Floodplains: self-recharging and self-sustaining aquifers for city water

Depletion of natural water resources and the increasing demand for water across the world have forced attention on the sustainability of our natural water resources. We have already crossed the sustainable limits of many of our local water resources. Preservation and management of local resources[1] is now of vital importance to ensure water security and avoid water conflicts.

In a previous work[2], we had estimated the enormous resource of the extended river floodplain aquifers that are several kilometres wide and run for thousands of kilometres along river basins[2]. We had found that the floodplains are an incredible natural storage for water, bequeathed to us by nature. They are created over millions of years by the yearly deposition of sand brought down by monsoon floods. In times of water scarcity, they may be the only viable source of water left as we have exhausted much of our groundwater resource[3,4].

Here we present hydrograph data that inform us that if we locally extract water, the surrounding extended floodplain aquifer recharges the site of withdrawal even in the absence of the rain recharge and monsoon flows. This means that even large-scale withdrawal of water from the floodplains is not ecologically damaging. We also present an operational framework of how a grid of tubewells can be optimally managed to yield the maximum sustainable supply of water.

We study the groundwater dynamics in the Palla Burari region of the Yamuna floodplains of Delhi, where 97 tube wells and five Ranney wells are installed in an influence area of approximately 25 sq. km (see Figure 1). The amount of water extracted over a period of 8–9 non-monsoon months (October–June) and the consequent observed variation in groundwater levels help us to analyse the horizontal recharge movements in the sandy aquifers of the floodplain. The analysis that follows from hydrographs prepared by the Central Ground Water Board (CGWB)[5] in the influence area, shows a remarkable and rapid recuperation of groundwater level.

If we consider the data for the years from 2003 to 2008 given in Figures 2–4, the hydrographs record that with the prevailing field conditions of withdrawal (~ 40–45 MCM/year) on the average, the groundwater level variation from minimum below ground to maximum below ground level is between 2 and 3 m.

A withdrawal of 45 MCM/year over an area of 25 sq. km translates to an average withdrawal of about 1.8 m column of water/year over this area in the Palla sector. Next, we calculate the fall in groundwater level from such a withdrawal under conditions of zero recharge. The specific yield is defined as the amount of water, as a percentage of the gross aquifer volume (including the volume of the soil and leftover water that sticks to the soil particles) that can be extracted. For this site at a specific yield of 15%, the groundwater level would diminish by 6.66 (100/15) times the column of water withdrawn or by about 12 m, under conditions of zero recharge. However, actual data above show a fall in groundwater levels of approximately 2–3 m. This means that the continuous and extended

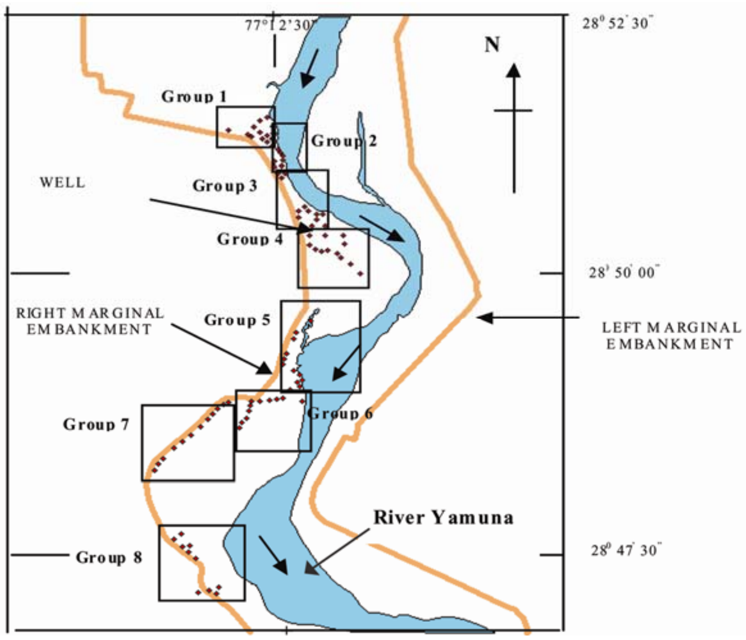

Figure 1. Location of tube wells in the Palla sector.

