Chapter 6

Groundwater responses due to various MAR structures: Case studies from Chennai, Tamil Nadu, India

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6.1 INTRODUCTION

Over-extraction of groundwater has resulted in seawater intrusion in coastal aquifers of many countries including India. Chennai, the fourth largest city in India, located on the coast of Bay of Bengal, is also affected by seawater intrusion. Furthermore, leaching of salts from marine deposits into the groundwater (Rao, 1959) and salt pan activities have caused high salinity in groundwater even at shallow depths. The current water requirement of Chennai city is met by desalination plants at Nemelli and Minjur, aquifers in Neyveli, Minjur and Panchetty, Cauvery water from Veeranam lake, the Krishna River from Andhra Pradesh, Poondi reservoir, and lakes at Red Hills, Chembarambakkam and Cholavaram (The Times of India, 2014). Rapid and heavy rains during short periods lead to a loss of large amounts of run-off to the sea and therefore natural rainfall recharge is very low. Recharge can be increased by different structures of Managed Aquifer Recharge (MAR).

As a part of Saph Pani, a detailed study was carried out to investigate the response of groundwater to the effect of recharge from three different structures, namely a percolation pond, two check dams and four temple tanks. The locations of the structures investigated are shown in Figure 6.1. The study area experiences a tropical monsoon climate. The average annual rainfall is around 1,200 mm/year, 35% falling during the southwest monsoon (June–September) and 60% during the northeast monsoon. The very dry period in this region is during March-May when the temperature rises above 40°C. Geologically, alluvial deposits are dominant in the northern part that comprises the Arani and Korattalaiyar rivers (Figure 6.1), whereas charnockites are exposed in the southern part along the Coovum and Adyar rivers (Suganthi *et al.* 2013). The percolation pond and check dam considered for this study are located in the Arani-Korattalaiyar river basin, and these locations mostly comprise of alluvium of about 60 m thickness overlying the impermeable formation. The coastal part where the percolation pond is located is characterized by the presence of marine sediments too. The groundwater level in the unconfined aquifer ranges from 2 to 6 m below ground level. In general, the regional groundwater flow leads towards the sea; however there may be variations in local hydraulic heads due to pumping. Groundwater recharge relies mainly on rainfall which feeds the non-perennial streams at the same time. At the temple tanks, groundwater occurs in shallow weathered charnockitic rocks. In this study, a comprehensive assessment was made of the role of MAR in coping with seawater intrusion and groundwater overexploitation. The salient aspects of the present study carried out in a percolation pond, two check dams and four temple tanks are discussed in this chapter.

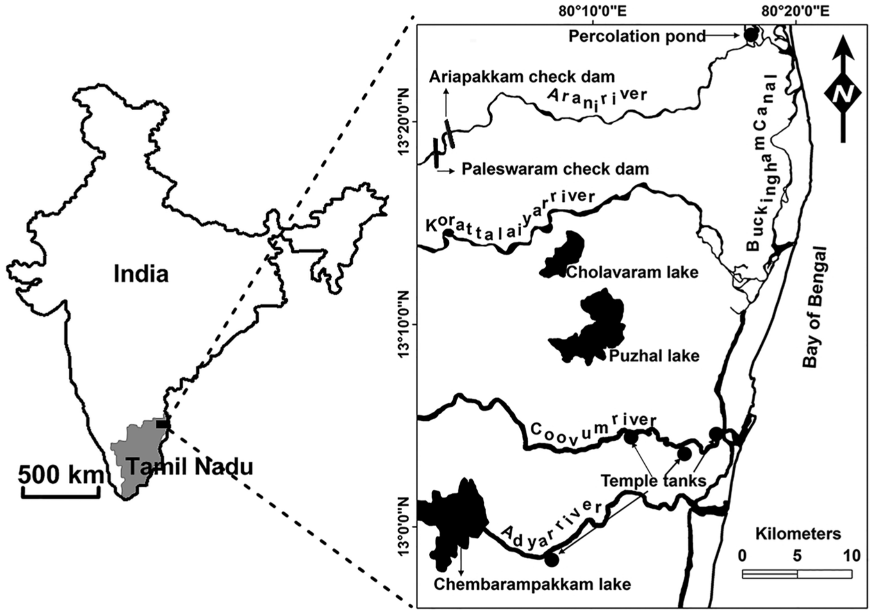

Figure 6.1 Location of check dam, percolation pond and temple tanks in the study area.

6.2 PERCOLATION POND

A percolation pond with a size of 8 m × 8 m × 1.5 m was constructed at Andarmadam in the Thiruvallur district of Tamil Nadu (Figure 6.1). It lies about 4 km west of the Bay of Bengal and 2 km south of Lake Pulikat. The Buckingham canal flows parallel to the Bay of Bengal on the eastern side of the pond.

6.2.1 Problem statement and objectives

The groundwater in the area is highly saline even at shallow depths due to the sediments of marine origin and due to seawater intrusion. Hence, the groundwater is not suitable for irrigation and domestic use. The objective of the study was to investigate the impact of the percolation pond on improving the groundwater quality and quantity in the area.

6.2.2 Results and interpretation

Water table rise

Three piezometers P_1, P_2 and P_3 of 2 m, 4 m and 6 m depth were installed at distances of 0.5 m, 1.0 m and 1.5 m from the pond (Figure 6.2a). The water levels in the pond and the nearby piezometers were monitored every three minutes by digital automatic water level indicators from September 2012 to May 2013 and from September 2013 to January 2014 (Raicy & Elango, 2015a). The water level in the pond was very high from September 2012 to February 2013 (Figure 6.2b), as the pond was filled with rain water during September-December (northeast monsoon). Afterwards, the water level gradually decreased and it dried up completely by May 2013. The groundwater level in the piezometer at 1.5 m from the pond gradually increased over the monitoring period and almost sustained at more than 30 cm above the water table measured before the construction of the pond (Raicy & Elango, 2015a).

