Geo-hydrological Study of Gorakhpur City, U.P, India

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CONCEPTUAL BACKGROUND

The seed of urbanization was germinated in ancient period around 2500BC in the Indus Valley but the urban centers of those periods were small in size and number, with narrow streets, small population, surrounded by rural society and vast agricultural fields.[1] During post industrial revolution period, the urbanization grew in concomitant with industrial development .Later on; during twentieth century it achieved its high acceleration due to growing impact of Technological and scientific development, industrialization, modernization and changing behavior of human life. During this period, not only in India but all over world, specially developing countries, have experienced a very high pace of urbanization from spear headed by push migration from rural areas to urban centers because urban areas have set up a tremendous magnetic pull factors like more and better employment opportunity, better living conditions, availability of basic civic amenities and as the central place, availability of various socio-economic, political, administrative and cultural activities and services. Thus a large number of big urban centers have sprung up and urbanization became and universal phenomena. Now urban centers are influencing directly or indirectly all human activities, developments and organizations.[2]

The role of urban centre as center of multi activities is pertinent enough in regulating the system of economic transition, challenging the resource mobility. Therefore, urbanization is being accepted as a way of life, a condition of man characterized by certain attitudes, a mode of behavior, essential part of socio-economic development as well as an important index of national progress and prosperity of human society.[3]

The migration of population to urban center gave impetus to the growth of urban centres of all size and the influx resulted the growth of size and extends of urban centers by process of outward extension of the structure along with internal reorganization of space during twentieth century.

On the other side, the population growing with fast pace in the cities adds a very heavy pressure on the land and other available facilities and services which originated various socio-economic, infrastructural and ecological problems like shortage of shelters, transportation, water supply, drainage, disposal of solid and liquid waste, shrinking area of parks, playground and open spaces, water logging, health, sanitation and educational services and over all to the pollution and unaesthetic environment. The rapid urbanization especially in developing countries like India has reached in such a dimension that the scientific analysis and proper efforts for solving the complex urban problems and for balanced urban development is a prerequisite for which the study of Geo-hydrological features of the individual urban centre is essential.[4]

The geomorphologic and hydrological aspects of studies are of great significance for selection of urban sites, their development, infrastructural development management and planning. The urban geomorphology is the study of land forms, relief, topography, ground surface conditions , geomorphic processes, sediment system, process, pattern and material of weathering and erosion, epeirogenesis movement, natural hazards and geomorphologic fragile zones such as unstable hill slope with week Lithology and surface,[5] where as urban hydrology is concern with surface and subsurface hydrological conditions. Both are very essential to

determine the size, rate of urbanization, stability of urban locality, to assess the impact of urban development on environment as well as for development planning and management of urbanized area and for planning of the areas where urban growth is expected. Thus urban geo-hydrological study can play two fold roles in urban development i.e. (i) prior to urban development, the survey and study of terrains, their classification and other features for identification and selection of suitable location for new urban centres and (ii) for old urban centres to assess the effect of development on environment, impact of natural events on community and the remedial measures for mitigation of their effects.[6] The proper management and planning of the urban centers requires a comprehensive survey and study of the physio-cultural features of the urban center in general and major problems in specific. In the present study, these aspects has been descrived for the purpose to analyze the various geo-hydrological problems of Gorakhpur city and to suggest some of their solutions.

Aims and Objectives:

The main objective of the present study is to assess the geo-hydrological conditions of the study area and their role in recognizing and mitigating the physical and anthropogenic problems manifested in the city. Besides this, the sub-objectives are:

1. To identify the underground structure and Lithology of the study area for which attempt has been made to make the cross section of the various points for showing the composition and structure of underground strata.

2. Gorakhpur city is facing the problem of water logging specially in rainy season because during rainy season general elevation of city became deeper than the water table of river Rapti and Rohin. These temporary anomalies in heights disturb the natural pluvial character of the city. Therefore, one of the objectives of the study is to analyze the general slope and direction of topography at micro level.

3. To draw a map to comprehend the pluvial nature of city showing the major and tributary drains and water bodies through which the liquid waste, storm water and sewage of area is being disposed off.

4. To trace the impact of changing land use pattern on natural water bodies of the city

5. To comprehend the spatio-temporal behavior of climatic elements to presume the feasible impact of climatic change on the city

Methodology

The methodology and techniques employed in the study are based on the identification and assessment of geomorphic factors influencing present land use scenario of the city. The present study is primarily based on the ground survey, though some secondary data has been taken in support of analyzing and comprehending the geo-hydrological condition of the city. The patterns thus emerging have been mapped by cartographic technique using GIS tools supported by diagram .

First of all a base map of city having the boundary of municipal Board, boundary of wards (sub-units) and superimposed with road map has been made. The main objective of this study is to analyze the terrain

and hydrological features of the Gorakhpur city in which the relief, hydrology, slope and drainage have been studied. The relief has been analyse on the basis of contours drawn with the help of SRTM data, spot heights taken with GPS and supplemented by the information about spot height and Bench Marks and contours drawn on the topographical and guide maps published by Survey of India (SOI). The available SRTM data have been verified by collecting the data of geo-coordinates and elevation of more than 200 spot selected all over the city. The selected spots have been earmarked on the base map and the areas were visited for collecting the ground data about spot height, location of drains, water logging area and places of water bodies.

On the basis of the relief map, the slope analysis has been done. A final map representing the isopleths of equal degree and percentage of slope have been made to present the amount of gradients and direction of slope.

The changing pattern of climatic condition especially temperature and precipitation of the city has been analyzed from the data of 35years collected from meteorological department and other sources. To apprehend the impact of climatic change especially the temperature and moisture contain in the atmosphere, climographs of different time period have been made.

Regarding the aquifer condition of the study area the subsurface information in the form of strata chart of different tubewells wells has been colleted from the 'Jal Nigam' department of Gorakhpur. These data were

finally computed and plotted in lithologs to show the aquifer condition in the different parts of the city.

To present the location of main open drains and sub drains with there direction of slope, a map has been drawn. A separate map representing the old lakes, tanks, ruminant of river channel which are the sources of the collection of the rain water and recharging the under ground water has been made presenting their spatio-temporal location. In this context the topographical sheets, developed by SOI of different period since 1916-17 have been consulted. Besides these, satellite image and ground surveyed data were also used.

Organization of work

The entire work has been organized into three sections and conceptual background of the study and summery and conclusions are in the beginning and in the last respectively. The conceptual background, which deals with concept of geo-hydrology and its application in urban planning. Aim and objectives of this study and method have been also described in the outset. The first section, Geographical personality of the study region consists of general geographical feature especially location, origin and growth, major relief and climatic conditions, their changing pattern, morphology and demography of the city. The geomorphologic characteristic such as relief and its characteristic, slope and Lithology of the city are the core points of section second. The third section, hydrology of the region give emphasis on drainage system, impact of shifting of channels of rivers on the relief, floods , spatio- temporal analysis of the

water bodies, number and direction of drains have been analyzed. The finally the work ended with summary and conclusion of the study.

Section I

Geographical Personality

Location

Gorakhpur city, the head quarter of the tahsil, district and the division of the same name, lies 83° 20′ to 83°27′E longitude to 26° 43′ to 26° 50′N latitude and on the confluence of Rapti(old known as Achirawati) and Rohin (Rohini) Where Rapti comes from west and Rohin from north and both farm the western boundary of the city (Fig.1).

After confluence to Rohin, Rapti took right angle turn and flow south word making the western boundary of the City is located in the north-east part of trans Saryu plain (north-east U.P.) of middle Ganga valley. It is biggest town (population 622701) after Varanasi (population 1103952) in the east U.P. It is a major center of socio-economic and commercial, cultural and administrative activities of north eastern U.P.. To the north -east of the city a large lake named Ram Garh Tal lies and on the east lies a forest tract of kushmi. City is 815 km. north-west from Kolkatta, 272 km. north-east from Allahabad, 232km north from Varanasi, 262km east from state capital,as well as Lucknow. The roads radiate from the city to Nautanwa and Sonauli, Maharajganj and Thuthibari (both up toIndo- Nepal border) Kasia (Kushinagar), Gopalganj to Assam in the south-east to Deoria Siwan-Chapra- Kolkatta; Barhalganj –Allahabad/Varanasi in the south and Lucknow, Kanpur ,Delhi in the west. The city is well connected by road and railway from the major cities of the country where as Kolkatta, Lucknow, Delhi are connected with air routes. Delhi-Kanpur-Gorakhpur-Barauni- Guwahati/Kolkatta main line of northern north east, central north east, and north east frontier railway traverse the city from east to west with

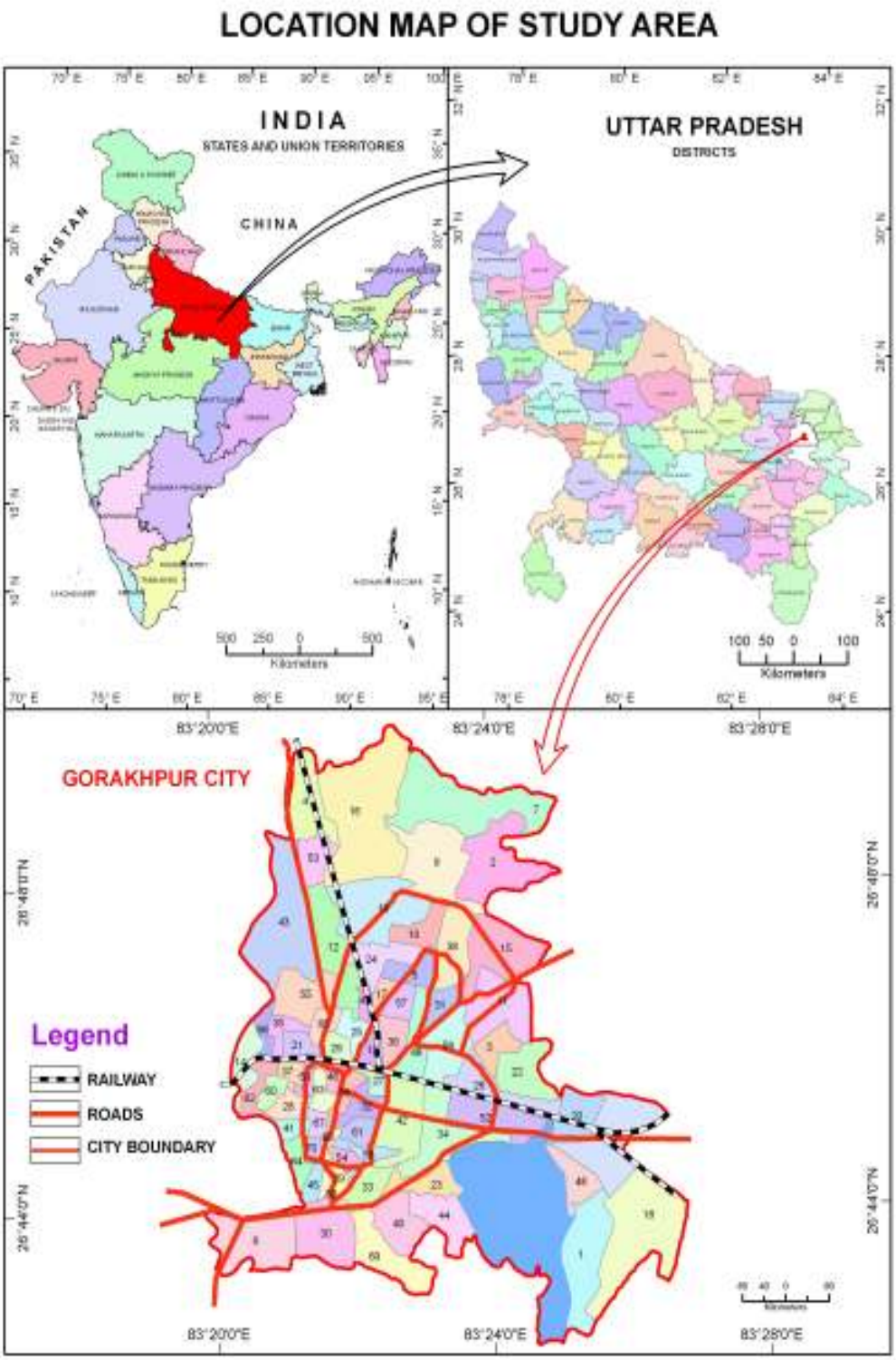
LOCATION MAP OF STUDY AREA
INDIA
STATES AND UNION TERRITORIES
PAKISTAN
CHINA
UTTAR PRADESH
DISTRICTS
GORAKHPUR CITY
Legend
RAILWAY
ROADS
CITY BOUNDARY
Kilometers
83°20'0"E
83°24'0"E
83°28'0"E
26°48'0"N
26°44'0"N

Fig.1

Domingarh–Gorakhpur- Gorakhpur cantt. Two branch lines run north ward to Nautanwa and Gonda while other one broad gauge runs north Bihar (Fig-1). The total area of the city 136.85 km^2. But table No.1 shows that the area of the city was 26.45km^2 in 1901, 38.85 km^2 in 1941 and 136.85km^2 in1982. With the extension of the area the numbers of the wards are also increasing which was 15 in 1961, 17 in 1981, 30 in 1991,60 in 1995 and now city has been divided into 70 wards (Fig.2.)[7]

location

Gorakhpur city is situated in Ghaghra- Gandak Doad which is a part of vast Gangetic Plain. It is made off the alluvial filling in Gorakhpur trough extending to a depth of about 6000 meters which gradually decrease to 3000 meters in the south near Ghaghra River[1]. *Khadar* (new alluvial) and *Bhangar* (old alluvial) are dominant lithological constituents of the area. The city is almost a featureless plain but there are some local topographic variations due to shifting of the river channels. The ox-bow lakes, tal and remanents of river channels produce a little heterogeneity in the physical land forms of the city. The average height of the city is about 80 meters above the sea level. The general slope of the city is towards the south and south east. A detailed study of the, topography, slope and Lithology of the area have been presented in the next section.

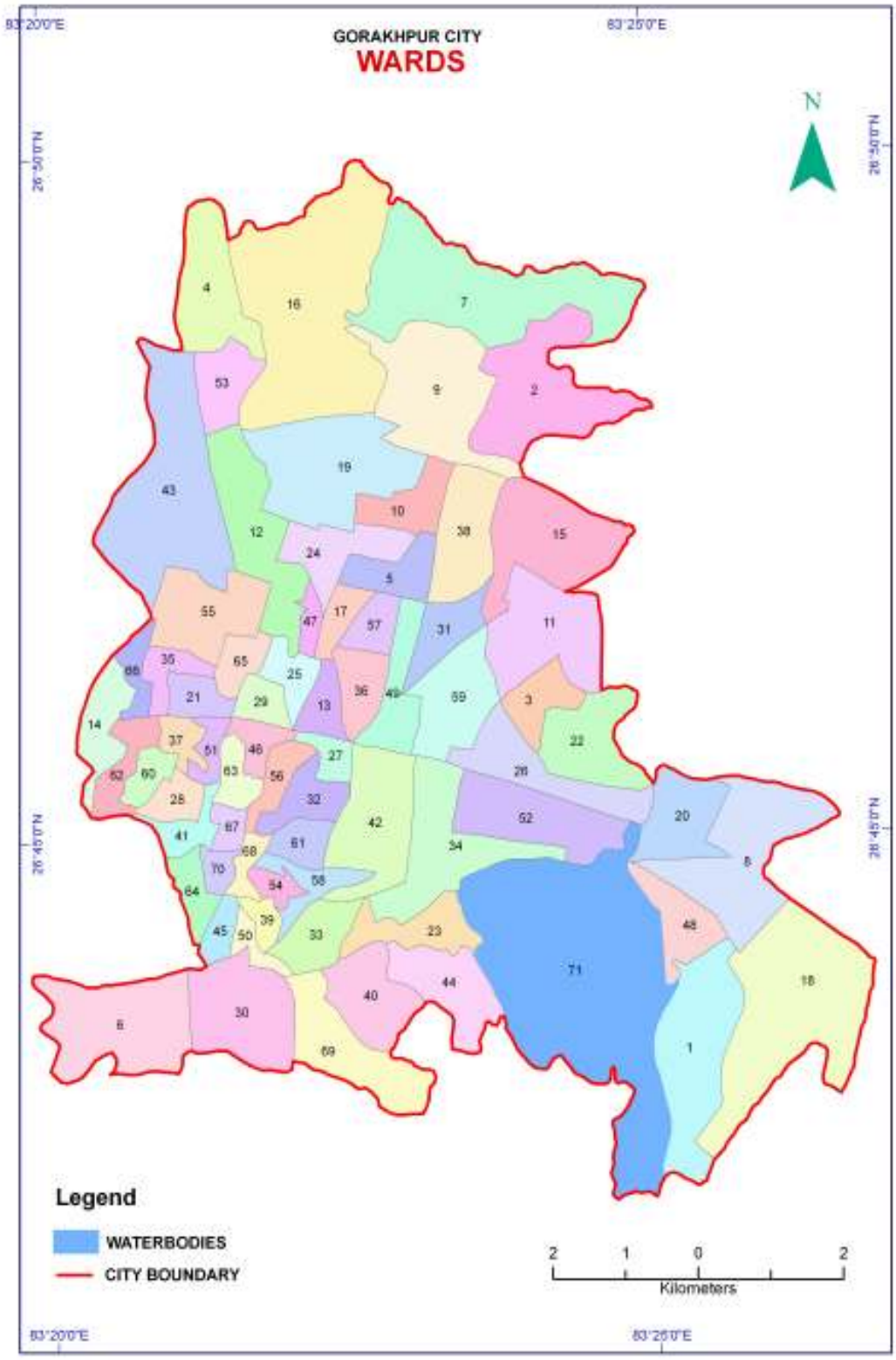

Fig.2 The name of the wards is given in the appendix I

History:

The city is said to drive its name and fame from renowned saint Goraksha Nath, Popularly known as Gorakhnath, a guru in the Nath Yogi Sampradaya which is also known as Siddh Yogi or Avadhut-Yogi Sampradaya Who came here in 9th century AD when the region was ruled by Deopal, king of west Bengal (810-850AD) and started practicing austerities on the spot where the famous temple named after his, stands[9]. In ancient times there was a shrine of Goraksha Nath, a local deity here which was located at left bank of river Rapti in four century BC. When the Rapti was flowing through center of the city following the path to Ram Garh Tal[10]. (Fig. 3)

