CONSERVING AND ENHANCING BIODIVERSITY OF A RESIDENTIAL AREA IN AN URBAN SETTING: CASE OF SARNATH, VARANASI

MASTERS OF ARCHITECTURE (LANDSCAPE ARCHITECTURE)

KSHITIJ SHIVAJEE

2015MLA010

SCHOOL OF PLANNING AND ARCHITECTURE, BHOPAL

NEELBAD ROAD, BHAURI, BHOPAL – 462030

MAY, 2017

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Under guidance of:
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Department of Architecture
School of Planning and Architecture, Bhopal

Declaration

I **Kshitij Shivajee**, **2015MLA010** hereby declare that the thesis titled **"CONSERVING AND ENHANCING BIODIVERSITY OF A RESIDENTIAL AREA IN AN URBAN SETTING: CASE OF SARNATH, VARANASI"** submitted by me in partial fulfilment for the award of Master of Landscape Architecture in School of Planning and Architecture Bhopal, India, is a record of bonafide work carried out by me. The matter embodied in this thesis has not been submitted to any other University or Institute for the award of any degree or diploma.

Kshitij Shivajee

Certificate

This is to certify that the declaration of **Kshitij Shivajee** is true to the best of my knowledge and that the student has worked for one semester in preparing this thesis.

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UNDERTAKING

I “*Kshitij Shivajee, 2015MLA010*, *Masters of Landscape Architecture*” have prepared a report titled “*Conserving and enhancing biodiversity of a residential area in an urban setting: case of Sarnath, Varanasi*” under the guidance of “*Ar. Sonal Tiwari*” for the purpose of in partial fulfilment of condition of masters of landscape architecture program at School of Planning and Architecture, Bhopal.

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Kshitij Shivajee

2015MLA010

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Abstract

Varanasi, said to be the oldest living city of human history, has gone through various phases of change whether cultural, social, religious or developmental changes after the industrialization period. During these processes of change the city has emerged as cultural, educational, industrial, trade and tourism centre for the surrounding areas. Thus receiving large number of footfall resulting into high demands of infrastructural support. In previous years it has been decided to develop the city as a smart city, which further creates pressure to develop infrastructural facilities.

City is expanding towards its outskirts as the core is already tightly packed with high density residential and commercial zones. This creates an alarming situation for the open/ green areas in and around the city and thus to the related biodiversity too.

If we go through the ancient scriptures the place was full of woodlands meadows, gardens, fruit orchards, ponds, lakes etc. which is an ideal condition for biodiversity to exist and grow. In one of the scriptures Lord Shiva describes the place to Goddess Parvati that see this is my favourite place which is full of fruit orchards, woods, dense forests, rivers, streams, wild animals, birds. That is why I like this place much over others.

So there are two extreme opposite situation if compare the two times. This thesis aims to minimize the gap between the above two situations. In today's era development is necessary but at the same time biodiversity is equally important for mankind to survive in a long run.

Sarnath is place which still has some large open spaces, manicured or natural. It was full of woods, deers, and peacocks even in the start of 20th century. Now days this parcel of land is also threatened by land mafias and developers. The attempt would be to create such an environment in which biodiversity will be in centre of every and any type of change which takes place in the region in order to conserve and enhance the area in terms of biological diversity.

1. Introduction

1.1 Contextual Background

Urban Biodiversity is the variety and richness of living organisms (including genetic variation) and habitat diversity found in and on the edge of human settlements. This biodiversity ranges from the rural fringe to the urban core. At the landscape and habitat level it includes:

- Remnants of natural landscapes (e.g. leftovers of primeval forests).
- Traditional agricultural landscapes (e.g. meadows, areas of arable land).
- Urban–industrial landscapes (e.g. city centres, residential areas, industrial parks, railway areas, formal parks and gardens, brownfields).

Diversity of plants and animals in the urban landscape shows some interesting patterns:

1. The number of plant species in urban areas often correlates with human population size more so than it does with the size of the city area.
2. The age of the city affects species richness; large, older cities have more plant species than large, younger cities.
3. Diversity may correlate with economic wealth. For example, plant and bird diversity in urban neighbourhoods and parks shows a significant positive correlation with median family income.
4. 20 percent of the world’s bird species and 5 percent of the vascular plant species occur in cities.
5. On average, 70 percent of the plant species and 94 percent of the bird species found in urban areas are native to the surrounding region.

Effect of Urbanisation on Biodiversity

Although cities occupy just 2 percent of the Earth's surface, their inhabitants use 75 percent of the planet's natural resources. Cities draw on their surrounding ecosystems for goods and services, and their products and emissions can affect regional and even global ecosystems.

As cities grow vital habitat is destroyed or fragmented into patches not big enough to support complex ecological communities. In the city, species may become endangered or even locally extinct as previously natural areas are swallowed up by the urban jungle.

1.2 Need of study

The most unique feature of Earth is the existence of life. Approximately 9 million types of plants, animals, protista and fungi inhabit the Earth. So, too, do 7 billion people. Two decades ago, at the first Earth Summit, the vast majority of the world's nations declared that human actions were dismantling the Earth's ecosystems, eliminating genes, species and biological traits at an alarming rate. This observation led to the question of how such loss of biological diversity will alter the functioning of ecosystems and their ability to provide society with the goods and services needed to prosper.

The loss of biodiversity has always existed as natural process. But the threat arise when the rate of extinction exceeds the natural rate of species extinction. According to the World Wildlife Fund's "Living planet Report 2014": between 1970 and 2010, the planet has lost 52 % of its biodiversity. In the same forty year period, the human population has nearly doubled. This shows that as human population expands its extent towards new areas under the tag of 'Development', some more species gets closer to extinction or gets extincted. In India, being a developing country, major focus is on infrastructure, supporting facilities, technical advancement etc. Governing body is proposing new smart cities with full of amenities & technological advancement, but there is no certain focus is being given on conservation of biodiversity or with required intensity.

Varanasi is one of the proposed smart cities of India with a prime focus on development. So need of conserving existing biodiversity & attempt towards enhancement of present scenario of the region becomes necessary. It will add very little to the global scale, but will definitely have impacts at regional or city scale and will cater to few more upcoming generations in terms of resources to prosper.

1.3 Aim and Objectives

1.3.1 Aim

Aim of the project is to conserve & enhance biodiversity of Sarnath, Varanasi while retaining its cultural and religious values.

1.3.2 Objectives

1. Assessing and collecting historical and contextual data/ information about the biodiversity of the region, then study area through primary & secondary data analysis.

2. Understand the relationship of biodiversity and landscape in urban residential area.

3. Finding issues related to biodiversity degradation/ threats to the biodiversity.

4. Design proposal taking care of conservation and enhancement of the area, while incorporating cultural & religious values.

1.4 Scope and Limitations

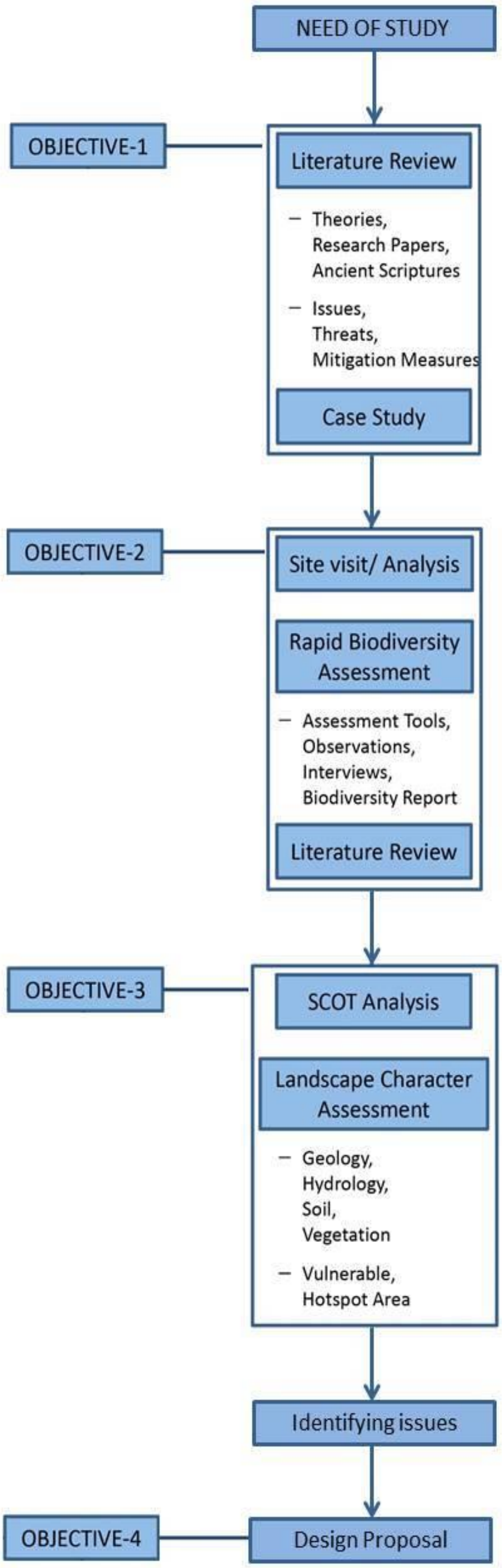
- The study will be structured as Macro- City Level (Banaras), Micro- Study Area Level (Sarnath- Buffer zone & heritage zone) & Meso- Any Open Space within the site area**.**
- Due to time constraint, the design proposal will be limited to Zoning/ Master Plan level only.

1.5 Expected Outcomes

- The existing condition of biodiversity of the region will define the intensity of intervention required. Accordingly norms/Guidelines will be formed to preserve/conserve/enhance the region.
- Biodiversity parks or enhancement of existing open/green areas in terms of flora and fauna, as a proposal, will be given.

- Certain areas can be proposed as ‘Biologically Protected Areas’. Assessment for those areas will be done and measures will be taken to enhance and protect the existing scenario of Biodiversity.
- Thus spreading the significance of biological diversity for an urban setting, engaging society/ locals as a stakeholder to participate in its conservation/ protection and enhancement.

1.6 Methodology



2. Varanasi City

2.1 Location

Varanasi also known as ‘Banaras’, ‘Benares’ or ‘Kashi’, one of the ancient cities and seat of learning in India is located on the left bank of the most sacred river Ganga. Varuna and Assi are the two streams bounding it from north and south. The city seems to have acquired its name from the combination of the names of these two streams and the district has been named after it

Varanasi lies 320 kilometres south-east of the state capital, Lucknow, and 121 kilometres east of Allahabad along National Highway 2, which connects it to Kolkata, Varanasi, Agra, and Delhi, and is served by Varanasi Junction railway station and Lal Bahadur Shastri International Airport. Sarnath, hardly 12 kms, from the city is the place where Lord Buddha preached his first sermon revealing the eight fold path that leads to the attainment of inner piece enlightenment and ultimate Nirvana.

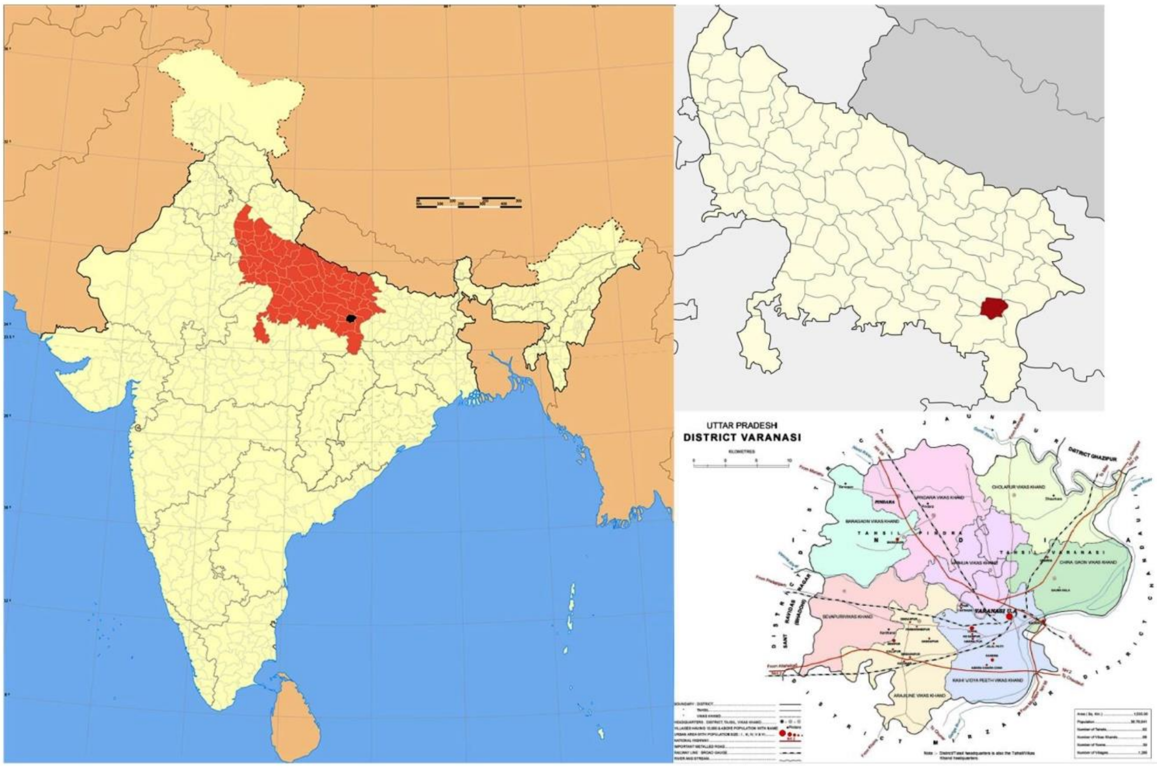


Figure 1: Location of Varanasi (India map, Uttar Pradesh map, Varanasi city)
Source: commons.wikimedia.org

2.2 History

Being a great religious centre of Hindus, it is visited by millions of people every year and so is the reason that it finds a mention in several ancient sacred texts like Purans, Mahabharat and Ramayana. Besides Hinduism, Buddha and Jain dharma have also flourished on this sacred place.

The district was originally a part of Kashi kingdom Pururavas Alia, the grandson of Manu, is said to be the founder of the earliest dynasty that ruled over this district. It acquired the ancient name Kashi, after the name of the seventh king of this dynasty, the Kasha. A few generations later there ruled a king named Dhanvantari who has been identified in Yayu Puran as the founder of Ayurveda, the indigenous system of medical treatment (the Pancham Veda).

According to Hindu mythology, in Satyug, the king Satya Harish Chandra with his wife sold himself to Dom Raja at Kashi, to pay the Dhakshina to Rajarshi Vishwamitra . History goes back to Vedas, Puranas, Ramayan, Mahabharat, Post Mahabharat, various dynasties and empires like Maunas, Magadh empire, Kaushalas, Angas, Kushans, Nagas, Nandas, Vanshas, Mauryas and Guptas.

After the death of Harshwardhana of Gupta dynasty it went under the reign of Gurjaras, Pratiharas, Mahmud of Gazni, Gaharwal, Muhammad ghauri, Tughlaques, Lodhis & then Mughals.

2.3 City growth

Varanasi is located at an elevation of 80.71 metres (264.8 ft) in the centre of the Ganges valley of North India, in the Eastern part of the state of Uttar Pradesh, along the left crescent-shaped bank of the Ganges, averaging between 15 metres (50 ft) and 21 metres (70 ft) above the river. The district measures 1535 square kilometres, out of which rural area is 1371.22 square kilometres & urban area covers 163.78 square kilometres. Being located in the Indo-Gangetic Plains of North India, the land is very fertile because low level floods in the Ganges continually replenish the soil. Varanasi is located between the Ganges confluences with two rivers: the Varuna and the Assi stream. The distance between the two confluences is around 2 miles (4 km), and serves as a sacred journeying route for Hindus.