Estimation of recharge

The amount of water recharged from the pond into the aquifer was estimated through a water balance approach. The approach considers the water level in the pond, surface area of the pond at different points in time, pan evaporation of the area and rainfall monitored by an automatic weather station in the area. It is assumed that the temporal decline in the water level of the pond is only due to evaporation and recharge of the nearby piezometers. As the water level in the pond was measured on daily basis and daily evaporation data was available, the groundwater recharge was estimated as equal to the change in storage in the pond minus the volume of water lost due to evaporation. The total volume of water recharged into the aquifer by the pond for a period from August 2012 to June 2013 was calculated to be between 250 and 300 m^3. The recharge rates were very high up to December 2012 and gradually decreased after that. Even though the water level in the pond was almost constant until February 2013, the volume of water recharged decreased after September 2012. This is attributed to the physical clogging of the bottom of the pond due to the presence of suspended particles in the pond water. The clogged layer was scrapped after the pond had dried up. Further, to overcome the problem of clogging, a recharge shaft of 0.15 m diameter and 9.5 m depth was constructedat the centre of the pond. The cross section of this arrangement is shown in Figure 6.3.

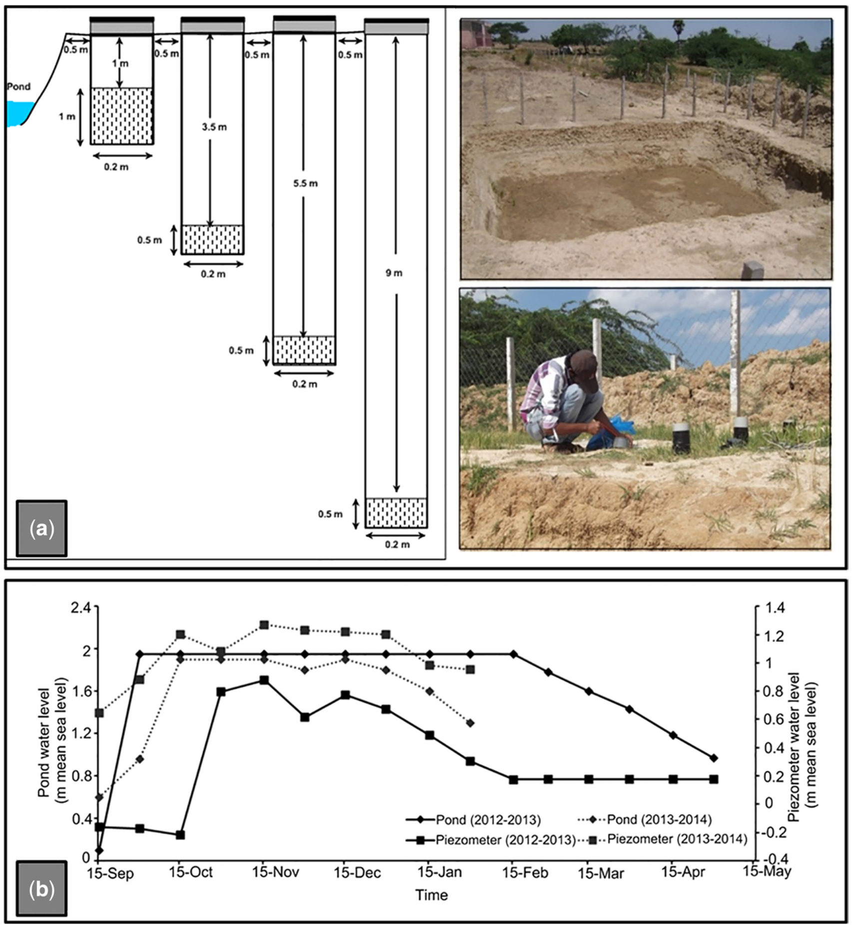

Figure 6.2 (a) Design of piezometer and field photographs (b) Water level in the pond and groundwater level in nearby piezometer (Raicy & Elango, 2015c).

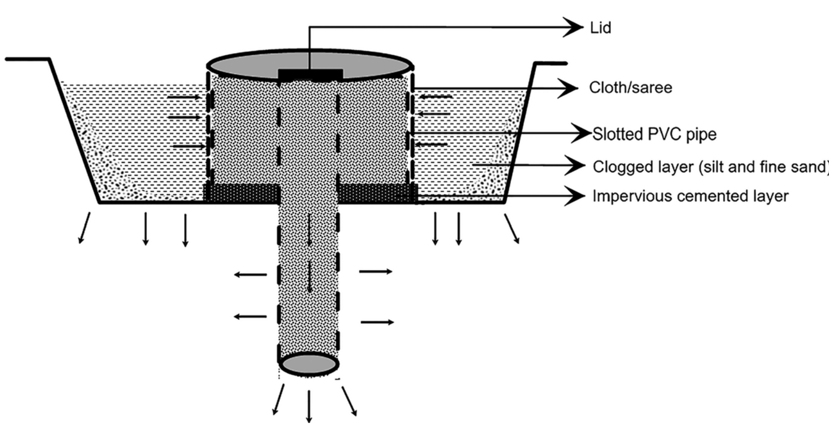

Figure 6.3 The conceptual design of the recharge shaft (not to scale).

The part of the recharge shaft above the bottom of the pond was slotted. Further, a slotted pipe of 0.254 m was installed around the recharge shaft. This outer slotted pipe was lined by an old saree to filter the fine suspended particles from entering into the recharge shaft. This has resulted in the enhancement of groundwater recharge in the following season (2013–2014) as shown in Figure 6.4.

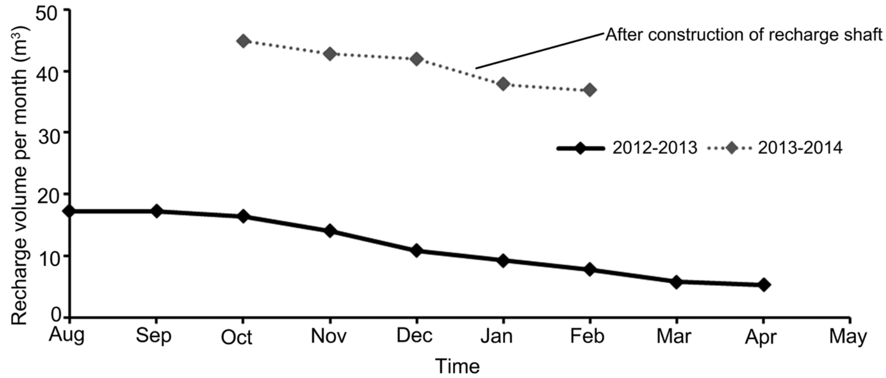

Figure 6.4 Volume of water recharged from the pond from August 2012 to June 2013 (Raicy & Elango, 2015c).

