CHAPTER – 9

GROUNDWATER RECHARGE STRUCTURES FOR SUSTAINABLE DEVELOPMENT OF THE KHAPRI WATERSHED

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9.1 Introduction

Groundwater is a crucial resource in supporting the livelihood of the inhabitants in Khapri watershed during scorching summers. It is not only the chief source of fresh water for domestic uses but also important for sustaining the agriculture activities during this period. The significant dependability for domestic and agriculture purposes has put an immense pressure on the non-sustainable groundwater resources of the Khapri watershed. To enhance the sustainability the heavy rainfall that is wasted as runoff should be conserved and optimally used to recharge the underlying groundwater aquifers through various recharge augmenting structures. The isotope studies have revealed that the groundwater recharge in Khapri watershed is mainly from infiltration of meteoric water through lineaments, water percolation from rivers, reservoirs, springs and agriculture return flow. To enhance the groundwater recharge, the terrain characteristics (Lineaments, Drainage, Slope, Land use and Geomorphology), groundwater potential zones, groundwater quality and recharge patterns derived through stable isotope tracers are integrated to propose suitable locations for groundwater augmenting structures and ensure the sustainability.

9.2 Site selection of groundwater recharge structures

“Groundwater recharge can be defined as the entry into the saturated zone of water made available at the water-table surface, together with the associated flow away from the water table within the saturated zone” (Freeze and Cherry pp. 211). According to Limaye, 2010 in the heavy rainfall regions (2000-5000 mm) in Deccan Volcanic Province where basalt occurs close to the surface, the shallow groundwater aquifers are often too thin to absorb hardly 3 % of the rainfall which may be true for Khapri watershed having rugged topographic setup.

Several artificial recharge techniques such as trenches, contour bunding, gully plugging, nala bunds, sub-surface dams, percolation tanks/check dams, farm ponds are successfully practiced in the hard rock terrains (Ravi Shankar & Mohan, 2005, Limaye, 2010, Patil et al., 2018, Ganguly & Ganguly, 2021, Kadam et al., 2023). These artificial recharge structures are site-specific and involves the recharging of dug and bore wells with fresh water. However, the selection of the appropriate sites for artificial recharge is most crucial for the effective groundwater recharge. The experimental study of (Raju, 1998) in different parts of India, has showed that if appropriate site is selected for percolation tank, the groundwater recharge through tank can reach upto 70%. In the study area, numerous check dams are observed on the various streams, however the silting (figure 9.1) due to severe soil erosion (Dongare et al., 2022) reduces its water storage capacity and in-turn reduces the recharge augmentation. Therefore, to augment the groundwater recharge effectively it is important to set-up structures along the lower order streams for preventing the siltation in check-dams. The factors that play a crucial role in selection of appropriate sites are the terrain characteristics (Lineaments, Drainage, Slope, Land use and Geomorphology), groundwater potential zones, groundwater quality and the existing groundwater recharge patterns derived from stable isotope analysis. In the Khapri watershed, the groundwater quality is excellent for drinking and agriculture purpose irrespective of groundwater potential zones, hence it is excluded from the site selection for recharge structures. The consideration of groundwater potential zones is useful because it helps excluding the regions with good and very good groundwater potential as the natural recharge in these zones is sufficiently available. The joints and fractures in the basalts are the excellent conduits because they provide the secondary porosity and permeability. The slope characteristics along the valley walls are considered to decide the type of structure as also suggested in NRSA, (1995). The different land uses discussed in chapter 5 also influence the water infiltration (figure 5.3). The regions with break in slopes serve as most appropriate regions to arrest the runoff from adjacent slopes and thus enhance the water accumulation. For the effective sustainable development in Khapri watershed, the regions with suitable combination of above factors and NRSA, (1995) guidelines, the specific sites for groundwater recharge structures are proposed at sub-watershed level.

9.3 Proposed structures and sites for augmenting groundwater recharge

For sustainable water resource development, overall, seven types of recharging structures are proposed in the Khapri watershed as per the guideline given by NRSA, (1995) and CGWB (2011) for artificial recharge. Among these, the suitable recharging structures are suggested in different sub-watersheds at appropriate locations for augmenting the groundwater recharge.

