INTERNATIONAL JOURNAL OF CONSERVATION SCIENCE
ISSN: 2067-533X Volume 8, Issue 4, October-December 2017: 731-742 www.ijcs.uaic.ro

STATUS OF GROUNDWATER SANCTUARY AND ASPECTS OF ITS CONSERVATION

Pramod Chandra SAHU *

Department of Geology, MPC Autonomous College, Baripada, Mayurbhanj District, Odisha, India.

Abstract

The study demonstrates the condition of ground water sanctuary in a Precambrian crystalline province of eastern India and aspects of its conservation .Ground water in the study area occurs primarily in four different aquifer systems such as weathered mantle, saprolitic zone, fractured zone and alluvial zone. The maximum thickness of the weathered mantle in the area is 20m where groundwater occurs in unconfined conditions and mostly developed by dug wells. The groundwater resource estimation of the area has been calculated using the water table fluctuation method. The net annual usable groundwater resources of Bonai, Gurundia, Koira and Lahunipada blocks are 3524.23HM, 3935.15HM, 3557.37HM and 5245.66HM respectively. The stage of development of groundwater in Bonai, Gurundia, Koira and Lahunipada blocks are 7.17%, 7.65%, 3.20% and 4.34% respectively. The most suitable planning for the assured source of water supply round the year can be achieved by different types of groundwater structures like dug wells, dug cum bore wells and bore wells in favorable sites. Artificial recharge techniques play a major role for the groundwater conservation. Suitable sites for specific water harvesting structures/ artificial recharge structures such as percolation tank, check dam, gully plugs have been demarcated.

***Keywords**: Groundwater; Aquifer; Sustainable Development; Artificial Recharge.*

Introduction

Water plays an extremely important role in man's life not only because it is indispensable for the sustenance of life, but also it determines the quality of life. The demand of water for various uses such as drinking, irrigation and industries is increasing with time. The demand of water has been estimated to grow by as much as 100% within the next two decades. Besides, in the coming years, groundwater has also to cater substantially to the rural and urban drinking water supply and industrial requirement as a safe and sustainable source. Groundwater plays an important role in economic development of the district in the backdrop of ever-increasing population. A consensus is growing among scientists, water planners, government and civil societies to adopt new policies and approaches within next two decades to avoid water stress in all sphere of human development.

The study area occupies the eastern part of the Sundargarh district, lying towards the northern extremity of Orissa. It is bounded by the North latitudes 21º35' – 22º10' and East longitudes 84º30' – 85º25' and falls in the Survey of India Toposheet Nos. 73B/12, 73B/16, 73C/9, 73C/10, 73C/13, 73C/14, 73F/4, 73G/1, 73G/2 and 73G/5. It is delimited by the state of Jharkhand in the North-East, Keonjhar district of Orissa in the East, Deogarh and Angul

* Corresponding author: pcsahugeol@gmail.com

districts in the South, Sambalpur district in the West and Panposh subdivision of Sundargarh district in the North (Fig. 1).

