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Groundwater Monitoring and Statistical Analysis in Bangalore

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Abstract

This study examines the hydrological processes of groundwater and the socio-economic variables that impact water use in the Mathikere and Malleshwaram areas of Bangalore City, Karnataka, India. The research investigates groundwater levels, land use, and water management techniques through a thorough methodology that includes site visits, primary and secondary data gathering, questionnaires, and statistical analysis. The findings indicate that groundwater levels remain relatively constant with slight variations due to factors such as precipitation and extraction. This emphasizes the prevalence of bore wells, the gradual increase in well depths, and the simultaneous use of several water sources for home and industrial purposes.

Keywords*: industrial, emphasizes, simultaneous, Malleshwaram*

Importance of Groundwater

India is the largest user of groundwater in the world. It uses an estimated 230 cubic kilometres of groundwater per year i.e., over a quarter of the global total. More than 60% of irrigated agriculture and 85% of drinking water supplies are dependent on groundwater. Groundwater is an important component in many industrial processes. Groundwater is a source of recharge for lakes, rivers, and wetlands.

About Bengaluru and its Groundwater

Historically, Bengaluru was referred to as the "city of numerous lakes". Situated in the area with reduced rainfall due to the presence of nearby mountains, this place relied on a sequence of artificial reservoirs to fulfill its water requirements. Bengaluru receives an average annual precipitation of approximately 800 millimeters over an area of 1,250 square kilometers, resulting in a daily water volume of 2,740 million liters. Although regulations require the installation of rainwater harvesting (RWH) systems in residences and business premises, authorities from the Bangalore Water Supply and Sewerage Board report that just 96,000 out of 1.96 lakh have complied with this requirement.

The groundwater level is influenced by several factors, including the rapid urbanization and reduced groundwater recharge, the rise in population and consequent water consumption, and the process of industrialization.

Shao Feng Yan's observations indicate that groundwater salinity is influenced by various factors, including aquifers, terrain, and the incursion of seawater. The mean groundwater level is rather shallow and highly susceptible to climate variables such as precipitation and evaporation. The infiltration of precipitation into groundwater resulted in the dilution of salinity, causing fluctuations in groundwater salinity in response to precipitation. The salinity of groundwater varied in response to changes in the groundwater level. During the wet season, the salt level remains low. The groundwater system experienced a continual growth, reaching its peak value in December, which coincided with the dry season. This analysis aims to describe and examine the impact of different urbanization variables on the groundwater system. According to John M. Sharp, urbanization leads to an increase in paved surfaces, roofs, and storm drains. It also changes the natural landscape and flora, modifies the flow of streams and causes flooding, affects temperatures both on land and in water, and impacts the quality of surface streams and groundwater.

In Veena Srinivasan's paper, it is emphasized that the over use of groundwater poses a significant risk to the security of food, water, and livelihood in India. The study delves into the hydrological cycle and highlights the interconnectedness between groundwater and surface water. Soil moisture and surface water constitute a unified and interconnected resource. Given that all precipitation on Earth has either evaporated or flowed into the ocean, any human water consumption necessitates substituting one of these previous forms of water utilization. Every instance of water usage necessitates making choices between human and ecological water needs. Neither the restoration of unspoiled water flows nor the preservation of groundwater without reduction can be considered as objective standards for control.

Gopal Penny's analysis indicates that the fluctuations in the size of the tank from year to year are primarily influenced by the differences in annual precipitation. An analysis of the hydrological patterns in conjunction with agricultural practices within the watershed revealed a consistent decrease in the size of tank water over a period of time. The main objective of this study was to utilize hydrochemical tracers to determine whether substantial groundwater recharge from tank water by Bentje Brauns could be detected within the groundwater system. Additionally, the study highlights that a significant portion of India's rural drinking water supply is obtained from groundwater, which also plays a crucial role in supporting irrigated agriculture and the livelihoods of numerous individuals. Nevertheless, the current proliferation of complex concepts is jeopardizing the long-term viability of groundwater usage, necessitating immediate measures to guarantee its ongoing availability.

A comprehensive monitoring network was established in 154 places in Bengaluru by M. Sekhar from 2015 to 2017. At a local scale, it was discovered that the behavior of groundwater is non-classical, with valleys exhibiting greater depth of groundwater compared to ridge tops. In the year 2016, there was a drought and the amount of groundwater depletion in the study region was assessed to be 27mm or 19Mm3. However, due to heavy rainfall in August-September 2017, there was a recharge of 67mm or 47 Mm3 of groundwater. The impact on the groundwater balance is contingent upon the extent of extraction from the aquifer. The net change in groundwater storage, which is also documented in this research, is determined by the difference between net outflow and recharge.

