

Groundwater evidences in confirmation of palaeo-course of Assi River in Uttar Pradesh, India

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The palaeo-course of the Assi river in Uttar Pradesh, India was delineated through visual image impressions using remote sensing data. To corroborate on the existence of this palaeo-course 192 open wells and several ponds along and within the palaeo-course were observed showing very shallow groundwater table. Also, eight trenches dug within the channel and over the natural levees confirmed the existence of very shallow groundwater conditions. The observations of wells were made and trenches were dug during January–February 2020, by which time most of the ponds away from the channel dry out and the water column in the wells outside the course is reduced compared to the ponds and wells located over the banks and wells within the palaeo-course and outside it corroborates the existence of the Assi palaeo-course.

Keywords: Groundwater, open wells and ponds, palaeo-course, remote sensing.

PALAEO-channel studies normally proceed first with mapping the surface expression of the channels using remote sensing data and aerial photographs^{1–7}, followed by other geological and chronological^{7–13}, geo-hydrological^{14–16} and geophysical studies^{13,17–23} to finally confirm their existence. Using multi-spectral remote sensing data and CORONA aerial photographs of various resolution, a continuous palaeo-course was delineated starting from near Prayagraj as a take-off from the Ganga river and ultimately linked to the present Assi river in Varanasi city, Uttar Pradesh, India (Figure 1). Though the visual impressions of the palaeo-channel are convincing and clear enough, a field study was carried out on the groundwater occurrences within and along the channel, as it is normally expected that palaeo-channels contain good aquifers than the surrounding floodplain. As part of the present study, 192 wells along the banks and within the palaeo-course were observed (Figures 1–3). Eight shallow trenches up to a depth of 4 m were excavated to determine the rate of accumulation of water (Figure 4). Several ponds within the channel and outside were observed for their water retention (Figures 5 and 6).

Palaeo-channels are good rechargeable aquifers, possible reservoirs and repositories of groundwater^{14,24–30}.

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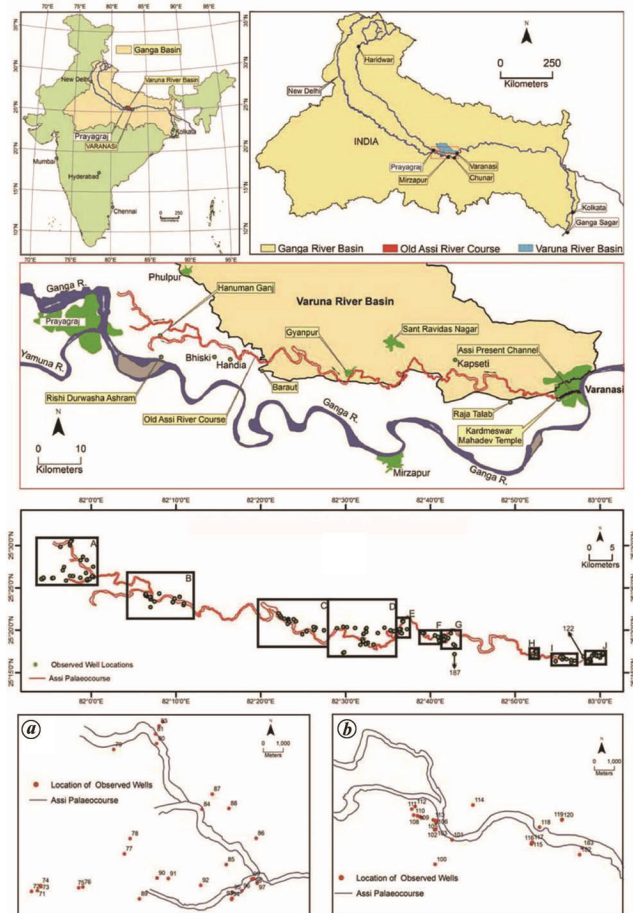


Figure 1. Location of Assi palaeo-course¹ (in red) and locations of observed wells (a and b show enlarged images of blocks A and B).

