ASSESSMENT OF IMPACT OF MANAGED AQUIFER RECHARGE STRUCTURES ON GROUND WATER IN VELLORE

A PROJECT REPORT

Submitted in partial fulfilment for the award of the degree of

Bachelor of Technology

in

CIVIL ENGINEERING

by

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JUNE 2020

DECLARATION

We hereby declare that the project report entitled **"ASSESSMENT OF IMPACT OF MANAGED AQUIFER RECHARGE STRUCTURES ON GROUND WATER IN VELLORE."** submitted by us to Vellore Institute of Technology University, Vellore in partial fulfilment of the requirement for the award of the degree of **Bachelor of Technology** in **Civil Engineering** is a record of bonafide project work carried out by us under the guidance of Prof. S.Parimala Renganayaki. We further declare that the work reported in this project has not been submitted and will not be submitted, either in part or in full, for the award of any other degree or diploma in this institute or any other institute or university.

Place: Vellore Signature of the Candidates

Date: 25-05-2020

CERTIFICATE

This is to certify that the project report entitled **"ASSESSMENT OF IMPACT OF MANAGED AQUIFER RECHARGE STRUCTURES ON GROUND WATER IN VELLORE."** submitted by **N.S.A.Vigneshwar (16BCL0107), R.P.Dhayanithi (16BCL0183), R.J.Rijul Kanth (16BCL0088)** to Vellore Institute of Technology, Vellore, in partial fulfilment of the requirement for the award of the degree of Bachelor of Technology in Civil Engineering is a record of bona fide work carried out by them under my guidance. The project fulfils the requirements as per the regulations of this Institute and in my opinion meets the necessary standards for submission. The contents of this report have not been submitted and will not be submitted either in part or in full, for the award of any other degree or diploma and the same is certified.

Prof. S. Parimala Renganayaki

Project Guide

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ACKNOWLEDGEMENT

We find immense pleasure in expressing our profound gratitude and thanks to our guide Prof. S. Parimala Renganayaki for her invaluable guidance, constant encouragement and keen interest in the progress and completion of this work. She has always been most willing to spend her valuable time for discussion. The discussions were always enjoyable as well as her comments have been extremely valuable. We learned a lot from the discussion. She has associated with us as a friend, philosopher and advisor. We would like to thank our Head of the Departments and Dean for providing all the infrastructure facilities to carry out our project successfully. We also like to thank research scholar and the Dr. Chandrasekaran kuppan and members of the Art of Living and local community in the study area, without them the project would not have been successful.

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ABSTRACT

Ever increasing demand for water has led to over exploitation of groundwater in several regions. Managed Aquifer recharge (MAR), which is one of the deliberate methods to increase the groundwater storage, which is to be practiced in aquifers that are over stressed. In arid or semi-arid regions the water bodies like rivers and streams flow only for few days in a year (non-perennial rivers) during the monsoon. MAR structures across not just the major canals but also across minor a stream which improve the groundwater recharge and reduces the loss of water due to evapotranspiration. Hence, the present study was carried out to accurately assess the impact of minor MAR structures on groundwater potential by an integrated study comprising of both quality and quantity of the groundwater and the zones benefitted by the recharge water in Salmanatham, Vellore, Tamil Nadu, India. For this purpose, primary data were generated through field investigation, laboratory work and secondary data required for this study were collected from Governmental and Non-Governmental Organizations. The water quality of the stream water i.e. the surface water used as the recharge water has been tested. The zones benefitted by the MAR structures have been identified with the help of EC and the major ion concentrations. The major ions have been determined with the help of Piper and scholar diagrams. The quality of the groundwater for the purposes of irrigation as well as the drinking has been verified with BIS and WHO standards. The groundwater quantity has also been improved over the years with the help of the recharge water from the streams. Economic study of the construction and maintenance of the MAR structures over the region have also been studied. The study clearly shows that the wells with a distance of 50 to 70 meters from the MAR structures show a similar concentration of ions of the surface water in the region.

Keywords: DTM (Digital Terrain Model), Total Station, Cut and Fill data, Geometric and Pavement Design

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CHAPTER – 1

INTRODUCTION

The groundwater is the largest available source of fresh water in the world. The major source of fresh water which is used for domestic, irrigation and industrial purposes in India is the groundwater resources (Varma and Tiwari 1995). The groundwater in earth's surface is over exploited due to the lack of proper water conservation practices despite receiving high rainfall during monsoons (Shankar and Mohan 2005). The depletion of groundwater is also due to the climate change in some regions (Hertig and Gleeson 2012). In order to overcome the groundwater depletion, groundwater recharge is found to be the only solution which can be either artificial or natural. In India the major source of ground water recharge is rainfall, which is supplemented by other artificial sources such as recharge structures across canals, irrigated fields and surface water bodies (Johan and Sinha 2007). Artificial recharge structures are a way to store water underground in times of water surplus to meet demand in times of shortage (Bhattacharya 2010). The artificial recharge structures are further called as Managed Aquifer recharge (MAR) structures which include check dams, percolation tanks, recharge wells, recharge bore wells, surface spreading basins, pits and sub- surface dykes. Construction of check dams across rivers is one of the methods of MAR to impound the surface runoff so as to increase the groundwater recharge (Renganayaki and Elango 2013). Percolation tank is a method of MAR which are constructed across stream or submerging a land area with adequate permeability in order to facilitate sufficient percolation to collect surface water run-off (Boisson et.al 2014). Surface spreading is an efficient means of recharging shallow unconfined aquifers (Maliva 2020). Sub-surface dykes have been proved as an effective ground water conservation structures in undulating or hilly terrains (Pullare et.al 2003). A recharge pit allows the rainwater to replenish groundwater by recharging bore wells or to help the water infiltration in a particular area (Rajshekar 2009). Recharge wells are mostly used in land of water scarcity (Hoopes and Harleman 1967).

1.1 Objectives

The objectives of the study are:

- To understand the recharge mechanism of boulders check and gravel based filtration system for groundwater recharge
- To assess the quality of stream water flowing across the boulders check and to identify the zones benefited using major and minor ions
- To identify the impact of recharge system on groundwater quality and quantity
- To assess the construction and maintenance cost of the recharge system

1.2 Motivation

The motivation and plan behind the project aroused as our guide and ourselves have been discussing about the groundwater depletion, which is due to the over exploitation of water in urban and rural areas. So, when discussing about the remedial methods that are available in the society which includes both the artificial and natural methods, Managed aquifer recharge is the intentional recharge of water to aquifers for subsequent recovery or environmental benefit (NRMMC, EPHC, and NHMRC 2009). Whereas formerly, the term “artificial recharge”, has been used to focus on augmenting the quantity of recharge, but with much less attention given to managing water quality, but MAR means that both quantity and quality are managed effectively (Dillon et al. 2018). Though there were lot of study have been made on major recharge structures, but these can only be built across large rivers or 1^{st} order streams. This led to the conclusion of the study of minor MAR structures that are being constructed across the 2^{nd} or 3^{rd} order streams which flow across villages in semi-arid regions in India for their domestic and irrigation purposes. The study of MAR structures mostly deals with the quantity of groundwater recharge. But this study deals with the impact of these minor MAR structures on the quality and the quantity of the groundwater in the semi-arid region in India.

1.3 Background

Managed Aquifer Recharge (MAR) interventions are widely adopted across India, often initiated or supported by, local communities, state and central governments to improve the availability of water for irrigation and To minimize or to counter decline of the groundwater levels and to improve the availability of water for crop production(Prathapar et.al 2015). These structures have been built in arid and semi-arid climatic regions which undergoes water scarcity (Famiglietti et.al 2011). One such region is Vellore district in Tamilnadu, India which is prone to water scarcity in the months of dry season. In the 2015, Vellore’s three major reservoirs and several tanks filled up following the monsoon but the later years saw only the water level being dwindled in a majority of the water bodies across the district (The Hindu 2016). In order to increase the groundwater level, many MAR structures have been constructed across the districts which includes the construction of check dams, recharge wells, recharge bore wells with the help of Non-Governmental Organizations (NGOs) being funded by the government (The Hindu 2016). Hence, this study was carried out to review the impact of minor MAR structures in improving the groundwater quantity and quality which has been supported by a case study from Vellore, Tamil Nadu, and India.

CHAPTER-2

PROJECT DESCRIPTION AND GOALS

The thesis comprise of seven chapters. Chapter 1 introduces the review, objectives, motivation and background of this study. Technical specifications are discussed in chapter 3. Chapter 4 describes the various methodology adopted for this study which includes field, laboratory investigations and secondary data collection. Schedule, tasks and milestones are discussed in chapter 5. The heart of the thesis, Results and conclusions which includes Assessment of regions benefited by the recharge structures using groundwater modelling is discussed in chapter 6. Finally, the chapter 7 highlights the conclusions, limitations and the summary of this study. The projects goals are, to understand the recharge mechanism of boulders check and gravel based filtration system for groundwater recharge, to assess the quality of stream water flowing across the boulders check and to identify the zones benefited using major and minor ions, to identify the impact of recharge system on groundwater quality and quantity and to assess the construction and maintenance cost of the recharge system.

2.3 Literature review

Sharda et al (2006) estimated groundwater recharge from water storage structures using water table fluctuation method and chloride mass balance method. Using the relation between the two the study has arrived at the conclusion that a minimum of 104.3 mm cumulative rainfall is required to generate 1 mm of recharge from the water storage structures.

Boisson et al (2014 A) assessed the impact on aquifers recharge rather than just finding the evaporation to infiltration ratio. It is done by implementing a methodology based on two independently computed water balances such as the groundwater balance a surface water balance. From this the study draws conclusions on (1) the limited amount of stored water in the aquifer, (2) the delayed recharge of the aquifer highlighting temporary storage/slow groundwater movement in the unsaturated zone and (3) the limited number of beneficiaries in years of medium monsoon rainfall.

Boisson et al (2014 B) have conducted a study on the efficiency of (MAR) managed aquifer recharge using a percolation tank in Andhra Pradesh, India. It is found that the enhanced infiltration of the tank is of the same magnitude as evaporation taken into account the net ‘‘unmanaged’’ water balance at a watershed scale compared to ‘‘managed’’ water balance.

Venkateswaran et al (2015) have conducted a study by measuring the water table levels around the artificial recharge structure constructed in the Vaniyar sub-basin of the Ponnaiyar River in South India. It is found that due to the construction of the structure the areas around it are benefitted by the increase in groundwater level. An area of about 300m, 500m and 1000m buffers are benefited by the rise in groundwater level around the check dam.

Salem et al (2012) have conducted a study on Natural and artificial recharge investigation on the impact of Sidi Saad Dam storage. Hydrochemical and isotopic data of waters from the Ze´roud aquifer have been used to identify anthropogenic recharge waters in the Ze´roud Basin, Central Tunisia. The computed mixtures using isotopic mass balance techniques demonstrate a contribution of about 13% of the dam water to the aquifer water suggesting that only 39% of the released water percolates to the aquifer.

Renganayaki and Elango (2013) have reviewed their research work on the impact of check dams in improving the groundwater quantity, quality, and livelihood of people. It is concluded that MAR through the check dam is found to be one of the efficient methods to improve the groundwater head, and quality which in turn improves the livelihood of the community.

Renganayaki and Elango (2016) conducted a survey on the locals about how useful the recharge structure that was built across the Arani River in the north of Chennai is. The results were affirmative and the respondents suggested maintaining the quality of the stored water to obtain the maximum benefit of the check dam.

Nair et al.,(2013) conducted a study to demarcate the seawater intruded areas of coastal aquifers located in the Arani-Korattalai river basin just north of Chennai by geochemical signatures and identify the efficiency of the check dam as a method of managed aquifer recharge for mitigating seawater intrusion. Their study also proved that check dams improved groundwater quality.

Prasanna et al., (2011) made a study on hydrochemical characteristics of surface and sub-surface water in Tamilnadu and investigated the hydro chemicals in and around the Perumal Lake. The researchers concluded that the water is relatively free from pollution and anthropogenic influences except in few locations for .saltwater intrusion and the geochemical process dominantly controls the groundwater chemistry of the region.

Katz et al., (1997) did research on the interaction between groundwater and surface water in the Suwannee river basin, Florida. They identified some of the elements in groundwater which indicated them there is a hydrochemical interaction between groundwater and surface water. The researcher’s solution to this problem might be the establishment of watershed coalitions, involving the private sector stakeholders.

Samuel and Mathew (2008) This study is conducted in Kerala. As the natural water bodies there are getting depleted, the study suggests many locally adaptable rainwater harvesting methods and finally concludes that the rainwater harvesting technology in UV resistant plastic-lined ponds is found to be very simple and economical and ensures effective storage of harvested water by hindering seepage losses.

Hussain et al., (2019) This study devised a practical solution to mitigate urban inundation and artificial recharge of groundwater using recharge wells. The study showed that Lahore city has great RWH potential from critical ponding roads that can be utilized to recharge the Lahore aquifer. With that ratio of recharge, the groundwater level can rise to 3.54 ft. after every monsoon period. This study identified that RWH using recharge wells is an alternative freshwater supply source for sustainable development of Lahore city and this technique should be the part of the Master Planning and Policy Decision of Lahore as a suggestion.

Ghazavi et al.,(2018) This study is all about the site selection for locating recharge wells in Urmia city located in the North-west of Iran using the fuzzy logic technique. Appropriate locations for recharge wells were determined based on different layers including distance to runoff harvesting points, distance to the production water wells, and depth of groundwater table. Hydraulic condition (hydraulic conductivity and specific recharge) was also used separately. All these layers were interpolated in software called ArcGIS (9.3) and in each area, the pixels with the highest values were proposed as a suitable location for recharge wells.

Satheeshkumar et al., (2016) This study is about the Temporary fluoride concentration changes in groundwater in the context of impact assessment of artificial recharge structures (ARS). The study showed that the construction of ARS at optimal distances along major streams has improved groundwater quantity and quality in the sub-basin. Before the construction of ARS, fluoride concentrations were higher; after construction, fluoride was reduced in most locations. In this study, WHO and BIS guidelines were used to determine the suitability of groundwater and found that the water stored in the check dam and groundwater in the wells closer to the structure was suitable for both drinking and irrigation purposes.

Shi et al., (2015) This paper, discusses the influences of AR for controlling land subsidence on (1) groundwater level and land subsidence rate, (2) groundwater quality, (3) aquifer thermal energy storage, in Shanghai, China. The AR's influence on groundwater quality was limited, with the radius<100 m for single-well recharge and<1000 m for well groups recharge. The study showed that groundwater exploitation is mainly concentrated in the suburban area. Adjusting the injected confined aquifers and the AR wells are the key issue to recover the groundwater level and to control the land subsidence in the near future

Brindha et al 2016: In this study, they have studied the relation between the fluoride concentration and groundwater levels in shallow and deep groundwater regions. It is observed that groundwater in the shallow region shows dilution effect due to rainfall recharge and decreases fluoride concentration whereas in deep groundwater, an increase in fluoride concentration with an increase in groundwater level due to leaching of fluoride-rich salts from the unsaturated zone. Hence MAR cannot be practiced in all regions for dilution of ions in groundwater and only in suitable places.

Bekele et al 2011: In this study secondary treated wastewater was infiltrated through a vadose zone during a 39-month MAR field trial and improvements were observed in the recycled water quality. The improvements were based on geochemistry and microbiology. The water was identified with a reduction of 30% for phosphorous, 66% for fluoride, 62% for iron and 51% for total organic carbon. However additional treatments may be required depending on the receiving environment or the end-use of the recovered water

Sidhu et al 2015: They have studied the pathogen decay characteristics in managed aquifer recharge structures with relation to geochemical characteristics and water source. It is found that it is indeed influenced by the geochemical factors and decay of micro-organisms is type-specific with bacterial pathogens showing the fastest decay rates, followed by protozoa and enteric viruses. This shows that human health risks related to the potable water reuse can be mitigated if the aquifer treatment is integrated with suitable post-treatment options.

Marie et al 2014: The water quality evolution due to the managed aquifer recharge is studied and a 1D transient reactive transport model to simulate the infiltration of a recharged tank through the critical zone is made. It is found that the beneficial effect of MAR can be variable over the year. The effect is best during the monsoon period whereas during the dry seasons the water quality is affected by fluoride accumulation

Massuel et al 2014: The study has been conducted on the managed aquifer recharge structure to find its impact which has been done by considering water accounting, geochemistry and hydrodynamic modeling collectively. After a period of 2 years observing it is found that the percolation efficiency of the tank ranged from 57% to 63% and the percolated water was mostly (80%) pumped straight back by the neighboring boreholes which were identified by modeling. This limits the area of MAR influence whereas increases percolation efficiency.

2.4 Goal of the project

Based on the literarute review it is understood that, recharge strucutres are very helpful in improving the groundwater potential. Whereas, the studies carried out so far indicates that there were only few studies carried out to assess the impact of minor recharge structures. Therefore, the main goal of the present study is to assess the impact of boulders of check and gravel well recharge system in Salmanatham village of Vellore district in Tamil Nadu, India.