During epic period, the region was covered by present Gorakhpur region (Basti and Gorakhpur Division) was known as karupatha which was a quiet calm and beautiful region and was part of the kingdom of Kosala, an important center of Aryan culture and civilization[11]. At this time city was originated in the North centre of the present city near present temple of Gorakhnath. The present purana Gorakhpur, Madhopur and Jatepur are the oldest settled Mohallas of the city which remanents are still found in the respective areas. After that during 900-950 AD Man Singh or Madan Singh became the ruler of the region and settled the city south of old city. By the time of Akbar, Gorakhpur has become a large town .The Gorakhpur got it extension in southern part around Urdu Bazar, Mian Bazar and became the head quarter of Gorakhpur Sirkar in the Subah of Awadh till British occupation (Fig.4). In about 1650 Basant Singh built a fort on the bank of Rapti in Basantpur Mohalla and established his stronghold.[12] After that, Aurangzeb and his son Muazzam visited the city and establish a new

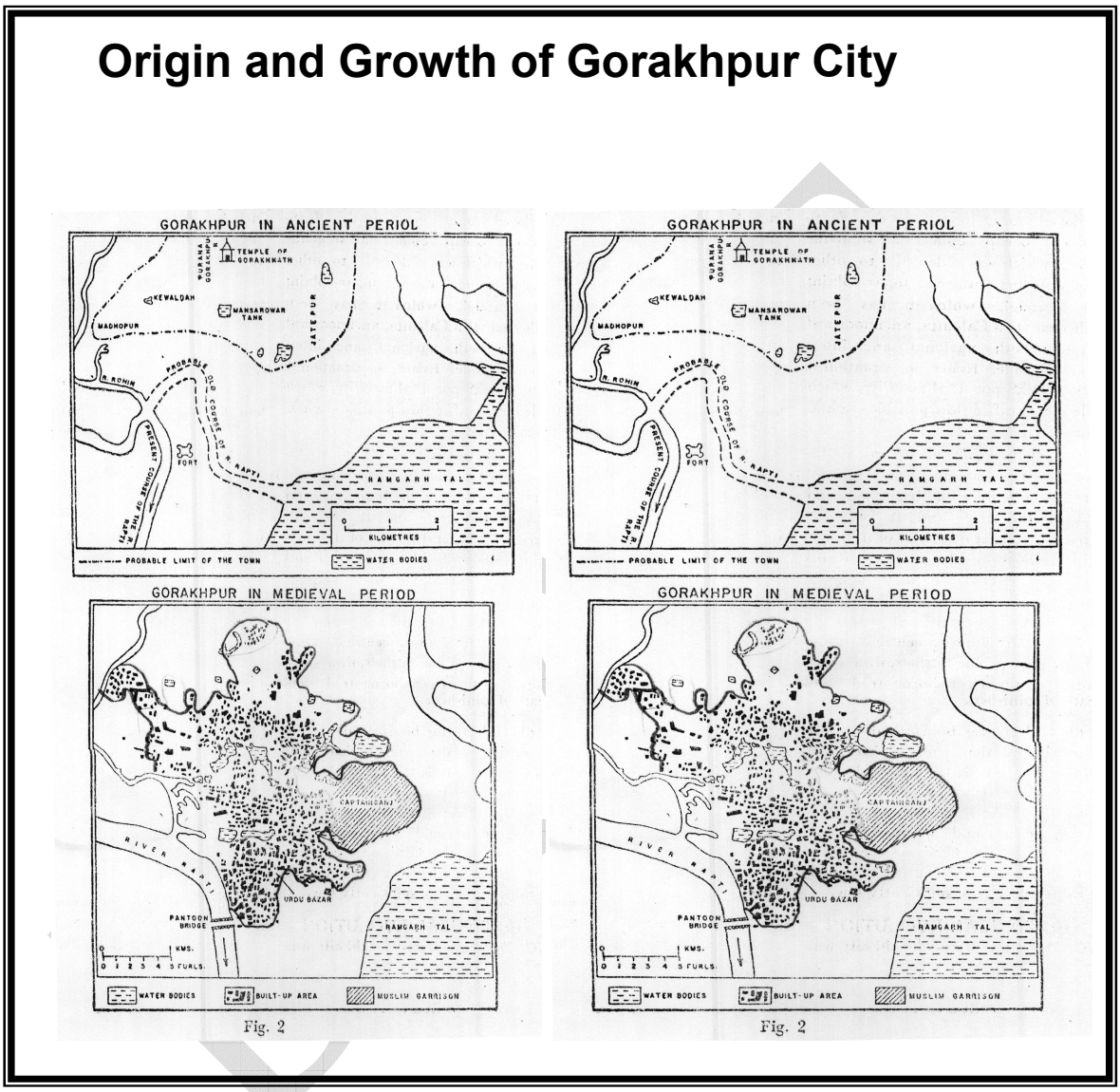

Fig 3

Mohallah Mazumnabad. In 1801 Sadat Ali Khan, the *Nawab* of Awadh handed over the city to British who made it the district headquarter and

the original civil station was established in Captainganj Mohalla which is at present civil lines.

Gorakhpur became military station in 1810 and a cantonment was established in the east of city. Some of the East India company's troops were brought here from Faizabad and shortly some officers started shifting from Captainganj to settle in cantonment area. The Fig. 4 presents the temporal development of city since ancient period to the modern period.

On September 7, 1869 the city was raised to the status of a Municipality and in 1891 it became Head Quarter of division of its name. After introduction of railway in 1884, a wide space of north and N.E part of then city near Railway station, Railway colonies Baulia, Dairy and Bichhia colony was developed and on the some space railway offices and railway loco workshops were constructed because city became the Head Quarter of N.E, Railway .

In the present, city is developing and expanding very fast in two directions - the east and North & North- East because in south and west direction there is limited scope of development due to River Rapti in west and depression and water logging area in south.

In 1982 the city became Municipal Corporation and in 1977 Gorakhpur Development Authority, an statuary and autonomous body was established for the development of the city and 47 villages of the fringe area were included in the boundary of the municipal corporation which extended the total area of the city from 30.85 km^2 to 136.85km^2(Table 1).

Sprawl of Gorakpur City

(Since ancient to present period)

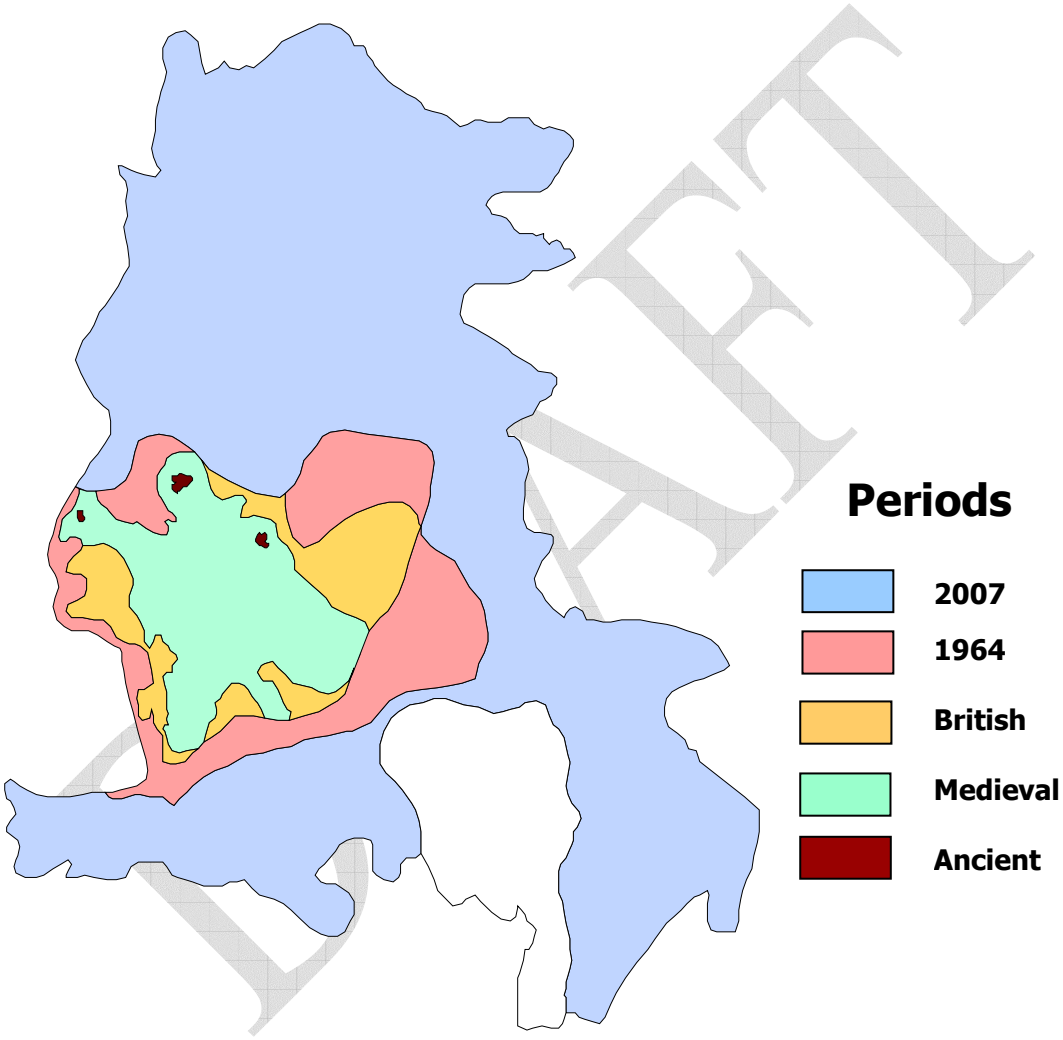

Fig 4

Table 1 Gorakhpur City :
Horizontal Expansion, Population Growth and Density

Years	Population	Decadal growth in %	Area in sq km	Density/ sq km
1901	64,148	-	26.45	2425
1911	56892	-11.31	26.45	2151
1921	57985	1.92	26.45	2192
1931	75644	30.45	26.45	2860
1941	95127	25.75	38.85	2448
1951	132436	39.22	38.85	3409
1961	180255	36.11	38.85	4640
1971	230911	28.10	38.85	5944
1981	307501	33.17	38.85	7915
1991	505566	64.41	136.85	3702
2001	622701	23.61	136.85	4559

Climate:

The climate of the city is moderate. Its average temperature is 25.68^0c but average maximum temperature is 31.95^0c where as average lowest temperature is above 19.57^0 c and the city receive an annual rainfall above 119.2cm.

The year may be divided into four seasons. The cold season from mid November to February is followed by the summer season from March

to mid June. The period from Mid June to end of September is the south west monsoon season and October to mid November the post Monsoon season. From the mid of November, there is a rapid fall in temperature and January is coldest month with the mean daily maximum temperature at 22.8^0 c and mean daily minimum temperature at 9.3^o C . In association with cold waves in wake of western disturbances passing east ward in winter season, temperature tends to go down to a degree and above of the freezing points. Day temperature begins to rise rapidly after February. May is the hottest month with mean daily maximum temperature at 38.4 ^{o} C and mean daily minimum at 25.1^o C. With advent of the monsoon by about the middle June there is appreciable drop in the day temperature. In September there is a slight increase again in day temperature. With the withdrawal of monsoon by the beginning of October temperature decreases progressively.

The city is experiencing the increasing trend in temperature. It is obvious from the figure-5 that till 2003 the temperature (average annual, maximum and minimum) remained unchanged because there was no much change in the various components of climate.

But after 2002, though the annual average temperature is unchanged because it is around 25^0c. But the annual maximum and minimum temperature have a pattern of continuous changing. It is apparent from the fig.5 and table-2 that since 2002 the annual maximum is consistently increasing. It was 30.6^{0c} in 2003 but now it is 33.51 in 2008. Thus there is

Table 2 Gorakhpur City Climatic Characteristics

Years	Average Temperature in centigrade			Rainfall in mm
	Max	Min	Avg	
1991	31.69	19.27	25.48	1246.9
1992	30.34	19.02	24.68	778.0
1993	31.76	19.22	25.49	620.8
1994	32.11	19.52	25.82	716.0
1995	32.13	19.56	25.85	1265.4
1996	31.67	19.54	25.61	1127.3
1997	31.23	19.11	25.17	667.0
1998	30.91	20.29	25.6	1265.2
1999	31.32	19.98	25.65	694.7
2000	31.37	19.02	25.19	1047.5
2001	30.71	19.63	25.17	1323.9
2002	31.45	19.63	25.54	449.3
2003	30.6	19.2	24.9	671.8
2004	33.6	17.41	25.51	959.9
2005	35.73	16.5	26.12	1103.1
2006	35.98	15.31	25.65	868.2
2007	35.53	15.69	25.61	1375.9
2008	33.51	15.98	24.75	1940.8

Sources: Meteorological department, Gorakhpur

about 9.51% growth in maximum temperature durind2003-2008, where as the annual minimum temperature recorded a decreasing trend. In 2002 it was 19.63^{oc} but now it is 15.98^{0}c. Thus there is 22.84% decrease in the minimum temperature during 2002 -2008. Hence, summer and winter both are becoming more severe than previous. Summer season is being hotter and winter comparably more cold.

Gorakpur city
Temporal Variation in Temperature (in centigrade)

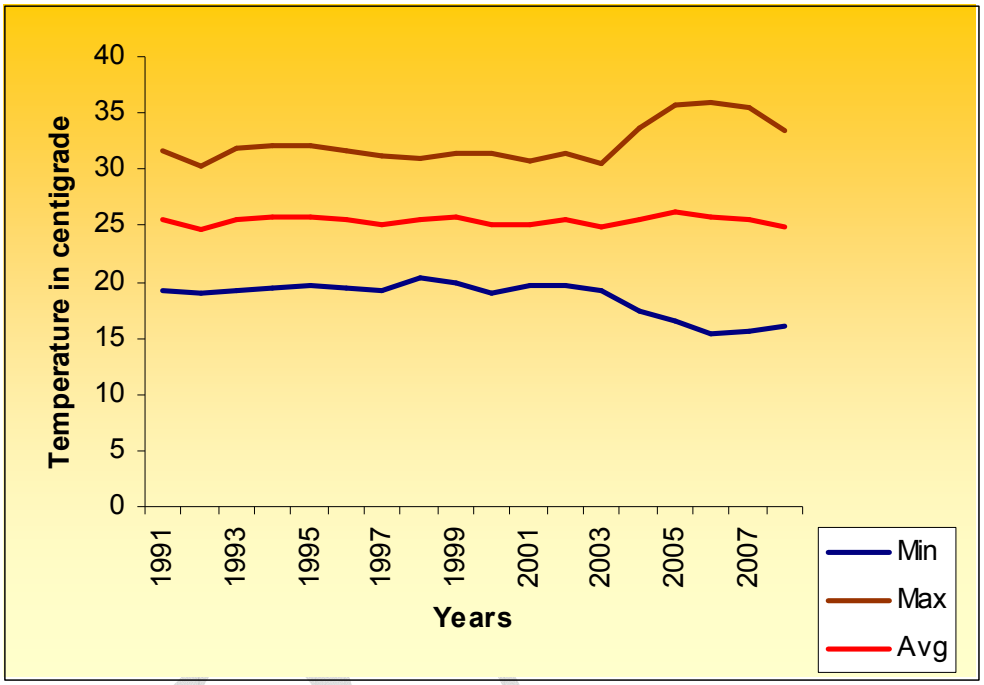

Fig. 5

The south west monsoon usually arrives over the city by the middle of June and withdraws by the end of September. As about 87 per cent of total rainfall is recorded during this period. August is the rainiest month of the year. Figure-6 Shows that there is a marked variation in annual rainfall since 1975. It is continuously increasing except in 2002, 2003 and 2006. In 2001 the total rainfall was 132.4 cm. but in 2007 it was 137.6cm and in 2008 it was 194.1cm. Thus the heaviest annual rainfall was recoded in 2008 which was 62.83 per cent more than the normal. Thus, the analysis of the data of precipitation reveals that the amount of rainfall is continuously increasing (Fig. 6)

Gorakpur city
Temporal Variation in Rainfall (in mm)

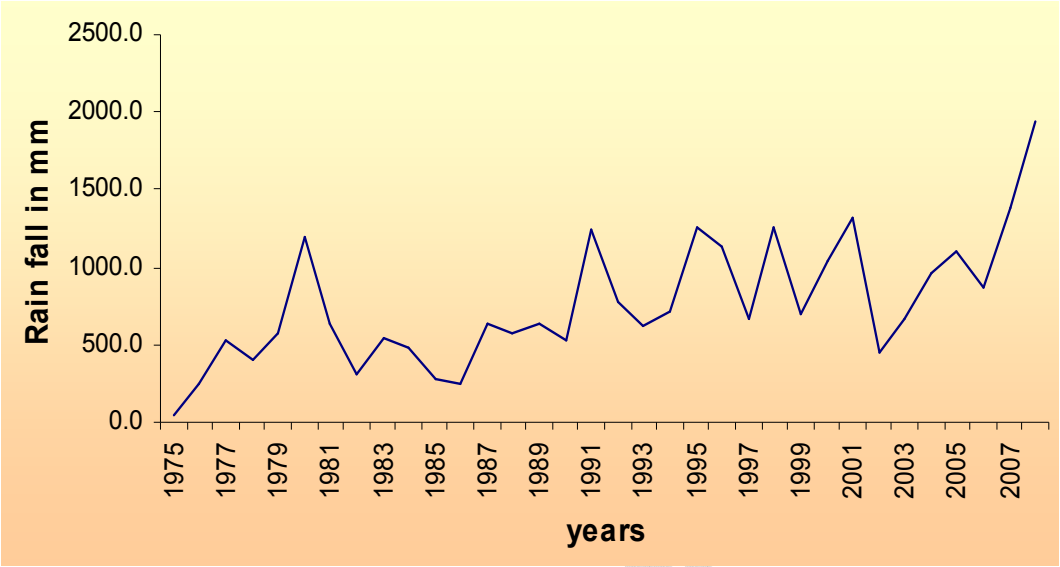

Fig .6

During the rainy season the amount of rainfall depend upon the number of rainy days too. The normal average annual number of rainy days (day with rain of 2.5 mm or more) is 54 days but it varies year to year. The occurrences of rainy days since 1975 are presented in the fig. 7. It is apparent from the figure that the number of rainy days is not uniform during the period 1975-2008. In 1998 the number of rainy days was highest (100 days) but there was a short fall in the rainy days in 2001. Again it has increased in 2002 and reached as much as 92 days. The number of rainy days as obvious from the figure 7 is quite undulating. After a decrease in year 2003-05 it has increased in 2008. Therefore, an abnormal growth in the the number of rainy days has been experienced after 1998

Gorakpur city
Occurrence of Rainfall

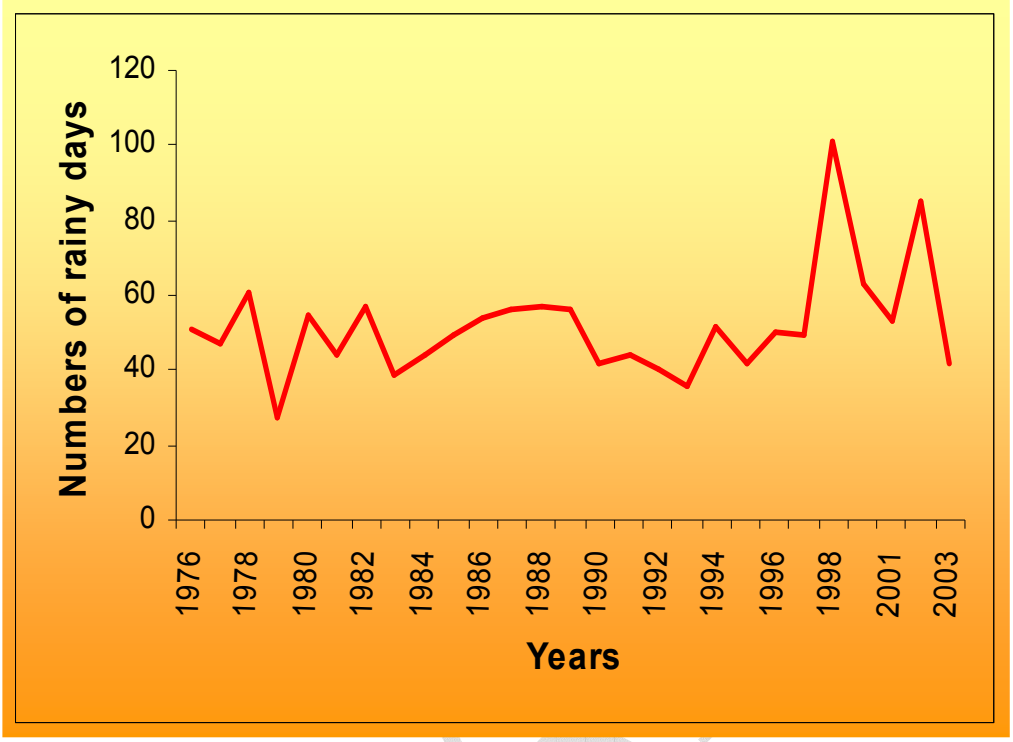

Fig 7

Climograph :

Climograph, is a diagram presenting some variables of climatic factors of particular place, was introduced by Griffith Taylor in the second decade of 20th century. This diagram shows the interrelation between two variables, wet bulb temperature and relative humidity as monthly average. It was devised to show the scale of habitability for European settlers within tropics. A tentative scale of discomfort has also been suggested by Taylor which can be mentioned on the diagram. Along with that, the graphs approaching the four corners indicate discomfortable climate.