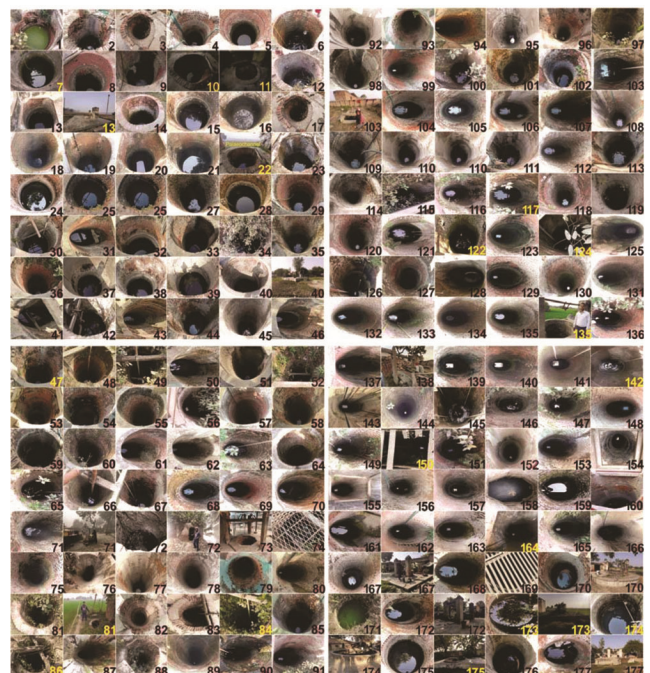


Figure 2. Field photographs of some observed wells (locations shown in Figure 1) along the Assi palaeo-course.

Within the floodplains there can be many palaeo-channels and many other features at meso- and macroscales like flood basins, natural levees, point-bar fields along active channels as well as along palaeo-channels which influence groundwater occurrences. Flood basins along large rivers on both sides away from natural levees and point-bar fields are built up with fine flood and wash deposits and are poor in groundwater occurrence. Natural levees with dominantly coarse sands are favourable locations for good quantities of groundwater. Also, point-bar deposits of mixed fractions have better groundwater potential than flood basins, but less than natural levee zones. The palaeo-channels (between the two banks of a river) are known to have good groundwater potential compared to natural levees. Also, palaeo-channels with a clear depression receiving waters during the rainy season, or connected with the main active channels have a perpetual occurrence of groundwater of high potential at shallow and/or greater depths.

Palaeo-channels which are not visible on the ground are visible in remote sensing data. Usefulness of remote sensing techniques for mapping of palaeo-channels and delineation of groundwater prospect zones for water resources development plan has been demonstrated in the Yamuna floodplain in Uttar Pradesh²⁵. In northwest India

in the Sutlej–Yamuna plain^{31–33}, the palaeo-channels are associated with alluvial fan systems near mountain fronts with well-drained and highly porous coarse sediments where groundwater percolation and subsurface run-off in greater depths and farther downslope is quick and high leading to natural depletion of groundwater at shallow depths. But in the case of Assi palaeo-course in the middle Ganga floodplain dominated by fine sands and silts mixed with clay, the groundwater depletion is more due to withdrawal rather than due to natural percolation and subsurface run-off (Figure 7). The litholog typically reflects deposition of dominantly medium to fine sand fractions and silts with minor percentage of clays, in dying stages of a shallow floodplain river/tributary receiving mostly wash deposits from the surrounding floodplain (Figure 7)^{1,2}.

In the present case, the palaeo-channel has a meandering course with 200–250 m width. There are somewhat prominent natural levees and point bar fields making up the banks of the palaeo-channel. They are clearly visible in remote sensing data as well as in the field (Figures 4 and 5). Among the 192 wells mapped most of them are located