Estimation of physical clogging

The effect of clogging in the pond was studied in a laboratory experiment (Figure 6.5). This experiment was carried out to calculate both the clogging potential of the recharge structure and the rate of infiltration. For this purpose, pond water and sediments from the pond bottom were collected. A column filled with sediments collected from the pond and the pond water was allowed to pass through the column maintaining a constant head. After saturation of the sediments, the pond water was allowed to pass through the column by upward flow from the bottom and the discharge volume was measured at intervals of 10 minutes (Figure 6.5) (Raicy & Elango, 2015c). Similar studies on clogging potential in landfill cover systems were done by Reddy *et al.* (2008) and Reddy & Saichek (1998). They both used similar test setups. In a laboratory study of clogging processes and factors affecting clogging in a tailing dam at Shanxxi province China, Jun *et al.* (2007) concluded that ferrous iron oxidation and precipitation were major issues that led to completely clogged columns (Jun *et al.* 2007). However, such a problem was not faced in this study, which indicates the absence of iron in the pond water. Column experiments were performed to simulate infiltration of untreated river water by Bartak *et al.* (2014). In the study of Bartak *et al.* (2014) the hydraulic conductivity of the filter sand decreased exponentially due to external clogging by two orders of magnitude from 126 to 4 m/d. However, in the column experiment carried out in this study the hydraulic conductivity reduced only by four times due to clogging (Figure 6.5). A laboratory study on the influence of fine particle size and concentration on clogging of labyrinth emitters was carried out by Niu *et al.* (2012). The results obtained from this physical clogging study are comparable with the study carried out by Niu *et al.* (2012), since the particles that were smaller than 0.1 mm in diameter deposited and resulted in clogging as observed during the experiment until 0.25 days (Figure 6.5). To overcome this problem, a piece of saree/cloth was wrapped around the recharge well at the pilot site as shown in Figure 6.3.

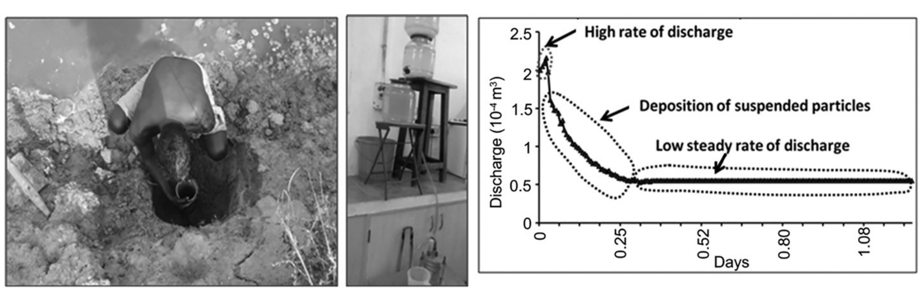

Figure 6.5 Photographs showing sediment collection from the field, the experimental setup for clogging assessment in the laboratory and the measured discharge rates in the laboratory experiment.

Groundwater quality

Pond water and groundwater from the piezometers was collected every two weeks and the major and minor ions were analysed by ion chromatography. The major hydro-chemical facies identified were Na-Cl, Ca-Mg-Cl and Ca-Cl. The type of water changed with the depth of the sampling point. Samples taken below 4 m from the surface fell in the Na-Cl type of water, whereas pond water and groundwater at shallow depths fell under the mixed water type category. This indicates that water from shallow depths was comparably fresh.

The concentrations of different ions in water samples from the pond and the piezometers are plotted in a Schoeller diagram (Figure 6.6). The concentration of major ions in the pond and piezometer P_1 were similar and both decreased during rainfall. In contrast, the concentration of ions in P_2 and P_3 remain the same even after a major rainfall event. The water in the pond and in P_1 had almost equal amounts of Ca^{2+} and Na^+ balanced by Cl^-, whereas the amount of Na^+ and Cl^- in the water of P_3 and P_4 varied (Raicy & Elango, 2015a). Figure 6.6 indicates that the concentration of major ions increase with respect to depth in samples collected before, during and after rainfall. Further, the concentration of ions in groundwater decreased after the commencement of recharge from the pond. Thus, the recharge of water resulted in improvement of groundwater quality up to a depth of about 5 m below the ground surface.

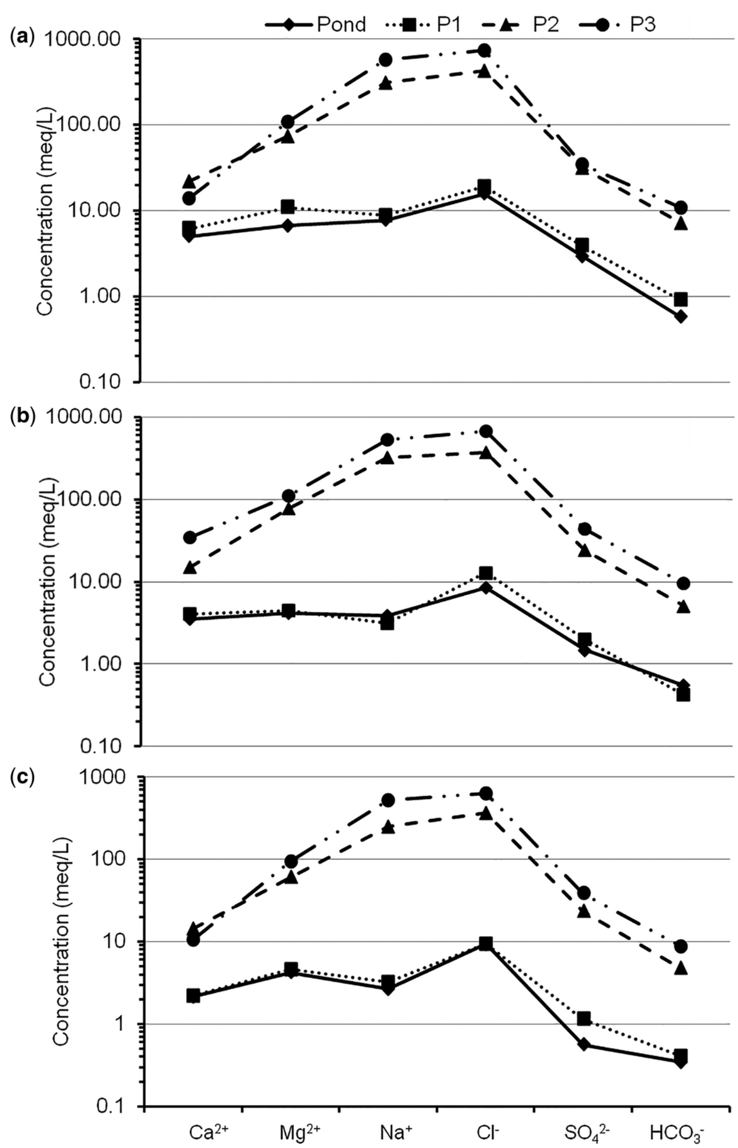

Figure 6.6 Schoeller diagram of samples collected (a) before rainfall, (b) during rainfall and (c) after rainfall to compare the ionic concentrations of different sets of samples (Raicy & Elango, 2015a).