CHAPTER-3

TECHNICAL SPECIFICATION

In order to determine the quality and suitability of water for different purposes parameters such as Percentage sodium, Sodium absorption rate, permeability index, Electrical Conductivity, Kelly's ratio and Total concentration of ions were determined through the employment of their respective formulas.

3.1 Formula used

Percentage sodium

$$\%\mathrm{Na} = \frac{(\mathrm{Na} + \mathrm{K})}{\mathrm{Ca} + \mathrm{Mg} + \mathrm{Na} + \mathrm{K}} \text{ x } 100$$

Sodium adsorption ratio

$$\mathrm{SAR} = \frac{\mathrm{Na}}{\sqrt{\frac{\mathrm{Ca} + \mathrm{Mg}}{2}}}$$

Permeability index

$$\mathrm{PI} = \frac{\mathrm{Na} + \sqrt{\mathrm{HCO3}}}{\mathrm{Ca} + \mathrm{Mg} + \mathrm{Na}} \text{ x } 100$$

Kelly’s index

$$\mathrm{KI} = \frac{\mathrm{Na}}{\mathrm{Ca} + \mathrm{Mg}}$$

Milliequivalents:

$$\mathrm{meq} = \frac{\frac{\mathrm{mg}}{\mathrm{L}} \times \mathrm{Valency}}{\mathrm{Molecular\ weight}}$$

3.2 Instruments used

YSI

The yellow spring instrument was used to measure the various in-situ parameters present in the field. It consists of a digital screen where the concentrations of the various parameters are displayed, combined with a flask and a sonde that is inserted in the sample to obtain the readings.

Flame photometer

This device was used to identify the concentration of Sodium (Na), Potassium (K) and Calcium (Ca) of the respective samples. It works on the basis of emission spectroscopy and the final end result is based upon the intensity of the light that is measured by the photo-detector in the flame photometer.

Ultra-Violet Spectrometer

A monochromatic ray of light is allowed to pass through the sample present in the cuvette and based on the absorbance of the radiation by the sample during the process, the concentration of the parameter is determined.

Thermo Scientific Orion 2109XP Fluoride monitor

Firstly, the standards of 10ppm, 1ppm and 0.1ppm of standards were prepared for device calibration following which the samples were placed in the cylindrical beaker and the respective reading of fluoride for each of the samples was noted from the device.

Magnetic Stirrer

The solution is placed in the cylindrical beaker which s then placed on the stirring device. A magnetic capsule is then dropped into the solution. Later by adjusting the RPM in the device a rotating magnetic field is created through which the contents are made to spin and ensuring thorough blending.

CHAPTER-4

DESIGN APPROACH AND DETAILS

This chapter describes about the methods that are followed throughout the project and all the investigation done to obtain required data. Also, this chapter shows the details about how these data are interpreted and compared with the Bureau of Indian Standards (BIS 2012) values in order to obtain the knowledge about the water samples collected from the study area. And the constraints while collecting the samples area also mentioned in this chapter.

4.1 Materials and Methods

The methodology adopted for this assessment includes field and laboratory examinations. This study has also required some secondary data that is mentioned in the flow chart below to carry out this study. These data were collected from a Non-Governmental Organisation (NGO). The procedure for this study is made into a flow chart and is shown in figure 4.1.

4.1.1 Flow chart

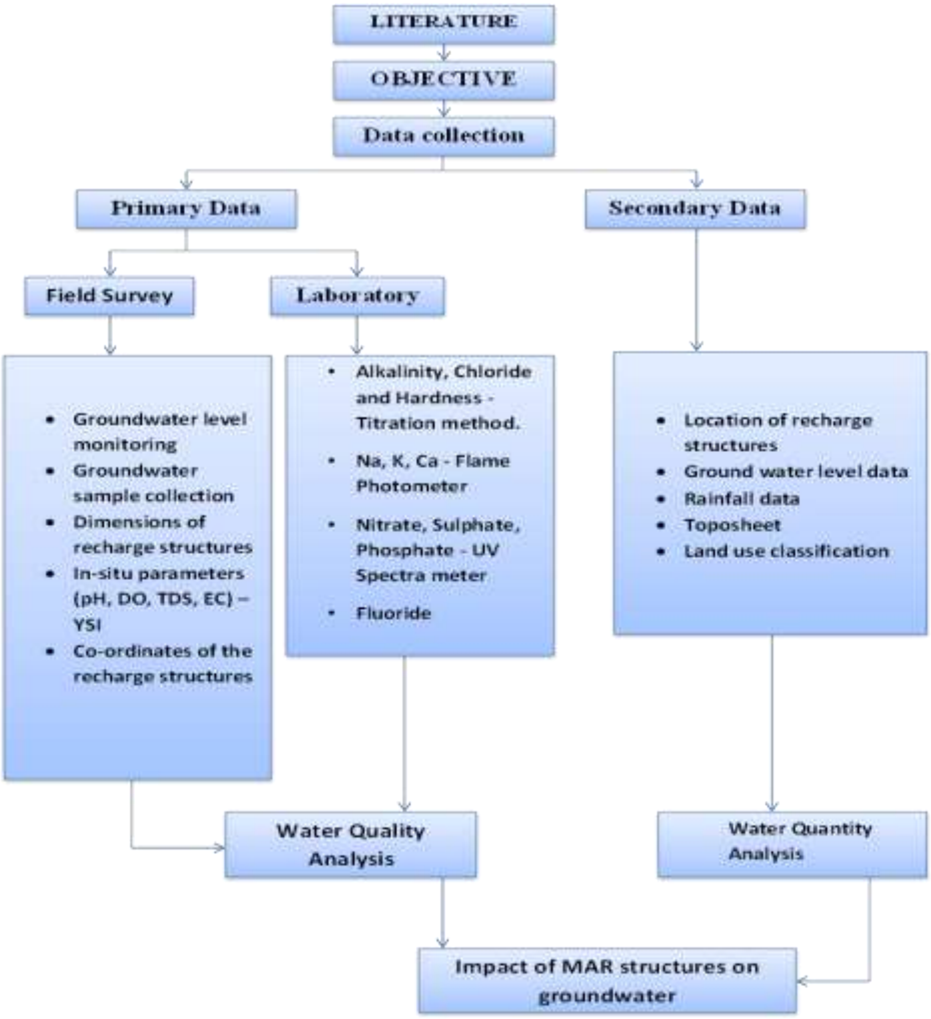

Figure 4.1 Flow chart showing the methodology adopted for this study

4.1.2 Field investigation

The field survey was done during December 2020 to study the cropping pattern, usage of groundwater for different purposes, the flow of streams, type of soil and the Number of wells in the study area. During December, mainly paddy and sugarcane were being cultivated. The type of soil in the study area is black soil. Number of wells in the study area was a total of 15 and for additional analysis; water samples from the villager's drinking water facility which is a bore well were also collected.

4.1.2.1 Identification of monitoring wells

A thorough search for wells was done during the field visit. During the site visit, all the Recharge structures and wells from the study area were identified and classified them as near well and far well based on primary parameters as Electrical conductivity and Secondary parameter as Distance from the recharge structure. There were a total of 15 wells and water samples from 2 bore wells located in the study area were also collected and they were tabulated based on their characteristics such as the depth to water, its purpose, electrical conductivity and its distance from the recharge structure which is shown in table 4.1. And its location in the study area is shown in figure 4.2.

Table 4.1 Details of the wells studied during initial field survey

Well. No	Latitude	Longitude	Nature of well	Depth	Purpose	Distance type from recharge structure	Electrical Conductivity (EC)
1	12.78604	79.19866	Dug well	3.2	Irrigation	Near to recharge structure 1,2 and 3	980
2	12.78704	79.19967	Dug well	4.4	Irrigation	Near to recharge structure 1,2 and 3	900
3	12.78762	79.19959	Dug well	3.79	Irrigation	Near to recharge structure 1,2 and 3	802
4	12.78721	79.19854	Dug well	2.4	Irrigation	Far to recharge structure 1,2 and 3	1144
5	12.78454	79.19702	Dug well	1.28	Irrigation	Far to recharge structure 1,2 and 3	1250
6	12.78454	79.19645	Dug	1.7	Irrigation	Far to	1119

			well			recharge structure 1,2 and 3	
7	12.79074	79.19504	Dug well	3.2	Irrigation	Near to recharge structure 7,8 and 9	1016
8	12.79165	79.19496	Dug well	5.3	Irrigation	Near to recharge structure 7,8 and 9	1426
9	12.79282	79.19452	Dug well	4.2	Irrigation	Near to recharge structure 7,8 and 9	1105
10	12.78985	79.1943	Dug well	5.7	Irrigation	Far to recharge structure 7,8 and 9	1652
11	12.7855	79.19412	Dug well	5.8	Irrigation	Far to recharge structure 5 and 6	2309
12	12.7866	79.1927	Dug well	>10	Irrigation	Near to recharge structure 5 and 6	1339
13	12.78683	79.19275	Dug well	5.2	Irrigation	Near to recharge structure 5 and 6	953
14	12.78763	79.19227	Dug well	>10	Irrigation	Far to recharge structure 5 and 6	1605
15	12.78661	79.19389	Dug well	7.5	Irrigation	Far to recharge structure 5 and 6	1901
16 (dw1)	12.79783	79.19778	Bore well	Nil	Domestic	Near to recharge structure 4	630
17 (dw2)	12.78935	79.19575	Bore well (Hand pump)	Nil	Domestic	Far to recharge structure 7,8 and 9	2309

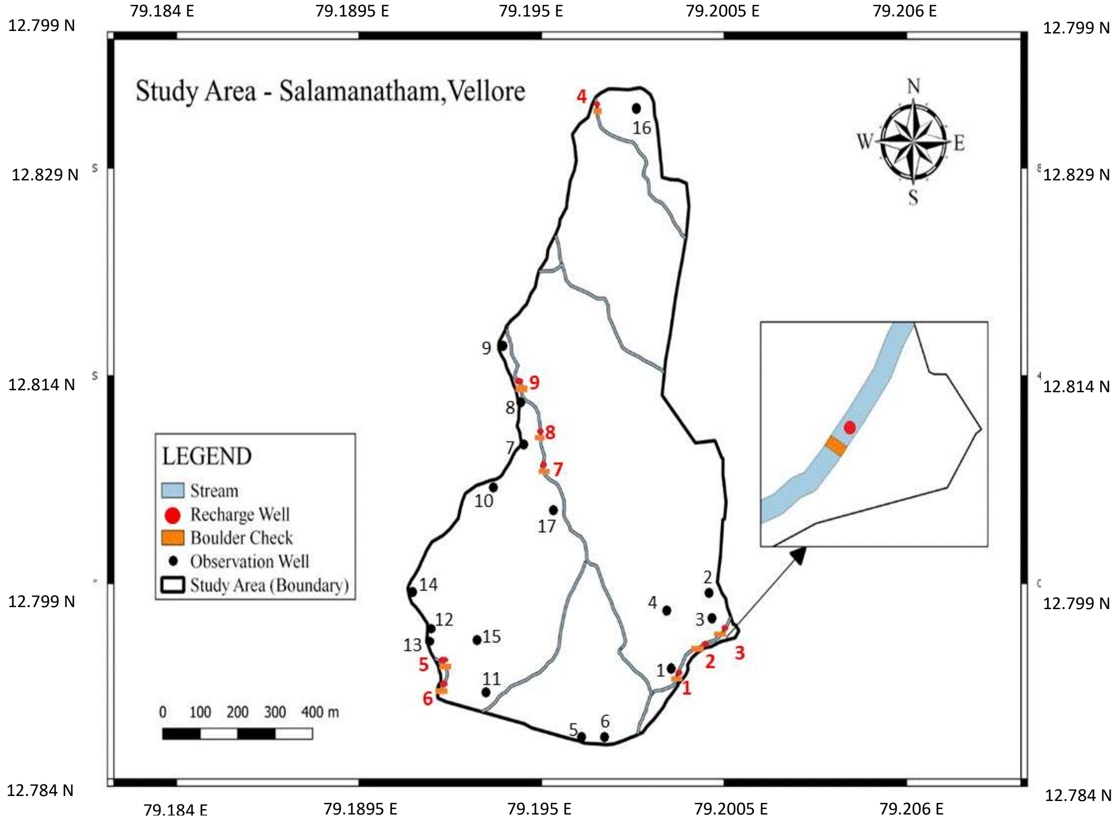

Figure 4.2 Locations of Observation wells

4.1.2.2 Water level measurement

The water level in the observation wells was measured two times during the monsoon and post-monsoon period respectively. The measuring tape was used to measure the depth of water in each observation well (Figure 4.3). This was done manually; no high-end technologies were used to measure the depth. So, it may subject to some small variations to its actual depth. The wells in which the water is at the depth of more than 10 meters are not measured, and were marked as “>10m”.

Figure 4.3 Water level measurement in the Observation wells

4.1.2.3 Water sampling and in-situ measurements

Water samples were collected twice from the observation wells during 2019 monsoon (Dec) and post monsoon (Mar) respectively (Figure 4.4).

Figure 4.4 Water sampling from Observation well

The collected samples were analysed for two parameter, in-situ and laboratory respectively. Sampling frequency is given in the Table 4.2. Data obtained from in-situ analysis of water samples were:

1. pH, Dissolved Oxygen (DO)
2. Total Dissolved Solids (TDS)
3. Electric Conductivity (EC)

These analyses were done using the instrument called YSI.

Data obtained from the laboratory analysis of the water samples were:

1. Alkalinity, Chloride (Cl) and Hardness using TITRATION METHOD
2. Sodium (Na), Potassium (K), and Calcium (Ca) using FLAME PHOTOMETER
3. Nitrate (NO_3^-), Sulphate (SO_4^{2-}) and Phosphate (PO_4^{3-}) using UV SPECTRA METER
4. Fluoride

During the sampling, field survey was also done. Data collected during the field survey were:

1. Groundwater level monitoring
2. Dimensions of recharge structures
3. Co-ordinates of the recharge structures
4. Socio-Economic survey

Table 4.2 Sampling frequency and month of water sampling

Analysis	Sampling Frequency	Sampling Duration	Number of Sampling wells
Geo-Chemical	Once in a month	Dec 2019, March 2020	17

In the case of groundwater samples only certain wells were chosen for sampling. Groundwater sampling locations are shown in Figure 4.5.

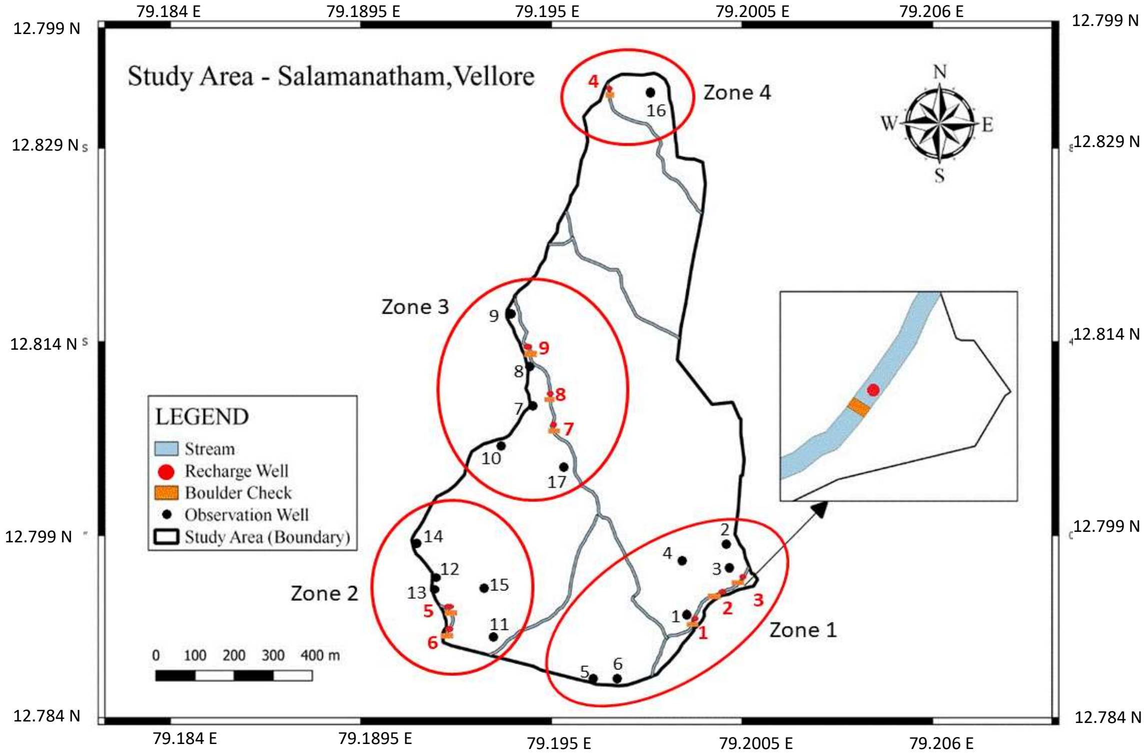

Figure 4.5 Locations of groundwater sampling wells

Samples were collected using a 1lt packaged drinking water bottle. These bottles were thoroughly washed before it was used for sampling purpose. These bottles were once again washed using the sampling water near the well itself and then the bottles were filled with the samples.