Findings from the Literature

- Essence of conservation of ground water since 80% of the rural population and 50% of the urban population use groundwater for domestic purposes.
- Groundwater level changed with fluctuation of rainfall.
- Recharge of ground water is dominated by precipitation and ground water recycling from irrigation, whereas in urban areas due to impermeable surface recharge from point sources such as tanks and rivers.
- The net effect on the ground water budget depends upon the level of pumping from aquifer. And the difference between net outflow and recharge gives net change in groundwater storage which is also observed in this paper

Objectives

The objectives of this study are identified as follows:

Groundwater monitoring of the study area.

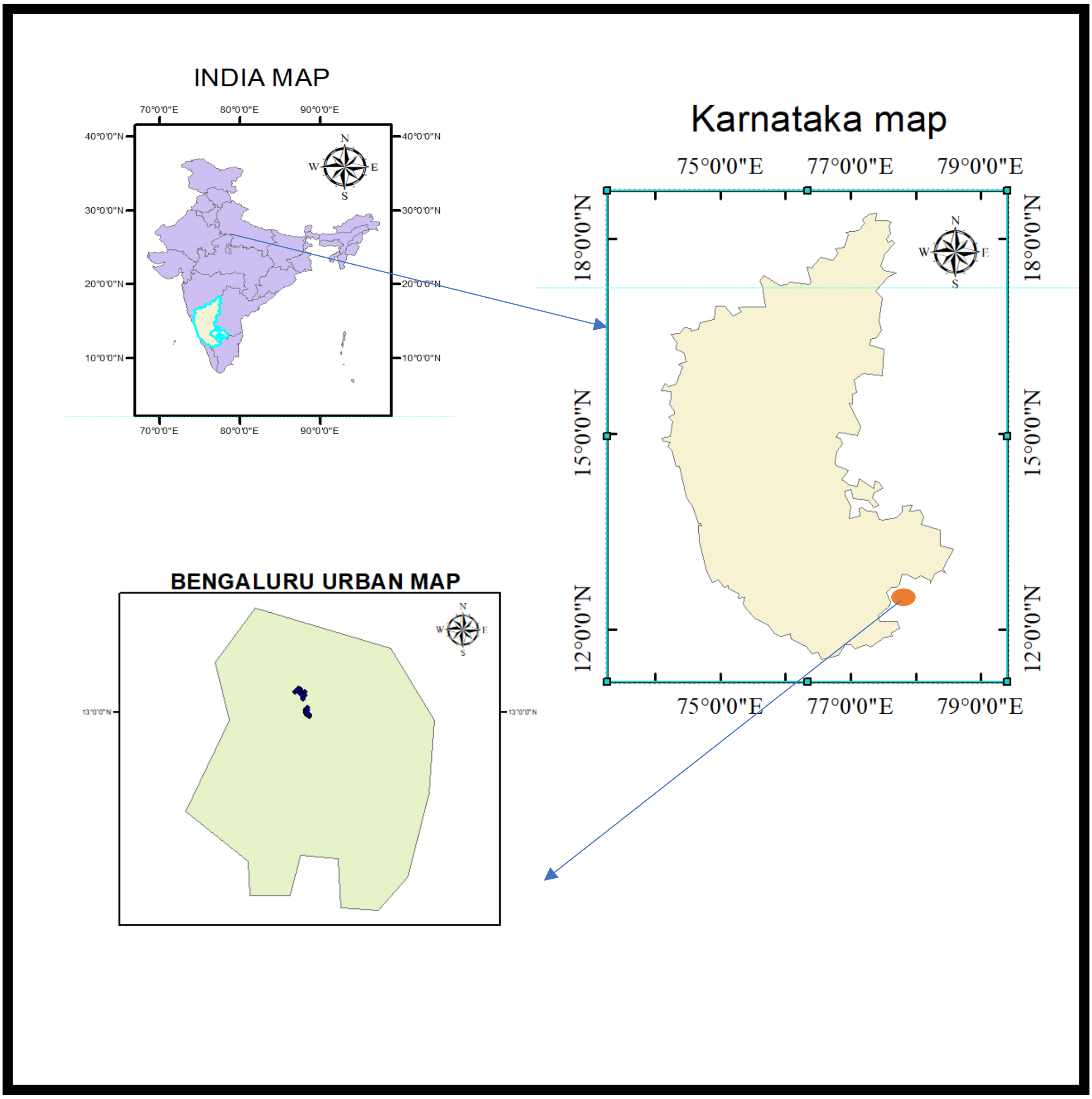
Statistical analysis adopting hydrological and socio-economic data.

