Chapter V

ARTIFICIAL RECHARGE SITES AND THEIR FEASIBILITY

INTRODUCTION

In this chapter, an attempt has been made to relate the information generated on computer related to artificial recharge sites. At the same time, this chapter also attempts to study the accuracy and feasibility of these recharge sites vis-à-vis proposed sites. This is primarily based on the data collected from primary survey. The location of recharge sites has been collected using GPS during August to September 2014.

For the selection of representative sites for verification through field visit, an inventory of these sites was prepared. It contains the geographic location i.e. latitude and longitude, names of the concerned sample site’s village, block in which it lies and column for recording the ground condition of all the 260 sample sites. A base map was then prepared for ground truthing of these sampled sites having the location and connectivity details of villages in which these sampled sites lie. GPS was carried in the field and used during the field visit to reach at the destined location of each sampled site. The existing ground condition over each sample site was then recorded in the remark column of the inventory against each site name (Annexure 2). This detail was further used to understand whether a site is feasible for artificial recharge of ground water or not or some type artificial recharge structure already exists at that location.

SAMPLING OF PROPOSED SUITABLE ARTIFICIAL RECHARGE SITES

In the study area, 1304 sites are identified suitable for artificial recharge of ground water table. These identified sites are distributed throughout the study area in and around the hilly parts. In order to check whether any recharge structure exist at those sites, a sample of 260 representative sites have been randomly selected for ground truthing. It is about 20 percent of the total identified sites. The logic of selection of these 260 sample sites was that at least one out of every five sites should be visited on the ground. Figure 5.1 shows the distribution of sampled sites in the study area. It is evident from the Figure that the identified suitable sites lie in 20 out of 25 blocks. The sample sites however have been covered for 16 blocks in the study area. It may be noted that in Rewari block there are only 4 sites which have been
Figure 5.1
Sites Selected for the Field Verification in Southern Haryana
identified as suitable recharge sites. Similarly in Nahar, there are only two suitable recharge sites while in Kanina and Palwal only one each such site has been identified and proposed for recharge. Hence, these blocks are excluded from sampling.

**STATUS OF SAMPLE RECHARGE SITES**

The sample sites in the study area are classified into 3 categories based on the data collected from field survey regarding the existing status of these sites. The three categories are

i) sites with no recharge structure,

ii) sites with existing recharge structures, and

iii) sites unsuitable for artificial recharge.

Sites with no recharge structure are where recharge structure is not constructed by the government but drainage is well developed, slope is also not very high, catchment area of the sites could provide sufficient runoff, soil texture is coarse that supports maximum percolation of stored water, ground water is also deep i.e. more than 6 meter below ground level and land use is either barren or scrub land or drainage course or waste land. These are ideal conditions for artificial recharge and are named as suitable sites.

There are some sites where recharge structure like percolation tank, stock pond, boulder bund, check dam etc. have been constructed by the government under different watershed development schemes. They are categorized as sites with existing recharge structures.

Sites unsuitable for artificial recharge lie in the areas where mining is in practice and terrain is such where no surface runoff is possible. It may also include those sites the sites where drainage is completely encroached by humans for agriculture.

Figure 5.2 shows the distribution of sample sites classified as suitable, unsuitable for artificial recharge and sites with existing recharge structures. It may be observed from the Figure that majority of the sample sites vindicates the suitability for artificial recharge. These are distributed throughout the study area. The highest concentration of such sites with existing recharge structures are found in Nangal Chowdhary block. It may also be noted that the concentration of unsuitable sites for artificial recharge of ground water are found more in Sohna block.
Figure 5.2
Status of the Sample Sites in Southern Haryana

STATUS OF SAMPLE SITES

- Sites with Existing Recharge Structures
- Sites with No Recharge Structures
- Sites Unsuitable for Artificial Recharge