4.1.2.4 In situ parameters

Parameters such as pH, Dissolved Oxygen, Total Dissolved Solids, and Electrical Conductivity of the collected water samples were measured on-site with the help of YSI Equipment. The probes and the flask were rinsed and washed repetitively with the respective samples before the calibration for better accuracy. The depth to the water level in each of the wells was also measured and noted down (Figure 4.7). Analysing the in-situ parameters using the YSI instrument is shown in Figure 4.6.

Figure 4.6 Measurement of EC, pH, TDS and DO in the field

Figure 4.7 Collection of water from well

4.1.3 Laboratory

Water samples collected from each of the minor recharge structures were analysed for various parameter using the following methods mentioned below.

4.1.3.1 Titration method

The parameters of water such as alkalinity, chloride and hardness were calculated using this method. Titration to identify alkalinity was done by using standard sulphuric acid as the burette solution and methyl orange as the indicator. The final color change of the solution observed was from pink to orange. In the case of chloride, silver nitrate was taken as the burette solution and the indicator used was potassium chromate. The endpoint was identified by the color change from yellow to brick red. For hardness, EDTA was used as a burette solution and Erichrome black T as the indicator. The endpoint was identified by the color change from Wine red to steel blue.

4.1.3.2 Flame photometer

This device was used to identify the concentration of Sodium (Na), Potassium (K) and Calcium (Ca) of the respective samples. It works on the basis of emission spectroscopy and the final end result is based upon the intensity of the light that is measured by the photo-detector in the flame photometer (Figure 4.8). The procedure was carried out by the preparation of sodium chloride, potassium chloride and calcium carbonate standards of 0ppm, 50ppm and 100ppm each.

Figure 4.8 Calibration using Flame photometer

4.1.3.3 Ultra-Violet Spectrometer

It was used to identify the concentration of Nitrate, Sulphate and Phosphate ions in the samples. The standards and samples (Figure 4.9) were placed in the device and the respective absorbance values of the samples were noted from the spectrometer.

Figure 4.9 Samples prepared for calibration

4.1.3.4 Thermo Scientific Orion 2109XP Fluoride monitor

Firstly, the standards of 10ppm, 1ppm and 0.1ppm of standards were prepared for device calibration (Figure 4.10) following which the samples were placed in the cylindrical beaker and the respective reading of fluoride for each of the samples was noted from the device.

Figure 4.10 Calibration of fluoride content

4.1.4 Secondary data collection

The fluctuations of water level in two observation wells over the period of four years period (sep16-Jan20) present inside the study area were collected from the Art of living (NGO) to monitor the groundwater level in the area. Data such as the dimensions, cross-section and coordinates of the minor recharge structures were also obtained from the above-mentioned organization.

4.1.5 Description of the study area

The study area forms the semi-arid region of the Naganadhi river basin located 17kms south of the Vellore, India. Naganadhi River flows through the districts of Vellore and Thiruvanamalai which is a non-perennial river. This study area covers an area of 1 sq.km which falls under the Kaniyambadi block of the Vellore district, Tamilnadu, India.

There are few tertiary streams that flow across the study area. The NGO named “Art of Living” has constructed a few minor recharge structures across minor streams. These come under the MGNREGA scheme. These structures are built in such a way that, they can be divided into two parts namely boulder check and recharge well has been constructed in the channel together called recharge structure (Figure 4.16 and 4.17). Boulder check is used to reduce the speed of the channel whereas the recharge well is constructed to infiltrate the water that was slowed down by the boulder check. The detailed diagram of the recharge structure can be seen in the following figure 4.11.

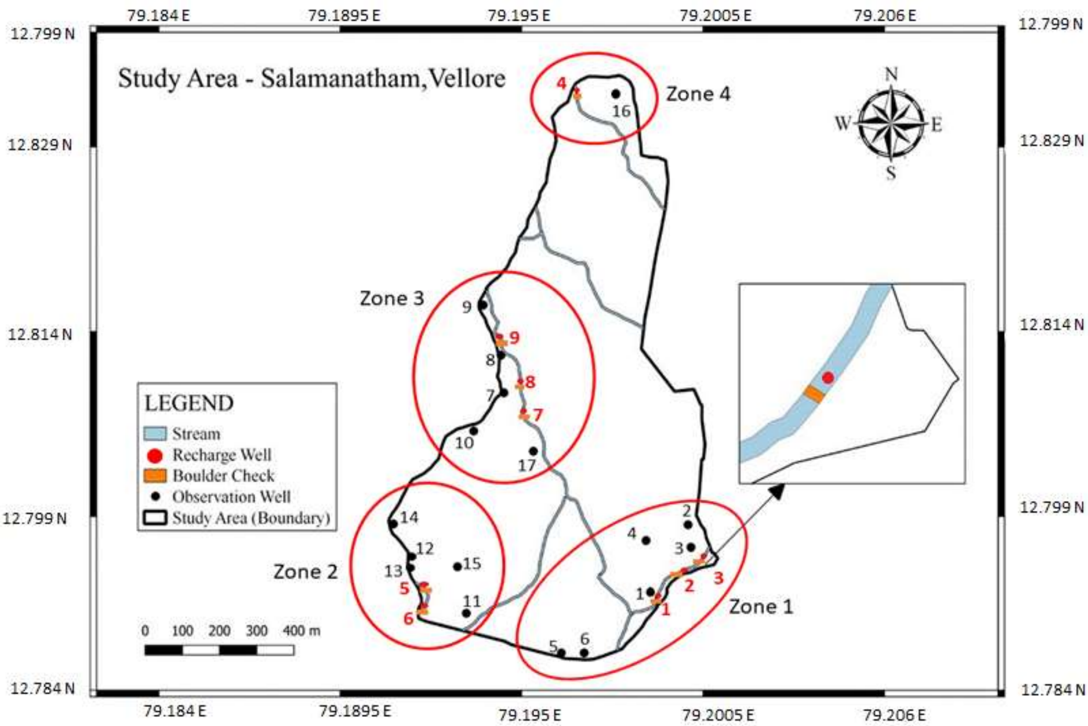

Figure 4.11 Location of sampling wells in - Salmanatham Panchayat

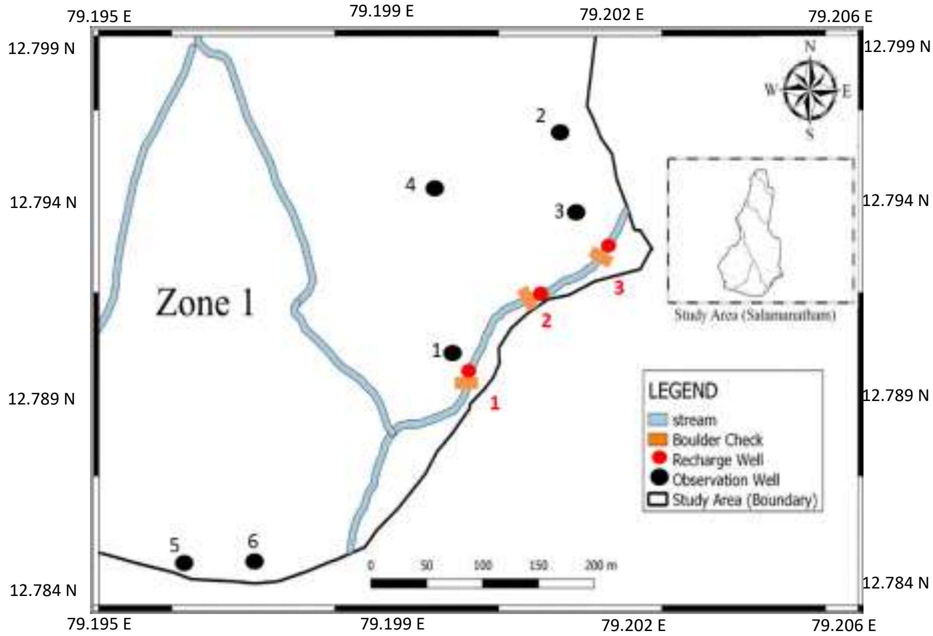

Figure 4.12 Location of sampling wells in – Zone 1

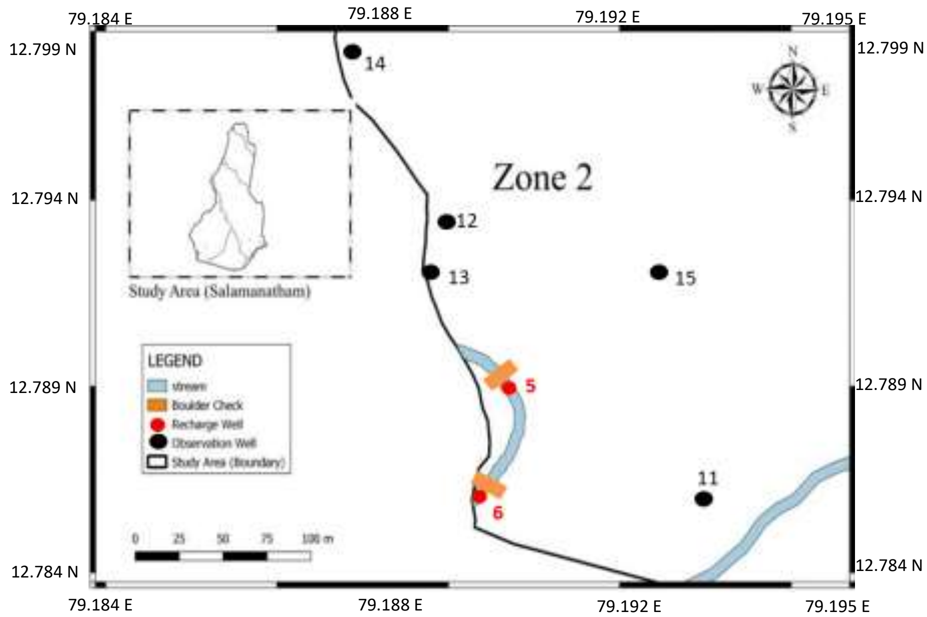

Figure 4.13 Location of sampling wells in – Zone 2

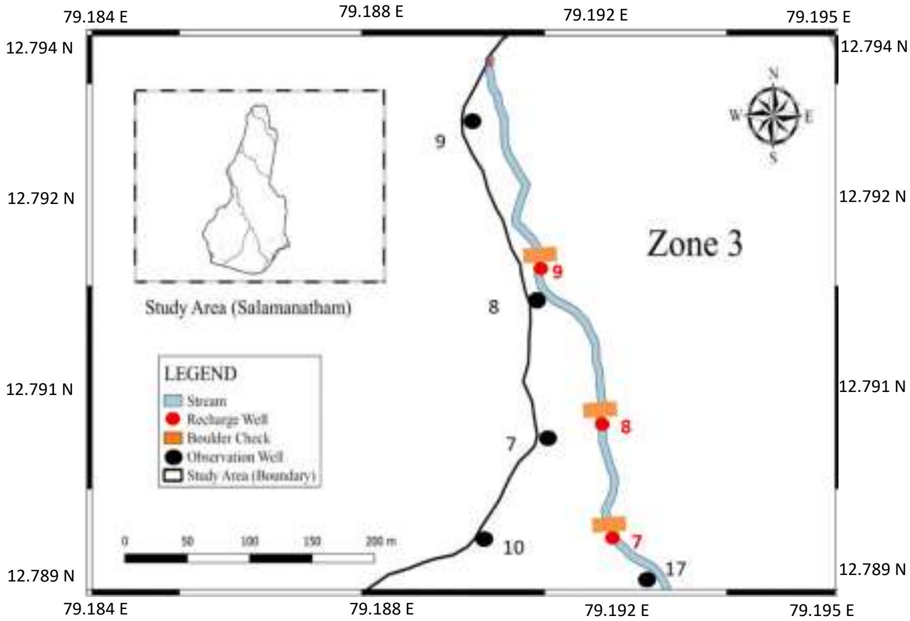

Figure 4.14 Location of sampling wells in – Zone 3

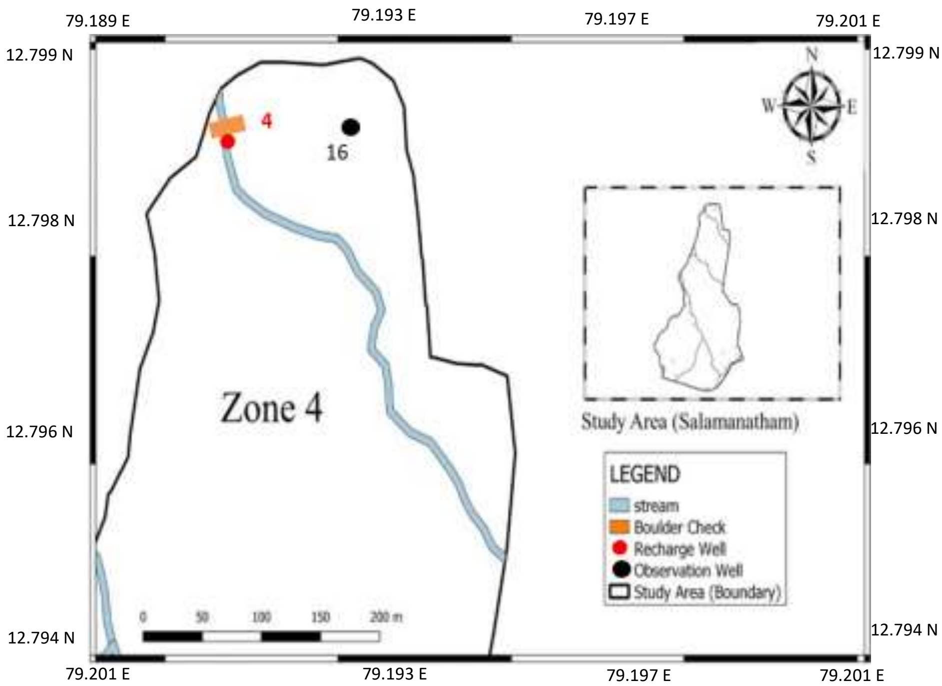

Figure 4.15 Location of sampling wells in – Zone 4

4.1.5.1 Climate and rainfall

The total Watershed area of salmanatham village is 12.12 square kilometres. The Vellore lies at 225m above sea level. This city has a tropical climate. In winter, there is much less rainfall than in summer. Vellore has an average rainfall of 128mm for rainfall considered for 30years; monsoon average rainfall is 816mm. The average annual temperature in Vellore is 27.9 °C. In a year, the rainfall is 971 mm. Rainfall conditions were studied from the year 2016 to 2020 and it is shown in Figure 4.18**.**

- Crops cultivated during normal year are: Maize, pulses and rice.
- Crops cultivated during moderate drought year are: Pulses, vegetables and maize.
- Crops cultivated during severe drought year are: Millet and wheat.

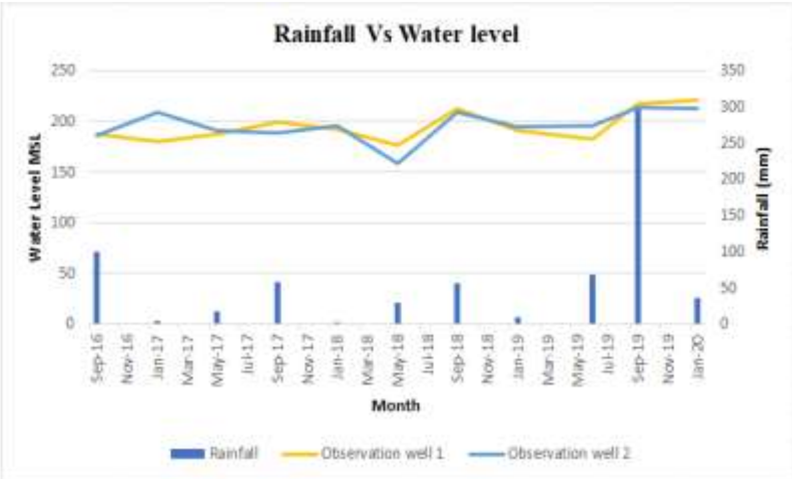

Figure 4.16 Graph showing rainfall and water level relationship in the study area

4.1.5.2 Topography

The topography of the study area was obtained from the DEM file from Bhuvan (Indian geo platform of ISRO). The Dem file has been studied with the use of QIS software named QGIS. The maximum elevation is about 80 m and whereas the minimum is about 65 m. thus the study clearly shows the slope is towards the eastern direction. There is no remarkable elevation difference in the North-South direction. The topography of the site is shown in Figure 4.19.

