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Implementation of Ground water Development and Management Strategy in Vicinity of Thandla, Jhabua Region, Madhya Pradesh, India

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ABSTRACT

Implementation of ground water development and management plan is essential to human civilization for their continued existence in the world. The paper deals with the ground water resource sacristy prevailing in the Thandla study area of Jhabua region in Madhya Pradesh, India. Hydrogeological investigation reveals favourable conditions for water resource development by implementing a plan for augmentation of rainfall and recharge of ground water resource followed by judicious management with a view to resolve the problem of sustained water supply in study area by implementation of a plan for development of ground water resource and appropriate management scheme of ground water resource with a view to provide water supply to the inhabitants of Thandla area, Jhabua Region.

KEYWORDS: *Implementation, Ground water, Development, Management, Plan, Thandla area, Jhabua Region, Madhya Pradesh, India.*

INTRODUCTION

Ground water is a natural, dynamic, and replenishable earth resource, which acts as a substitute for water supply. Ground water acts as a elixir of life. In India, Madhya Pradesh is a tribal area, which facing critical situation of sustained water supply being facing crisis of water supply for Thandla inhabitants. The present paper is concerned with the implementation of a ground water development and management plan in Thandla area located in tribal region of Madhya Pradesh, in India.

Concept of water resource is generally involves surface water and Ground water (also known as sub-surface water). The utilizable surface water resources are inadequate to meet out requirement of the country. Water resource is mainly substituted by the ground water. In the life of present trends of population rapid explosion, increase in population, organization, industrialization, energy and sport sectors are generating enormous pressure on ground water resource. As a result, ground water is depleting at a fast speed, which is resulting into shortage of water ground water supply. Hence it is essential to increase development ground water resource.

In India, Madhya Pradesh is one of the states which are facing problem of sustained water supply, that causes even drought situation most of the parts of the country. Madhya Pradesh region is well-known for a good net work of rivers; however, it is having the problem of water crisis, because most of the rivers are seasonal and hence resulting into the scarcity of regular supply of water in most of the districts of the states. Hence, it is necessary to implement a scheme for augmentation of water resources.

Sustainable development is a reasonable process that increases both the current and future potential to meet human requirements and aspirations. The sustainable development involves the optimum realization of different economic, environmental and social objectives of the society at one and same time. Ground water is a renewable natural resource, however, it has limited extent and hence, only a definite quantity of water must be withdrawn annually from a ground water basin. Artificial recharge is a main globally adopted technique to augment the ground water system (Singh and Dev, 2012).

CHARACTERISTICS FEATURES OF STUDY AREA

The study area is confined to Thandla tehsil of Jhabua Region, Madhya Pradesh, within Latitude 23^{0} 0' to 23^{0} 10 ' N and Longitude 74^{0} 30 ' to 74^{0} 40 ' E (Survey of India Toposheet No. 46 I/12, Figure 1) in Thandla area. The study area covers 366.58 sq. km. Study area is approachable by both road as well as rail throughout the year.

Physiographic features of study area are developed due to the denudation brought by water and wind and area is divided into three physiographic regions specifically, Hilly Terrain, Undulating country, and Plain country. Climate of the area is of tropical - monsoon type and temperature varies from 6^{0}C to 46^{0}C. Usually, study area is mainly dry. Annual rainfall ranges from 423.00 to 2086.20 mm, with an average of 964.324 mm. Relative humidity is observed as 34.4 to 50 %. Study area is characterized by the occurrence of Quartzite, and Phyllite developed in the Padmavati River basin. Basaltic lava flows having joints, fractures with different black cotton, lateritic, and alluvial soils.

Geology plays an important role in the ground water exploration. The field setting reveals different rock formations. The lithological and structural features control hydrological conditions, landforms, drainage pattern and inflow of water into the sub-surface. Rock types such as Quartzite, Phyllites and others dominate geological features. These rock types have resemblance with the Aravalli Super group (Archaean) of Rajasthan. Three Lava flows of Deccan traps have been observed in Thandla area on the basis of characteristic features. Lava flows belonging to the Deccan Traps are dominant unit in study area. Black cotton, Lateritic and alluvial soils are well developed.