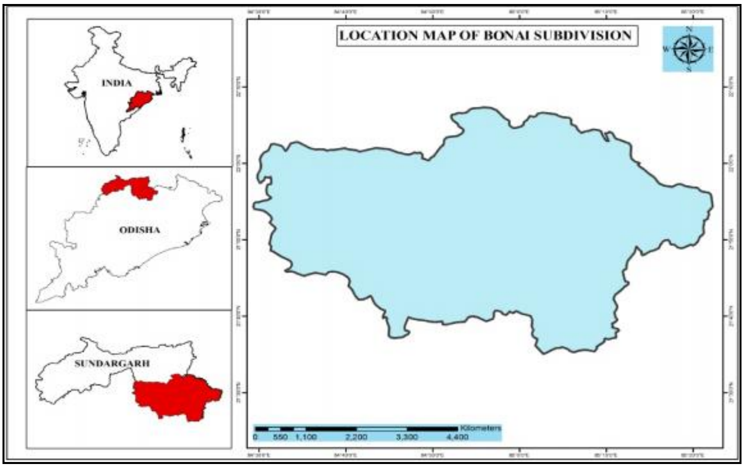

Fig. 1. Location map of the study area

The total geographical area of the study area is around 2200sq·km. The Bonai subdivision is divided into 4 administrative blocks namely Bonai, Gurundia, Koira and Lahunipada. According to 2011 census, the total population of the area is 276,792. The area enjoys a sub-tropical climate with very hot summer (46ºC). The average annual rainfall is 1648mm. The area experiences mild to normal drought frequently due to the erratic nature of rainfall over space and time. The water scarcity is chronic during summer season. Physiographically, the area is marked by hills with intervening narrow intermountain valleys, isolated hillocks and flat to gentle undulating plains. Brahmani River forms the major drainage of the area. The drainage pattern is dendritic. The area is underlain by crystalline rocks of Iron Ore Group (IOG), Darjing Group, Deogarh Group and Bonai Granite. The lithological assemblage comprises of Banded Hematite Quartzite (BHQ), Banded Hematite Jasper (BHJ), Quartzite, Phyllite, Slate, Mica-Schist, Staurolite-Schists and Granite, which are intruded by dolerite dykes. These rocks are intensely folded, fractured and have been weathered to varying degrees at different places. The occurrence and movement of groundwater depends mainly on secondary porosity. The dolerite dykes form a barrier for the movement of groundwater resulting in the compartmentalization of the groundwater regime. The weathered and fractured dykes at places that serve as potential sites for groundwater occurrence. Laterite and alluvium occur as small patches in the area. Lateritic soils of considerable thickness are a good repository of groundwater due to their high porosity and permeability. The groundwater potential of alluvium is very good. Some authors [1-6] in their studies relating to ground water exploration and targeting potential ground water zone, have emphasized that integrated geological, geophysical, remote sensing and GIS techniques should be adopted for targeting potential ground water zones in hard rock areas. Authors [7-15] have emphasized the need to adopt modern know-how i.e. Remote Sensing and GIS to evaluate the ground water potential in hard rock provinces. Authors [16-23] in their studies on ground water development and management has remarked that artificial recharge structures/rain water harvesting structures play a key role in sustainable development of ground water resources.

Methodology

All the available data on geology, hydrogeology, rainfall, population, agriculture were collected from different agencies/publications and suitably processed. Topographic maps of

Survey of India and district planning map were used. The different thematic maps on lithology, drainage and geomorphology generated from satellite data were used. Electrical Resistivity Method (VES) has been employed to understand the gross aquifer condition in the area. Ground Water Estimation and Budgeting has been worked out employing guidelines prescribed by the Ground Estimation Committee (GEC-1997). In this method, the thickness of aquifer layer (T) is determined based on water table fluctuation recorded from the observation wells. Specific yield(s) of each aquifer/formation is taken from the pumping test data. By multiplying the aquifer thickness (T) with specific yield(s) and rechargeable area (A), the gross ground water is worked out. For the calculation of rechargeable area (A), satellite data have been used. In the present study, data of the hydro geo morphological map prepared from IRS-IA (LISS II) have been used.

Results and discussions

Groundwater Resource Location

The study area is characterized by varied hydro geological set-up. The hydro geological framework has been revealed through deep exploration combined with hydro geological surveys. Topography, weathered residuum and fracture lineaments control groundwater occurrence and movement. Groundwater in the study area occurs primarily in four different aquifer systems such as weathered mantle, saprolithic zone, fractured zone and alluvial zone. The maximum thickness of the weathered mantle in the area is 20m where groundwater occurs in unconfined conditions and mostly developed by dug wells. The saprolitic zone is a kind of transition zone between weathered mantle and fresh rock and yield of this aquifer may go up to 3 lps (CGWB). The occurrence of potential saturated fractures is mostly restricted down to 60 to 70m depth. Occurrences of saturated fractures are frequent in granitic rocks than other hard rocks in the area. In hard rocks, a failure of wells is a common experience due to discontinuous nature of aquifers and wide variation in porosity and permeability. The hydro-geomorphological map of the study area prepared from the IRS-IA (LISS-II) data depicts the different geomorphic units (Fig. 2).

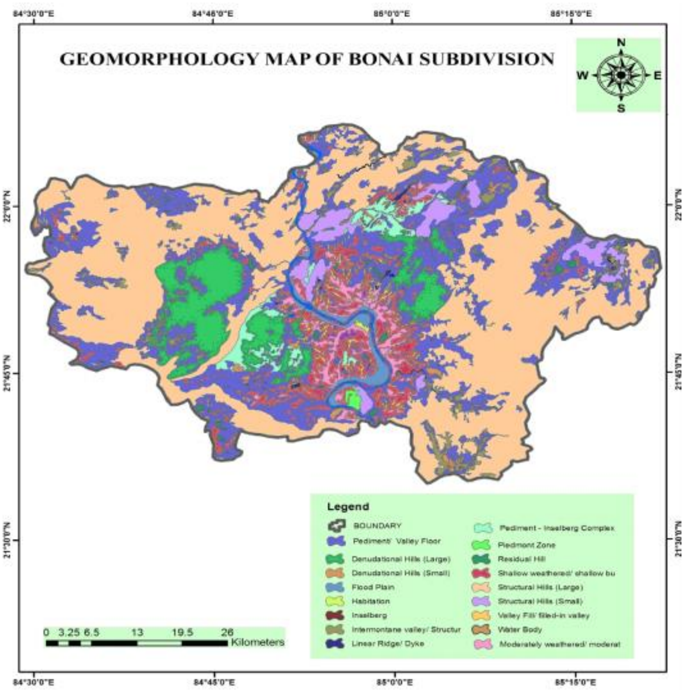

Fig. 2. Hydro-geomorphology map of the study area

The geomorphic units developed on various litho-stratigraphic units are presented (Table1). The ground water prospects of different geomorphic units are interpreted as follows.

