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Stream Rejuvenation in Granitic Regions

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Abstract—*It is well known that river basins in the hard rock terrain are going negative in their natural water balance. This is mainly the reason for scarcity of groundwater in Karnataka. This paper describes a scientific approach using Remote Sensing and GIS to rejuvenation of streams in hard rock (Granitic) regions of Karnataka. A process of developing action plans for execution of the proposed rejuvenation of the stream through recharge of groundwater body adjacent to the streams is described in detail. A case study wherein this methodology has been successfully adopted in the recharging of the groundwater aquifer pertinent to the upper reaches of the stream Kumudvathi in Karnataka is described. The action plan could be so designed that it could be executed through people's participation through utilization of available funding mechanisms such as MGNREGA and/or CSR.*

1. INTRODUCTION

Currently in India, groundwater is an essential part of the water resources development of the country to such an extent that nearly 80% of drinking water supply and about 60% of water of the irrigation demand of the country is met by groundwater sources. In view of its importance as a significant source of water in the lives of communities all over the country, various aspects of groundwater starting from exploration through development and management has been studied by various scientific disciplines.

Rural electrification for well irrigation, improved method of groundwater exploration and improved well drilling techniques all lead to major land use changes. Naturally vegetated areas are converted to agriculture. Forests are degraded and replaced by Eucalyptus and other exotic monoculture plantations.. Increased soil erosion due to loss of natural vegetation caused sedimentation in the streams and tanks reduce annual groundwater recharge and increase evaporation. At the same time, the vastly increased draft from irrigation wells and exotic species plantations deplete the groundwater level. The combination of the above factors lead to drastic changes in the hydrology of the area and the eventual drying up of river systems. Without shallow groundwater levels and supporting base flows, the surface water flows dry up. The natural integrated process of rainfall, surface runoff and interlinked factors like infiltration, base flow in the paths of the stream network, rate of rise in the water levels of aquifers get disturbed and distorted.

The recent droughts in the country have highlighted the critical state of the availability of groundwater in many parts of the country. In the drought prone areas of hard rock terrain, the drying up of streams, lakes and other water bodies and depletion of dynamic groundwater resources has led to many attempts to rejuvenate the natural streams and water bodies through recharge of ground water resources.

There have been many methodologies developed in these attempts of groundwater recharge to suit the local geology and other constraints. This paper describes a scientific approach to rejuvenation of streams in hard rock (Granitic) regions of Karnataka. This methodology which uses Remote Sensing and GIS has been successfully tried by the Vyakti Vikas Kendra, India, (VVKI) an NGO of Art of Living, India, in more than 1000 sites in Kolar, Bangalore Rural, Ramanagara, Ckickballapur and Chikkamagalore districts of Karnataka.

The streams in granitic areas of Karnataka generally are trained by lineaments. The streams are narrow and compact. The depth of weathered zones of granite in 2nd and 3rd order streams vary from a few meters to depths greater than 10-15 meters. The granite in the pedi-plain is generally more weathered and is good place for storing recharged water. Buried pediment and valley fills are the most important land forms for groundwater recharge in a hard rock area. The soil is generally red sandy loamy and of varying thickness. The object of the investigation phase of the work is essentially to identify the locations in the stream where the Pedi-plain/valley fill have maximum water holding capacity and are overlying over a deep fractured zone of rock formation (See Fig. 1).

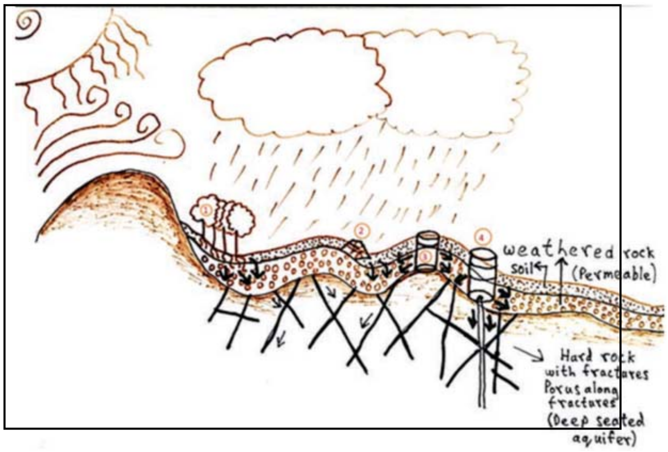

Fig. 1: Cross section of hard rock terrain

2. METHODOLOGY

Given the hydrological situation of hard rock (Granitic) regions, a process was developed using Remote Sensing (RS) and Geographical Information System (GIS) tools to integrating thematic map layers such as soil texture, slope, drainage network & waterbodies and geomorphology. Analysis of these maps can indicate the surface flow & infiltration characteristics and subsurface aquifer characteristics. An action plan can then be prepared to suit the specific identified micro-watershed.