GROUND WATER DEVELOPMENT

Development of ground water requires the energy, except where artesian conditions are develop existence of free flowing wells and springs. Ground water has also certain disadvantages and inadequate water supply within areas, due to presence of impervious rocks or saline water. In recent years, the phenomenal increase in ground water use for domestic, irrigation, industrial and municipal supplies have resulted, in a large area, in extraction of ground water for in excess of not natural recharge. Critical local water shortage has developed under these conditions adverse effects such as persistent water level declines and consequent increase in pumping costs, development of adverse salt balance, subsidence of land surface and saline water intrusion into fresh water aquifers (Davis and Dewiest, 1966, Todd, 1980, 2010, Karanth, 1994, 2003).

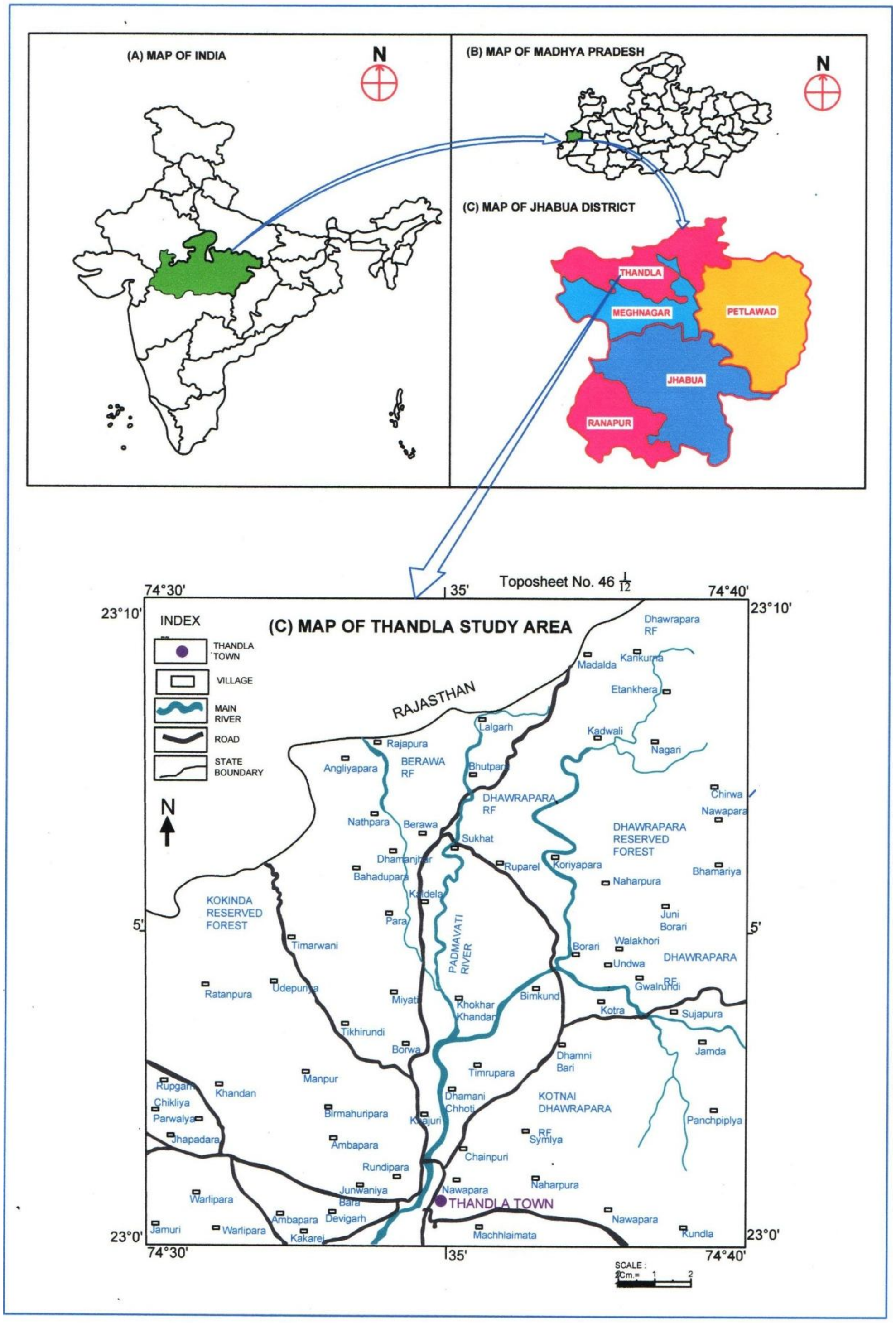

Figure 1: Location Map of Thandla area, Jhabua Region, Madhya Pradesh, India.

