CONSTRICTION OF THE YAMUNA RIVER FLOODPLAINS WITHIN DELHI REGION SINCE 19TH CENTURY: A SERIOUS CONCERN

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Abstract

India's capital Delhi has been encompassed serious problems due to scarcity of groundwater. The recharge zones are very limited and that too not having any effective enriching source except the annual rainfall and the Yamuna River. The most valuable recharge zone is the floodplain of the Yamuna River but unfortunately it has been extensively used for the settlements/ urbanization and thus squeezed up leaving a paltrier area for recharging groundwater reservoirs. Since 19th century, continuous encroachment over the floodplains of the Yamuna River has resulted into the constriction of the most suitable recharge zone of the capital. The water level in the Yamuna River remains usually low throughout the year except in the rainy season due to which the recovery periods for the groundwater aquifers are very long in comparison to a high pumping (discharge) rate. As a consequence, Over-exploitation (Over-pumping) of groundwater especially over the occupied floodplains caused the compaction of the underlying sediments that has been resulted into ground subsidence at many places due to collapse of the groundwater reservoirs or aquifer disposition. The present study provides a hydrogeological evaluation by delineating the floodplain of the Yamuna River that can further direct towards the sustainable groundwater augmentation and management practices in the area.

Keywords: *Yamuna River, Floodplain, Groundwater, Aquifers, Recharge Zones, Urbanization.*

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1. INTRODUCTION

Delhi region has no suitable groundwater resources in the current scenario. Aquifers are limited and generally contain saline water, except for the few areas in northern and eastern parts. The situation worsens further in the southwestern part of the region, where the subsurface strata mostly consists of clay and kankar, containing saline water. In last ten years, the heavy exploitation in the rocky tracts and upland areas has completely depleted the groundwater. Only expectation is the floodplain [1, 12]. At present, the water supply to Delhi region is through canals and reservoirs from neighboring states.

Through last decade, heavy exploitation of the shallow aquifers through the tube wells constructed by Central Ground Water Board (CGWB) within the Yamuna floodplain has given a high relief to fresh water supply. This resort to shallow aquifers within the floodplain is feasible because of availability of the fresh groundwater and its annual recharge during monsoon and periodic flooding. Even in the floodplain, the aquifers beyond the depth of 50m contain brackish to saline water. Beyond the floodplain the shallow aquifers have permanently depleted almost a decade back [7].

Fast and unending urbanization has limited the flow of rainwater down the drain instead of recharging the aquifers through floodplain. Farmers cry for flood, however devastating, as the flood is only left as an alternative for reviving lost groundwater reservoirs. The Sahibi River can be used effectively for water supply, so called the Najafgarh jheel in South Delhi at present filled with black clay, which can be excavated for heavy storage of water. Still so far the supply and requirement of water in Delhi is far off [7].

In view of groundwater being dependable only in the shallow aquifers, it has become imperative, to find out measures of retaining the same. Such measures would basically involve the delineation of the active floodplain of the Yamuna River and its palaeochannels, which were earlier known for their heavy groundwater storage. It is also imperative to determine the migration path of the course of the Yamuna River through different years in the past. Also this is important for the delineation and distinction of the older floodplain from the present. This would properly facilitate in mapping of land use with the present urbanization. The present work has been undertaken as an attempt of the same.

2. STUDY AREA

Yamuna River is the largest tributary of the River Ganga. The main stream of the river Yamuna originates from the Yamunotri glacier in the Mussourie range of the lower Himalayas at an elevation of about 6320 meter above mean sea level in the district Uttarkashi [5]. The river stretch of 22km within Delhi region is the maximum polluted amongst all where the stretch between Wazirabad barrage and Chambal river confluence is critically polluted (Figure 1).

Delhi sprawls over 1483-sq km between latitude 28^0 34' N and a longitude of 77^0 07' E having an elevation of 233 m above the mean sea level [6] (Figure 1). It also experiences heavy rains primarily during monsoon. The temperature ranges between 18.70C (mean minimum) and 40.30^{0}C (mean maximum). The normal annual average rainfall is 72 cm. The average annual evaporation is about 254 cm in Delhi. The mean relative humidity is 66% [6]. Our study area covers the periphery of the available floodplain of the Yamuna River within Delhi region.