2.1 Thematic Maps

For the given watershed, the following geospatial thematic maps are prepared:

- Slopes
- Soils
- Lithology
- Lineaments
- Geomorphology
- Village maps
- Land use maps

2.2 Integration of Thematic Layers

Depending upon the normal rainfall in each mini-watershed, sites where the surface runoff can be effectively used to recharge the groundwater in the Pedi-plain/valley fill areas of the stream are located based upon slope, soil texture, land use, geomorphology, lithology and lineaments. Finally, overlaying the cadastral land parcels will enable one to identify the sites on the ground with the help of GPS instruments for execution.

2.3 Structures and Type Designs

As a result of various trials, the following structures and type designs were evolved by Vyakti Vikas Kendra, India (VVKI) in the initial field work connected with the recharging activity in Kumudvathi basin of Karnataka.

2.3.1 Boulder Checks. Boulder checks are constructed across the natural streams on the sloping ground based on the topography of the area and approximate quantity flow (See Fig. 2). The foundations of the structure are excavated based on the strata met with and dimension of the stream. The foundation is filled with hard graded boulders and is set interlocked with each other. The super structure on this foundation is constructed with slopes on the upstream and downstream side. The apron is provided on the downstream side to avoid erosion due to impact of the flow in stream. On the projected surface of boulder checks, header of about 0.8 m to 1.00 m length hard boulders are pegged at 2.00 m intervals in zig-zag way to reduce the speed of the flow in the stream. This type of structure would check the speed of water, increase soil moisture and thereby reduce erosion and siltation further downstream.

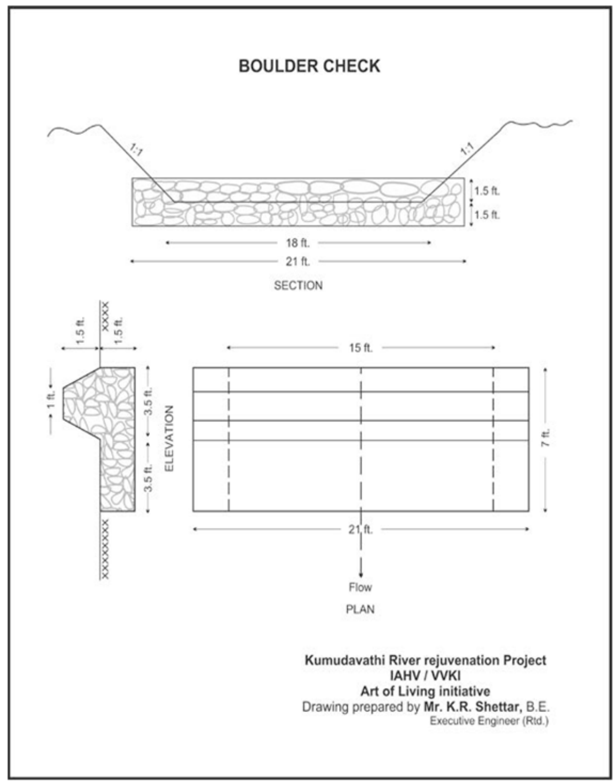

Fig. 2. Boulder check

2.3.2 Recharge Wells. The recharge wells are constructed downstream of the boulder checks. The type of structure is based on the type of topography and hydrology. The foundation is excavated to a depth of 6.00 m. The top and bottom of the structure are as in the Fig. 3. This structure will enable the running water to percolate vertically into the horizontally spread aquifer (weathered rock zone) and enable raise of water level in the shallow open wells and deeper bore-wells.