Table 1. Hydro Geomorphic Units Vis-a-Vis Lithostratigraphyof the Study Area

Map Unit	Geomorphic Unit	Litho- Stratigraphic Unit	Description
AP_8	Alluvial Plain	Alluvium (Sand, Silt and Clays)	A level or gently sloping, slightly undulating land surface produced by extensive deposition of alluvium.
SH_5	Structural Hill	Darjing Group (Quartzite, Phyllite and Schist)	Liner to arcuate hills showing definite trend line.
IV_5	Intermontane Valley	Darjing Group (Quartzite, Phyllite and Schist)	Linear to curvilinear valleys occurring within the hills. The depression generally filled with colluval deposits.
$BPPS_5$	Shallow Weathered Buried Pediplain	Darjing Group (Quartzite, Phyllite and Schist)	Flat terrain with shallow overburden. Extensive occur-ence of buried pediment forms this unit.
DH_4	Denudational Hill	Bonai Granite	Relict hills which have undergone the process of denudation.
RH_4	Residual Hill	Bonai Granite	Isolated hill, surrounded by plains on all sides.
P_4	Pediment	Bonai Granite	Broad, gently sloping rock floor, erosional surface of low relief.
BP_4	Buried Pediment	Bonai Granite	Gently sloping rock floor covered with thick unconsolidated sediments.
$BPPD_4$	Deeply Weathered Buried Pediplain	Bonai Granite	Flat terrain with 15 - 20 m thick overburden
SH_3	Structural Hill	Iron Ore Group (BHQ, BHJ, Phyllite, Quartzite, Lava, Conglomerate)	Linear to arcuate hills showing define trend lines.
DH_3	Denudational Hill	Iron Ore Group (BHQ, BHJ, Phyllite, Quartzite, Lava, Conglomerate)	Relict hills which have undergone the process of denudation generally expressing themselves as barren, rocky and steep sided.
IV_3	Intermontane Valley	Iron Ore Group (BHQ, BHJ, Phyllite, Quartzite, Lava, Conglomerate)	A linear or curvilinear depression valley within the hills, filled with colluvial deposits of IOG sediments
$BPPS_3$	Shallow Weathered Buried Pediplain	Iron Ore Group (BHQ, BHJ, Phyllite, Quartzite, Lava, Conglomerate)	A flat, slightly undulating land surface with shallow overburden.
SH_2	Structural Hill	Deogarh Group (Quartzite and Schist)	Linear to arcuate hills showing definite trend lines.
SH_2	Structural Hill	Deogarh Group (Quartzite and Schist)	Linear to arcuate hills showing definite trend lines.
P_2	Pediment	Deogarh Group (Quartzite and schist with BIF)	Gently sloping rock floor, erosional surface of low relief covered with thin veneer of detritus.

Alluvial Plain

It is level or gently sloping and slightly undulating land surface produced by extensive deposition of alluvium found near the bank of Brahmani River. The ground water potential is good to excellent which can be tapped through dug well.

Weathered Pediplain

These units are characterized by the presence of relatively thicker weathered material. Depending upon the depth of weathered materials, these are broadly classified as shallow (up to 5m), moderate (5-20m) and deep (>20m). These hydro-geomorphic units are mostly developed upon Bonai Granite and rarely over the metasediments of Darjing group. Most of the area under this unit is agricultural land. Depending upon the thickness of the weathered zone, the ground water potential is moderate to good and important for construction of dug well and dug-cum-bore well.

Pediment

It is gently sloping rocky surface with or without a thin veneer of soil cover. Part of Bonai and Gurundia blocks come under this unit. The area under this unit is generally considered to be the poor ground water potential zone. The presence of fractures represented by lineaments over pediment indicates some ground water potentiality.

Intermontanevalley

These are almost flat valleys surrounded by hills all around and mostly observed in Koira and Gurundia blocks. Owing to their position, these units are highly favorable loci for ground water occurrence and important for dug well.

Inselbergs

These are isolated hill made up of quartizite of Deogarh Group with limited areal extension surrounded by plain land all around, observed in Bonai block. Ground water potential is very poor in these units.

Structural Hills

These are group of curvilinear folded hill ranges. Compositionally these hills consist of Banded Iron Formation (BIF) in Koira block and metasediments in Gurundia block. They act as runoff zone with poor recharge condition.

Residual hills

Residual hills of Quartzite are found in the central part of the area. They act as runoff zone and ground water potential is very poor.

Lineament

The lineament of the study area unfolds the fact that fractures control the movement and storage of ground water in the area. Lineaments of NE-SW, N-S, NW-SE and E-W trend are observed in the area. However, the NE-SW trending lineament is dominant over the study area. The "ground truthing" studies reveal that better yields are found from the area in the vicinity of NE-SW trending lineament). It is also marked that the areas of intersection points of lineaments in pediplains, intermountain valleys, pediments and alluvial plains area to be considered during selection of well sites because such locations have good ground water potentialities.