According to Todd and Mays (2005) ground water development dates back from ancient times. The older evidence contains several references to ground water, springs, and wells. Garg (1973), considered that development plan for water resource has been defined as a detailed study of the pros and cons of different promising behavior of harnessing this amazing resource and finally writing down the means and ways of achieving the best and optimum benefits. Nagabhushaniah (2001) remarked that ground water is almost always in movement in spite of very small, velocities, in the analysis of ground water movement. Ground water movement, the direction and quantity of which have been supposed to be under mineble has been treated as percolation. The sub-surface stream flow takes place generally by percolation and rarely by turbulent flow, which occurs chiefly in solution conduits.

Artificial recharge technique controls the infiltration of surface water into the ground water reservoir altering natural conditions, is one of the procedures adopted to restore or enhance supplies from depleted aquifers, control or prevent subsidence of land surface, improve quality of native water and renovate quality of waste water. Recharging is completed by pounding water in specially prepared or natural land surfaces, injecting water into wells or by capturing stream flow (Karanth, 2003). He has described the problem of ground water development. Assessment of development potentialities of an aquifer requires the following information:

(a) Geometry of reservoir defining dimensions and boundaries.
(b) Conditions at boundaries, in particular sources of the recharge.
(c) Lithology and aquifer characteristics.
(d) Hydrodynamic conditions (phreatic, confined or semi confined).
(e) Order of the magnitude of reserves.
(f) Average natural recharge and discharge.
(g) Quality of the water.

DETERMINATION OF GROUND WATER POTENTIAL

Sudarsana (1994) remarked that Spatial variation in the ground water potential within area can be brought by modeling techniques in Geographical Information System (GIS) employing satellite derived thematic maps and collateral data. Evaluation of ground water potential is extremely essential for planned development of study area (Jeyaram *et.al* 1996). Ground water potential of an area has been estimated by methods, based on analyzed rainfall data and aquifer parameters obtained from aquifer analysis. Relationship of rainfall infiltration and hydrodynamic methods determine ground water recharge of an study area. Ground water recharge is determined as per following methods: (A) Rainfall Infiltration method, and (B) Hydrodynamic method.

(A) Rainfall Infiltration Method

Determination of ground water recharge is described as:
Total area of study basin (A) = 366.58 sq.km. = 366.58×10^6 sq. m.
Annual Average Rainfall of study area = 964.324 m. m. = 0.964 m.
Rainfall Infiltration Index (RII) = 10 % Assumed value (after Charlu and Dutt, 1982)
Ground Water Recharge = A x RII x AR (Average Rainfall)

$= 366.58 \times 10^6 \times (10/100) \times 0.964$

$= 366.58 \times 10^6 \times 0.1 \times 0.964$

$= 3533.83 \times 10^4 \, m^3$

(B) Hydrodynamic Method

Hydrodynamic method has been considered dependable by Central Board of Irrigation and Power (CBIP, 1976), and Adyalkar and Rao (1979). This method considers effects of ground water level variations, which reveals a real picture of ground water system. Hence, the hydrodynamic method is more reliable as it involves the value of annual average water level fluctuation in the formula for estimation of ground water recharge. The procedure of computation of hydrodynamic method of is described as:

Total study area (A) = 366.58×10^6 sq. m.
Average annual water level fluctuation = 4.59 m. (b.g.l.)
Level fluctuation specific yield of hard rocks = 3 % Assumed value (Charlu and Dutt, 1982)

Ground water recharge = A x Water level fluctuation x Specific yield

$= 366.58 \times 10^6 \times 4.59 \times (3/100)$

$= 366.58 \times 10^6 \times 4.59 \times 0.03$

$= \mathbf{5047.80 \times 10^4\ m^3}$

Assessment of Ground Water Balance

Ground water quantity in reservoir has been estimated on the basis of average saturated thickness of the aquifers derived from open dug wells examination by using procedure:

Area under investigation (A) = 366.58×10^6 sq. m.

Average Saturated Thickness (AST) = 15 m.