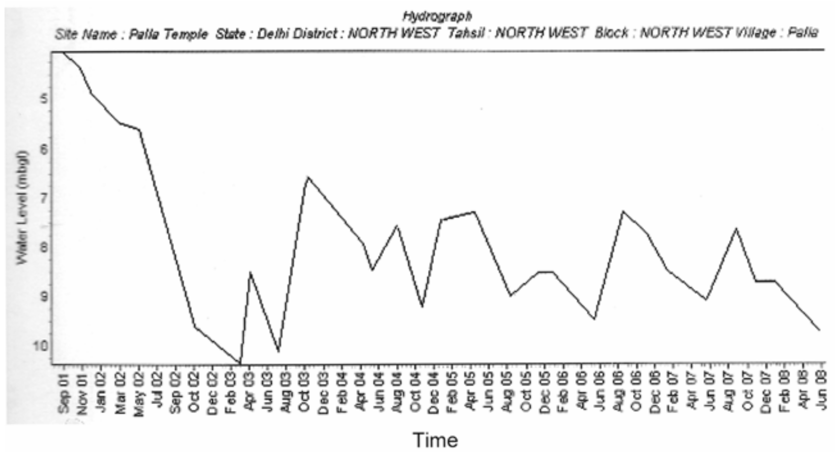

Figure 2. Annual hydrographs of groundwater of the Yamuna floodplain. Site name: Palla Temple, District: North West, Tehsil: North West, Block: North West, Village: Palla, NCT, Delhi (data from CGWB[5]). Location of the monitoring well at Palla Temple is 700 m from the river.

aquifer of the floodplain and the river is recharging (non-monsoon) the aquifer effectively and dewatering will not cause too much decrease in the groundwater level. The rain recharge and the monsoon flows recharge the remaining groundwater deficit of 2–3 m every year. This means that over 80% of water extracted is continuously recharged in the non-monsoon months through horizontal movement within the floodplain aquifer.

There is a difference in variation levels noticed at different monitoring wells in the North District. The well at Burari Auger Pz shows the least variation for two reasons. First, the pumping wells are at a distance of 200 m from the monitoring well, whereas in case of the other two monitoring wells, the pumping wells are in the distance range 50–100 m. Also, the monitoring well at Burari Auger is close to the river. The above factors could explain the variation in water levels.

We should add for clarity that the recharge has two contributions: (a) induced recharge from the river in response to pumping, (b) redistribution within the aquifer through vertical percolation from the river banks. The magnitude of induced recharge will be governed by the hydraulic gradient (relative water levels in the river and aquifer). This water is extracted at a typical tube well of depth of 30 m, and is recharged by gravity from the surrounding aquifer and the river.

The above data are a minor revelation. The water extraction data show that instead of a drop of over 10–12 m in the groundwater level of a localized aquifer with zero recharge, the floodplain aquifer shows a loss of only 2–3 m. This indicates that a surrounding floodplain area which is about 4–5 times the localized area compensates for the local water loss. This will allay any ecological concerns and is promising for increasing the yield under this scheme. Unlike other aquifers, floodplain aquifers are so large that they can easily compensate for water extraction. The monsoon flows recharge the remaining groundwater deficit of 2–3 m every year. Of course, there are ecological limits for the quantum of water extraction, depending on the amount of natural recharge (rain and flood), but this is a subject for future work (Figure 5).

