Journal of Natural Sciences Research www.iiste.org
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.5, No.14, 2015

# Groundwater Resource Management Strategy in the Nigerian Sector of the Chad Basin

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**Abstract**
Groundwater is predominant source of water supply for domestic and other applications in the Nigerian sector of the Chad Basin. Excessive groundwater abstractions have caused serious declines in the groundwater levels and increase in cost of operation. Data from 1960-2010 indicated that the water levels of Upper, Middle and Lower aquifers of the Chad Formation declined from – 19.8 m, +11.2 m and +5.80 m to – 33.1 m, + 0.1 m and – 61.81 m respectively. Management strategy for this dwindling scarce resource in the region becomes very fundamental. The paper examines the problems associated with over exploitation of the groundwater from the Chad Formation and proffering management strategy to improve/ alleviate the problems of the existing management practices. The participatory source enhancement and water conservation methods have been determined to be the best management options for the groundwater resource of the Nigerian sector of the Chad Basin.
**Keywords:** Groundwater, Management strategy, Chad Formation, Water level, Chad Basin.

## Introduction
The Nigerian sector of the Chad basin falls within the semi-arid region of northeastern Nigeria (Figure 1) which is characterized by low rainfall (500 mm/annum), high evaporation (> 2000 mm/annum) and almost non – existent surface water, apart from the Lake Chad and seasonal rivers. The area is mostly underlain by the Chad Formation, the youngest stratigraphic sequence in the Chad Basin. This Formation is a Plio- Pleistocene mainly argillaceous sequence with three well defined arenaceous horizons (Figure 2) which serve as aquifers and termed Upper, Middle and Lower aquifers (Barber and Jones, 1960). The Upper aquifer is unconfined and semi-confined in places where as the Middle and Lower aquifers are confined .These confined aquifers are under sufficient pressure in some places and provide artesian wells with piezometric heads of upto 20 m above ground level (Goni, et al.,2000). The confined aquifers are generally exploited via boreholes, whereas the shallow unconfined aquifer is mostly abstracted by large diameter wells.

Eighty one boreholes were used in the study area as in the table 1 below

| Year of Drilling | Upper Aquifer Boreholes | Midddle Aquifer Boreholes | Lower Aquifer Boreholes |
|---|---|---|---|
| 1960 | - | 11 | - |
| 1970 | - | 5 | - |
| 1980 | 4 | 6 | 5 |
| 1990 | 8 | 4 | 8 |
| 2000 | 1 | 8 | 4 |
| 2010 | 3 | 4 | 10 |
| Total | 16 | 38 | 27 |

There is need for efficient groundwater management in order to sustain the existing water resource. This is important because human existence and development schemes (agricultural, industrial or health related) in the region are strongly dependent on the reliability of water supplies. There is generally a high rate of abstraction without complementary recharge to the system. There is a general decline in rainfall caused by climate change which led to over exploitation of the groundwater leading to serious decline in water levels and boreholes yields in the study area since surface water is almost unavailable. Groundwater sustainable management especially from the context of supply planning becomes fundamental in the managing of the scarce resource.

## Hydrogeology and Hydrology
### The Upper aquifer System
The Upper aquifer system consists of at least three zones in the Chad Basin. These zones referred to as A, B and C system is found at depths of 10- 40 m, 40-70 m and 78-99 m respectively. The system is heterogeneous in nature consisting of arenaceous deposits intercalated with clay layers. The Upper aquifer is in hydraulic continuity with the water table therefore, direct recharge by infiltration through the soils, clay cracks, fractures and fissures, constitute a major component, (Anyaeche, 1985; Adeniji, 1985; Ezenwa, 1988). The boreholes tapping the Upper aquifer are usually screened under a multiple screening arrangement in the boreholes where they are found to exist together. The yields from these boreholes range from 2-5 liters per second (l/sec).

 

Recharge in this aquifer occurs through vertical infiltration of rainfall as well as seepage along rivers and streams.