Study Area
Block Boundary

40 Kilometers
### Table 5.1

**Status of Sample Suitable Artificial Recharge Sites in Southern Haryana**

<table>
<thead>
<tr>
<th>Blocks</th>
<th>Total Sample</th>
<th>Suitable</th>
<th>Already have Structure</th>
<th>Unsuitable</th>
<th>Mining</th>
<th>No Drainage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faridabad</td>
<td>12 (100)</td>
<td>9 (75.01)</td>
<td>2 (16.66)</td>
<td>1 (8.33)</td>
<td>0 (0.00)</td>
<td></td>
</tr>
<tr>
<td>Gurgaon</td>
<td>12 (100)</td>
<td>7 (58.35)</td>
<td>2 (16.66)</td>
<td>2 (16.66)</td>
<td>1 (8.33)</td>
<td></td>
</tr>
<tr>
<td>Sohna</td>
<td>33 (100)</td>
<td>26 (78.79)</td>
<td>3 (9.09)</td>
<td>3 (9.09)</td>
<td>1 (3.03)</td>
<td></td>
</tr>
<tr>
<td>F Nagar</td>
<td>3 (100)</td>
<td>3 (100)</td>
<td>0 (0.00)</td>
<td>0 (0.00)</td>
<td>0 (0.00)</td>
<td></td>
</tr>
<tr>
<td>Pataudi</td>
<td>4 (100)</td>
<td>4 (100)</td>
<td>0 (0.00)</td>
<td>0 (0.00)</td>
<td>0 (0.00)</td>
<td></td>
</tr>
<tr>
<td>Taoru</td>
<td>16 (100)</td>
<td>10 (62.50)</td>
<td>3 (18.75)</td>
<td>1 (6.25)</td>
<td>2 (12.50)</td>
<td></td>
</tr>
<tr>
<td>Nuh</td>
<td>10 (100)</td>
<td>9 (90.00)</td>
<td>1 (10.00)</td>
<td>0 (0.00)</td>
<td>0 (0.00)</td>
<td></td>
</tr>
<tr>
<td>Nagina</td>
<td>6 (100)</td>
<td>5 (83.34)</td>
<td>1 (16.66)</td>
<td>0 (0.00)</td>
<td>0 (0.00)</td>
<td></td>
</tr>
<tr>
<td>F P Jhirka</td>
<td>17 (100)</td>
<td>14 (82.36)</td>
<td>2 (11.76)</td>
<td>1 (5.88)</td>
<td>0 (0.00)</td>
<td></td>
</tr>
<tr>
<td>Jatusana</td>
<td>5 (100)</td>
<td>4 (80.00)</td>
<td>0 (0.00)</td>
<td>1 (20.00)</td>
<td>0 (0.00)</td>
<td></td>
</tr>
<tr>
<td>Bawal</td>
<td>10 (100)</td>
<td>8 (80.00)</td>
<td>0 (0.00)</td>
<td>2 (20.00)</td>
<td>0 (0.00)</td>
<td></td>
</tr>
<tr>
<td>Khol</td>
<td>32 (100)</td>
<td>26 (81.26)</td>
<td>3 (9.37)</td>
<td>3 (9.37)</td>
<td>0 (0.00)</td>
<td></td>
</tr>
<tr>
<td>Mahendergarh</td>
<td>35 (100)</td>
<td>30 (85.73)</td>
<td>2 (5.71)</td>
<td>2 (5.71)</td>
<td>1 (2.85)</td>
<td></td>
</tr>
<tr>
<td>Ateli</td>
<td>10 (100)</td>
<td>8 (80.00)</td>
<td>0 (0.00)</td>
<td>1 (10.00)</td>
<td>1 (10.00)</td>
<td></td>
</tr>
<tr>
<td>Narnaul</td>
<td>25 (100)</td>
<td>20 (80.00)</td>
<td>2 (8.00)</td>
<td>2 (8.00)</td>
<td>1 (4.00)</td>
<td></td>
</tr>
<tr>
<td>N Chowdhary</td>
<td>30 (100)</td>
<td>23 (76.67)</td>
<td>4 (13.33)</td>
<td>3 (10.00)</td>
<td>0 (0.00)</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>260 (100)</td>
<td>206 (79.85)</td>
<td>25 (9.22)</td>
<td>22 (8.46)</td>
<td>7 (2.67)</td>
<td></td>
</tr>
</tbody>
</table>

(Figure in parenthesis is percent of total samples)
Table 5.1 shows the block wise analysis of the sample sites in the study area. It is evident from the Table that at the majority of sample sites there is no recharge structure exists for artificial recharge. Such sites constitute about 80 percent of the total visited sites i.e. 206 out of 260. It may be noted that these sites are suitable for artificial recharge and structures like check dam, boulder bund, gully plug, percolation embankment, percolation tank, stock ponds etc. can be immensely useful. Basic information such as soil texture, geology, drainage order, recharge potential, slope, type of land use and lineament also suggests these sites as extremely favorable for artificial recharge. The type and size of structure to be constructed may vary.