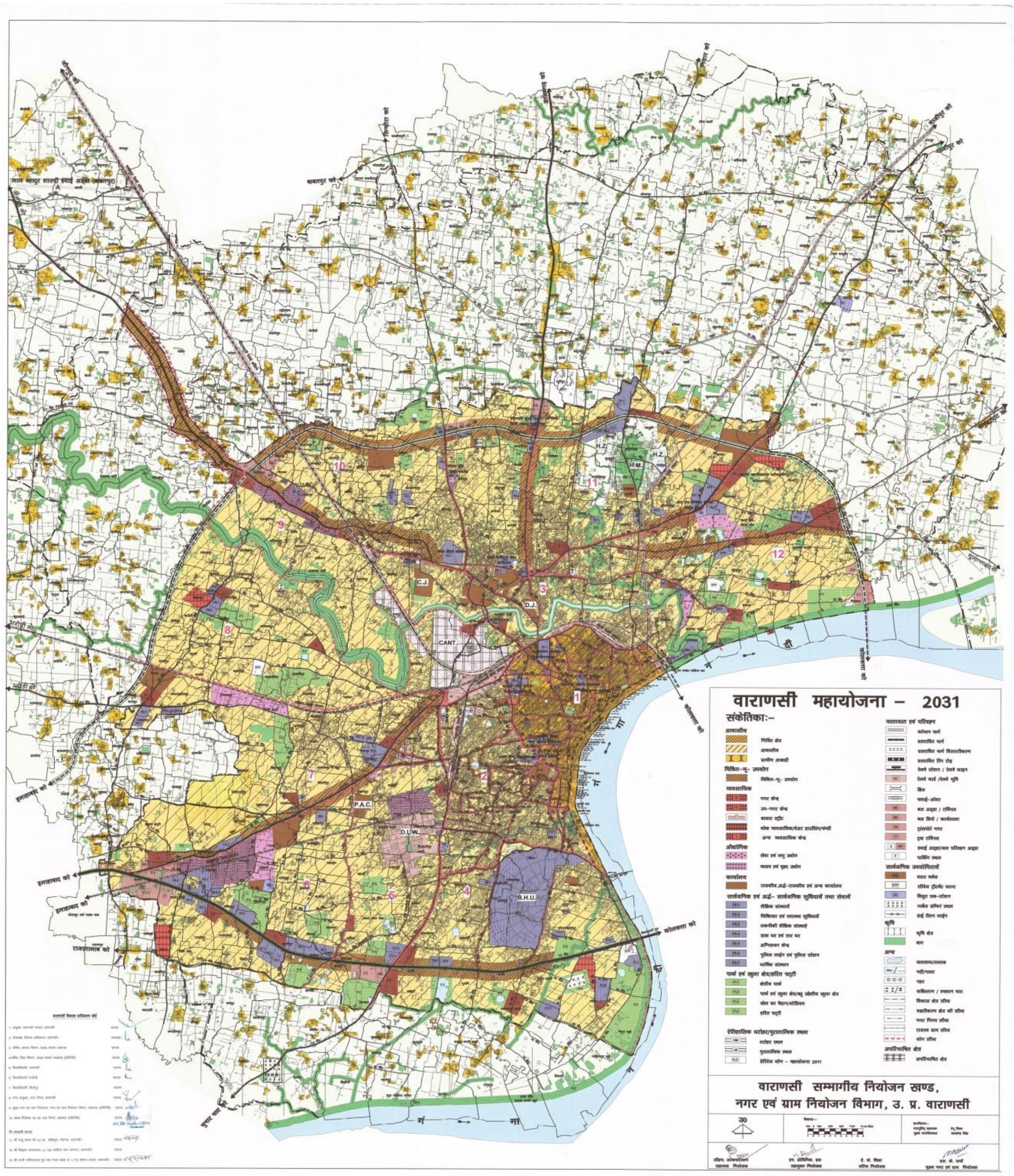


Figure 2: Map showing the proposed growth of the Varanasi city till 2031

2.4 Demography

		2001	2011	Variation			
No. of Households	Normal	427,492	555,728	128,236			
	Institutional	2,378	2,921	543			
Total population		Absolute			Percentage		
		Total	Rural	Urban	Total	Rural	Urban
	Persons	3,676,841	2,079,790	1,597,051	100.0	56.6	43.4
	Males	1,921,857	1,076,526	845,331	100.0	56.0	44.0
	Females	1,754,984	1,003,264	751,720	100.0	57.2	42.8
Decadal change 2001-2011		Absolute			Percentage		
		Total	Rural	Urban	Total	Rural	Urban
	Persons	538,170	201,690	336,480	17.1	10.7	26.7
	Males	272,670	100,471	172,199	16.5	10.3	25.6
	Females	265,500	101,219	164,281	17.8	11.2	28.0
Area in Sq. Km.		1,535.00	1,371.22	163.78			
Density of Population		2,395	1,517	9,751			
Sex Ratio 2011		913	932	889			

Figure 3: Table showing demographic trend between last two censuses
Source: District census handbook, Varanasi

2.5 Climate

The Climate of a region can be a major determining factor for the type and extent of intervention required for desired output. City experiences a humid subtropical climate (Köppen climate classification *Cwa*) with large variations between summer and winter temperatures.

The dry summer starts in April and lasts until June, followed by the monsoon season from July to October. The temperature ranges between 22 and 46 °C in the summers. Hot dry winds, called loo, blow in the summers.

Climate data for Varanasi													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C	32.3	35.8	42.4	45.3	46.8	48.0	43.9	39.8	42.3	39.0	35.3	32.7	48.0
Average high °C	23.0	26.2	32.6	38.5	40.3	38.4	33.7	32.9	32.8	32.7	29.4	24.7	32.1
Average low °C	9.2	11.6	16.2	21.9	25.5	27.2	25.7	25.4	24.4	20.6	14.4	10.1	19.2
Record low °C	0.3	2.4	7.9	11.4	17.8	14.3	21.4	21.7	19.1	8.9	4.3	2.3	0.3
Average precipitation mm	19.0	18.2	8.3	6.1	10.3	107.3	309.3	288.4	244.9	32.3	9.3	4.8	1,058.2
Average rainy days	1.6	1.7	1.0	0.6	1.2	5.4	13.9	13.1	10.0	1.8	0.6	0.5	51.5

Table 1: Varanasi climate chart. Chart figures are taken form Year 1970- 2001 (source: IMD Varanasi)

Winters see very large diurnal variations, with warm days and downright cold nights. Cold waves from the Himalayan region cause temperatures to dip across the city in the winter from December to February and temperatures below 5 °C are very common. Fog is common in the winters. The average annual rainfall is 1,110 mm (44 in).

3. Sarnath: Detailed study area

3.1 Location and Significance

Sarnath is located 12 kms. north to north- east of the city core of Varanasi, also towards north of the confluence of river Varuna into ganga.

Lord Buddha founded Buddhism here around 528 BCE when he gave his first sermon at Sarnath. The deer park in Sarnath is where Gautama Buddha first taught the Dharma, and where the Buddhist Sangha came into existence through the enlightenment of his first five disciples.

Singhpur, a village approximately one kilometre away from the site, was the birthplace of Shreyansanath, the Eleventh Tirthankara of Jainism, and a temple dedicated to him, is an important pilgrimage site.

After excavation of Buddhist monuments around the site, several Buddhist temples of different styles and architecture have come up, funded by different countries, which attracts lots of local as well as national and international tourists throughout the year. Thus increasing the footfall in the vicinity.

Figure 4: Map showing location of Sarnath in Varanasi
Source: uptourism.gov.in

3.2 Historical Background

Sarnath- The Mrigadaya/ Mrigadava

The name 'Sarnath' is named after a Brahmanical deity Siva/Shiva, although the place is famous as vibrant Buddhist pilgrimage site. "Sarnath means simply 'best of Lord', which title is here applied to the god Mahadeva, whose symbol- the Lingam- is enshrined in the small temple on the bank of the lake(Sarang Taal). It is an abbreviation of saranganatha, or the 'Lord of Deer', appropriate address of Mahadeva, who holds a deer in his left hand" (Cunningham, 1871a:105)

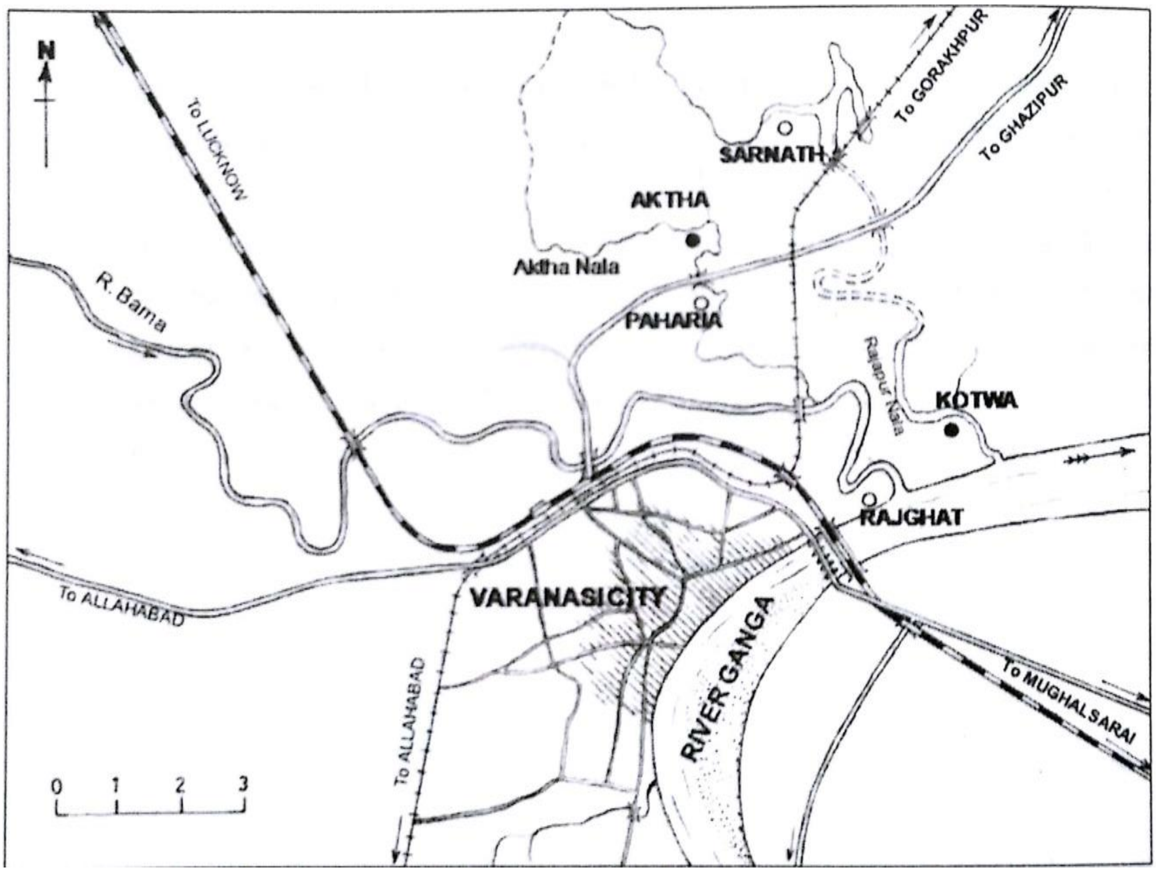


Figure 5: Ancient sites in Varanasi

Source: V. Jayaswal, The Buddhist Landscape of Varanasi

But, this certainly is a later address to this holy place. Since association of the place with the dear is also mentioned in the Buddhist scriptures. it is said that Gautam Buddha, in one of his previous births, roamed here as king of the deer. imprssed by his commitment to save a fellow deer, to be offered to the king of banaras for his meals, the king not only stopped the practice to accept the deer for his kitchen, but,"... made over the park, for the perpetual use of the deer, on which account it was called the 'deer Park' (Mrigadava)" (Cunningham 1871a:106).

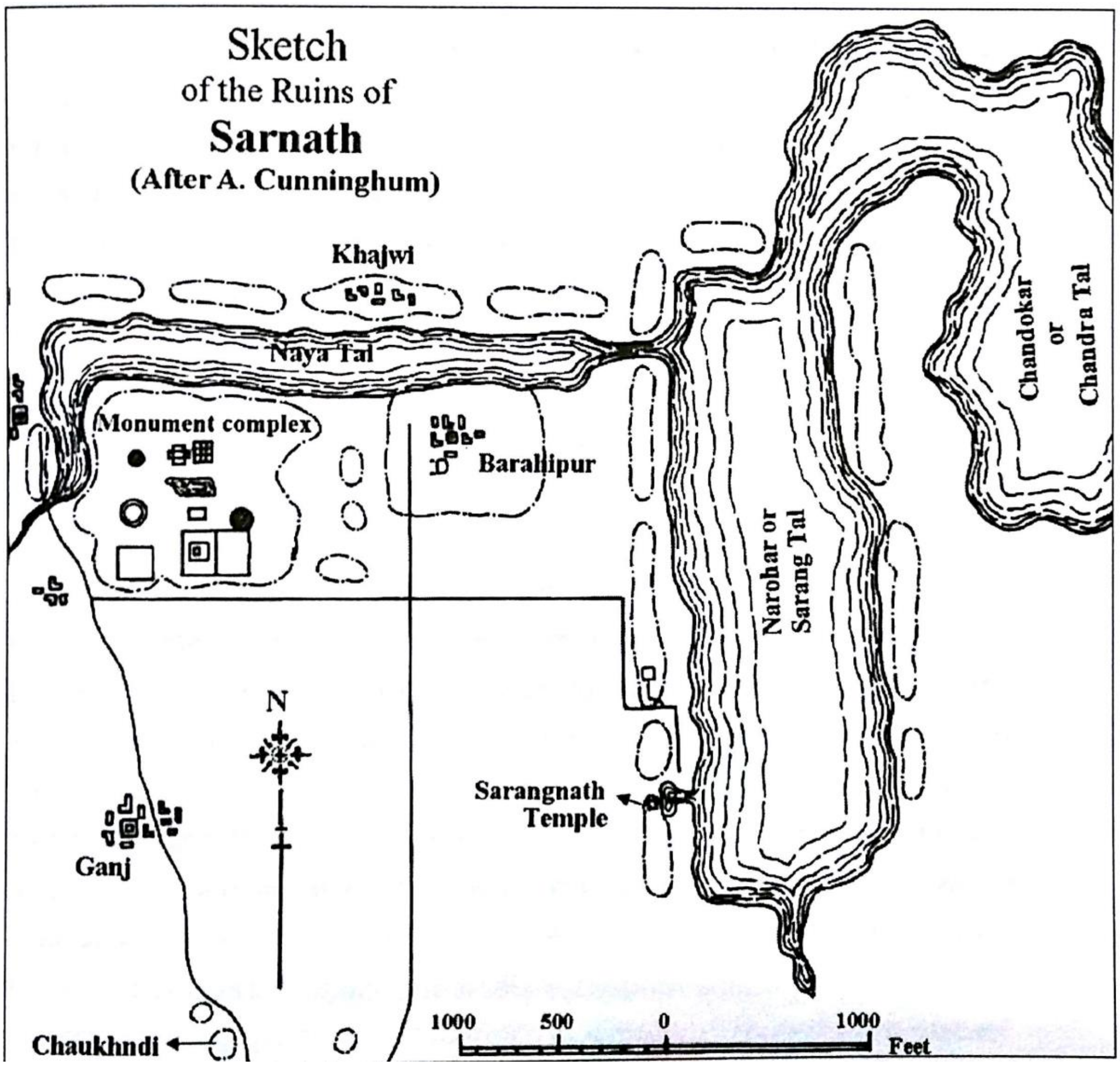


Figure 6: Geophysical Map of Sarnath, Cunningham
Source: V. Jayaswal, The Buddhist Landscape of Varanasi

Cunningham also mentions that the mound at Sarnath was surrouned on three sides by water pools. "On the north and east there are three large sheets of water which communicate with one another. To the east lies the Narokar or Sarang-tal, which is 3000 ft long and 100 ft broad. On the north east this communicates with the Chandodar or Chandra-tal, which is of the same size but of less irregular shape. On the north lies the Naya tal or 'New tank', which is upwards of half a mile in length, but little more than 300 feet in width" (Cunningham 1871a:106).

Prior to Cunningham, travel record of Chinese monk Xuanzang also have recorded existence of these water bodies at Mrigdaya. he describes..."In each the water is deep and the taste sweet, it is pure and resplendent in appearance and neither increases nor decreases".

