Groundwater resources at risk in the basalts (Deccan traps) of western India

S. D. LIMAYE

Groundwater Institute, 2050, Sadashiv Peth, Poona 411 030, India

U. S. LIMAYE

Department of Civil Engineering, Utah State University, Logan, Utah 84321, USA

Abstract Basalts of western India or the Deccan traps occupy an area of about 500,000 km$^2$ including several agro-climatic and hydrogeological regions. During the last two decades digging and drilling of irrigational wells was encouraged in the basaltic terrain by making institutional finance available to farmers. These programmes for providing irrigation for up three crops per year resulted in over-exploitation of the resource in some sub-basin. Groundwater quality in some coastal areas got impaired while in some of the inland basins water table declined and the yields were reduced. In order to mitigate this over-exploitation, efforts were made on the positive side i.e. recharge augmentation and also on the negative side i.e. pumpage control. This paper discusses the effectiveness of these efforts. Normally, the future risks to groundwater resources are considered from the point of view of diminishing quantity and degrading quality. But the paper also discusses "economic risk" in which the resource stays healthy but the people cannot obtain continuous benefit from it, due to financial constraints.

INTRODUCTION

Basalts or the Deccan traps of late Cretaceous to early Eocene age cover about 500,000 km$^2$ area in western India. The basaltic terrain extends from the western coast and coastal hills onto the Deccan plateau which has been a gentle slope eastward. The evolution on the plateau ranges from about 1200 m near the coastal hills to about 300 m at the eastern ens. The annual rainfall of about 2000 mm on the coast and 6000 mm on the hills, sharply reduces to about 300 mm in the central plateau. The precipitation results from southwesterly Monsoon winds from June to September. This is followed by about eight months of dry period comprising four month of winter and four month of summer. The year is thus divided into three cropping seasons, viz. rainy, winter and summer. From the farmers viewpoint the summer crops are most profitable. Unfortunately, they can be grown only on a small area due to decreased yield from wells in the summer season.

Only about 15% of cultivable land gets assured irrigational supply from surface water resources for two to three cropping seasons. Most of the agricultural land is thus under dry farming or depends on groundwater for irrigation. Irrigational supply is even required in Monsoon season for protective irrigation during long breaks in Monsoon rains. Groundwater in whatever small quantity available is an important source for
irrigational and domestic water supply for the majority of the population of around 50 million people.

HYDROGEOLOGICAL FEATURES

Deccan trap formation is a pile of basaltic lava flows horizontally stacked one over the other. After consolidation, the pile has not been subjected to appreciable disturbances. The primary porosity is due to cooling cracks, joints, fissures, open flow junctions, fractures and occasionally due to a porous lava flow. Near the ground surface, the porosity is further accentuated by weathered rock, river or stream alluvium or the lateritic cap over hard basalt, usually contain the phreatic water body. In the fissures, fractures and flow junctions within the underlying hard basalt, groundwater occurs under semi-confined state. Circulation of water is most confined to about 100 m depth below ground surface.

The streams and rivers in basaltic terrain are effluent i.e. their dry season flow is maintained by groundwater discharge from their catchment area. Only in the case of a pumping well located on stream bank, seepage can be induced from the stream towards the well. Groundwater flow across surface water divide or ridges, does not take place and each stream basin or sub-basin can be treated as a separate hydrogeological unit. Annual recharge to groundwater is estimated between 3% to 14% of the annual rainfall. The hard rock aquifer gets fully recharged by the end of Monsoon and during the remaining eight month of the year, this storage gets depleted considerably, due to pumpage and outflow. Groundwater flow from the marginal portion of sub-basin towards the central valley portion causes dewatering of the marginal portion but helps in maintaining the yields of wells located in the central valley portion. Perennial wells are thus normally found in the vicinity of streams and their flood-plains. The average residence time of water in a sub-basin is up to 5 years or so.

Dug wells of about 8 m diameter and 8 to 15 m depth, are suitable for obtaining irrigational supply for small farms. A dug well usually penetrates the overburden and goes a few metres deep into the hard basalt below. The water from the phreatic water body in the overburden passes into the well through the holes provided in the masonry retaining wall. Horizontal bores are often drilled radially outwards from the well, in order to increase its yield. The bottom portion of the well serves as a receptacle or storage for water coming from the overburden. Vertical bores of 100 to 150 mm diameter are sometimes drilled in the bottom of dug wells, upto about 50 m depth below the bottom. When such bores meet a permeable flow junction, water under sub-artesian condition rises into the well. An average dug well supports upto 0.5 ha crop in summer. However, yields as low as 5000 l day$^{-1}$ in summer are also considered useful.

Recently, 150 mm diameter bores are also drilled upto 100 m depth with the help of pneumatic drills. These bores yield drinking water supply in many villages but occasionally they tap yields higher than 1000 l hr$^{-1}$ and are used for irrigation. In some of the sub-basins hundreds of such irrigation bores have been drilled and submersible pumps have been installed in them. But within a few years of working they have affected each others yield and have also depleted the phreatic aquifer which is the main reservoir for feeding water to the deeper fracture network. Eventually, the dug wells drawing water from the phreatic aquifer have also suffered. Because most of these wells have been drilled or dug with the help of institutional funding, it is of great concern to protect
their sustainability. For this purpose, recharge augmentation and pumpage control are the commonly accepted techniques.