Interpretation of Resistivity data

On the basis of resistivity survey, 4 or 5 geo-electrical sub-surface layers set-up were found in the study area. These layers are top soil, highly weathered zone, semi-weathered zone, fractured zone and bedrock. It has also been marked that in some cases, the semi-weathered and fractured zones are not distinguished clearly from each other because of similarity in resistivity values.

The correlation of lithology with resistivity values are presented in Table 2.

Table 2. Correlation of Lithology with Resistivity Values

Resistivity range (ohm – m)	Probable Lithology
9 – 188	Top soil (clayey sands, sandy loams, lateritic soils)
55 –155	Highly weathered zone
156 – 384	Semi- weathered zone
385 – 500	Fractured zone
> 500	Massive bedrock

The top soil layer of variable nature has resistivity values from 9 to 188ohm-m, with a maximum thickness of 4.5m. The highly weathered layer identifies with resistivity value ranging from 55 to 155ohm-m having a maximum thickness of 19.5m. The semi-weathered zone is indicated by resistivity values of 156 to 384ohm-m, having a maximum thickness of 25m. The fractured zone is indicated by resistivity valuea of 385 to 500ohm-m. The hard rock layer shows very high resistivity value, usually greater than 500ohm-m, indicating the devoid of water. However, the prominent fracture zones are restricted within a depth of 60 to 70m below the ground level. In a four layered case, the 2nd and 3rd layers are interpreted as potential ground water horizons from which a good amount of ground water can be extracted. In this case, the second layer represents weathered zone and the third layer represents partially weathered zone or fractured zone. In a five layered case, the 2nd, 3rd and 4th layers constitute the aquifer system. In this case the 2nd layer, 3rd layer and 4th layers represent weather zone, semi-weathered zone and fractured zone respectively. On the basis of geophysical investigation and results obtained it is inferred that the thickness of the aquifer varies from place to place. In most part of the study area, the thickness of the aquifer materials is more than 30m. In small patches of Bonai, Koira and Lahunipada block, the thickness of aquifer is between 15 to 30m. The potential aquifers are confined to weathered and fractured granitic rocks of Bonai and Lahunipada blocks. The aquifer systems of IOG and Darjing Group are relatively less productive than that of the Bonai Granite. The depth of the bedrock is higher than 30m in most part of the study area. In small patches of Bonai, Koira and Lahunipada block, the depth to bedrock ranges from 15 to 30m.VES studies in the area reveal that the area has high potentiality for ground water exploitation through different kinds of ground water structures. Depending upon the depth to the massive bedrock, suitable ground water structures may be developed. The depth to bedrock ranges from 30 to 70m in most parts of the geomorphic units like Alluvial Plains, Intermontane Valleys and Buried Pediplain. However, the depth to massive bedrock is 15 to 30m in pediment. The dug-cum-bore wells along with dug wells may be constructed in areas where depth to bedrock lies between 15 to 30m and bore wells along with dug wells and dug-cum-bore wells are suitable in areas where the depth to bedrock is higher than 30m.

Ground Water Potential

The study reveals that the net annual utilizable ground water resource of Bonai, Gurundia, Koira and Lahunipada blocks are 3,524.23HM, 3,935.13HM, 3,557.37HM and 5,245.66HM respectively. These findings are in accordance with the findings of Paul and Sahu (2000) who reported that the groundwater potential in the state is high. The maximum annual utilizable ground water resource is in Lahunipada block and minimum is in Bonai block. The net ground water draft of Bonai, Gurundia, Koira and Lahunipada blocks are 252.70HM, 301.00HM, 114.10HM and 227.50HM respectively (Table 3-6). The maximum ground water draft is in Gurundia block and minimum is in Koira block.

Table 3. Groundwater Resource Estimation and Budgeting (Bonai Block)

Resource	
1. Gross Groundwater Resource	5034.62 HM
2. Net Utilisable Resource (70% of Gross)	3524.23 HM
Draft (Based on well census)	
1. Gross Groundwater Draft (Annual)	361.00 HM
2. Net Groundwater Draft (70% of Gross)	252.70 HM
Groundwater Balance	3271.53 HM
Stage Of Development	7.17%
Category	**White / Safe**
Allocation	
1.Domestic and drinking (10% of balance)	327.15 HM
2. Available for irrigation	2944.38 HM

The groundwater balance as of December 2011 of Bonai, Gurundia, Koira and Lahunipada blocks are 3,271.53HM, 3,634.13HM, 3,443:27HM and 5,018.16HM respectively. The total ground water balance of the study area is 15367.09HM out of which 13830.39HM can be utilized for additional irrigation purpose. The ground water stage developments of Bonai, Gurundia. Koira and Lahunipada blocks are only 7.17%, 7.65%, 3.20% and 4.34% respectively. All the blocks come under White/ Safe categories. The ground water development in the study area is abysmally low and needs further development through suitable ground water structure to combat drought.