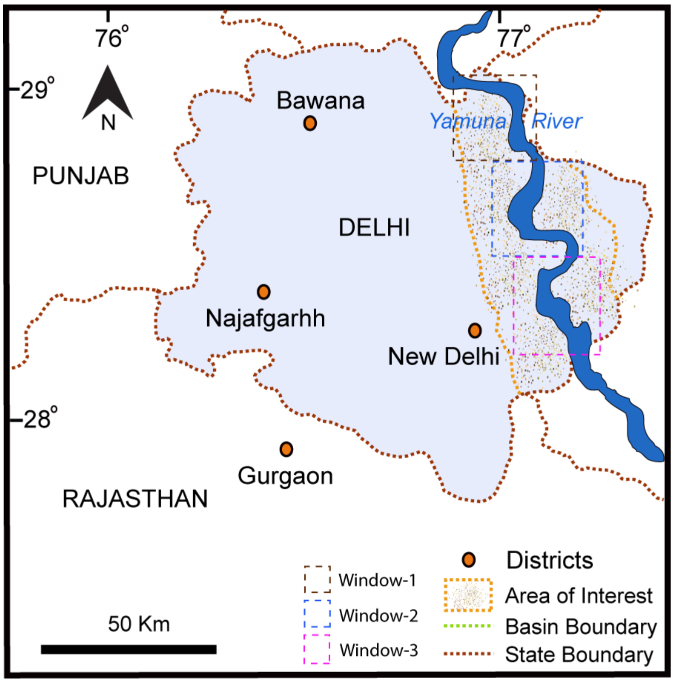

Fig -1: Index Map of the study area within Delhi Region showing three windows (1, 2, 3). Orange dotted borders mark the area of interest in which three windows are taken for detailed studies on the river courses and floodplains.

2.1 Hydrogeological Setting

The hydrogeological settings within Delhi region are mainly characterized by alluvial formations and hard rocks such as quartzite. The following distinct physiographic units show direct influence on the ground water occurrences: (a) Older Alluvial Plain on the eastern and western side of the ridge, (b) Yamuna Floodplain deposits, (c) Isolated and nearly closed Chattarpur alluvial basin and (d) NNE-SSW trending Quartzite Ridge [1]. Out of which the abandoned and the active floodplains have the largest reservoirs of the fresh groundwater.

Lithology of Delhi region shows diversified geological formations consisting of unconsolidated Newer and Older alluvium and Quartzites of Delhi Super Group. Southern regions are mainly comprised of quartzite rocks where groundwater sources are confined to fracture planes and the weathered zone. The older alluvium in the Chattarpur basin consists of predominantly sand with subordinate silt, clay and kankar however thickness of alluvium is highly variable due to underlying subsurface ridges and faults in the South district [1]. The alluvial deposits within the region belong to Quaternary age, where the newer alluvium deposited in the form of floodplains of Yamuna River shows the sediments ranging in texture from clay/silt mixed with tiny mica flakes to medium/coarse sand and gravel. On the other hand, older alluvium comprises the sediments that deposited during past cycles of sedimentation of Pleistocene age and spread extensively in the alluvial plains of the territory. Sediments of older alluvium are predominantly comprised of clay in form of inter bedded, lenticular and inter-fingering deposits, silt and sand ranging in size from very fine to very coarse with occasional gravels in major parts of territory except the nearly closed alluvial basin of Chattarpur where the alluvial formation is derived from the weathered quartzites rocks [1].

Major sources of fresh groundwater in the region are mainly concentrated within the quaternary alluvial formations (Yamuna river floodplains) in the form of hydrogeological reservoirs (silty-sandy sediments). The permeability varies from 0.5 to 8m/day and transmissivity from 10 to 100 m2/ day. The hydraulic gradient is approximately 1.3 Km/m to 2.0 Km/m [4, 5].