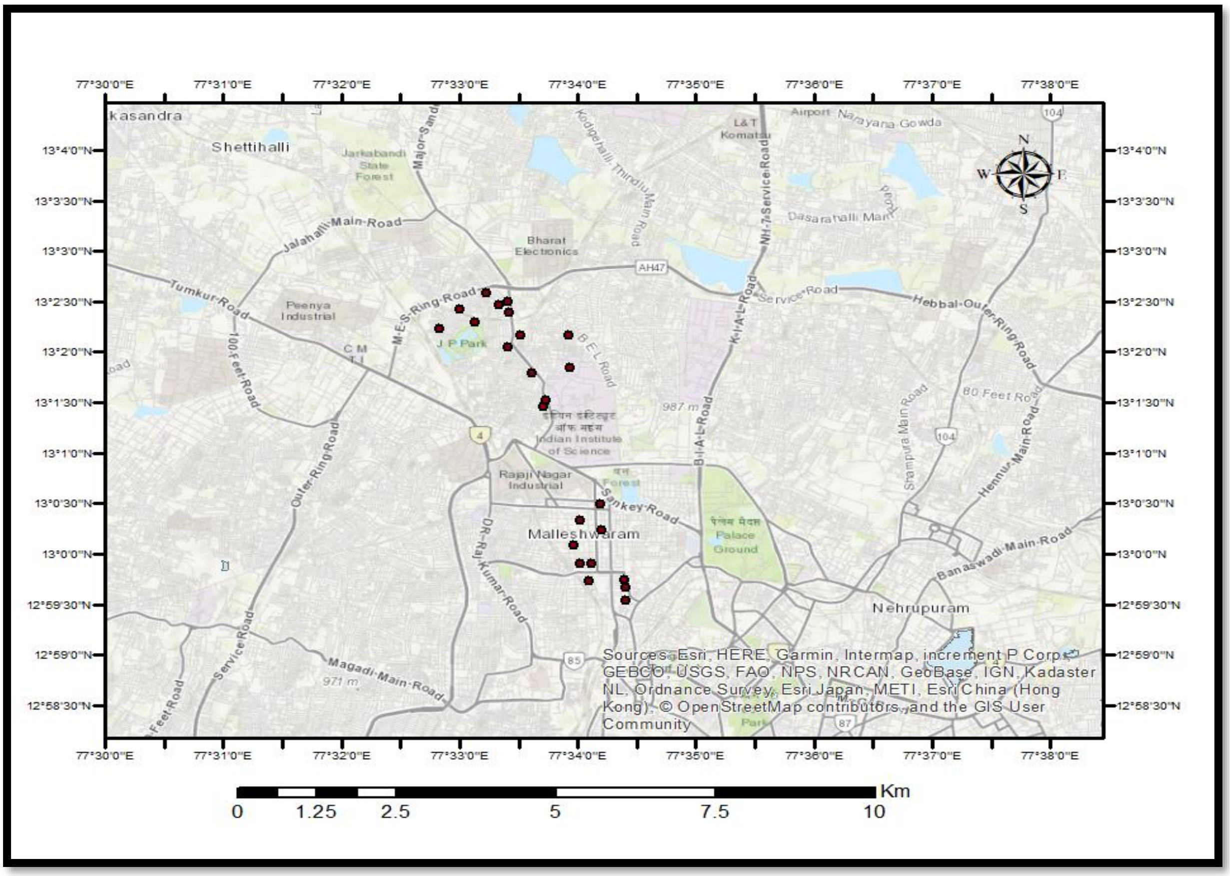
Hydrological analysis of the data.

Study area

Bangalore City, sometimes referred to as the City of Parks and the Capital City of Karnataka, was created and developed in accordance with Karnataka State Policy Rules. In 1986, in accordance with the Karnataka State Policy Rules. This district is situated in the southeastern region of the state.

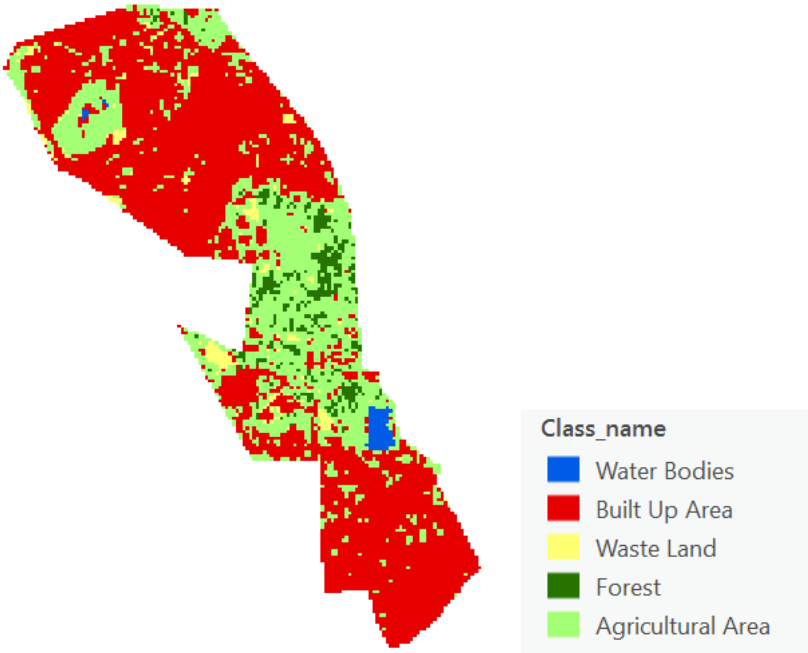
The city is situated in the southeastern region of the state of Karnataka in South India. The city is located in the central part of the Mysore Plateau, which is a subregion of the Cretaceous Deccan Plateau. Its average height is 900 m (2,953 ft). The coordinates of its location are 12°58′44″N 77°35′30″E, and it spans an area of 741 km2 (286 sq mi). Mathikere and Malleshwaram are residential areas situated in the northern part of Bangalore City, Karnataka, India. The location falls inside the Malleshwaram constituency of the Karnataka State assembly. Both regions possess a high concentration of high-quality groundwater, which includes both confined and unconfined aquifer zones. A significant amount of precipitation, specifically during the rainy season, occurs in the months of May, June, July, August, September, and October. The mean annual precipitation is 990 mm (39 inches). The population recorded in the 2020 census is 75,147 and 99,625 in the areas of Mattikere and Malleshwaram, respectively. The population density is 16,108 people per square kilometer overall, with a population density of 25,196 people per square kilometer in Mattikere and Malleshwaram.