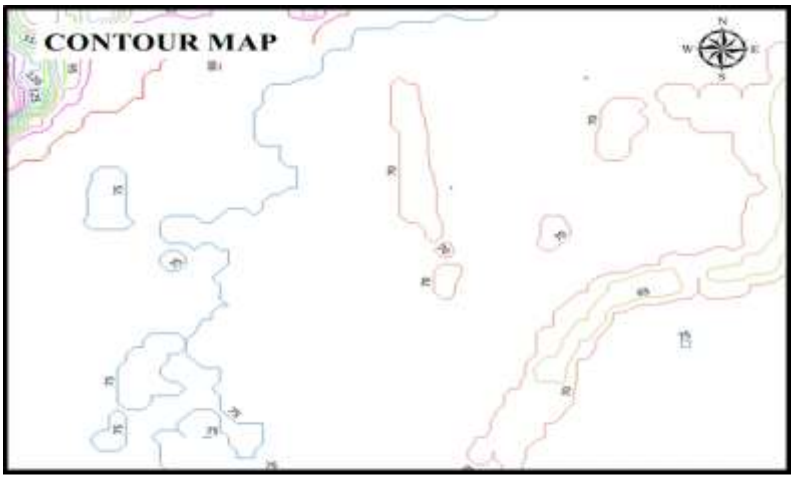

Figure 4.17 Topographic map of the study

4.1.5.3 Land use/ Land Cover

Land use and land cover map of the study are shown in Figure 4.20. This map shows that almost 65% of the land area is used as agricultural land, which is followed by Trees which cover an area of 20% of the total area. Then the human settlement covers the remaining part of the total area. Thus agriculture is the major part of the lifestyle. Paddy forms the major crop to be cultivated which is followed by other crops such as millets, pulses like green grams, rice, sugarcane and black grams. Paddy is cultivated twice the agricultural year. Groundwater is the major source for the agriculture purpose which is recharged by Rainfall.

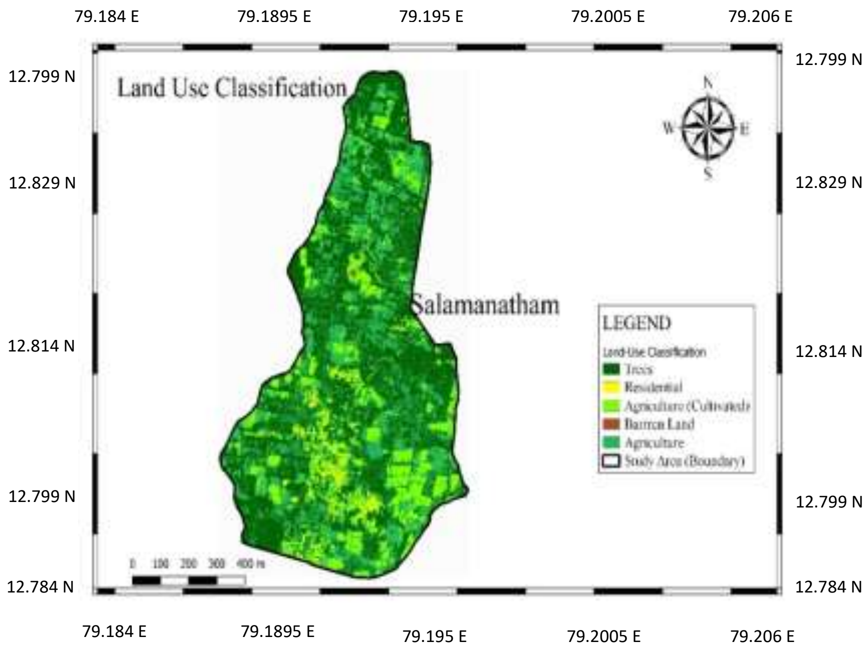

Figure 4.18 Land use classification map of the study area

4.2 Codes and standards

The codes and standards followed in the study are taken from BIS 10500: 2012. This Indian Standard (Second Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Drinking Water Sectional Committee had been approved by the Food and Agriculture Division Council. This standard was originally published in 1983. The standards are shown in the table 4.3.

Table 4.3 Standard values from BIS 10500: 2012

Parameters	Acceptable limit	Permissible limit in the absence of alternate source
pH	6.5-8.5	No Relaxation
EC	/	/
TDS	500.000	2000.000
TH	200.000	600.000
HCO_3^-	/	/

Cl^-	250.000	1000.000
SO_4^{2-}	200.000	600.000
NO_3^-	45.000	No Relaxation
F^-	0.500	1.500
Ca^{2+}	75.000	200.000
Mg^{2+}	30.000	100.000
Na^+	50.000	200.000
K^+	/	/

4.3 Constraints

During the field visit for sample collection, the difficulties faced includes, reaching the site on time as the frequency of transport facility for the study area is very low. The climate during our field visit was very hot and as the area is used for agriculture purposes, there were not enough trees for shades. As there is no enough transport facility in the village, the observation wells have to be covered by walk only.

During the testing in laboratory , the tests have been conducted with at most protection from the acids and other bases which have been used for testing, still the odour of the gases emitted have made uncomfortable. During the interpretation of the data collected, the soft wares used for interpreting were difficult to use as the basics for the soft wares were not taught during the B-tech course.

CHAPTER-5

SCHEDULE, TASKS AND MILESTONES

The project schedule have been varied throughout the months, the project have been divided into major tasks. The project have been initiated in the month of December 2019 and ended up lately in the month of May 2020. The delay in the process is due to the Corona pandemic across the nation. Detailed task and schedule of the project is given in Table 5.1

December 2019 – The project has been finalized and the objective of the project as the impact of the quality, quantity and the zones benefitted by the recharge water from the MAR structures in the groundwater has also been finalized. The literature review on the MAR structures across the world helped in finalizing the objectives of the project. The first set of water sampling has been carried out at the end of the month. The in situ parameters have been carried out in the site itself.

January 2020 – the collected water samples from the study area have been tested for the various parameters which includes the Cations such as Na, Ca, Mg, k and the Anions such as F, Cl, HCO_3, and SO4 in the laboratory.

February 2020 – The data collected have been interpreted based on various standards for both the drinking and irrigation purposes.

March 2020- an0other set of sampling have been made and the water have been analysed for the later set of sampling in the laboratory and the data have been interpreted for the later as well based on the standards for both the drinking and irrigation purposes.

April 2020 – the results and discussions work have been started in the previous month and have been completed in this month, this delay in work have been caused because of the Covid-19 pandemic.

May 2020 – The thesis writing work have been started and completed by the second week of this month.

Table 5.1 Detailed task and schedule of the project

Task	Dec-19	Jan-20	Feb-20	Mar-20	Apr-20	May-20
				Delay in project due to Covid-19		
Objective						
Literature Review						
Water Sampling						
Water Sampling Analysis						
Data interpretation						
Results and Discussion						
Thesis writing						

CHAPTER-6

RESULTS AND DISCUSSION

6.1 Working principle of boulder check and recharge well

In order to overcome the groundwater exploitation, the groundwater has to be recharged either by natural or artificial ways. There are numerous artificial ways which includes check dams, percolation tanks, recharge wells, recharge bore wells, surface spreading basins, pits and subsurface dykes. These are called Managed aquifer recharge structures. Managed aquifer recharge (MAR) is the most purposeful recharge of water to aquifers for environmental benefit or subsequent recovery (Gruetzmacher and Kumar, 2012). These MAR structures are further classified as major and minor structures. These minor recharge structures can be constructed along the second order or third order streams. The recharge structure which is found in the study area (i.e.) Salamanatham, Vellore consists of two structures namely, boulder check and recharge wells as shown in figure 6.1 and 6.2. The boulder check is constructed across the stream which is about 2m to 4m in width and the boulder check has a width around 200cm. The structure is built in such a way that the boulders are placed one over the other and they are covered by chicken mess. The chicken mess wire is used in order to restrict the misalignment of the boulders in the boulder check by the speed of water in the stream. The work of the boulder check is to reduce the velocity of the water flowing in the stream. The water with the reduced velocity meets the recharge well which is covered with a perforated concrete lid. The recharge well is constructed in the downstream direction of the stream at a distance of 2m to 3m from the boulder check. The recharge well is built in such a way that the perforated concrete rings of diameter 3ft have been inserted in the middle and it is covered by gravels on all the sides in order to increase the infiltration and percolation of the water that get accumulated in the recharge well from the stream. The figure 6.1 gives the detailed sectional view of the recharge structures.

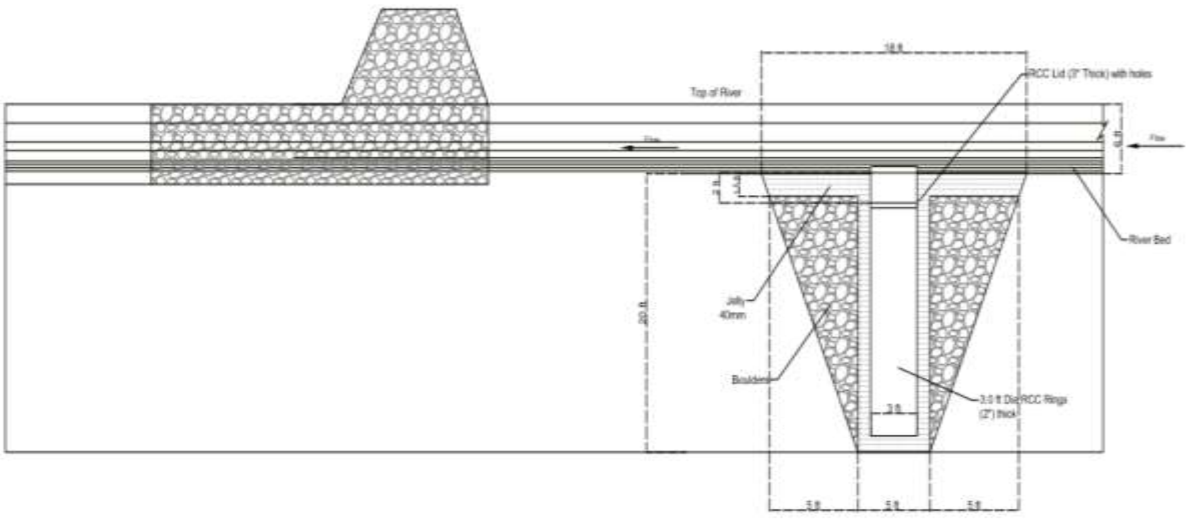

Figure 6.1 Cross sectional view of recharge Structure

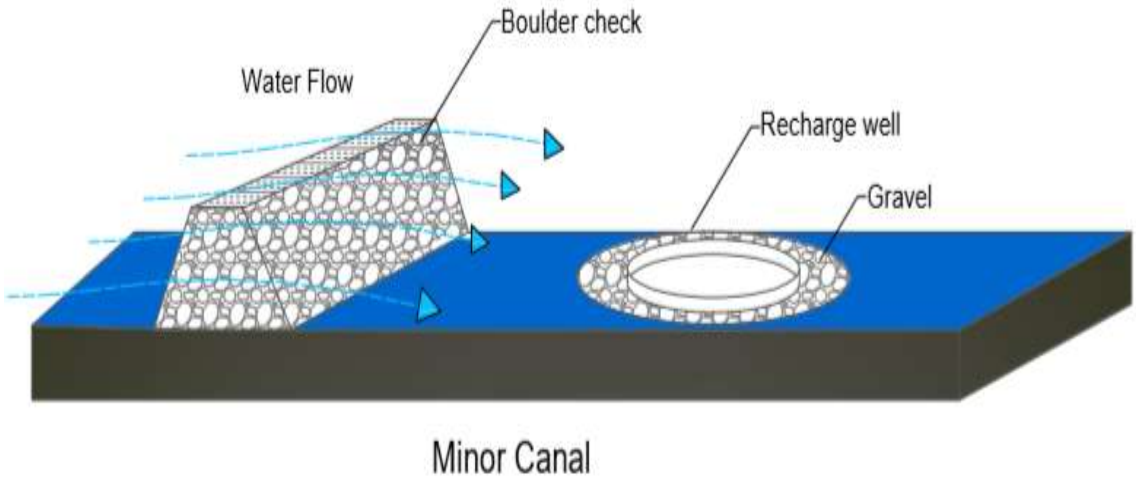

Figure 6.2 Conceptual diagram of boulders check and gravel well system for groundwater recharge

6.2 Quality of surface water

The surface water is the water that is collected from the lakes, rivers, and streams. The sample water has been collected from the stream located in the study area – Salmanatham, Vellore during the monsoon season. These streams fall under the Naganadi river basin. This surface water flows along the secondary and tertiary canals built for irrigation purposes during the monsoon season. This water is slowed down and it is infiltrated into the aquifer with the help of the MAR structures constructed along the streams. The measured parameters include pH, electrical conductivity (EC), dissolved oxygen (DO), total dissolved solids (TDS),Alkanet, Total Hardness, anions(Chloride, Sulphate, Nitrate , Fluoride) and cations(calcium, magnesium, potassium, sodium). These parameters of the samples are compared with the BIS and are tabulated as shown in table 6.1. The table 6.1 clearly shows that no parameters have been exceeded the BIS limit which eventually means that the surface water quality is good. Among the anions, the chloride concentration is more when compared to that of the sulphate, nitrate, phosphate and bi carbonate. And among the cations, sodium concentration is more which is followed by calcium, magnesium and potassium respectively.

Table 6.1 Concentration of ions in surface water and their comparison with drinking water quality standards of BIS 2012; WHO 2008					
Chemical Parameter	Expressed	Value	AL	PLAAS	% of samples exceeding the PLAAS
pH	Units	7.000	6.5-8.5	No Relaxation	/
EC	µS/cm	625.000	/	/	/
TDS	mg/L	400.000	500.000	2000.000	/
TH	mg/L		200.000	600.000	/
HCO_3^-	mg/L	91.500	/	/	/
Cl^-	mg/L	96.884	250.000	1000.000	/
SO_4^{2-}	mg/L	37.246	200.000	600.000	/
NO_3^-	mg/L	0.001	45.000	No Relaxation	/
F^-	mg/L	0.053	0.500	1.500	/
Ca^{2+}	mg/L	41.530	75.000	200.000	/
Mg^{2+}	mg/L	13.440	30.000	100.000	/
Na^+	mg/L	88.215	50.000	200.000	/
K^+	mg/L	4.310	/	/	/
AL = Allowed limit ;PLAAS =Permissible limit in absence of allowed limit; (/)= NA					

6.3 Ground water quality

Managed aquifer recharge (MAR) structures are used to enhance the quantity and quality of groundwater. MAR is a term which is conceived by the British hydro geologist Ian Gale, who was the founding co-chair of the International Association of Hydro geologists (IAH) Commission on Managing Aquifer Recharge from 2002 to 2011 (IAH-MAR 2018a). Managed aquifer recharge refers to a suite of methods that is increasingly used to maintain, enhance and secure groundwater systems under stress (Dilton 2018). From the study, it is found that, a sum-up of minimum, maximum, and mean values of physico-chemical parameters measured in situ and in laboratory are presented in the Table 6.3. Concentration of hydrogen ion shows the measure of pH of a solution. Solutions with a high concentration of hydrogen ion normally have a low pH, while solutions with a low concentration of hydrogen ion have a very high pH. However, hydrogen ion concentration (pH) in groundwater is an important hydro chemical parameter, which has no direct impact on human health (Adimalla and Venkatayogi 2018). In the study, pH ranged from 7.2 to 7.76, with a mean of 7.489, indicating the groundwater is slightly alkaline in condition in the study region. As shown in Table 6.3, all groundwater locations are within the acceptable limit of 6.5 to 8.5 (BIS 2012).

Slightly higher pH values are recorded in the study area, and this may possibly be endorsed to the geological factors, and also the combination of CO_2 with water forms carbonic acid, which solely affects the pH of the groundwater in the study region. The concentration of EC in the study region groundwater ranged from, 644 µS/cm to 2309 µS/cm, with a mean of 1365.385 µS/cm (Tables 6.2 and 6.3). In general, the EC is a measure of the ability of material to conduct an electric current, so the elevated EC discloses the increase of salts in the groundwater. Thus, EC can be classified into three categories such as: category-I, if the increase of salt is very low (EC < 1500 µS/cm); category-II, if the increase of salts is medium (EC: 1500 and 3000 µS/cm); and category-III, if the increase of salts is high (EC > 3000 µS/cm; Subba Rao et al. 2012). As per the classification of EC, 70.5% and 29.5% of the total groundwater samples are category-I and category-II, respectively. TDS in the groundwater of the study area ranged from 419.61 to 1456 mg/L, with a mean of 828.914 mg/L (Tables 6.2 and 6.3), and all groundwater samples are within the permissible limit of 2000 mg/L (BIS 2012), whereas Total hardness (TH) is observed between 167.5 and 537.5 mg/L, with a mean of 357.941 mg/L, and no groundwater samples are above the maximum permissible limit of 600 mg/L for drinking purposes (Table 6.3; BIS 2012).