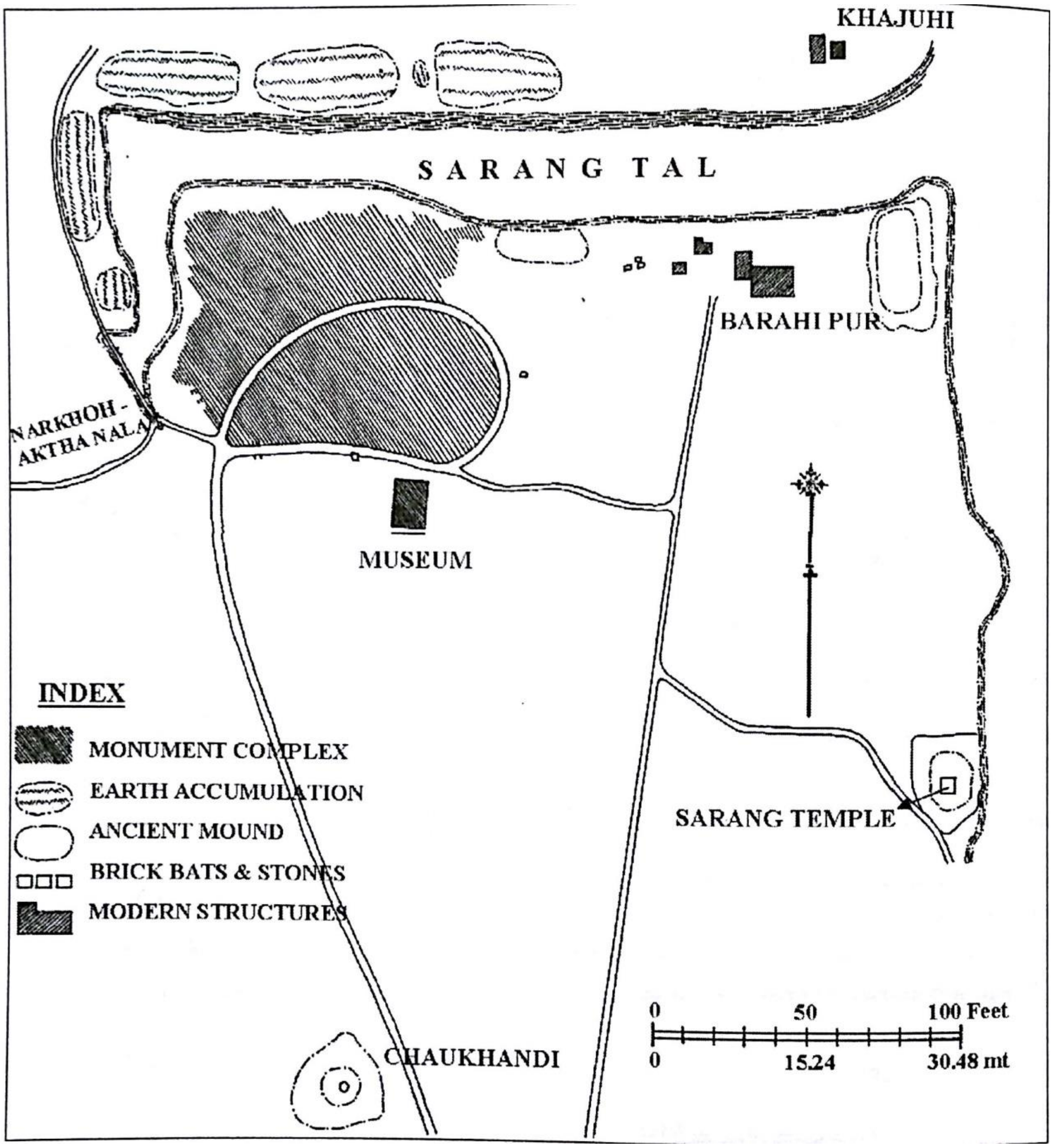


Figure 7: Site plan of sarnath monumrts, Cunningham
Source: V. Jayaswal, The Buddhist Landscape of Varanasi

The life span of the Buddhist establishment has been ascertained between 3rd century BCE and 12th century CE. It was abandoned after the late period. Once deserted it was also erased from the memory of people. After about eight centuries, the site came to light because of scavenging operation to obtain material from the ruins. Cunningham, when he visited Sarnath in 1862, noticed a mound and five monuments- Dhamek, Chaukhandi, Jagat singh stupa and two monasteries.

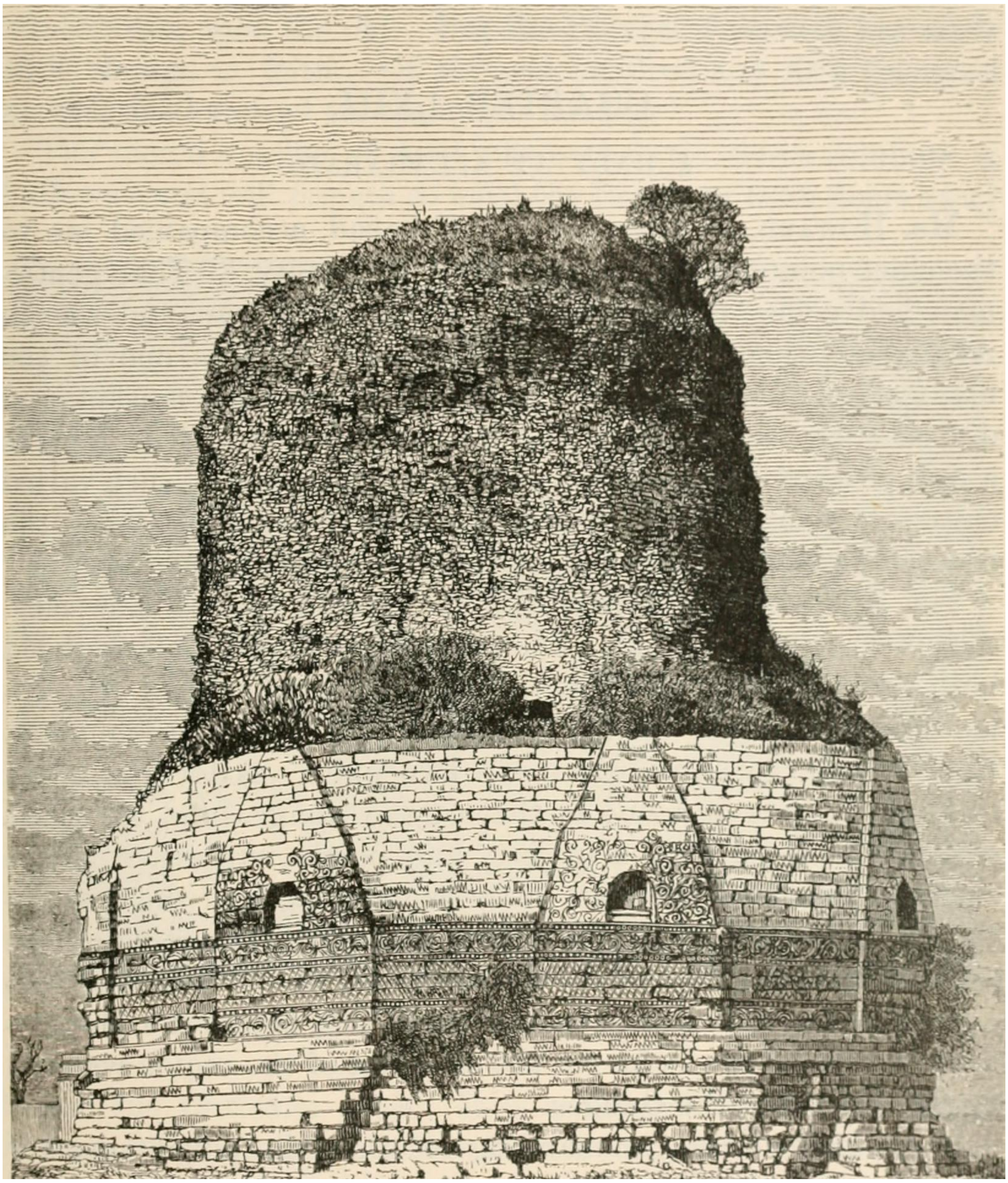


Figure 8: Dhamek stupa in 1891
Source: en.wikipedia.org

3.3 Site and Zoning

The ancient Buddhist site and its surroundings have been declared as Heritage Monument and Heritage zone measuring approximately 501 Ha/ 1238 Acres as follows:

Heritage Monument (H.M.) (Core area) - 131.37 Ha/ 324.62 acres (approx..), Nothing is permitted as a new construction in this zone to protect the ancient structures.

Buffer Zone (200m from core area) – 89.03 Ha/ 220 acres (approx..), G+1 structures are allowed that too with either special permission or with conditional ground depending upon their uses.

Heitaze Zone (H.Z.) (As demarcated) – 278.6 Ha/ 690 acres (approx..), Public utility and open/ green spaces are allowed on conditional ground or with special permission.

The site chosen for study & intervention comprises of buffer zone & heritage zone collectively.

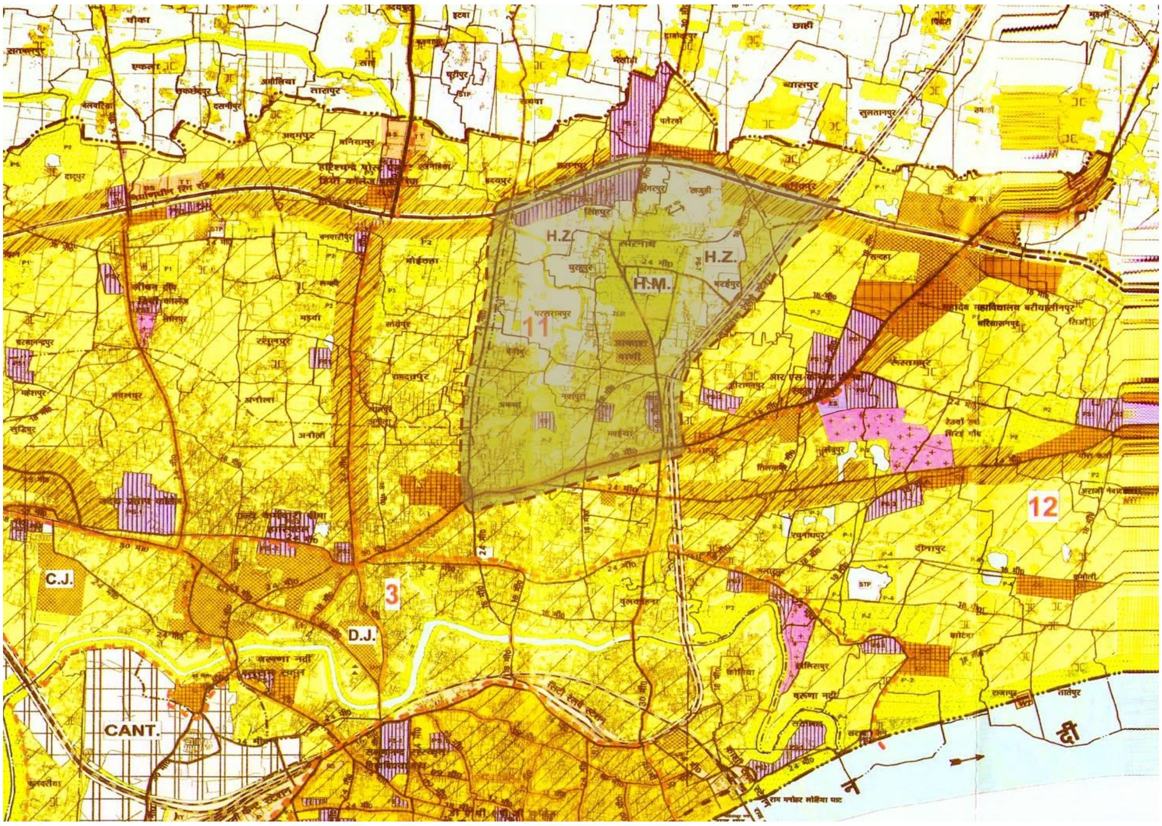


Figure 9: Map showing the site location and zones
Source: Varanasi Development Authority

The site is surrounded by 12m wide road and densely populated settlement beyond on southern side, to the west lies 9m wide road and densely populated settlement beyond, on the northern side falls 50m wide proposed highway and fields beyond and on the eastern side site gets its limit to the railway line whichconnects Varanasi to Ghazipur city.

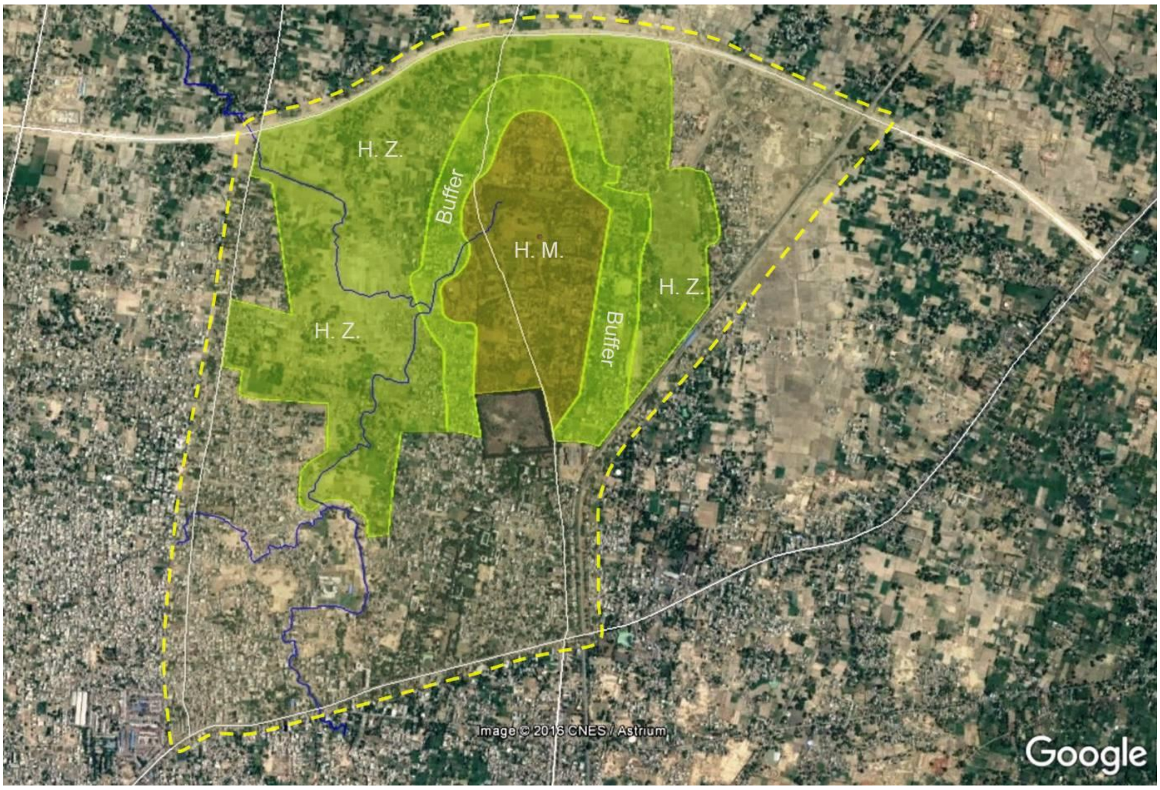


Figure 10: Satellite Imagery of site
Source: Author

3.4 Landuse

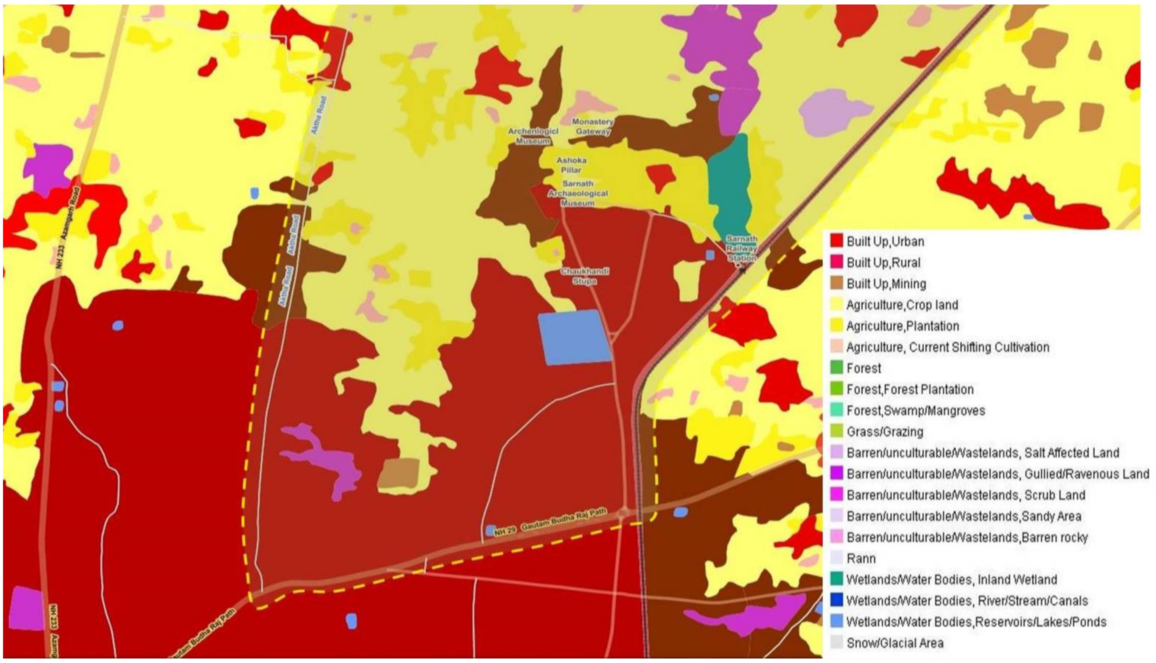


Figure 11: Map showing landuse pattern of the site
Source: bhuvan.nrsc.gov.in

Heritage zone is having maximum of Agricultural (Cropland as well as plantation), Heritage monument (Core area) and buffer is having less of it and more of built-up area.