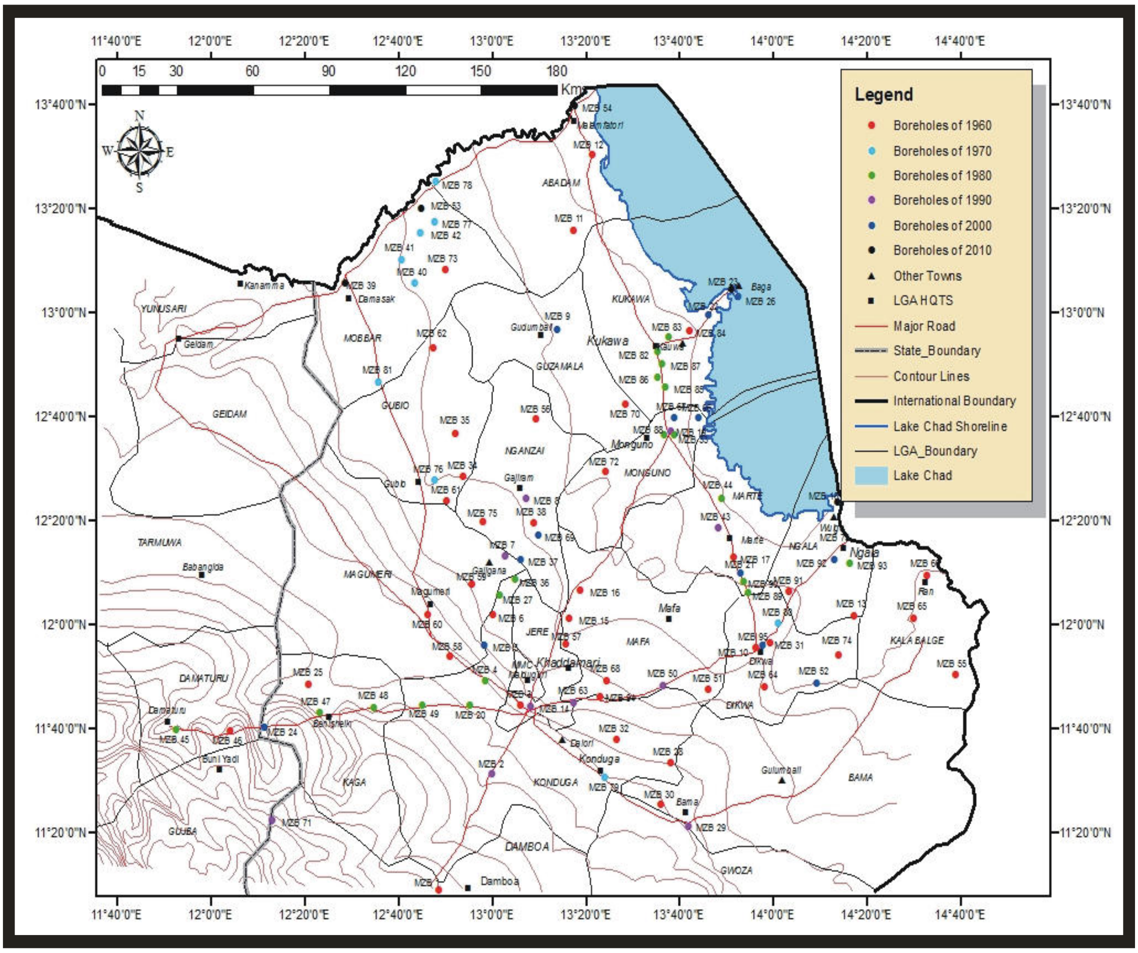


Figure 1: Map of the Study area showing boreholes tapping the Upper, Middle and Lower Aquifers of the Chad Formation