Results showed that the ranges of cation concentrations in the groundwater of Salamanatham village are 35.348 to 270.955 mg/L, 7.74 to 85.069 mg/L, 57.638 to 392.887 mg/L, and 2.592 to 6.776 mg/L for $Ca2^+$, $Mg2^+$, Na^+, and K^+, respectively (Tables 6.2 and 6.3). The mean values of these cations are 80.281, 43.786, 192.629 and 4.115 mg/L for $Ca2^+$, $Mg2^+$, Na^+, and K^+, respectively (Table 6.2 & 6.3). Only 5.88% and 41.17% of groundwater samples are above maximum allowable limit of 200 mg/L for $Ca2^+$ and Na^+ for drinking purposes (Table 6.3). The mean concentrations of cations in the samples are in the order of $K^+ < Mg2^+ < Ca2^+ < Na^+$. Maximum concentration of $HCO3^-$ in groundwater of study region is 460 mg/L, with a mean value of 311.029 mg/L (Table 6.3). Cl^- level in groundwater is found to range from 39.988 to 289.910 mg/L, with a mean value of 134.076 mg/L, and no groundwater samples are found to exceed the maximum permissible limit of 1000 mg/L, set by the Bureau of Indian Standards (BIS 2012; Tables 6.2 and 6.3). The ranges of anion concentrations in the groundwater of Salamanatham village are 200 to 460 mg/L, 39.988 to 289.91 mg/L, 12.46 to 113.46 mg/L, 2.089 to 83.299 mg/L, and 0.519 to 2.29 mg/L for $HCO3^-$, Cl^-, SO_4^{2-}, NO^{3-}, and F^-, respectively (Tables 6.2 and 6.3). The mean values of these anions are 311.029, 134.076, 51.978, 27.841, and 1.235 mg/L for $HCO3^-$, Cl^-, SO_4^{2-}, NO^{3-}, and F^-, respectively. The mean concentrations of anions in the samples are in the order of $F^- < NO^{3-} < SO_4^{2-} < Cl^- < HCO3^-$.

Table 6.2 Analytical results of the groundwater samples from the study region.

Sample ID	pH	EC	TDS	TH	HCO_3^-	Cl^-	SO_4^{2-}	NO_3^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	F^-
1	7.255	1247.500	950.450	442.500	305.000	189.941	62.660	17.358	103.061	44.963	146.125	3.836	1.040
2	7.305	854.400	540.316	392.500	217.500	129.960	25.260	41.970	48.219	66.075	80.439	3.430	0.676

3	7.555	832.150	528.786	312.500	200.000	59.981	26.460	12.856	35.348	54.453	57.638	2.263	0.519
4	7.540	1095.000	696.620	352.500	250.000	99.969	50.660	22.635	85.880	33.525	115.196	2.592	0.656
5	7.510	1552.000	958.280	482.500	345.000	289.910	113.460	2.524	270.955	47.128	311.467	3.396	1.250
6	7.620	1314.500	718.700	367.500	277.500	139.957	85.660	41.970	128.489	11.332	312.741	3.137	1.200
7	7.685	1088.500	743.470	242.500	232.500	119.963	58.460	2.089	84.351	7.741	242.679	4.947	1.760
8	7.335	1390.000	871.130	270.000	332.500	99.969	57.860	7.875	86.703	12.993	392.887	5.305	2.200
9	7.595	1180.500	761.320	240.000	322.500	69.978	21.460	4.155	73.321	13.822	258.001	6.776	2.290
10	7.600	1408.000	667.830	315.000	282.500	109.966	40.660	11.048	46.028	48.584	100.310	5.403	0.888
11	7.240	2309.000	1456.000	475.000	385.000	279.913	104.260	83.299	78.310	67.860	367.500	3.690	1.250
12	7.560	1494.000	942.280	435.000	357.500	119.963	80.660	77.100	62.244	67.891	131.856	4.613	1.330
13	7.760	992.500	628.640	332.500	325.000	59.981	20.460	26.657	47.638	51.857	116.772	4.234	1.270
14	7.200	1605.000	564.200	295.000	330.000	59.981	22.860	26.731	37.030	49.180	70.890	3.630	1.290
15	7.525	1875.500	1187.900	537.500	430.000	259.919	53.060	57.063	74.965	85.069	271.784	5.010	1.070
16	7.520	664.000	419.610	167.500	235.000	39.988	12.460	12.229	38.513	17.323	104.705	3.225	0.822
17	7.500	2309.000	1456.000	425.000	460.000	149.954	47.260	25.734	63.730	64.560	193.700	4.470	1.480

Table 6.3 Concentrations of ions and their comparison with the drinking water quality standards

Chemical Parameter	Expressed	Minimum	Maximum	Mean	SD	AL	PLAAS	% of samples exceeding the PLAAS
pH	Units	7.200	7.760	7.489	0.163	6.5-8.5	No Relaxation	/
EC	µS/cm	644.000	2309.000	1365.385	469.648	/	/	/
TDS	mg/L	419.610	1456.000	828.914	304.141	500.000	2000.000	/
TH	mg/L	167.500	537.500	357.941	100.036	200.000	600.000	/
HCO_3^-	mg/L	200.000	460.000	311.029	72.887	/	/	/

Cl^-	mg/L	39.988	289.910	134.076	78.083	250.000	1000.000	/
SO_4^{2-}	mg/L	12.460	113.460	51.978	30.118	200.000	600.000	/
NO_3^-	mg/L	2.089	83.299	27.841	25.738	45.000	No Relaxation	17
F^-	mg/L	0.519	2.290	1.235	0.494	0.500	1.500	17
Ca^{2+}	mg/L	35.348	270.955	80.281	55.266	75.000	200.000	5.88
Mg^{2+}	mg/L	7.740	85.069	43.786	32.377	30.000	100.000	/
Na^+	mg/L	57.638	392.887	192.629	109.478	50.000	200.000	41.17
K^+	mg/L	2.592	6.776	4.115	1.146	/	/	/
SD = Standard deviation								

6.3.1 Identification of zones benefited by MAR structures

The study covers an area of about 1 sq.km. This area has been divided into 4 zones. The concentration of the major ions present in the samples and the Electrical conductivity of the sample have been used to identify the zones that are benefited by the recharge of the MAR structures. The graph between Electrical Conductivity which is a function of TDS and chloride which is the dominant concentration of anion present in the sample water was plotted to identify the zones benefitted by the MAR structures. In zone 1, the figure 6.3 indicates that the points closer to the origin have an electrical conductivity of 830 to 1,100 µS/cm and chloride concentration of 50 to 200 mg/L. These values are much closer to that of the data collected from the surface water which has an electrical conductivity of 624 µS/cm and chloride of concentration of 94 mg/L. So, the wells numbered 1, 2, and 3 are considered as near wells, whereas, the wells that are numbered 4, 5, and 6 are considered as far wells. In the similar way, figure 6.4 also indicates that in zone 2 ,the point nearer to the origin are the wells with EC and chloride concentration much closer to that of the values of the surface water. Thus, in zone 2, wells numbered 12 and 13 are considered as near wells and the wells that are numbered as 11, 14 and 15 are considered as far wells. In zone 3 (fig. 6.5), the points nearer to the origin are the wells having an EC and Chloride concentration similar to that of the surface water's EC and Chloride concentration. So, in zone 3, the wells numbered 7, 8, and 9 are considered as near wells and the wells that are numbered 10 and 17 are considered as far wells. Figure 6.6 also shows that in zone 4, the point value is much smaller when compared to the wells in the other zones. This water is being used for domestic purposes throughout the village. Similarly, the other major concentrations present in the water samples are Na, Ca, Cl, and HCO_3. Thus the four dominant ions in the water samples in each zone of the study area have been plotted as Na/Cl versus Ca/HCO_3 as shown in the figure 6.7, 6.8, 6.9 and 6.10. The grouping of the wells similar to that of the figure 6.3, 6.4, 6.5, and 6.6 of all the zones can be seen in figure 6.7, 6.8, 6.9 and 6.10 of all the respective zones. Figure (6.7 to 6.10) shows that the points closer to the origin are the wells with concentration ratios of

Na/Cl and Ca/HCO_3 much closer to that of the surface water sample taken from the stream. These wells are considered as near wells in the respective zones, whereas the points that are plotted away from the origin are the wells with concentration ratios of Na/Cl and Ca/HCO_3 much higher to that of the surface water sample taken from the stream, these wells are considered as far wells in the respective zones in the study area. The figures (6.3 to 6.6) and figures (6.7 to 6.10) clearly show that, the concentrations of the ions present in the surface water are much less and the near wells that are recharged by surface water have low concentration of ions compared to that of the far wells. Therefore, in general, the concentration of the ions in the near wells is lesser when compared to that of the far wells in their respective zones.

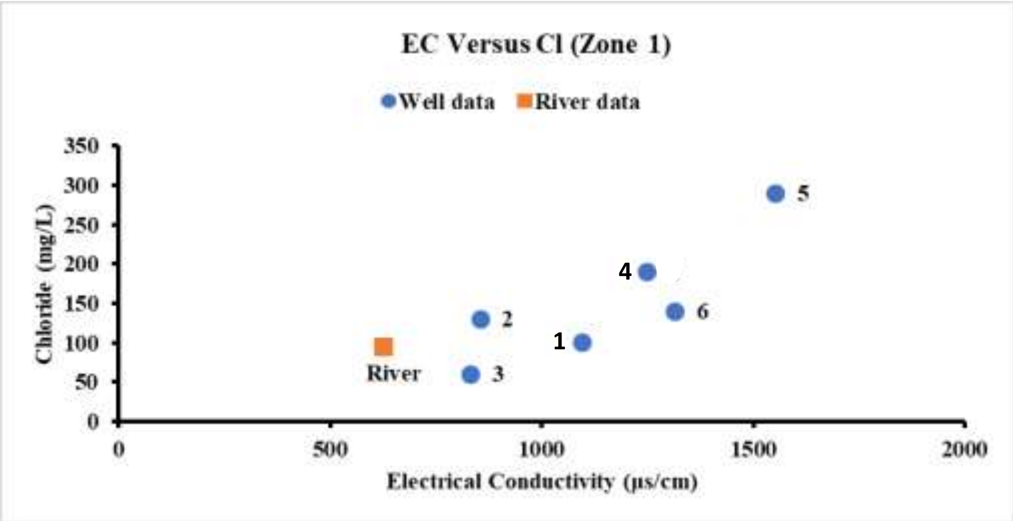

Figure 6.3 Plot of EC versus Cl concentration of the water samples (Zone-1)

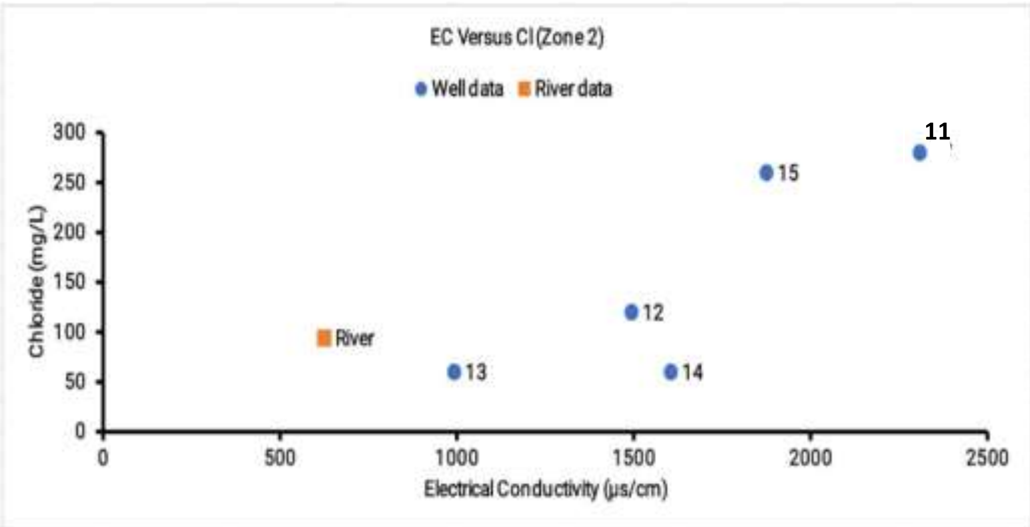

Figure 6.4 Plot of EC versus Cl concentration of the water samples (Zone-2)

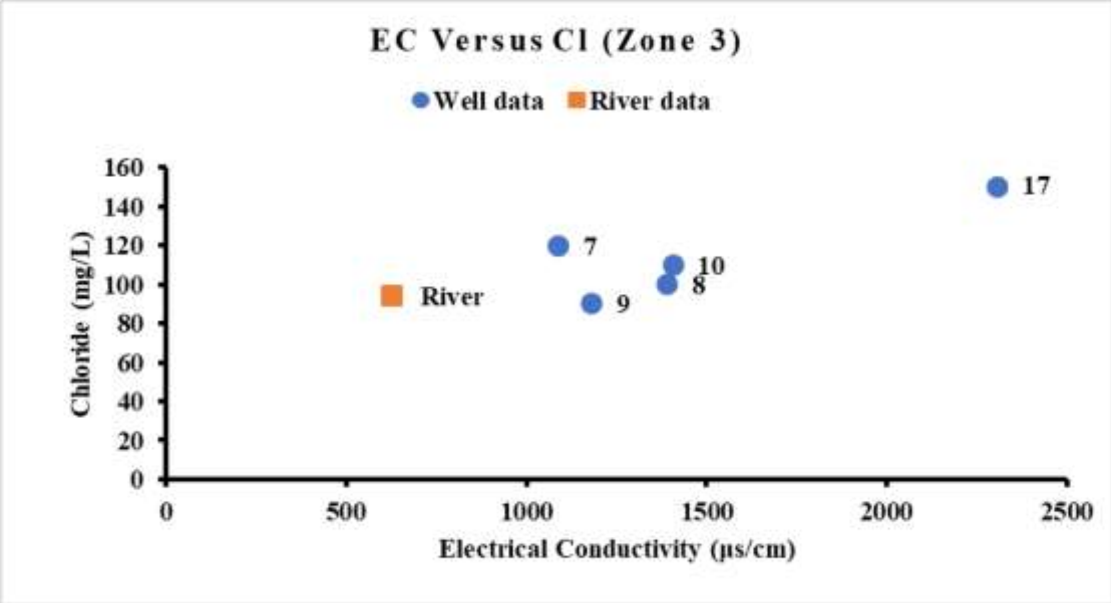

Figure 6.5 Plot of EC versus Cl concentration of the water samples (Zone-3)

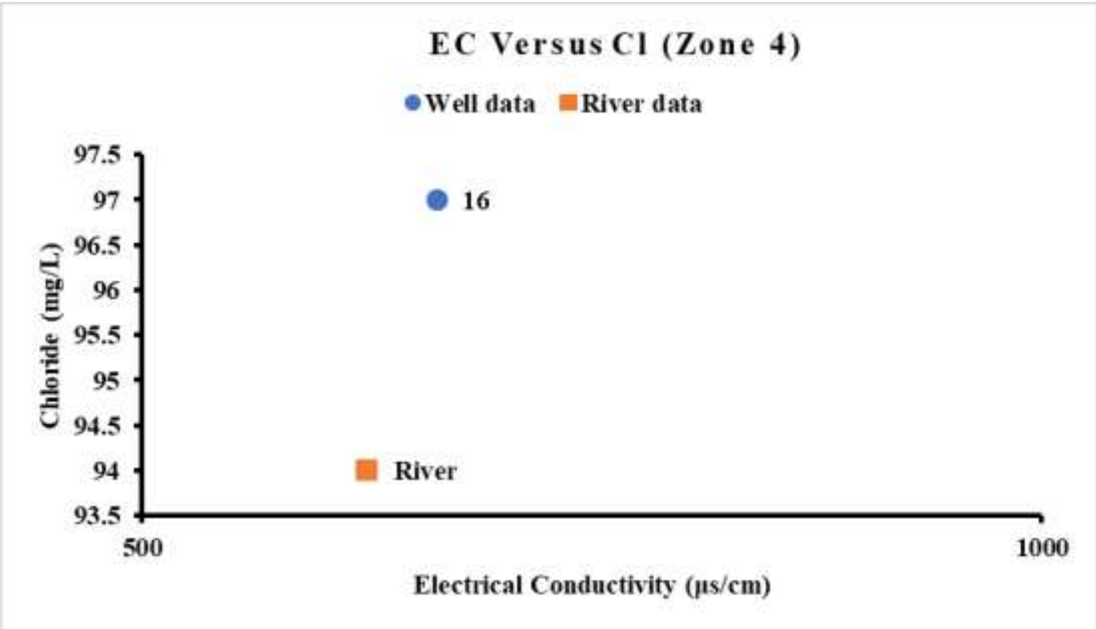

Figure 6.6 Plot of EC versus Cl concentration of the water samples (Zone-4)