3. METHODOLOGY

A three stage approach was adopted to meet the goals of the present work. In the first stage, major geomorphic features, river courses and palaeochannels were mapped by using toposheets and IRS 1C LISS III digital imageries. The river courses for years 1807, 1952 and 1980 were digitized from the toposheets compiled from Survey of India while same for years 1990, 2007 and 2014 were performed over IRS 1C LISS III imageries and Google Earth images.

At the second stage, the identification of the river migration plains, migration paths and shifting directions were mapped for years 1990 and 2007 to understand river dynamics and degree of freedom for sprawling of the river in the current and future scenario. The reason behind making the comparison upto year 2007 is that henceforth there started a rapid encroachment over the Yamuna River floodplains leaving no space for river to migrate naturally towards its levees. This was achieved by superimposing the toposheets of years 1990 and 2007 with the satellite images of the same to avoid erroneous mapping. Finally at the third stage, the encroachment of the urbanization over the floodplains or boundaries of floodplains were mapped through digitization techniques on IRS 1C LISS III imageries and Google Earth images, which has marked the distinction between the older and the active floodplains.

4. TEMPORAL CHANGES IN THE COURSES AND DELINEATION OF THE FLOODPLAINS OF YAMUNA RIVER

In the natural domain, rivers have tendency to migrate along their floodplains under favorable conditions, i.e., high discharge, availability of free space, regional slope, eroding agents, natural levees, extensive floodplains and a thick alluvium. In river growing stages whenever the natural boundary conditions are violated, rivers start to behave unpredictably in terms of maintaining discharge, sediment load, course shifting, flowing conditions and seasonal flooding. Here we present a similar example of the Yamuna River stretch within Delhi region, where this river has been continuously barricaded from flowing naturally. Yamuna

River enters into Delhi State near Palla Village on the northern-most end where it traverses a straight distance of about 41 Kms upto its exit near Badarpur at the southern-most end. The river water maintains a reasonably good quality from its origin point upto Wazirabad in Delhi (a stretch of about 396 kms). However 80 percent of the pollution in Yamuna's 1375 kms stretches is equivalent to that of its 22 kms stretch (1.6 percent stretch) from Wazirabad barrage and the Okhla barrage. Thus, in its 22 kms stretch through Delhi, discharge of domestic and industrial wastewater through 16 drains between the Wazirabad barrage and the Okhla barrage, renders the mighty and sacred river into a sewage drain [7, 9].

The detailed observations of the satellite images and toposheets have been carried out to determine the relative shift of the channel and meander loops in terms of distance and direction in general to understand the dynamic behavior of the Yamuna River. Morphology of Yamuna River has changed through the last few decades due to onset of the rapidly growing land use / land cover of the region. Due to commence of heavy urbanization within Delhi in last few decades, floodplain areas have been extensively used for the settlements. The Yamuna River has shown temporal variations both in channel position and geometry since the onset of 19th century.

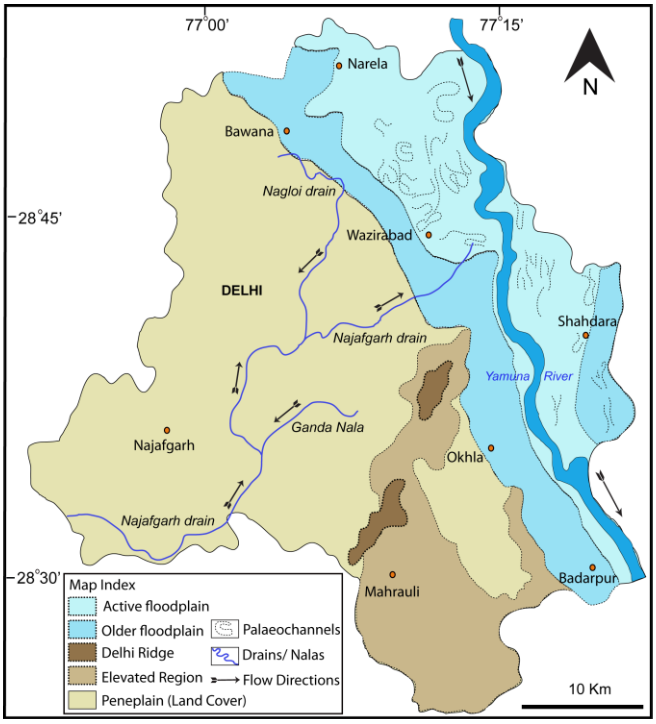

Fig -2: Geomorphic Map of Delhi Region with main emphasis on the areas along the Yamuna River floodplains, prepared by superimposing toposheets and satellite images. Map shows only major geomorphic features in the region and Yamuna River course and the floodplains represent the 2007-2008 scenario.