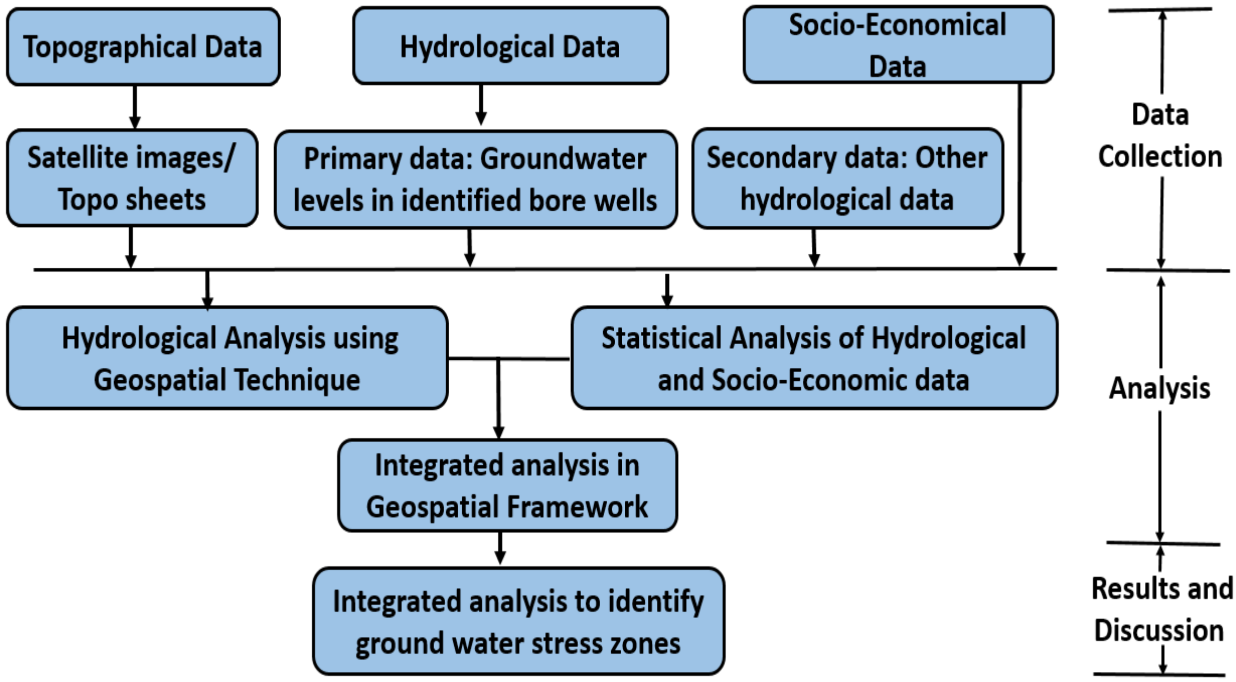
Land use land cover

Land use land cover of the study area shows extensively high built-up area, some agricultural area, decreased water bodies, waste land and forest cover.



Methodology

1. **Preliminary Site Visits:** These were carried out to gather first-hand knowledge and view about the existing system and the activities which are being carried out in our study area. This also eased the identification of well locations.
2. **Primary Data Collection:** it is one of the most important data which serve as a primary source of analysis for our work. Here we are collecting groundwater level of identified wells in mathikere and malleshwaram region.
3. **Secondary Data Collection:** Secondary data regarding the meteorological and topographical data, was collected from various sources like government offices, project authorities and so on.
4. **Survey:** Survey was conducted to know various socio economic factors.
5. **Data Analysis:** The data collected in the course of the project duration was analysed thoroughly using various economic and statistical tests.
6. **Results:** The results from the tests were arrived at and compiled.
7. **Conclusion/Inference:** Based on the results obtained from the study, a conclusion was drawn on what the result reflected in context to depth of groundwater level & effect of urbanization on groundwater level.



