242.32	120	6/1/2013
DASSUYA S	563107.2	3518461.03	250.52	1	243.62	243.19	365	10/1/2013
DASSUYA S	563107.2	3518461.03	250.52	1	243.62	243.62	485	6/1/2014
DASSUYA S	563107.2	3518461.03	250.52	1	243.62	242.57	730	10/1/2014
DASSUYA S	563107.2	3518461.03	250.52	1	243.62	242.13	850	6/1/2015
DASSUYA S	563107.2	3518461.03	250.52	1	243.62	242.97	1095	10/1/2015
DASSUYA S	563107.2	3518461.03	250.52	1	243.62	241.65	1215	6/1/2016
DASSUYA S	563107.2	3518461.03	250.52	1	243.62	240.17	1460	10/10/2016
DASSUYA S	563107.2	3518461.03	250.52	1	243.62	241.82	1580	6/1/2017
DASSUYA S	563107.2	3518461.03	250.52	1	243.62	240.68	1825	10/1/2017
ADOWAL GARHI	558455.38	3536446.17	251.85	1	235.97	235.91	120	6/1/2013
ADOWAL GARHI	558455.38	3536446.17	251.85	1	235.97	235.97	365	10/1/2013
ADOWAL GARHI	558455.38	3536446.17	251.85	1	235.97	235.56	485	6/1/2014
ADOWAL GARHI	558455.38	3536446.17	251.85	1	235.97	233.54	730	10/1/2014

Village	Easting	Northing	Surface Elevation	Screen ID	Screen Elevation	Head Observation	Time	Date
ADOWAL GARHI	558455.38	3536446.17	251.85	1	235.97	232.81	850	6/1/2015
ADOWAL GARHI	558455.38	3536446.17	251.85	1	235.97	233.94	1095	10/1/2015
ADOWAL GARHI	558455.38	3536446.17	251.85	1	235.97	231.36	1215	6/1/2016
ADOWAL GARHI	558455.38	3536446.17	251.85	1	235.97	231.2	1460	10/10/2016
ADOWAL GARHI	558455.38	3536446.17	251.85	1	235.97	231.18	1580	6/1/2017
ADOWAL GARHI	558455.38	3536446.17	251.85	1	235.97	230.1	1825	10/1/2017
GARHDIWALA	570244.71	3512964.88	289.79	1	278.9	278.09	120	6/1/2013
GARHDIWALA	570244.71	3512964.88	289.79	1	278.9	278.68	365	10/1/2013
GARHDIWALA	570244.71	3512964.88	289.79	1	278.9	277.02	485	6/1/2014
GARHDIWALA	570244.71	3512964.88	289.79	1	278.9	277.41	730	10/1/2014
GARHDIWALA	570244.71	3512964.88	289.79	1	278.9	274.98	850	6/1/2015
GARHDIWALA	570244.71	3512964.88	289.79	1	278.9	278.9	1095	10/1/2015
GARHDIWALA	570244.71	3512964.88	289.79	1	278.9	274.27	1215	6/1/2016
GARHDIWALA	570244.71	3512964.88	289.79	1	278.9	274.27	1460	10/10/2016
GARHDIWALA	570244.71	3512964.88	289.79	1	278.9	274.14	1580	6/1/2017
GARHDIWALA	570244.71	3512964.88	289.79	1	278.9	275	1825	10/1/2017
MAHILPUR	599072.57	3469784.03	296.19	1	277.73	277.73	120	6/1/2013
MAHILPUR	599072.57	3469784.03	296.19	1	277.73	277.61	365	10/1/2013
MAHILPUR	599072.57	3469784.03	296.19	1	277.73	277	485	6/1/2014
MAHILPUR	599072.57	3469784.03	296.19	1	277.73	276.44	730	10/1/2014
MAHILPUR	599072.57	3469784.03	296.19	1	277.73	275.75	850	6/1/2015
MAHILPUR	599072.57	3469784.03	296.19	1	277.73	275.64	1095	10/1/2015
MAHILPUR	599072.57	3469784.03	296.19	1	277.73	274.6	1215	6/1/2016
MAHILPUR	599072.57	3469784.03	296.19	1	277.73	274.8	1460	10/10/2016

Village	Easting	Northing	Surface Elevation	Screen ID	Screen Elevation	Head Observation	Time	Date
MAHILPUR	599072.57	3469784.03	296.19	1	277.73	273.44	1580	6/1/2017
MAHILPUR	599072.57	3469784.03	296.19	1	277.73	274.78	1825	10/1/2017
SIMBLI-Pz	612326.24	3446053.72	260.70	1	245.88	244.6	120	6/1/2013
SIMBLI-Pz	612326.24	3446053.72	260.70	1	245.88	245.28	365	10/1/2013
SIMBLI-Pz	612326.24	3446053.72	260.70	1	245.88	245.88	485	6/1/2014
SIMBLI-Pz	612326.24	3446053.72	260.70	1	245.88	243.34	730	10/1/2014
SIMBLI-Pz	612326.24	3446053.72	260.70	1	245.88	245.1	850	6/1/2015
SIMBLI-Pz	612326.24	3446053.72	260.70	1	245.88	244.9	1095	10/1/2015
SIMBLI-Pz	612326.24	3446053.72	260.70	1	245.88	244.27	1215	6/1/2016
SIMBLI-Pz	612326.24	3446053.72	260.70	1	245.88	242.74	1460	10/10/2016
SIMBLI-Pz	612326.24	3446053.72	260.70	1	245.88	239.79	1580	6/1/2017
SIMBLI-Pz	612326.24	3446053.72	260.70	1	245.88	241.8	1825	10/1/2017
KARTARPUR S	547382.7	3478043.15	233.21	1	217.62	214.52	120	6/1/2013
KARTARPUR S	547382.7	3478043.15	233.21	1	217.62	217.62	365	10/1/2013
KARTARPUR S	547382.7	3478043.15	233.21	1	217.62	214.45	485	6/1/2014
KARTARPUR S	547382.7	3478043.15	233.21	1	217.62	216.44	730	10/1/2014
KARTARPUR S	547382.7	3478043.15	233.21	1	217.62	216.08	850	6/1/2015
KARTARPUR S	547382.7	3478043.15	233.21	1	217.62	215.82	1095	10/1/2015
KARTARPUR S	547382.7	3478043.15	233.21	1	217.62	214.45	1215	6/1/2016
KARTARPUR S	547382.7	3478043.15	233.21	1	217.62	214.57	1460	10/10/2016
KARTARPUR S	547382.7	3478043.15	233.21	1	217.62	214.32	1580	6/1/2017
KARTARPUR S	547382.7	3478043.15	233.21	1	217.62	211.31	1825	10/1/2017
JALANDHAR S	556027.8	3465770.7	235.51	1	202.46	201.45	120	6/1/2013
JALANDHAR S	556027.8	3465770.7	235.51	1	202.46	201.71	365	10/1/2013