Another distinct feature is that groundwater flow in the floodplain aquifers is efficient. This depends on the soil content, which is medium grain sand and kankar in our case. We have carried out

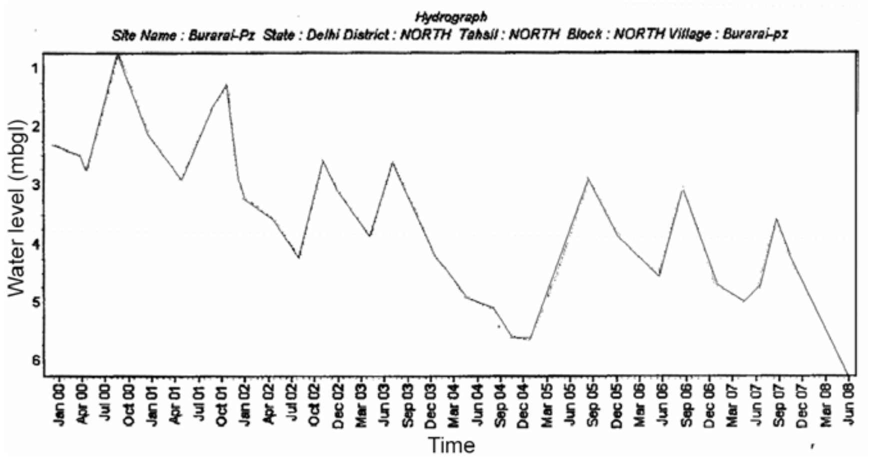

Figure 3. Annual hydrographs of groundwater of the Yamuna floodplain. Site name: Burari-Pz, District: North Tehsil, North Block, North Village, Burari of NCT, Delhi (data from CGWB[5]). Location of the monitoring well at Burari Pz is 1700 m from the river.

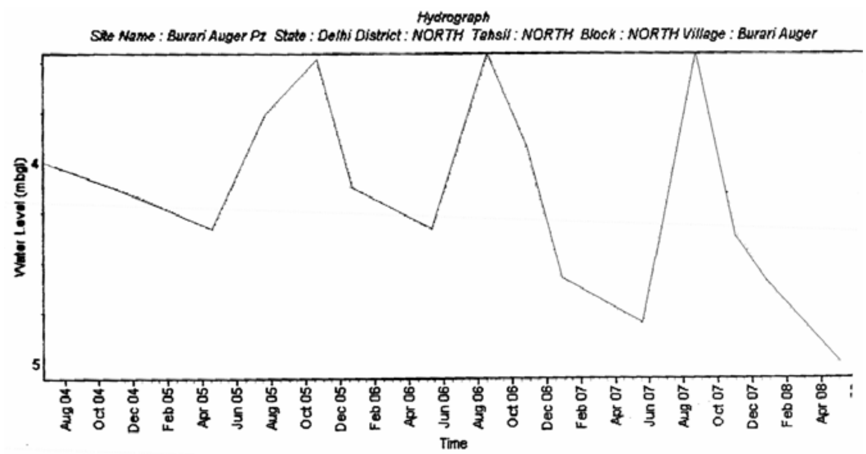

Figure 4. Annual hydrographs of groundwater of the Yamuna floodplain. Site name: Burari Auger Pz, District: North Tehsil, North Block, North Village, Burari Auger, NCT, Delhi (data from CGWB[5]). Location of the monitoring well at Burari Auger Pz is 600 m from the river.

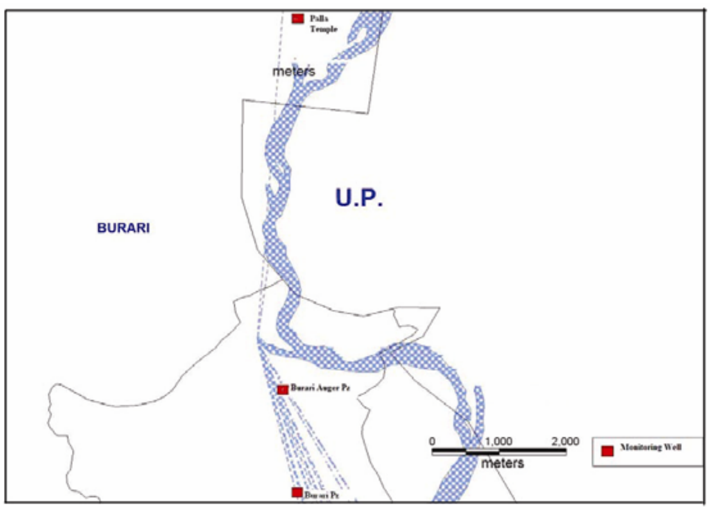

Figure 5. Monitoring wells in Palla and the North District of Burari.