Table 4. Groundwater Resource Estimation and Budgeting (Gurundia Block)

Resource		
	1. Gross Groundwater Resource	5621.62 HM
	2. Net Utilisable Resource (70% of Gross)	3935.13 HM
Draft (Based on well census)		
	1. Gross Groundwater Draft (Annual)	430.00m HM
	2. Net Groundwater Draft (70% of Gross)	301.00 HM
Groundwater Balance		3634.13 HM
Stage Of Development		7.65 %
Category		**White / Safe**
Allocation		
	1. Domestic and drinking (10% of balance)	363.41
	2. Available for irrigation	3270.72 HM

Table 5. Groundwater Resource Estimation And Budgeting (Koira Block)

Resource		
	1. Gross Groundwater Resource	5081.97 HM
	2. Net Utilizable Resource (70% of Gross)	3557.37 HM
Draft (Based on well census)		
	1. Gross Groundwater draft (Annual)	163.00 HM
	2. Net Groundwater Draft (70% of Gross)	114.10 HM
Groundwater Balance		3443.27 HM
Stage Of Development		3.20%
Category		**White / Safe**
Allocation		
	1. Domestic and drinking (10% of balance)	344.32 HM
	2. Available for irrigation	3098.95 HM

Table 6. Groundwater Resource Estimation And Budgeting (Lahunipada Block)

Resource		
	1. Grouses Ground water Resource	7493.81 HM
	2. Net Utilisable Resource (70% of Gross)	5245.66 HM
Draft (Based on well census)		
	1. Gross GW Draft (Annual)	325.00 HM
	2. Net GW Draft (70% of Gross)	227.50 HM
Groundwater Balance		5018.16 HM
Stage Of Development		4.34%
Category		**White / Safe**
Allocation		
	1. Domestic and drinking (10% of balance)	501.81 HM
	2. Available for irrigation	4516.35 HM

Prospects for Ground Water Development

As the present level of ground water development in the study area is low (5%), the total irrigated area from all sources is also very less. The development of balance ground water resources will certainly provide irrigational facility round the year. In the study area, the ground water can be developed through dug wells, dug-cum-bore wells and bore wells. But deep bore wells appear to be advantageous structure for ground water exploitation due to their high yields, and continuous discharge throughout the year and utilization of deeper storage ground water. In low lying area, the ground water development is feasible through dug wells with depth range of 8-10m. The recommended diameter of the well is 4 to 6m. Each dug well can have a command area of 0.75 to 1ha. In case of moderately elevated area, ground water can be developed through dug wells and dug-cum-bore wells. In the high land areas, the suitable structures for ground water development are bore wells having a depth range or 50-70m, since the potential fracture zones are restricted within a depth of 70m. Each bore well can have command area up to 8 ha.

Groundwater resource conservation

Keeping in view the above facts, rainwater harvesting, groundwater conservation and augmentation are considered to be the only solution to maintain a balance between the annual recharge and discharge. Artificial recharge techniques play a major role for conservation of groundwater. The main source of groundwater recharge is rainfall, which is mostly lost as surface runoff and hence the only alternative to replenish the groundwater is by artificial means.

Groundwater Recharge Zones

Generally artificial recharge means intentional replenishment of water into groundwater bodies. It is a means of augmenting the natural infiltrations of surface water into a groundwater reservoir at a rate that vastly exceeds that of the natural percolation. The following objectives can be achieved through artificial recharge techniques:

1. To prevent decline of the groundwater reserves and to improve groundwater levels and availability.
2. To supplement existing supplies
3. To improve water quality in aquifers.
4. To check surface runoff during monsoon.
5. To ensure availability of groundwater at specific place and time.

The study area can be grouped into 4 natural groundwater recharge zone based on the porosity, permeability and runoff characteristics of the land .The landforms, lithology, presence of lineaments, slope factor, land use/ land cover and surface water bodies available play an important role to infer these natural recharge sites.

Zone 1 The fracture controlled small valleys filled with unconsolidated sediments, buried pediments with thick weathered zones, intermountain valleys and areas with good vegetative covers in the foothill regions are the zones of good recharge. These areas are very gently sloping and are mostly cultivated land, which help in the retention of surface water.

Zone 2 This zone occupies the shallow weathered pediplains adjacent to the zone 1, with good concentration of lineaments. The recharge rate is good to moderate.

Zone 3 This zone represents the higher slope area of buried pediments with scanty vegetation and structural hills traversed by fractures and fissures. The groundwater recharge rate is moderate to low.

Zone 4 The denudation and residual hills of the study area which have only open and degraded forest cover with steep slope are runoff zones and categorized as zone 4, where the minor fractures are the only linear area through which percolation may take place.

Artificial Recharge

Considering the hydro geological set-up, natural recharge conditions, groundwater potential, future optimal use of groundwater, soil and slope of the area, prevailing land use and cropping pattern in the study area proposed artificial recharge structures have been proposed (Fig. 3).