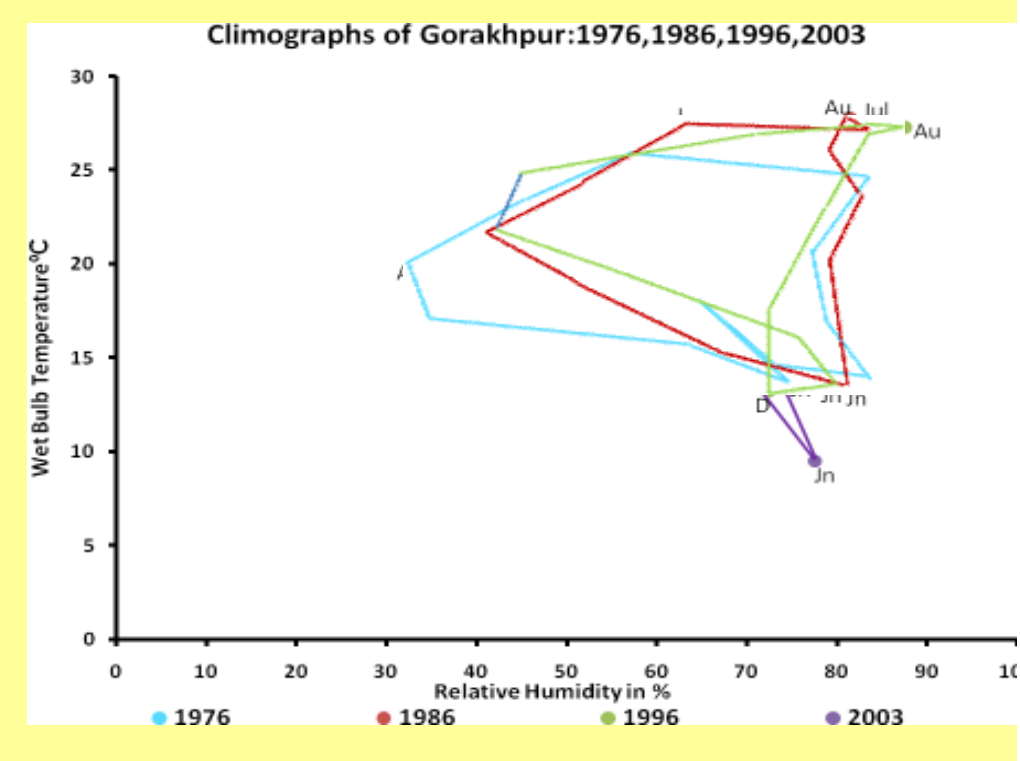

Fig.8

The Climographs of Gorakhpur city have been represented in the fig.8 for four years-1976,1986,1996 and 2003 which are confined to North-east corner, called Muggy and temperature are between 15^0 to27^0. Thus according to the scale of discomfort, the city is within "often comfortable" area. It is also apparent from the figure that the graphs of the late years retreating towards Y axis due to decreasing the relative humidity of October to January month. it presents that the dryness during post monsoon is increasing . It is a significant sign of climatic change of the city.

Demography:

Population Growth: The city has a total population of 622701 in an area of 136.85km^2, yielding an overall density of about 4559 person/km^2

which is quite high. In 1901 the population of the city was 64148 which reached to 57985 in 1921 recording a decrease of 9.6%. The population became 95127 in 1941 recording 64.05 percent growth during the period of1921-41. The population has increased by 143 per cent during 1941-71. But even more faster during last three decades with a record growth during 1981-1991(66.7 percent) and a moderate growth during last decade, 1991-2001(23.16 per cent). Table 1 and Figure 9 shows the growth of the population in the city during last 10 decades.

It is obvious from the fig.9B that after 1921, there was a sharp growth in the population of the city because some of the villages of the fringe were classified as urban and were included in the city boundary. Thus, their population was included in the population of the city. Like wise a remarkable growth of population was recorded during 1981-91 because 47 adjacent villages were incorporated within its boundary. Thus 64.1% of population growth was experienced which was a record growth of population since ever.

The growth rates during different decades have been presented in Fig.9A which shows that there was a decreasing trend of growth till 1921. After that since 1921-81 the population growth rate was constant about 30% per decade but a higher growth during 1981-91

Gorakhpur City
Population Growth

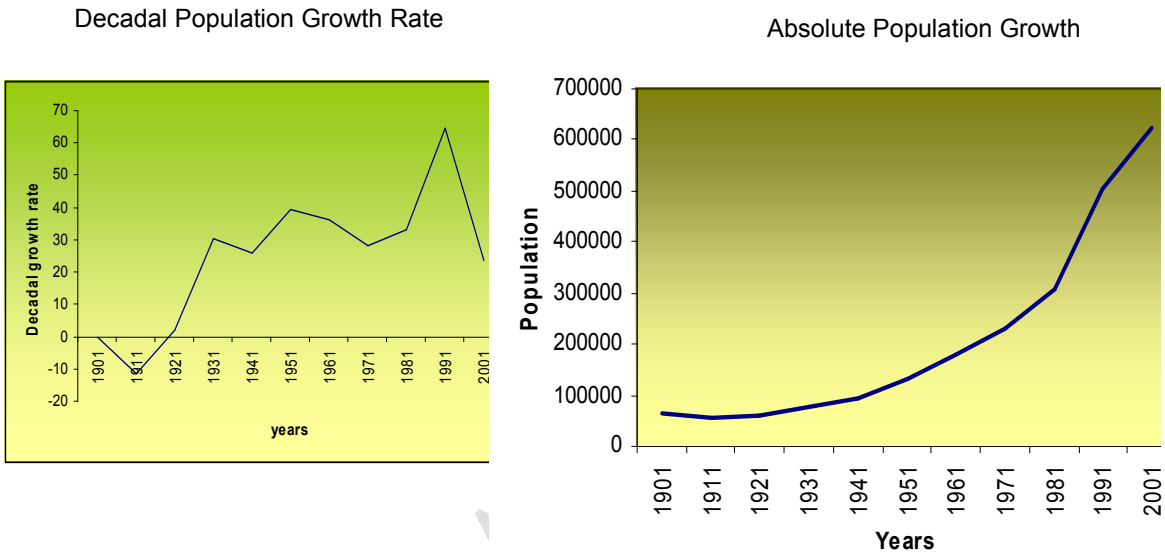

Fig .9

Population Distribution: The distribution of population within the city is very uneven. The distribution of population has been presented in Fig.10. It is evident through the figure that a very dense population is found in the area of old city which is in central west part of the city. The population became sparse toward the outer side.

Thus, the population decreases according to the distance from the city centre in all directions from city centre. Along the northern and eastern boundary of the city the population concentration is least.

Gorakhpur City

Distribution of Population 2001

Fig 10

The population of density has been presented in Fig.11 which shows that the population is concentrated in western and south west mohalls. These mohallas are early settled namly Khunipur, Ghasikatara, Muftipur Turkmanpur, Chotekazipur, Basantpur, Urdu Bazar, Alinagar and Mian

Gorakhpur City
Density 2001

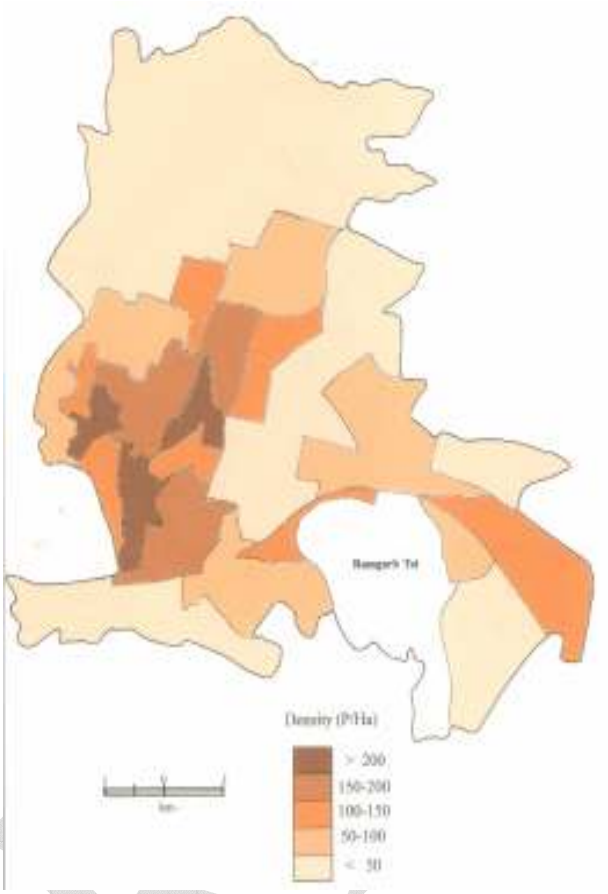

Fig.11

Bazar, Zafra Bazar and Dharmshala Bazar which density is more than 200 persons per hac. The area having the population density between150-200 persons/Hac is situated around the densely populated mohallas. The areas having the average population (100-150 per./hac.) are Daudpur, Shahpur, Basanpur, Mirzapur , Kazipur and Jharkhandi. The area with low and very low population density are in the outer zone of the city specially in north , north east , south west and east of the city.

City Morphology - The morphology of city includes the internal and external structure of the city. Like other city of the country, the growth and development of the city was unplanned. The city gets its origin in the north and then after southern portion was inhabited. Now the southern part became the main city. The morphology of the city is the product of relief. As changing course of river Rapti in the west in south and ramgarh tal in south east and presence of depressions restrict the growth of the city in respective directions where as in east due to Cantonment, Aerodrome and forest city growth is not possible. Only in the north along Nautanwa , Maharajganj and Pipraich road and in south-east along Deoria road beyond Ramgarh tal, there is the scope of development due to availability of open/agricultural land. Therefore, the city is expanding in these directions only.

The Fig. no.12 shows the land use of 2007 of the city. The share of the land in different uses and their ratio is sown in table-3. It is very obvious from the figure and table that the major share of the land (72.10 % of the total area) is in residential use, where as area under public and semipublic services and facilities and industrial pursuit were 7.01 and 7.82 respectively and the rest land use has minimum share of the land. Residential areas are developing very fast along Gorakhpur-Nautanwa upto Chiluatal, along Maharajganj Road up to medical college, on Pipraich road up to Padri Bazar and on Deoria road up to khorabar. Big residential colonies came into existence by GDA, Avash Vikash Parishad and private colonizers between Deoria road and Deoria bypass. Being an important center of commerce

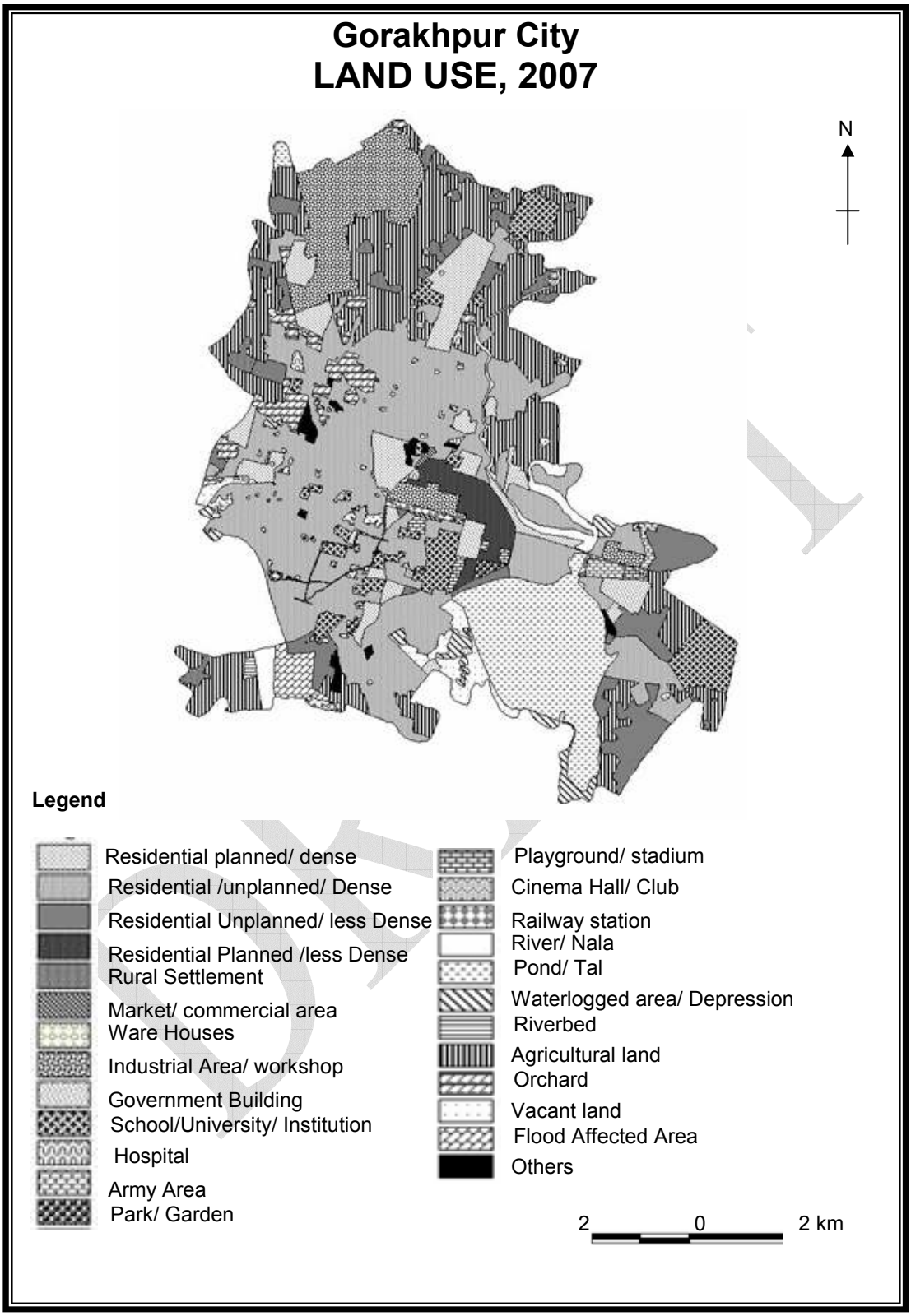
Gorakhpur City
LAND USE, 2007
N
Legend
Residential planned/ dense
Residential /unplanned/ Dense
Residential Unplanned/ less Dense
Residential Planned /less Dense
Rural Settlement
Market/ commercial area
Ware Houses
Industrial Area/ workshop
Government Building
School/University/ Institution
Hospital
Army Area
Park/ Garden
Playground/ stadium
Cinema Hall/ Club
Railway station
River/ Nala
Pond/ Tal
Waterlogged area/ Depression
Riverbed
Agricultural land
Orchard
Vacant land
Flood Affected Area
Others
2 0 2 km

Fig 12

and trade Gorakhpur has its commercial activities on about 173.20 ha. Land. Alongwith Urdu Bazar , Sahebganj, Alinagar and Golghar are main commercial zoneof the city. Commercial shops and organizations are along the most of the roads of the city.

Table-3 Gorakhpur city: Land Use

S.No.	Land Use	Area in ha.	% of Developed Area
1	Residential	4103.3	72.10
2	Commercial	173.20	3.05
3	Industrial	445.00	7.82
4	Govt. Organization	161.00	2.83
5	Public & Semi Pub. Services	398.32	7.01
6	Park & Open Space	291.20	5.12
7	Transport	117.10	2.07
	Total	**5689.12**	**100.00**

Sources: Gorakhpur Development Authority

Industries are less important in the city. F.C.I., a major industry is now inoperative where as small scale industries are around railway station in Golghar area. One industrial state is near Gorakhnath temple where different types of industries have been developed. Powerloooms industry has developed in Gorakhnath Area. Government has established GIDA, about 15 km. away from city on NH28 near to Sahjanwa which has various

major industries. Administrative, public and semi public utility and services and institutional areas are having about 9.84 per cent of total area of the city which are mostly in Civil lines area except engineering college in the east and medical college in the north. As like other cities, parks, Playground, greenbelt and open spaces are very few and they are not even maintained.

Only 5.12 percent area of the city open space as park , play ground and ideal land. Transport services (Railway, Road, Bus Stand and concern workshops) have 2.07 percent. Thus the city has maximum share of land under residence.