3.5 Elevation and Hydrology

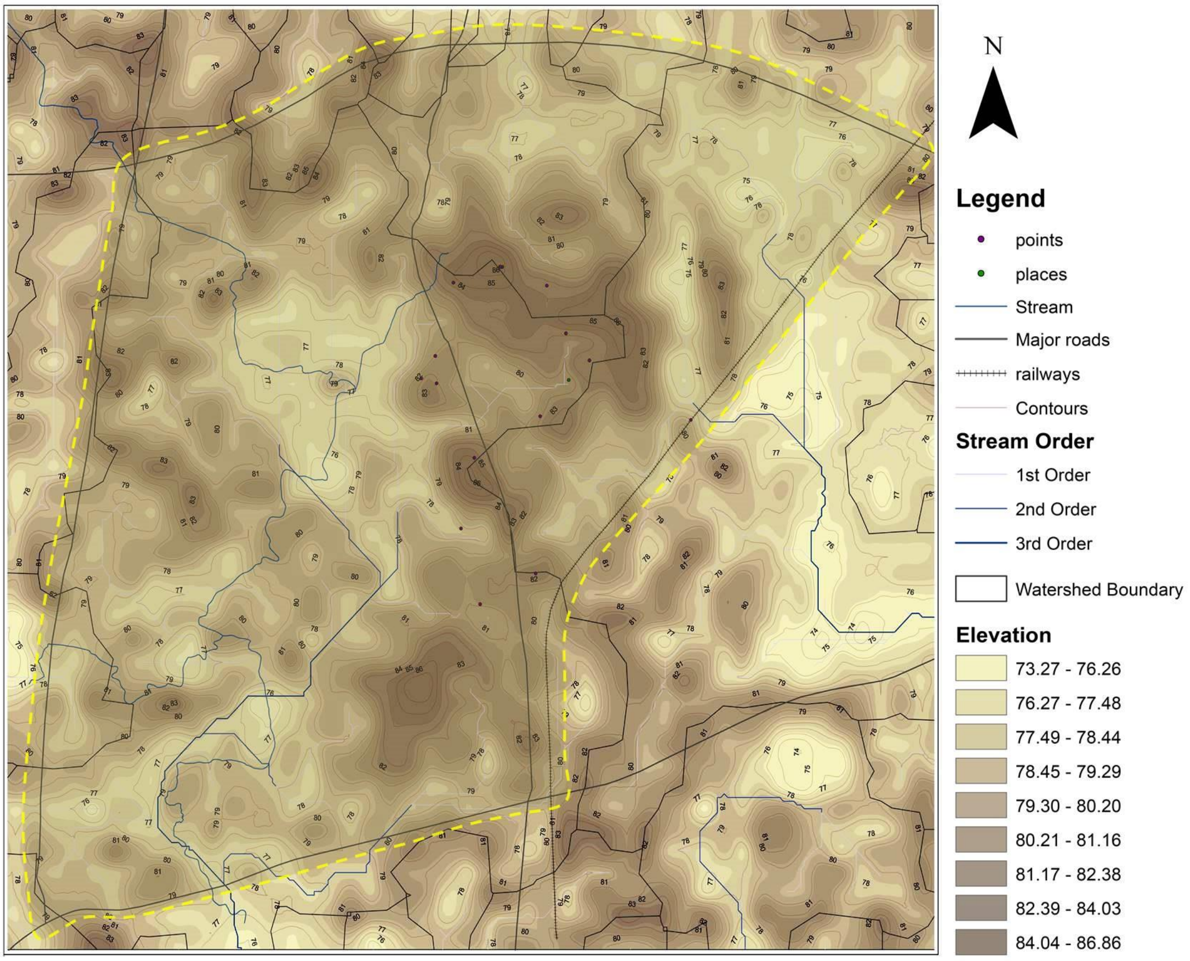


Figure 12: Map showing Elevation and Hydrology of the site
Source: Author

The elevation map clearly shows that the Heritage Monument (Core Area) is majorily lying in high elevations. Buffer and Heritage Zone has got maximum low lying areas which is favourable for wetland construction and thus for the wetland species.

3.6 Open vs Built up

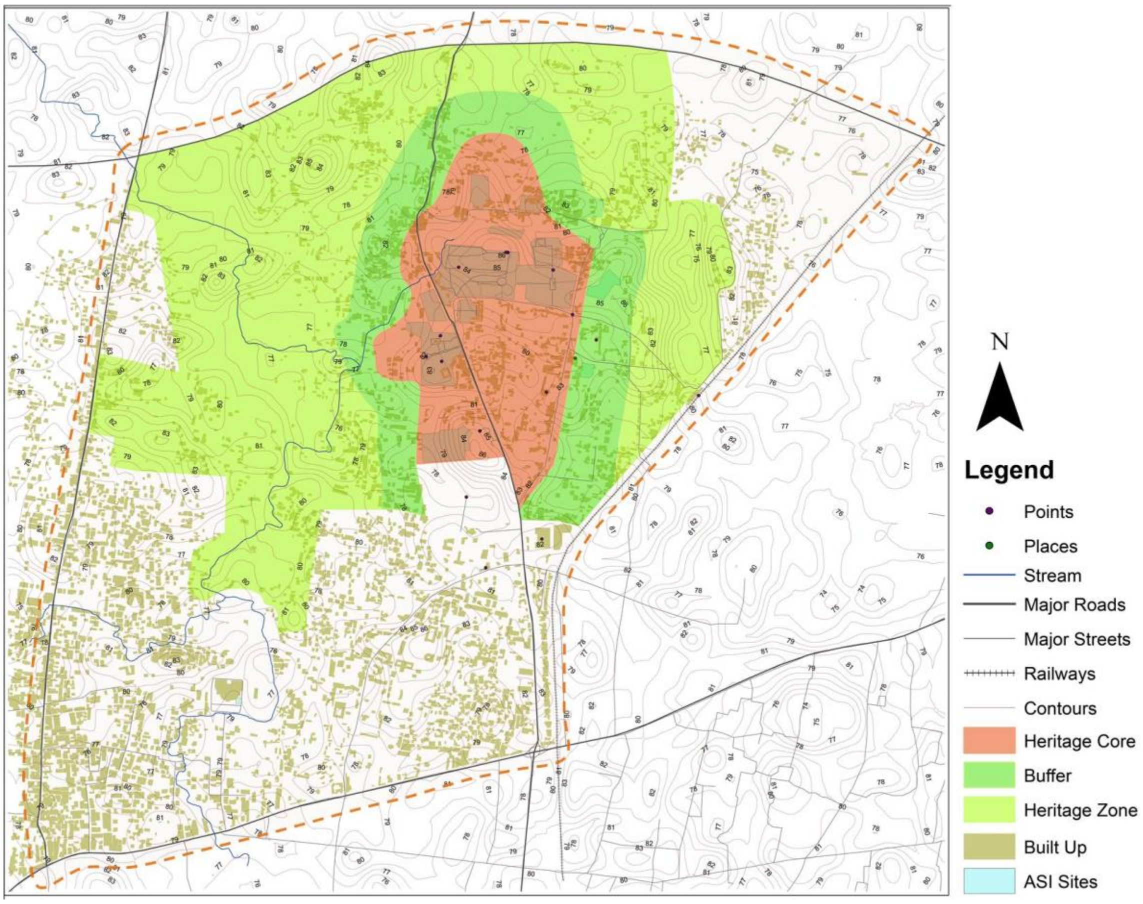


Figure 13: map showing open vs built-up ratio for the site area
Source: Author

Most of the open area with very sparse distribution of built mass can be seen in Heritage zone, while core and buffer areas are having reverse of it i. e. less of open & more of Built ups.

3.7 Geology (Regional)

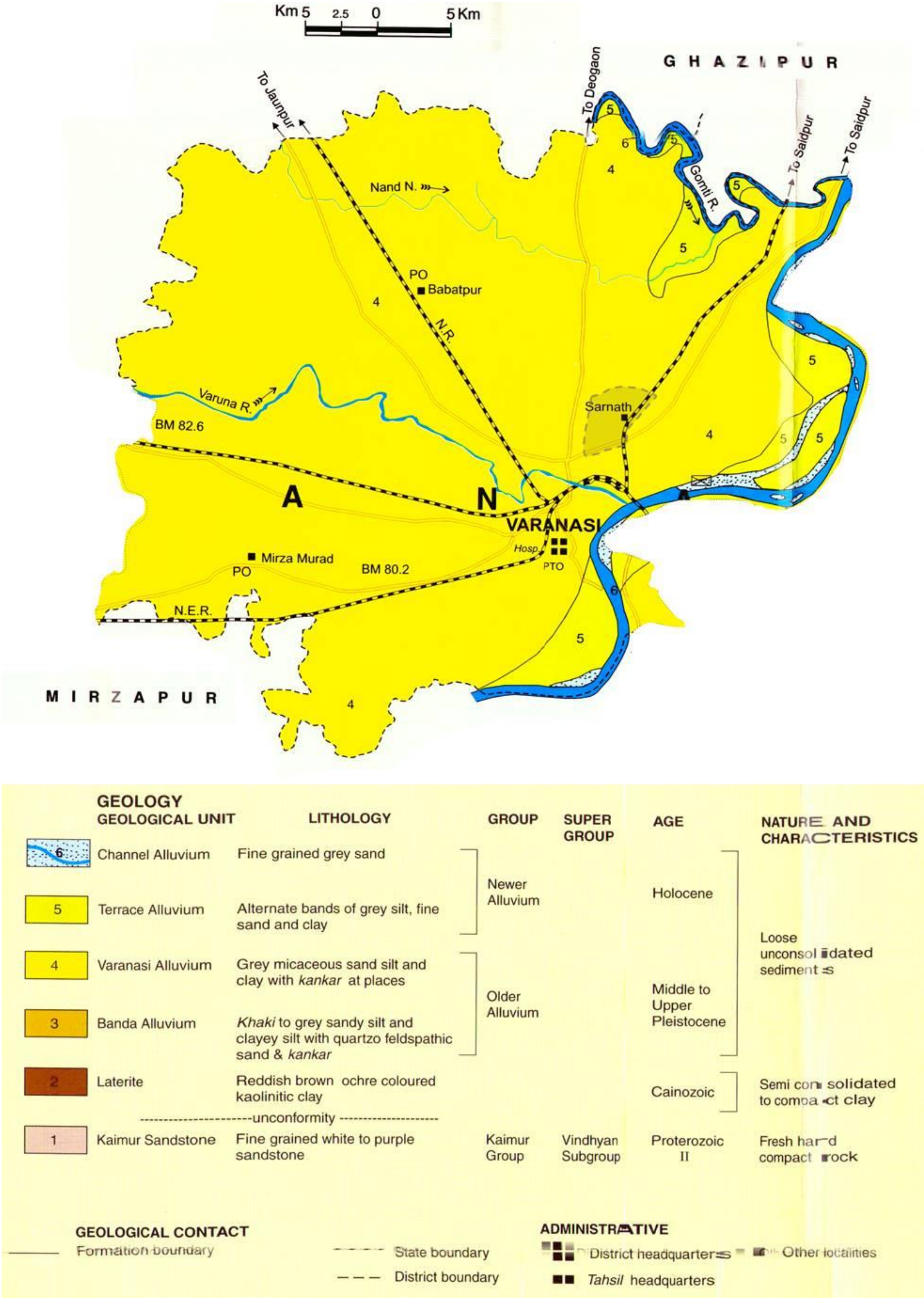
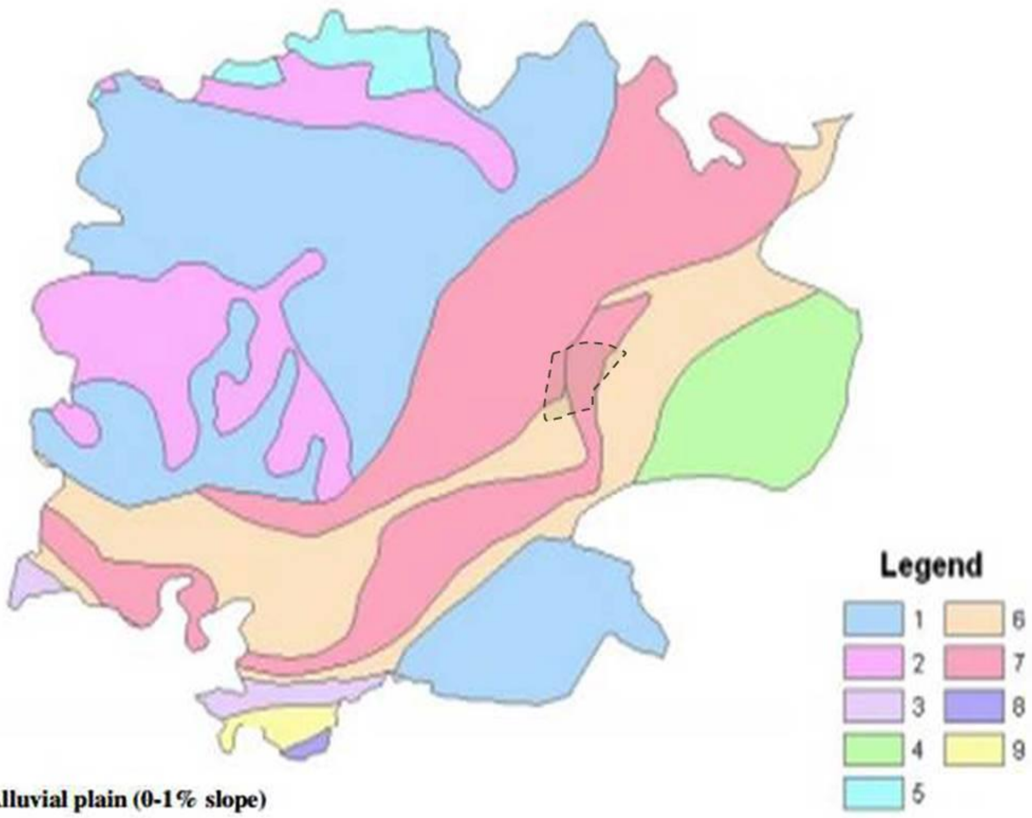


Figure 14: Map showing the broad idea of geology of site
Source: District Resource Map, GSI

The site falls under Varanasi alluvium category which is an older alluvial deposit and has grey micaceous sand silt and clay with kankar at places. Character wise it is loose unconsolidated sediment.

3.8 Soil (Regional)



Alluvial plain (0-1% slope)

1. Deep, loamy soils and slightly eroded.
2. Deep, fine soils moderately saline and sodic associated with loamy soils, slightly eroded.
3. Deep, fine soils and slightly eroded associated with loamy soils slightly saline and moderately sodic.
4. Deep, silty soils with moderately salinity and sodicity associated with loamy soils with moderate salinity and sodicity and water logging.
5. Deep, silty soils and slightly eroded associated with loamy soils slightly saline and slightly sodic.

Active Flood Plain (1-3% slope)

6. Deep, sandy soils with moderate flooding associated with stratified loamy soils and slight flooding.
7. Deep, stratified loamy soils, with severe flooding associated with loamy soils with moderate flooding.

Plateau (Sandstone on 1-3% slope)

8. Deep, loamy soils and moderately eroded
9. Deep, loamy soils and moderately eroded associated with fine soils and moderately eroded

Figure 15: Map showing the broad soil characteristics of site
Source: EIA report, Varanasi Metro

Inferences:

- Site has very strong historical and cultural connect since the time of Buddha and even before dating back to Vedas.
- Zoning regulations are such to provide conservation of Sarnath precinct and surroundings, which indicates that there are issues related to authenticity of sense of place.
- Expansion of city & its pressure has resulted into unauthorised development and encroachments, which may result into loss of open/ green spaces.
- There is a strong demand of biologically protected area which will bring back the authentic sense of place.
- Heritage zone is the most preferable area for the elements which supports biodiversity such as wetlands, grasslands, forests etc. and related activities.
- Soil and geology suggest that the place is very much fertile in nature, which is an ideal condition to develop the region as a biodiversity hotspot
- Water percolation rate is high because of the soil nature, which needs to be catered while designing the wetlands.

4. Key features (site and surroundings)

4.1 Sarnath Heritage Monument Complex

It comprises of Dharmarajika Stupa. Dhamek Stupa, Moolgandh Kuti Vihar, Ashoka Pillar from which national emblem on India has been taken and small Viharas spread throughout the complex.