Suitable sites for specific water harvesting structures/ artificial recharge structures such as percolation tank, check dam, gully plugs have been demarcated. Besides these, sites for agriculture- related measures which will aid artificial recharge have also been shown in the map. The construction of artificial recharge structures will not only augment groundwater resources, but also will help in solving geo-environmental problems like land degradation by soil erosion and loss of soil moisture.

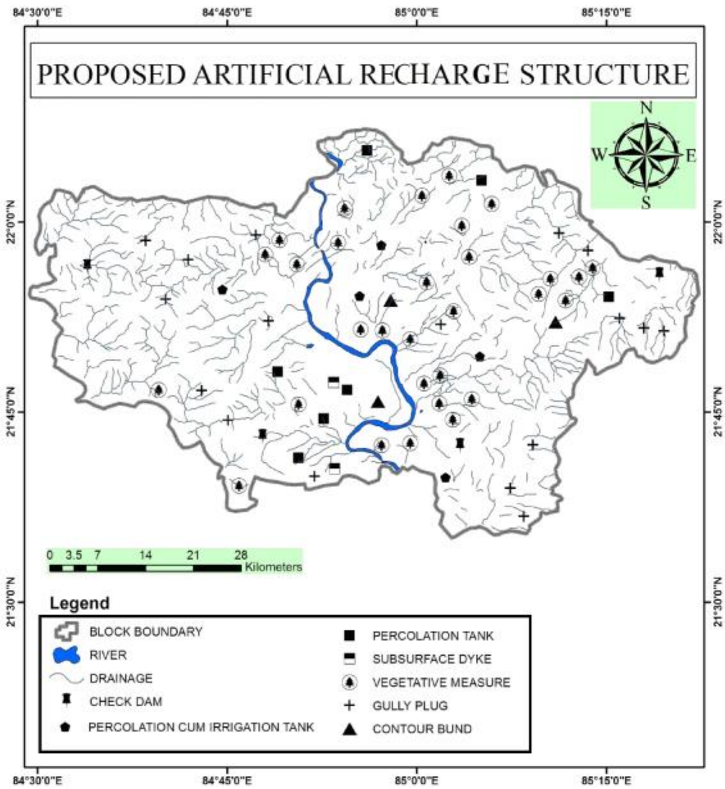

Fig. 3. Proposed artificial recharge structure map of the study area

Percolation Tank

Percolation tanks are shallow tanks constructed at appropriate places in natural or diverted stream courses and provided with a waste weir to allow excess water to continue its course. The ideal site for construction of percolation tanks are gently slope, terrain of light soils, weathered materials of moderate thickness and fractures zones. However, these tanks need scraping of bottoms once in a year or two depending on the rate of accumulation of fine sediments at the bottom of the tank. Percolation tanks are the most suitable structure for recharging groundwater in the hard rock areas, because in addition to artificial recharge they contribute directly to irrigation from the stored water. Percolation tanks in the study area may be selected at comparatively higher elevations with creation of embankments only on sideways and on down slope sides. The upslope sides should remain open for easy entry of surface runoff water. Within the study area such structures may be constructed around Sarsara, Jhirdapali, Talita, Kello, Kasada, Koira, Ergeda, Kuradihi etc.

Percolation - Cum- Irrigation Tank

The main purpose of this tank is percolation and to hold flow of silt. In addition, the stored water is used for cultivation in the nearby areas through field canals. This type of tank is usually created on the upstream side of first order stream having a good catchment area for sufficient entry of runoff water. Accordingly suitable sites can be selected around the villages Tikayatpali, Sarasara, Kasada, Kantasara, Khandadhar, Lahunipada, Damdhara etc.

Check dam

The purpose of check dam is to reduce runoff velocity, to minimize erosion and to allow percolation of surface water. Sites for check dams have been selected on lower order stream (up to 3rd order) with catchment area of about 40hect., where the level of groundwater fluctuation is high and slope is moderate. Such structures can be of help around villages Ergeda, S. Balang. Sole, Malda etc.

Subsurface Bund/Artificial Dyke

Artificial subsurface dykes are feasible in hard rock areas in narrow gently sloping valleys, where the bedrock occurs at shallow depth and valley fills consists of about 4 to 8m of pervious materials. Groundwater reservoirs can be created by constructing subsurface dykes across the flow direction of groundwater. Subsurface dykes of 1 to 4m height are found to be effective in augmenting the groundwater resources particularly in hard rock areas underlain by fractured aquifers. By keeping the top of the dyke 1m below the land surface, the riparian rights of the farmers downstream are not violated and water logging or salt accumulation on the upstream side of the dam is prevented. The dyke can be constructed with materials like clays, bitumen, polythene sheets besides bricks and concrete depending on local conditions. Such structures in the study area may be constructed around the–Dharanidharpali,Kasada, Talita villages etc.

Contour Bonding

Contour bounding is the construction of small bunds across the slope of the land on a contour. Each contour bund acts as a barrier to the flow of water and check the runoff water, thus contributing a part to recharge of groundwater through water spreading. In the study area suitable sites are in upland and hilly regions of Koira, Gurundia and Lahunipada blocks. The upslope of the cultivated lands may be selected for contour bounding to save the cultivated areas from soil erosions and to facilitate groundwater recharge.