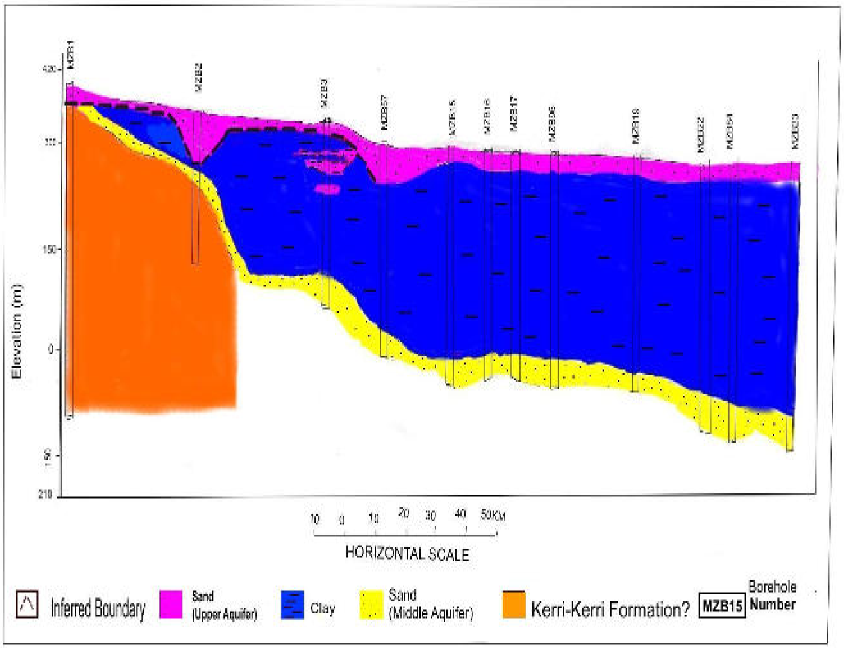


Figure 2: Geological section from Damboa to Lake Chad showing the relative positions of the aquifers of the Chad Formation.

**The Middle aquifer system**
This is the most widespread and best exploited confined aquifer in the Nigerian sector of the Chad Basin with surface area in excess of 50,000 km$^2$ ( Barber, 1960). Its depths range from about 200 to 350 m. Lithologically it is the most varied aquifer, consisting mainly of sand and gravels with silt and clay intercalations. It is isotropic in nature. Recharge to this aquifer is reported to occur by horizontal inflow around the ridge of the rocky areas bridging the Chad basin and also by vertical percolation from a ridge popularly referred to as the Bama ridge. Also recharge to deep aquifer is known to have taken place around the fringes of the Chad basin about 9 km SW-NE to Damboa (Yusuf, 2014) where the aquifer outcrop to the surface and serves as a recharge zone to the system. Yields of boreholes tapping this aquifer range between 5 and 10 l/sec.

**The Lower aquifer system**
The lower aquifer system is found at depths of 420-650 m, with varying yields according to location ranging from about 15 l/sec to as high as 30 l/sec. Initially it was taught that the aquifer was mainly confined to Maiduguri area but geophysical investigation later indicates its presence beyond Maiduguri in the shores of Lake Chad in Baga. The geometry, lithology and hydrogeology of this aquifer are fairly well known due to the greater number of boreholes drilled in and around Maiduguri (Bumba, et.al., 1985). Not much is known about the recharge to this aquifer but it is believed to be at a far distance at the fringe of the basin.

**Hydrology**
The area has many rivers and streams and most of them are ephemeral flowing for only couple of months in a year. Some of the rivers have their tributaries within the study area while others rise from outside .The climate semiarid with a long dry season and a short rainy season lasting approximately between may and September. The temperature is generally high with a mean annual value of about 32$^o$C. Rainfall is generally low with a mean annual value of about 625 mm, while the mean annual evaporation rate is about 1600 mm (Marte, 1986).

Groundwater resources management involves a sequence of activities and decisions including needs assessment, problem analysis, resource allocation, planning and design, implementation, operation and maintenance, as well as utilization of groundwater resources of a given area to produce a pre-determined result, all of which are interwoven in a complex way. These activities use information on demand and supply, quality, technology, availability, sustainability and environmental and economic factors (Bunu, 1999).

**WATER ABSTRACTION RATE AND CONSEQUENCES**
Groundwater resource is the main source of potable water supply for domestic, livestock and industrial use in this area. The domestic and livestock consumption which amount to over 80 percent of the groundwater use. There is general over-exploitation of the aquifers as indicated by the falling water levels (Table 2).

Table 2: Decline in SWL of boreholes tapping the Chad Formation.

| Year | Upper aquifer | Middle aquifer | Lower aquifer |
|---|---|---|---|
| 1960 | - 19.8 | +11.2 | +5.80 |
| 1970 | - 13.6 | +10.10 | +0.87 |
| 1980 | - 28.04 | +6.7 | - 25.05 |
| 1990 | - 31.95 | +4.7 | - 42.91 |
| 2000 | - 32.9 | +1.8 | - 59.44 |
| 2010 | - 33.10 | +0.1 | - 61.81 |

Source: (Yusuf, 2014).

Groundwater development and utilization have reached alarming rates in the Nigerian sector of the Chad Basin since 1970 (Olugboye, 1995). Over-exploitation and the economic, social and environmental consequences have to be tackled with scientific approach to avert the wastage of the scarce resources. Deptol, Consultants in 1984 reported cases of uncontrolled artesian flow in Monguno areas leading to wastages due to high evaporation rate in the area. These artesian boreholes are flowing without control throughout the year. Methods of water resources management have to be given a critical look for future scientific and technical management of this scarce resource.