Village	Easting	Northing	Surface Elevation	Screen ID	Screen Elevation	Head Observation	Time	Date
JALANDHAR S	556027.8	3465770.7	235.51	1	202.46	196.49	485	6/1/2014
JALANDHAR S	556027.8	3465770.7	235.51	1	202.46	201.98	730	10/1/2014
JALANDHAR S	556027.8	3465770.7	235.51	1	202.46	202.15	850	6/1/2015
JALANDHAR S	556027.8	3465770.7	235.51	1	202.46	199.87	1095	10/1/2015
JALANDHAR S	556027.8	3465770.7	235.51	1	202.46	199.59	1215	6/1/2016
JALANDHAR S	556027.8	3465770.7	235.51	1	202.46	202.46	1460	10/10/2016
JALANDHAR S	556027.8	3465770.7	235.51	1	202.46	198.76	1580	6/1/2017
JALANDHAR S	556027.8	3465770.7	235.51	1	202.46	201.64	1825	10/1/2017
SHAH KOT D	531504.25	3438453.25	224.02	1	200.59	199.63	120	6/1/2013
SHAH KOT D	531504.25	3438453.25	224.02	1	200.59	199.32	365	10/1/2013
SHAH KOT D	531504.25	3438453.25	224.02	1	200.59	200.53	485	6/1/2014
SHAH KOT D	531504.25	3438453.25	224.02	1	200.59	198.9	730	10/1/2014
SHAH KOT D	531504.25	3438453.25	224.02	1	200.59	200.57	850	6/1/2015
SHAH KOT D	531504.25	3438453.25	224.02	1	200.59	198.56	1095	10/1/2015
SHAH KOT D	531504.25	3438453.25	224.02	1	200.59	199.13	1215	6/1/2016
SHAH KOT D	531504.25	3438453.25	224.02	1	200.59	200.42	1460	10/10/2016
SHAH KOT D	531504.25	3438453.25	224.02	1	200.59	198.19	1580	6/1/2017
SHAH KOT D	531504.25	3438453.25	224.02	1	200.59	200.59	1825	10/1/2017
NAKODAR - M	546236.75	3444479.92	229.84	1	202.51	201.28	120	6/1/2013
NAKODAR - M	546236.75	3444479.92	229.84	1	202.51	201.51	365	10/1/2013
NAKODAR - M	546236.75	3444479.92	229.84	1	202.51	201.08	485	6/1/2014
NAKODAR - M	546236.75	3444479.92	229.84	1	202.51	198.7	730	10/1/2014
NAKODAR - M	546236.75	3444479.92	229.84	1	202.51	199.53	850	6/1/2015
NAKODAR - M	546236.75	3444479.92	229.84	1	202.51	197.98	1095	10/1/2015

Village	Easting	Northing	Surface Elevation	Screen ID	Screen Elevation	Head Observation	Time	Date
NAKODAR - M	546236.75	3444479.92	229.84	1	202.51	202.51	1215	6/1/2016
NAKODAR - M	546236.75	3444479.92	229.84	1	202.51	195.56	1460	10/10/2016
NAKODAR - M	546236.75	3444479.92	229.84	1	202.51	194.1	1580	6/1/2017
NAKODAR - M	546236.75	3444479.92	229.84	1	202.51	195.66	1825	10/1/2017
PHILLOUR D	575688.02	3433104.4	244.88	1	225	228.68	120	6/1/2013
PHILLOUR D	575688.02	3433104.4	244.88	1	225	228.45	365	10/1/2013
PHILLOUR D	575688.02	3433104.4	244.88	1	225	228.4	485	6/1/2014
PHILLOUR D	575688.02	3433104.4	244.88	1	225	229.16	730	10/1/2014
PHILLOUR D	575688.02	3433104.4	244.88	1	225	229.4	850	6/1/2015
PHILLOUR D	575688.02	3433104.4	244.88	1	225	228.8	1095	10/1/2015
PHILLOUR D	575688.02	3433104.4	244.88	1	225	228.59	1215	6/1/2016
PHILLOUR D	575688.02	3433104.4	244.88	1	225	227.44	1460	10/10/2016
PHILLOUR D	575688.02	3433104.4	244.88	1	225	227.91	1580	6/1/2017
PHILLOUR D	575688.02	3433104.4	244.88	1	225	228.23	1825	10/1/2017
GORAYA-D	572171.12	3443393.75	244.12	1	224.03	223.1	120	6/1/2013
GORAYA-D	572171.12	3443393.75	244.12	1	224.03	222.44	365	10/1/2013
GORAYA-D	572171.12	3443393.75	244.12	1	224.03	223.4	485	6/1/2014
GORAYA-D	572171.12	3443393.75	244.12	1	224.03	222.64	730	10/1/2014
GORAYA-D	572171.12	3443393.75	244.12	1	224.03	224.03	850	6/1/2015
GORAYA-D	572171.12	3443393.75	244.12	1	224.03	221.84	1095	10/1/2015
GORAYA-D	572171.12	3443393.75	244.12	1	224.03	221.11	1215	6/1/2016
GORAYA-D	572171.12	3443393.75	244.12	1	224.03	220.32	1460	10/10/2016
GORAYA-D	572171.12	3443393.75	244.12	1	224.03	221.54	1580	6/1/2017
GORAYA-D	572171.12	3443393.75	244.12	1	224.03	220.62	1825	10/1/2017