Methodology Flow Diagram

Data collection:

Primary data ground water levels in identified bore wells:

Primary data is obtained by means of interviews, surveys, experiments, and other methods. Primary data is typically obtained directly from the point of origin and is considered the most reliable form of data in research. We are now gathering real-time measurements of groundwater levels in the Mathikere and Malleshwaram areas of Bengaluru using a device known as a water level indicator. This data serves as our major source of information. The selection and customization of primary data sources are typically done to fulfill the specific objectives or prerequisites of a particular research study. Prior to selecting a data collecting source, it is necessary to identify factors such as the study objective and the specific population being studied.

Secondary Data:

Secondary data is data gathered by a party other than the original user. Primary sources of secondary data for social science study encompass government departments' census information, organizational records, and data initially gathered for alternative research objectives. On the other hand, primary data is gathered directly by the researcher performing the study.

Secondary data analysis offers a time-saving alternative to data collection and, especially for quantitative data, enables access to larger and superior datasets that would be impractical for an individual researcher to gather

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alone. Furthermore, experts in the field of social and economic transformation see secondary data as vital. This is because it is impractical to carry out a fresh survey that can effectively encompass previous changes and/or advancements.

Secondary data collected:
Data related to groundwater scenario in Bengaluru from CGWB
Land use & Land cover data of our study area.
Recent developments by government in view of protecting groundwater.
Water management by different institutions

Socio-Economical Data:

Socio-economic indicators provide a background to understand the user conditions. These indicators will help in identifying the linkages between socio-economic indicators and their effect on groundwater level.

Statistical Analysis of Hydrological Data

Statistical Analysis of Hydrologic Variables: Methods and Applications provides a compilation of state-of-the-art statistical methods for analysing and describing critical variables that are part of the hydrological cycle. Understanding and describing the variability of hydro-climatological processes and measurements is essential for assessing the performance of water resources infrastructure and its management. Analyzed data provide valuable insights into the dynamics of hydrological differences occurring with time. This knowledge is critical for planning successful and efficient water resources projects, as well as environmental systems management alternatives.

We have conducted various statistical analysis between different attributes listed below:

- Statistical analysis of real time groundwater,
- Type of wells used for study,
- Number of fractures observed in wells,
- Groundwater level with time,
- Usage of groundwater for various purposes,
- Different sources of water for different points in our study area,
- Variation of depth of wells with time.

Data Collection and Analysis

Field Data Collection:

Ground water level identificationThe ground water level was identified using water level indicator.

Water level indicator

It is portable instruments used to accurately measure water levels in monitoring wells and bore holes. Some water level indicators use a combination of probe sensors or float switches to sense water levels.

site no	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21
landmark	registrar	Ser mati	Ser jp	RAMAIAH HOUSE	Ramaiah Function	IISC	devnarpa llya	Ganesh temple	aunt	NANDU HOME
Type of well (open well or bore well)	BW	BW	BW	BW	BW	BW	BW	BW	BW	BW
DEPTH OF WATER**(in meter)**	10.3	13.05	6.61	30.6	25.08	10.6	4.53	51	24	15.56
Depth of well **(in feet)**	620	400	450	550	680	678	450	1000	600	800
Year of drilling	2001	2015	2017	2000	2012	2000	2021	2002	1998	2000
Litholog of well if available										NA
No. Of fractures encountered during drilling**(in feet)**	62, 98, 132	100, 130	150	90, 110	120, 144,	137, 173, 177, 232, 570	80	200, 320	40	90, 116
Depth of water initially observed										
Type of use (domestic - single house, group of houses or apartment, industry, gardening, etc)	domestic (3 families)	comercial	comercial	domestic	comercial	underconstruction building	underconstruction building	BBMP	domestic (3 families)	APARTMENT (22FLATS)
Approx amount of use (how many hours of pumping happens per day or per week, sump capacity,)**(hr/day)**	2	3	2	10	12	1.5	1	2	2	3
Other source of supply any if considered (like BWSSB, Rain water harvesting)	BWSSB		BWSSB	BWSSB+RWH	BWSSB+RWH				BWSSB	BWSSB &RWH