Transport

The city is well connected with other parts of the country through road and railway The major roads radiate from city in all direction. NH28 approaching towards Delhi- lucknow in west goes to Gopalganj in Bihar and onward to Kolkatta and Assam in east . Another important road connect the city to Deoria, and Kolkatta through Bihar . Indo- Nepal border to Varanasi and Allhabad through this city NH29 connect the city to southern part of the country. Other local rood radiated from the city to maharajganj, Thothibari (Indo- Nepal Border) and other towards Captainganj and Baghaha in Bihar. North East broad gauge railway line passes through the city and connects to the other parts of the country. It is the main line joining the capital of the country to Guwahati and Kolkata. Two Branch lines one meter gauge which is on the verge of conversion into broad gauge, goes to Nautanwan near Indo- Nepal International border. Another broad gauge loop line connects Gorakhpur to Chappra and Siwan

as well as Rakhsaul near Indo- Nepal Border. The main route Delhi and onwards to Assam and West Bengal in the east is the backbone of the transport in the region.

Though the city is not well connected through air ways but a alternate days flight from Delhi touches the city. Some time this facility remains terminated due to shortage of the passenger.

Section II

Geomorphology

GEOMORPHOLOGY

Relief:

Gorakhpur city is located in the Ghaghra-Gandak Doab on the left bank of River Rapti at its confluence with river Rohin. Its whole area is a level plain which is a part of Gangetic plain, made with the process of deposition of alluvial brought by the Rivers. The plain form a level tract which has very gentle slope. The height above sea-level range from 72 meters in south and south west to 95 meters in North. In the north newly developed part of the city has elevation more than 85 Meters and decreases toward south. The least elevation is in the southern part of the city which is along the Ramgarh Tal and Hobert embankment and NH 28.

The relief of the city is clearly visible in the Fig.13 in which contours are drawn at one meter interval using the SRTM data and supplemented by BM, Spot Height and other data available on toposheets and Guide maps published by Survey of India.

It is very clear from the Fig.-13 that most of the area of northern part has the elevation between 80 to 85 mts and the height has heterogeneous in nature because very circuitous contour lines present that the area is not level tract. It also shows that the elevation is much irregular and gradients are also very uneven. But there are three north-south elongated low lying land which is deeper land having the height less than 80 mts. It seems that these are the older beds of Rohin in west, Gorghoia Nala in east and any other channel between them. The areas along river Rohin and nala

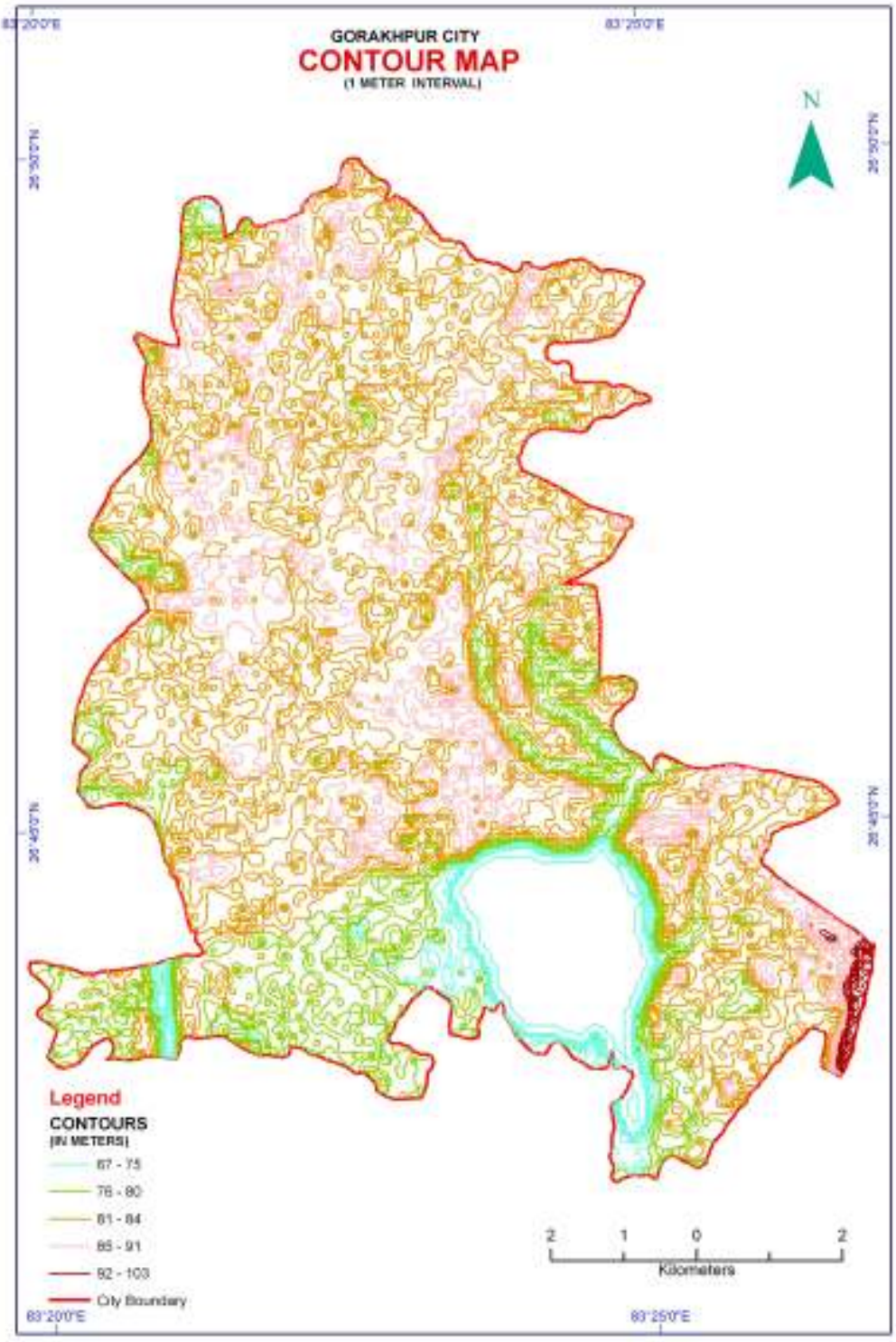
GORAKHPUR CITY
CONTOUR MAP
(1 METER INTERVAL)
N
83°20'0"E
83°25'0"E
26°50'0"N
26°45'0"N
Legend
CONTOURS
(IN METERS)
67 - 75
76 - 80
81 - 84
85 - 91
92 - 103
City Boundary
2 1 0 2
Kilometers

Fig 13

Gordhoia have the height between 75 to 80 mts. The height from eastern bank of Ramgarh Tal to extreme east, up to city boundary, is continuously increasing.

The southern part of the city has comparatively lesser height which ranges between 75 to 80 mts. It is lowest part of the city The Ramgarh Tal and its water covered area has the height around 70 mts. Thus southern part from Ramgarh Tal to west word is low-lying area whichheight increases from east to west.

A chorochromatic map (Fig.14) showing the height above sea level has been prepared to provide an over view of relief at glance. The map shows that most of the northern and eastern parts of the city have the height between 82 to 86 mts. with some patches of higher elevation (86-90 mts.) . Where as southern part has the height less than the northern part between 74 to 82 mts. The area of Ramgarh Tal and around it has least height.

Hence according to the height, the city can be divided in two parts- first- northern half part of the city which has more than 79 meters height while second -half southern part has the elevation between 74 to 79 mts., except higher patches of area of civil lines and Dharmshal bazar around Railway station. The area along Gordhoia Nala to Ramgarh Tal and extreme southern part between river Rapti to Ramgarh Tal has lowest elevation.

.

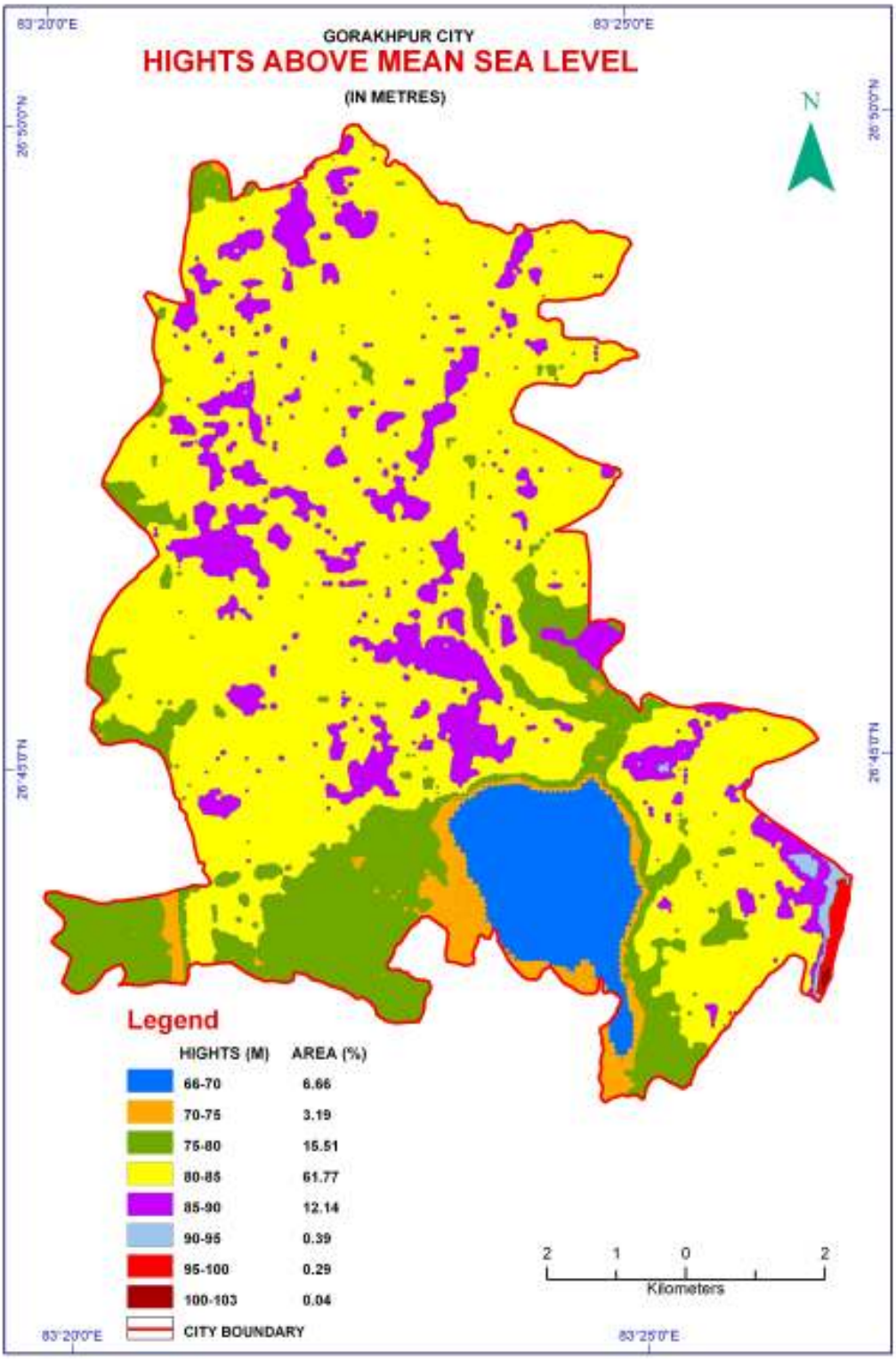
GORAKHPUR CITY
HIGHTS ABOVE MEAN SEA LEVEL
(IN METRES)
N
83°20'0"E
83°25'0"E
26°50'0"N
26°45'0"N
Legend
HIGHTS (M) AREA (%)
66-70 6.66
70-75 3.19
75-80 15.51
80-85 61.77
85-90 12.14
90-95 0.39
95-100 0.29
100-103 0.04
CITY BOUNDARY
2 1 0 2
Kilometers

Fig 14

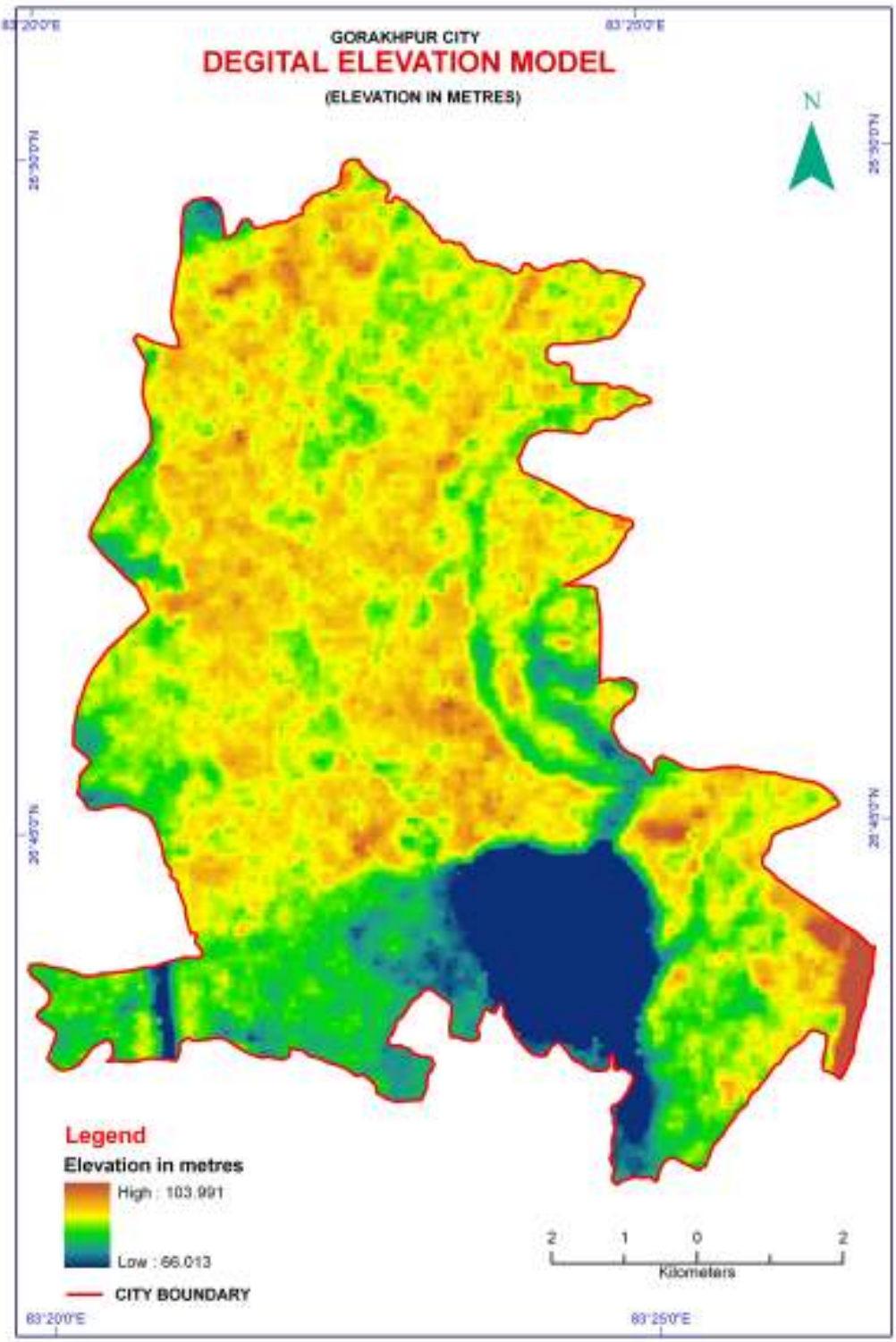
GORAKHPUR CITY
DEGITAL ELEVATION MODEL
(ELEVATION IN METRES)
N
83°20'0"E
83°25'0"E
26°35'0"N
26°40'0"N
Legend
Elevation in metres
High : 103.991
Low : 66.013
CITY BOUNDARY
2 1 0 2
Kilometers

Fig 15

The elevations and slope of the area is much affected by the course of River Rapti and its abandoned channels which is bordered by a chain of depressions and lakes in the city. Most of the southern half of the city which has lower elevation has been affected by process of shifting course of river Rapti.

The central area adjacent to the railway line to the whole southern part is a low lying area which average height is lower than the elevation of bank of river Rapti, 75 mts. Therefore, the area was subject to heavy flood during heavy rain before the construction of Hobert embankment along the river bank from railway line in north to Rajghat in south, in the early British period. Now it provides a large tract of flood protected land on which the southern western part of the city was developed. Fig No.14 shows that the newly developed northern part of the city are on higher ground which is 05 to 09 mts. higher than the southern part.

A three dimensional Digital Elevation Model(DEM) of the city is presented in Fig.15. But due to less difference in the height the three dimensional view is not very apparent. Even though a picture of the actual elevation can be had with this presentation. The abandoned stream channels are also very clearly visible in the map.

The area of different elevations have been calculated and presented in Table No.4. The table No.3 shows that the area having highest elevation (more than 90mts.) is only 0.82% where as 85 to 90 mts elevated areas is about 12.14%. The area between the heights of 80 to 85 mts. has highest

Table : 4 Gorakhpur City

Area according to Heights

S. No	Height in mts.	% of Area
1	Less than 70	6.6
2	70-75	3.19
3	75-80	15.51
4	80-85	61.77
5	85-90	12.14
6	90-95	0.39
7	More than 95	0.43
Total		100

share ofthe area (61.77%). The area more than75mts and less than 80 mts hight is 15.51% Where as areas having lowest elevation (Less than 75mts height) is 9.79% of the total area. Therefore, 89.42% area of the city is between 75 to90 mts elevation. The area having the height is about 9.79% which has lower height than the bank of river Rapti(75 mts).

SLOPE

The slope of the city is one of important factors for planning of the drainage and sewer of the city. The general slope of the gorakhpur city is from north to south because whole of the northern portion is higher than the southern portion. The general slope of the area is about 1mt/km. which

is very gentle. But there is spatial variation in the slope. Northern portion has more slope than the southern portion .Fig.No.21 shows the general slope of the city in degree. The slope and corresponding area is presented n table-5.