6.2.3 Discussion

The percolation pond was effective in augmenting groundwater resources in this site. However, physical clogging was a major problem faced during this study. Several researchers (e.g. Rebhun & Schwarz, 1968; Behnke, 1969; Ripley & Saleem, 1973; Wood & Bassett, 1975; Vigneswaran & Suazo, 1987; Warner *et al.* 1994) reported the accumulation of suspended particulate matter that causes the progressive clogging of the soil in the ponds or trenches used for aquifer recharge. When the recharging water contains suspended solids of a size commensurate with that of the particles of the porous medium, suspended solids penetration does not occur to any significant extent, and accumulation at the surface leads to the formation of a filter cake, which reduces the overall hydraulic conductivity of the medium as reported by Baveye *et al.* (1998). To understand the process of clogging, a column experiment was carried out as a part of this project. However, Bouwer (1996) indicated that the parameters such as suspended solids content and biodegradable organic carbon and column flow tests, used to compare clogging potentials of recharge waters, are not useful predictors of plugging in injection wells. Even though, Bouwer (1996) reported that the column experiments are not very useful, in the present study the experiment helped to develop the innovative design of a recharge well with cloth screen as shown in Figure 6.3. This design considerably improved the recharge as the recharging water was made to bypass the clogged layer at the bottom of the pond. The groundwater quality also improved through recharge of water from the percolation pond up to a depth of about 6 m. The implementation of several such recharge structures in this area is expected to improve the groundwater potential of the area on a regional scale. The effect of physical clogging of the recharge shaft, however, needs to be assessed. The provision of few layers of saree at the outer slotted pipe of the recharge shaft, as carried out in this study, will overcome or at least reduce the problem of clogging. Such recharge shafts may not be needed in hard rock regions as the percolation efficiency (percolated fraction of stored water) of the pond ranged from 57% to 63% as estimated by another Saph Pani study carried out near Hyderabad, India (Massuel *et al.* 2014).

6.3 CHECK DAM

Check-dams are small barrier structures constructed across rivers and streams for the purpose of water harvesting. The small dams overflow when the river's water flow exceeds the river capacity. The increase in head due to storing of water helps to improve recharge, thereby replenishing the groundwater reserves. In this section, the effect of recharge from two check dams is described.

6.3.1 Problem statement and objectives

The area suffers from seawater intrusion and the Government of Tamil Nadu has constructed several MAR structures, including check dams, to enhance the groundwater availability and to improve the groundwater quality and quantity of the area. The objective of the study was to identify the impact of check dams in improving groundwater potential and quality.

6.3.2 Check dam at Paleswaram

The Paleswaram check dam is located north of Chennai in the Thiruvallur district (Figure 6.1). This check dam was constructed in the year 2010 across the Araniriver, near Paleshwaram village at a distance of about 35 km from the sea. The Arani River enters Tamil Nadu at Utthukottai and joins the Bay of Bengal near Pulicatlake. This check dam is 260 m long with a crest height of 3.5 m from the river bed and has a storage capacity of 0.8 million m^3 of water.

Results and interpretation

Estimation of recharge from the check dam

The water level fluctuation in the check dam is shown in Figure 6.7. The maximum water level in the check dam was observed during monsoon season (October to December), during which the check dam overflows for a few weeks per year. The lowest water level was reached during May to June, after which the river becomes dry. The water surface area and volume of water stored at various water levels in the check dam was estimated using the three dimensional capabilities of Arc GIS9.2 software. The topography of the river bed was measured using the Differential Global Positioning system (Leica GS09).

Based on the height of the check dam (3.5 m) and the river bed topography it was estimated that this check dam is capable of storing 0.8 million m^3 of water. Figure 6.8 shows the storage volume corresponding to various water levels in the check dam. The storage volume of the check dam is nearly 0.9 million m^3 when it overflows or when the height of water in the check dam is above the crest (+23.8 m). These values are used for the estimation of groundwater recharge.

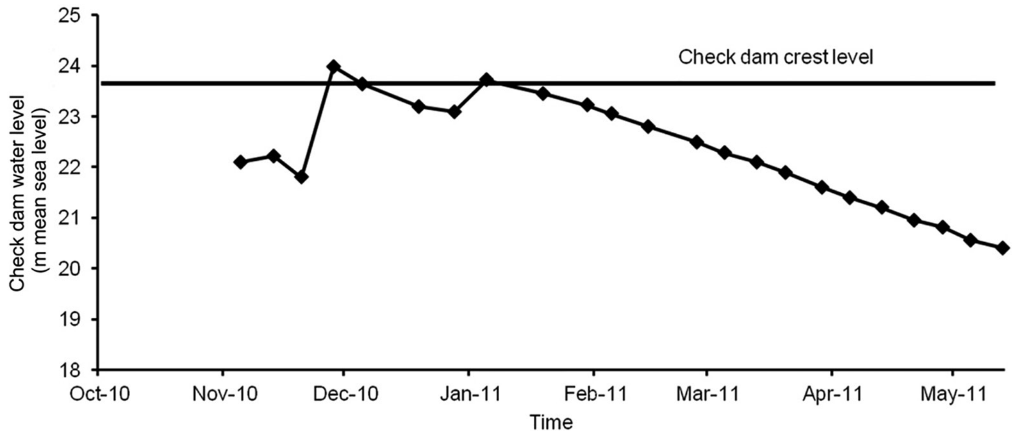

Figure 6.7 Temporal variation in water level fluctuations in the Paleswaram check dam.