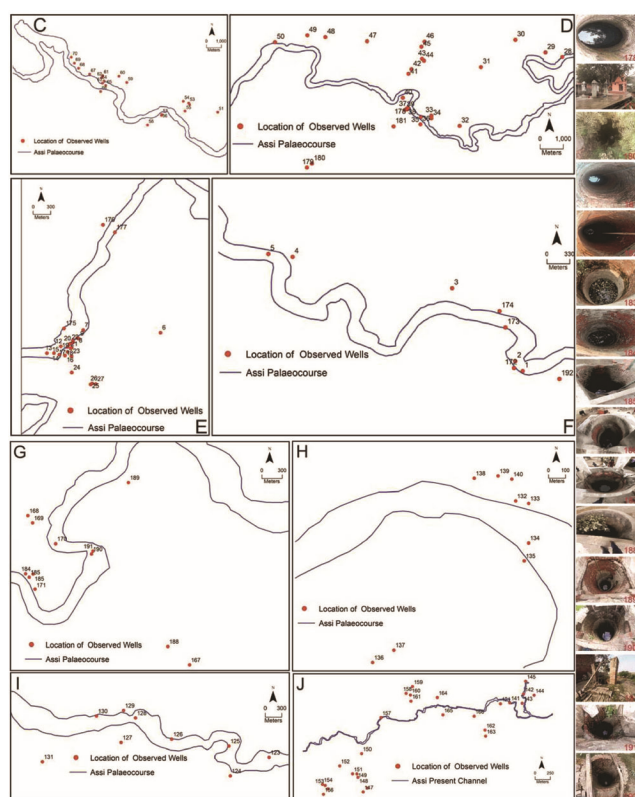


Figure 3. (Left) Locations of some observed wells (blocks C–J; see Figure 1), along and within the Assi palaeo-course (blocks C–I) and along the present Assi river (block J). (Right) Field photographs of some observed wells.

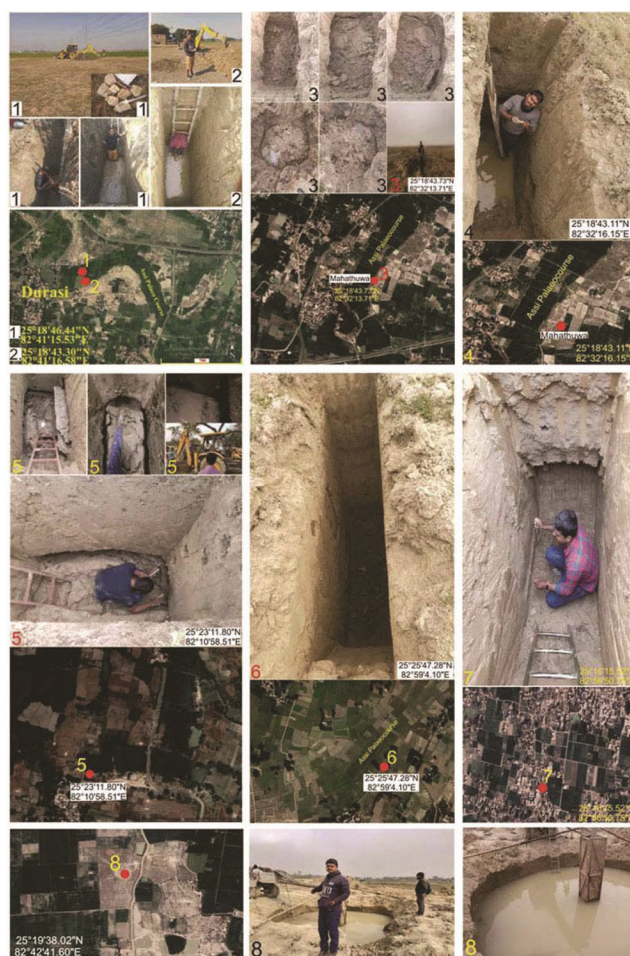


Figure 4. Excavated trenches in the field and their respective locations are marked and given on remote sensing data bits.

over natural levees, a few are located within the point-bar fields and very few are located within the palaeo-channel (Figures 1–3). As has been mentioned earlier, eight trenches were dug to have a measure of groundwater situation (Figure 4) and accumulation rate of water into the trenches.

The groundwater table over the natural levees and point bars (as observed within the wells) was found at depths ranging from 1 to 3 m from the ground surface. In both cases, water was available perpetually year round within the wells. During rainy season in some wells the water level was up to the local ground surface. In order to prevent overflow onto the surface and mix up, the locals erect 3–6 ft high platforms around the wells (see 40, 138, 174, 175, 177, 179, 191 in Figures 2 and 3).