Village	Easting	Northing	Surface Elevation	Screen ID	Screen Elevation	Head Observation	Time	Date
SARIH -D	552435.8	3444047.13	235.61	1	209.45	208.7	120	6/1/2013
SARIH -D	552435.8	3444047.13	235.61	1	209.45	206.91	365	10/1/2013
SARIH -D	552435.8	3444047.13	235.61	1	209.45	209.45	485	6/1/2014
SARIH -D	552435.8	3444047.13	235.61	1	209.45	206.01	730	10/1/2014
SARIH -D	552435.8	3444047.13	235.61	1	209.45	208.78	850	6/1/2015
SARIH -D	552435.8	3444047.13	235.61	1	209.45	207.89	1095	10/1/2015
SARIH -D	552435.8	3444047.13	235.61	1	209.45	205.98	1215	6/1/2016
SARIH -D	552435.8	3444047.13	235.61	1	209.45	202.9	1460	10/10/2016
SARIH -D	552435.8	3444047.13	235.61	1	209.45	205.92	1580	6/1/2017
SARIH -D	552435.8	3444047.13	235.61	1	209.45	206.48	1825	10/1/2017
KHARAL-S KALAN	561659.78	3496591.3	239.59	1	226.6	224.19	120	6/1/2013
KHARAL-S KALAN	561659.78	3496591.3	239.59	1	226.6	226.13	365	10/1/2013
KHARAL-S KALAN	561659.78	3496591.3	239.59	1	226.6	226.6	485	6/1/2014
KHARAL-S KALAN	561659.78	3496591.3	239.59	1	226.6	225.76	730	10/1/2014
KHARAL-S KALAN	561659.78	3496591.3	239.59	1	226.6	225.89	850	6/1/2015
KHARAL-S KALAN	561659.78	3496591.3	239.59	1	226.6	225.09	1095	10/1/2015
KHARAL-S KALAN	561659.78	3496591.3	239.59	1	226.6	225.1	1215	6/1/2016
KHARAL-S KALAN	561659.78	3496591.3	239.59	1	226.6	224.14	1460	10/10/2016
KHARAL-S KALAN	561659.78	3496591.3	239.59	1	226.6	224.79	1580	6/1/2017
KHARAL-S KALAN	561659.78	3496591.3	239.59	1	226.6	223.66	1825	10/1/2017
LALIAN KALAN-S	546808.71	3458798.35	231.70	1	200.26	200.26	120	6/1/2013
LALIAN KALAN-S	546808.71	3458798.35	231.70	1	200.26	199.07	365	10/1/2013
LALIAN KALAN-S	546808.71	3458798.35	231.70	1	200.26	200.25	485	6/1/2014
LALIAN KALAN-S	546808.71	3458798.35	231.70	1	200.26	197.85	730	10/1/2014

Village	Easting	Northing	Surface Elevation	Screen ID	Screen Elevation	Head Observation	Time	Date
LALIAN KALAN-S	546808.71	3458798.35	231.70	1	200.26	199	850	6/1/2015
LALIAN KALAN-S	546808.71	3458798.35	231.70	1	200.26	198	1095	10/1/2015
LALIAN KALAN-S	546808.71	3458798.35	231.70	1	200.26	197.59	1215	6/1/2016
LALIAN KALAN-S	546808.71	3458798.35	231.70	1	200.26	196.34	1460	10/10/2016
LALIAN KALAN-S	546808.71	3458798.35	231.70	1	200.26	196.55	1580	6/1/2017
LALIAN KALAN-S	546808.71	3458798.35	231.70	1	200.26	195.26	1825	10/1/2017
JANDIALA	558773.81	3447313.08	236.35	1	210.83	210.12	120	6/1/2013
JANDIALA	558773.81	3447313.08	236.35	1	210.83	209.23	365	10/1/2013
JANDIALA	558773.81	3447313.08	236.35	1	210.83	210.5	485	6/1/2014
JANDIALA	558773.81	3447313.08	236.35	1	210.83	208.72	730	10/1/2014
JANDIALA	558773.81	3447313.08	236.35	1	210.83	210.83	850	6/1/2015
JANDIALA	558773.81	3447313.08	236.35	1	210.83	207.3	1095	10/1/2015
JANDIALA	558773.81	3447313.08	236.35	1	210.83	208.13	1215	6/1/2016
JANDIALA	558773.81	3447313.08	236.35	1	210.83	205.09	1460	10/10/2016
JANDIALA	558773.81	3447313.08	236.35	1	210.83	206.1	1580	6/1/2017
JANDIALA	558773.81	3447313.08	236.35	1	210.83	204.07	1825	10/1/2017
SULTANPUR S	519049.37	3453939.49	214.88	1	202.48	199.58	120	6/1/2013
SULTANPUR S	519049.37	3453939.49	214.88	1	202.48	200.72	365	10/1/2013
SULTANPUR S	519049.37	3453939.49	214.88	1	202.48	201.45	485	6/1/2014
SULTANPUR S	519049.37	3453939.49	214.88	1	202.48	199.75	730	10/1/2014
SULTANPUR S	519049.37	3453939.49	214.88	1	202.48	198.85	850	6/1/2015
SULTANPUR S	519049.37	3453939.49	214.88	1	202.48	198.9	1095	10/1/2015
SULTANPUR S	519049.37	3453939.49	214.88	1	202.48	202.48	1215	6/1/2016
SULTANPUR S	519049.37	3453939.49	214.88	1	202.48	197.84	1460	10/10/2016