9.3.1. Percolation tank

Percolation tank is an effective artificial structure for collection of surface runoff and thereby recharge the groundwater aquifers of hard rock terrains through the lineaments in the bed rocks (figure 9.2). The structure is generally 2-3 m wide with wall height of about 5 m without any outlet for irrigation (Ahirwar et al., 2020, CGWB, 2011). It is designed with a waste weir near the top to release surplus water and avoid overtopping which may cause erosion of embankment. As per CGWB (2011), the significant aspects to be observed for construction of percolation tanks are as follows:

a) It is either constructed on second and third order streams as their catchment area will remain relatively smaller or in uncultivated land adjoining streams, through excavation and providing a delivery canal connecting the tanks and the stream.
b) The sub-mergence area should preferably be a barren land to avoid loss of land resource.
c) It should be placed in regions with moderate to high lineament density to facilitate the groundwater recharge.
d) The shallow aquifers should have considerable thickness of porous unsaturated zone to facilitate the groundwater recharge.
e) The location of the tank should preferably be downstream of runoff zone or in the upper part of the transition zone, with a land slope gradient of 3 to 5%.
f) Spillway should be properly designed to allow the surplus water to flow, when tank is filled to its maximum capacity.

Figure 9.1 Heavily silted check dams near Garvi and Bhavandagadh.

Figure 9.2 Percolation tank near Galkund.

The proposed locations and number of percolation tanks in various sub-watersheds are represented in figure 9.7 and table 9.1 respectively.

9.3.2. Check dams and Nala bunds

Check dams are barrier walls of small heights (2 m), larger length (16 m) constructed across the streams with gentle slopes (figure 9.3). The structure is feasible in both hard as well as soft rock formations. The check dams can be built with the use of the ground material, stones, mud and rubble stone filled masonary dam wall usually in the proximity to agricultural lands. The check dams would help to store the precipitated water and infiltrate to the ground, which otherwise would be wasted as surface runoff. The check dams should preferably be constructed in sequence at appropriate distances in the stream. In addition to construction of new check dams the number of existing check dams in Khapri watershed which are heavily silted and failing in its purpose, needs to be monitored. To increase the effectiveness of such check dams, their de-siltation is recommended at high priority. The use of gully plugging and nala bunds on lower order tributary streams will be helpful in reducing the siltation in the existing as well as proposed check-dams.

Figure 9.3 Check dam near village Khapri.

The nala bunds are series of small bunds (figure 9.4) constructed along the specific nala segments to impede the surface runoff with a view to increase its residence time on the surface. The increased residence time allows water to percolate and contribute to groundwater recharge. These act as mini-percolation tanks and are specifically constructed along the larger nala usually constituting second order streams with 0-3° slope (CGWB, 2011). The nala bunds operate similar to the percolation tanks, with only difference in their size (Length 10 to 15 m, height 2 to 3 m and width 1 to 3 m). The important aspects to be considered in the construction of check dams and nala bunds are as follows:

a) The total catchment of the nala should normally be between 40 to 100 Hectares though the local situations can be a guiding factor in this.
b) The width of nala bed should be at least 5 meters and not exceed 15 meters and the depth should not be less than 1 meter.
c) The soil downstream of the bund should not be prone to water logging.
d) The land downstream of check dam/ nala bund should have irrigable land under well irrigation (This is desirable but not an essential requirement).

Figure 9.4 Nala bund structure.

The proposed locations as well as number of check dams and nala bunds in various sub-watersheds are presented in figure 9.7 and table 9.1 respectively.

9.3.3. Gabions and Gully plugs

The gabion structure is a type of check dam that is commonly constructed across the small streams to reduce the runoff speed, conserve the silted stream flows and cause groundwater recharge. It is usually constructed with the help of stone rubbles fabricated with the heavily galvanized steel wires (figure 9.5a). The structure is usually half a meter tall and 10 to 15 m wide. The gabion structures are highly recommended in the regions experiencing soil erosion. The main advantage of gabion structure is that it reduces the runoff speed and arrests the soil which reduces the silting of check dams as well as percolation tanks such that their water holding capacity is not affected.