All the well observations were made and the trenches were dug during January and February 2020. The trenches measuring $L3\text{ m} \times W1\text{ m} \times D4\text{ m}$ excavated got filled up with a column of water of 3 m (3000 l of water) almost within 15 min in the channel and within 2 h in the trenches dug over natural levees. At the upstream parts of the channel at Hanumanganj near Prayagraj, only moisture oozed out at 4 m depth. This trench location being in the upstream of the palaeo-channel, naturally, the groundwater is expected at somewhat deeper levels²⁹. Attempts to excavate a few more trenches at some other places within the palaeo-channel downstream were not successful

because of simultaneous pooling of water from 1 m depth onwards (see 3, 5, 8 in Figure 4).

Normally ponds in these floodplains have an inlet (from either a small local stream or a big river) and an outlet for outflow. During rainy season, water collects into this strip of the Assi palaeo-course and to prevent flooding of agricultural fields within this strip, a number of canals/

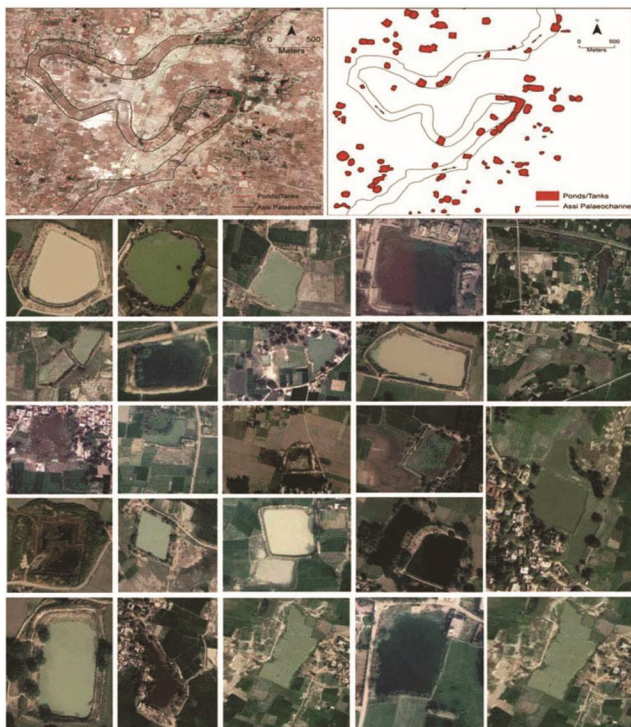


Figure 5. (Top left) Remote sensing data showing a segment of the Assi palaeo-course¹. (Top right) Related map of the same. (Middle and bottom panel) Remote sensing images showing some selected ponds from within the palaeo-course.



Figure 6. (Top panel) Field photographs of ponds (1–24) within the palaeo-course and their locations (bottom).

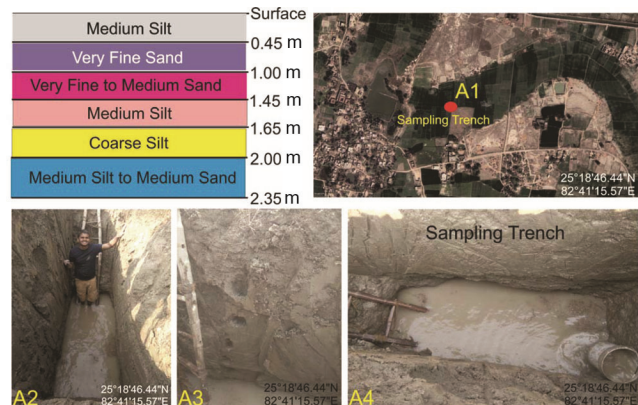


Figure 7. Litholog (top left) and its location (A1) marked on remote sensing data bit (top right) and field photographs of trenches (A2–A4) near Durasi Village, Uttar Pradesh, India.

food channels are constructed to drain off flood water out of this palaeo-course. Further, due to good porosity of sand deposits along natural levees and point-bar fields and also very shallow water table, there is good capillarity because of which the soils over natural levees and point-bar deposits have turned saline and are registered in white tone in remote sensing data (see 1, 2, 3, 4 and 8 in Figure 4 and Figure 5). The occurrence of such a high potential of groundwater within the palaeo-channel and relatively better potential on the concave side channel (on the side of natural levees) and moderate potential along the convex banks (on the side of point bars) of the palaeo-channel, strongly indicates the existence of the palaeo-course.