4.1 Window-1 (Temporal Changes 1990 – 2007)

Window-1 shows wide migration of about 1.2 Km of river towards eastern side before entering into Delhi State which has ultimately reshaped its prominent meander into a straight course. On crossing the borderline, river regained a shallow meander through bending its course towards Palla on the western side. River also performed the channel cutting along its meanders as shown by the dotted black curved lines within the channel. On descending towards Abdulpur, river remains more or less within its previous course however developed a sharp meander from a shallow meander through narrowing its course. Also in this section, river performed the channel cutting along its meanders as shown by the dotted black curved lines within and outside the channel that generally results in the palaeochannels after the shifting of river. On moving below near Muhammadpur, river has shown omission of a sharp meander and formation of the straight course through migrating about 0.3 Kms towards eastern side; however it has ultimately given rise to a large meander in its lower reaches. Towards the end of this meander near Nawada, river has shifted the notch of its next meander about 0.2 Km in the south-east direction. Along the point bar of this meander, a palaeochannel indicated by the dotted black line has formed due to river migration towards the eastern side. At the bottom-most part of this window, river has shifted about 0.5 Km towards Sabhaypur on the eastern side borderline (Figure 2 & 3).

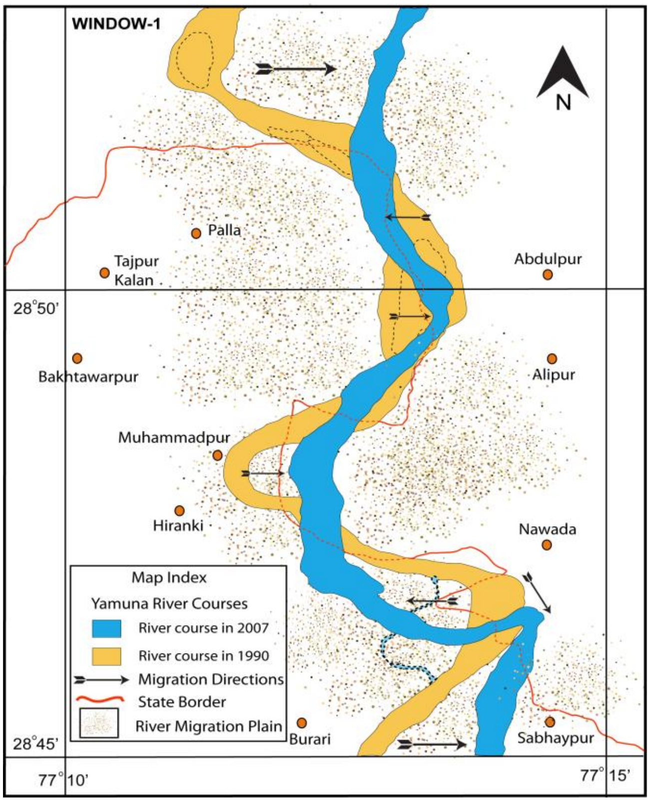

Fig -3: Window-1 showing the upper one-third part of the Yamuna River basin. Comparative scenario of river courses, migration plains, migration path and directions during 1990 to 2007 is mapped using satellite images and toposheets. Shaded area shows river migration plain in the current scenario.