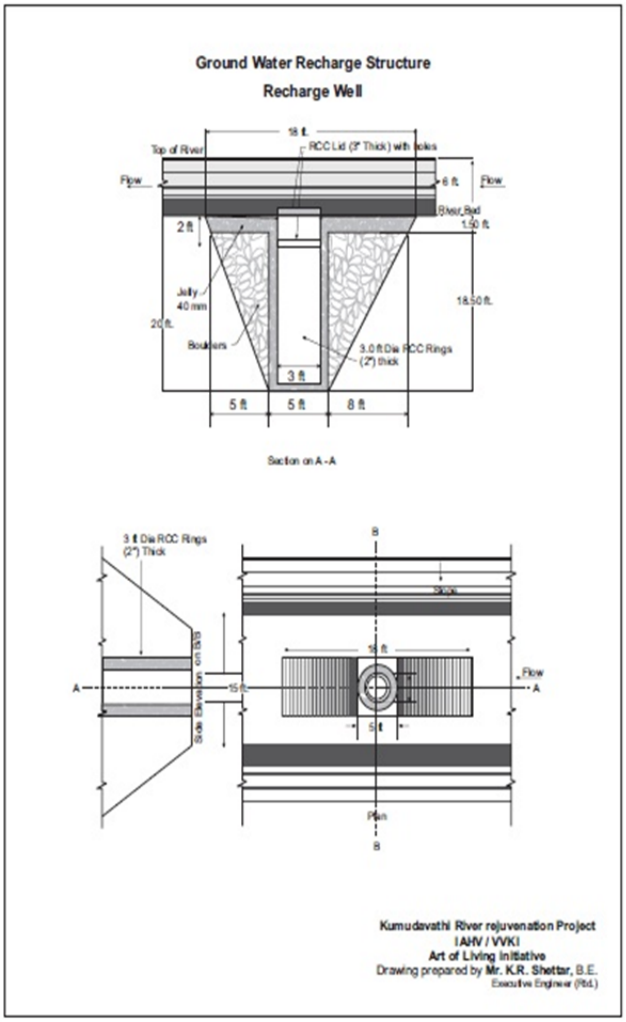

Fig. 3. Recharge well

2.3.3 Recharge Bore-wells (Injection well). To enhance the process of recharge in the deeper aquifers, the recharge wells are to be supported by drilling a bore from the bottom to a depth of 20-30 m. An MS casing pipe is inserted at about 3.00 m height above the foundation bed of the recharge well. This projected portion of the casing pipe is drilled with holes of 1mm diameter at a gap of 5 cm and is zig-zagged vertically. This is tightly covered with polythene perforated sheets to avoid silt and debris entering into the bore-wells (See Fig. 4).

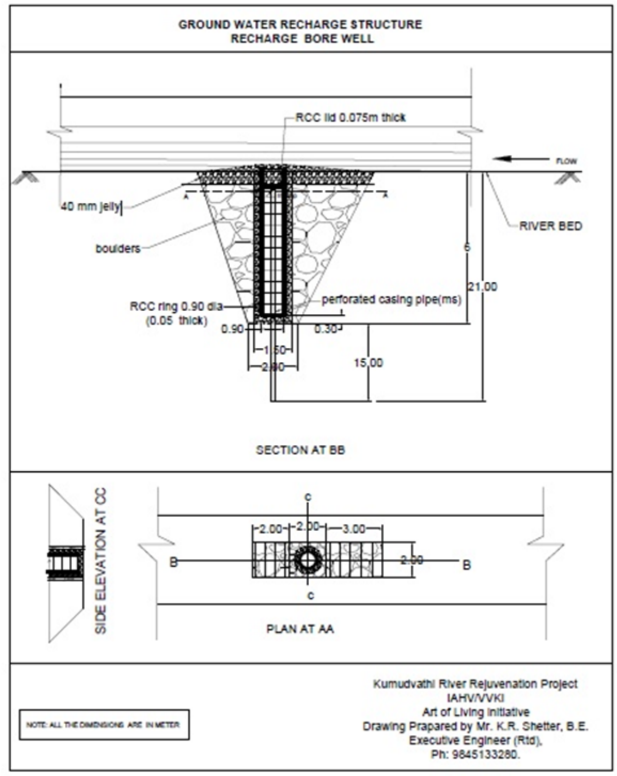

Fig. 4. Recharge borewell (injection well)

2.3.4 Water Pools. When the streams flowing through the boulder checks and recharge wells reach the tanks at the end of their run, the water usually spreads out as a thin sheet of water the the tanks because the tanks are generally silted up and have lost their major storage capacity. The flow from the streams are thus subjected to faster evaporation due to the action of solar energy and wind. To avoid this situation and to conserve the water, a structure called water pool is designed at the head of the tanks. The water pools are constructed at the junction point of the stream and tail end of the water spread area of the irrigation tanks (See Fig. 5).

The pools are generally excavated to a depth of 3-8 m depending on the size of the tank and inflow. The size of the pool is based on the size of the tank and the intended quantity of water to be stored in them. The pool system includes two silt traps; one at about100 m upstream and another at the entry point to trap the silt and debris. The entire connecting feeder channel and water pool is covered with boulder pitching and revetment. The stone headers of 0.80 m to 1.00 m length at a distance of 2 m are projected above the surface in the bed of the feeder channel to check the speed of the flow.