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ACKNOWLEDGEMENTS. We thank the villagers of the study area for their cooperation during field work. This study is a part of the Ph.D. thesis work of M.M., who thanks University Grants Commission, New Delhi for awarding Junior Research Fellowship and Senior Research Fellowship (3043/NET-JUNE 2014). The authors thank anonymous reviewers for critically evaluating the manuscript and for improving it.

Received 26 July 2021; revised accepted 30 December 2021

doi: 10.18520/cs/v122/i3/333-337

Solar photovoltaic pump sets as a substitute for conventional pump sets

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The growing energy demand for feeding the ever-increasing population has triggered the issue of energy security. This has made it essential to utilize the untapped potential of renewable resources. Punjab, India, has great potential of generating solar energy. In the present study, the cost of running electrical and diesel tube wells has been estimated along with the cost of replacement of the conventional pump sets with solar photovoltaic (SPV) pump sets. It was found that the cost of running the electric and diesel-operated pump sets for shallow and medium tube wells was almost Rs 73.9 million per year. If these are replaced by SPV pump sets, then installation cost of the latter is Rs 212.71 billion without subsidy. According to the Government scheme, the farmer's share is Rs 96.18 billion and the Government share is Rs 132.71 billion. Further, with replacements using the solar pumping system, green energy will be available and additional energy can be released into the grid system. This might be especially true for a state like Punjab, where 30–35% electricity is

consumed in the agricultural sector for irrigating about 72% of the total irrigated area (99%) through groundwater pumping. The cost of SPV pump sets is expected to reduce as it is gaining popularity. Also, with the advancement of technology, electronic goods are becoming cheaper and compact.

Keywords: Energy demand, renewable resources, solar photovoltaic pumps, tube wells.

IRRIGATION has played a major role in the agricultural growth of Punjab, India, and a substantial share of irrigation is contributed by minor irrigation schemes across the state. As stated in the Fifth Minor Irrigation (MI) Census Report of India, there are 1,120,963 MI schemes in Punjab, accounting for 5% of the total MI schemes in the country¹. Also, Punjab is a leading state in the use of shallow, medium and deep tube wells. The number of shallow (0–35 m), medium (35–70 m) and deep (70–150 m) tube wells in Punjab is 248,655, 384,707 and 485,378 respectively, with a total of 1,118,740 MI schemes in the state that use groundwater as a source¹. Among these schemes, 1,068,914 are electric pumps, 48,052 diesel pumps, 192 wind mill pumps, 106 solar pumps and 1503 use other sources of energy for lifting groundwater.

Electricity in Punjab is generated in various plants with the burning of coal. A large amount of electricity is used for running pumps. So a large quantity of coal is being burnt on a daily basis to meet the energy demands, which further leads to a huge amount of carbon emissions in the state. The number of diesel pumps in Punjab is also high and therefore, a large amount of carbon emissions comes from diesel being burnt to run pumps on a daily basis. The oil stock of the world is being depleted at a fast pace and we will run out of oil in the next four decades. Coal will be exhausted in about 140 years. Switching to solar energy can help slow down the depletion of coal and oil stock. Further, these resources will be available for use for a longer period and for critical needs, when other alternatives are not viable. So, there is a need of replacing the power generated by electricity and diesel with solar photovoltaic (SPV) energy. The Ministry of New and Renewable Energy (MNRE), Government of India (GoI) is promoting the use of solar energy for irrigation in the agriculture sector. It has launched the Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahabhiyan (PM-KUSUM) scheme with the aim of providing energy security to the farmers, increase their income, and conserve fossil fuels and protect the environment. The Government of Punjab decided to implement the scheme by providing 30% subsidy to the general category farmers and 50% to farmers from the scheduled caste over and above the 30% GoI subsidy under the funding pattern CS (centre scheme) : SS (state scheme) : Benf (beneficiary) = 30 : 30 : 40 and

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