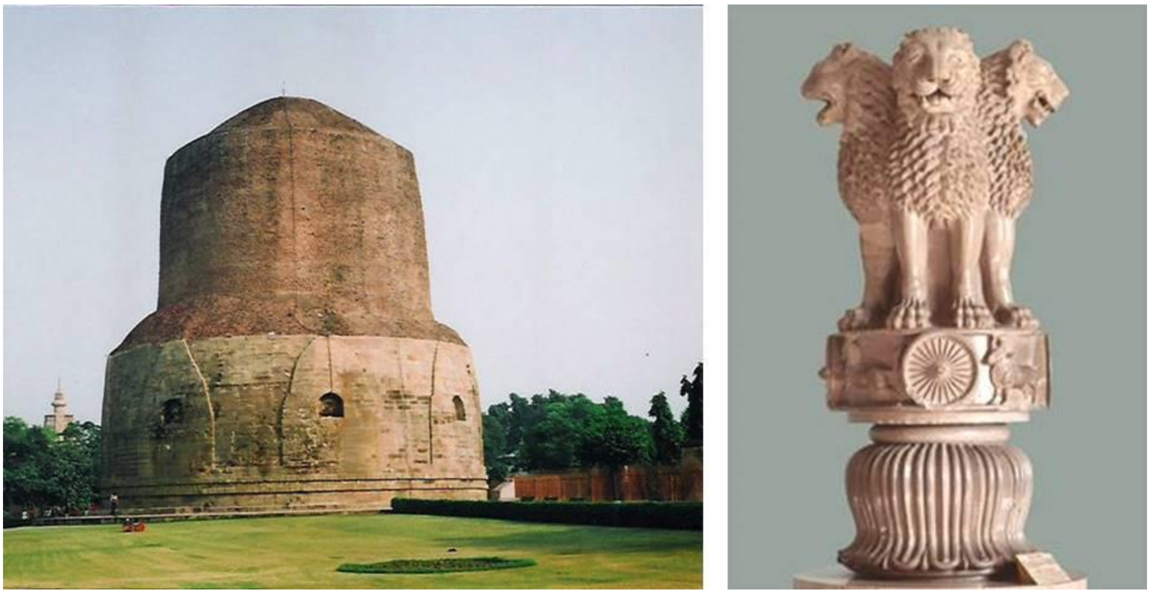


Figure 16: Dhamek Stupa and Ashoka Pillar, Sarnath
Source: en.wikipedia.org

Figure 17: Aerial view of Moolgandh Kuti Vihar and dharmrajika Stupa
Source: Author, Display centre at Sarnath

4.2 New Moolgandh Kuti Vihar

In 1930, The Mahabodhi Society Sri Lanka built the new temple which is located 350m (approx.) on the eastern side of the ancient Moolgandh Kuti Vihar. It is said to be the replica of the original ancient temple. The idol of Lord Buddha inside the temple is also the replica of the one which was found in archaeological excavation.

Figure 18: The new Moolgandh Kuti Vihar and Lord Buddha in Dharmachakra Pravartan Mudra
Source: en.wikipedia.org

4.3 The Deer Park and Small Zoo

Behind the new Moolgandh Kuti Vihar towards north lies the zoo which have got crocodiles, gharial, rabbits, indian crested porcupines and variety of birds. On the western side of the zoo & up till excavation site lies the deer park spread in approximately 4 hectares.

Figure 19: The Deer park and Bird cage
Source: Author

Figure 20: The Zoo and Cages for small birds
Source: Author

4.4 Sarnath Archaeological Museum

To the south of main excavated site and across the road lies the oldest site museum of Archaeological Survey of India. It houses the findings and excavations at the archaeological site of Sarnath and has 6,832 sculptures and artefacts. It also houses the famous Ashokan lion capital which became the National Emblem of India and national symbol on the Indian flag.

Figure 21: Sarnath Archaeological Museum
Source: en.wikipedia.org

4.5 Sarangnath Shiv Temple and Sarang Talaab

On the south-eastern side of the main excavation site and on the right hand side of the road heading towards the Sarnath railway station lays Sarang talaab followed by Sarangnath temple situated on a high elevated piece of land. Main deity of temple is lord Shiva & history of temple dates back to approximately 2500 years and said to be founded by Adi Shankaracharya.

Figure 22: Sarang talaab being renovated and Sarangnath temple
Source: Author

4.6 Chinese, Japanese, Tibetan, Korean and Thai temples

There are several small and big temples spread across the surroundings of Sarnath area. Some important old temples are Chinese, Japanese, Tibetan, Korean and Thai temple built by their respective country to spread their belief of Buddhism. The architectural styles of these temples clearly depict their key elements of design.

Figure 23: Chinese, Japanese and Tibetan temple at Sarnath
Sources: www.tripadvisor.in, www.holidify.com

Figure 24: Korean, Wat Thai temple and Buddha Statue, Thai temple campus
Sources: picssr.com, www.goibibo.com, Author

4.7 Existing Wetlands

There are wetlands with sufficient capacity to hold water. It is said that in ancient times those were the main source of water and were fully functional. It was constructed by Ashoka for the priests of Hindu and Buddhist beliefs, who were the main residents of the area.

In today's time also it can be seen but in a very bad condition. Primarily this is because of blockage of canal through which it was getting water earlier, now it gets only seasonal precipitation. Secondarily its catchment area has been encroached by settlements. As a result it is facing fragmentation, eutrophication, and water scarcity in summers.

Figure 25: Sarang Talaab and present condition of Existing Wtland
Source: Author

There are small wetlands falling in core area, maintained by Forest department as it is a part of Deer park and surrounding landscape. The overflow of these water bodies also goes to the above wetland.

Figure 26: Water Bodies inside dear park maintained by forest department
Source: Author

4.8 Existing Canal

On the western side of the main road, which divides the site into two parts, there is an old canal with lock gate system. Before lock gate the canal is mostly dried up except very tiny patch near the lock gate but that is mainly the waste water from some of the residences. This gets converted into drain after emerging from the Heritage zone as it enters the densely populated residential area. It is facing issues like eutrophication, lack of maintenance, drying up of channel etc.

Figure 27: Eutrophication of the canal after lock gate
Source: Author

This may act as a main source to bring in water to the wetland and to take out excess of water from wetland, thus needs revival.



Figure 28: Dried up channel before lock gate
Source: Author

4.9 Turtle Breeding Centre

Towards the eastern side of the new Moolgandh Kuti Vihar and adjacent to the existing wetland a turtle breeding centre is established in 1986 which is a part of the 'Kachhua Wildlife Sanctuary' as a whole. In this centre turtles are hatched and reared for one to one and a half years and then are released to river Ganga to remove bio pollutants.

The centre aims to provide the natural but safe environment to the newly born hatchlings. The pond is designed in such a way that they give a feeling of river channel along with the sand beds on its banks to train the hatchlings to hide themselves into the niches created in sand bed.


Figure 29: Turtle Breeding Centre adjacent to the existing wet land
Source: Author

5. Literature review

5.1 Erosion control techniques

5.1.1 Mechanical measures

- *Retaining walls*

  These are artificial structures that hold back soil, rock, or water from a building, structure, or area. Retaining walls prevent down slope movement and soil erosion, and provide support for vertical or near-vertical changes in gradient. The walls are generally made from timber, masonry, stone, brick, concrete, vinyl, steel, or a combination of these. Retaining walls act to support the lateral pressure exerted by a soil mass which may cause slope failure. Retaining walls are strongly recommended where the toe of slope has collapsed and the slope failure is likely to progress upward along the slope. Retaining walls should be constructed on a stable foundation.

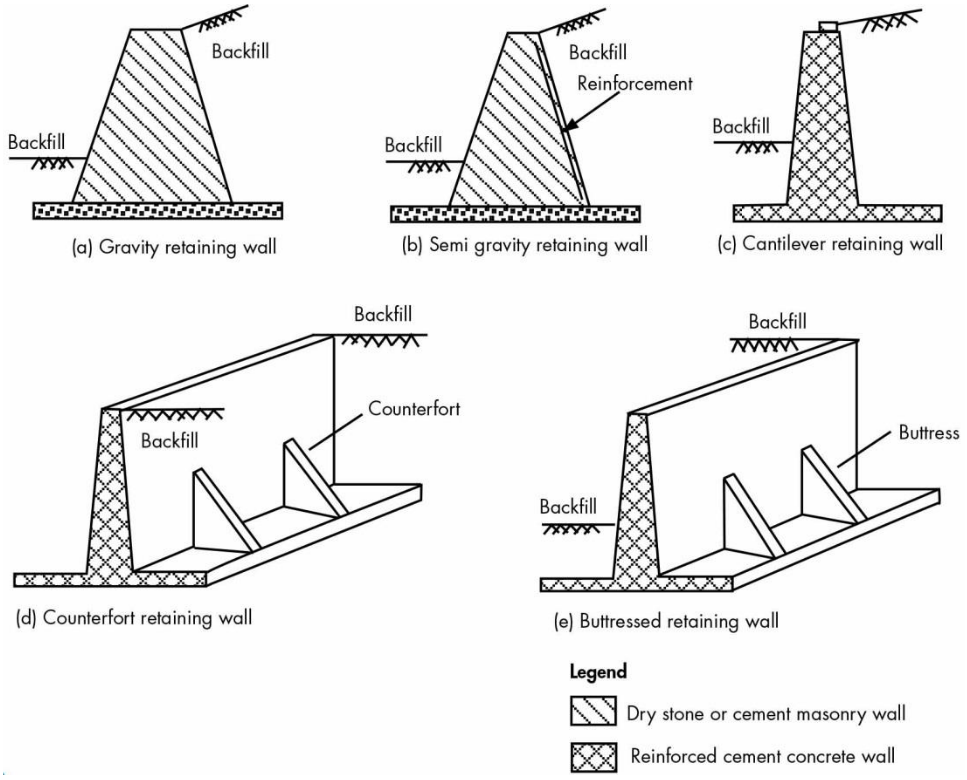


Figure 30: Types of retaining walls

Gravity retaining wall. A gravity retaining wall is low and depends on its own weight or mass to hold back the earth behind it

(Figure 33a). It is constructed with a large volume of material in such a way that, when stacked together, the weight and friction of the interlocking material exceeds the forces of the earth behind. The wall supports the pressure from the earth by means of its dead weight, and generally requires a good foundation with sufficient bearing capacity. The wall is thicker at the bottom than at the top; the thickness at the base should be between one-half and three-quarters of the height. Gravity walls are very cumbersome to construct because they require large amounts of material. They are usually constructed with concrete and masonry. The size of the section of a gravity retaining wall can be reduced if a small amount of reinforcement is provided near the back face.

Cantilever retaining wall. A cantilever retaining wall has a relatively thin stem, usually made of concrete reinforced with steel to resist the tensile force (Figure 33c). The width of the footing is very important as it is designed to resist the sliding forces which the earth exerts upon the wall. The wall requires significant steel reinforcing in both the footer and the wall structures. The steel should extend from within the footer up into the wall so that the two pieces become one integral unit. This type of wall is generally economical up to a height of 6–8 m.

Counterfort retaining wall. A counterfort retaining wall is similar to a cantilever retaining wall, but further supported by additional thin triangular shaped walls, or counterforts, built at right angles to the main trend of the wall. The counterforts are spaced at regular intervals along the wall and connect the back of the wall to the top of the footing (Figure 33d). The footing, retaining wall, and support walls must be tied to each other with reinforcing steel. The counterforts reduce the shear force and bending moments in the stem and the base slab and add strength to the retaining wall. They are hidden within the earthen or gravel backfill of the wall. Counterfort retaining walls are economical at heights of more than 6–8 m.

Buttressed retaining wall. Buttressed and counterfort retaining walls are similar, with the main difference that in buttressed walls the vertical brackets are provided in front of the wall (Figure 33e). The buttresses add strength and help to stabilize the overall wall system. Depending upon the overall length of the main wall, several buttresses can be constructed at regular intervals.

- *Bioswales*

Bioswales are linear, vegetated ditches which allow for the collection, conveyance, filtration and infiltration of storm water. The can also be referred to as "grass swales," "vegetated swales," or "filter strips." Bioswales have four functions for storm water management: collection, conveyance, filtration and infiltration. These four traits reduce and delay peak run off volumes as well as treat storm water quality.

- *Brush layering*

Brush layering consists of embedding live branches on successive horizontal rows along contours on the face of a slope. Rooted plants can also be placed among the live branches. The technique is useful for rehabilitating eroded slopes and gullies and for stabilizing fills and embankments during construction.

- *Brush fences*

Brush Fencing is a natural alternative to fencing. Treatments are intended to promote sediment deposition and protect the bed from erosion. Each fence is constructed over a timber frame and can be finished with a roll top brush capping ensuring the longest maintenance free life.

- *Buffer strip*

A buffer strip is an area of land maintained in permanent vegetation that helps to control air, soil, and water quality, along with other environmental problems.The root systems of the planted vegetation in these buffers hold soil particles together which alleviate the soil of wind erosion and stabilize stream banks providing protection against substantial erosion and landslides.

- *Mulches*

A mulch is a layer of material applied to the surface of an area of soil. It conserves moisture, and conserves the soil underneath from soil erosion.

- *Fibre roll*

  A fiber roll is a temporary erosion control and sediment control device used on construction sites to protect water quality in nearby streams, rivers, lakes and seas from sediment erosion. It is made of straw, coconut fiber or similar material formed into a tubular roll.

- *Gabions*

  Gabions are compartmented rectangular containers made of galvanized steel hexagonal wire mesh or rectangular plastic mesh and filled with hand-sized stone.The growth of native plants is promoted as gabions collect sediment in thestone fill .They are also resistant to being washed away by moving water.

- *Geotextile*

  Geotextiles are permeable fabrics which, when used in association with soil, have the ability to separate, filter, reinforce, protect, or drain. Geotextiles can be used to reinforce soils to improve bearing capacity, extending the range of moisture that can be accommodated under a load.

- *Hedgerows*

  A hedgerow is a line of closely spaced shrubs and tree species, planted and trained to form a barrier or to mark the boundary of an area. Vegetation holds in to soil and prevents soil erosion.

- *Live retaining wall*

  Live Retaining wall combines the techniques to combine vegetation and structural elements in retaining sloped embankments and accommodating changes in elevation. This system is ideal in climates with sufficient rainfall to naturally support the vegetation.

- *Rock armouring*

In this rock is used to armour shorelines, streambeds, bridge abutments, pilings & other shoreline structures against scour & water / ice erosion. it is made from a variety of rock types, commonly granite, limestone, concrete rubble and paving demolition. it can be used on any waterway or water containment where there is potential for water erosion.

- *Wind breaks*

  A windbreak or shelterbelt is a plantation usually made up of one or more rows of trees or shrubs planted in right angles to erosive winds to reduce wind velocity and protect soil from erosion.

5.1.2 Vegetative measures

Establishing vegetation can be a very effective way to stabilize a slope. Plant roots help anchor the soil and reduce compaction, allowing precipitation to infiltrate rather than flow down the slope. Above ground structures such as leaves and stems protect the soil surface from the impact of raindrops and slow down surface flow so that it has a better chance of infiltrating.

- *Hydrologic Mechanisms*

  Foliage intercepts rainfall, causing absorptive and evaporative losses that reduce rainfall available for infiltration.

  Roots extract moisture from the soil which is lost to the atmosphere via transpiration, leading to a lower pore-water pressure.

- *Mechanical Mechanisms*

  Roots reinforce the soil, increasing soil shear strength.

  Tree roots may anchor into firm strata, providing support to the upslope soil mainly through buttressing and arching.

  Weight of trees surcharges the slope, increasing normal and downhill force components. (Tree weight in some situations is beneficial to slope stability. Trees should not be arbitrarily cut to "unweight" slopes).

  Roots bind soil particles at the ground surface, reducing their susceptibility to erosion.

5.2 Constructed Wetlands

5.2.1 Introduction

A constructed wetland (CW) is an artificial wetland created for the purpose of treating municipal or industrial wastewater, grey water or storm water runoff. It may also be created for land reclamation after mining, refineries, or other ecological disturbances such as required mitigation for natural areas lost to land development.

Constructed wetlands are engineered systems that use natural functions of vegetation, soil, and organisms to treat different water streams. Depending on the type of wastewater that has to be treated, the system has to be adjusted accordingly which means that pre- or post-treatments might be necessary.

Constructed wetlands for water treatment are complex, integrated systems of water, plants, animals, microorganisms, and the environment. While wetlands are generally reliable, self-adjusting systems, an understanding of how natural wetlands are structured and how they function greatly increases the likelihood of successfully constructing a treatment wetland.

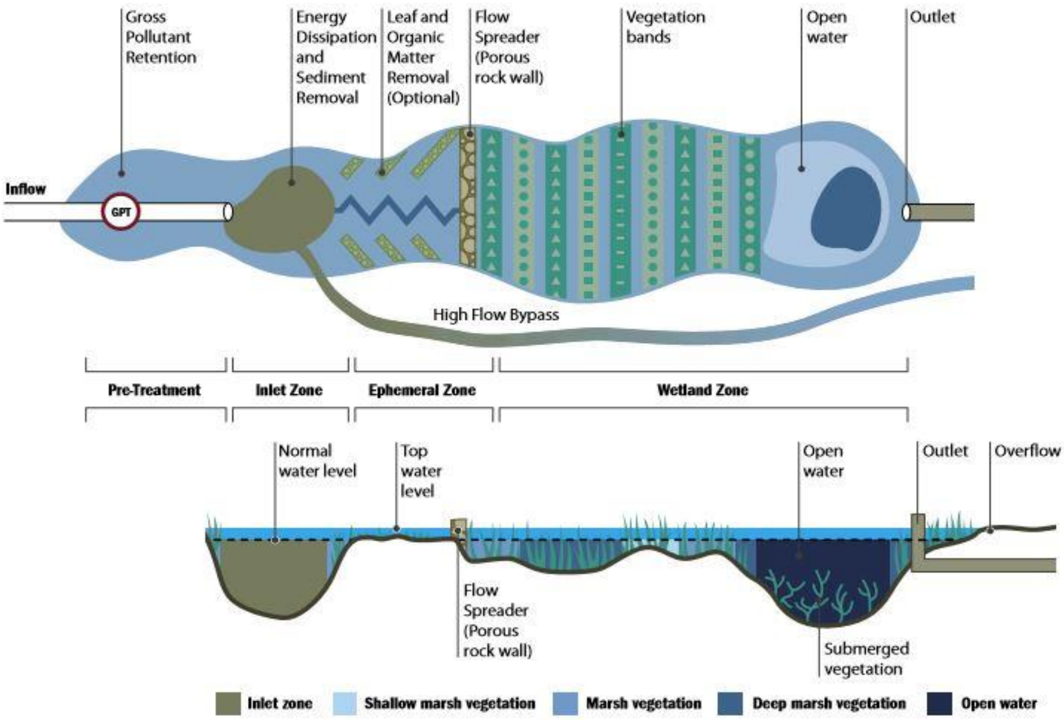


Figure 31: Schematic representation of typical constructed wetland
Source: Constructed wetland systems, Design guidelines for developers, Version 3, Nov. 2005

5.2.2 Wetland, Its function and Values

Wetlands are transitional areas between land and water. The boundaries between wetlands and uplands or deep water are therefore not always distinct. The term “wetlands” encompasses a broad range of wet environments, including marshes, bogs, swamps, wet meadows, tidal wetlands, floodplains, and ribbon (riparian) wetlands along stream channels. All wetlands - natural or constructed, freshwater or salt - have one characteristic in common: the presence of surface or near-surface water, at least periodically. In most wetlands, hydrologic conditions are such that the substrate is saturated long enough during the growing season to create oxygen-poor conditions in the substrate. The lack of oxygen creates reducing. (oxygen-poor) conditions within the substrate and limits the vegetation to those species that are adapted to low-oxygen environments.