Gully Plugs (figure 9.5b) are small runoff conservation structures built across small gullies and streams to conserve runoff, arrest soils and enhance recharge locally during the rainy season (Ahirwar et al., 2020; CGWB, 2011). These structures usually range from 2.25 - 3.0 m in height and 4.5 to 10.5 m in width.

Figure 9.5 (a) Gabion and (b) Gully plugs (After Naseri et al. 2021).

The proposed locations as well as number of gabions and gully plugs in various sub-watersheds are presented in figure 9.7 and table 9.1 respectively.

9.3.4. Necklace trenches and Recharging ponds

The necklace trenches are excavated at flat to gently sloping surfaces adjacent to the steeply sloping faces, where water from the slope can accumulate and enter the sub-surface (figure 9.6). These trenches can either be continuous or in segments ranging from 10-30 m in length and about 100 cm deep in form of necklace. Limaye & Limaye, (1994), have also proposed trenches as an effective groundwater recharge structure in Deccan traps.

Recharge ponds (figure 9.6) are proposed as special ponds placed at the top of the elevated planation surfaces which can store the precipitated water during the monsoon season and simultaneously recharge the groundwater through the available joints and fractures.

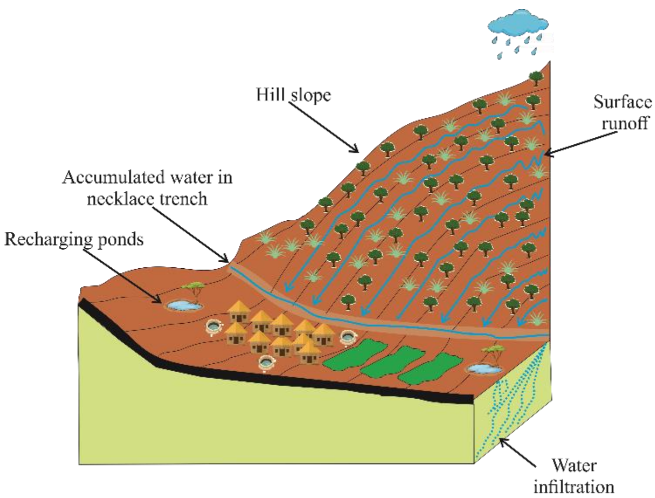

Figure 9.6 Necklace trench and Recharging ponds.

The proposed locations as well as number of necklace trenches and recharging ponds in various sub-watersheds are presented in figure 9.7 and table 9.1 respectively.