Table - 5 : Slope and Corresponding Area

Slope in Degree	Percent of total area
0	4.36
0-1	74.29
1-2	18.42
2-3	2.52
3-4	0.28
More than 4	0.13
Total	100.00

It is very clear from table that only Ramgarh Tal has no slope, means its slope is 0^{o} which covers about 4.36 percent of area. The 74.29 per cent of the total area of the city has 0 -1 degree slopes. Thus maximum part of the city has very gentle slope. Only some patches,18.42 per cent of the total

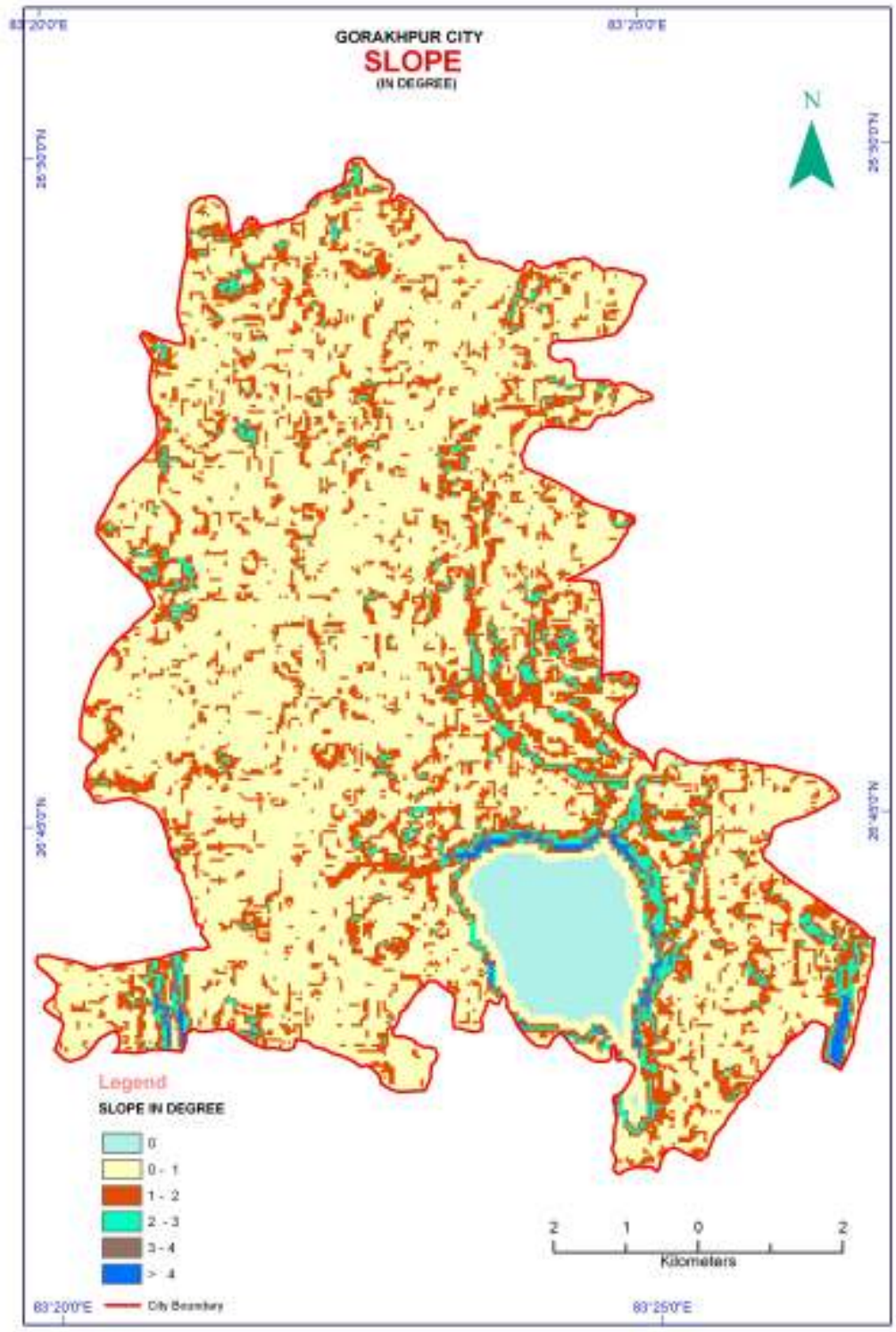
GORAKHPUR CITY
SLOPE
(IN DEGREE)
N
83°20'0"E
83°25'0"E
26°35'0"N
26°40'0"N
Legend
SLOPE IN DEGREE
0
0 - 1
1 - 2
2 - 3
3 - 4
> 4
City Boundary
2 1 0 2
Kilometers

Fig 16

area has 1to 2 degree slope. The area having more slope (more than 2^o) is very few which area is about 2.93 percent of the total area. The areas around the rivers and Nalas- Rapti River, Gordhhoia and Bichhia Nalas have some steeper slope 2^o-3^o which total area is about 2.52 percent of city. In the eastern part of the city, the highest elevetion is near the engineering college which has highest gradient of slope of 3^o to 4^o and even more than 4^o. But its area is very minute around 0.41 per cent of the total area of the city.

Fig. No 22 shows the slope in percent. The slope in percent is ratio of vertical interval and horizontal distance between two points and multiplied by 100 to present in percent form. About 1^o of slope shall be the slope of 1:60 which mean the height of the area increase/decrease 1 unit after a distance of 60 units of horizontal distance and the ratio shall be 1.66 percent (1/60x100=1.67 per cent). This map also depicts the same pattern of slope in the city. The maximum area of the city has 0-3 per cent of slope which is very gentle slope where as Ramgarh Tal area has no slope and some patches of eastern portion has highest slope 12 to 27 per cent.

The direction of the slope is very regular and general slope is from North to South but western of the central part of the city has slope towards west. In Fig. 25 slope direction along with its amount is presented. It is very apparent from the map that the major area of the city has slope from north to south direction. Only south east part which comprises with Mahadeo Jharkhandi, Girdhar Ganj and engineering college area, has the slope from north-east to south–west direction whereas towards Hobert embankment slope is in west direction.

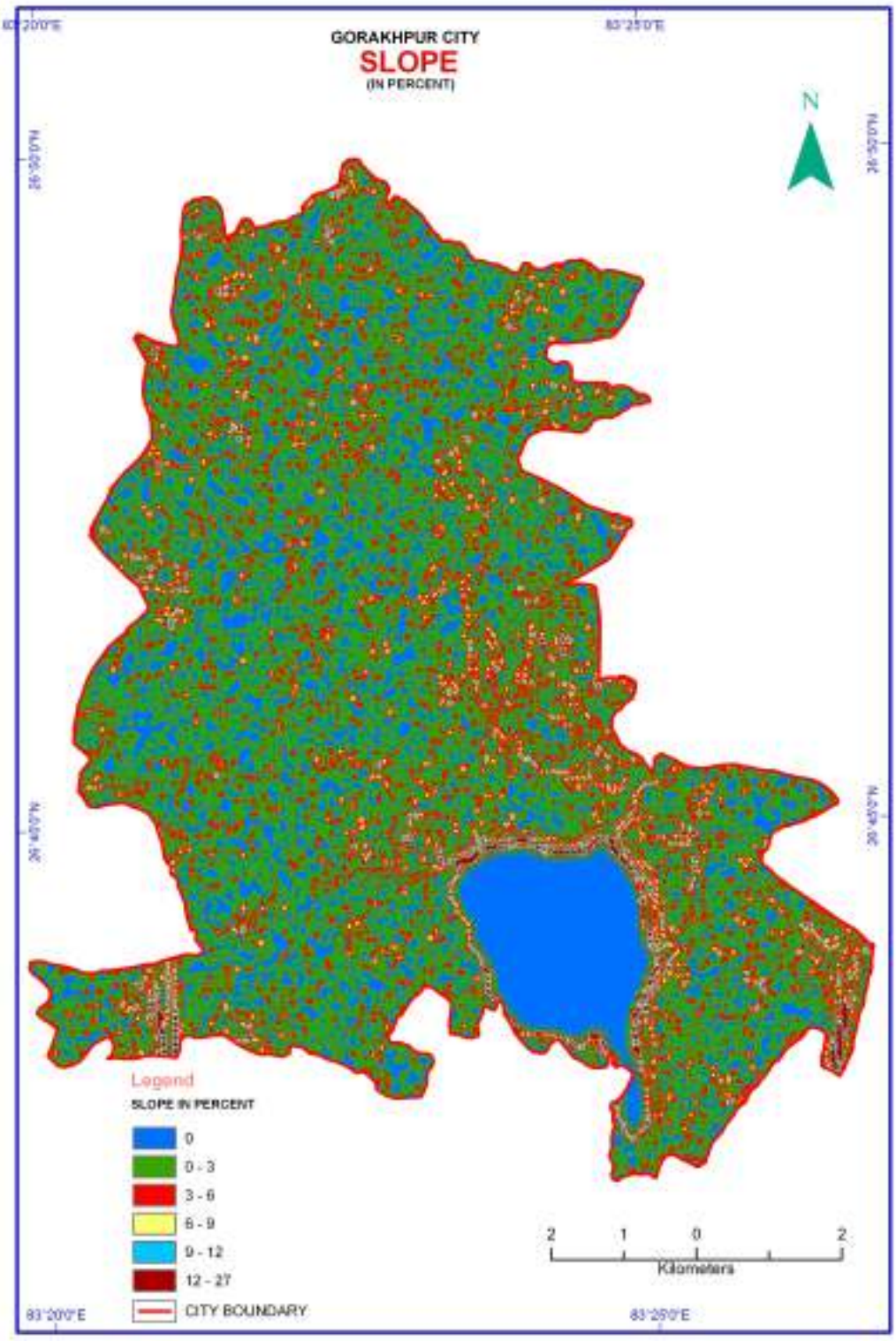
GORAKHPUR CITY
SLOPE
(IN PERCENT)
N
83°20'0"E
83°25'0"E
26°50'0"N
26°45'0"N
Legend
SLOPE IN PERCENT
0
0 - 3
3 - 6
6 - 9
9 - 12
12 - 27
CITY BOUNDARY
2 1 0 2
Kilometers

Fig 17

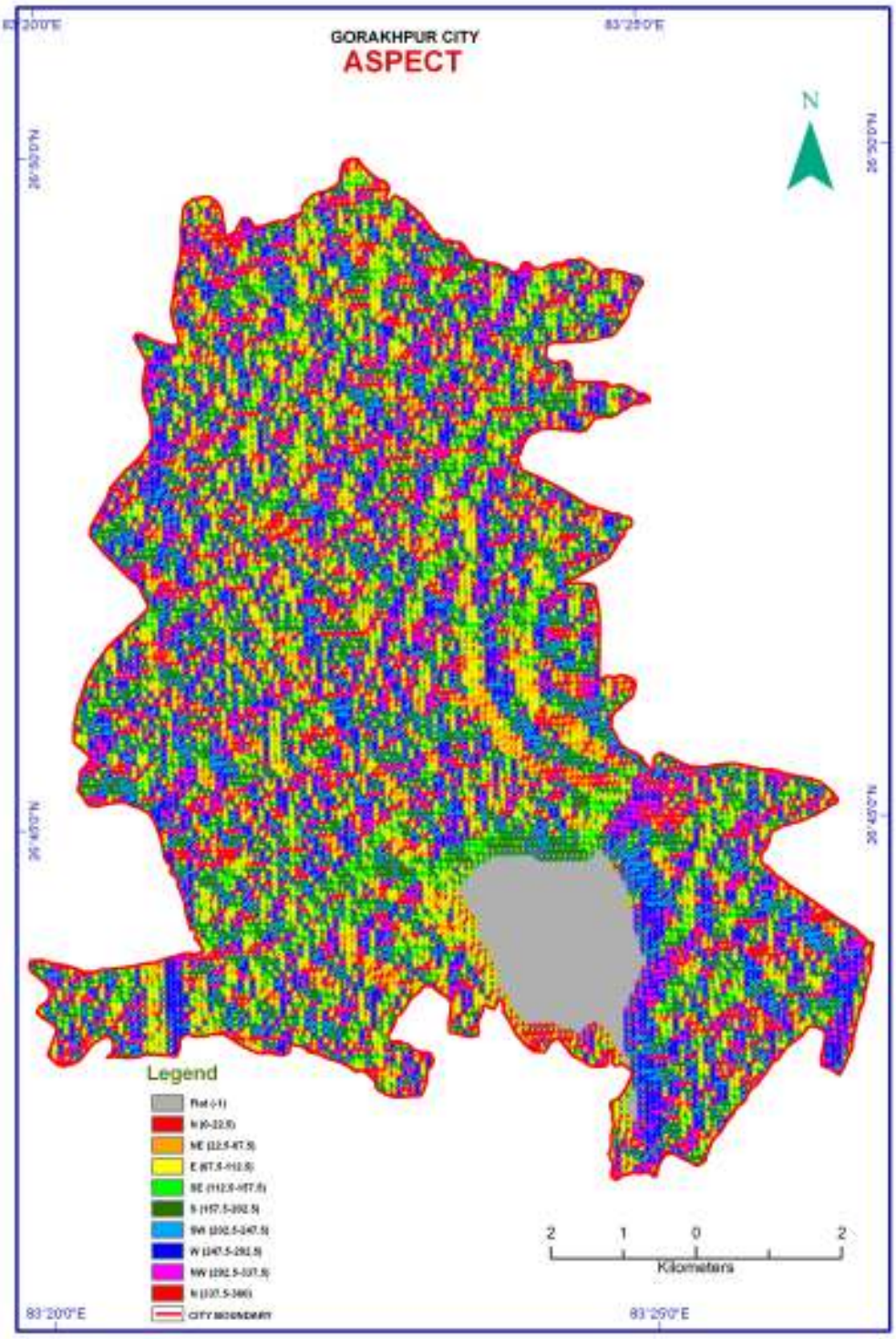
GORAKHPUR CITY
ASPECT
N
Legend
Flat (-1)
N (0-22.5)
NE (22.5-67.5)
E (67.5-112.5)
SE (112.5-157.5)
S (157.5-202.5)
SW (202.5-247.5)
W (247.5-292.5)
NW (292.5-337.5)
N (337.5-360)
CITY BOUNDARY
2 1 0 2
Kilometers
83°20'0"E
83°25'0"E
26°30'0"N
26°45'0"N

Fig 18

LITHOLOGY:

The under ground structure, sedimentation and bed succession are the major components of the study of the structure and the lithological features. As it has been mentioned earlier that the city is in the region of alluvial trough in Ghaghra-Gandak Doab, where alluvial filling extent to a depth of 6000 mts. but within the city boundary area, it is about 5500 mts deep. The detail study regarding Lithology of the area has not been so far.. Here for this present study a minor analysis has been attempted on the basis of the strata chart collected from Jal Nigam of tube wells in the different parts of the city.

There are total 102 tubewell in the city out of which 75 were the public and municipal board tube well bored by the Jal Nigan for Municipal Corporation. Rest 27 tubewell are installed by private colonizer to supply the water in the colonies developed by them. The specification of the under ground strata are not available of those tube wells points but the same data of tube well board by Jal nigam are available. (Fig 19). On the basis of those data two cross sections were drawn along the lines drawn between surajkund (west) and Jail Road tube well point (east) and GDA colony Rapti nagar tube well point (north) to Rawat Pathsala , turkmanpur Tubewell point (south) are presented in the fig.-20 and 21. It apparent from the lithologs of the tube well in the city area is that mostly clay and sand (medium and fine quality) are deposited. The sand deposited in the area has different structure, composition and texture but coarse sand is not found in the area. Clay is found with or without sand. Therefore, in the area fine to moderate sand and clay are found. Due to capillary action in

some parts of the city Kankar (nodular limestone) is also found in between the layer of sands.

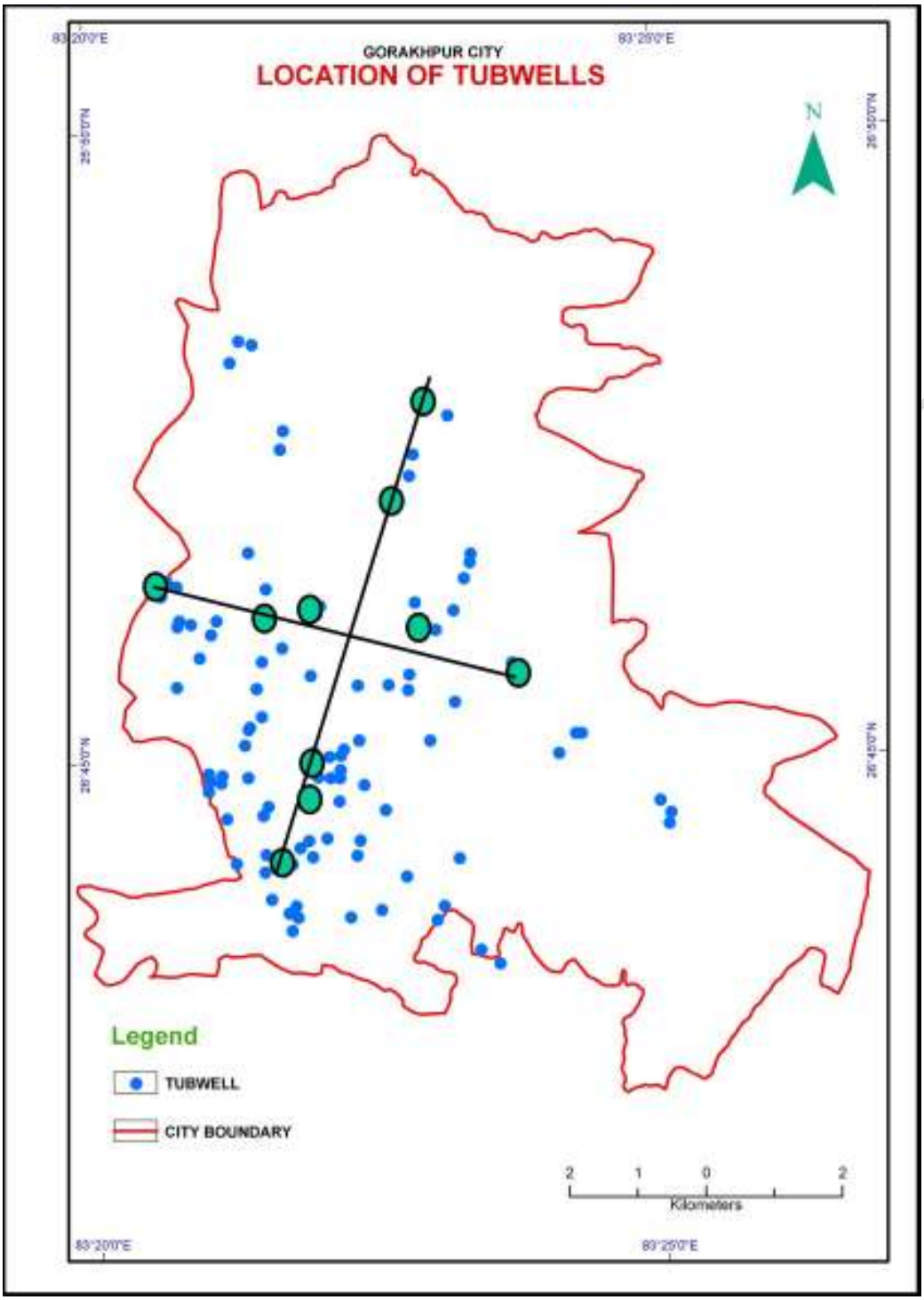

Fig 19

The sandstone is highly restricted layer because of the great incidence of the different types of sands. But at some places a thin layer of sandstone is also recorded which has been deposited by the river transporting them from Himalyan region. River Rapti is not expected to bring the such big load of sandstone from the Himalaya or the Bhabhar area adjacent to Siwalik to gorakhpur because the distance from the entry point of this river in plain to Gorakhpur, it is about 120 km away. Thus a heavy load of sandstone can not be bear to transport up to such distance but the Rohin river can transport it becauset the distance between gorakhpur and himalaya and the Bhabhar where sandstone is found is shorter. During rainy season Rohin can transport it as a heavy load due to the heavy water discharge. Therefore, most of the sandstone layers are found in the area which is liable to be deposited by Rohin River.