Village	Easting	Northing	Surface Elevation	Screen ID	Screen Elevation	Head Observation	Time	Date
SULTANPUR S	519049.37	3453939.49	214.88	1	202.48	201.02	1580	6/1/2017
SULTANPUR S	519049.37	3453939.49	214.88	1	202.48	197.74	1825	10/1/2017
BHOLATH S	547992.31	3488975.77	228.40	1	220.55	219.7	120	6/1/2013
BHOLATH S	547992.31	3488975.77	228.40	1	220.55	220.18	365	10/1/2013
BHOLATH S	547992.31	3488975.77	228.40	1	220.55	220.55	485	6/1/2014
BHOLATH S	547992.31	3488975.77	228.40	1	220.55	219.77	730	10/1/2014
BHOLATH S	547992.31	3488975.77	228.40	1	220.55	219.15	850	6/1/2015
BHOLATH S	547992.31	3488975.77	228.40	1	220.55	220.26	1095	10/1/2015
BHOLATH S	547992.31	3488975.77	228.40	1	220.55	219.53	1215	6/1/2016
BHOLATH S	547992.31	3488975.77	228.40	1	220.55	218.78	1460	10/10/2016
BHOLATH S	547992.31	3488975.77	228.40	1	220.55	218.66	1580	6/1/2017
BHOLATH S	547992.31	3488975.77	228.40	1	220.55	219.14	1825	10/1/2017
KAPURTHALA D	537608.86	3472584.77	227.76	1	209.18	203.96	120	6/1/2013
KAPURTHALA D	537608.86	3472584.77	227.76	1	209.18	206.51	365	10/1/2013
KAPURTHALA D	537608.86	3472584.77	227.76	1	209.18	205.54	485	6/1/2014
KAPURTHALA D	537608.86	3472584.77	227.76	1	209.18	205.93	730	10/1/2014
KAPURTHALA D	537608.86	3472584.77	227.76	1	209.18	205.71	850	6/1/2015
KAPURTHALA D	537608.86	3472584.77	227.76	1	209.18	209.18	1095	10/1/2015
KAPURTHALA D	537608.86	3472584.77	227.76	1	209.18	206.97	1215	6/1/2016
KAPURTHALA D	537608.86	3472584.77	227.76	1	209.18	204.58	1460	10/10/2016
KAPURTHALA D	537608.86	3472584.77	227.76	1	209.18	206.83	1580	6/1/2017
KAPURTHALA D	537608.86	3472584.77	227.76	1	209.18	205.12	1825	10/1/2017
PHAGWARA S	573042.46	3455253.31	241.46	1	217.41	215.79	120	6/1/2013
PHAGWARA S	573042.46	3455253.31	241.46	1	217.41	215.56	365	10/1/2013

Village	Easting	Northing	Surface Elevation	Screen ID	Screen Elevation	Head Observation	Time	Date
PHAGWARA S	573042.46	3455253.31	241.46	1	217.41	217.41	485	6/1/2014
PHAGWARA S	573042.46	3455253.31	241.46	1	217.41	214.54	730	10/1/2014
PHAGWARA S	573042.46	3455253.31	241.46	1	217.41	216.36	850	6/1/2015
PHAGWARA S	573042.46	3455253.31	241.46	1	217.41	214.01	1095	10/1/2015
PHAGWARA S	573042.46	3455253.31	241.46	1	217.41	214.28	1215	6/1/2016
PHAGWARA S	573042.46	3455253.31	241.46	1	217.41	212.54	1460	10/10/2016
PHAGWARA S	573042.46	3455253.31	241.46	1	217.41	214.36	1580	6/1/2017
PHAGWARA S	573042.46	3455253.31	241.46	1	217.41	212.09	1825	10/1/2017
TALWANDI CHAUDRI	519034.03	3462405.67	217.53	1	208.21	207.48	120	6/1/2013
TALWANDI CHAUDRI	519034.03	3462405.67	217.53	1	208.21	208.21	365	10/1/2013
TALWANDI CHAUDRI	519034.03	3462405.67	217.53	1	208.21	208.04	485	6/1/2014
TALWANDI CHAUDRI	519034.03	3462405.67	217.53	1	208.21	207.8	730	10/1/2014
TALWANDI CHAUDRI	519034.03	3462405.67	217.53	1	208.21	207.9	850	6/1/2015
TALWANDI CHAUDRI	519034.03	3462405.67	217.53	1	208.21	207.7	1095	10/1/2015
TALWANDI CHAUDRI	519034.03	3462405.67	217.53	1	208.21	206.84	1215	6/1/2016
TALWANDI CHAUDRI	519034.03	3462405.67	217.53	1	208.21	207.28	1460	10/10/2016

Village	Easting	Northing	Surface Elevation	Screen ID	Screen Elevation	Head Observation	Time	Date
TALWANDI CHAUDRI	519034.03	3462405.67	217.53	1	208.21	207.28	1580	6/1/2017
TALWANDI CHAUDRI	519034.03	3462405.67	217.53	1	208.21	207.21	1825	10/1/2017
RAHON	607337.14	3436610.43	262.01	1	250	252.31	120	6/1/2013
RAHON	607337.14	3436610.43	262.01	1	250	252.28	365	10/1/2013
RAHON	607337.14	3436610.43	262.01	1	250	252.28	485	6/1/2014
RAHON	607337.14	3436610.43	262.01	1	250	252.6	730	10/1/2014
RAHON	607337.14	3436610.43	262.01	1	250	252.97	850	6/1/2015
RAHON	607337.14	3436610.43	262.01	1	250	252.87	1095	10/1/2015
RAHON	607337.14	3436610.43	262.01	1	250	252.89	1215	6/1/2016
RAHON	607337.14	3436610.43	262.01	1	250	252.26	1460	10/10/2016
RAHON	607337.14	3436610.43	262.01	1	250	252.84	1580	6/1/2017
RAHON	607337.14	3436610.43	262.01	1	250	252.18	1825	10/1/2017
BALA CHOUR	624046.09	3435869.13	278.21	1	263.51	258.84	120	6/1/2013
BALA CHOUR	624046.09	3435869.13	278.21	1	263.51	260.55	365	10/1/2013
BALA CHOUR	624046.09	3435869.13	278.21	1	263.51	259.01	485	6/1/2014
BALA CHOUR	624046.09	3435869.13	278.21	1	263.51	260.68	730	10/1/2014
BALA CHOUR	624046.09	3435869.13	278.21	1	263.51	263.21	850	6/1/2015
BALA CHOUR	624046.09	3435869.13	278.21	1	263.51	260.73	1095	10/1/2015
BALA CHOUR	624046.09	3435869.13	278.21	1	263.51	260.65	1215	6/1/2016
BALA CHOUR	624046.09	3435869.13	278.21	1	263.51	262.11	1460	10/10/2016
BALA CHOUR	624046.09	3435869.13	278.21	1	263.51	259.55	1580	6/1/2017
BALA CHOUR	624046.09	3435869.13	278.21	1	263.51	263.51	1825	10/1/2017
RAIPUR DABA	595879.48	3443212.79	252.90	1	238.67	238.13	120	6/1/2013