4.2 Window-2 (Temporal Changes 1990 – 2007)

Window-2 starts with the mid-point of the meanders last marked in the Window-1, where it shows the similar trend of migration on the eastern side. However the river section between Jagatpur, Wazirpur and Sonia Vihar shows the juxtaposed meanders of similar patterns developed during 1990 and 2007. Previously existing straight course near Wazirpur has curved down into a meander by shifting about 0.2 Km towards Sonia Vihar. Along this portion, a few palaeochannels have resulted due to shifting of the river. This meander passes through Wazirpur Barrage and at the bottom of the meander; Nagloi and Najafgarh drains join the Yamuna River above Majnu ka Tila. River doesn't mark any noticeable change except a slight lateral displacement in its course from Majnu ka Tila upto the lower reaches of Seelampur. Towards Raj Ghat area, river has deflected to originate a minor channel through cutting the meander which deciphers the traces of the western flank of the river course however it should not necessarily be subjected to the migration of river. Formation of a sharp meander can take place towards Shastri Nagar on the eastern side in the near future at this part. At the bottom-most part of this window both the courses seem to flow congruently (Figure 2 & 4).

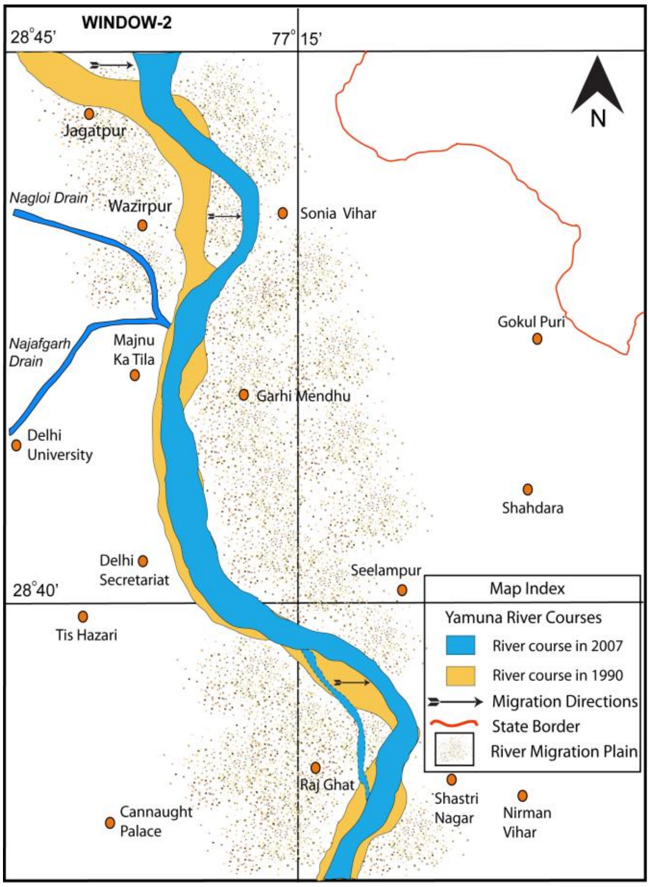

Fig -4: Window-2 showing the middle one-third part of the Yamuna River basin. Comparative scenario of river courses, migration plains, migration path and directions during 1990 to 2007 is mapped using satellite images and toposheets. Shaded area shows river migration plain in the current scenario.

4.3 Window-3 (Temporal Changes 1990 – 2007)

Window-3 starts with the congruently flowing courses last marked in the Window-2 forming a large meander and flowing through Indraprastha upto the lower reaches of Trilokpuri area. These congruent courses do not mark significant changes within its migration plain but contains traces of the palaeochannels. This window covers the remaining part of an important stretch of the Yamuna River, i.e. from Wazirabad barrage to Okhla barrage which is the most polluted amongst all due to being drained from the heavily urbanized area. Especially in this window river finds itself completely trapped on both the flanks, therefore the river has lost its effective migration plain and forcefully maintaining its straight course. After 1990 a rapid increase in the urbanization in and around Okhla area has affected the western meanders of the river due to which its course has constricted to flow straight at a distance of 0.3 Kms. Traces of the channel cut-offs, meander cut-offs and palaeochannels are left out along this section. In the lower parts of this window, river course passes along Jasaula, Sarita Vihar and Badarpur where it favors to flow congruently with the previous courses, however satellite images show that it is gradually migrating towards Badarpur on the western side (Figure 2 & 5).