The Table 5.1 further reveals that there are 17 sample sites where some kind of artificial recharge structure has been constructed by the government under watershed development programs. These constitute about 9 percent of the total sample sites. The watershed development programs implemented in the study area are Integrated Watershed Development Project (IWDP), Integrated Watershed Management Plan (IWMP), National Watershed Development Program (NWDP), Desert Development Program (DDP) and Haryali project. At these sites, the artificial recharge structures like check dam, boulder bund, stock pond, percolation embankment, earthen bund and percolation tanks have been verified during the field visit. Another 37 sites which constitute about 11 percent of total sample have been found unsuitable for artificial recharge of ground water. Human encroachment of drainage and mining are the factors that make these sites unsuitable for artificial recharge. It has been found that in about half of these sites, the drainage is almost extinct. It is largely due to the continuous cultivation in the channels since long period. The mining activity for extraction of stones at the origin place of these channels has generated a terrain which looks like vertical hill and hence generating no surface runoff. Consequently these channels have dried up and consequently encroached by humans. Mining activity has generated the unfavorable conditions over 11 sites. Though mining activity has been banned in the Aravali hills of Gurgaon and Mewat districts since June 2002 and again a complete ban on any kind of mining has been imposed in entire Aravalli Hills of Southern Haryana since October, 2009 yet it has been found during the primary survey that illegal mining is in practice at places in the study area. This is leading to continuous degradation of the hills in the study.
Plate 5.1a Sites Suitable for Artificial Recharge of Ground Water
Plate 5.1b Sites Suitable for Artificial Recharge of Ground Water
Plate 5.1c Sites Suitable for Artificial Recharge of Ground Water
Plate 5.1d Sites Suitable for Artificial Recharge of Ground Water
Plate 5.2a Sites having Structures for Artificial Recharge
Plate 5.2b Plate 5.2a Sites having Structures for Artificial Recharge
Plate 5.3a Sites Unsuitable for Artificial Recharge
area. This is reducing the favorable sites for artificial recharge of ground water which is almost priority for sustainable development of ground water in the study area. The Table further reveals that the accuracy of the proposed artificial recharge sites in Farukh Nagar, Pataudi, Nuh and Nagina blocks is 100 percent and in Firozpur Jhirka, Khol, Nangal Chowdhary and Mahendergarh blocks it is more than 90 percent. It may also be noted in these blocks, the sites are also not encroached upon. However, the proposed sites are adversely affected by mining in Gurgaon and Taoru blocks. In these blocks, primary investigation suggests that 25 and 18 percent sites may be unsuitable for artificial recharge of ground water, respectively.

Plates 5.1a, b, c and d reveal the existing status of some sample sites. These are the proposed artificial recharge sites which have been visited during ground truth in the study area and are considered suitable for artificial recharge of ground water. Plates 5.2a and b shows the artificial recharge structures constructed by government to augment the ground water resource. These sites are categorized as sites with existing recharge structures. Plates 5.3a and b reveal the ongoing activity of mining and human encroachment at some proposed artificial recharge sites in the study area. This is the true reflection of how these sites become unsuitable for artificial recharge of ground water.

CONCLUSION

The analysis of primary data suggests that about 89 percent of the identified sites may be suitable for the artificial recharge of ground water in Southern Haryana. At these sites artificial recharge structures like check dam, gully plug, boulder bund, earthen dam, embankments, percolation tanks and stock ponds could be constructed to cope up with the problem of continuous depletion of ground water table. These recharge sites are identified on logical and scientific basis and may provide additional water to augment the ground water storage in the study area. The analysis further reveals that about 11 percent of the total identified sites may be unsuitable for artificial recharge of ground water due to mining and human encroachment.
Chapter VI

SUMMARY OF CONCLUSIONS

Ground water has acquired greater significance due to its ubiquitous occurrence, reliability and availability in all seasons as compared to surface water. The phenomenal growth of population, urbanization, industrialization and resultant need leads to more and more demand of ground water. Consequently, humans have started mining the ground water massively and bring the annual extraction of ground water far in excess of net average recharge from natural sources which results in the decline of ground water level. In this context, the present research attempts to study the availability and draft of ground water in Southern Haryana. The study also estimates the gap between the availability and draft as well as it to evaluate the stage of ground water development in southern Haryana. Another objective of present research is to identify the suitable sites for artificial recharge of ground water. These sites are being verified by conducting a field work to assess the feasibility for the construction of artificial recharge structures over the identified sites.