A21	A22	A23	A24	A25	A26	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19
NANDU HOME	Service stat	uncle	Hemsagar	RIMS	agarwal	suzuki	union road	7th cross	club	slum	near mantri	near cornr house	seva sadan	corner house	west cost road
BW	BW	BW	BW	BW	BW	BW	BW	BW	BW	BW	OW	OW	BW	OW	BW
15.56	16.21	29.23	20.17	33.05	52	3.78	16.9	9	19.05	5	1.25	2.5	4.8	3	11
800	800	700	550	1000	1000	800	260	143	600	700	30	25	500	18	550
2000	2019	2011	2009	2021	2022	2021	1996	2009	2005	2022	1972	1985	2018	1990	2004
NA	NA			NA	na										
90, 116	150, 210	70, 110, 1	110	300	500	120, 132	40	90	70	80, 280	10	10	110	6	60, 75
				\\\\\\											
APARTMENT (22FLATS)	comercial	domestic (4 families)	domestic (6 families)	underconstruction building	underconstruction building	underconstruction building	domestic (2families)	domestic (3families)	commercial	underconstruction building	domestic (3families)	domestic (2family)	underconstruction building	domestic (1family)	domestic (2family)
3	3.5	1.5	4	1	1	0.5	0.16	0.25	5	1	0.33	0.16	1	0.16	0.33
BWSSB &RWH		BWSSB &RWH	BWSSB				BWSSB &RWH	BWSSB	BWSSB		BWSSB	BWSSB	BWSSB	BWSSB	BWSSB &RWH

Name	latitude	longitude	Reading 1(in m)	Reading 2(in m)
a12	13∘02'10.7"	77∘33'56.5"	10.3	11.21
a13	13∘01'50.4"	77∘33'55.8"	13.05	10.95
a14	13∘02'09.9"	77∘33'55.6"	6.61	7.2
a15	13∘02'09.8"	77∘33'31.1"	30.6	50.76
a16	13∘02'23.3"	77∘33'24.9"	25.08	22.4
a17	13∘02'27.7"	77∘33'20.3"	10.6	11.07
a18	13∘02'02.9"	77∘33'24.3"	4.53	4.24
a19	13∘01'31.5"	77∘33'44.1"	51	49.7
a20	13∘012'27.2"	77∘33'42.4"	24	22.3
a21	13∘00'29.4"	77∘34'11.7"	15.56	12.2
a22	13∘02'17.4"	77∘33'07.8"	16.21	15.1
a23	13∘02'13.7"	77∘32'50.0"	29.23	28.3
a24	13∘02'25.0"	77∘33'00.3"	20.17	22.3
a25	13∘02'34.9"	77∘33'13.7"	33.05	18.2
a26	13∘01'47.4"	77∘33'36.9"	52	50.1
m10	13∘00'20.0"	77∘34'01.0"	3.78	4.2
m11	13∘00'04.7"	77∘33'58"	16.9	16.3
m12	12∘59'54.1"	77∘34'01.2"	9	10.43
m13	12∘59'54.0"	77∘34'07.1"	19.05	17.83
m14	12∘59'43.9"	77∘34'05.5"	5	5.68
m15	12∘59'32.4"	77∘34'24.2"	1.25	1.3
m16	12∘59'39.9"	77∘34'24.1"	2.5	2.7
m17	12∘59'44.4"	77∘34'23.6"	4.8	4.2
m18	13∘00'14.0"	77∘34'11.9"	3	3.1
m19	13∘00'29.4"	77∘34'11.6"	11	9.7

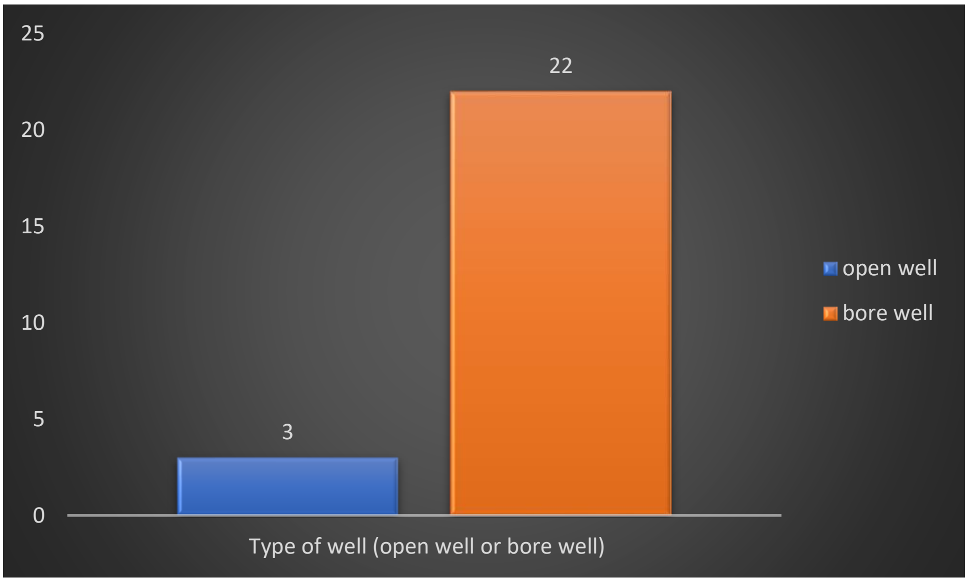
Following are questions that were asked in the questionnaire survey:

Table contains Questions from Survey

S. No.	Questions
1.	**Landmark of the wells.** latitude and longitude of particular well
2.	**Type of well** Open well Bore well
3.	**Depth of water(in m)**
4.	**Depth of well (in feet)**
5.	**Year of drilling**
6.	**No. Of fractures encountered during drilling(in feet)**
7.	**Type of use** domestic - single house, group of houses or apartment industry gardening
8.	**Other source of supply any if considered** BWSSB, Rain water harvesting

Data Analysis

Type of wells: This chart tells us about type of wells which we have considered for study purpose



Depth of groundwater level (Below G.L.): This graph indicates depth of groundwater level observed in different identified wells for study.

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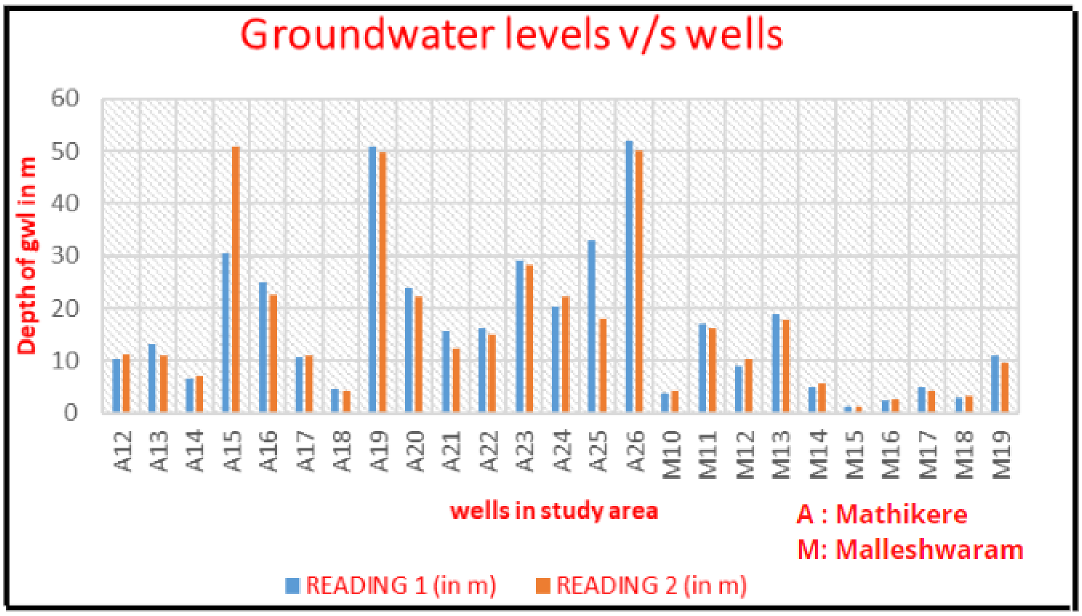
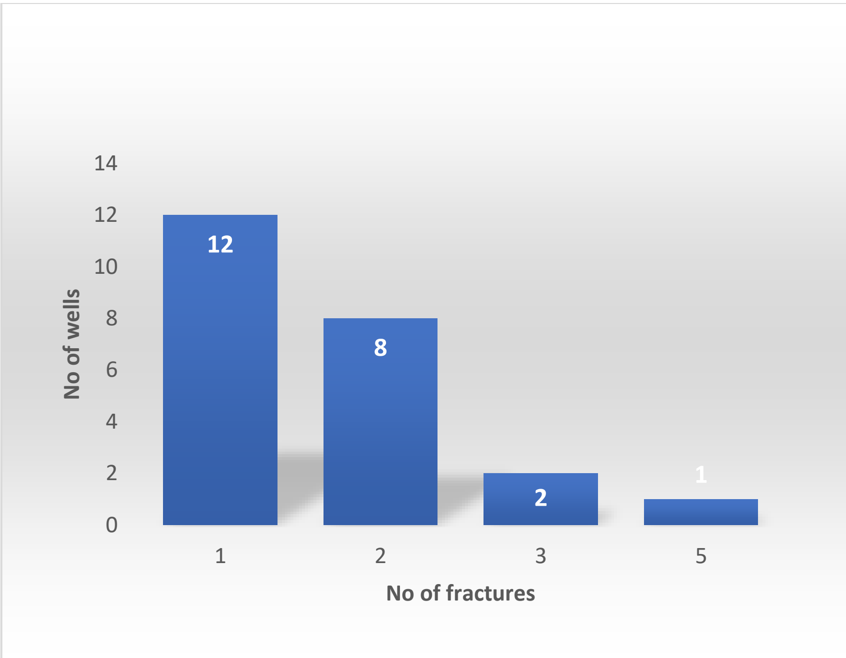
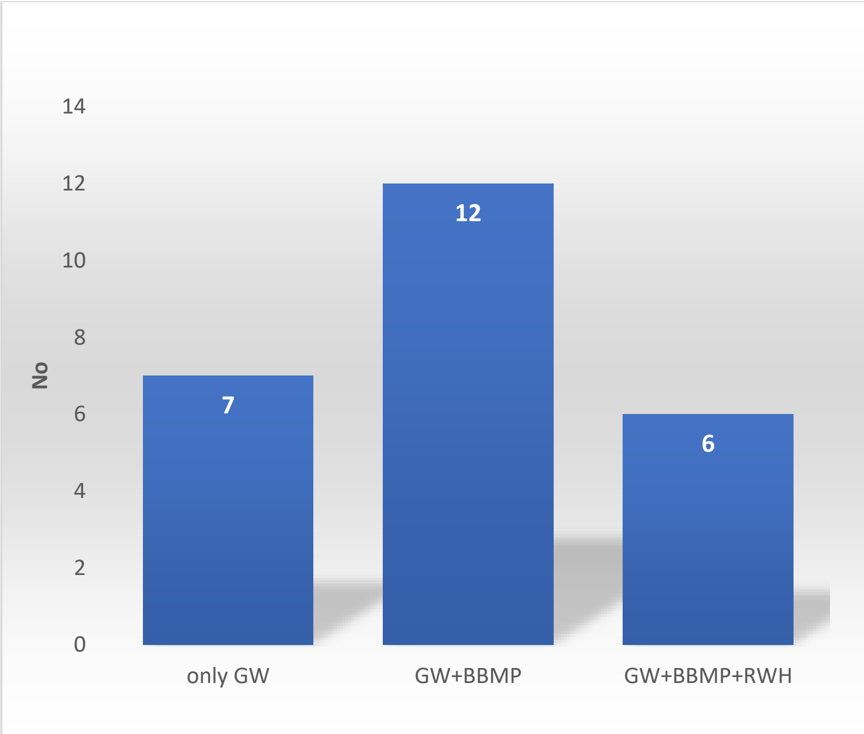