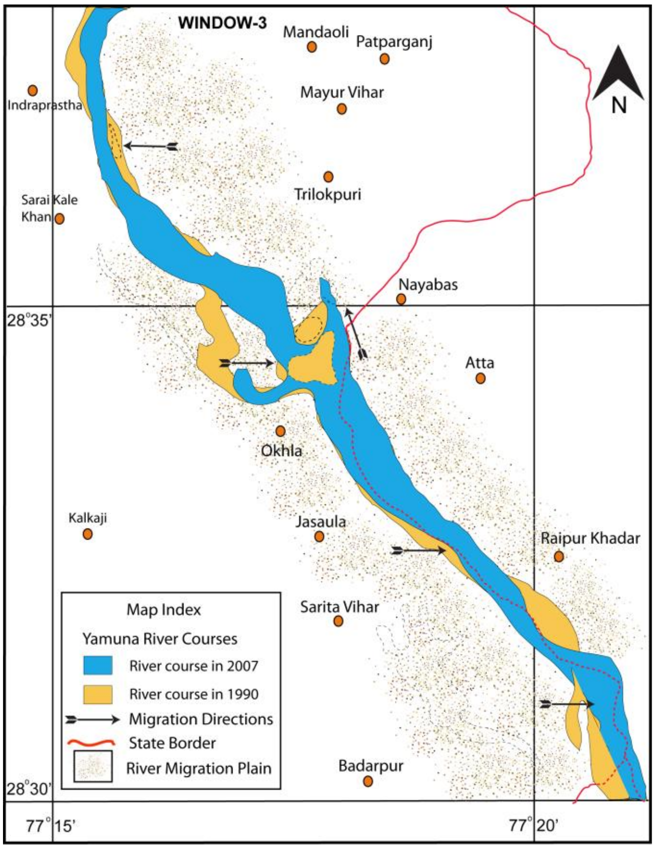

Fig -5: Window-3 showing the lower one-third part of the Yamuna River basin. Comparative scenario of river courses, migration plains, migration path and directions during 1990 to 2007 is mapped using satellite images and toposheets. Shaded area shows river migration plain in the current scenario.

4.4 Encroachment over Yamuna River Floodplain (1807 – 2014)

In the beginning of 19th century, Yamuna river used to flow just on the eastern side of Narela and Wazirabad that is witnessed by the prominent palaeochannels, meander cut offs, terrace markers, older floodplains and river migration/shifting plains. The floodplains marked by the black dotted line corresponding to 1807 river course is on the basis of a probabilistic approach for the periods of peak seasonal flooding. Therefore the floodplain boundaries marked in these figures are actually the maximum possible extents of floodplain corresponding to a particular course and period. Similarly red and green dotted lines represent the extent of the floodplains for 1952 and 1980 river courses respectively. By superimposing the river courses during this period their temporal and spatial variations are well justified (Figure 6). The period from 1807 – 1980 shows a gradual rate of encroachment over the Yamuna river floodplain when compared to period from 1980 – 2014, which shows a rapid incursion of the urbanization over the floodplains.