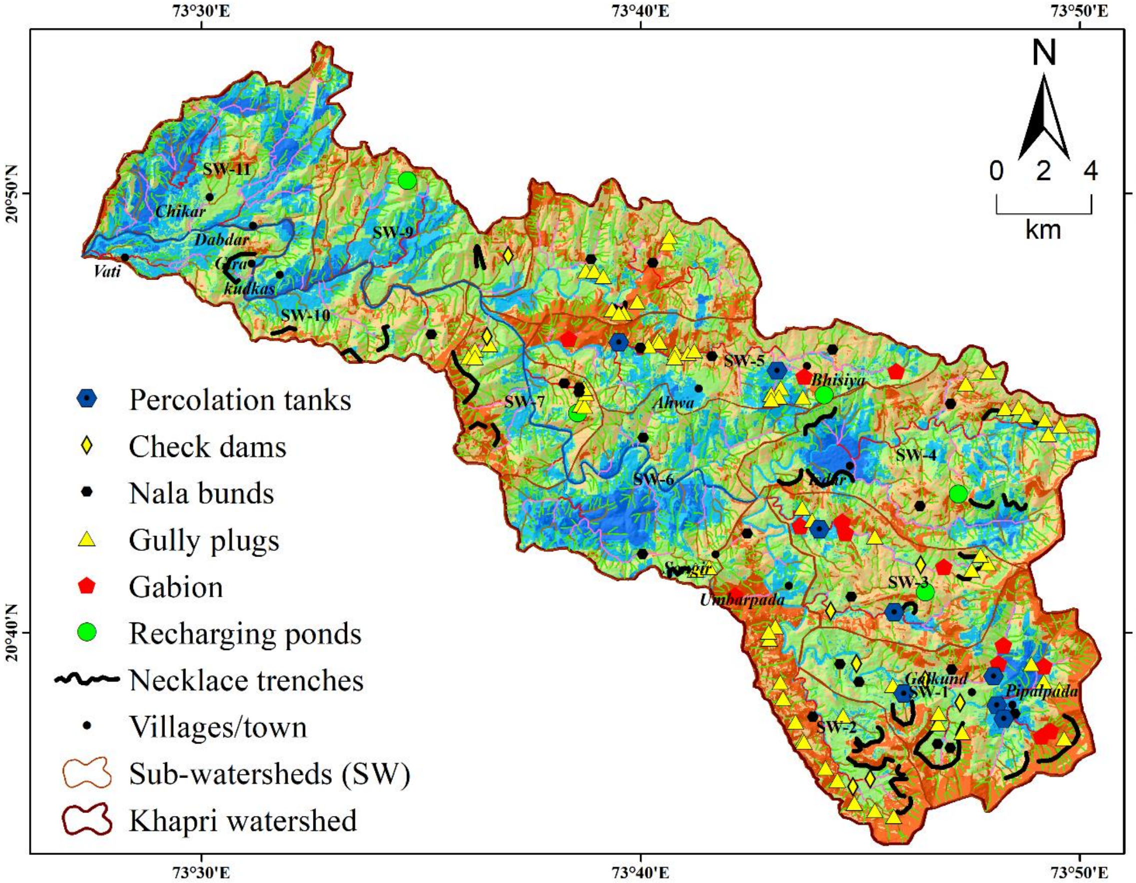

Figure 9.7 Location of proposed recharging structures at sub-watersheds level overlaid on Groundwater Potential Zones and Drainage map of the Khapri watershed.

Table 9.1 Sub-watershed wise proposed recharge structures in the Khapri watershed.

Sub-watershed	Percolation tank	Check dam	Nala bunds	Gabions	Gully plugs	Necklace trenches	Recharging ponds
SW-1	4	3	6	5	8	4	--
SW-2	--	2	2	1	14	6	--
SW-3	2	2	2	4	6	2	1
SW-4	--	--	2	--	8	8	1
SW-5	2	--	3	3	11	--	1
SW-6	--	--	3	--	2	1	1
SW-7	--	--	3	--	9	3	--
SW-8	--	--	2	--	9	1	--
SW-9	--	--	--	--	--	1	--
SW-10	--	--	1	--	--	4	--
SW-11	The sub-watershed shows maximum coverage of very good groundwater potential zone category, therefore no recharging augmenting structures are proposed.						

Besides the proposed artificial groundwater recharging structures, other measures recommended to enhance the groundwater recharge in Khapri watershed are:

(i) **Afforestation** – The forest canopy will prevent soil erosion occurring from rain drop impact and provide organic matter (humus) to bind the soil particles into aggregates which will enhance the infiltration (Valdiya, 2013). It will also be useful for reducing the silting of the surrounding artificial recharge structures.

(ii) **De-siltation of existing check-dams -** The removal of sediments from the reservoirs of check-dams and percolation tanks will increase water storage capacity significantly and enhance the groundwater recharge. The studies of ICAR (2015) have reported 40 % increase in water storage capacity of check dams in Jalgaon after de-siltation. Thus, the de-siltation can be an effective step towards the sustainable management of water resources.

(iii) **Sheltering the wells through solar panel** - Nowadays solar panels are installed adjacent to dug-wells for operating the pumps in exploitation of groundwater. During post-monsoon the dug-wells experience significant loss of water by evaporation as also indicated by stable isotope analysis. To minimize this evaporative loss, the solar panels can be made movable such that it acts as shelter for the dug wells.

(iv) **Restoration of the existing contaminated and unused dug wells –** number of dug-wells are abandoned in the study area either due to litter or their distances from the existing habitats/development of new dug wells near to habitats. Such wells can be revived and used after proper cleaning.

The proposed seven recharge structures, their locations and recommended measures will enhance the groundwater potential in the Khapri watershed. For the sustainable development of water resources, the required number of recharging structures can be finalized after assessing its feasibility and ground-truth verification.