RECHARGE AUGMENTATION

The groundwater balance equation for sub-basin, during the post-Monsoon dry period of eight months, can be written as follows:

Initial storage (maximum value) - Streamflow supported by groundwater - Groundwater outflow - Pumpage from wells + Return flow from irrigated crops + Recharge available, if any, during the dry season = Final storage (minimum value)

Increased pumpage is partly compensated by reduction in streamflow and groundwater outflow. But such reduction from several sub-basins affects the dry season flow of the main stream of the catchment, thereby creating problems in operating water supply schemes based on the water resources of the main stream. The only positive approach for over-exploited sub-basins is to augment the recharge during the rainy season and also to create runoff water storages for providing additional recharge during the dry season.

Afforestation of the watershed, contour trenching on the hill slopes, gulley plugging and stream bunding, contour bunding of farms, construction of underground impermeable bunds across stream beds and construction of percolation tanks for harnessing runoff water, are the activities undertaken for recharge augmentation. All these activities require a high degree of acceptance and participation by the rural community. It is important to note that the increase in pumpage takes place due to individual initiative and efforts of well digging/drilling, whereas recharge augmentation is the need of the whole community. The degree of benefits derived by an individual from recharge augmentation is variable and uncertain. Therefore, if the people are not willing to participate in the activities for recharge augmentation initiated by Government Departments, the afforested plots become barren again due to poor rate of survival of saplings or due to grazing by stray cattle; the field bunds and stream bunds get washed away in rains and the percolation tanks get silted. Involvement of Voluntary Agencies or Non Governmental Organizations (NGOs) in planning, execution and maintenance stages of soil and water conservation programmes is very helpful as the NGOs, through their influence and contacts with the farmers, can motive them for active participation.

PUMPAGE CONTROL

The pumping from existing wells can be controlled by switching of the electric supply mains in an over-exploited sub-basin, for a few days in a week. This measure is effective for bore wells because from the dug wells the farmers can still pump water using animal power or diesel pump-set. Some of the affluent farmers even have their own electric generator set, running on diesel or bio-gas. Another way of pumpage reduction is to instruct to Banks for financing new wells in over-exploited sub basins. This is also partly effective as the farmers may arrange for private loans if Banks refuse to give loan for new wells.
Yet another method is specify rules for minimum spacing between two wells and not to allow digging and drilling of new wells within the specified distance from the existing wells. This method, however, meets with a lot of social resistance because the farmers have a very strong feeling about the ownership of groundwater that lies below their own farm. The basic right of any farmer to dig/drill a well in his farm and grow irrigated crops for upgrading his standard of living cannot be denied just because his neighbours in the surrounding land have already dug their wells. At the most, it is feasible to limit the pumping from each well proportionate to size of the farm and adopt a suitable cropping pattern for the three cropping seasons.

It may be noted that any rules and regulations on well construction or pumpage control, must be made operative at the level of "village council", where the farmers be allowed to monitor each others activities. Corrupt practices may easily creep in, if a farmer has to go to the Country or District offices to obtain any kind of permission for well construction or for pumpage.

Educating farmers on efficient use of groundwater pumped from a well and granting subsidy on sprinkler or drip irrigation equipment, also helps in reducing pumpage of water for the first few years. Later on, the farmers pump the original quantity of water and irrigate more land, if the size of their farm is big enough.

One side-effect of drip and sprinkler irrigation methods is that most of the pumped water is used by the plants and there is very little deep percolation going back to phreatic water table. "Recharge augmentation" schemes are therefore viewed as a positive way of tackling over-exploitation while "pumpage control" methods are viewed as a negative way.

**ECONOMIC RISK**

The main aim of recognizing the future risks to groundwater resources and planning to mitigate them, is to enable the beneficiary users to enjoy the resource in future also. Risks of diminishing yields from wells and deterioration of quality of groundwater are relatively easy to foresee. However, there is one more type of risk especially in the developing countries, in which the resource stays healthy but the beneficiaries of today may not be able to derive the same benefit in future, due to their inability to maintain the well, repair the pump-set or reconstruct a new facility after the useful life of the present facility is over, because of financial constraints.

This is particularly the case for wells constructed for irrigation and/ or domestic use in developing countries, through donations from aid agencies. Once the subsidies and the donations are discontinued, the developmental activity comes to a halt. The economic condition of the poor farmers and villagers does not permit them to maintain the facility. Once the bore gets clogged or the deep well pump fails, the groundwater resource is lost to the people. Only in the case of dug wells, a limited use is still possible because the villagers are able to clean and repair the dug well by using rural technology. If the pump-set fails, animal power can still be used for irrigation of small plots. The use of appropriate technology in the development schemes of Aid Agencies is therefore advisable.
CONCLUSIONS

1. Future risk to groundwater resources in basalts or Deccan traps of western India, is likely to occur in sub-basins in which groundwater pumpage for irrigational use has increased considerably in the past two decades. Such sub-basins occur in the high rainfall area as well as in the low rainfall area. The main threat is the declining yields from dug wells and bore wells. Degradation of water quality is a problem only in some of the coastal sub-basins.

2. The only positive way to safeguard the resource for future use is to undertake soil and water conservation activities for recharge augmentation. These activities involve a high degree of community acceptance and participation. It is therefore advisable to involve NGOs or Voluntary Agencies in the planning and execution of these activities and ensure popular support through them.

3. Pumpage control often meets with social resistance because the farmers have a strong feeling of ownership of groundwater occurring in their farms. The basic right of any farmer, of digging/drilling a well in his own farm and pumping an equitable share of groundwater resource commensurate with his land holding, should always be upheld. Recharge augmentation should therefore be given priority over pumpage control.

4. In the developing countries, the foreign aid programmes for groundwater utilization should preferably use appropriate technology, taking into consideration the economic constraints under which the poor farmers may have to manage the programme in the future.