The drastic decline in the water levels of the Chad Formation aquifer boreholes has major implications for the management and this poses major threats to sustainability. Water demand has increased over the last few decades, due to increase in social and economic development in the region associated with increasing population and changes in the life style of the people due to modernization .This has led to the establishment of some highly water - demanding industries such as soft drink factory, leather tannery and shoe factory, etc. These have evidently put enormous pressure on the groundwater to decline as these industries need plenty of water to function properly (Goni et al 2000). There is evidence of present day recharge, at least qualitatively (Yusuf, 2014).The decline generally produced high pumping heads hence making pumping more expensive.

## CURRENT GROUNDWATER MANAGEMENT PRACTICE

There is no formal or documented management practices in the Chad Basin. However, rather individuals, trying to understand the system are involved in research mainly for academic purposes. This is in contra-distinction from plan-less-ness or the laissez faire model. In this model, every one drills holes in the ground in whatever way, wherever and whenever he likes, to pump or take water out at will, without any form of regulations, monitoring or controls. Recently, the groundwater management practices in the Chad Basin aquifers have been, at best a hybrid of the PLANNED and the LAISSEZ FAIRE models, but certainly more of the latter (Adeniji, 1991). Such efforts have somehow become a way of managing the groundwater resources of the area .Borehole sitting, pump test, operation and maintenance of water supplies by professionals have become a way of managing the resource in the basin.

Due to the financial implications of drilling deep wells only the government is caring out such activities. The Chad Basin Development Authority and local government areas are complementing such activities. In the late 1970, a surface water supply scheme for the town of Maiduguri was been implemented. Similarly, other surface water supply schemes have been recommended for some of the major towns in the area. Personnel's in charge of water management should fully be train on the management strategies of groundwater in basin.

## FUTURE GROUNDWATER MANAGEMENT PERSPECTIVE

Groundwater is the most important source of water supply in the area meeting the requirements, for both domestic and livestock consumption in this area. Managing this resource becomes paramount for the sustainability of the resource and poverty reduction in the basin. The following groundwater management strategies for the scarce resource in the region are opted for:

### (i) Establishment of a Groundwater Data Base and Monitoring

This consists of collecting regular data on boreholes (an inventory), abstraction rates (quantity), water quality, water demand, water level monitoring, etc. This is achieved by the establishment of a groundwater monitoring network from which such data could be obtained and analyzed (Olugboye, 1995). The data should be continuous for a long period of time to allow for a long term groundwater plan projections in the area.

### (ii) Groundwater Aquifer Characteristics

The recharge amounts/ capacity and areas of possible recharge zones have to be identified and furthermore the relationships between groundwater – surface water has to be fully understood. The recharge amount into the aquifer has to be determined so that the amount extracted from the aquifer should be less than the recharge amounts; this is to avoid "mining" the aquifer. Furthermore, the recharge zones to the aquifer be established and used for artificial recharge. The groundwater – surface water relation is important in terms of recharge capability of the groundwater if the surface water level is higher than the groundwater level, hence recharging the groundwater or vice viser.

### (iii). Dissemination of Research Findings on Groundwater.

The importance of proper groundwater resources management has to be emphasized to the public by the water resources professionals. The professionals have to be trained on new water resources management strategies which impact the knowledge to the public through the electronic media, posters, and jingles on radio etc. This is by organizing discussion forum in the radio and television in which professionals are invited to highlight on the issues relating to water quality and scarcity to public and how to over come such problems. Posters and advertisements over the radio and public places like hospitals, markets and offices should be regular to draw the attention of the people to the importance of managing the scarce groundwater resource.

## 2. WATER CONSERVATION MEASURES

Groundwater conservation measure is very important in this area of dwindling groundwater resources. Two types of resource conservation identified to be non structural and structural methods.

### (i) Repair of Burst Water Pipeline.

The quick and prompt repair of all burst water pipeline to reduce excess wastage at consumer connections, taps, etc. this will greatly enhance the water conservation. These burst line are sometime caused due to corrosion/ ageing of pipes or by individual tempering with it. The prompt repair will conserve the water for future use by the populace. Thus corrosion resistant pipes are highly recommended to avert some of the cause's pipes damages.