In the north- South Cross section of the city the pattern of underground deposition are also same as it is west to east but in the southern part the sandstone deposition is not found. Mostly sand and clay are found as sediment. In the northern part (Rapti nagar) a thin layer of sandstone is found at the depth of 25-40 mts from the surface . The kankar is found in lower strata (Fig 20& 21).

Thus, the geological structure of the city area is very favorable for infiltration of surface water to the under ground because most of the sediments are made of sand and clay through which water can percolate easily to the permeable strata. Like wise the sub surface water can easily be draft for various uses because due to soft rock. The hand pumps and tube well can easily be bored.

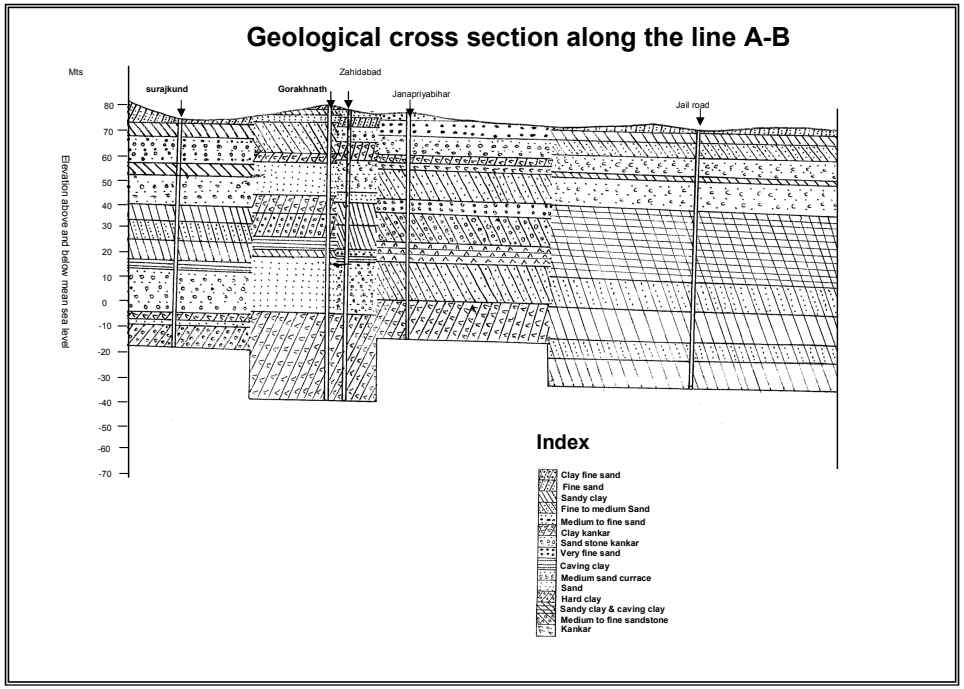
Geological cross section along the line A-B
Mts
surajkund
Gorakhnath
Zahidabad
Janapriyabihar
Jail road
Elevation above and below mean sea level
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
Index
Clay fine sand
Fine sand
Sandy clay
Fine to medium Sand
Medium to fine sand
Clay kankar
Sand stone kankar
Very fine sand
Caving clay
Medium sand currace Sand
Hard clay
Sandy clay & caving clay
Medium to fine sandstone Kankar

Fig 20

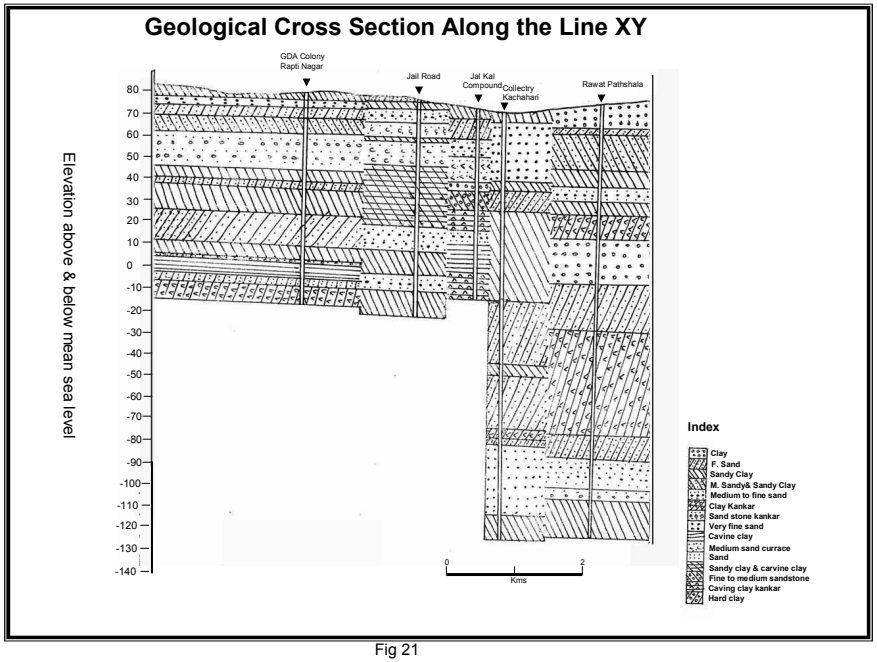
Geological Cross Section Along the Line XY
GDA Colony
Rapti Nagar
Jail Road
Jal Kal
Compound
Collectry
Kachahari
Rawat Pathshala
Elevation above & below mean sea level
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
0
2
Kms
Index
Clay
F. Sand
Sandy Clay
M. Sandy& Sandy Clay
Medium to fine sand
Clay Kankar
Sand stone kankar
Very fine sand
Cavine clay
Medium sand currace
Sand
Sandy clay & carvine clay
Fine to medium sandstone
Caving clay kankar
Hard clay

Fig 21

In short it can be summarized that gorakhpur city have variation in the elevation from north to south and east to west. Northern and eastern part is higher than the southern part. Slope of the area is from north to south but southern half portion of the city has slope in three different directions. South-eastern part has slope towards east to west whereas south-central part is the water dividing. Therefore, eastern parts have the slope towards east and rest western part in the east. The geology of the area is made of sedimentary rocks with sand and clay. The harder rock sand stone are found at the depth of 25 to 40mts from the surface.

Section III

Hydrology

Hydrology

Water sustains the life. It the basic need for the human and other bio organs as well as an important component of ecosystem. It is found in air in the form of water vapor, on the surface and underground. The availability of water depend s upon the quantity and speed of rainfall timing of rains quality of evaporation temperature slope of land dryness of air voids and non permeability of rocks, vegetation cover and water adsorption capacity of land soil. Man can use the water which is on the ground stored in tanks and running water into the streams and rivers as well as under ground water collected in the non permeable rocks. In this section attempt have been made to analyze the various factor which regulates the amount and quality of water of the surface and subsurface both, for which the area under surface water, the depth of aquifers, and factors influencing its amounts like season of rainfall, condition of water logging, and flood along with the measures adopted to drain out the excess water.

As it has been described in section I that rainfall is the only sources of water in the city and the city receives an annual rainfall of about 199. 2 cm. Because the city has monsoon climate which arise over the city in the middle of June and withdraws at the end of September and about 87% of total rainfall is received during this period. Therefore the heavy downpour during a limited period creates the havoc of water logging and flood and most of the water use to flow without economic use except some water which is collected in the water bodies and the depressions spread in the

city . The physiography of the city is main controlling factor of the spatio temporal location of the depression and amount of water into them.

Water Bodies

As it has been mentioned earlier that the city's physiology is a product of process of changing the course of river Rapti, due to which various ponds, lakes, depressions and abandoned river channels were found in the city. These depressions are mostly elongated and extra large in shape and size but their numbers and area are decreasing with a high pace. The Fig No.22 shows the extant and the location of lakes and tanks in 1916-17. It is obvious from the map that during the period the city, especially in central part, was full of such type of depressions. Two small streams, Gordhoia and Bichhia were also present. The total area of all these depressions was about 12.36 Km^2 including Ramgarh Tal (7.79 Km^2). Thus about 4.57 Km^2 areas was covered by the other natural depressions excluding Ramgarh. But now a day most of the tanks and lakes of central part are not in existence and their area has been use for the development of the settlements. Even the size and length of Gordhoia Nala and Bichha Nalahas been decrease . The fig. no.23 presents the location of the water bodies in 2009. According to this, the total area of natural depressions and tank is about 9.28 Km^2 including Ramgarh tal. Out of which2.28 km^2 area is under other natural depressions. Therefore, the area of water bodies is reducing at an unusual rate which is about 3.08km^2 (33.19%) during the period 1916 -17 to 2009. The Ramgarh Tal has recorded less decrease in the area (7.79 km^2 to 7.01 km^2) during this period whereas the area of the other depression was 4.57 km^2 in 1916-17 and at present it is 2.28 km^2. Hence there is about 96.05% decrease in the area of the other water bodies.[14]

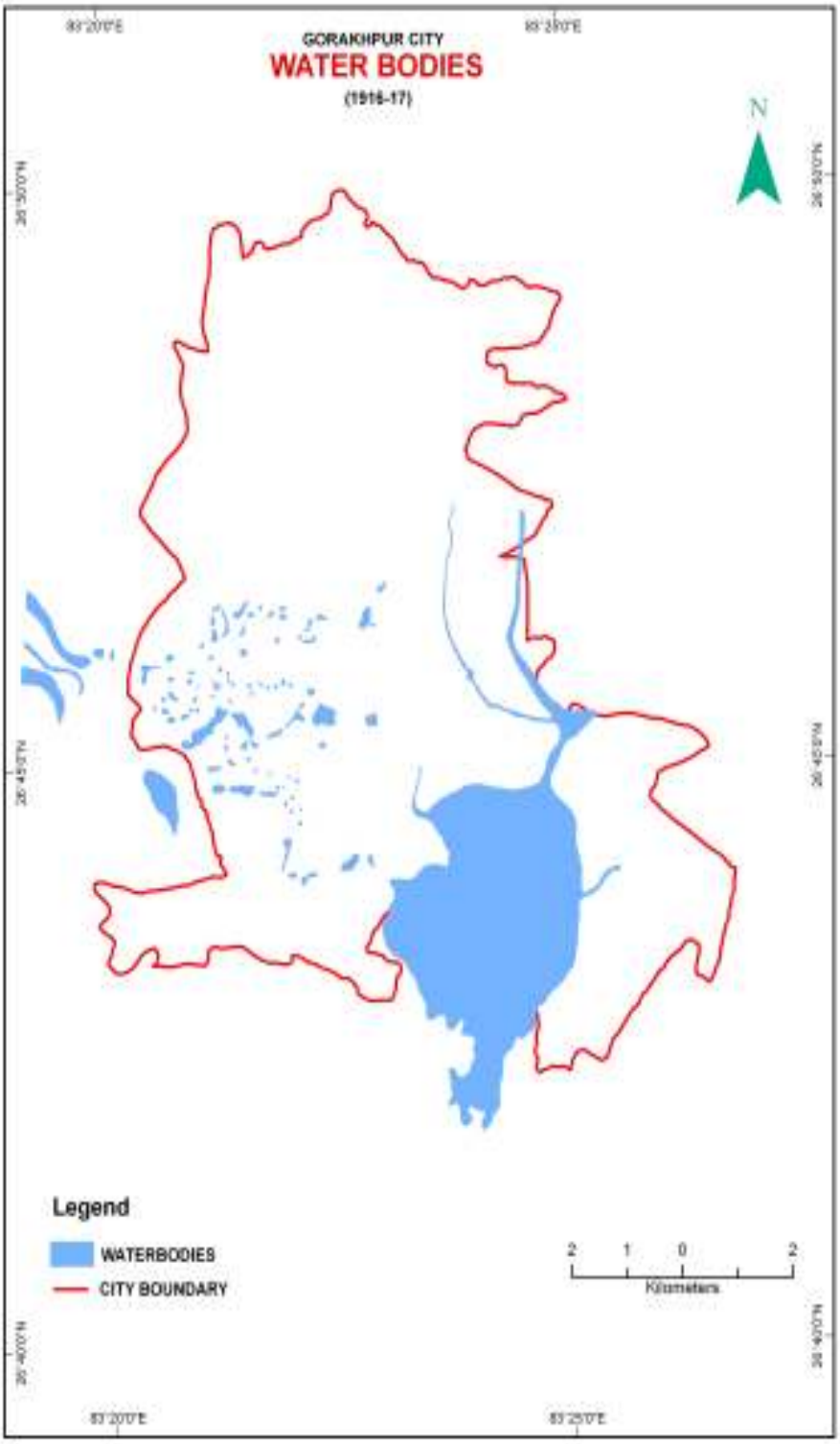
GORAKHPUR CITY
WATER BODIES
(1916-17)
N
Legend
WATERBODIES
CITY BOUNDARY
2 1 0 2
Kilometers

Fig22

The role of these depressions was very important for the collection of water in the rainy season and percolation of their water to the underground. Thus they were the source of recharging of the under ground water stock as well as they were natural storage tank of rain water and liquid waste. Most of the tanks and depressions became full of water rather overflow during raining season and water remained for whole of the year. Thus they were acting as buffer zones for storage of surface water and recharging the underground water level, which was main source of water for drinking and domestic use. But with growth of population most of the lakes and depressions were used for construction of permanent settlement after filling them. The built up area has been extended to the lower ground in the east and the centre part of city using the low laying area after filling them. Daudpur Mohalla lying in the lower ground, once occupied by Ramgarhtal, is fully covered by settlement. Likewise other lakes like Monsrovar, Jatashanker , Kavaldah, Kauabag and lake near Vishnu Mandir have been used for development of residential houses.

The short fall in the area and unplanned development over these buffer zones has an adverse effect on water logging in those areas which were not prone earlier and the seepage and recharging of the subsurface water. This is the main cause of shortage of under ground water and its level especially in summer season. Most of the sallow hand pumps get dry and became inoperative till the next monsoon.

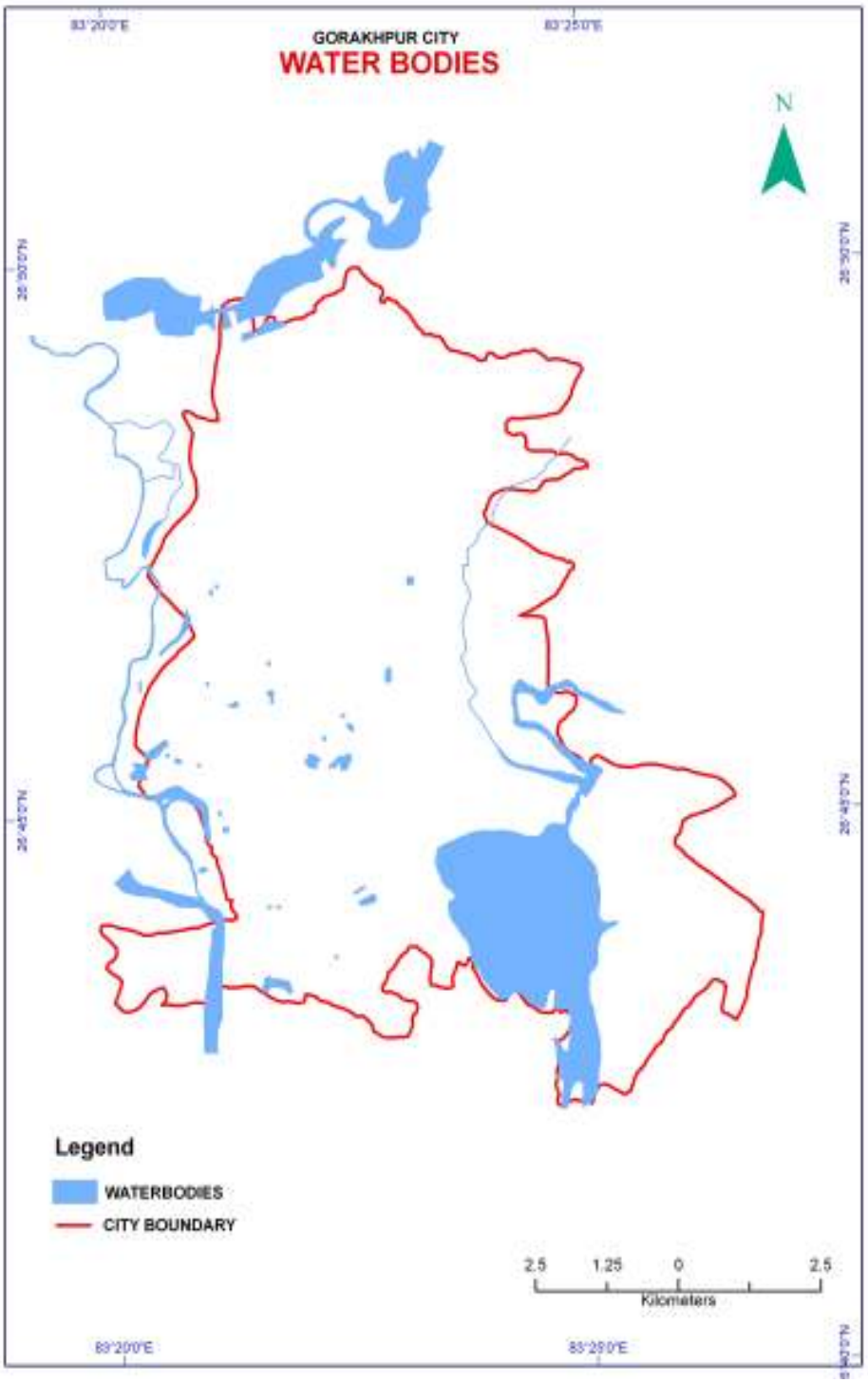
GORAKHPUR CITY
WATER BODIES
N
83°20'0"E
83°25'0"E
26°50'0"N
26°45'0"N
Legend
WATERBODIES
CITY BOUNDARY
2.5
1.25
0
2.5
Kilometers

Fig 23

The accumulated water in the depressions gets contaminated due to the mixing of sewage and other liquid waste disposed off in these depressions. The under ground water also get contaminated by the recharging through percolation of the polluted water and became unsuitable for drinking purposes. Thus the liquid waste and sewage should not be disposed off directly in to them without the treatment, so that the quality of under ground water could not be degraded by coming contact with such water.

Accepting the positive role of these buffer zones for recharging the subsurface water, collection of the rain water and for maintaining the ecological balance in respect to open space, the presence of such areas are very important. Hence attempt should be made to maintain the size of lakes and their quality .So that they and their water can be used for various proposes without causing any serious impact on human and ecosystem.