Ground water is the main source to fulfill the water requirement in southern Haryana due to prevailing arid and semi-arid climatic conditions. The assessment and management of ground water resource in this area is the need of hour as about three fourth part is facing acute shortage of water and the ground water table is receding at a rate of 76 cm per year which is much higher than the rate of ground water decline of the whole state i.e. 38 cm per year.

For the assessment of the ground water resource of the study area, methodology of Ground Water Resource Estimation Committee-1997 (GWREC-97) has been used. This methodology has been recommended by Government of India for the estimation of ground water resource of all the States and Union Territories. The estimation is carried out for kharif and rabi seasons separately by taking block as an assessment unit. The assessment period is 2006 to 2010. The study is based on both primary and secondary data sources. Primary data is used for the verification of proposed artificial recharge sites and to assess their status and feasibility. All other objectives are based on secondary data. The satellite data has also been used for delineation of potential recharge zones. The net annual ground water availability is considered as the sum of recharge from rainfall, return flow from irrigated fields,
seepage from canals, ponds, tanks, lakes and recharge from rainwater harvesting structures. The gross annual draft is considered as the sum of ground water abstracted for domestic and irrigation uses. The stage of ground water development has also been arrived at and the assessment units (blocks) have been marked as ‘safe’, ‘semi critical’, ‘critical’ and ‘over exploited’ based on the stage of ground water development and long term (2000-10) fluctuation trends in the ground water level for pre and post monsoon seasons. Satty’s analytical hierarchy process is used to delineate the potential recharge zones and identification of suitable sites for artificial recharge of ground water. One out of every five identified site has been verified on ground to check the feasibility of artificial recharge at these sites.

The analysis reveals that the estimated net annual availability of ground water which is the summation of recharge from rainfall (Rrf), irrigation return flow (Rirf), canal seepage (Rc), ponds, tanks lakes (Rt) and rainwater harvesting structures (Rhs) in southern Haryana is 161889 ha-m during 2006-10. A major portion of this recharge, 118078 ha-m is available during kharif season and 43811 ha-m is available during rabi season. Rainfall is the main component of ground water recharge in the study area during kharif season. It contributes about 63 percent of the total ground water available in this season. It is followed by return flow from irrigated fields and seepage from canals. These sources provide about 19 and 12 percent of the total recharge, respectively. These three components of ground water recharge collectively contribute about 94 percent of the total available ground water during kharif season. Remaining 6 percent is received from ponds, tanks, lakes and rainwater harvesting structures. On the contrary, return flow from irrigated fields contributes highest amount of ground water recharge during rabi season i.e. 58 percent. It is followed by canal seepage and rainfall in this season. Their contribution is 21 and 16 percent of the total available ground water, respectively. Overall rainfall, irrigation return flow and canal seepage are the main components of ground water recharge in southern Haryana, as they provides more than 90 percent of the total available ground water during both kharif and rabi seasons.

The spatial analysis on availability reveals that there are spatial variations in its availability. The highest net annual as well as seasonal availability is in Palwal block (14365 ha-m) while it is lowest in Taoru block (2892 ha-m). Gurgaon, Farukh Nagar, Pataudi, Taoru and Firozpur Jhirka blocks are deprived of canal networks.
Hence, recharge from canal seepage is nil in these blocks. It may also be noted that five blocks (Palwal, Hathin, Hodal, Ballabgarh and Faridabad) contains about one third of the total net annual as well as seasonal ground water resource of southern Haryana. It is also observed that the blocks with a good network of canals, especially unlined canals and more irrigated area (under water intensive crops; paddy in *kharif* season and wheat in *rabi* season) comparatively have more recharge during both the seasons. On the other hand, blocks with smaller irrigated areas and with no canal network or having dominance of lined canals receives less ground water recharge in both the seasons.