**(ii) Rationing of Water Supplies and Creation of Water Scarcity Awareness**

This is a process of imposition of water on a rotational basis (shifting). This practice made consumers to collect and conserve water until their next turn to get the supply. In this process the government is managing the resource by pumping the water twice daily to consumers from 6 am – 10 am and 2 pm- 6 pm. This is to avoid over pumping the water by using the ethics of demand and supply. This is to reduce wastage of the resource and cost. A campaign strategy needs to be initiated to create awareness among consumers regarding the scarce nature of water resources and the need for its quality protection and quantity conservation. The use of radio, television, stickers and water user associations can be used for this campaign.

**(iii) Control of Free-Flow (Artesian) Boreholes in the Area**

The continuous flow from artesian boreholes in the area leads to serious water wastage; by plugging the outflow vent the flow can be controlled. The resistance from villagers/ herdsmen in the 1980's on the Borno State Government policy on plugging some artesian wells to conserve the scarce resource was due to inadequate enlightenments. The problem is further compounded by the high temperatures of the water that come from the boreholes, in which case the water has to be allowed to cool before use. With the present level of awareness of the need for water conservation and the level of determination to solve the problem, the issue needs to be reconsidered. The water that is free from iron, sulphur and manganese will have less corrosion effect on the pipes hence reduce burst line and increase the life span of the borehole.

## 3. DEMAND MANAGEMENT

The major criteria to reduce the wastage in the groundwater are by the application of the ethics of demand and supply. There are a variety of ways through which this can be achieved.

**(i) Population Increase.**

Increase in population means increase in water demands. For effective water resource management, the trend of population growth must be taken into consideration. It is true that increase in population means increase in water demand and might be a major factor of water scarcity especially in arid countries. However, the main problem is more of management than of the available water resources to meet the needs of the increasing populace.

**(ii) Metering of Consumers to Improve Water Use Effectiveness**

Water metering of consumers can reduce water wastage greatly. A metered system can save water more than unmetered one. However, with increasing awareness of the water scarcity situation and increased cost of water, the economic viability of metering all consumers can be effective. Improvement of water use effectiveness can be achieved through the imposition of low prices for water for domestic use as well as other purposes. The government should enlighten the public of how much it spent on providing water to the people. The amount of money spent by government should be such as to convey the scarcity value of the resource to the users and to foster the motivation for economic use of water. The present water rates of N600.00 per month is relatively inadequate (i.e. N20.00 per day) in Maiduguri as government spent millions of naira daily to treat and pump surface water from Alau dam and cost of daily maintenance of the treatment plan is high. A reasonable rate of N1,500.00 per month (i.e.N50 per day) is good to complement government efforts in proving clean and safe drinking water to the people of Maiduguri and minimize wastage. Regular repairs of faulty pipe and plumbing facilities in pipe distribution systems and at houses could become routine conservation practices if consumers are made to pay for water equitably.

## 4. SOURCE ENHANCEMENT

This is aimed at improving the source of water. This may consist of rehabilitation of existing facilities or the provision of new facilities, or their combination.

**(i) Recharge zones determination.**

The Chad Formation has outcropped to the surface 9 km southwest of Damboa with a lateral extension of 2 km evidence from geophysical investigation conducted in the area be Yusuf, 2014. In this area the Upper, Middle and Lower aquifers merged with the Clay Formation separating them completely pinching out. The merged aquifer outcrops to the surface and serve as a recharge zone to the aquifers in the in the southwestern fringe of the basin.

**(ii) Rain Water Harvesting and Artificial Recharge**

Rainwater harvesting comprises of the collection, storage of rainwater in surface and subsurface reservoirs for future use and prevention of water so stored from evaporation and seepage losses. The *in situ* storage includes roof water collection, collection in ponds and collection in other artificial storage structures. Todd (1980) defined artificial groundwater recharge "as augmenting the natural movement of surface water into the underground formations by some methods of construction, by spreading of, or by artificially changing natural conditions".

**GOOD MANAGEMENT PRACTICE**

In choosing any good groundwater management model, and any good model for that matter, the system identified and selected must be based on thorough investigation of all probable alternatives and constraints before zeroing in on a particular system or combination of systems to be adopted. Where inputs are constrained, the goals must be selected to match the available inputs. But where goals or targets are constrained, inputs must be sought to fulfill the set goals. Either way, some form of deliberate planning or systematic ordering of activities is necessary. Regulations, monitoring and controls are mandatory issues to be accomplished by the State Water Agencies. With the application of good management practices, most of these problems can be tackled effectively.