The hydrology of wetlands is generally one of slow flows and either shallow waters or saturated substrates. The slow flows and shallow water depths allow sediments to settle as the water passes through the wetland. The slow flows also provide prolonged contact times between the water and the surfaces within the wetland. The complex mass of organic and inorganic materials and the diverse opportunities for gas/water interchanges foster a diverse community of microorganisms that break down or transform a wide variety of substances. Most wetlands support a dense growth of vascular plants adapted to saturated conditions. This vegetation slows the water, creates microenvironments within the water column, and provides attachment sites for the microbial community. The litter that accumulates as plants die back in the fall creates additional material and exchange sites, and provides a source of carbon, nitrogen, and phosphorous to fuel microbial processes.

Following are the functions of wetlands:

- Water storage
- Storm protection and flood mitigation
- Shoreline stabilisation
- Ground water recharge and discharge

- Water purification
- Retention of sediments, nutrients and pollutants
- Stabilization of local climate particularly temperature and rainfall

And values as follows:

- Water supply – maintenance of quantity and quality
- Fisheries
- Agriculture – through maintenance of water table
- Grazing
- Timber production
- Energy sources such as peat and plant matter
- Wildlife resources
- Recreation and tourism opportunities
- Biological diversity
- Cultural heritage

5.2.3 Components of constructed wetlands

A constructed wetland consists of a properly designed basin that contains water, a substrate, and, most commonly, vascular plants. These components can be manipulated in constructing a wetland. Other important components of wetlands, such as the communities of microbes and aquatic invertebrates, develop naturally.

Water

Wetlands are likely to form where landforms direct surface water to shallow basins and where a relatively impermeable subsurface layer prevents the surface water from seeping into the ground. These conditions can be created to construct a wetland. A wetland can be built almost anywhere in the landscape by shaping the land surface to collect surface water and by sealing the basin to retain the water. Hydrology is the most important design factor in constructed wetlands because it links all of the functions in a wetland and because it is often the primary factor in the success or failure of a constructed wetland. While the hydrology of constructed wetlands is not greatly different than that of other surface and near-surface waters, it does differ in several important respects:

- Small changes in hydrology can have fairly significant effects on a wetland and its treatment effectiveness
- Because of the large surface area of the water and its shallow depth, a wetland system interacts strongly with the atmosphere through rainfall and evapotranspiration (the combined loss of water by evaporation from the water surface and loss through transpiration by plants)
- The density of vegetation of a wetland strongly affects its hydrology, first, by obstructing flow paths as the water finds its sinuous way through the network of stems, leaves, roots, and rhizomes and, second, by blocking exposure to wind and sun.

Substrates, sediments, and litter

Substrates used to construct wetlands include soil, sand, gravel, rock, and organic materials such as compost. Sediments and litter then accumulate in the wetland because of the low water velocities and high productivity typical of wetlands. The substrates, sediments, and litter are important for several reasons:

- They support many of the living organisms in wetlands
- Substrate permeability affects the movement of water through the wetland
- Many chemical and biological (especially microbial) transformations take place within the substrates
- Substrates provide storage for many contaminants
- The accumulation of litter increases the amount of organic matter in the wetland. Organic matter provides sites for material exchange and microbial attachment, and is a source of carbon, the energy source that drives some of the important biological reactions in wetlands.

Vegetation

Both vascular plants (the higher plants) and non-vascular plants (algae) are important in constructed wetlands. Photosynthesis by algae increases the dissolved oxygen content of the water which in turn affects nutrient and metal reactions. Vascular plants contribute to the treatment of wastewater and runoff in a number of ways:

- They stabilize substrates and limit channelized flow
- They slow water velocities, allowing suspended materials to settle
- They take up carbon, nutrients, and trace elements and incorporate them into plant tissues
- They transfer gases between the atmosphere and the sediments
- Leakage of oxygen from subsurface plant structures creates oxygenated microsites within the substrate
- Their stem and root systems provide sites for microbial attachment
- They create litter when they die and decay.

Constructed wetlands are usually planted with emergent vegetation (non-woody plants that grow with their roots in the substrate and their stems and leaves emerging from the water surface). Common emergents used in constructed wetlands include bulrushes, cattails, reeds, and a number of broad-leaved species.

Microorganisms

A fundamental characteristic of wetlands is that their functions are largely regulated by microorganisms and their metabolism (Wetzel 1993). Microorganisms include bacteria, yeasts, fungi, protozoa, rind algae. The microbial biomass is a major sink for organic carbon and many nutrients. Microbial activity:

- Transforms a great number of organic and inorganic substances into innocuous or insoluble substances
- Alters the reduction/oxidation (redox) conditions of the substrate and thus affects the processing capacity of the wetland
- Is involved in the recycling of nutrients.

Some microbial transformations are aerobic (that is, they require free oxygen) while others are anaerobic (they take place in the absence of free oxygen). Many bacterial species are facultative anaerobes, that is, they are capable of functioning under both aerobic and anaerobic conditions in response to changing environmental conditions. Microbial populations adjust to changes in the water delivered to them. Populations of microbes can expand quickly when presented with suitable energy-containing materials. When environmental conditions are no longer suitable, many microorganisms become dormant and can remain dormant for years (Hilton 1993). The microbial community of a constructed wetland can be affected by toxic substances, such as pesticides and heavy metals, and care must be taken to prevent such chemicals from being introduced at damaging concentrations.

Animals and birds

Constructed wetlands provide habitat for a rich diversity of invertebrates and vertebrates. Invertebrate animals, such as insects and worms, contribute to the treatment process by fragmenting detritus and consuming organic matter. The larvae of many insects are aquatic and consume significant amounts of material during their larval stages, which may last for several years. Invertebrates also fill a number of ecological roles; for instance, dragonfly nymphs are important predators of mosquito larvae. Although invertebrates are the most important animals as far as water quality improvement is concerned, constructed wetlands also attract a variety of amphibians, turtles, birds, and mammals.

Constructed wetlands attract waterfowl and wading birds, including mallards, green-winged teal, wood ducks, moorhens, green and great blue herons, and bitterns. Snipe, red-winged blackbirds, marsh wrens, bank swallows, red tailed hawks, and Northern harriers feed and/or nest in wetlands.

Aesthetic and landscape enhancement

While wetlands are primarily treatment systems, they provide intangible benefits by increasing the aesthetics of the site and enhancing the landscape. Visually, wetlands are unusually rich environments. By introducing the element of water to the landscape, constructed wetlands, as much as natural wetlands. add diversity to the landscape. The complexity of shape, color, size, and interspersion of plants, and the variety in the sweep and curve of the edges of landforms all add to the aesthetic quality of the wetlands. Constructed wetlands can be built with curving shapes that follow the natural contours of the site, and some wetlands for water treatment are' indistinguishable, at first glance, from natural wetlands.

5.2.4 Advantages of constructed wetlands

Constructed wetlands are a cost-effective and technically feasible approach for treating wastewater and runoff for several reasons:

- Wetlands can be less expensive to build than other treatment options
- Operation and maintenance expenses (energy and supplies) are low
- Operation and maintenance require only periodic, rather than continuous, on-site labour
- Wetlands are able to tolerate fluctuations in flow
- They facilitate water reuse and recycling.

In addition:

- They provide habitat for many wetland organisms
- They can be built to fit harmoniously into the landscape
- They provide numerous benefits in addition to water quality improvement, such as wildlife habitat and the aesthetic enhancement of open spaces
- They are an environmentally-sensitive approach that is viewed with favour by the general public.

5.2.5 Limitations of constructed wetlands

There are limitations associated with the use of constructed wetlands:

- They generally require larger land areas than do conventional wastewater treatment systerns. Wetland treatment may be economical relative to other options only where land is available and affordable.

- Performance may be less consistent than in conventional treatment. Wetland treatment efficiencies may vary ‘seasonally in response to changing environmental conditions, including rainfall and drought. While the average performance over the year may be acceptable, wetland treatment cannot be relied upon if effluent quality must meet stringent discharge standards at all times.
- The biological components are sensitive to toxic chemicals, such as ammonia and pesticides
- Flushes of pollutants or surges in water flow may temporarily reduce treatment effectiveness
- They require a minimum amount of water if they are to survive. While wetlands can tolerate temporary drawdowns, they cannot withstand complete drying.

Also, the use of constructed wetlands for wastewater treatment and storm water control is a fairly recent development. There is yet no consensus on the optimal design of wetland systems nor is there much information on their long-term performance.

5.2.6 Types of constructed wetlands

There are majorly three types of constructed wetlands: surface flow wetlands, subsurface flow wetlands, and hybrid systems that incorporate surface and subsurface flow wetlands. Constructed wetland systems can also be combined with conventional treatment technologies.

a) Surface flow wetlands

A surface flow (SF) wetland consists of a shallow basin, soil or other medium to support the roots of vegetation, and a water control structure that maintains a shallow depth of water. The water surface is above the substrate. SF wetlands look much like natural marshes and can provide wildlife habitat and aesthetic benefits as well as water treatment. In SF wetlands, the near surface layer is aerobic while the deeper waters and substrate are usually anaerobic. Storm water wetlands and wetlands built to treat mine drainage and agricultural runoff are usually SF wetlands.

SF wetlands are sometimes called free water surface wetlands or, if they are for mine drainage, aerobic wetlands. The advantages of SF wetlands are that their capital and operating costs are low, and that their construction, operation, and maintenance are straightforward. The main disadvantage of SF systems is that they generally require a larger land area than other systems.

b) Subsurface flow wetlands

A subsurface flow (SSF) wetland consists of a sealed basin with a porous substrate of rock or gravel. The water level is designed to remain below the top of the substrate. In most of the systems in the United States, the flow path is horizontal, although some European systems use vertical flow paths. SSF systems are called by several names. Including vegetated submerged bed, root zone method, microbial rock reed filter, and plant-rock filter systems. Because of the hydraulic constraints imposed by the substrate, SSF wetlands are best suited to wastewaters with relatively low solids concentrations and under relatively uniform flow conditions. SSF wetlands have most frequently been used to reduce 5-day biochemical oxygen demand (BOD5) from domestic wastewaters. The advantages cited for SSF wetlands are greater cold tolerance, minimization of pest and odor problems, and, possibly, greater assimilation potential per unit of land area than in SF systems.

It has been claimed that the porous medium provides greater surface area for treatment contact than is found in SF wetlands, so that the treatment responses should be faster for SSF wetlands which can, therefore, be smaller than a SF system designed for the same volume of wastewater. Since the water surface is not exposed, public access problems are minimal. Several SSF systems are operating in parks. with public access encouraged.

The disadvantages of SSF wetlands are that they are more expensive to construct, on a unit basis. than SF wetlands. Because of cost, SSF wetlands are often used for small flows. SSF wetlands may be more difficult to regulate than SF wetlands, and maintenance and repair costs are generally higher than for SF wetlands. A number of systems have had problems with clogging and unintended surface flows.

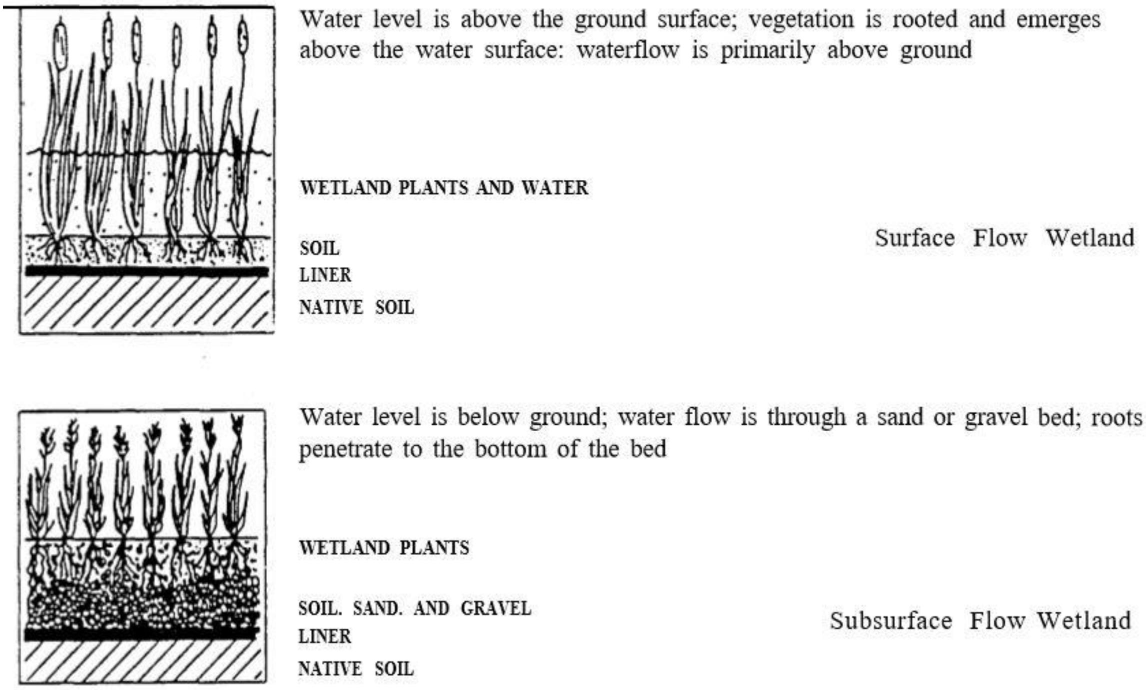


Figure 1. Surface flow and subsurface flow constructed wetlands (from Water Pollution Control Federation 1990).

Figure 32: Types of constructed wetlands
Source: A handbook of constructed wetlands, Volume 1, General Considerations

c) Hybrid system

Single stage systems require that all of the removal processes occur in the same space. In hybrid or multistage systems, different cells are designed for different types of reactions. Effective wetland treatment of mine drainage may require a sequence of different wetland cells to promote aerobic and anaerobic reactions. as may the removal of ammonia from agricultural wastewater.

5.2.7 Design considerations

Many constructed wetland systems have not been adequately monitored or have not been operating long enough to provide sufficient data for analysis. Among the systems that have been monitored, performance has varied and the influences of the diverse factors that affect performance, such as location, type of wastewater or runoff, wetland design, climate, weather, disturbance, and daily or seasonal variability, ‘have been difficult to quantify. In general, wetland designs attempt to mimic natural wetlands in overall structure while fostering those wetland processes that are thought to contribute the most to the improvement of water quality. Mitsch (1992) suggests the following guidelines for creating successful constructed wetlands:

- Keep the design simple. Complex technological approaches often invite failure.
- Design for minimal maintenance.
- Design the system to use natural energies, such as gravity flow.
- Design for the extremes of weather and climate, not the average. Storms, floods, and droughts are to be expected and planned for, not feared.
- Design the wetland with the landscape, not against it. Integrate the design with the natural topography of the site.
- Avoid over-engineering the design with rectangular basins, rigid structures and channels, and regular morphology. Mimic natural systems.
- Give the system time. Wetlands do not necessarily become functional overnight and several years may elapse before performance reaches optimal levels. Strategies that try to short-circuit
- The process of system development or to overmanage often fail.
- Design the system for function, not form. For instance, if initial plantings fail, but the overall function of the wetland, based on initial objectives, is intact, then the system has not failed.

Site selection

A site that is well suited for a constructed wetland is one that:

- Is conveniently located to the source of the wastewater
- Provides adequate space
- Is gently sloping, so that water can flow through the system by gravity
- Contains soils that can be sufficiently compacted to minimize seepage to groundwater

- Is above the water table
- Is not in a floodplain
- Does not contain threatened or endangered species
- Does not contain archaeological or historic resources.