The gross annual ground water draft in the study area for domestic and irrigation purposes is estimated as 181534 ha-m for 2006-10. About 37 percent of this draft is during *kharif* season and 63 percent during the *rabi* season. The higher ground water draft in *rabi* season may be attributed to the low rainfall during *rabi* season and need of watering for crops and less number of canal running days as compared to *kharif* season. This increases the dependence of farmers on ground water to meet the water requirements of crops. It may be noted that agriculture sector is the leading consumer of ground water in southern Haryana. The share of irrigation draft accounts for 80 percent in *kharif* season and 89 percent in *rabi* season. The draft for domestic uses accounts for 20 percent in *kharif* season and 11 percent in *rabi* season. The analysis further reveals that about 86 percent of the gross annual draft of ground water is utilized for irrigation purposes and 14 percent for domestic uses.

The spatial pattern of ground water draft reveals that the draft also varies widely in the study area. The highest volume of ground water is drafted in Palwal block (20086 ha-m) and lowest in Nagina block (2056 ha-m). It has been found that the annual ground water draft of five blocks (Palwal, Gurgaon, Faridabad, Pataudi and Rewari) accounts for about one third of the gross annual ground water draft of Southern Haryana. However, it may be noted that Palwal, Pataudi and Rewari blocks are recorded as the blocks with very high irrigation draft while Gurgaon and Faridabad are the blocks with high domestic draft. The high irrigation draft in a block corresponds with the cultivation of water intensive crops (paddy in *kharif* season and wheat in *rabi* season) and more area under irrigation while high domestic draft corresponds with the large number of persons living in that block.
The analysis reveals that the gross annual draft of ground water (181534 ha-m) in southern Haryana is much higher than the net annual ground water available (161889 ha-m) through recharge from various sources. The study area is facing a deficit of 19639 ha-m in the annual availability of ground water. This deficit in the ground water availability is leading towards the continuous depletion of ground water table. The spatial pattern of gap between water availability and draft has also been mapped. It shows that out of the 25 blocks, 16 blocks are facing a deficit in the annual availability of ground water. The annual deficit in the availability of ground water in six blocks (Pataudi, Palwal, Farukh Nagar, Kanina, Sohna and Khol) is more than 3000 ha-m while in Nangal Chowdhary and Nahar blocks the annual deficit of ground water is relatively less i.e. less than 500 ha-m. Only 9 blocks show surplus availability of ground water. This surplus availability of ground water also varies widely. In the blocks namely Nuh, Sohna and Narnaul, its availability is more than 3000 ha-m while in Punhana and Firozpur Jhirka blocks the annual surplus availability of ground water is low i.e. less than 800 ha-m.

The analysis reveals that the southern Haryana is in a disadvantageous position with regard to the quantity of ground water. The stage of ground water development in the study area is 112 percent which indicates the over development of ground water. The gross annual ground water draft in the study area is far in excess of net ground water available. The analysis of long term fluctuation suggests that the depletion rate of ground water table is also significant during both pre and post monsoon seasons and it is continuously dipping. It is receding at a rate of 82 cm per year in pre-monsoon season and 70 cm per year in post-monsoon season. The average annual rate of decline of ground water table is 76 cm per year. The block wise pattern of stage of ground water development and long term water level fluctuations for pre and post monsoon seasons reveal that 12 blocks are over-exploited, 7 blocks are critical, 2 blocks are semi-critical and 4 are safe from ground water development point of view. It has been found that the stage of ground water development in 4 blocks namely Pataudi, Kanina, khol and Farukh Nagar is over 200 percent which indicates that the gross annual draft of ground water in these blocks is two times more than that is available through natural recharge. Pataudi block with 221 percent shows the highest stage of ground water development followed by Kanina block. The lowest stage of ground water development has been found in Nuh block i.e. 39 percent and it
is followed by Narnaul block. The analysis further reveals that 21 blocks shows a significant long term decline in the water table during pre-monsoon season. This decline is significant for 18 blocks during post-monsoon season. Highest rate of decline is observed in Narnaul block (2.94 meter) during both pre and post-monsoon seasons. During pre-monsoon season, it is lowest in Nuh block (0.12 meter) and during post-monsoon season it is lowest in Jatusana block (0.02 meter).