Since the boulder checks and recharge wells are constructed in all feeder channels, the pools will get water even during non-rainy season due to base flow. The evaporation losses in the pools are less due to their relatively small areas. Thus the pools will serve as a fairly perennial source of water for the community to meet the drinking water needs of animals and to some extent humans also. In some cases, they have been found to be useful as sources for limited protective irrigation by farmers.

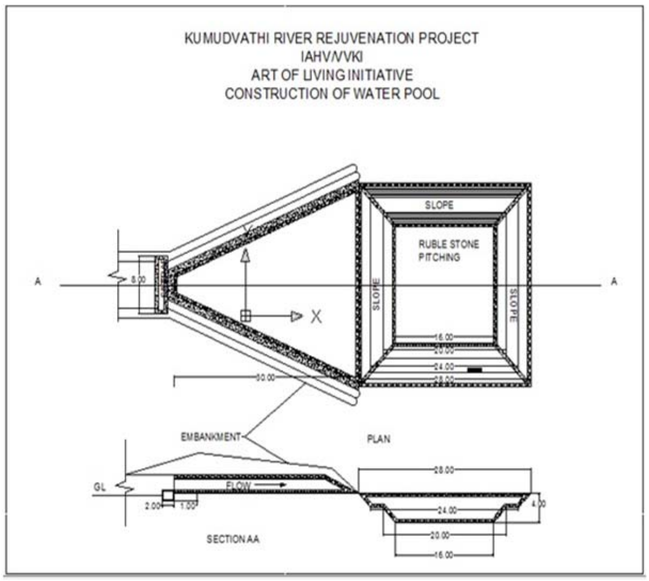

Fig. 5. Water pool

2.3.5 Tree Planting. Each tree has its own root system which is capable of attracting the water molecules. The water attracted will be partially utilized for transpiration and majorly percolated into the vadose zone through capillary fringe, reaching the water table. It is feasible to plant trees along the stream network, along the side of roads and around farmers' land parcels. Native species of trees should be recommended by local Forest Officers and protected and cared for by local people.

3.3 Action Plan

For each mini-watershed, an action plan is prepared and this consists essentially of:

- Maps with geomorphology, streams network and sites of structures clearly marked
- Detailed table of coordinates of each structure in the proposed activity
- Areas and number of trees (including exact locations) identified for planting

3.4 Estimates

Relevant detailed cost estimates are then prepared for each structure and each component of work. The components are so designed that they could be executed through people's participation and utilization of available funding mechanisms such as MGNREGA and/or CSR. A software for management of related construction activity is prepared and used for monitoring the progress of the work

Fig. 6 and 7 show photographs of a completed water pool and boulder check & recharge well used in Kumudwathi watershed. These are typical of such structures constructed in this project

Fig. 6. Water pool

Fig. 7. Boulder check & recharge well

3. CASE STUDY: KUMUDVATHI RIVER

Kumudvathi River is one of the sources for Tippagondana Halli Reservoir, near Bangalore. This reservoir was supplying water to Bangalore city before its inflows dwindled a decade back, due to catchment degradation by deforestation, quarrying and overexploitation of. The basin has been declared as overexploited by the Karnataka Groundwater Authority and further drilling of bore-wells in the area has been banned. Current bore-wells are drying up and farmers are buying water cans from other areas to meet drinking water needs. A major share of land use is under Eucalyptus plantation.

The catchment was divided into 18 mini-watersheds ranging in size from 12.14 km^2 to 40.36 km^2. After systematically studying the thematic maps of each mini-watershed using the methodology described above, sites for the following structures were identified as part of the action plan:

Table 1: List of proposed recharge locations of Kumudvathi Basin

Boulder Checks	Recharge Wells	Injection Wells	Water Pools
1749	885	54	223

As an example of a typical action plan and map, Tyamagondal Mini-Watershed is given below, (See Fig. 8). The base map is the geomorphology theme showing only shallow weathered pedi-plain, valley fills and waterbodies. Overlaid on top is the drainage network and recharge structures. Boulder checks are placed in the steeper upstream areas, followed by recharge wells. Water pools are placed at the junction of the stream and the existing tanks. In the higher order streams and along lineaments, recharge injection wells (bore-wells) are placed.