Village	Easting	Northing	Surface Elevation	Screen ID	Screen Elevation	Head Observation	Time	Date
RAIPUR DABA	595879.48	3443212.79	252.90	1	238.67	238.51	365	10/1/2013
RAIPUR DABA	595879.48	3443212.79	252.90	1	238.67	237.93	485	6/1/2014
RAIPUR DABA	595879.48	3443212.79	252.90	1	238.67	238.55	730	10/1/2014
RAIPUR DABA	595879.48	3443212.79	252.90	1	238.67	238.67	850	6/1/2015
RAIPUR DABA	595879.48	3443212.79	252.90	1	238.67	238.02	1095	10/1/2015
RAIPUR DABA	595879.48	3443212.79	252.90	1	238.67	238.52	1215	6/1/2016
RAIPUR DABA	595879.48	3443212.79	252.90	1	238.67	236.15	1460	10/10/2016
RAIPUR DABA	595879.48	3443212.79	252.90	1	238.67	235.4	1580	6/1/2017
RAIPUR DABA	595879.48	3443212.79	252.90	1	238.67	234.25	1825	10/1/2017
BAHLOOR KALAN	611096.18	3432030.55	252.59	1	248.02	246.7	120	6/1/2013
BAHLOOR KALAN	611096.18	3432030.55	252.59	1	248.02	247.29	365	10/1/2013
BAHLOOR KALAN	611096.18	3432030.55	252.59	1	248.02	247	485	6/1/2014
BAHLOOR KALAN	611096.18	3432030.55	252.59	1	248.02	247.6	730	10/1/2014
BAHLOOR KALAN	611096.18	3432030.55	252.59	1	248.02	247.58	850	6/1/2015
BAHLOOR KALAN	611096.18	3432030.55	252.59	1	248.02	248.02	1095	10/1/2015
BAHLOOR KALAN	611096.18	3432030.55	252.59	1	248.02	247.19	1215	6/1/2016
BAHLOOR KALAN	611096.18	3432030.55	252.59	1	248.02	247.38	1460	10/10/2016
BAHLOOR KALAN	611096.18	3432030.55	252.59	1	248.02	247.28	1580	6/1/2017
BAHLOOR KALAN	611096.18	3432030.55	252.59	1	248.02	247.27	1825	10/1/2017
MAUHAR	611251.36	3442501.23	305.03	1	265	273.62	120	6/1/2013
MAUHAR	611251.36	3442501.23	305.03	1	265	274.88	365	10/1/2013
MAUHAR	611251.36	3442501.23	305.03	1	265	273.5	485	6/1/2014
MAUHAR	611251.36	3442501.23	305.03	1	265	273.13	730	10/1/2014
MAUHAR	611251.36	3442501.23	305.03	1	265	271.98	850	6/1/2015

Village	Easting	Northing	Surface Elevation	Screen ID	Screen Elevation	Head Observation	Time	Date
MAUHAR	611251.36	3442501.23	305.03	1	265	271.68	1095	10/1/2015
MAUHAR	611251.36	3442501.23	305.03	1	265	270.54	1215	6/1/2016
MAUHAR	611251.36	3442501.23	305.03	1	265	270.16	1460	10/10/2016
MAUHAR	611251.36	3442501.23	305.03	1	265	269.69	1580	6/1/2017
MAUHAR	611251.36	3442501.23	305.03	1	265	269.85	1825	10/1/2017

Annexure-2

Ground Water Draft & Recharge data assigned to the Model

Start Time	District	GW Draft m/day	Recharge (m/day)	Net Recharge {Recharge- Draft} (m/day)
0	Hoshiarpur	0		
120	Hoshiarpur	0.001925	0.002250	0.000324
365	Hoshiarpur	0.000332	0.000341	0.000009
485	Hoshiarpur	0.001907	0.002269	0.000362
730	Hoshiarpur	0.000332	0.000347	0.000015
850	Hoshiarpur	0.001889	0.002289	0.000399
1095	Hoshiarpur	0.000332	0.000353	0.000021
1215	Hoshiarpur	0.001883	0.002168	0.000286
1460	Hoshiarpur	0.000328	0.000346	0.000018
1580	Hoshiarpur	0.001876	0.002047	0.000172
1825	Hoshiarpur	0.000325	0.000339	0.000015
0	Jalandhar	0	0	0
120	Jalandhar	0.005182	0.003098	-0.002084
365	Jalandhar	0.001606	0.000506	-0.001100
485	Jalandhar	0.005154	0.003276	-0.001878
730	Jalandhar	0.001597	0.000530	-0.001068
850	Jalandhar	0.005127	0.003455	-0.001672
1095	Jalandhar	0.001589	0.000554	-0.001035
1215	Jalandhar	0.005153	0.003273	-0.001880
1460	Jalandhar	0.001606	0.000531	-0.001076
1580	Jalandhar	0.005179	0.003090	-0.002088
1825	Jalandhar	0.001624	0.000508	-0.001116
0	Kapurthala	0	0	0
120	Kapurthala	0.005662	0.003314	-0.002348
365	Kapurthala	0.000871	0.000326	-0.000545
485	Kapurthala	0.005632	0.003444	-0.002188
730	Kapurthala	0.000867	0.000339	-0.000528
850	Kapurthala	0.005601	0.003574	-0.002028
1095	Kapurthala	0.000862	0.000352	-0.000510
1215	Kapurthala	0.005648	0.003464	-0.002184