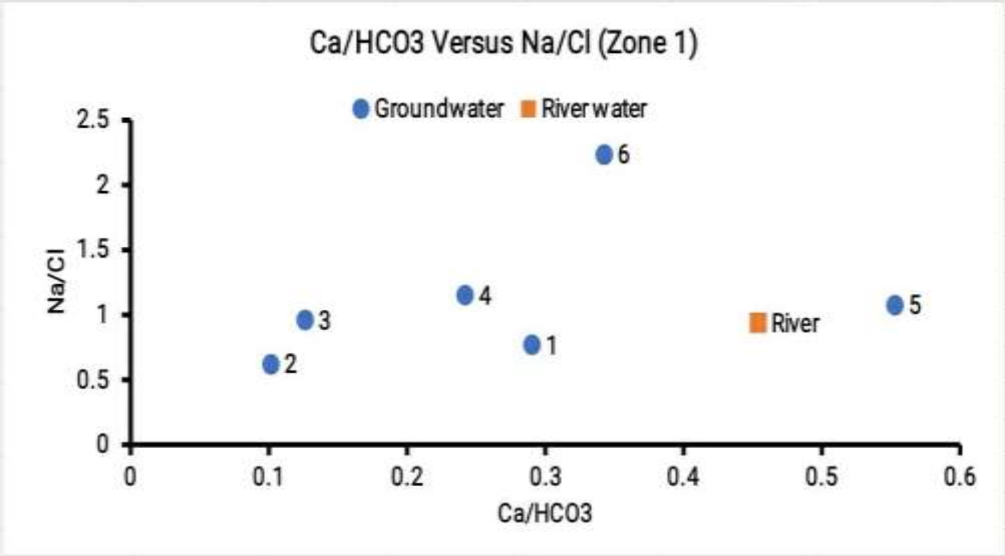

Figure 6.7 Plot of Ca/HCO3 versus Na/Cl of the water samples (Zone-1)

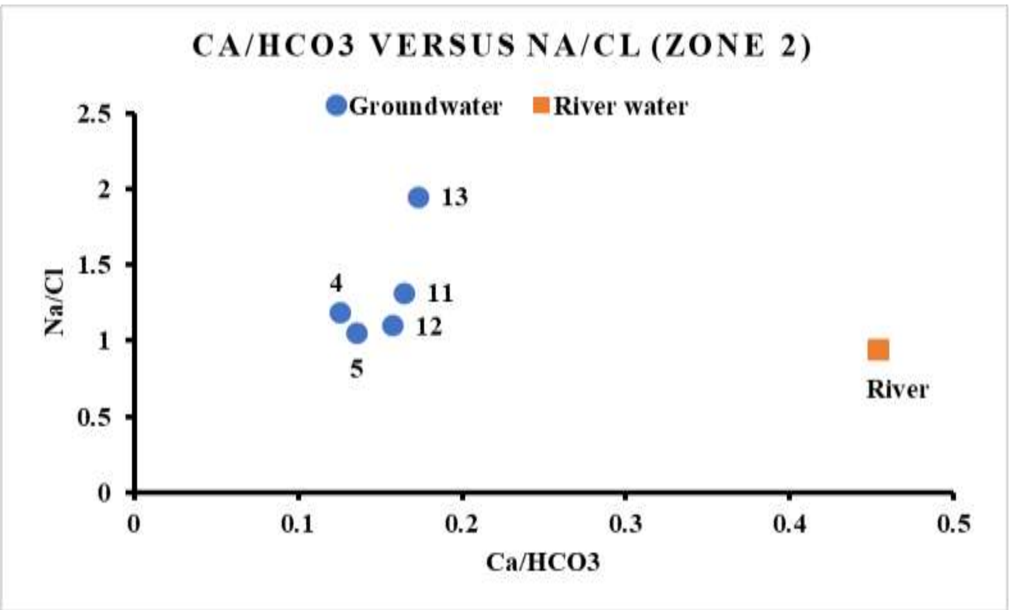

Figure 6.8 Plot of Ca/HCO3 versus Na/Cl of the water samples (Zone-2)

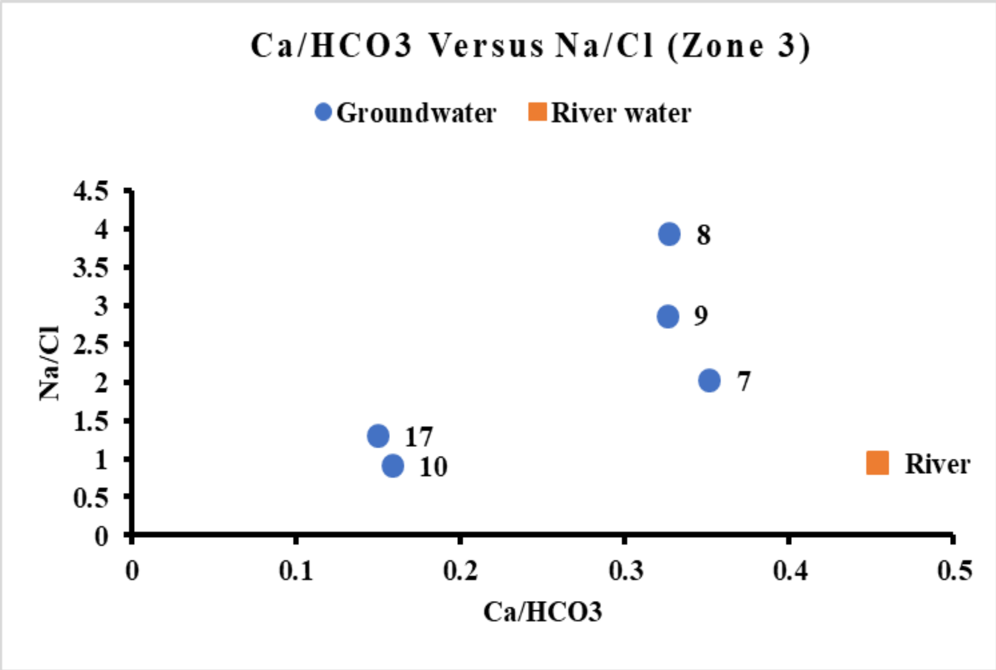

Figure 6.9 Plot of Ca/HCO3 versus Na/Cl of the water samples (Zone-3)

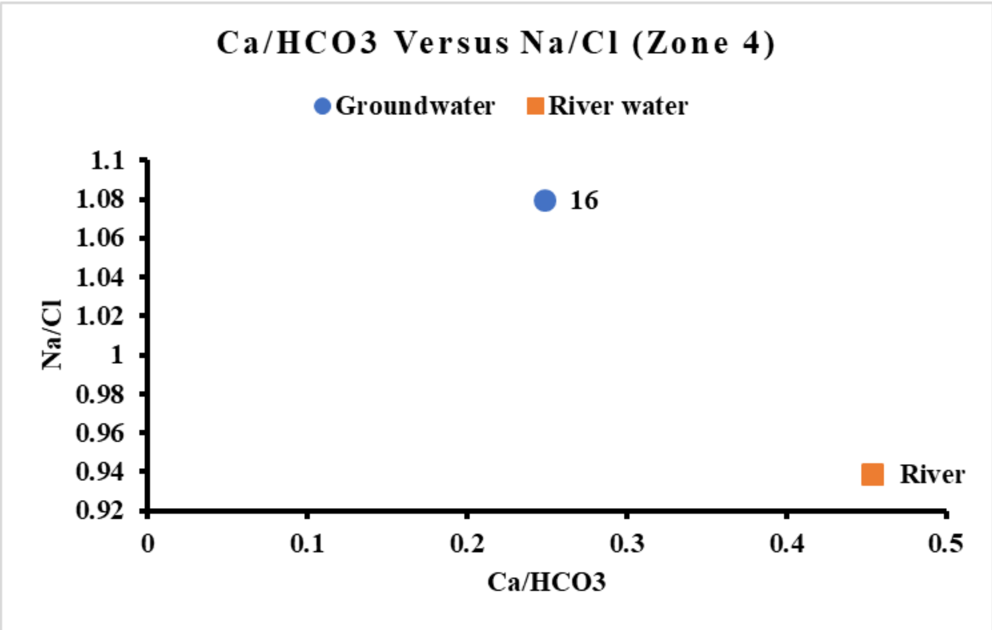

Figure 6.10 Plot of Ca/HCO3 versus Na/Cl of the water samples (Zone-4)

6.3.2 Major ion concentration

The major ions of each sample are studied and compared with the River water's major ions to identify the impact of river water on the characteristics of groundwater. With the help of this data, efficiency of the recharge structures and its influence range on groundwater can be found. The chemistry of groundwater was studied using two different methods. They are piper and schoeller diagram. These are explained briefly in the following topics 6.3.2.1 and 6.3.2.2.

6.3.2.1 Piper

The geochemical evolution of ground water can be understood by constructing Piper (1944) trilinear diagram (Ravikumar et al. 2017). In the present study, the GW_chart software has been used for plotting samples in the piper diagram. The water samples from the study area have been plotted in the piper diagram which includes the samples from near wells, far wells and the surface water. The water samples with the similar quality i.e. the sample with similar concentration of the ions will tend to plot together as groups (Todd, 2001).The water type or hydro chemical facies in the water samples can be decided with the help of the subdivisions of the diamond shaped field in the piper diagram. It is evident from the Figure 6.11 that among cations, the majority of the samples 44% (near wells -4, far wells – 3 and even the surface water) demonstrates the dominance of Sodium and Potassium concentration which is followed by no dominance of any particular cation in their concentration (far wells – 6 and near wells – 3) and only 2 samples, both from near wells have a dominance of Mg in their concentration. Similarly among the anions almost all the samples both near wells and fall wells in the study area have the dominance of bicarbonate in their concentration whereas the surface water have the dominance of chloride in the concentration. The diamond plot in the piper diagram is classified into 5 parts; they are 1,2,3,4 and 5 which represents "Magnesium bi-carbonate type", "Sodium chloride type", "Mixed type", "Mixed type", "Calcium chloride type" and "Sodium bi-carbonate type". Characteristics of samples were analysed using piper diagram and it was found that, River water falls under "sodium chloride" type, 44.5% of near wells fall under "Magnesium bi-carbonate type", 33.3% of near wells fall under "Mixed type" and 22.2% of near wells fall under "Sodium chloride type". 50% of far wells fall under "Magnesium bi-carbonate type", 37.5% of far wells fall under "mixed type" and 12.5% far wells fall under "Sodium chloride type".

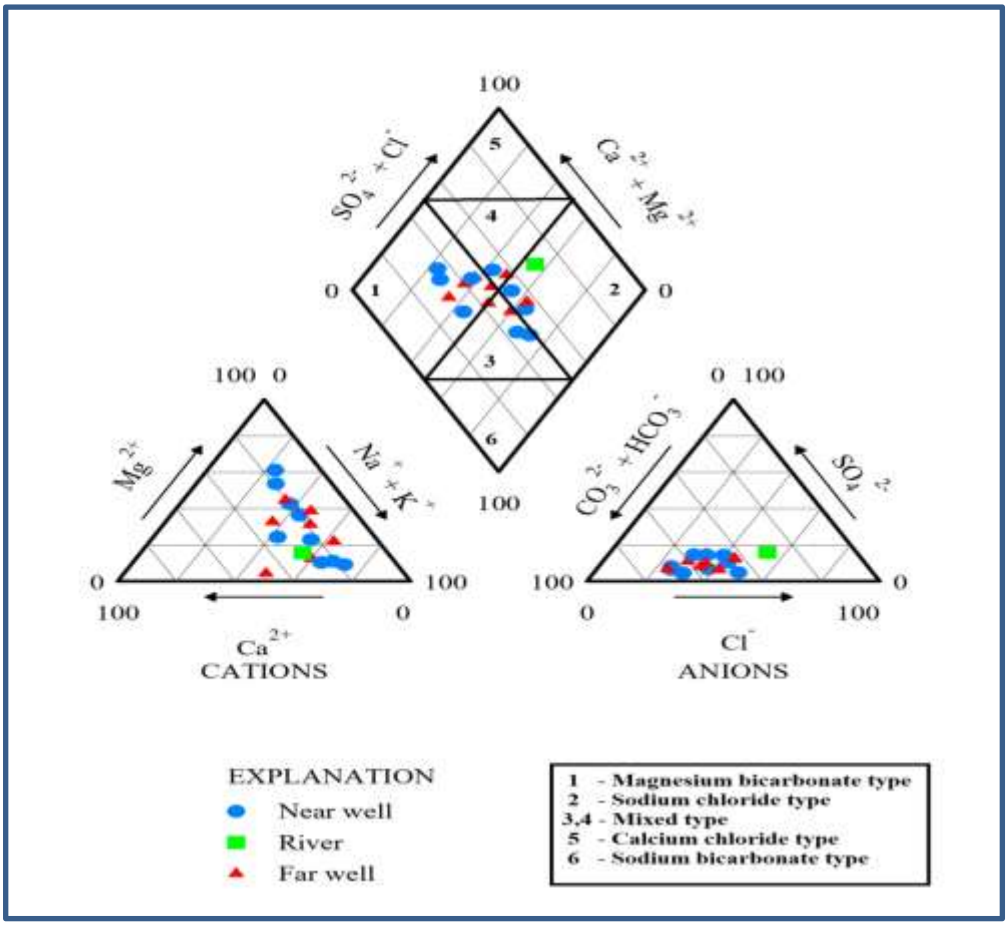

Figure 6.11 Piper trilinear classifications of river and groundwater

6.3.2.2 Schoeller diagram

The Schoeller graph is used to identify the variation between the quality of water present in wells near the groundwater recharge structures and those that are present far from them. The quality of the river water present as the source is also taken into account. These observations are made in the month of December 2019. In the Schoeller plot, blue lines are used to represent the near wells and the red lines represent the far wells, shown in the figure 6.12, 6.13, 6.14 and 6.15. A general pattern can be observed where the concentration of major ions in the near wells is lesser in comparison to those that of the far wells. This higher quality of water shows that the wells near the recharge structures are benefitted by them. Hence, the Electrical Conductivity and the major ion concentration which help in determining the overall quality of water are used as a means to determine the area benefitted by each of those recharge structures which has been discussed in the previous topic 6.3.1. The results based on Electrical Conductivity are also found to be similar to that obtained from the major ion concentration.

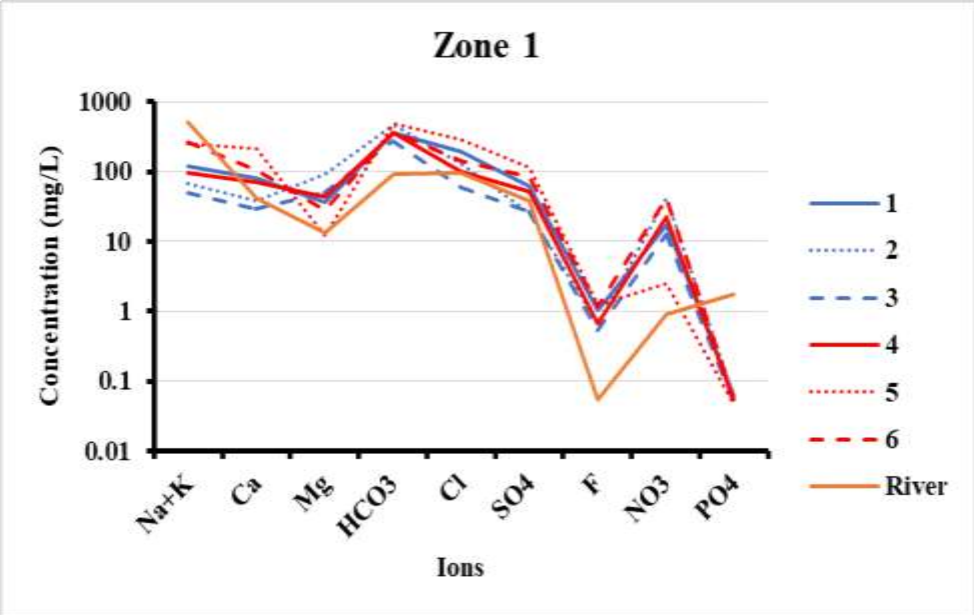

Figure 6.12 Schoeller diagram of groundwater from the wells located closer to and away from MAR structure. (Zone-1)