All the blocks in the study area show declining trend in ground water level though the intensity varies from one block to another. A composite picture however reveals that 0.19 meter per hectare (m/ha) ground water is annually available for different uses in the study area. The eastern part of the study area is comparatively in a better position with regards to its per hectare availability. Here, the average availability is over 30 meter per hectare, with the highest in Hodal and Hassanpur blocks i.e. 0.39 meter per hectare. The concern however is the stage of ground water development, which is more than 100 percent in this part. The western part of the study area is in a disadvantageous position with regard to its availability. In this area, the average availability of ground water is 0.12 meter per hectare with lowest in Mahendergarh block i.e. 0.09 meter per hectare. The ground water availability in the central part of the study area varies between 0.16 to 0.22 meters per hectare. The analysis reveals that the per hectare ground water availability in the western part of the study is lower than the other parts and it is as well over-exploited from ground water development point of view.

The analysis do reveals that there is no further scope of ground water development by installing shallow or deep tube wells. Only 4 blocks of the study area are classified as ‘safe’ due to the surplus availability of ground water. Apart from these 4 blocks, all the remaining 21 blocks are either at over-exploited, critical or semi-critical stage of ground water development. In the semi-critical blocks, cautious development of ground water is suggested. In critical and over-exploited blocks, there is no scope for further development of ground water rather they should be linked with water conservation measures to accelerate the rate of natural recharge. In such areas identification of suitable artificial recharge sites is necessary to arrest the excessive runoff during rainy season to alleviate the further depletion of ground water table.

The study also identifies the suitable sites for artificial recharge of ground water on scientific and logical basis so that maximum percolation of rainwater during
rainy season could be achieved. This has been carried out by taking seven thematic layers of soil texture, geology, geomorphology, lineament density, drainage density, slope and land use land cover. These seven thematic layers and their corresponding categories are ranked on 1 to 9 scale. The ranks of particular themes and their categories have been given depending on their hydraulic significance in storage and transmittance of ground water as well as their influence over recharge process. Higher ranks are assigned to the theme and category that has higher potential for ground water recharge and lower ranks represents the comparatively lower potential for ground water recharge. Ranks 9 and 8 are assigned to the themes and categories that have higher potential for recharging ground water; 7 and 6 represent moderate to high potential; 5 and 4 stands for moderate potential and 3, 2, 1 symbolize poor potential for ground water recharge. Satty’s analytical hierarchy process is used to prepare the pair-wise matrix for all themes and their categories and their normalized weights are calculated. Consistency ratio of each matrix has also been calculated to check whether the assigned ranks are appropriate or not. The value of consistency ratio for all matrixes has been less than 0.10 which is acceptable. It indicates that the ranks assigned to each theme and their corresponding categories are as per their influence over ground water recharge process.

In order to delineate the potential zones for artificial recharge of ground water the normalized weight of each theme and their corresponding categories are used to integrate with one another. This integration is performed using ‘raster calculator’ tool available in Arc GIS software. The final normalized weight of each pixel in the resultant integrated layer is the result of the combined effect of the weights of each thematic layer and their sub categories. These weights of the integrated layer are used to classify the study area into ‘Highly Favorable’ (4.01 – 5.37), ‘Moderate to Highly Favorable’ (3.01 – 4.00), ‘Moderately Favorable’ (2.01 – 3.00) and ‘Least Favorable’ (0.47 – 2.00) zones for artificial recharge. It is found that about 59 percent of the study area comes under highly favorable, 33 percent has moderate to highly favorable and 5 percent area has moderately favorable conditions for artificially recharging the ground water. The analysis further reveals that the highly and moderate to highly favorable zones are mainly characterized by the dominance of unconsolidated material deposition of aeolian and fluvial origin with loamy sand, sandy loam and loam textured soil and agricultural land. It provides high primary porosity leading to
the generation of favorable condition for artificial recharge. Furthermore, low drainage density and nearly level to very gentle slope in these areas provides more scope for rainwater to percolate downward by adopting artificially recharge methods. The moderately favorable zones are mainly characterized by piedmont alluvium, moderate to high lineament density and vegetation covers. The presence of moderate to strong slope in this zone generates more run off during the rainy season. Only 2 percent of the study area is least favorable for ground water recharge and is confined to the upper parts of hills. This part is represented by Alwar and Delhi supergroup of hard rocks which have the absence of primary porosity. Secondary porosity in hard rock areas results from the development of lineaments and their density is also moderate in this region. Moreover, due to strong to very steep slope and high drainage density, most of the rainwater results in run off having poor potential for artificial recharge of ground water.