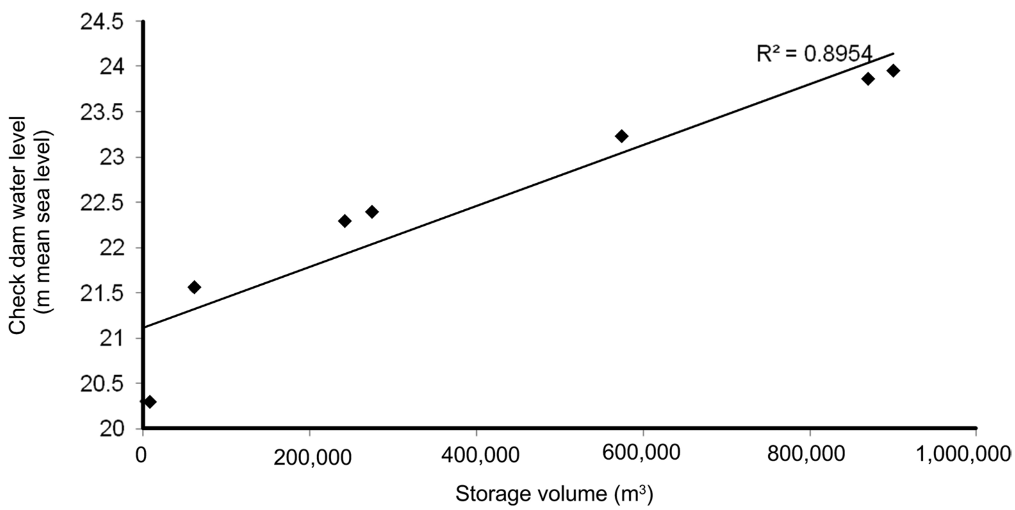

Figure 6.8 Storage volumes corresponding to water levels in the check dam.

Recharge was calculated during the period when there was no flow into the check dam either from the upstream side or as run-off from the nearby areas. As this is a newly constructed check dam, loss due to leakage through sluice gates was very minimal and hence considered negligible. Water stored in the check dam was not directly used for domestic and irrigation purposes, hence, the water lost from the check dam is due to groundwater recharge and evaporation (Eq. 6.1).

$$\text{Recharge}\,(\text{m}^3) = \text{Change in storage volume}\,(\text{m}^3) - \text{Water loss due to evaporation}\,(\text{m}^3) \tag{6.1}$$

Potential evaporation data was obtained from the Indian Meteorological Department, Chennai. Figure 6.9 gives the calculated monthly recharge from the check dam during the period when there was no inflow. The estimated volume of water stored by the check dam was about 1.7 million m^3 during the year 2011–2012. This estimation indicates that during 2011–2012, out of 1.7 million m^3 of water stored by the check dam, 1.14 million m^3 (66%) was recharged into the aquifer (Parimalarenganayaki & Elango, 2013) and about 0.56 million m^3 (34%) of water was lost due to evaporation from the check dam.

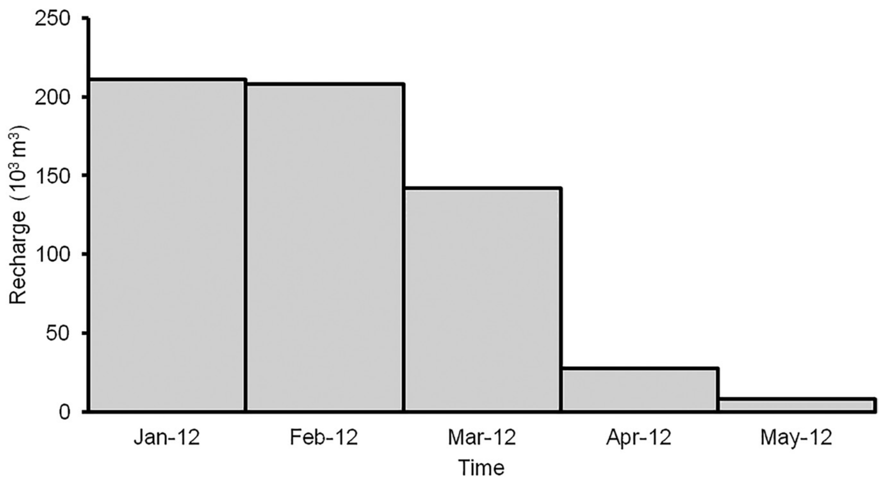

Figure 6.9 Volume of water recharged from the check dam.

Impact on groundwater level

The efficiency of the check dam in augmenting the groundwater recharge was assessed by comparing the temporal variation of the water level in the check dam and the groundwater level in the nearby wells used for drinking water purposes. The wells could be classified into two groups based on their similarity with the water level fluctuation in the check dam. Well number 1 and 12 are located within 1.5 km from the check dam towards the groundwater flow direction (west to east) and well number 11 and 13 are located within 1.5 km to 2.5 km in the flow direction (Figure 6.10). In the first group of wells (11, 13), the groundwater level rises twice a year and this coincides with the northeast and southwest monsoon. This indicates that rainfall is the major source of recharge at these locations. In the other group of wells (1, 12), the fluctuation in groundwater levels is very similar to the water level fluctuation in the check dam. This similarity indicates that surface water stored by the check dam is the major source of recharge at these locations. Taking into account the additional wells up to a distance of 1.5 km from the check dam towards east, an increase of groundwater levels between 1 m and 2.5 m could be observed after the construction of the check dam.

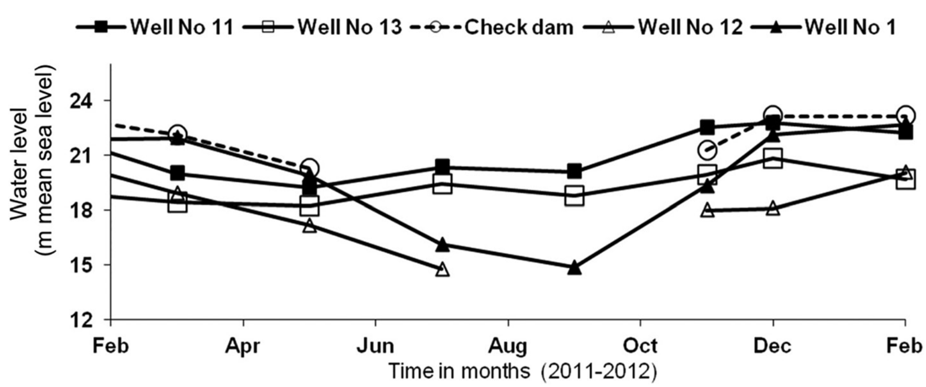

Figure 6.10 Water levels in the check dam and monitoring wells.