Effect of Shifting of River Rapti :

Many historical evidences have been cited by the different scientists about the changing course of river rapti. Due to its frequent shifting of course, it was regarded as 'sorrow of Gorakhpur'. The fig. 24 depicts the River Rapti's changing course and its confluence with Rohin during its historical past. There is hardly any place in and around the southern portion of the city over which the Rapti has not been active at one time or other. It is accepted fact that old Gorakhnath Temple was on the left bank of Rapti during early period on the higher ground between Rapti in south and Rohin in west. During the course of the survey done by Prof. U. Singh

; (1970-73)[13], it was observed that in early period , the Rapti was flowing adjacent to modern Gorakhnath temple in the centre of the city toward east bisecting the city north-south and passing through the Ramgarh Tal. A number of continuous depressions and lakes which were in existence even at the time of survey were in elongated shape. Mansarowar and Asuran lakes are some of them, prove the fact that they once formed a part of old channel of river. Since then the Rapti has been shifting towards south and west, which is proved by existence of a large number of depressions by both side of the railway line as well as in southern part of the city in form of Sumer Sagar, Kawaldah, Bahuladah, Kawaldah and a remnant channel in Golf course, Bilandpur, Turkmanpur, Paharpur. During Medieval period the Rapti was flowing by the side of fort contruced by Raja Basant Singh in about 1610 AD. The toposheet published by survey of India, in 1916-17, the channels of then Rapti and Rohin have been shown and now they are shifted west ward. Even their confluence has also shifted about 1.5 km south from the period of 1916-17 (Fig. 18). In Fig.25 the pattern of changes in the course of river Rapti has been presented on the relief map of the city.

Various historical evidences also prove that the Rapti has been consistently shifting from north to south and then west. Therefore early settler probably occupied near Gorakhnath Temple, which is still known as

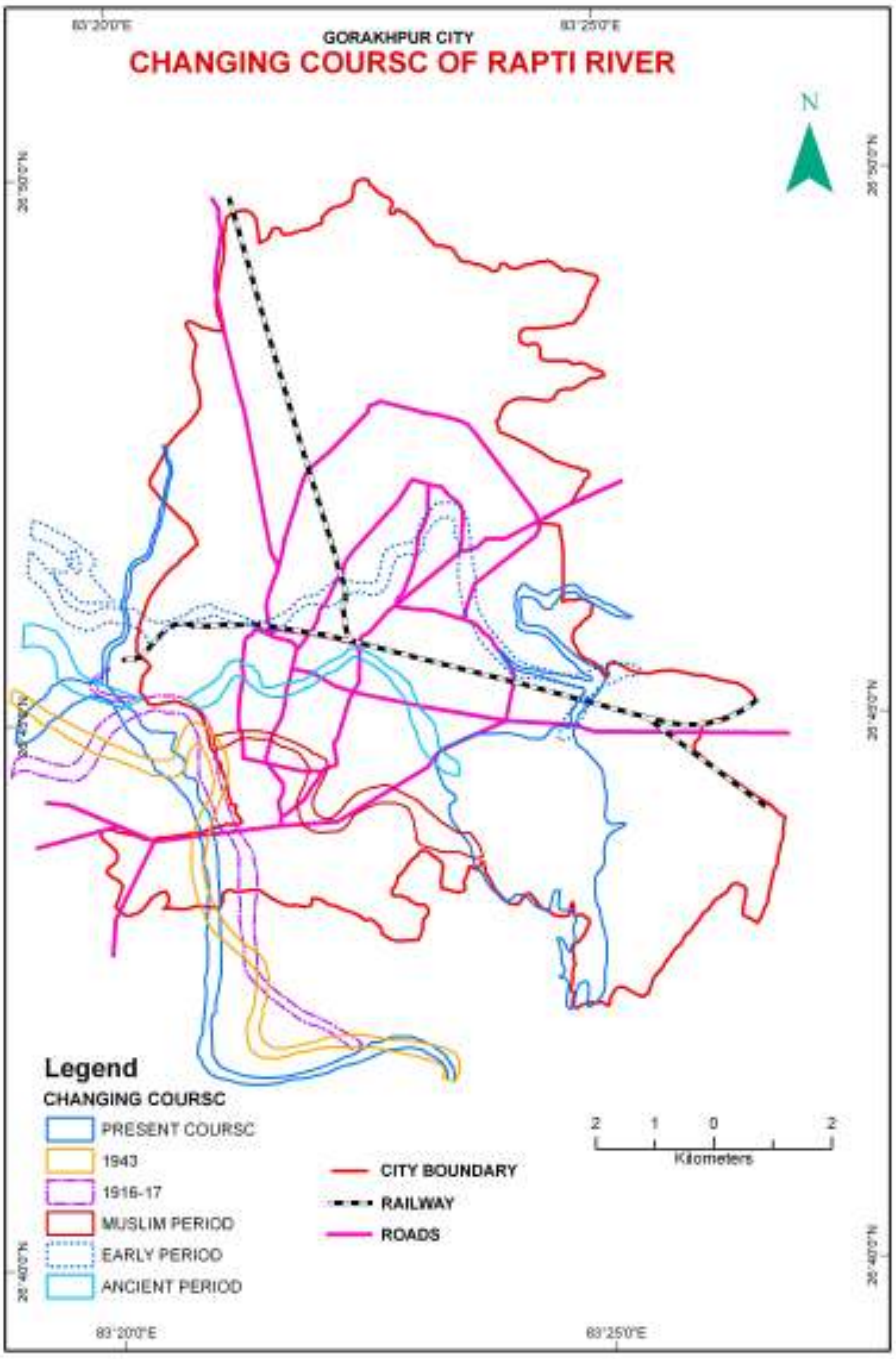
GORAKHPUR CITY
CHANGING COURSC OF RAPTI RIVER
N
83°20'0"E
83°25'0"E
26°50'0"N
26°45'0"N
26°40'0"N
Legend
CHANGING COURSC
PRESENT COURSC
1943
1916-17
MUSLIM PERIOD
EARLY PERIOD
ANCIENT PERIOD
CITY BOUNDARY
RAILWAY
ROADS
2 1 0 2
Kilometers

Fig. 24

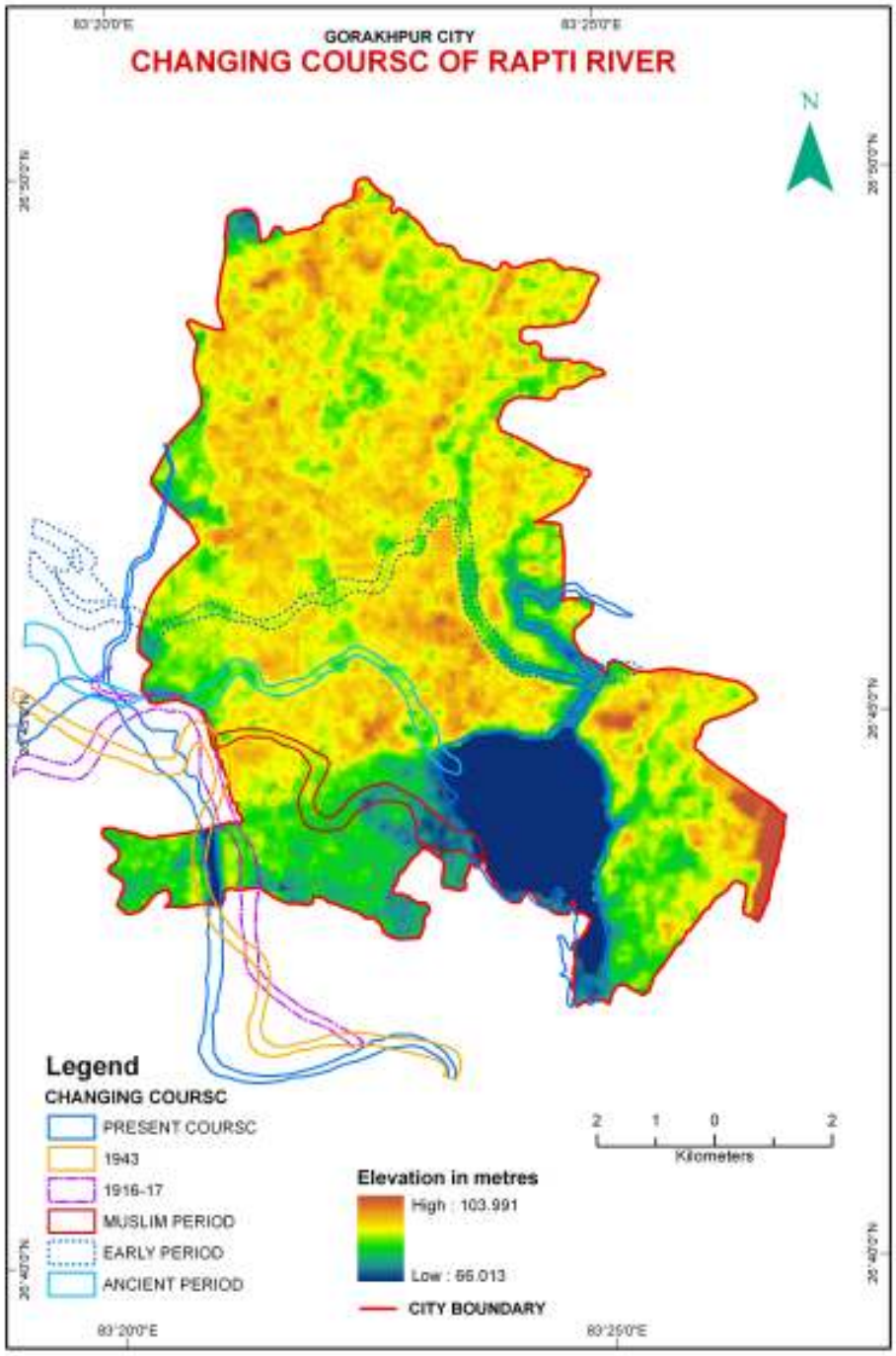

Fig. 25

*Purana (*old*)* Gorakhpur, on the higher ground bounded by Rohin in west and Rapti in south. From that area, Rapti has shifted its channel to the present situation. This action of the Rapti is a major factor of influencing

the geomorphology, physiography ,slope, lithology and hydrology of the city.

Aquifer:

The water present in the pore spaces of layer of loose and unconsolidated materials lying over the bed rock below the ground surface is called ground water and if it is collected in large quantity that saturated zone of the rocks is know as aquifer which is found in the area of varying size, location and depth. Sands form the most ideal condition for aquifer but permeable sandstone also form extensive aquifers in this area. There are four layers of aquifers at different depth. The First under ground water zone (upper aquifer) is situated at 6 to 8 mts depth from the surface. After that a second layer of aquifer is found between 22-34 mts depth from the surface. The third and fourth layers of aquifers are at the depth of 40-46 mts and 60-80mts from the surface respectively. Between this aquifer the impermeable beds are found which separate the two aquifers which are made of clay, sandy clay, cavin clay and hard clay.

Thus, the under ground water which is 6-8mts deep, can easily be tapped for different purposes. The domestic hand pump draw the water of the first layer of aquifer where as the India mark II hand pump are bored up to the second layer of aquifer. The Tube well draws the water of third layer of aquifers which is safe and unpolluted. Most of the tube wells of the city have their Vail plug (Last point of pipe) at the depth of 80-85 mts. Thus, due to very soft rock and sandy structure, the Lithology of the city is very favorable for infiltration of water down ward for recharging the under ground water stock and to draw it again on the surface for the various uses.

It is also obvious from the interpretation of the quality of water and its depth that water of the first layer is contaminated due to the infiltration of polluted water accumulated in the lakes and depression areas found in all over the city. Hence to get the safe and unpolluted water the third layer of aquifer are being tapped. But the amount of recharge is not equivalent to the amount of draft. Therefore, the depth of the water in the third layer of aquifers is decreasing continuously which may create a serious problem in coming futures and tube well may get dry which will need to rebore up to the fourth layer of aquifers.

Flood:

Though the city is well protected from the flood with embankments in west and high rise road in south, but most of the area south to railway line except civil lines and along railway line in western side of city (Madhopur, Surjkund to Subhas Nagar) is water logging prone in rainy season. The basin shape of the city (specially south part) has experienced a great magnitude of flood in 1974,1989, 1993, 1998, 2001, 2007 and 2008 when city became the island (Fig.20). But in 1998 the situation was worst when the Malauli embankment was cut down due to heavy downpour in the catchments area of the river continuously for many days and heavy water flowing in the River Rapti. It was abnormal heavy flood because it surpassed all the earlier records. Its level was 77.54mts. which was 3mts. higher than the danger level of river Rapti 74.98mts and it remains about 76mts from July 13 to August 30.

The city may be affected by flood every year but due to the embankment security, the water could not enter into the city area. It is

obvious from the Fig.20 that the every year the city and its contiguous surrounding area has to face the problem of flood but the embankments constructed around the city save it with this natural calamity.

Table-3 **Gorakhpur city**

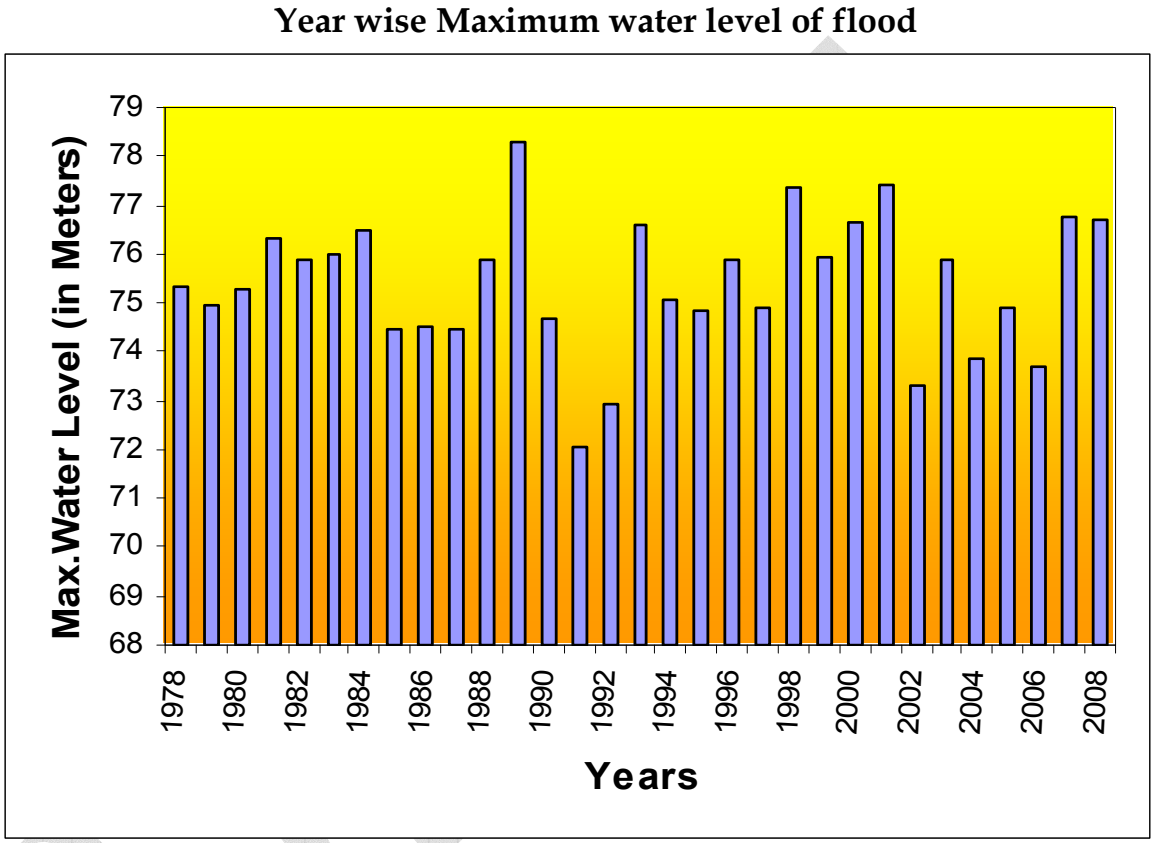

Fig .26

Tthe minimum discharge of the river rapti at Birdghat is 15000cusecs where as the maximum is 160000cusecs during monsoon period. But it is observed that when the water level at Birdghat was 72.3, 74.8 and 75.9 mts, level, the discharge of water was 1000, 2000 and 3000 cusecs respectively.

The main cause of the flood is heavy rainfall during monsoon season. The Rapti and its distributaries receive very high rainfall from upper

catchments area (Himalayan and adjacent tarai region). Therefore a huge volume of water reaches quickly which inundates a large area.

Water logging:

The water logging is a major problem of the city due to the height of the surface of city. Mostly the southern part of the city is more prone to water logging but some places in the other part of the city is also liable to water logging. The water logged prone areas in the city were visited and their location were recorded through GPS. The places of water logging are also shown on DEM (Fig.27). The water logging area is found not only in southern part but in the northern part too due to haphazard and unplanned settlement development.

The topographical conditions of the city is the main cause of water logging in the low-lying area of the southern and northern parts because the rain water as well as the liquid waste coming through the various drains towards west can not be disposed off directly in the river due to five mts. high Hobert embankment. For disposing these water five regulators are constructed but they are operative in rainy season only. After the rising the water level of river Rapti and Rohin in rainy season the gates of the regulators remain closed and the water collected in the man made tank is pumped at ten points with electric/ diesel operated pumps.