The selection of suitable sites for artificial recharge has been carried out by using drainage and lineament layers. Drainage of different order provides water during the rainy season and presence of lineaments accelerates the rate of ground water recharge. Therefore, the locations where drainage lines intersect with the lineament lines are considered as favorable sites for artificial recharge. This resulted point map shows the probable location of suitable sites from where maximum percolation of rainwater could be achieved. These sites are superimposed over artificial recharge zone map and depth of water table map. With the help of artificial recharge zone map potential of the area for artificial recharge is evaluated and depth of water table map suggested the requirement of artificial recharge. The sites are finalized in the areas where ground water depth is more than 5 meter below ground level with favorable recharge conditions. About 1304 suitable sites are identified in the study area that could provide maximum recharge to ground water table by arresting the excessive runoff during rainy season. Out of these 1304 sites, 458 sites lie in the highly favorable zone, 598 sites in moderate to highly favorable zone, 204 in moderately favorable zone and only 44 sites lies in the least favorable zone. The sites which lie in the moderate, moderate to highly and highly favorable zones are suitable for artificial recharge of ground water. Sites located in least favorable zones may be used mainly to harvest the rainwater for use in the non-monsoon season and marginally for ground water recharge. The block wise distribution of these sites
suggests that the identified suitable sites lie in the 20 out of 25 blocks of southern Haryana. More sites lie in the blocks which are either critical or over exploited from ground water development point of view and have deep ground water level. In the blocks like Khol, Mahendergarh, Narnaul, Sohna and Nangal Chowdhary ground water is more 30 meter deep and are either critical of over exploited. Therefore, more than 100 sites are identified to alleviate the further deepening of ground water table by artificially augmenting the aquifer of these blocks. These suitable sites are suggested in the blocks where slope gradient is sufficient enough to generate runoff. There are five blocks (Ballabgarh, Hathin, Hodal, Hassanpur and Punhana) in the study area in which due to very low slope gradient and absence of hilly part, no drainage system develops. Only Yamuna River flows on the eastern boundaries of Ballabgarh and Hassanpur blocks and the construction of artificial recharge in this river is very difficult. Hence, no recharge site is identified in these blocks.

The present study also verifies the status of existing recharge over the identified sites. This verification is based on primary survey and 260 sites have been visited with the help of GPS for ground truthing which is about 20 percent of the total identified sites. The sample sites are grouped into three categories – sites with no recharge structure, sites with existing recharge structures and sites unsuitable for artificial recharge. Sites with no recharge structure are where recharge structure is not constructed by the government but drainage is well developed, slope is also not very high, catchment area of the sites could provide sufficient runoff, soil texture is coarse that supports maximum percolation of stored water, ground water is also deep (more than 6 meter below ground level) and land use is either barren or scrub land or drainage course or waste land. They are considered as suitable sites for artificial recharge. There are some sites where recharge structure like percolation tank, stock pond, boulder bund, check dam etc. has been constructed by the government under different watershed development schemes. Sites unsuitable for artificial recharge are where mining is in practice and that part of hill is made vertical generating no surface runoff. It also includes the sites where drainage is completely encroached by humans for agriculture.