**(i) Participatory Management.**

There is need to involve stakeholders in water resources management, educating and training of water management staff at all levels and ensuring that women participate equally in the educating and training programmes. Particular emphasis has to be placed on the role of women, youths and the communities. Obtaining the above will entail:

1. Awareness creation programmes, including mobilizing commitment and support at all levels and initiating global and local action to promote such programmes.
2. Training of water resources managers at all levels so that they have an appropriate understanding of all the elements necessary for their decision making.
3. Strengthening of training capacities in developing communities.
4. Appropriate training of the necessary professionals including extension workers.
5. Improvement of career structures.
6. Sharing of appropriate knowledge and technology both for the collection of data and for the implementation of planned development including non-polluting technologies and the knowledge needed to extract the best performance from the existing investment system.
7. Establishment of publicity forum for the dissemination of research findings on groundwater.

**(ii) Combined Utilization Surface/Groundwater and Management**

Using groundwater in conjunction with surface water is a very important aspect of water resources management. Such conjunctive use is especially important in arid and semiarid regions. When water resources are a limiting factor in the development of a region, then their optimum utilization is a main concern to society. The aim of the groundwater-surface water conjunctive use scheme is to use water from both surface and ground sources in a combined (conjunctive) manner, i.e. taking advantage of the complementarities in hydrologic, hydrogeologic, environmental and socioeconomic features of utilizing from each source to achieve the given objective. In general, where surface water and groundwater are managed as part of a conjunctive scheme, a decrease in the rate of draft in the groundwater is possible. Furthermore, a lower overall cost of supplies can be obtained through a conjunctive use scheme. Greater flexibility and better control in supply and use of water to meet demands, and a more meticulous and assured way of providing water will be achieved, which will greatly help the management of the State Water agencies concerned. Planned groundwater utilization will also improve hydrogeological conditions of the aquifer systems. Thus, conjunctive use of the two sources for water supply is not only highly imperative and prospective, but also eminently suitable in scheduling usage (Bunu, 1999).

At present, a conjunctive groundwater – surface scheme has been implemented for Maiduguri, the Borno State capital is pumping about 20 million litres of surface water daily to Maiduguri and environs and complemented with over 5 million litres of water from boreholes (Personal Communication with Borno State Water Board). The Borno State Government has started the second phase of the Maiduguri surface water supply in 2014 budget at a target of 40 million litres per day. The previous project of the 40 million litres per day in 2014 budget will be implemented in 2015 fiscal year (personal communication with Borno State Water Borno personel). In Damaturu, the Yobe State capital is mainly supplied with the groundwater of 4,984 $m^3$ per day (5 million litres per day). The Damaturu surface water supply at Katarko Dam is in progress and will be completed before the end of the decade (Personal Communication with Yobe State Water Board).

**Conclusions**

Due to the scarcity of surface water and low rainfall in the region, groundwater development and utilization have reached alarming rates in the basin. The major fundamental key factors in groundwater management skills in the region are pointed out to include a favorable balance between water demand and water supply while satisfying the various constraints of quality, technology, availability, sustainability and environmental and economic factors in relation to time frame ( short, medium and long term) economic, political and technological or environmental gains.

Geochemical and Geophysical Investigation data indicate that there is recharge to the deep aquifers at the fringe of the basin near Damboa (about 9 km to Damboa in a SW- NE direction) where the Upper, Middle and Lower aquifers merged and outcropped to the surface with a lateral extent of 2 km but the amount of recharge is yet to be estimated (Yusuf, 2014). The recharge rate of the shallow groundwater (Upper aquifer) in this region is significant and sustainable with the current rate of abstraction. Scientific and technical management skills have been suggested for future use aimed at reducing wastage, which must be adopted.

**Recommendations**

The rate of abstraction from the aquifers should be minimized, so that the rate at which the water level is declining should be tackled with seriousness to aver the water levels falling drastically increasing operational cost of maintenance. The recharge zones should be protected from construction of permanent structures like roads and housing. Furthermore, boreholes should be sunk in the recharge zones areas to determine amount/ rate of recharge in the area. The amount of abstraction should be less than the recharge amount to the system to avoid water level decline. Water conservation and participatory source enhancement measures are recommended as the best management practice to conserve the dwindling groundwater resource in the region. The cost involved in managing is very paramount factors. Reliable databases and regular monitoring progammes are essential to assess changes in both quality and quantity of the groundwater resource. Constant enlightenment on issues related to water and environment can make costing and planning easier. Management strategy aimed at reducing wastage and must be adopted and taking cognizance of fundamentals of water demand and water supply in the region.

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