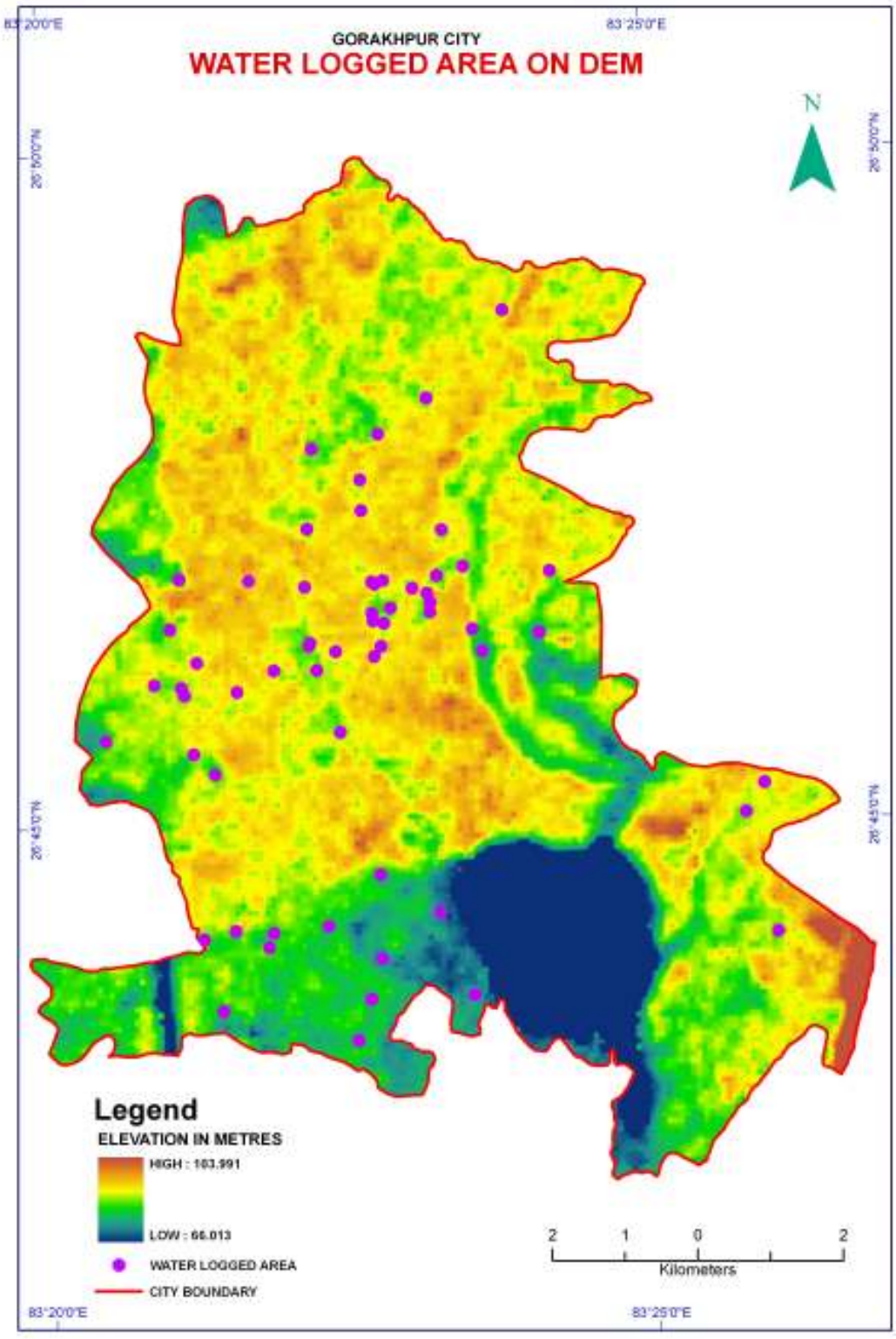
GORAKHPUR CITY
WATER LOGGED AREA ON DEM
N
83°20'0"E
83°25'0"E
26°50'0"N
26°45'0"N
Legend
ELEVATION IN METRES
HIGH : 103.991
LOW : 66.013
WATER LOGGED AREA
CITY BOUNDARY
2 1 0 2
Kilometers

Fig 27

Drains

Natural and man made drains are two sources to draw out the rain water and the liquid waste. There are two means of disposal of liquid waste-underground sewage and surface open drains. A plan was formulated in 1958-59 for making the available the facility of sewer and city was divided in two zones–North and South for this purpose and constructions work was started in 1961 and was completed in 1968-69 by Jal Nigam. Nowadays only in the older part of the city Urdu Bazar, Raniganj, Alhadadapur, Golghar, Mian Bazar, Daudpur and in Avash Vikash Colonies like Shahpur, Surajkund and, Betiahata the sewer facility is available (Fig.28).

Total length of the underground sewer line is about 55 km. and size of the sewer pipe is 300 mm to 150mm.The length and the size of the sewer pipe, both are very meager in respect to fast pace of growing population and growth of use of water and generation of liquid waste. There are only three sewer pumping stations which pump the sewage from other side of Hobert embankment to disposed off it in the River Rapti where as one pump located in Betia Hata near Reed's Sahib Dharmshala to pumps the sewage into Ramgarh Lake and in Rapti near Maheva. The total area cover by the underground sewer system is only 22 percent of the city area which is not sufficient for a developing city (Fig.24). Thus about 78 percent of the area of city still unserved with sewerage. Even there is no any sewer treatment plant in the city and raw sewers are disposed without any treatment in river Rapti, Ramgarh Lake and other streams. Due to unavailability of sewer in the rest part, the city disposes the liquid waste

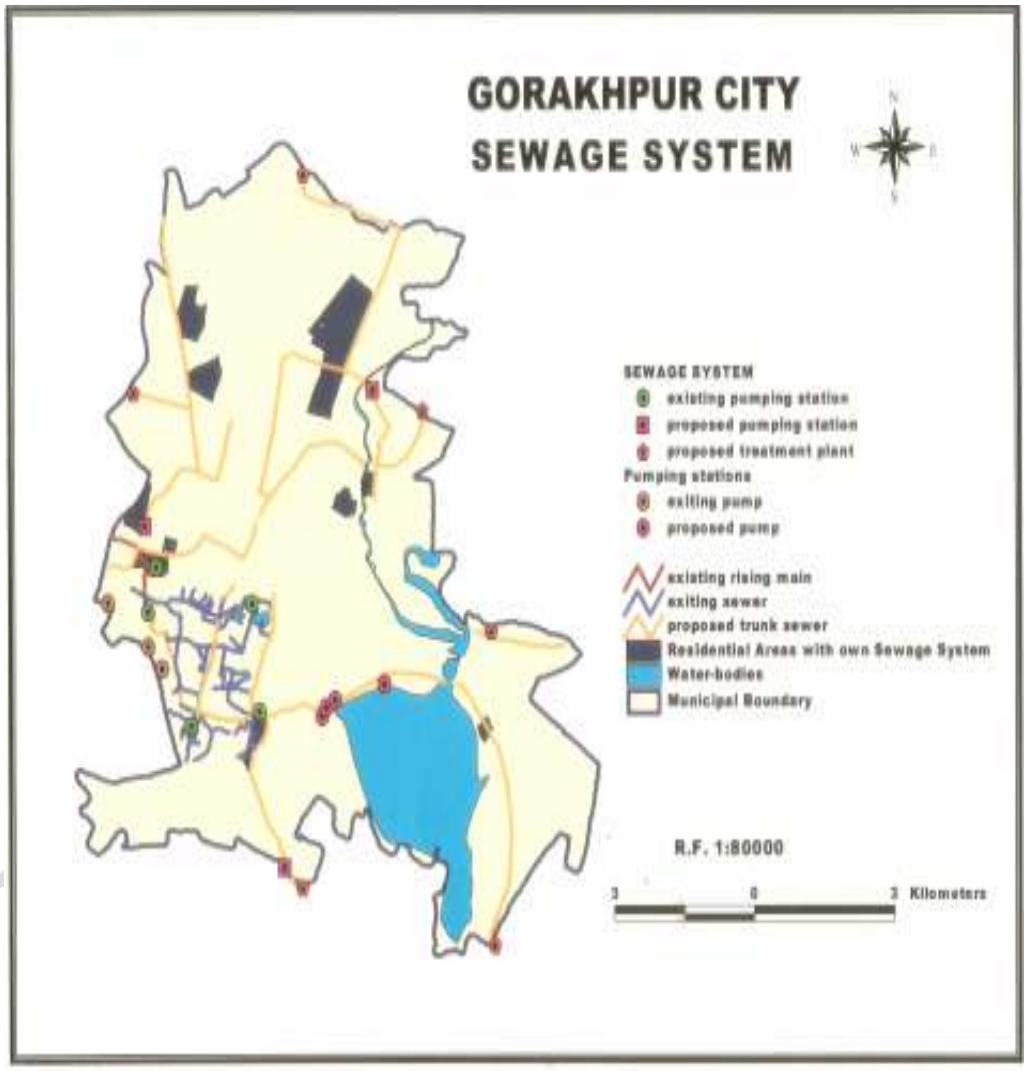

Fig 28

through open drains. There is no proper arrangement of draining the liquid waste even after building 229 open drains of about 191km length. Table-5 shows the number of drains according to their length.

Table : 5 Drains According to Length in Gorakhpur City

Length in mts	No. of Drains	Percentage
<500	130	56.77
500-1000	69	30.13
>1000	30	13.10
Total	229	100.00

The highest number of drains (130) are less than 500 meters length which accounts 56.77 percent of the total number of the drains whereas only 69 (30.13 percent) drain are of the length between 500-1000 mts where as 13.1% of drains are of maximum length of more than 1000 meters.

The drains constructed for disposal of waste water are of different size of width and depth which numbers are given in Tables 6 and 7.

Table : 6 Drains According to Width in Gorakhpur City

Width in mts	No. of Drain	Percentage
<1	135	58.95
1-2	81	35.37
>2	13	5.68
Total	229	100.00

The table shows that these 229 drains are major which has wide width. About 135(58.95%) drains are lass than one mt wide. But 94 have more than one mts. Width which is 41.05% of total number of the major drains of the city (table 6).

The drains constructed in the city are of different depth too. 101 drains are sallow depth which have depth of less than one metre while 128 are of more than one mts.The depth of the drains depends upon the slope and height of the area.

Table: 7 Drains According to Depth in Gorakhpur City

Depth mts	No. of Drain	Percentage
<1	101	44.11
1-1.5	87	37.99
> 1.5	41	17.9
Total	229	100.00

The spatial location of the major drains is shown in the Fig.29. Their locations have been surveyed with help of GPS and it has also been recorded whether the water is properly flowing or they are choked .It was found during the study that most of the drains are full of solid sediments and some of them are even discharging the water properly. But major numbers of drains are choked and their water is stagnant.

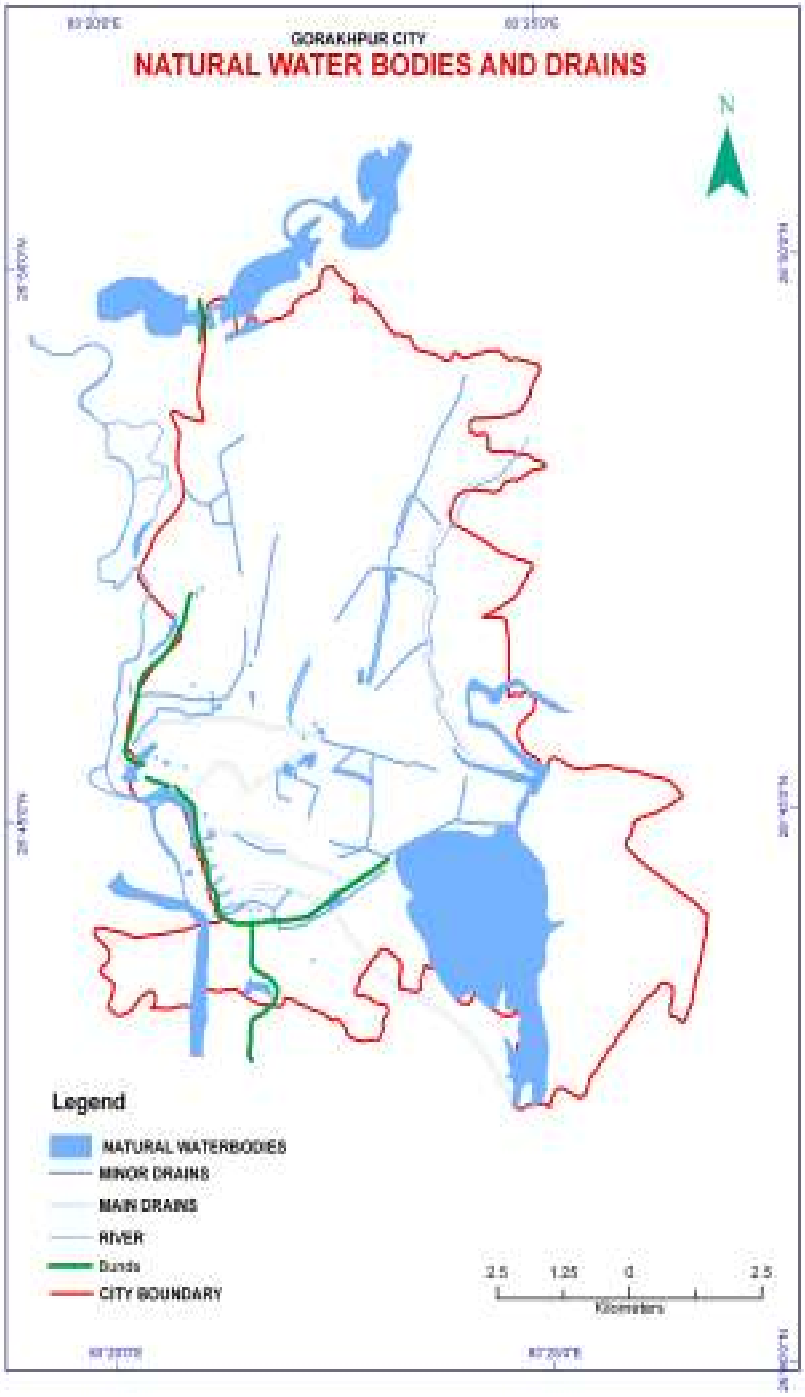
GORAKHPUR CITY
NATURAL WATER BODIES AND DRAINS
N
Legend
NATURAL WATERBODIES
MINOR DRAINS
MAIN DRAINS
RIVER
Bunds
CITY BOUNDARY
2.5 1.25 0 2.5
Kilometers

Fig 29

The distribution map of drains (fig.29) shows that in the older part of the city (southern part) have more drains. The drains of both part of the city has different pattern. The drains of northern part is north to south and their flow are also north to south, where as the drains of southern part are in east-west direction and their flow are in two directions. Flow of the drains of western part of south city is in west and finally discharge in river Rapti but the drains of eastern part of south city finally go to Ramgarh Lake. Thus their flow is towards east direction.

Except these major drains, there are some minor and subsidiary open drains along most of the roads for draining the domestic effluents which go to the major drains before finally discharged.

Thus the city is settled on the leveled ground but it has some variation in slope and its direction is recorded which is followed during the constructed of the drains.

In short it can be summarize that the height of the city varies from 72 t0 95 mts. But maximum part has 80 to 85 mts. height. The height decreases from north to south. The process of shifting the course of river Rapti is as one of the important factors for variation in elevation, presence of water bodies, lakes and depressions. The area of lake and depressions is decreasing very fast. City is facing the problem of water logging and flood due to its physiography.

SUMMERY AND CONCLUSIONS

The present study can be summarized that the Gorakhpur city which derived its name from renowned saint Gorakhnath, is a major socio economic, cultural, commercial, administrative and educational centre in the north-east of U.P. It is well connected with other parts of the nation through road and railways. It is located in Indo-Gangatic Plain. Thus the geology of the city exposes nothing beyond ordinary river borne new alluvium. The city is located in feature less plain area but there are some local elevation and topographical variation. The average height of the city - 80 mts.. The northern part is higher than the southern.

The topography of the city has great impact of shifting process of river Rapti which was flowing in early period west to east joining the Ramgarh Lake and it shifted its channels south ward and finally west ward in due course of time which is prove by various historical and topographical evidences. Due to the shifting of the Rapti river channels, a number of continuous lakes and remanents of river are present in the centre and southern portions of the city. But now the size and number of the lakes are decreasing very fast due to encroachment and process of infilling for the development of settlement. The total area of this depression has decrease as much as 96.05 percent during 1916 -17 to 2009.

The origin and growth of the city has also an interesting legend. The early site of the city was near present Gorakhnath Mandir which was after ward extended toward south ward. In the medieval period- Muslim and

Mugals periods the Gorakhpur city developed as a large town around Urdu Bazaar, Maya Bazar and Humanunpur.

In 1801 Sadat Ali Khan handed over the city to the British and they established a cantonment in 1810 in the Captainganj Mohalla in the east of the old city. The city got the status of Municipality in 1969 and Municipal Corporation in1982. Presently the total area of the city is 146.86 km^2. The climate of the city is moderate summer with pleasant winter and a rainy season between them. The temperature as well as the amount of rainfall is increasing during last years which may be the impact of climate change. The population growth of the city is exponential. At present the total population of the city is 6.2 lakh(2001) with an average density of 4559 persons /km^2. There was 170% growth in population during 1981-2001. The central part is denser than northern and eastern part.

The average height of the river bank area is about 75mts but the south central has less height whereas the northern part is comparatively higher. Therefore the general slope is from north to south. There is marked variation in the elevation and the slope in the city. The city terrain is just like bowel shape which is the cause of the problems related to the topography, sanitation, drainage, flood, hygiene and housing. A major part of the city (south part) on which the town is settled, lie below the high water level of the Rapti. Therefore water can easily inter in the city just after increase the level of water of river Rapti. But the Various embankments have been constructed to protect the city from the flood and inundation.

The city consists of an aggregation of inhabited sites separated by considerable space of cultivated land, tanks, low-lying areas and dirty pools. This has created an acute drainage and sanitation problems.

After heavy downpour as it was experienced in1998, water enter in the city due break of embankment and stagnated at places for several weeks. As the railway line running in the centre of the city through Dharmshala market at a raised bund which present the obstruction to flow the water north-south. In Dharmshala market, the store water flows through this road and stay there till it is pumped out. But a new flyover is constructed to solve this problems. The low lying areas along the 29th NH and Deoria bypass road which are made on the high embankments, are enclosed by these roads go under several feet of water because there are no any way of discharging the water from inner side to the outer except some choked drains. The bowl shaped surface of the city is an other great problem in providing the under ground drainage to the city.

The slope of the area is gentle but creates some problem of the draining the water in river Rapti and Ramgarh tal. Because the city is mostly enclosed by the embankment and high elevated road made without considering the natural drainage of the city. Thus the water of the inner side of the city can not go naturally into Ramgarh tal and river Rapti without pumping it.

Various major drains and sub drains are constructed to solve the problem of water logging but these drains are neither properly maintained nor cleared. Most of them are choked are semi choked due to disposal of the solid waste into them by local people. The city is also facing

the problems of solid waste and liquid waste disposal. The sewer facility is available in limited area (only in south central part). Only 22% of the total area is covered by under ground sewer facility. Therefore the dwellers of the major part of the city (78%) are still using the primitive method of sewage disposal. But due to least number of sewer pumping station (two), the sewer lines are not in proper working condition. There is no any sewer treatment plant. Most of the sewer goes directly into the river Rapti and Ramgarh Tal which is the major source of pollution of the water of the respective water bodies.

The natural water bodies which are the natural buffer zones for collection and infiltration of water to the under ground are being filled up to raise the buildings. It has a direct impact on the recharging the underground water. In summer the sallow hand pumps which are the main source of domestic water, remain dry. The Lithology of the city is very favorable for infiltration and recharging the underground water as well as to draw it on the surface for various uses.

Thus for the proper planning of the city specially to solve the problem of water logging, draining out the liquid waste and rain water and to make available the fresh water for domestic and other uses a comprehensive survey is required. In this respect the present study is a minor attempt which can be used as guide line for detailed study.

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