The analysis of the field data reveals that at the majority of sample sites there is no recharge structure exists for artificial recharge. Such sites constitute about 80 percent of the total visited sites i.e. 206 out of 260. It may be noted that these sites are
suitable for artificial recharge and structures like check dam, boulder bund, gully plug, percolation embankment, percolation tank, stock ponds etc. can be immensely useful. Basic information such as soil texture, geology, drainage order, recharge potential, slope, type of land use and lineament also suggests these sites as extremely favorable for artificial recharge. The type and size of structure to be constructed may vary. The analysis further reveals that there are 17 sample sites where some kind of artificial recharge structure has been constructed by the government under watershed development programs. These constitute about 9 percent of the total sample sites. The watershed development programs implemented in the study area are Integrated Watershed Development Project (IWDP), Integrated Watershed Management Plan (IWMP), National Watershed Development Program (NWDP), Dessert Development Program (DDP) and Haryali project. At these sites, the artificial recharge structures like check dam, boulder bund, stock pond, percolation embankment, earthen bund and percolation tanks have been verified during the field visit. Another 37 sites which constitute about 11 percent of total sample have been found unsuitable for artificial recharge of ground water. Human encroachment of drainage and mining are the factors that make these sites unsuitable for artificial recharge. It has been found that in about half of these sites, the drainage is almost extinct. It is largely due to the continuous cultivation in the channels since long period. The mining activity for extraction of stones at the origin place of these channels has generated a terrain which looks like vertical hill and hence generating no surface runoff. Consequently these channels have dried up and consequently encroached by humans. Mining activity has generated the unfavorable conditions over 11 sites. Though mining activity has been banned in the Aravali hills of Gurgaon and Mewat districts since June 2002 and again a complete ban on any kind of mining has been imposed in entire Aravalli Hills of Southern Haryana since October, 2009 yet it has been found during the primary survey that illegal mining is in practice at places in the study area. This is leading to continuous degradation of the hills in the study area. This is reducing the favorable sites for artificial recharge of ground water which is almost priority for sustainable development of ground water in the study area. It is also found that the accuracy of the proposed artificial recharge sites in Farukh Nagar, Pataudi, Nuh and Nagina blocks is 100 percent and in Firozpur Jhirka, Khol, Nangal Chowdhary and Mahendergarh blocks it is more than 90 percent. It may also be noted in these blocks, the sites are also not encroached upon. However, the proposed sites are adversely
affected by mining in Gurgaon and Taoru blocks. In these blocks, primary investigation suggests that 25 and 18 percent sites may be unsuitable for artificial recharge of ground water, respectively.

RECOMMENDATIONS

The analysis reveals that southern Haryana is in a very critical position with regards to the ground water availability. The annual draft of ground water is far in excess of the annual availability through natural recharge from different sources. In view of rapidly changing demographic profile and land utilization pattern, artificial recharge of ground water is urgently required to control the prevailing imbalance of ground water resource. Though, the construction of rainwater harvesting structures like check dam, marginal bunds, gully plugs, percolation embankment, percolation tanks and stock ponds have been reported by different government agencies under various watershed development programs yet the continuous alarming depletion of ground water table of the study area during the last decade suggests that either these structures are not providing the sufficient amount of recharge to ground water table or they are just constructed on paper not on ground.

The visit of 260 sample sites and collected data reveals that only at 17 sites some kind of recharge structure is found. The evaluation of these reported structures and their subsequent recharge should be performed through field verification before the inclusion of amount of recharge from these reported structures in the total annual available ground water resource of the study area. It would help to make a realistic estimation of annual availability of ground water.

Though the mining activity has been banned in the areas of Aravali hills of Gurgaon and Mewat districts, yet this was not enforced. A complete ban on the mining activities of all types in the entire Aravali hills region of Southern Haryana since October, 2009 has been further imposed. Yet it was observed during the field visit that illegal mining is still in practice at places. It is continuously degrading the hills and disturbing the ecology as well. The study recommends that continuous monitoring from time to time and strict action is required against the mining mafia. The mining activity is decreasing the chances of the construction of recharge structures to artificially augment the ground water resource of the study area.
The factual situation as revealed from the present study does indicate that if preventive measures are not taken up to rationalize the demand with ground water availability, the southern Haryana may be in a more crucial situation in terms of ground water availability in the coming year. Though, the construction of artificial recharge structure is a big engineering work yet the basic information about soil texture, lithological composition, drainage order, recharge potential, slope, and types of land use and presence of lineament at the proposed sites could help to decide the type and size of artificial recharge structure that could be constructed.

Phased construction of artificial recharge structures on these sites might help to bridge the gap between recharge and draft of ground water and alleviate the further decline of ground water table by increasing the ground water storage through additional recharge. In areas where suitable recharge sites are not proposed, the study further recommends that on the basis of the potential artificial recharge zone map, structures could be constructed for rainwater harvesting and ground water recharge.

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