Gully Plugging

In the hard rock areas particularly in plateau regions formation of numerous gullies is a common phenomenon and the study area is not an exception.The main cause of such gullies formation is large-scale deforestation followed by heavy soil erosion due to surface runoff creating waste land on both sides of the stream courses. In such a rocky area, where the cultivation scope is limited, the land suitable for agriculture is being converted to waste land rapidly. In the study area there is an urgent need for gullies plugging with the use of locally available materials particularly in the cultivated areas of Koira, Lahunipada and Gurundia blocks. By adopting such measures, the top soil can be protected as well as the rate of infiltration of water can be increased.

Agriculture-related measure

The wasteland areas such as land with/ without scrubs, undercultivated cropped areas and open and degraded forest land are to be brought under afforestation which is also a measure of rainwater harvesting. Areas with/without scrubs are mostly located on shallow buried pediplain and less frequently on pediments. These areas, because of the gentle to moderate slope, are suitable for agro-horticulture and hortipasture. Suitable species of horticultural plants can be planted on these lands to check runoff and augment groundwater recharge. The scrubs lands with higher slopes may be planted with fodder and fuel wood varieties. The degraded forest land of the area around Kuliposh, Khuntgaon, Kasada, Dharidharpali, Telidihi etc., can be brought under afforstation. These vegetative measures will check the soil erosion besides recharging the groundwater.

Hydrofracturing

The unconventional technique of hydro fracturing may be undertaken for improving the yields of bore wells in hard rock areas. This technique has the following advantages.

1. Widening of existing fractures
2. Removal of clogging in the fracture connectivity.
3. Creation of interconnection of fractures
4. Extending the length of the old fractures
5. Creation of new fractures in the aquifers.

Conclusions

The sustainable groundwater development of the area requires scientific management in the fields of resource location, estimation, development, conservation and augmentation and protection. The study reveals that the weathered residuum and fracture systems control the groundwater occurrence and movement. Since the stage of development of groundwater in the area is very low (6%), there is a vast scope for groundwater development through suitable structures to face drought condition. A large-scale intensive groundwater development programme needs to be launched on a scientific basis. The most suitable planning for the assured source of supply round the year can be achieved by different types of site-specific groundwater structures such as dug wells, dug-cum-bore wells and bore wells. The change in cropping pattern and adoption of modern irrigation practices like sprinkler and drip irrigation systems is the need of the hour.

Rainwater harvesting, groundwater conservation and augmentation is needed to maintain the balance between annual recharge and discharge. Artificial recharge techniques play a major role for conservation of groundwater. Considering the hydro geological set-up, natural recharge condition, soil and slope of the area, land use pattern, future optimal use of groundwater, suitable sites for specific artificial structures like percolation tank, check dam, subsurface dyke, gully plug etc. have been demarcated. The unconventional technique of hydro fracturing may be undertaken to rejuvenate the sick wells or for improving the yields of tube wells in hard rock areas. The artificial recharge structures will also help in solving geo-environmental problem like land degradation by soil erosion, loss of moisture etc. It can be concluded that the Water Resource Management (WRM) is a highly dynamic process, covering wide spectrum of activities. These activities are highly multidisciplinary, involving earth scientists, engineers in the area of hydrology, hydraulics, water supply, irrigation and environmentalists, agriculturalists, ecologists, economists, lawyers, sociologists, politicians and end-users. Implementation of groundwater scheme can be more effective through people's participation. Hence, involvement of Non-Government Organizations (NGO's) and voluntary organizations is needed to assist in this gigantic task employing local volunteers and unemployed youths who have clear understanding of the landforms and land uses etc.

References

[1] B. Deepika, K. Avinash, K.S. Jayappa, *Intregation of Hydrological Factors and Demarcation of Groundwater Prospects Zones: Insights from Remote Sensing and GIS techniques,* **Environmental Earth Science, 70**(3), 2013, pp. 1319-1338.

[2] V.M. Rokade,P. Kundal, A.K Joshi, *Groundwater Potential modeling through Remote sensing and GIS : A case study from Rajula Taluka, Chandrapur District, Maharastra,* **Journal of Geological Society of India, 69**, 2007, pp. 943-948.

[3] P.C. Sahu, *Groundwater Resource Conservation And Augmentation In Hard Rock Terrain:An Integrated Geological And Geo-Spatial Approach,* **International Journal of Conservation Science, 8**(1), 2017, pp. 145-156.

[4] G.P. Reddy Obi, A.K. Maji, *Delineation and Characterization of Geomorphological Features in a part of Lower Maharastra Metamorphic Plateau using IRS-ID LISS-III Data.* **Journal of Indian Society of Remote Sensing, 31**(4), 2003, pp. 241-250.