Land use and Access

Access is an important consideration; the wetland should be placed so that the water can flow by gravity. If the odours or insects could be a problem, as with some agricultural wastewaters, the wetland should be placed as far from dwellings as possible. The site should be accessible to personnel, delivery vehicles, and equipment for construction and maintenance.

The current and future use and values of adjoining land also will affect the suitability of a site for a constructed wetland. The opinions of area residents and those of environmental and public interest groups should be considered. A large buffer zone should be placed between the wetland and neighbouring property. The wetland should not be placed next to the edge of the property.

Land availability

The effectiveness of a constructed wetland in treating wastewater or stormwater is related to the retention time of the water in the wetland. The usefulness of a constructed wetland may therefore be limited by the size of the wetland needed for adequate retention time. The site selected should be large enough to accommodate present requirements and any future expansion.

Topography

Landform considerations include shape, size, and orientation to the prevailing winds. While a constructed wetland can be built almost anywhere, selecting a site with gradual slopes that can be easily altered to collect and hold water simplifies design and construction, and minimizes costs

Since the best location for a constructed wetland is a low, flat area where water flows by gravity, it is important to ensure that the area is not already a wetland: not all wetlands have standing water throughout the year.

Climate and weather

Because wetlands are shallow water bodies open to the atmosphere, they are strongly influenced by climate and weather. Rainfall, snowmelt, spring runoff, drought, freeze, and temperature can all affect wetland treatment.

The high flows caused by heavy rains and rapid snowmelt shorten residence times. The efficiency of a wetland may therefore decrease during rainfall and snowmelt because of increased flow velocities and shortened contact times. High flows may dilute some dissolved pollutants while increasing the amount of suspended material as sediments in the wetland are resuspended and additional sediments are carried into the wetland by runoff.

Minimum temperatures limit the ability of wetlands to treat some, but not all, pollutants.. Wetlands continue to treat water during cold weather.

Hydro period

Hydro period is the seasonal pattern of water level fluctuations and is described by the timing, duration, frequency, and depth of inundation. The hydro period of a wetland results from the balance of inflow, outflow, and storage. Hydro period determines the availability of water throughout the year, the extreme wet and dry conditions that can be expected, the extent of storage and drainage that may be required, and the criteria to be used in designing the water control facilities. While hydro period can be engineered to control surface flow and to reduce its variability, the hydro period of a wetland will be strongly affected by seasonal differences in precipitation and evapotranspiration.

Ground water exchange

The movement of water between a ‘wetland add groundwater will affect the hydrology of the wetland. Constructed wetlands for domestic wastewater, agricultural wastewater, and mine drainage are usually lined to avoid-possible contamination of groundwater. If the wetland is properly sealed, infiltration can be considered negligible.

Other storm water wetlands are designed to intercept groundwater to ensure sufficient base flow. In this case, the wetland will receive groundwater when the water table is high and may discharge to groundwater when the water table is low.

Evapotranspiration

Evapotranspiration (ET) is the combined water loss through plant transpiration and evaporation from the water surface. In wetlands, the amount of surface area is large relative to the volume of water and ET is an important factor. Also, many wetland plants do not conserve water during hot, dry weather as most terrestrial plants do, and can transfer considerable amounts of water from a wetland to the atmosphere in summer. If ET losses exceed water inflows, supplemental water will be required to keep the wetland wet and to avoid concentrating pollutants to toxic levels.

Water balance

The overall water balance for a constructed wetland is an account of the inflow, storage, and outflow of water. Water inflow to the wetland includes surface water (the wastewater or storm water), groundwater infiltration (in unlined wetlands), and precipitation: Storage is the surface water plus that in the pore spaces of the substrate. Outflow comprises evaporation from the water surface, transpiration by plants, effluent discharge, and exfiltration to groundwater.

5.2.8 Vegetation

The function of plants in constructed wetlands is largely to grow and die: plant growth provides a vegetative mass that deflects flows and provides attachment sites for microbial development; death creates litter and releases organic carbon to fuel microbial metabolism. In addition, plants stabilize substrates while enhancing its permeability, and plants add greatly to the aesthetic value of the wetland. A dense stand of vegetation appears to moderate the effects of storms.

Plant selection

The plants that are most often used in constructed wetlands are persistent emergent plants, such as bulrushes (Scirpus), spikerush (Efeocharis), other sedges (Cyperus). rushes (Juncus), common reed (Phragrnites), and cattails (Typha). Not all wetland species are suitable for wastewater treatment since plants for treatment wetlands must be able to tolerate the combination of continuous flooding and exposure to wastewater or storm water containing relatively high and often variable concentrations of pollutants.

Recommended Species	Maximum water depth	Notes
Arrow arum *Peltandra virginica*	12 inches	Full sun to partial shade. High wildlife value. Foliage and rootstocks are not eaten by geese or muskrats. Slow grower. pH: 5.0-6.5.
Arrowhead/duck potato *Saggitaria latifolia*	12 inches	Aggressive colonizer. Mallards and muskrats can rapidly consume tubers. Loses much water through transpiration.
Common three-square bulrush *Scirpus pungens*	6 inches	Fast colonizer. Can tolerate periods of dryness. High metal removal. High waterfowl and songbird value.
Softstem bulrush Scirpus validus	12 inches	Aggressive colonizer. Full sun. High pollutant removal. Provides food and cover for many species. of birds. pH: 6.5-8.5.
Blue flag iris Iris versicolor	3 - 6 inches	Attractive flowers. Can tolerate partial shade but requires full sun to flower. Prefers acidic soil. Tolerant of high nutrient levels.
Broad-leaved cattail** Typha latifolia	12-18 inches	Aggressive. Tubers eaten by muskrat and beaver. High pollutant treatment, pH: 3.0-8.5.
Narrow-leaved cattail** Typha angustifolio	12 inches	Aggressive. Tubers eaten by muskrat and beaver. Tolerates brackish water. pH : 3.7-8.5.
Reed canary grass Phalaris arundinocea	6 inches	Grows on exposed areas and in shallow water. Good ground cover for berms
Lizard's tail Saururus cernuus	6 inches	Rapid grower. Shade tolerant. Low wildlife value except for wood ducks.
Pickerelweed Pontedaria cordata	12 inches	Full sun to partial shade. Moderate wildlife value. Nectar for butterflies. pH: 6.0-8.0.
Common reed** Phragmites australis	3 inches	Highly invasive; considered a pest species in many states. Poor wildlife value. pH: 3.7-8.0.
Soft rush Juncus effusu	3 inches	Tolerates wet or dry conditions. Food for birds. Often grows in tussocks or hummocks.
Spikerush Eleocharis palustris	3 inches	Tolerates partial shade.
Sedges Carex spp	3 inches	Many wetland and several upland species. High wildlife value for waterfowl and songbirds
Spatterdock Nuphar luteum	5 ft, 2 ft min	Tolerant of fluctuating water levels. Moderate food value for wildlife, high cover value. Tolerates acidic water (to pH 5.0).
Sweet flag Acorus calamus	3 inches	Produces distinctive flowers. Not a rapid colonizer. Tolerates acidic conditions. Tolerant of dry periods and partial shade. Low wildlife value.
Wild rice Zizania aquatica	12 inches	Requires full sun. High wildlife value (seeds, plant parts, and rootstocks are food for birds). Eaten by muskrats. Annual, non persistent. Does not reproduce vegetatively.

- These depths can be tolerated, but plant growth and survival may decline under permanent inundation at these depths.
- **Not recommended for storm water wetlands because they are highly invasive, but can be used in treatment wetlands if approved by regulatory agencies

Figure 33: Emergent plants for Constructed wetland (adapted from scheuler and thunhorst, 1993)
Source: A handbook of constructed wetlands, Volume 1, General Considerations

6. Case studies

6.1 Aravalli Biodiversity Park, Gurugram, Haryana

6.1.1 History

The history of the place dates back to the thousands of years as it is a part of Aravalli range which starts from Gujarat and ends into Delhi as central ridge. The site had active mining pit which were active since 1980s-90s and active stone crushing zone till 2002 when Supreme Court banned these two, but it was completely stopped in 2009. Municipal Corporation of Gurgaon came into existence and the whole land was given to MCG.

Later 'iamgurgaon', an NGO, identified the site and gave a proposal of urban park to MCG, which was not working efficiently in terms of generating revenue. Later iamgurgaon was engaged in developing the area as an ecological restoration project and since 2011 the site is being restored and rewild with help of professionals. After reworking the vision by professionals MCG got convinced that the place should be made forest to showcase the native flora of Aravalli.

6.1.2 Location and about

The park is located near Guru Dronacharya metro station. It gets its entry from the Mehrauli- Gurgaon road and spreads over 350 acres of land. It also shares its northern boundary with Delhi.

Owned by Municipal Corporation of Gurgaon(MCG) and Developed by 'iamgurgaon', an NGO, the site had barren hill slopes of 'Aravali' range with a deep water table, almost no soil cover & few forest patches in a much degraded state, mainly covered with 'Prosopis juliflora'. it was used for grazing, fodder & fuel wood collection and dumping of garbage Once developed completely, the park would give 600 acres of pristine space for leisure walks, jogging, trekking, bird watching, gardening, contemplation and cultural expression.

SOURCE: commons.wikimedia.org

SOURCE: www.delhionline.in

Figure 34: Location of park (India map, Haryana map and satellite imagery of site)
Source: Author

6.1.3 Plant listing and seed propagation

As of today, 160 species of trees, shrubs and climbers of the Aravalis have been planted with a number of about 75000. The aim was to reintroduce the lost flora of the Northern Aravalli. An extensive survey of the Aravalli flora through literature as well as field surveys was done to match the research with site realities, before the enlisting of trees was done.

Seeds were being collected from various places during travelling, through locals and from the forests of Mangar, Nahargarh and Kumbhalgarh, that showed compatibility with the kind of natural conditions prevailing on site. The seed collection is still going on and an onsite nursery has been established to meet up the requirement of variety of species, which unfortunately was not available with the commercial nurseries.

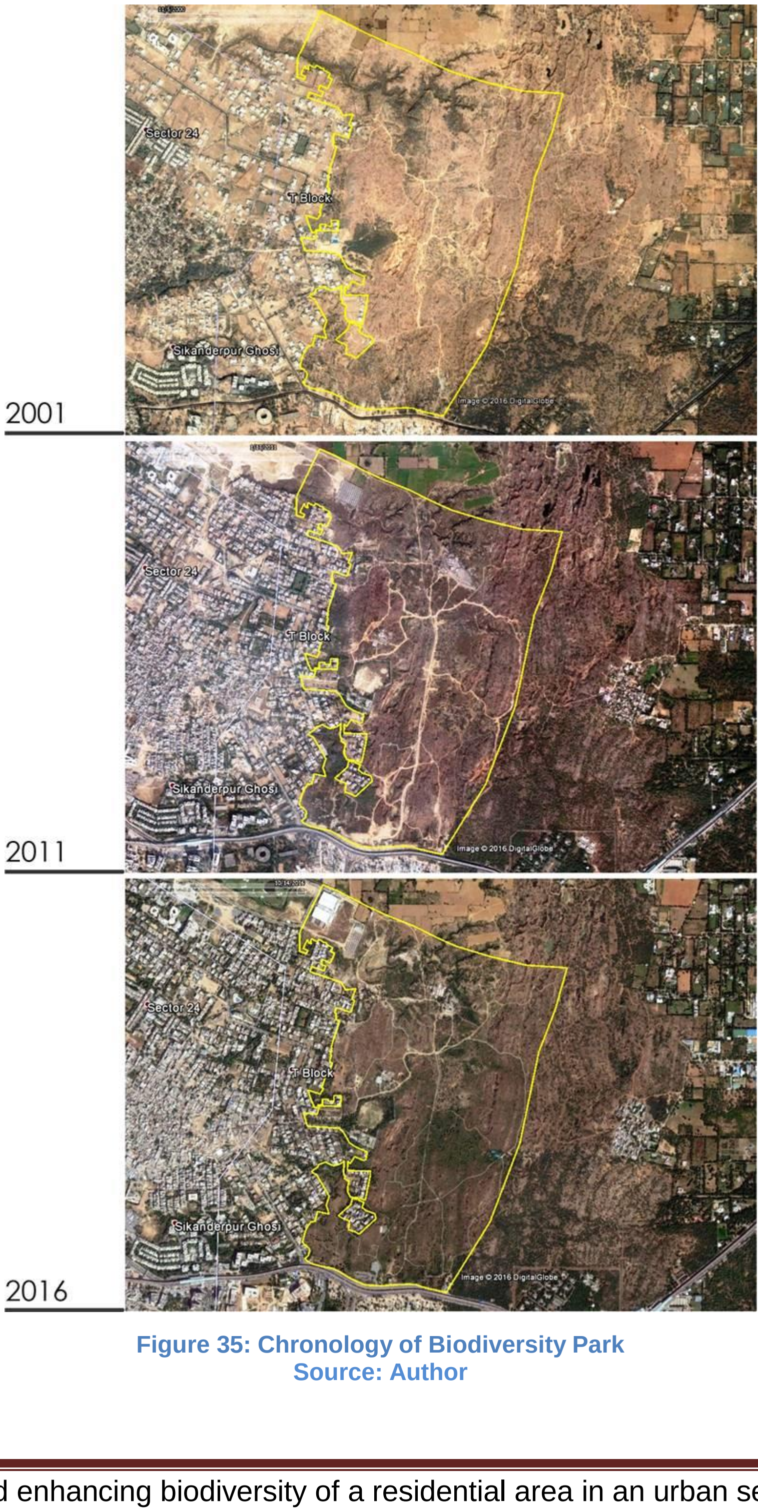


Figure 35: Chronology of Biodiversity Park
Source: Author

The broad theme of the plantation was to plant the hilltops with:-

a) Boswellia serrata and its associates (Sterculia urens, lannea coromendalica etc).

b) Anogeissus pendula and its associates (Acacia leuchophloea, Acacia senegal, Bauhinia racemosa etc).

The valleys were planted with Mitragyna parviflora and its associates. The deep sandy patches prone to flooding were planted with Acaia nilotica, Pheonix sylvestris and associates. A large number of shrubs and climbers were planted along with the tree species, also several species of native grasses such as Cymbopogon martinii, Desmostachya bippinata etc were also introduced.

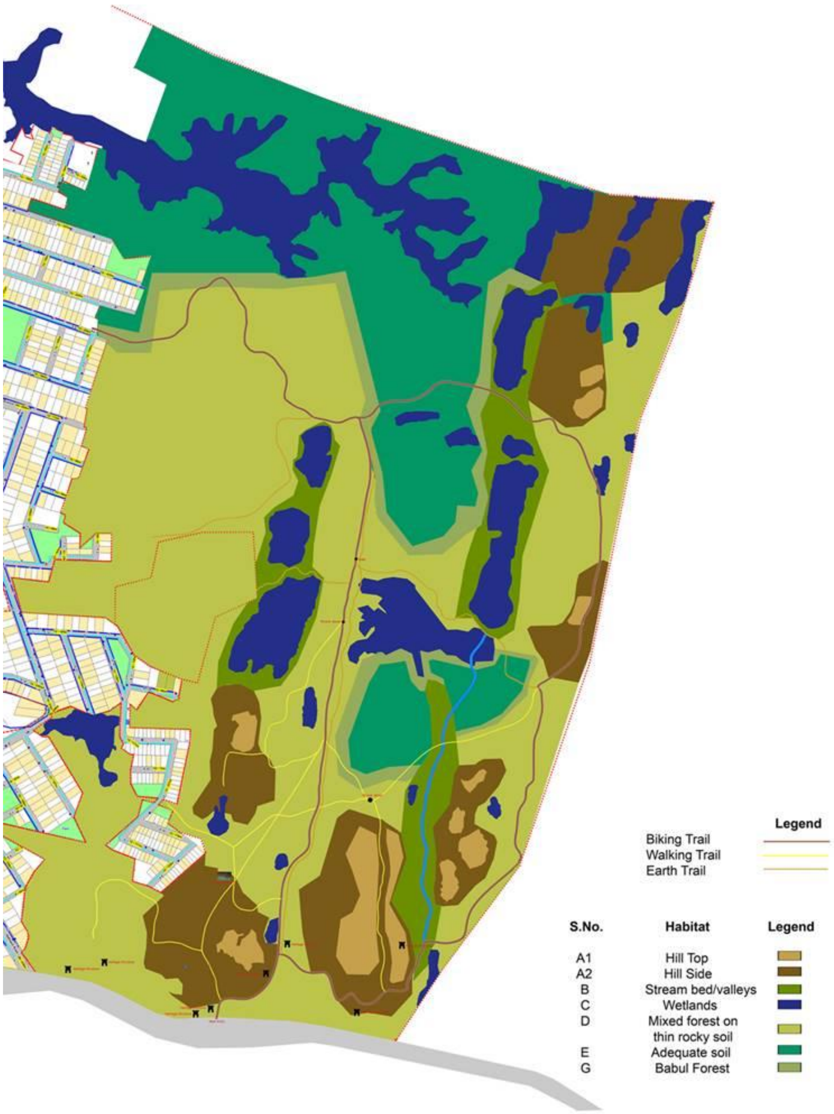


Figure 36: Habitat Plan of Biodiversity Park
Source: Municipal Corporation of Gurgaon