1460	Kapurthala	0.000872	0.000349	-0.000523
1580	Kapurthala	0.005695	0.003355	-0.002339
1825	Kapurthala	0.000881	0.000346	-0.000536
0	Phagwara	0	0	0
120	Phagwara	0.005408	0.002102	-0.003306
365	Phagwara	0.001826	0.000388	-0.001439
485	Phagwara	0.005380	0.002559	-0.002820
730	Phagwara	0.001817	0.000480	-0.001337
850	Phagwara	0.005351	0.003016	-0.002335
1095	Phagwara	0.001807	0.000573	-0.001234
1215	Phagwara	0.005376	0.002850	-0.002526
1460	Phagwara	0.001823	0.000560	-0.001262
1580	Phagwara	0.005401	0.002684	-0.002717
1825	Phagwara	0.001838	0.000548	-0.001290
0	Nawanshahr	0	0	0
120	Nawanshahr	0.002999	0.003170	0.000171
365	Nawanshahr	0.000762	0.000646	-0.000116
485	Nawanshahr	0.002983	0.003310	0.000327
730	Nawanshahr	0.000758	0.000653	-0.000106
850	Nawanshahr	0.002967	0.003450	0.000483
1095	Nawanshahr	0.000754	0.000659	-0.000095
1215	Nawanshahr	0.002990	0.003346	0.000356
1460	Nawanshahr	0.000759	0.000644	-0.000115
1580	Nawanshahr	0.003014	0.003242	0.000229
1825	Nawanshahr	0.000765	0.000629	-0.000136

Annexure-3

Calculated Vs Observed Head difference for various period of Calibration and Validation

Stress Period (Days)					1	120	365	485	730	850	1095	1215	1460	1580	1825
Location	X-Model	Y-Model	X-World	Y-World	Calc.-Obs.	Calc.-Obs.	Calc.-Obs.	Calc.-Obs.	Calc.-Obs.	Calc.-Obs.	Calc.-Obs.	Calc.-Obs.	Calc.-Obs.	Calc.-Obs.	Calc.-Obs.
ADOWAL GARHI	558455.4	3536446	558455.4	3536446	4.68	5.22	5.64	6.64	9.15	10.50	9.84	12.91	13.49	13.86	15.31
BAHLOOR KALAN	611096.2	3432031	611096.2	3432031	-1.23	-1.27	-2.13	-1.76	-2.57	-2.38	-3.01	-2.06	-2.43	-2.25	-2.42
BALACHOUR	624046.1	3435869	624046.1	3435869	1.16	1.32	-0.65	1.20	-0.72	-2.79	-0.54	-0.13	-1.87	0.90	-3.38
BHOLATH-S	547992.3	3488976	547992.3	3488976	0.41	-1.65	-3.03	-5.43	-5.66	-6.95	-9.09	-10.46	-10.79	-12.94	-14.55
CHOHAL	592219.1	3497742	592219.1	3497742	0.98	1.44	0.98	2.14	2.28	2.86	0.90	3.37	1.45	3.69	3.44
DASSUYA-S	563107.2	3518461	563107.2	3518461	2.69	3.05	2.27	2.23	3.38	4.24	3.50	5.13	6.69	5.23	6.43
GORAYA-D	572171.1	3443394	572171.1	3443394	-0.43	-2.59	-4.34	-7.26	-8.81	-11.94	-11.97	-13.17	-14.65	-17.99	-19.39
HAZIPUR	570863.8	3537602	570863.8	3537602	-3.15	-2.94	-5.15	-3.93	-4.44	-3.68	-4.27	-3.20	-4.22	-2.37	-4.94
JANDIALA	558773.8	3447313	558773.8	3447313	0.89	-1.06	-2.22	-5.29	-5.54	-9.26	-7.74	-10.40	-9.48	-12.54	-12.73
KAPURTHALA-D	537608.9	3472585	537608.9	3472585	9.76	7.37	3.61	2.35	0.79	-1.05	-5.66	-5.67	-4.45	-9.08	-8.57
KARTARPUR-S	547382.7	3478043	547382.7	3478043	3.63	1.83	-0.01	-1.72	-3.60	-5.14	-7.00	-8.76	-10.73	-12.71	-14.76
KHARALKALAN-S	561659.8	3496591	561659.8	3496591	19.58	18.38	15.19	13.80	13.58	12.72	12.57	11.69	11.70	10.03	10.21
LALIAN KALAN-S	546808.7	3458798	546808.7	3458798	9.85	7.76	6.72	3.66	3.93	1.11	0.06	-1.40	-2.27	-4.55	-5.45
MAHILPUR	599072.6	3469784	599072.6	3469784	1.40	1.79	2.07	3.11	3.83	4.98	5.26	6.65	6.61	8.20	7.00
NAKODAR-M	546236.8	3444480	546236.8	3444480	7.91	6.07	4.19	2.47	0.56	-1.00	-2.91	-4.70	-6.73	-8.75	-10.90

NANGAL BHIALA	566973.1	3530494	566973.1	3530494	1.71	2.12	-0.34	0.91	2.19	2.34	0.44	2.75	2.97	3.53	3.14
PHAGWARA-S	573042.5	3455253	573042.5	3455253	1.56	-1.37	-3.46	-7.84	-7.13	-11.00	-10.61	-13.13	-13.41	-17.67	-17.47
RAIPUR DABA	595879.5	3443213	595879.5	3443213	0.34	0.63	0.19	1.18	0.43	0.83	1.29	1.14	3.22	4.16	4.93
SARIH-D	552435.8	3444047	552435.8	3444047	-0.19	-2.22	-2.58	-6.96	-5.62	-10.03	-11.18	-11.12	-10.18	-15.26	-18.05
SHAH KOT D	531504.3	3438453	531504.3	3438453	-0.81	-2.98	-5.06	-8.19	-8.73	-12.03	-11.97	-14.31	-17.47	-17.15	-21.36
SHAM CHOURASSI	571091.2	3485413	571091.2	3485413	1.07	-0.06	-1.39	-2.86	-3.72	-4.54	-5.92	-9.23	-6.71	-7.24	-8.42
SIMBLI-PZ	612326.2	3446054	612326.2	3446054	5.61	6.00	5.47	5.31	7.98	6.72	7.04	8.04	9.64	12.82	10.84
SULTANPUR-S	519049.4	3453939	519049.4	3453939	0.11	-2.27	-4.68	-7.68	-7.24	-8.46	-9.72	-15.56	-12.13	-17.72	-15.63
TALWANDI CHAUDRI	519034	3462406	519034	3462406	-2.83	-5.58	-7.87	-10.02	-10.94	-13.05	-13.76	-14.98	-16.20	-18.37	-18.98
TALWARA	585065.1	3534323	585065.1	3534323	4.65	5.04	4.24	5.23	5.18	6.05	5.50	5.99	5.56	8.20	5.70
THAKKAR WALA	587173.1	3470910	587173.1	3470910	2.10	2.19	1.23	1.97	2.07	2.18	1.05	2.90	0.83	4.66	0.70