Improvement in groundwater quality due to recharge

In order to understand the effect of recharge on groundwater quality, correlations between electrical conductivity and chloride concentration of water in the check dam and groundwater of wells located at different locations were made (Figure 6.11). The wells that plot close to the data points of water from check dam have similar water compositions like the check dam, which indicates that the groundwater of these wells is mainly derived due to the recharge from the check dam. This group of wells are located within 1.5 km from the check dam. Wells located away from the check dam (>1.5 km) have higher electrical conductivity and chloride values, which indicates that these wells are mostly recharged by rainfall.

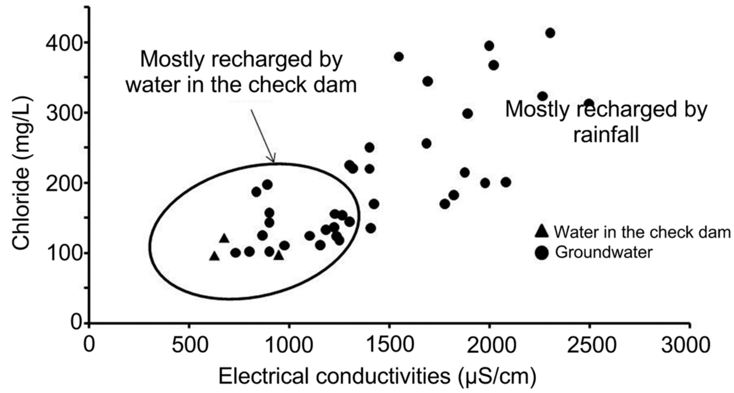

Figure 6.11 Plot on electrical conductivity and chloride concentration of groundwater and Paleswaram check dam water.

6.3.3 Check dam at Ariapakkam

The Ariapakkam check dam is located in the Thiruvallur district, north of Chennai, Tamil Nadu, about 2.5 km upstream of the Paleswaram check dam. Hydrogeochemical modelling using the thermodynamic computer program PHREEQC, Version 3 (Parkhurst & Appelo, 2013) indicates mineral dissolution within the aquifer. Although the exact mineral composition of the alluvial aquifer is unknown, the basic minerals can be estimated from studies of similar environments (Achyuthan & Thirunavukarasu, 2009). The phases used for the modelling of water-rock interaction within the aquifer are calcite, albite, anorthite, plagioclase, kaolinite/halloysite, gibbsite and Fe $(OH)_3$.

It was shown, using the method of inverse modelling, that dissolution and/or precipitation of these minerals can explain the hydrochemical characteristics of the groundwater within the study area.

Near the coast, other processes like ion exchange according to the following equation (Eq. 6.2) play a major role:

$$Ca^{2+} - X + 2Na^{+} \leftrightarrow 2Na^{+} - X + Ca^{2+} \tag{6.2}$$

in which '*X*' indicates the exchanger.

The general evolution of the groundwater, i.e. the resulting groundwater facies (in parenthesis), from inland to the coast and the corresponding hydrogeochemical processes (italic) are illustrated in Figure 6.12.

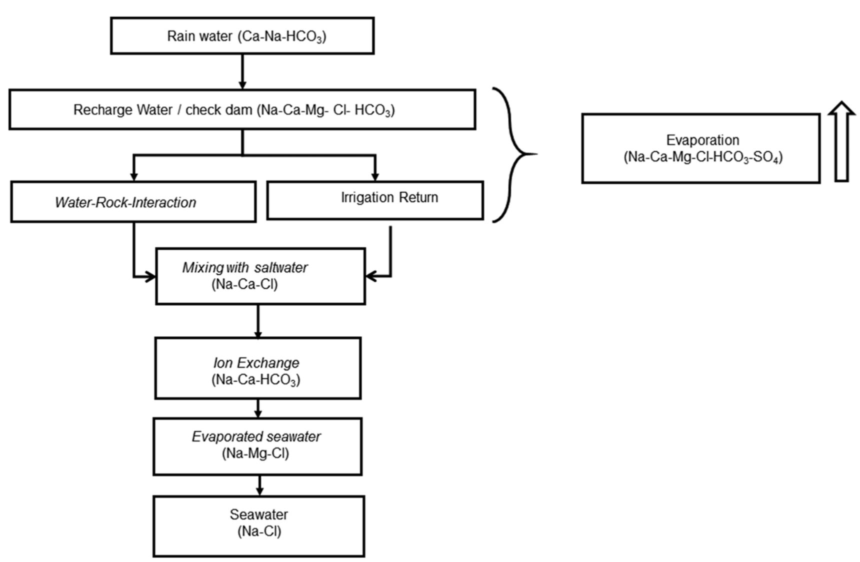

Figure 6.12 Hydrogeochemical evolution of the groundwater from inland to coast.

The wells around the Ariapakkam check dam all show the same ratio of equivalent concentrations of the major ions. This, as well as measured electrical conductivities from the wells, suggests that check dam water recharges groundwater leading to a similar hydrochemical composition. The same processes can be observed at the Paleswaram check dam (Figure 6.11). Near the coast, saltwater intrusion can be detected using the bromide/chloride ratio of groundwater. Bromide is a very good tracer to determine the ratio of saltwater in groundwater because it is a non-reactive ion and residual solutions are enriched in bromide in the course of evaporation.

Hydrogeochemical modelling shows that different mixing ratios of freshwater and seawater can explain the hydrochemical composition of groundwater, sampled in different wells in the coastal region (Table 6.1).

Table 6.1 Mixing of freshwater and seawater in the coastal region and comparison with groundwater sampled in wells using bromide as tracer ion, as well as analyzed chloride concentrations.

Sample	Mixing Ratio (Freshwater: Seawater)	Seawater [%]	Chloride [mg/L]	Water Type (Analysed Samples)
Freshwater (well)	1.0 : 0.0	0.0	52	Ca-Na-HCO_3-Cl
Well A	0.98 : 0.02	2.0	466	Na-Cl
Well B	0.97 : 0.03	3.0	620	Ca-Na-Mg-Cl-HCO_3
Well C	0.97 : 0.03	3.0	972	Na-Cl-SO_4
Well D	0.965 : 0.035	3.5	1,075	Na-Ca-Cl
Well E	0.74 : 0.26	26.0	4,800	Na-Cl
Seawater (Elliots Beach)	0.0 : 1.0	100.0	14,600	Na-Cl

Nevertheless, the analysed concentrations of calcium, magnesium and sodium form different water types, indicating that further processes like ion exchange and mineral dissolution or precipitation play an important role in the mixing zone of the coastal region. Wells in the southwest of the study area around the Ariapakkam check dam have low overall ion concentrations, whereas wells in the north have higher ion concentrations (Figure 6.13).