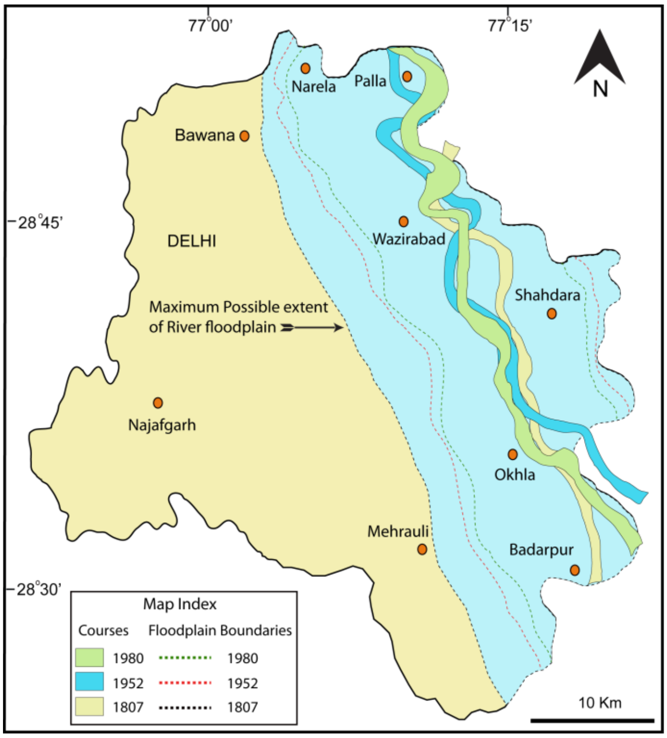

Fig -6: Map showing the temporal changes in the river courses and maximum possible extents of the associated floodplains for years 1807, 1952 and 1980; digitized from the toposheets compiled from Survey of India. River courses from year 1807 - 1980 are adopted from reference [8].

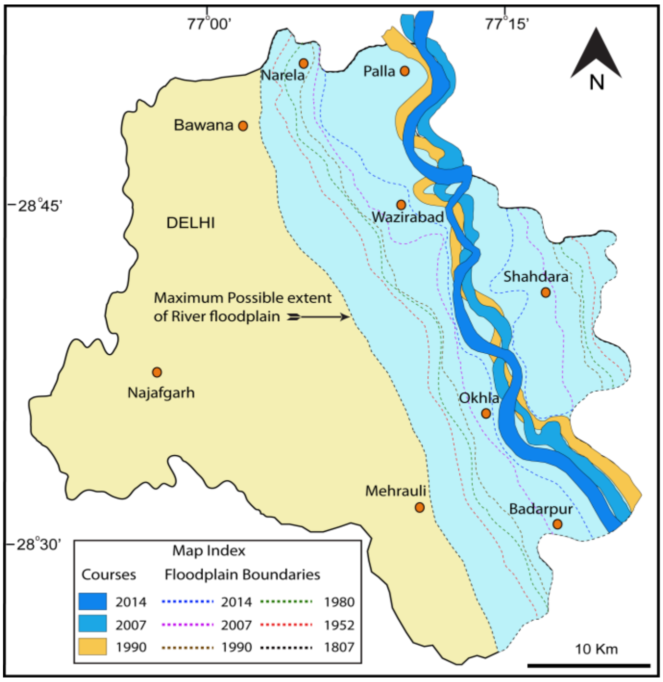

Fig -7: Map showing the temporal changes in the Yamuna river courses for years 1990, 2007, 2014 and maximum possible/ visible extents of the associated floodplains for years 1807, 1952, 1980, 1990, 2007 and 2014; digitized from the toposheets compiled from Survey of India, IRS 1C LISS III imageries and Google Earth images.

The topographic maps and the satellite images of Delhi region from 1980 to 2014 indicate temporal variation in channel geometry and the position of the Yamuna River, which have been well explained with reference to river migration plains in the previous sections. In figure 7, the temporal and spatial variations of the river courses and their corresponding floodplain boundaries are well illustrated. Encroachment over the floodplains or in other terms the available active floodplains during the years 1990, 2007 and 2014 are marked by the brown, pink and blue dotted lines respectively. Here it is easily observable that after 1980 the remaining floodplain areas were rapidly occupied by the settlements, civic structures, roads, bridges, flyovers, playgrounds and metro stations upto the present time.

Due to non availability of the floodplain in the present scenario, the excess discharge in the river during seasonal rainfall or by other means would not be able to spill over the levees and get wasted by flowing downstream through its channel. Thus the largest reservoir of the fresh groundwater underneath the floodplains would not be recharged through infiltration during the period of flooding, as flooding is the most efficient natural process for recharging the aquifers. Unplanned land-use and increasing urbanization in the periphery of the Yamuna River floodplains is a curse for Delhi region because of two major reasons (a) Delhi doesn't have any better options for obtaining groundwater except the floodplain areas (b) Due to increased urbanization, aquifer neither can be recharged through the floodplains during the flooding nor through run-off during the rainy seasons.