[5] P.C. Sahu, H.K. Sahoo, *Targetting Ground water in tribal dominated Bonai Area of drought prone sundergarhdisrict, Orissa India- A combined Geophysical and Remote sensing Approach*, **Journal of Human Ecology, 20**(2), 2006, pp. 109-115.

[6] P.C. Sahu, *Geomorphological and Lineament Studies for targeting Ground water in Digapahandi block, Ganjamdisrict, Orissa*, **Vistas in Geological Research,** Utkal University Spl. Publication in Geology, **(7)**, 2008, pp. 193-200.

[7] P.R. Reddy, *Remote sensing in Ground water studies,* **Remote sensing for Earth Resources,** 2nd Edn., Publication of Association of Exploration Geophysists, Hyderabad, India, 1999, pp. 183-203.
[8] D. Nandi, J. Kant, C.K. Sahu, *Integrated Approach Using Remote Sensing and GIS for Hydrogeology of Moroda Block In Mayurbhanj District, Odisha, India*, **International Journal of Conservation Science, 6**(3), 2015, pp. 383-390.
[9] N.S. Magesh, N. Chandrasekar, J.P. Soundranayagam, *Delineation of groundwater potential zones in Theni district, Tamilnadu, using remote sensing, GIS and MIF,* **Geosciences Frontiers, 3**(2), 2012, pp.189-196.
[10] D. Nandi, S.R. Mishra, *Groundwater quality mapping by using geographic information system (GIS): A case study of Baripada city, Odisha, India,* **International Journal of Conservation Science, 5**(1), 2014, pp. 79-84.
[11] P.K. Dinesh Kumar, G. Gopinath, P. Serelathan, *Application of remote sensing and GIS for the demarcation of groundwater potentials zones of a river basin in Kerala, southwest coast of India,* **International journal of Remote Sensing, 28**(24), 2007, pp. 5583-5601.
[12] R.K., Jaiswal, S. Mukherjee, J. Krishnamurthy, R. Saxena, *Role of remote sensing and GIS techniques for generation of groundwater prospect zones towards rural development – an approach*, **International journal of Remote Sensing, 24**(5), 2003, pp. 993-1008.
[13] M. Al Saud, *Mapping potential areas for groundwater storage in Wadi Aurnah Basin, westernArabian Peninsula, using remote sensing and geographic information system techniques,* **Hydrogeology Journal, 18**(6), 2010, pp. 1481-1495.
[14] I.M. Bahuguna, S. Nayak, V. Tamilarasan, V.J. Moses, *Ground water prospective zones in basaltic terrain using remote sensing,* **Journal of the Indian Society of Remote Sensing, 31,** 2003, pp. 101-105.
[15] R.S. Suja Rose, N . Krishnan, *Spatial Analysis of Groundwater Potential using Remote Sensing and GIS in the Kanyakumari and Nambiyar Basins, India,* **Journal of the Indian Society of Remote Sensing, 37,** 2009, pp. 681-692.
[16] B.M. Jha, *Sustainability of water resources in Orissa*, **Proceding of Seminar on "Groundwater Resources of Orissa for 2020"**, Central Ground Water Board, Bhubaneswar, Orissa, 2000, pp. 13-22.
[17] K. Pradhan, *Artificial Recharge to Ground water. The need and scope in Hill region of Orissa*. **Proceeding of National Seminar. "Ground Water Management in Orissa its Prospects and Challenges** "CGWB, Bhubaneswar, 2003, pp. 50-54.
[18] D.K. Chadha, *Groundwater Resource Potential and Scope for Development in Orissa***."** **Proceding of Seminar on "Prospect of Groundwater Development and Management in Orissa**" Central Ground Water Board, Bhubaneswar, Orissa, 2000, pp. 1-9.
[19] B.N. Umrikar*, Artificial Recharge and Water Conservation Techniques in Deccan Trap Aquifers of Maharastra,* **Journal of Applied Hydrology, 15(**1), 2002, pp. 23-30.
[20] A. Shaban, M. Khawlie, C. Abdallah, *Use of remote sensing and GIS to determine recharge potential zone: the case of Occidental Lebanon,* **Hydrogeology Journal, 14**, 2006, pp. 433-443.
[21] A. Chowdhury, M.K. Jha, V.M. Chowdhury, *Delineation of groundwater recharge zones and identification of artificial recharge sites in West Medinipur district, West Bengal, using RS , GIS and MCDM techniques,* **Environmental Earth Science, 59**, 2010, pp. 1209-1222.
[22] S.O. Tweed, M. Leblanc, J.A. Webb, M.W. Lubczynski*, Remote sensing and GIS for mapping recharge and discharge areas in salinity prone catchments, Southeastern Australia*, **Hydrogeology Journal, 15**(1), 2007, pp. 75-96.
[23] A.K. Sharma, R.K. Ray, *A Remote Sensing and GIS based approach to evaluate the groundwater prospects of Baghain watershed , Pann and Satna districts of M. P. India; a case study*, **Journal of Geological Society of India, 86**(6), 2015, pp. 733-741.

Received: October 25, 2016
Accepted: August 20, 2017