Annexure-4

Details of district wise water Savings through Implementing Supply Side & Demand Side Interventions

District	Supply side Intervention	Demand side Intervention			Grand Total (MCM)
	Adopting Artificial Recharge Techniques (MCM)	Using Underground Pipe Line (UGPL) (MCM)	Crop diversification (change from Paddy to Maize & Pulses) (MCM)	Total (MCM)	
1	2	3	4	5	6
Hoshiarpur	16.30	225.60	21.30	246.90	263.20
Jalandhar	26.54	538.86	708.80	1247.66	1274.20
Kapurthala	14.43	297.50	172.60	470.10	484.53
Phagwara	3.49	84.40	84.00	168.40	171.89
Nawanshahr	8.91	95.20	33.00	128.20	137.11
Total	**69.67**	**1241.56**	**1019.70**	**2261.26**	**2330.63**

Annexure-5(A)

Comparison of Simulated Heads for Various Prediction Scenario during Pre-monsoon period

Well/Point Name	District	X-Model	Y-Model	X-World	Y-World	Base Value 1580 days	Prediction Scenario-1 (3040 days)	Difference (P1- base value 1580)	Prediction Scenario-2 (3040 days)	Difference (P2-P1)	Prediction Scenario-3 (3040 days)	Difference (P3-P1)	Prediction Scenario-4 (3040 days)	Difference (P4-P1)
AdowalGarhi	Hoshiarpur	558455.4	3536446	558455.4	3536446	245.04	247.46	2.41	247.98	0.52	247.49	0.04	248.01	**0.56**
BahloorKalan	Nawanshahr	611096.2	3432031	611096.2	3432031	245.03	244.81	-0.22	245.06	0.25	244.83	0.02	245.08	**0.27**
BalaChour	Nawanshahr	624046.1	3435869	624046.1	3435869	260.45	260.07	-0.38	260.62	0.55	260.11	0.04	260.66	**0.59**
Bholath S	Kapurthala	547992.3	3488976	547992.3	3488976	205.72	192.18	-13.54	194.46	2.28			194.53	**2.35**
Chohal	Hoshiarpur	592219.1	3497742	592219.1	3497742	355.09	355.92	0.83	356.44	0.52	355.95	0.04	356.48	**0.56**
Garhdiwala	Hoshiarpur	570244.7	3512965	570244.7	3512965	247.05	281.43		290.71	9.28	281.46	0.04	281.99	**0.56**
Goraya-D	Jalandhar	572171.1	3443394	572171.1	3443394	203.55	186.24	-17.31	188.65	2.41	186.30	0.06	188.71	**2.47**
Hazipur	Hoshiarpur	570863.8	3537602	570863.8	3537602	296.28	296.29	0.02	296.82	0.52	296.33	0.04	296.85	**0.56**
Jandiala	Jalandhar	558773.8	3447313	558773.8	3447313	193.56	176.34	-17.21	178.75	2.41	176.41	0.06	178.81	**2.47**
Kapurthala D	Kapurthala	537608.9	3472585	537608.9	3472585	197.75	183.42	-14.33	185.68	2.26	183.49	0.07	185.75	**2.33**
Kartarpur S	Jalandhar	547382.7	3478043	547382.7	3478043	198.60	182.45	-16.16	184.86	2.41	182.51	0.06	184.92	**2.47**
Kharal-S Kalan	Jalandhar	561659.8	3496591	561659.8	3496591	234.82	227.30	-7.51	228.97	1.66	227.36	0.05	229.02	**1.71**
LalianKalan-S	Jalandhar	546808.7	3458798	546808.7	3458798	192.00	175.06	-16.95	177.46	2.41	175.12	0.06	177.52	**2.47**
Mahilpur	Hoshiarpur	599072.6	3469784	599072.6	3469784	281.64	283.05	1.42	283.58	0.52	283.09	0.04	283.61	**0.56**
Nakodar-M	Jalandhar	546236.8	3444480	546236.8	3444480	186.91	170.04	-16.87	172.45	2.41	170.10	0.06	172.51	**2.47**
NangalBhiala	Hoshiarpur	566973.1	3530494	566973.1	3530494	269.50	270.77	1.26	271.29	0.52	270.80	0.04	271.33	**0.56**
Phagwara S	Kapurthala	573042.5	3455253	573042.5	3455253	196.69	178.73	-17.96	181.49	2.76	178.80	0.07	181.56	**2.83**
Raipur Daba	Nawanshahr	595879.5	3443213	595879.5	3443213	239.56	238.37	-1.19	238.93	0.56	238.41	0.04	238.97	**0.60**
Sarih -D	Jalandhar	552435.8	3444047	552435.8	3444047	190.66	173.47	-17.19	175.88	2.41	173.54	0.06	175.94	**2.47**
Shah Kot D	Jalandhar	531504.3	3438453	531504.3	3438453	181.04	167.52	-13.53	169.92	2.41	167.58	0.06	169.98	**2.47**

Well/Point Name	District	X-Model	Y-Model	X-World	Y-World	Base Value 1580 days	Prediction Scenario-1 (3040 days)	Difference (P1- base value 1580)	Prediction Scenario-2 (3040 days)	Difference (P2-P1)	Prediction Scenario-3 (3040 days)	Difference (P3-P1)	Prediction Scenario-4 (3040 days)	Difference (P4-P1)
Sham Chourassi	Hoshiarpur	571091.2	3485413	571091.2	3485413	238.60	229.24	-9.36	230.90	1.66	229.29	0.05	230.95	**1.71**
Simbli-Pz	Hoshiarpur	612326.2	3446054	612326.2	3446054	252.61	253.37	0.76	253.91	0.53	253.41	0.04	253.95	**0.57**
Sultanpur S	Kapurthala	519049.4	3453939	519049.4	3453939	183.30	169.42	-13.88	171.68	2.26	169.49	0.07	171.75	**2.33**
TalwandiChaudri	Kapurthala	519034	3462406	519034	3462406	188.91	178.60	-10.31	180.85	2.24	178.68	0.07	180.92	**2.32**
Talwara	Hoshiarpur	585065.1	3534323	585065.1	3534323	348.76	349.64	0.88	350.16	0.52	349.67	0.04	350.20	**0.56**
Thakkar Wala	Hoshiarpur	587173.1	3470910	587173.1	3470910	249.55	246.05	-3.50	246.62	0.57	246.09	0.04	246.66	0.60