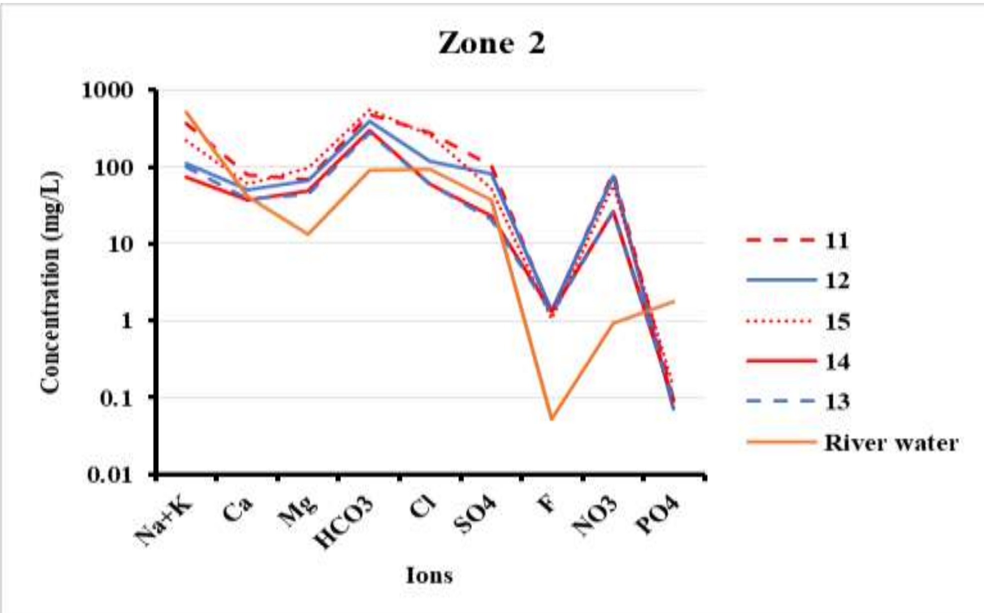

Figure 6.13 Schoeller diagram of groundwater from the wells located closer to and away from MAR structure. (Zone-2)

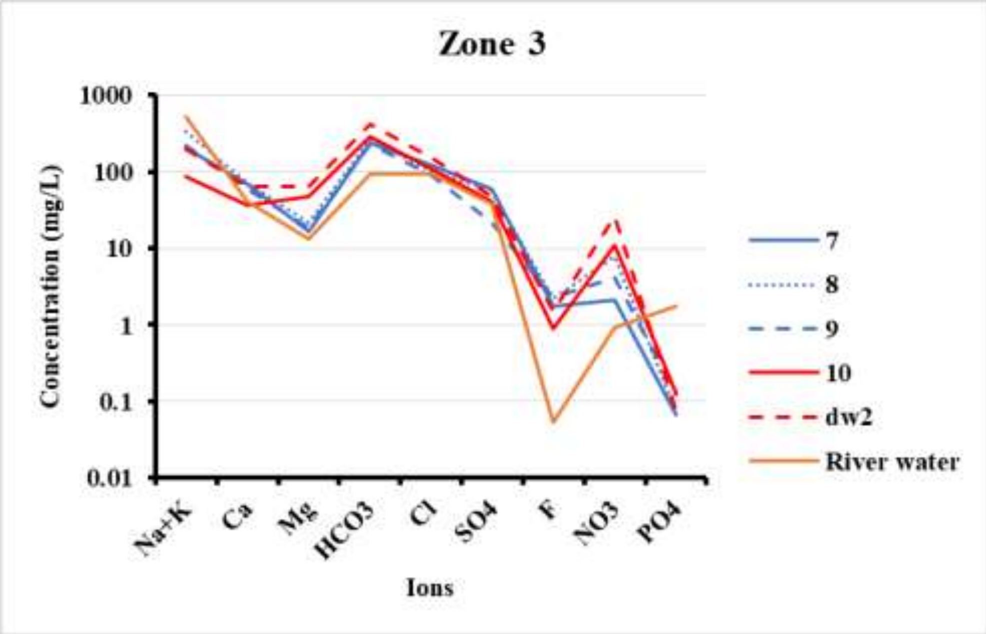

Figure 6.14 Schoeller diagram of groundwater from the wells located closer to and away from MAR structure. (Zone-3)

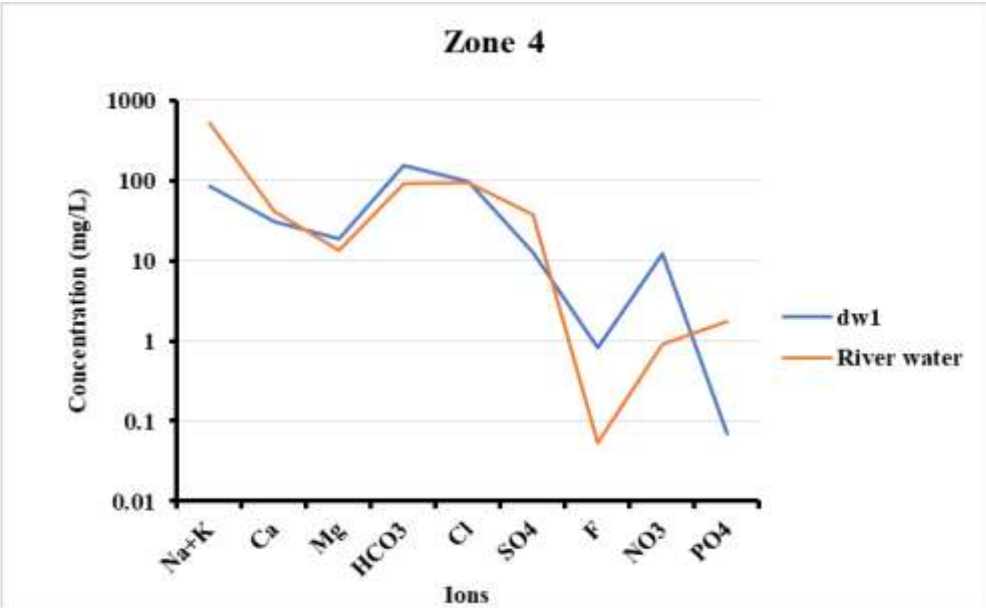

Figure 6.15 Schoeller diagram of groundwater from the wells located closer to and away from MAR structure. (Zone-4)

6.3.3 Water quality for drinking purposes

The water samples from the observation wells have been classified based on various parameters. They are Total Dissolved Solids (TDS), Total Hardness (TH), Electrical Conductivity (EC), pH, major cations and anions present in the samples. TDS present in the water samples from the observation well varies from 420 to 1450 mg/L with an average of 828.9 mg/L. The water is mostly fresh (82%) to brackish (18%) and these 18% is mostly the wells far from the MAR structures in the respective zones whereas the 82% i.e. the samples which falls under the fresh category are mostly the samples from the wells near the MAR structures in the respective zones, and the water from the stream (i.e.,) the surface water is fresh in nature as per the classification suggested by Freeze and Cherry (1979) (Table 6.4). Groundwater is classified as desirable(11%) to permissible (70%), these 11% mostly represents the value of the wells which are near from the MAR structures in the respective zones, the 70% represents both wells from near and far from the MAR structures in respective zones, and the remaining percentage represent the far wells of the respective zone and these are permissible for drinking and irrigation purposes, whereas the surface water falls under desirable limit as per the classification of TDS suggested by David and Dewiest (1966) (Table 6.5).

The Suitability of the groundwater and surface water for the drinking standards as per the various parameter includes the pH, and other major cations and anions have been verified with the WHO standards (2006) and BIS (2003) in the Table 6.6. The near wells in respective zones mostly falls under the permissible limits of pH, major cations and anions, whereas the far wells mostly falls under the non-permissible limits among the few major cations which includes Ca, Na, Mg and among the anions Cl falls under non permissible limits based on the WHO standards(2006) and BIS(2003). The percentage of the samples that exceed the permissible limit of the various ions like Ca, Mg, Na, and Cl are 23%, 29%, 35%, 17% respectively. The surface water when compared with the WHO standards (2006) and BIS (2003), it is found that the water sample is permissible for drinking purposes.

Total Hardness (TH) concentration of the water mostly depends upon the concentration of the Ca and Mg. The water from the observation wells and the surface water have been classified based on the Hardness as suggested by the Sawyer and Mcartly (1967). The samples from the observation wells are classified as hard (47%) and very hard (53%) whereas the surface water falls under the very hard category (Table 6.7). The samples from the near wells mostly fall under the hard category whereas the samples from the far well mostly fall under the far category in the respective zones. The minimum, maximum, and mean of the water samples from the observation wells are 170, 540 and 360 mg/L respectively. Thus the water samples from the near wells and the surface water is suitable for drinking based on the WHO standards (2006) and BIS (2003).

TABLE 6.4 Classification of water samples based on TDS (in milligrams per litre)

TDS (mg/L)	Water type (Freeze and Cherry 1979)	Groundwater							Surface water
		Zone 1		Zone 2		Zone 3		Zone 4	
		Near well	Far well	Near well	Far well	Near well	Far well	Near well	
<1000	Fresh	1,2,3	4,5,6	12,13	14	7,8,9	10	dw1	1
1000-10000	Brackish	Nil	Nil	Nil	11,15	Nil	dw2	Nil	Nil
10000-100000	Saline	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
>100000	Brine	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

Table 6.5 Classification of groundwater based on TDS (in milligrams per litre)									
TDS (mg/L)	Classification (David and DeWiest 1966)	Groundwater							Surface water
		Zone 1		Zone 2		Zone 3		Zone 4	
		Near well	Far well	Near well	Far well	Near well	Far well	Near well	
<500	Desirable for drinking	Nil	6	Nil	Nil	Nil	Nil	dw1	1
500-1000	Permissible for drinking	1,2,3	4,5	12,13	14	7,8,9	10	Nil	Nil
1000-3000	Useful for drinking and Irrigation	Nil	Nil	Nil	11,15	Nil	dw2	Nil	Nil
>3000	Unfit for drinking and Irrigation	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

Table 6.6 Comparison of water quality parameters with the permissible limits											
Parameter	Unit	WHO (2006)	BIS (2003)	Well numbers in which limits are exceeded							Surface water sample exceeding the limit
				Zone 1		Zone 2		Zone 3		Zone 4	
				Near well	Far well	Near well	Far well	Near well	Far well	Near well	
pH	No Unit	6.5-8.5	6.5-8.5	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Ca	mg/L	75	75	1	5,6	Nil	11	Nil	Nil	Nil	Nil
Mg	mg/L	50	30	2	Nil	12	11,15	Nil	dw2	Nil	Nil
Na	mg/L	200	-	Nil	5,6	Nil	11,15	8,9	Nil	Nil	Nil
K	mg/L	55	-	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Cl	mg/L	250	250	Nil	5	Nil	11,15	Nil	Nil	Nil	Nil
SO4	mg/L	400	400	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

Table 6.7 Classification of groundwater based on TH									
Total hardness (mg/L)	Type of water (Sawyer and Mcartley 1967)	Groundwater							Surface water
		Zone 1		Zone 2		Zone 3		Zone 4	
		Near well	Far well	Near well	Far well	Near well	Far well	Near well	
<75	Soft	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
75-150	Moderately hard	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
150-300	Hard	3	Nil	13	14	7,8,9	10	dw1	Nil
>300	Very hard	1,2	4,5,6	12	11,15	Nil	dw2	Nil	1

6.3.4 Water quality for irrigation purposes

The pH of groundwater and water in the River is lower than the prescribed maximum limit of 8.5 (Ayers and Westcot 1994) for irrigation purposes. EC is the other important factor to determine the quality of water for irrigation purposes. Based on the USSL classification, groundwater samples are classified as good (11.8 %), permissible (76.4 %), and unsuitable (11.8 %) (Table 3.8) (USSL Staff 1954). The water stored in the River is classified as good.

Table 6.8 Suitability of groundwater for irrigation based on the USSL classification									
Electric Conductivity	Salinity class and remarks	Groundwater							Surface water
		Zone 1		Zone 2		Zone 3		Zone 4	
		Near well	Far well	Near well	Far well	Near well	Far well	Near well	
<250	C1, excellent	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
250-750	C2, good	Nil	6	Nil	Nil	Nil	Nil	dw1	1
750-2250	C3, permissible	1,2,3	4,5	12,13	14,15	7,8,9	10	Nil	Nil
2250-5000	C4, unsuitable	Nil	Nil	Nil	11	Nil	dw2	Nil	Nil

6.3.4.1 Sodium adsorption ratio

Sodium content in high concentration reduces the infiltration rates of the water, which causes various effects on soil aeration and seed germination, increases the growth of weed, and promotes mosquito breeding due to waterlogging. SAR helps to identify the sodium hazard. The following formula is used to calculate SAR, in which the concentrations are expressed in milli-equivalents per litre (Richards 1954):

$$\mathrm{SAR} = \frac{\mathrm{Na}}{\sqrt{\frac{\mathrm{Ca} + \mathrm{Mg}}{2}}}$$

The classification of water samples of the study area based on SAR are given in Table 6.9. Surface water in that area comes under good water class when checked with SAR. Likewise, water samples from the wells 2 and 3 are in excellent condition, wells 1,4,10,12,13,14 and 16 comes under good water class as that of Surface water and wells 5,15, 17 and 6,7,8,9,11 are in doubtful and unsuitable water class. Water samples of the study area are classified into four types based on the USSL diagram (Fig. 6.16). From Fig. 6.16, it is observed that 23.5 % of the groundwater samples fall in the C3–S2 type, 35.3 % samples fall in the C3–S3 type, 5.9% samples falls under C2-S3 type and 35.3% falls under C3-S4 type. Surface water falls under C2-S3 type.

Table 6.9 Classification of water samples based on SAR

SAR	Water class	Groundwater							Surface water
		Zone 1		Zone 2		Zone 3		Zone 4	
		Near well	Far well	Near well	Far well	Near well	Far well	Near well	
<10	Excellent	2,3	Nil	Nil	Nil	Nil	Nil	Nil	Nil
10 to 18	Good	1	4	12,13	14	Nil	10	dw1	1
18 to 26	Doubtful	Nil	5	Nil	15	Nil	dw2	Nil	Nil
>26	Unsuitable	Nil	6	Nil	11	7,8,9	Nil	Nil	Nil

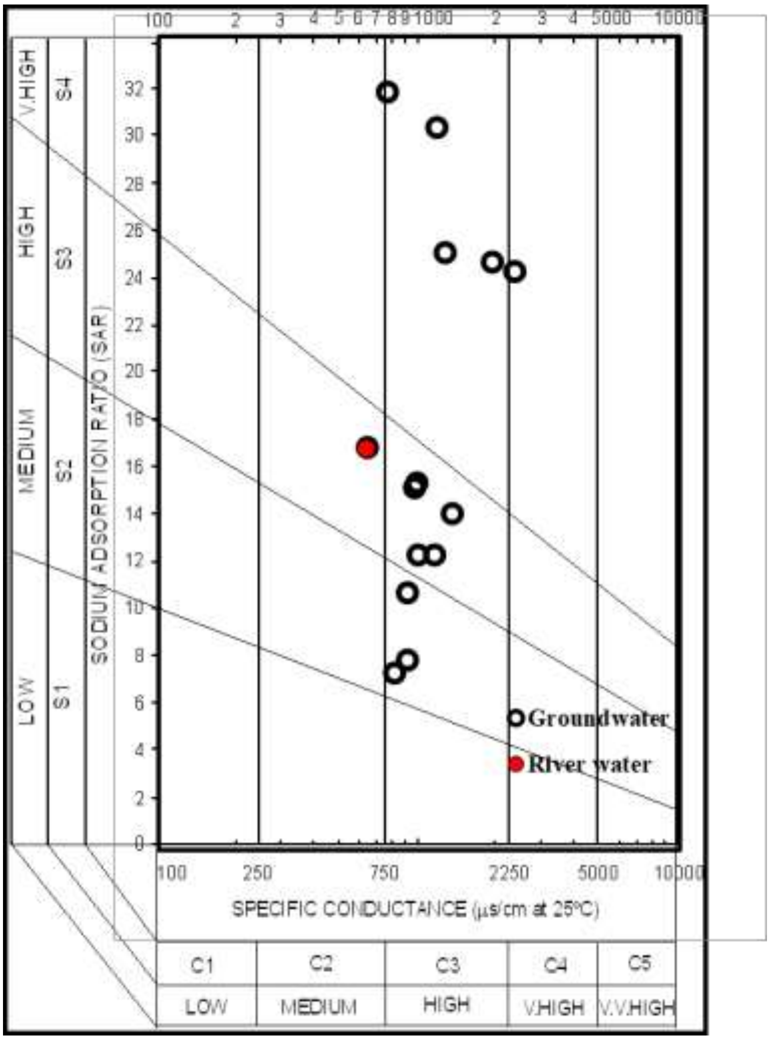

Figure 6.16 Classification based on the USSL

6.3.4.2 Percentage sodium

Classification of irrigation water based on exchangeable sodium is important because, sodium content affects both crops and soil. So, Na% is also used to determine the effect of sodium. %Na is calculated using the formula:

$$\%Na = \frac{(Na + K)}{Ca + Mg + Na + K} \text{ x } 100$$

Here, all the ionic concentrations are expressed in milli-equivalents per litre. The classification of water samples based on %Na is given in Table 6.10. It indicates that 11.8 % of the groundwater samples are classified as good, 47% as permissible, and 41.2% as doubtful. Surface water sample collected from the study area is classified as Doubtful. Based on Wilcox’s (1955) plot, groundwater samples are classified as excellent to good (11.8%), good to permissible (76.4%), doubtful to unsuitable (11.8%), and unsuitable (0%) (Fig. 6.17).