intensive pumping tests on wells to establish that well recuperation is almost instantaneous. This facilitates the extraction of groundwater.

We have thus found that the floodplains are not only an incredible natural source of water, but also largely recharge naturally on their own. This makes them a perfect local source of water for cities on their banks and, further, a completely non-invasive solution to the water problem of cities. Having lost so much of our natural water repositories, it is vital that we have a non-invasive, 'preserve and use' solution to source water. This is unlike dams, which permanently damage river catchments and require long-distance transport of water from far-away water basins. Transport of water by canals involves major losses and causes groundwater salinity through waterlogging. Recycling sewage water is expensive and leaves its own waste. On the other hand, the scheme presented herein[2] is a perennial and very low cost solution for city water.

The recharge can be enhanced during the monsoon period when there is plenty of free flow in the river. As we have indicated, this can be accomplished by running shallow channels from an upstream barrage along the elevated embankments and let the water drain over the floodplains. Such inundation produces rapid recharge in the floodplains.

At present, the wells in Palla are run manually, without proper coordination and do not produce an optimum yield. To get an optimal yield would require that each well be fitted with monitoring equipment such as piezometers (or equivalent) to obtain real-time data of the local groundwater level and sensors to determine the discharge, salinity, and other chemical parameters of the water coming out from the delivery pipes of the tube wells. Wells would then have to be fitted with remote logic-based microprocessors (remote terminal units or RTUs) that would transmit real-time data on all parameters to regulate pumping from a central computer. For this, we can use an automated supervisory control and data acquisition (SCADA) system based on GSM technology that is employed in many groundwater applications (Such SCADA control systems are operational in many locations – e.g. in Holland and in Chandigarh (by the CGWB for the city groundwater supply), which has nearly 200 tube wells managed using a SCADA system.) This would give us a complete picture of the underground floodplain aquifer. All parameters would be monitored in tandem on a real-time basis for all wells. Controlled pumping will then ensure a maximum and sustainable yield without any invasion of the saline water that may reside at the bottom.

We have highlighted some remarkable features of floodplain aquifers that have natural storage and natural recharge, even in the absence of sufficient rainfall recharge. This makes it possible to have a systemic and ecological solution for water extraction. Such a solution is presently being implemented by us in collaboration with the Delhi Jal Board for the Yamuna floodplains. This will help in extending non-invasive, self-sustaining, local solutions for water-short cities located on rivers all over the world.

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Petrographic evidence as an indicator of volcanic forest fire from the Triassic of Allan Hills, South Victoria Land, Antarctica

The Mesozoic ecosystems, as of today, were subjected to various natural disasters like volcanism, earthquakes, floods, droughts and forest fires[1–4]. Wildfire has important influences on the environment, climate and biota, but our ability to understand these linkages in geologic past has been hampered by difficulties in identifying evidence for palaeowildfires and their proximate cause. The Gondwana System of the Allan Hills, southern Victoria Land, Antarctica offers a unique window to understand past volcanic activity. Continental volcanism was considered to be one of the major causes of forest fire during the Late Triassic of Allan Hills. The nature and source of forest fire can be addressed through the studies of organic matter, geochemistry and fossil signatures[5,6]. Based on geochemical, palaeobiological and palaeowildfire evidences, many researchers have established volcanic activity in Antarctica during the Triassic[5,7–9]. Earlier palaeobotanical studies recorded well-preserved plant fossil assemblage (rich flora of *Dicroidium*) from A and C members of