Specific yield = 3 % Assumed value (Charlu and Dutt, 1982)

Ground water Storage = A x AST x Specific yield

$= 366.58 \times 10^6 \times 15 \times (3/100)$

$= 366.58 \times 10^6 \times 15 \times 0.03$

$= \mathbf{16496.1 \times 10^4\ m^3}$

Ground water annual draft of the present study area has been calculated by observing average annual decline in the water levels. Annual ground water draft of study area has been determined as per following procedure:

Area under study (A) = 366.58×10^6 sq. m.

Annual decrease in water level from post-monsoon to pre-monsoon period (D) = 9.7

Specific yield of hard rock aquifers = 3 % Assumed value (Charlu and Dutt, 1982)

Annual draft = A x D x Specific yield

$= 366.58 \times 10^6 \times 9.7 \times (3/100)$

$= 366.58 \times 10^6 \times 9.7 \times 0.03$

$= \mathbf{10667.47 \times 10^4\ m^3}$

(1) Ground water Balance = Ground water recharge **-** Annual draft

$= 3533.83 \times 10^4\ m^3 - 10667.47 \times 10^4\ m^3$

$= \mathbf{-7133.64 \times 10^4\ m^3}$

(2) Ground water Balance = Ground water recharge **-** Annual Draft

$= 5047.80 \times 10^4\ m^3 - 10667.47 \times 10^4\ m^3$

$= \mathbf{-5619.67 \times 10^4\ m^3}$

The computed values of ground water recharge **($5047.80 \times 10^4\ m^3$)** and annual draft **($10667.47 \times 10^4\ m^3$)** indicate that there is an over draft of ground water is **($-5619.67 \times 10^4\ m^3$)** and even causing acute water crisis particularly during summer season.

GROUND WATER MANAGEMENT

Concept of management has been described by Bear and Levin (1967) that basic thought is to observe the aquifer as a system that has to be operated in an best possible manner. Burdon (1972) considered that ground water management includes the technical ground water management and in general, integrated ground water management (*vide etiam*, Karanth, 2003).

Management of a ground water basin concerns with the development and utilization of ground water for main purpose, commonly of a social or economic nature. Usually the preferred objective is to obtain the maximum quantity of water to meet the predetermined quality requirements at least cost (Todd, 1980, 2010).The optimum development of ground water resources for valuable use involves planning of an total ground water basin (Todd, op.cit). Hence, ground water management requires the quantity as well as quality of water.

Karanth (1994, 2003) explained the assessment for development of aquifer potentialities, following are essential requirements - (1) Reservoir geometry (dimension and boundaries), (2) Condition at boundaries (sources of recharge), (3) Lithology and aquifer characteristics, (4) Hydrodynamic conditions (phreatic, condition and semi confined), (5) Order of magnitude of reserves, (6) Average natural recharge and discharge, and (7) Quality of water.

Fetter (1990) remarked that study of ground water development essentially encompasses several aspects of surface water flow, drainage basin, topographic boundaries, flow in direction towards land surface is sloping not topographic divides. Development and management of ground water is more complicated than that of surface water, based on the mode of occurrence. According to Nagabhushaniah (2001) established that proposal of ground water management in a basin is to increase optimum ground water to assure the requirements of all users within basin and to meet up specific pre-determined conditions, for example water quality, cost of development and operation, certain legal, social, and political constraints. Hence, ground water management implies development and utilization of aquifer water in order to obtain maximum quantity of ground water at the least cost.

GROUND WATER RECHARGE

Rainfall factor is the most important source of ground water recharge. Rain from sky to earth moves to surface of the earth, which is occupied by cover of soil, and absorbs water from ground surface followed by infiltration. If the infiltration process is in permeable zone, than water moves downward through the soil and sub-soil or rock. Infiltration process, continues in permeable zone downwards, through unsaturated zone, until infiltrating water reaches to the water level. Nagabhushaniah (2001) remarked that precipitation reaching to water table is called recharge, because it is helping to replenish the ground water storage. Ground water in a certain basin, is recharged from either surface water within basin or ground water percolating from another basin. Recharge may be of two types - (1) Natural recharge and (2) Artificial recharge.

(A) Natural Recharge

Natural recharge of ground water system includes deep percolation from precipitation, seepage from streams, lakes, and sub-surface under flow. Natural discharge (or) out flow from the ground water body consists of seepage to streams, flow from springs, sub-surface under flow, transpiration, and evaporation.