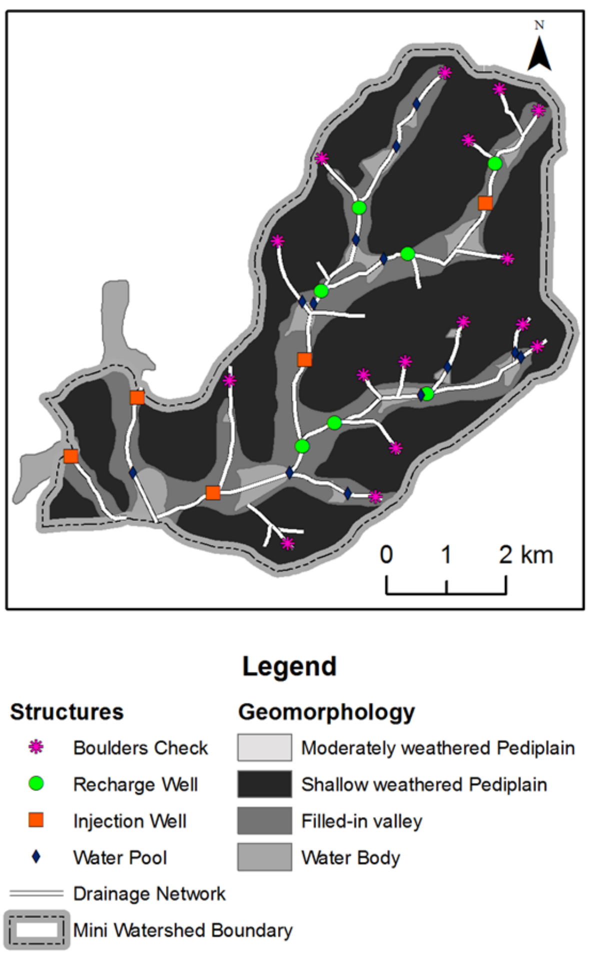

Fig. 8. Action plan for Tyamagondal Mini-Watershed

The GPS coordinates of each structure is identified for field use (See Table 2 for a sample). The sites were verified and the structures were constructed.

Table 2: Locations of proposed injection wells in Tyamagondal Mini-Watershed

No.	Latitude	Longitude	Village
1	13 ° 14 ' 30 "	77 ° 21 ' 49 "	Balligere
2	13 ° 13 ' 6 "	77 ° 20 ' 8 "	Dodbele
3	13 ° 12 ' 14 "	77 ° 17 ' 57 "	Thyamagondlu Amnikere
4	13 ° 12 ' 46 "	77 ° 18 ' 35 "	Thyamagondl Amnikere
5	13 ° 11 ' 54 "	77 ° 19 ' 16 "	Kalalaghatta

Estimates of unit cost of recharge structures were prepared according to the Karnataka government schedule of rates (2014-15) and the drawings of each type structure (See Table 3). Using these unit costs and the cost of tree plantation, the costs of the entire works related to the rejuvenation programme as per the action plan of the mini-watershed is prepared.

Table 3. Estimated Unit Cost of Recharge Structures

Structures	Unit Cost[Rs]
Boulder Checks	18347
Recharge Well	56871
Recharge bore well	114549
Water pool	437542
Planting of saplings	650

Participation of local people and volunteers were crucial to implementing the action plan. Sri Sri Ravishankarji's call for youth action in 2013 "Volunteer for a Better India" attracted hundreds of volunteers to visit villages in the basin and bring awareness of the importance of groundwater. Volunteer driven river rejuvenation activities and tree planting efforts continue to this day. However, systematic implementation has been made possible by corporate social responsibility (CSR) funds contributed mainly by Robert Bosch and Hindustan Aeronautics Limited. Tyamagondlu mini-watershed action plan was implemented by CSR support from HAL under the 2015-2016 (Phase II) MOU with International Association of Human Values (IAHV).

Complete execution of projects in three mini-watersheds has given very good results after subsequent rainy days. Wells and bore-wells which were dry for more than a decade have started yielding water. The water pools constructed as a part of the project have made water available throughout the year. Anecdotal references indicate that the local population is very happy with the outcome of the rejuvenation work. The success has encouraged many more sources for CSR support to this stream rejuvenation activity. The new funding supporters include Coal India and Hans Foundation.

4. CONCLUSION

A scientific approach to rejuvenation of streams in hard rock (Granitic) regions of Karnataka is described. A methodology of developing action plans for execution of the proposed rejuvenation of the stream through recharge of groundwater body adjacent to the streams is described in detail. A case study wherein this methodology has been successfully adopted in the recharging of the groundwater aquifer pertinent to the upper reaches of the stream Kumudvathi in Karnataka is described. The action plan could be so designed that it could be executed through people's participation through utilization of available funding mechanisms such as MGNREGA and/or CSR. Central and State Government and NGOs working in the areas of groundwater recharge and stream rejuvenation would find the methodology of this paper very useful and adaptable to their specific needs.

5. ACKNOWLEDGEMENTS

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