Groundwater level have been observed twice which is shown in above graph and variation in groundwater level have seen, this is because of various reasons such as rainfall, use of groundwater, large pumping hours.

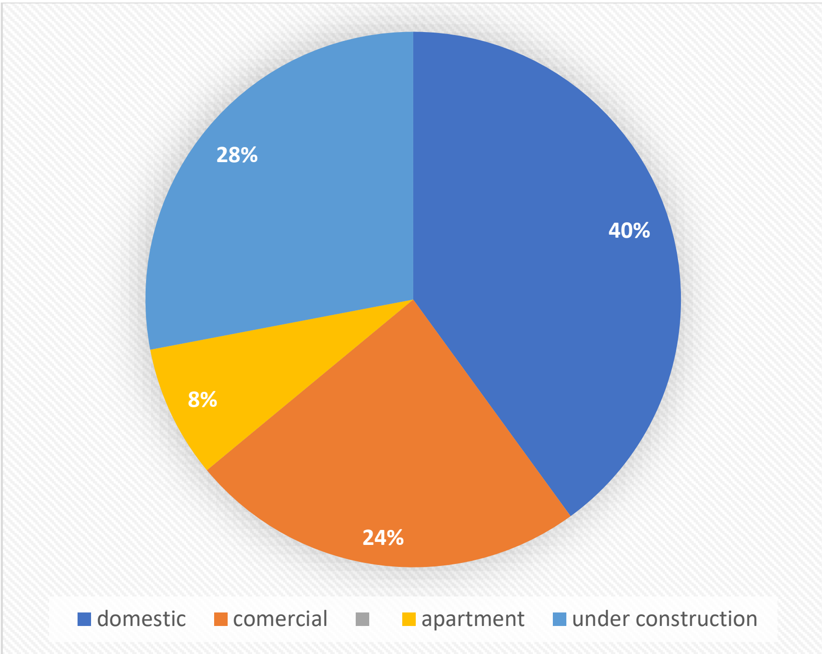
Number of fractures: This graph indicates number of fractures found in different wells which were identified for study.



Sources of water: The above graph indicates different water supplies available for the different study locations identified.



Uses of water: This graph indicates different types of usages of water supply for study locations.



Conclusion From Data Analysis

- Groundwater levels have been monitored twice. The variation in groundwater level observed is not significant in most of the wells. The variation seen in some wells can be attributed to groundwater recharge from rainfall, extraction of groundwater, large pumping hours.
- It is observed that there are significantly more borewells in the area than open wells.
- Most of the wells have observed to be yielding with single fracture. Some have water yielding from two fractures.

- It is evident that with year of drill, depth of wells have increased notably. This trend is also observed in groundwater level.
- It is also observed that most of the users have both groundwater and Municipal supply as source. And others have only groundwater or groundwater with Municipal supply and rain water harvesting as source of water

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