(B) Artificial Recharge

Artificial recharge has been described as a process of infiltration of the surface water into ground water system. This phenomenon is augmented by changing natural condition of renewable ground water is being achieving significance as one of the strategies of water management (Karanth, 2003). Artificial recharge operations undertaken for a specified purpose may achieve beneficial results. Main aim of artificial recharge is to help in the conservation of ground water resources.

Numerous techniques of artificial recharge are in practice, the choice being dictated by local condition. The techniques have been described by Muckel (1948), Todd (1959, 1980, 2010), Chow (1964), Karanth (1994, 2003); Nagabhushaniah (2001) and others. The commonly used techniques of artificial recharge are: (1) Spreading method, (2) Pit method, (3) Induced - recharge method, (4) Well method.

(1) Spreading method

The spreading methods are most widely adopted and have been categorized as basin, ditch or furrow, flooding, natural channel and irrigation, water is either pounded or allowed to flow into channels or ground surfaces. The principle of spreading methods is to increase the detention time of an area of contact with water, in order to increase recharge to ground water. Spreading methods are used to recharge phreatic aquifers and semi - confined aquifers. It is essential that materials in zone of aeration have good vertical permeability to aid percolation and aquifer has good transmissivity for transport of water away from spreading area. Presence of layers having low hydraulic conductivity in vadose zone, forms perched zones of saturation and retards deep percolation of water (Karanth, 1994, 2003).

(2) Pit method

This method is used to construct a pit or shaft to expose permeable formation. Recharge pits are usually provided with a layer of filtering material for protection against silt intrusion of aquifer. The gravel pits and excavation in permeable formations with minor modification may be used to save excavation costs. The silt-laden water increase rate of recharge in pits having steep side slopes. Pits in Sweden are constructed on tops of eskers are used to recharge aquifers. Recharged water is extracted by wells located at the fringe of aquifer. The infiltration rate in pits ranges from 1.5 to 15 m/day (Karanth, 2003).

(3) Induced-recharge method

Induced recharge implies to the diversion process of surface flow to aquifer. It also refers to water, which is diverted to an aquifer from a surface - water body by extraction of ground water. Induced recharge does not increase amount of ground water in storage, however, it permits withdrawals at higher than normal rates. Diversion of water is accomplished by diminution in stream flow, due to a reduction in ground water contribution and diversion of surface water (Karanth, 2003).

(4) Well method

Recharge well is used for purpose of increasing ground water supply by feeding surface water into an aquifer. Recharge well may be called an inverted well as the movement of water in a recharge well is in reverse direction to that in ordinary wells (Meinzer, 1923). A few recharge wells (diffusion wells), do not extent down to the zone of aeration precludes the adoption of spreading methods. When a well is recharged, a recharge cone or cone of impression is formed, which is similar in shape to but the reverse in configuration of a cone of depression around a pumping well (Karanth, 2003).

ARTIFICIAL RECHARGE STRUCTURE CONSTRUCTION

Artificial recharge structures are constructed to increase water in a well for sustained supply. The following structures are generally constructed: (a) Pits and Trenches, (b) Shafts, (c) Nala Bunds and Contour Bunds, (d) Ponds, (e) Check Dam, (f) Percolation Tank, (g) Gully Plug, (h) Sub-surface Dyke, (i) Injection Wells, and (j) Rainwater Harvesting structures.

(a) Pits and Trenches

A pit is excavated structure in a permeable formation, which serves as an ideal artificial recharge structure. Expenses of excavation and removal of materials are high, and uses of abandoned excavations, such as gravel pits, are most economic (Todd, 1980, 2010). The pit may be of 14 m in length and 2 m in width. A view of pit contracted in the study area is illustrated (Figure 2).

Figure 2: A view of large pit constructed near Junwaniya Bara village, Thandla study.

Recharge trenches are also known as infiltration trenches and are used for shallow application. These trenches are excavated from the surface using conventional excavation. Recharge trench method is used in unconfined aquifers with water tables near ground level, and allowing shallow trenches to be used (Figure 3).

Figure 3: A view of trenches constructed at Junwaniya Bara village, Thandla area.

(b) Shafts

Recharge shafts are commonly deeper and of smaller diameter than pits (Figure 4). The purpose is also to penetrate low permeability layers. Shafts may be lined or unlined open or filled with coarse materials, and large or small. They are constructed by hand, drilled or bored. Where the recharge water contains sediment, shafts may become plugged rapidly. Generally, recharge shafts are used in conjunction with pits (Nagabhushaniah, 2001).