Annexure-5(B)

Comparison of Simulated Heads for Various Prediction Scenario during Post-monsoon period

Well/Point Name	District	X-Model	Y-Model	X-World	Y-World	Base Value 1825 days	Prediction Scenario-1 (3285 days)	Difference (P1-Base value 1825)	Prediction Scenario-2 (3285 days)	Difference (P2-P1)	Prediction Scenario-3 (3285 days)	Difference (P3-P1)	Prediction Scenario-4 (3285 days)	Difference (P4-P1)
AdowalGarhi	Hoshiarpur	558455.4	3536446	558455.4	3536446	245.41	247.67	2.26	248.40	0.73	247.72	0.05	248.44	**0.78**
BahloorKalan	Nawanshahr	611096.2	3432031	611096.2	3432031	244.85	244.68	-0.18	244.98	0.30	244.70	0.02	245.00	**0.32**
BalaChour	Nawanshahr	624046.1	3435869	624046.1	3435869	260.13	259.78	-0.36	260.56	0.78	259.83	0.06	260.61	**0.84**
Bholath S	Kapurthala	547992.3	3488976	547992.3	3488976	204.59	191.10	-13.49	194.22	3.12			194.31	**3.21**
Chohal	Hoshiarpur	592219.1	3497742	592219.1	3497742	355.17	355.89	0.71	356.63	0.74	355.94	0.05	356.67	**0.79**
Garhdiwala	Hoshiarpur	570244.7	3512965	570244.7	3512965		281.50		282.23	0.74	281.54	0.05	248.79	
Goraya-D	Jalandhar	572171.1	3443394	572171.1	3443394	201.23	184.09	-17.14	188.05	3.97	184.17	0.08	188.14	**4.05**
Hazipur	Hoshiarpur	570863.8	3537602	570863.8	3537602	296.16	296.21	0.05	296.95	0.74	296.26	0.05	296.99	**0.79**
Jandiala	Jalandhar	558773.8	3447313	558773.8	3447313	191.34	174.09	-17.25	178.04	3.95	174.17	0.08	178.12	**4.03**
Kapurthala D	Kapurthala	537608.9	3472585	537608.9	3472585	196.55	182.23	-14.33	185.21	2.98	182.32	0.09	185.30	**3.07**
Kartarpur S	Jalandhar	547382.7	3478043	547382.7	3478043	196.55	180.39	-16.16	184.34	3.95	180.47	0.08	184.42	**4.03**
Kharal-S Kalan	Jalandhar	561659.8	3496591	561659.8	3496591	233.87	226.47	-7.40	228.96	2.49	226.53	0.07	229.03	**2.56**
LalianKalan-S	Jalandhar	546808.7	3458798	546808.7	3458798	189.81	172.89	-16.92	176.80	3.91	172.97	0.08	176.88	**3.99**
Mahilpur	Hoshiarpur	599072.6	3469784	599072.6	3469784	281.78	283.17	1.39	283.91	0.74	283.22	0.05	283.96	**0.79**
Nakodar-M	Jalandhar	546236.8	3444480	546236.8	3444480	184.76	167.84	-16.92	171.79	3.95	167.92	0.08	171.88	**4.04**
NangalBhiala	Hoshiarpur	566973.1	3530494	566973.1	3530494	269.63	270.85	1.23	271.59	0.74	270.90	0.05	271.64	**0.79**
Phagwara S	Kapurthala	573042.5	3455253	573042.5	3455253	194.62	176.69	-17.93	181.36	4.67	176.79	0.10	181.45	**4.76**
Raipur Daba	Nawanshahr	595879.5	3443213	595879.5	3443213	239.18	237.87	-1.31	238.70	0.83	237.92	0.06	238.75	**0.89**
Sarih -D	Jalandhar	552435.8	3444047	552435.8	3444047	188.43	171.24	-17.19	175.19	3.95	171.32	0.08	175.27	**4.03**
Shah Kot D	Jalandhar	531504.3	3438453	531504.3	3438453	179.23	166.15	-13.08	170.04	3.89	166.23	0.08	170.12	**3.97**

Well/Point Name	District	X-Model	Y-Model	X-World	Y-World	Base Value 1825 days	Prediction Scenario-1 (3285 days)	Difference (P1-Base value 1825)	Prediction Scenario-2 (3285 days)	Difference (P2-P1)	Prediction Scenario-3 (3285 days)	Difference (P3-P1)	Prediction Scenario-4 (3285 days)	Difference (P4-P1)
Sham Chourassi	Hoshiarpur	571091.2	3485413	571091.2	3485413	237.38	228.04	-9.34	230.56	2.52	228.11	0.07	230.63	**2.58**
Simbli-Pz	Hoshiarpur	612326.2	3446054	612326.2	3446054	252.64	253.32	0.68	254.09	0.77	253.37	0.05	254.14	**0.82**
Sultanpur S	Kapurthala	519049.4	3453939	519049.4	3453939	182.11	168.42	-13.68	171.40	2.98	168.51	0.09	171.49	**3.07**
TalwandiChaudri	Kapurthala	519034	3462406	519034	3462406	188.23	178.28	-9.96	181.15	2.87	178.36	0.09	181.24	**2.96**
Talwara	Hoshiarpur	585065.1	3534323	585065.1	3534323	348.80	349.68	0.88	350.42	0.74	349.73	0.05	350.47	**0.79**
Thakkar Wala	Hoshiarpur	587173.1	3470910	587173.1	3470910	248.92	245.32	-3.60	246.24	0.92	245.37	0.05	246.29	**0.97**