Table 6.10 Classification of water samples based on %Na									
%Na	Water class	Groundwater							Surface water
		Zone 1		Zone 2		Zone 3		Zone 4	
		Near well	Far well	Near well	Far well	Near well	Far well	Near well	
0-20	Excellent	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
20-40	Good	2,3	Nil	Nil	Nil	Nil	Nil	Nil	Nil
40-60	Permissible	1	4,5	12,13	14,15	Nil	10	Nil	1
60-80	Doubtful	Nil	6	Nil	11	7,8,9	dw2	dw1	Nil
>80	Unsuitable	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

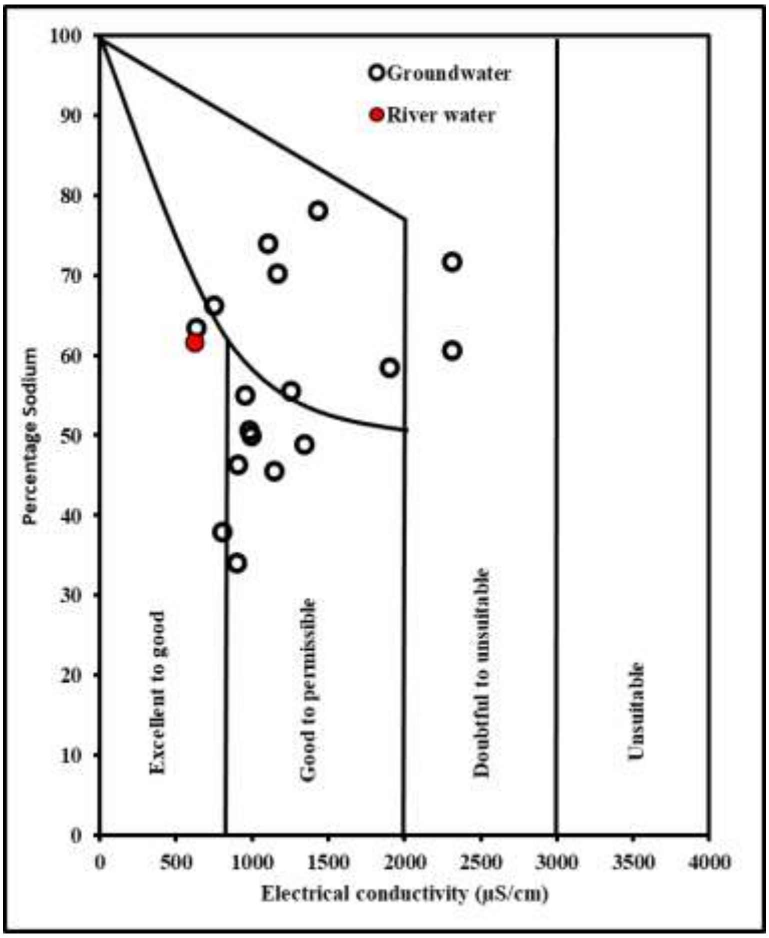

Figure 6.17 Classification based on the Wilcox

6.3.4.3 Kelly's index

The KI is based on the ratio of concentration of sodium to calcium and magnesium. The KI is calculated using the following formula (Kelly 1963):

$$KI = \frac{Na}{Ca + Mg}$$

Here, all the ionic concentrations are expressed in milli-equivalents per liter. Infiltration rate will be reduced when there is a soil depression which is created by low calcium content. And if the calcium content is high, it causes poor seed emergence and reduced aeration. Problems that are created by the magnesium are very similar to that of calcium. The classification of the quality of irrigation water based on KI is given in Table 6.11. The groundwater is classified as suitable (41.2 %), marginal (35.3 %), and unsuitable (23.5 %) based on KI. Surface water samples collected from the study area is classified as marginally suitable for irrigation purpose based on KI.

Table 6.11 Classification of irrigation water based on Kelly's ratio

Kelly's ratio	Water class	Groundwater							Surface water
		Zone 1		Zone 2		Zone 3		Zone 4	
		Near well	Far well	Near well	Far well	Near well	Far well	Near well	
<1	Suitable	1,2,3	4	12	14	Nil	10	Nil	Nil
1 to 2	Marginal	Nil	5,6	13	15	Nil	dw2	dw1	1
>2	Unsuitable	Nil	Nil	Nil	11	7,8,9	Nil	Nil	Nil

6.3.4.4 Permeability index

Doneen (1964) had developed a chart based on the PI and the total concentrations of all ions. PI is given by:

$$PI = \frac{Na + \sqrt{HCO3}}{Ca + Mg + Na} \text{ x } 100$$

Here, the concentrations are expressed in milli-equivalents per litre. The plot between total concentration and PI is shown in Fig. 6.18. All of the groundwater samples, i.e., 100 % fall under class I (good for irrigation purpose). Water from River is also classified as good for irrigation purpose (class I) for irrigation purposes. The concentration of ions in groundwater is high in certain regions as groundwater used for irrigation purposes undergoes evaporation which leads to an increase in concentration of ions. This evaporation-enriched irrigated water enters the groundwater zone as recharge, which is pumped again for irrigation. Therefore, the use of groundwater for irrigation and its evaporation from the irrigated area lead to an increase in the concentration of ions in the groundwater of this area. Such observations are also made by Bouwer (1987), Elango et al. (2003), and Rajesh et al. (2011).

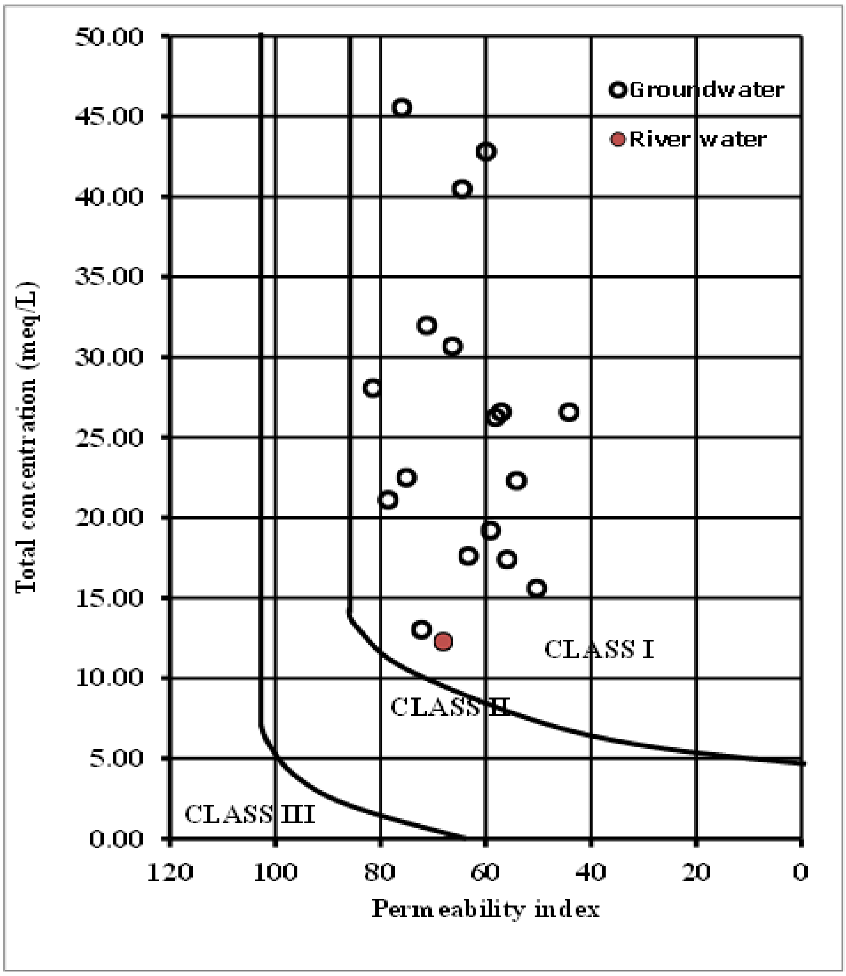

Figure 6.18 Classification of water samples based on PI plot

6.4 Groundwater Quantity

The hydraulic connection plays an important role on the impact of the groundwater quality and groundwater level between surface water bodies and groundwater well. However the accuracy of this method is questionable as the groundwater level fluctuation may also happen due to pumping, local drainage, changes in atmospheric pressure, evapotranspiration, earth tides and even entrapped air into the well. Hence proper care has been taken by the NGO to choose the monitoring wells and the data have been collected. As the monitoring wells in the study area are located in the agricultural area, the rise and fall of the groundwater level because of the abstraction and irrigation return flow in the wells will be same in all the observation wells. Even the pumping of groundwater and irrigation return flow will have minimal impacts as the groundwater level have been measured over the year with a periodical gap of three to four months in the past three years. The groundwater level has been monitored in two observation wells across the study area before the construction of the MAR structures and after the construction of MAR structures.

Figure shows that in both the wells during the year of construction i.e. 2017, the groundwater level is low when compared to that of the groundwater levels of the observation wells after the construction of MAR structures (2018 and 2019). The ground water level is low during the summer season (May) as the groundwater is the only source of irrigation and even there will be loss in groundwater level due to the evaporation as well. The groundwater level rises during the monsoon season as there will be least usage of groundwater pumping for the irrigation purposes. Thus this clearly shows that the MAR structures played a vital role in the rise in the groundwater level in the observation wells in the study area.

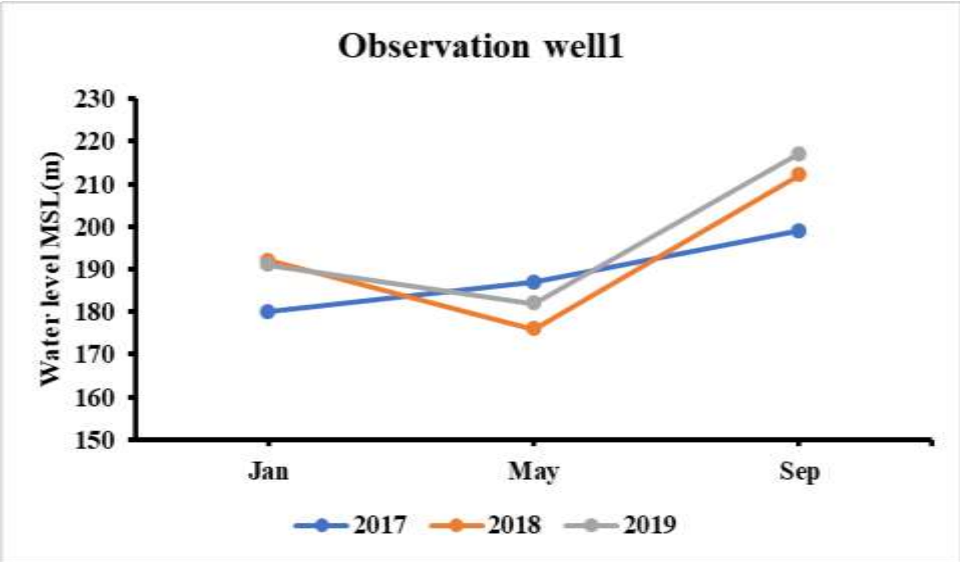

Figure 6.19 Temporal variations of Ground water level

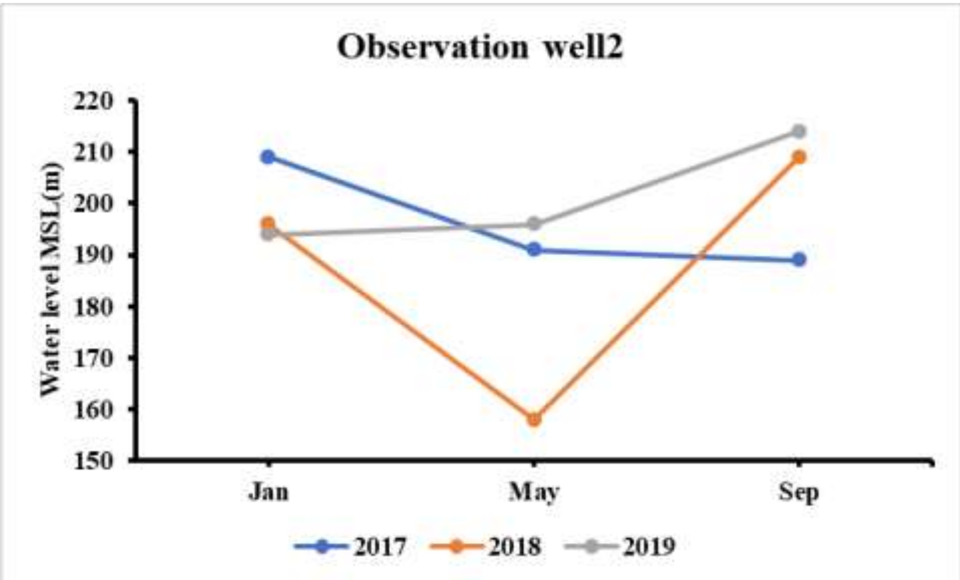

Figure 6.20 Temporal variation of Ground water level

6.5 Construction and maintenance cost of recharge structures

The recharge structures in Salamanatham village are constructed by an NGO called "ART OF LIVING" which is partnered with the government of Tamilnadu to execute the projects. The NGO is funded by the government and they take donations from the people and also welcome volunteers. Their project is to rejuvenate the River and to increase the ground water level by maximizing the percolation of water from the third order streams by constructing minor recharge structures.

There are mainly two structures in the construction of recharge structure, they are the construction of boulder checks and the construction of recharge wells. For the construction of boulder check it costs Rs.70,000/- and for the construction of recharge well it costs Rs.97,000/-. Action plan cost is calculated based on Rs.2,000/- per village panchayat and training cost is arrived based on Rs.14,000/- per village panchayat. The administration expenses here are the salary expenses, Recurring expenses and one-time expense.

- The salary expenses are, District coordinator (salary - Rs.20,500/-), Taluka coordinators (salary – Rs.12,500/-), Bare foot technicians (salary – Rs.8,500/-), Documentation coordinators (salary Rs.8500/-) and Accounts (salary – Rs.8000/-). The salary that is mentioned here is for one person and the number of person varies accordingly.
- The recurring expenses are, Vehicle expenses (Rs.85,000/-), Mobile based monitoring and evaluation (Rs.12,000/-) and Stationary and printing (Rs.5,000/-). The expense mentioned here are for one month and the number of months varies accordingly.
- The one-time expense is the GIS expense. It costs Rs.2,000/- per village panchayat.

The boulder check is used to reduce the velocity of the stream water and this stream water carries solid particles which gets sedimented in the upstream side of the boulder check. When the stream velocity is high, then the solid particles carried by the water will be more and when the stream velocity is low, the solid particles carried by the water will be less. From the field investigation, it is found that the stream velocity is low in the channels located in the study area. In this case, sediments that are deposited will be very low and therefore, dredging will be done occasionally. Therefore, these recharge structures doesn't need much maintenance. So the maintenance cost is pretty low for this type of recharge structures.

CHAPTER-7

SUMMARY

The primary objective of this project is to observe the functioning of the minor recharge structure constructed along the minor streams of the Salmanatham Village and to identify its efficiency as well as the benefits it brings to the locality. The minor recharge structure helps in storing the runoff water on the occasions of rain. This is done by retarding the velocity of runoff water by the boulders check. This, in turn, gives adequate time for the lagged water to percolate into the soil and get filtered and infiltrate in the gravel wells located downstream of the boulders check. This facilitates in improving the groundwater potential in terms of quality and quantity. The improvement in quantity is observed with the help of the observation wells present near each of such minor recharge structures. The depths of water in such wells are taken note of periodically over the period of three years, where the increase in water level is observed gradually in this period. The quality was determined by collecting samples from wells near and far from the recharge structures from which its parameters were measured both in-situ as well as laboratory methods. The total study area was divided into four zones based upon each of the clusters of recharge structures present in the area. Near and far wells were determined in each of such zones. The parameters observed from the wells were compared with standards of BIS and WHO to determine its quality. The surface water when compared with the WHO standards (2006) and BIS (2003), it is found that the water sample is permissible for drinking purposes. The suitability of water for irrigation purposes was also determined by calculating percentage sodium, Sodium absorption rate, permeability index, Electrical Conductivity, Kelly's ratio and Total concentration of ions present in the water. This was useful in determining and identifying the zones benefitted by the minor recharge structures present in the area. Four Schoeller graphs were plotted for each zone with the parameters found. In this, a general trend can be identified were the wells present near the recharge structure exhibit a better quality in comparison to those wells present far from such structures. This helps in conclusion that, even the recharge structures across the small streams do play a vital role in improving the quality of groundwater present in the area furthermore also improve the quantity of groundwater as mentioned above. Since the velocity of the stream in such minor channels are low, less sedimentation takes place there by reducing the maintenance cost. This makes the minor recharge structures an essential and indispensable necessity in places like Vellore where the climate is very irregular and erratic.

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