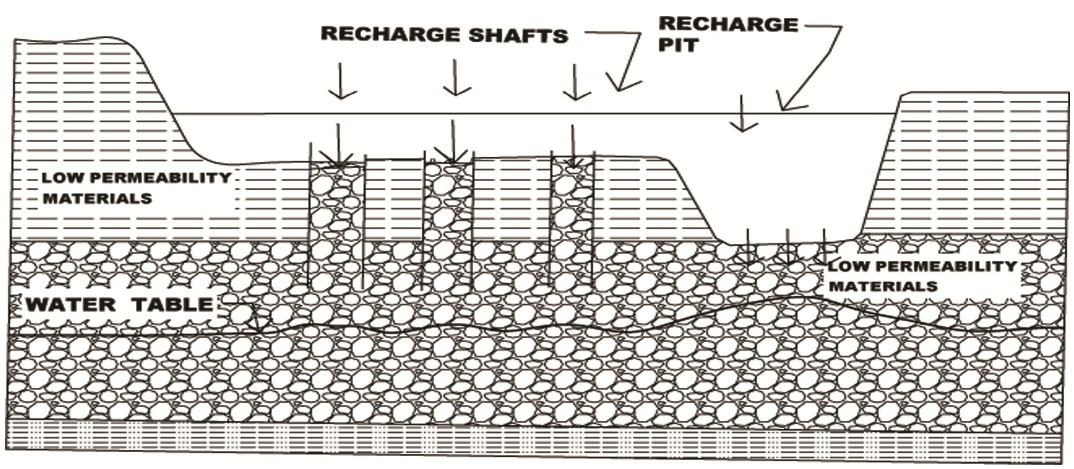

Figure 4: A view of shaft artificial recharge structure (After Nagabhushaniah, 2001).

(c) Nala Bunds and Contour Bunds

Generally, Nala bunds are fairly large structures and commonly constructed across Nalas. It is essential that Nala bed must have a good permeable soil. In study area, important Nala bund exist namely, Chhota Nala near village of Munjal, Thandla area (Figure 5).

Figure 5: A view of Nala bund near Munjal village, Thandla area, Jhabua district.

Contour bunds are mainly constructed along contour lines. They are typically prepared by employing stones or soil, and rarely in variation with crop remains. Contour bunds are constructed along a contour in order to best check water flowing downwards slope, which augmented water pool of soil and prevents erosion (Figure 6).

Figure 6: A view of contour bunds near Lalgarh village, Thandla study area, Jhabua.

(d) Ponds

Ponds are well-known as a man-made or natural water body ranging from 1 m^2 and 2 ha (~5 acres or 20,000 m^2) in area that holds water for four months of a year or more. Pond's water is also facing pollution as like other water bodies are getting polluted due to discharge of effluents from various domestic waste, land and agricultural drainage resulting in degradation of water quality (Figure 7).

Figure 7: A view of Pond constructed near Ratanpura village, Thandla area, Jhabua.

(e) Check Dam

Check dams are usually constructed to augment recharge from existing streams or temporary channels (Petty john, 1988). Check dams are generally 10 to 15 m long, 1 to 3 m wide and 2 to 3 m in height and these are constructed in a trapezoidal from (Figure 8). Site selection for check dam construction should have sufficient thickness of permeable soil or weathered materials to make easy recharge of stored water within a short span. Water stored in these structures is mostly confined to stream course and height is generally less than 2 m. Check dams are designed based on stream width and excess water is allowed to flow over the wall (Singh and Dev, 2012).

Figure 8: A view of Check Dam near Rundipara village, Thandla area, Jhabua district.

(f) Percolation Tank

Construction of percolation tank is one of the most significant artificial recharge structures to augment ground water reservoir. It helps in providing water supply during summer season as well. Percolation tanks are generally made on streams having a sizeable catchment area. Site is selected at place having adequate sub-surface storage space. The suitable site for contraction of percolation tank in Padmavati River basin is suggested at Devigarh village of Thandla area (Figure 9).