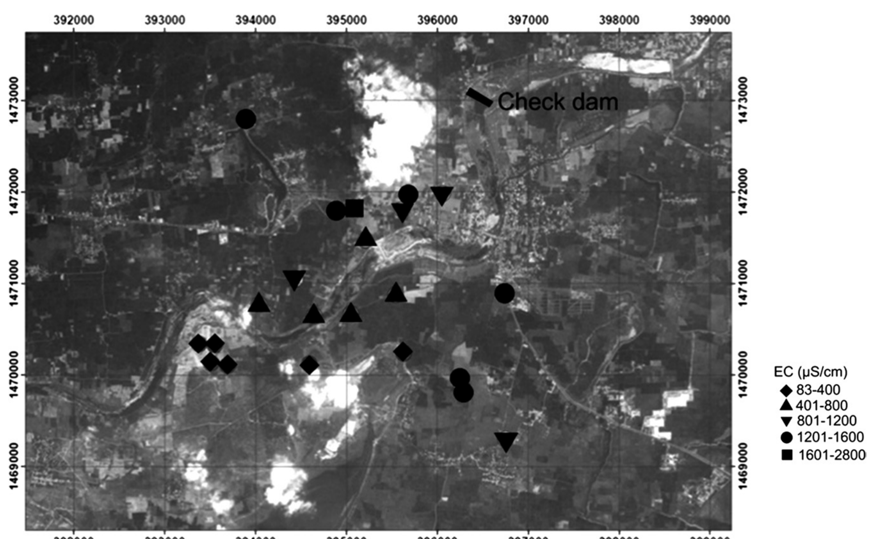

Figure 6.13 Measured electrical conductivities [µS/cm] in the groundwater near the Ariapakkam check dam (Base Map: Google Earth, 2012).

6.3.4 Discussion

The influence of the check dams at Paleswaram andAriapakkam in the Arani-Korattalaiyar aquifer on groundwater quality and usability at nearby areas was assessed using electrical conductivity and groundwater level measurements. Rain water is the most important recharge source. The infiltration of surface water from the check dam is indicated by similar groundwater chemistry and can be observed within a distance of about 1 km to the north and to the south of the check dam. Based on these measurements, the region that is positively influenced by this recharge structure could be delineated. The hydrochemical and hydraulic processes are identical at both locations.

At Paleswaram the groundwater within an area of 3 km^2 around the check dam has electrical conductivity values similar to the check dam water (indicating substantial recharge). The measurement of groundwater level before and after filling up of the check dam indicate that the groundwater level in the wells located within 500 m from the dam has increased by 2.5 m. About 66% of the total water harvested by the check dam has infiltrated into the aquifer during the year 2011–12. The approximate annual rainfall recharge is only about 15% and the increase in recharge is about 51%, which is much higher than the values reported by Alderwish (2010). Alderwish (2010) reported an increase of recharge by about 36% due to check dams in Yemen. Similarly, Gale (2006) carried out a study on check dams in three different hydro-meteorological and geological environments in the states of Gujarat (fractured granite rocks), Tamil Nadu (fractured charnockite rocks) and Maharashtra (Deccan basalt) in India and estimated an additional recharge of 4% to 16%, 23% and 13% due to the construction of check dams in Gujarat, Tamil Nadu and Maharashtra respectively. In comparison to these studies the estimated recharge in the Saph Pani case study was higher. This is due to the conducive geological, hydrogeological conditions at these locations, larger size of the dams and filling up of the dam two times a year.

6.4 TEMPLE TANKS IN CHENNAI CITY

Tanks are usually constructed to obtain water and to perform religious activities in several temples in India. They are usually constructed very close to temples or within a temple. There are about 2,359 temple tanks in Tamil Nadu. Out of these, 64 are in Chennai and its suburbs (Times of India, 2011). The temple tanks are usually not paved at the bottom and thus allow percolation of water. These tanks ensure the sustenance of groundwater supply in the surrounding areas. There is always an arrangement to collect rainwater into the tank from the sprawling temple complex as well as from surrounding streets and an outlet to drain any surplus (Raicy *et al.* 2014b). The stored water usually lasts until the next rainy season. There will not be any large scale direct extraction of water from the tank. The temple tanks are usually not paved at the bottom and thus allow percolation of water. So the loss of water from the tank is only due to evaporation and percolation.

6.4.1 Site description

Four of the temple tanks located within the urban region of Chennai city were selected for this study. The selection of these tanks was based on logistical convenience and their spatial distribution so as to understand their effect on a regional basis (Table 6.2).

Table 6.2 Name of the temple, tank size and location.

Temple Name and Location	Temple Tank Size Length × width × depth [m]	Lithology
Adipuriswarar, Chinthadiripet	35 × 33 × 3.45	Unconsolidated sediments
Agatheeswarar, Numgampakam	45.72 × 30.48 × 3.01	Alluvium
Kurungaleeswarar, Koyambedu	54.9 × 53 × 3	Sandyclay
Suriyamman, Pammal	180 × 100 × 3	Weathered/ fractured charnockite

The lithology of the first three tanks was ascertained by drilling boreholes using hand boring methods. During drilling, soil samples were collected from different depths. The fourth tank is known to fall in hard rock terrain.

6.4.2 Problem statement and objectives

As the temple tanks receive surface run-off and store it during most of the year, they interact with the groundwater. The objective of this study is to investigate the effect of recharge from temple tanks on groundwater quality.

6.4.3 Results and interpretation

Water samples from the temple tanks and the nearby wells were collected at periodical intervals and were analysed for pH and major ions. The pH of water from the temple tank and nearby groundwater varies from 6.8 to 9.5 indicating that the water is of alkaline nature. There was no good correlation between the quality of water in the tank and the nearby ground water in the case of Adipuriswarar, whereas there was reasonable correlation in the case of Agatheeswarar, Kurungaleeswarar and Suriyamman. The trend of temporal variations in the concentration of these ions in surface and groundwater confirms the interaction between them (Figure 6.14).