Under such circumstances, people shall remain totally dependent on the remaining aquifer resources until unless it starts providing saline water. Over-exploitation (over-pumping) to fulfill such a huge requirement of Delhi region will further worsen the conditions. Groundwater table has been already depleted upto a greater extent in most of the districts of Delhi. According to a comparative study on groundwater levels in Delhi, the southern regions show effective depletions; water level which was at 20 to 30m below ground level in 1960 has gone down to 30 to 45 meters below ground water level in 2002 [1, 13]. As a consequence, south and south west districts of Delhi have acquired continuously dropping deeper water levels. As per CGWB data, nearly 50% wells of south district shows depth to water level more than 40 meters below ground level and nearly 35% wells show depth to water level in the range of 20 to 40 meters below ground level [2, 3, 5]. Decadal pre-monsoon water level data has suggested that nearly 95% monitoring stations shows decline in water level in the range of 0.08 to more than 20 meters as compared with 10 year mean of May water level. Thus water level studies from all the major blocks concludes that the maximum fall has taken place in the South and South-West districts, where the decline of more than 20 m has been observed in Mehrauli block [5, 6, 7, 11]. A serious concern to the capital is that the groundwater level is depleting continuously in all the regions except along the Yamuna river basin. Groundwater level is depleting with rates varying between 1 to 4m per annum. In few pockets in the district, the rate of decline has been recorded to be 3 to 4m per annum, which is really an alarming condition for Delhi [1].

5. CONCLUSION AND DISCUSSIONS

India's capital Delhi has been encompassed serious problems due to scarcity of groundwater. The recharge zones are very limited and that too not having any effective enriching source except the annual rainfall and the Yamuna River. The most valuable recharge zone is the floodplain of the Yamuna River but unfortunately it has been extensively used for the settlements/ urbanization and thus squeezed up leaving a paltrier area for recharging groundwater reservoirs. Since 19th century, continuous encroachment over the floodplains of the Yamuna River has resulted into the constriction of the most suitable recharge zone of the capital. The water level in the Yamuna River remains usually low throughout the year except in the rainy season due to which the recovery periods for the groundwater aquifers are very long in comparison to a high pumping (discharge) rate. As a consequence, Over-exploitation (Over-pumping) of groundwater especially over the occupied floodplains caused the compaction of the underlying sediments that has been resulted into ground subsidence at many places due to collapse of the groundwater reservoirs or aquifer disposition. Aquifers have already exhausted in terms of water storage. In spite of depletion known to everybody, no remedial measures to increase groundwater storage are taken, rather many parks and open lands have become sites of concretization. Thus the overall sequence in hydrologic cycle has failed, which is really a calamity. We are dependent on the water supply from the neighboring states in Delhi and this supply depends upon give and take relationships. Geomorphologically the floodplain is the only expectation for the present needs of groundwater for Delhi region. Floodplain is the resort for the fresh groundwater within the shallow aquifers.

Scope of fresh water availability left only with the shallow aquifers has already drastically reduced due to over-exploitation. An unplanned installation of numerous tube wells has also resulted in the heavy overdraft and overdeveloped shallow groundwater resources. Fast urbanization and developing agricultural practices have further led stress on deeper aquifers with brackish water. Availability of fresh water can only be expected in shallow water aquifers gets recharge over a vast area during occasional floods. Farmers in the area pray for the flood in the Yamuna River for accentuating the groundwater situation in the region for several years.

All these situations warrant a careful hydrogeological study of the area in order to delineate and exploit the fresh groundwater aquifers. Since the area comes under the catchment of Yamuna River, identifying and delineating features such as older and active floodplain, palaeochannels and meandering channels etc. are essential in terms of hydrogeological evaluation. No systematic study is available on relation of Yamuna drainage system to the disposition of shallow fresh water aquifers in the area. Further there has not been substantial thinking on the lines of finding remedial measures to the water depleting situation. Thus the present study provides a better hydrogeologic picture by delineating the floodplains of the Yamuna River since 19th century, that can further direct towards the sustainable groundwater augmentation and management practices in the area.

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BIOGRAPHIES

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(Late) Prof. V N Bajpai, Prof. Bajpai was a Professor of Hydrogeology and Remote Sensing at Department of Geology, North Campus, University of Delhi. He has published number of quality papers in his field. His work has been recognized and appreciated at the international levels. He has left us in 2014.