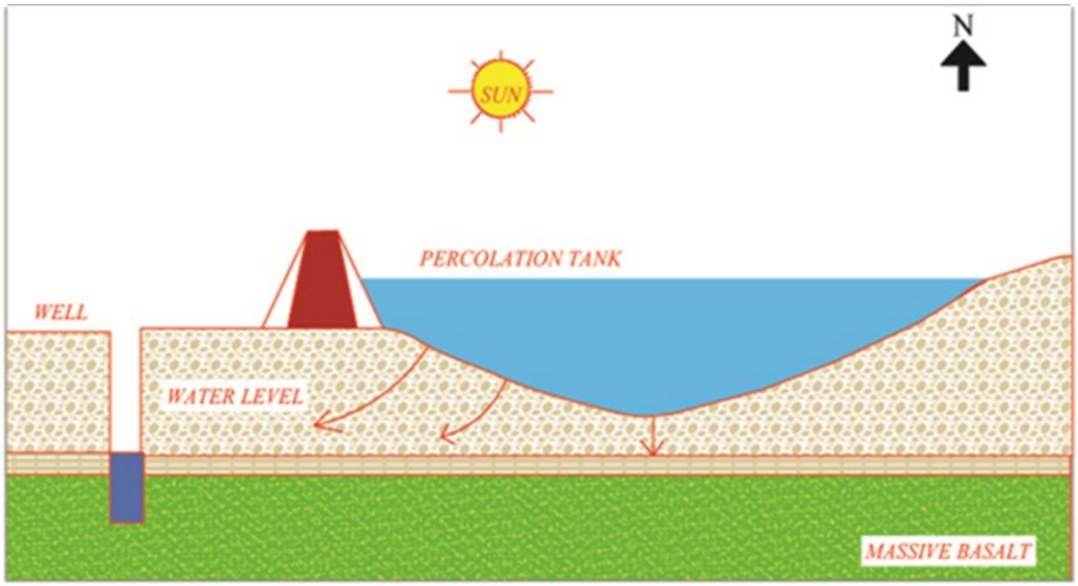

Figure 9: A general view of Percolation tank recommended for construction in study area (Modified after, www.Google.com).

(g) Gully Plug

Gully plugs are commonly constructed across first order streams (Figure 10), Nala bunds and Check dams are mainly built across large streams and in area having gentle slopes. The civil and agro-engineering methods are to be applied in design, plan and construction of permanent check dams to ensure proper storage and adequate out flow of surplus water for long-term stability of dam (Centre Science and Environment, 2003).

Figure 10: A view of Gully Plug structure near Madalda village, Thandla area, Jhabua.

(h) Sub-surface Dyke

Subsurface dyke is a recognized structure, which is constructed in an aquifer with objective of obstructing natural flow of subsurface water. Therefore, increasing ground water level and augmenting amount of stored water in an aquifer. Subsurface dyke has established that it is one of the most practicable techniques for conservation and exploitation of ground water resource. Dykes are presently largest rainwater harvesting structure. Suitable site for construction of dyke is recommended in Padmavati River basin at Rundipara village.

(i) Injection Wells

Injection wells are structures generally constructed on dry lands for aquifer augmentation by transmitting contamination free surface water. It has been regarded that injection wells are drilled downstream of a dam and water released from spillway is conveyed into wells (Raghunath,1982, 1985). The operation of recharge by injection wells involves treatment of balanced matter so that aquifer should be clean.

(j) Rainwater Harvesting

Rainwater harvesting involves tapping rainwater where it falls. A major portion of rainwater that falls on earth's surface is runoff into streams, rivers, and finally in the sea. Rainwater harvesting technique involves collecting rain from localized catchment surfaces e.g, roofs, plain or sloping surfaces, either for direct use or to augment ground water system. Roof top rainwater harvesting is one of most suitable options for increasing ground water recharge / storage in urban areas. Simplest technique of roof top rainwater harvesting involves collection of rainwater in a large pot / vessel kept beneath edge of roof. Water accordingly collected can meet immediate domestic needs. In this process, water is collected from roof using drain pipes or gutters fixed to roof edge. Several organization including Central Ground Water Board are implementing roof top rainwater harvesting scheme in parts of India. Roof top rainwater harvesting structures are being constructed in different states of the country.

CONCLUSION

The paper presents a brief account of development and management problem of ground water system in Thandla area of Jhabua Region, Madhya Pradesh. The ground water resource of Thandla may be augmented by constructing artificial recharge structures at suitable sites in Thandla area. Management of ground water resource would resolve the present crisis prevailing over Thandla tehsil of Jhabua Region by adopting appropriate methods of judicious management of water supply to the inhabitants.

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