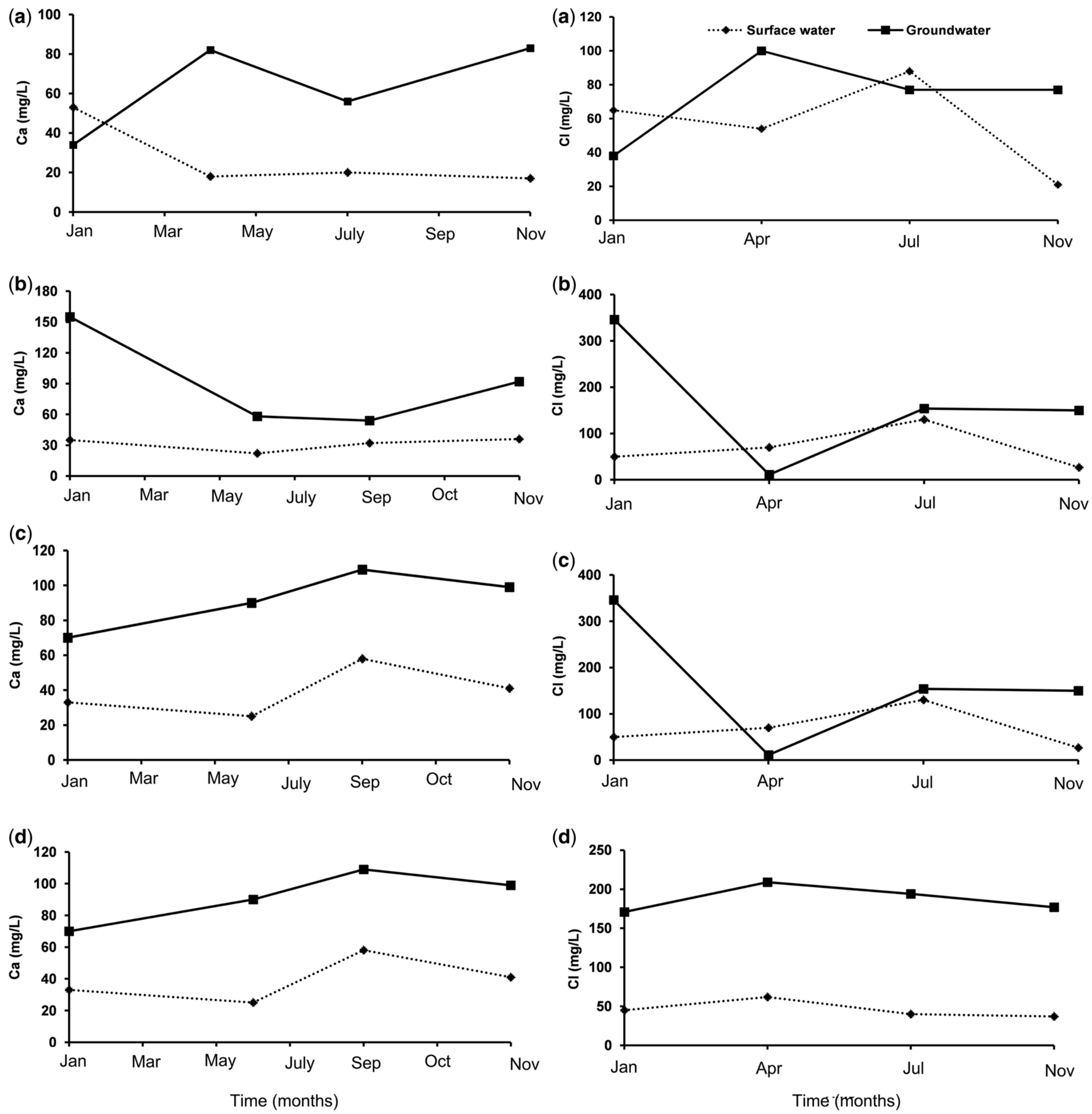

Figure 6.14 Temporal variations in concentration of calcium and chloride in water from temple tank and nearby groundwater at (a) Adipuriswarar, (b) Agatheeswarar, (c) Kurungaleeswarar and (d) Suriyamman.

6.4.4 Discussion

The major ions like Ca^{2+}, Mg^{2+}, Cl^- and SO_4^{2-} in surface water and groundwater are within the permissible limits of drinking water quality as per BIS standards (2012). The Ca^{2+} and Cl^- are the dominant ions in the water from the tank and groundwater. The similarity in the seasonal variation in the concentration of ions confirms the recharge of water from the tank. Thus, temple tanks acts as recharge structures and could improve the groundwater quality. However, great care has to be given to maintain the surrounding so that the rain water draining into the tank is reasonable clean. The recharge efficiency of the temple tanks will also diminish with time due to clogging as observed in the pilot study carried out by the construction of percolation pond as a part of Saph Pani. The temple tanks thus need to be cleaned by removing the finer materials settled at the bottom at least once in three years or when it becomes dry. Coarse sand may also be dumped after removing the clogged layer during the cleaning process.

6.5 CONCLUSION

In this study three different type of groundwater recharge structures were investigated to understand their benefits in terms of improving groundwater resources. In the case of the constructed pilot percolation pond, the groundwater head nearby increased about 30 cm and the quality of groundwater also improved in the top 4 m of the saturated zone (Raicy & Elango, 2015a). Percolation ponds are a simple method which can be implemented to recharge the aquifer. This method can easily be adopted by local farmers (Raicy & Elango, 2015a). Cost-effectiveness per recharged volume needs to be confirmed after additional studies on the influence of physical clogging on the percolation efficiency. If the costs, including the effect of clogging, are reasonable, construction of many such ponds could help improve the groundwater quality in the entire region. The comparison of groundwater levels, of water levels in the check dam and of rainfall assisted in demarcating the area that is highly benefited by the storage of water in the check dam. During the study period it was estimated that about 1.3 million m^3 of water was recharged out of the 2 million m^3 of water harvested by the check dam and the storage of water resulted in an increase in groundwater levels from 1 to 3.5 m within a radius of 2 km (Parimalarenganayaki & Elango, 2014). The recharge from the dam led to improvements in groundwater quality, which is evident from lower concentrations of major ions in the groundwater in the vicinity of the dam. The costs of 1 m^3 of water recharged by the check dam are about INR 1.20 (Parimalarenganayaki & Elango, 2014). Temple tanks act as recharge structures. The main advantage of such structures is that they are free from contamination by discharge of wastewater due to religious concerns and social aspects. This study also generated data for carrying out numerical modelling to study the impact of check dams and percolation ponds in improving groundwater level which is presented in Chapter 14.

6.6 REFERENCES

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