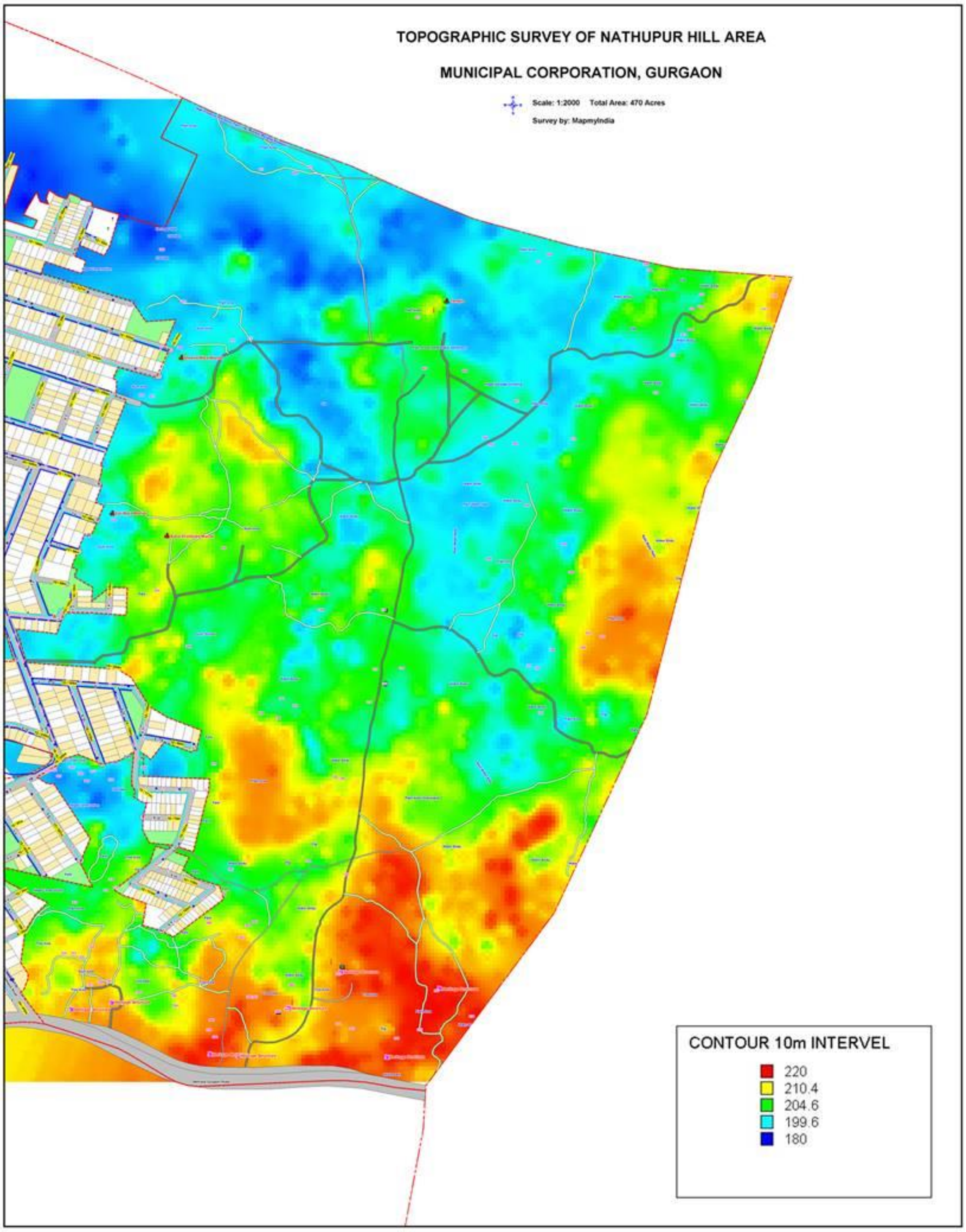


Figure 37 : Topography Map

6.1.4 Conclusion

Topography of the site has been used to create the natural forest of Aravallis. In terms of planting also it has got sufficient variety to create a diversity of plants which further leads to the complete biodiversity hotspot. Till date more than 175 species of birds have been spotted in and around the biodiversity park.

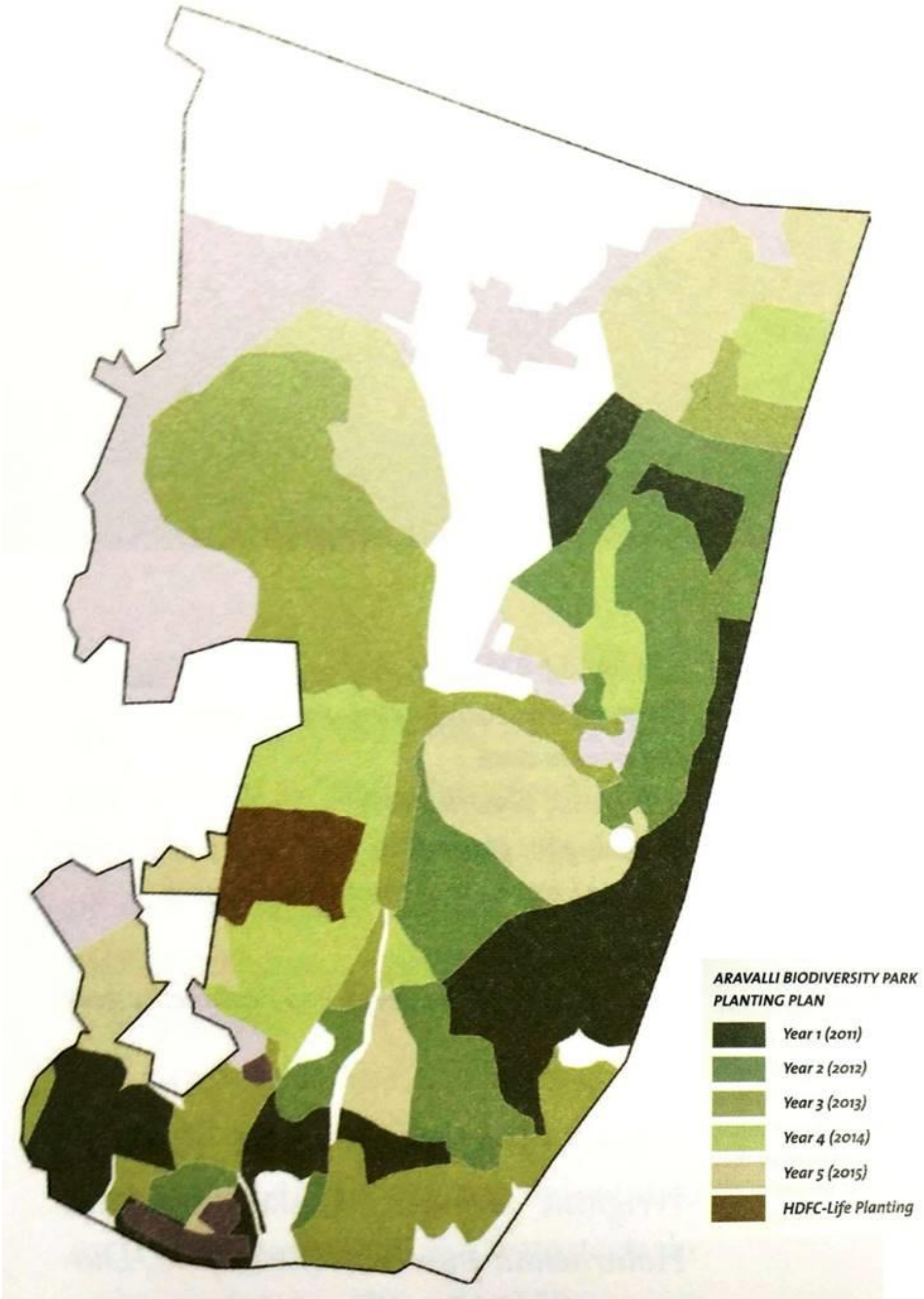


Figure 38 : Phase Wise Planting Plan
Source: Healing touch, LA, Journal of Landscape Architecture

The strength of the park is that it has always received the support & participation of people. Nature trails, Walking tracks, jogging & bicycling tracks & amphitheatre are some key features of the park. Phase wise planting is being done by corporates, NGOs, local communities and some of them also look after the park. Interaction between them makes the place alive and a place for a good learning opportunity.

6.2 Yamuna Biodiversity Park, Wazirabad, New Delhi

6.2.1 Introduction

The Park is a home for biologically rich wetlands, grassland communities, a wide variety of fruit yielding species and an abundance of medicinal herbs. The Park also comprises a native flora and fauna which used to exist a 100 years ago and then became extinct locally. It further, acts as a natural conservation site for specific group of endangered plants. The Yamuna Biodiversity Park is presently spread over an area of approximately 457 acres near Wazirabad village on the flat alluvial plains of the Yamuna.

Figure 39 : Location of the YBP (India map, Delhi map and YBP)
Sources: commons.wikimedia.org, www.delhionline.in, www.google.co.in/map

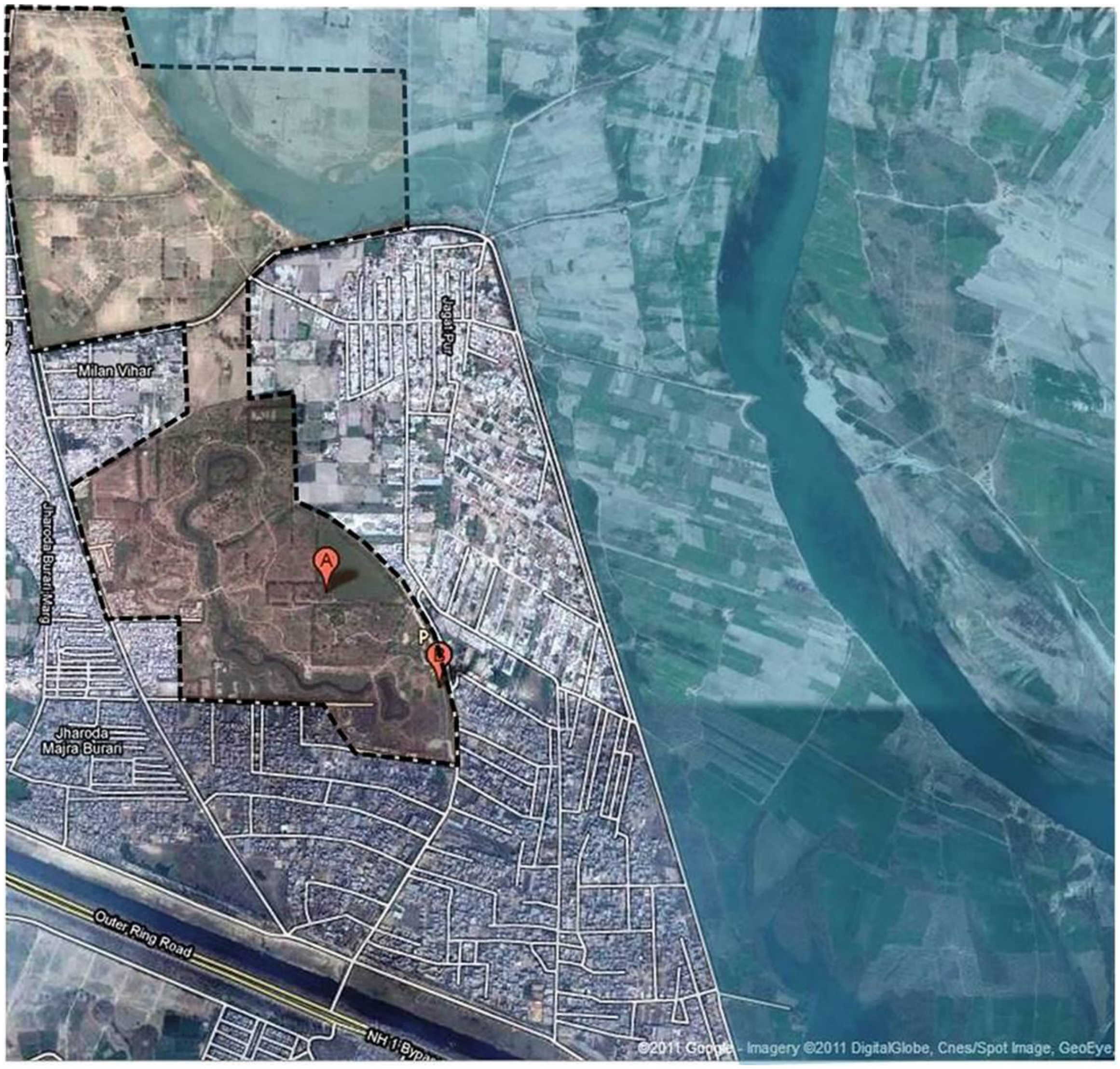


Figure 40 : Satellite Imagery of the YBP
Source: Author

Owned and Developed by Delhi Development Authority (DDA), with technical inputs by the Centre for Environmental Management of Degraded Ecosystems (CEMDE), University of Delhi and DDA. The park has been developed in two phases: Phase 1- Southern chunk of land and Phase 2- Northern chunk of land.

Phase 1 is fully functional and is opened for visitors while phase 2, which was part of Yamuna’s flood plain, is still under developing stage and is not opened for general public except research scholars, students with prior permission to administration.

6.2.2 Chronological development

If we analyse chronological development through satellite imagery, it is clearly visible that the green cover has increased remarkably during the span of fifteen years.

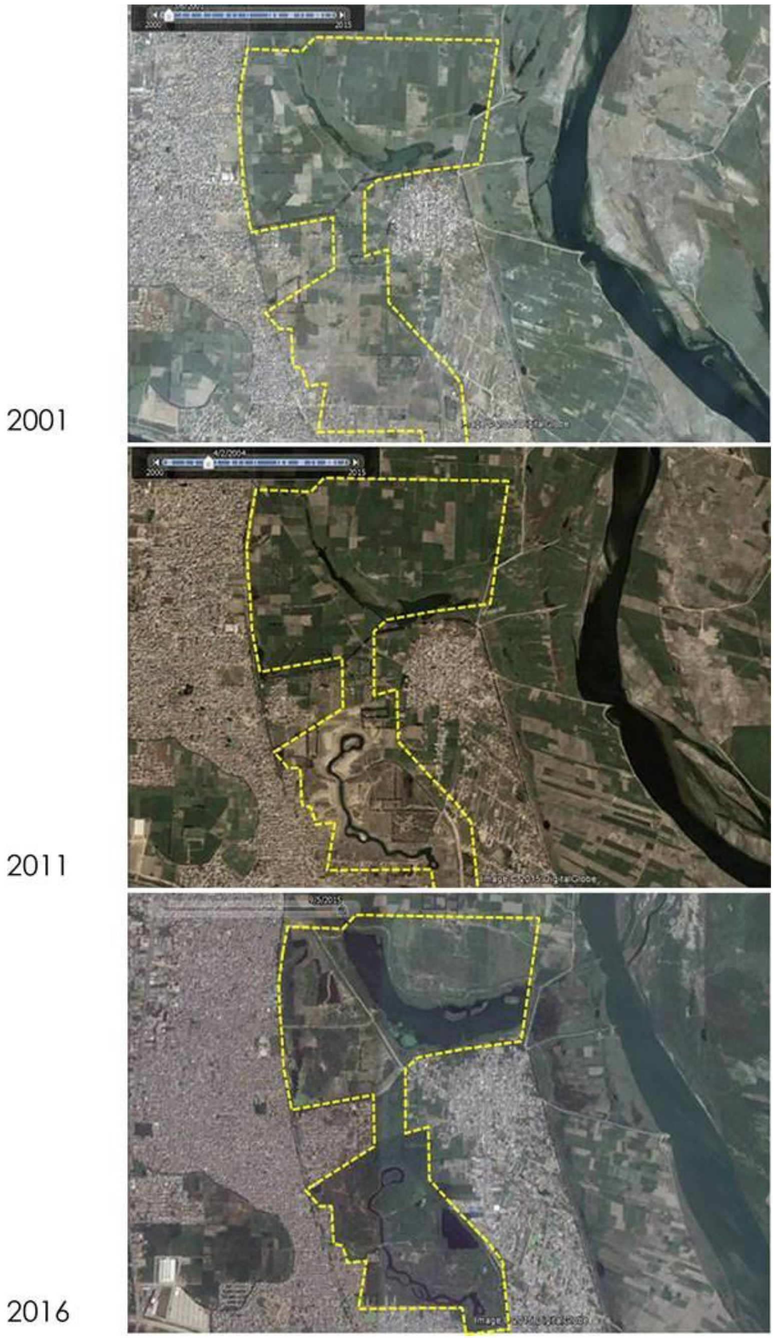


Figure 41 : Chronology of Bio-Diversity Park

Source: Author

This park is located close to river Yamuna,   Jharoda, Wazirabad. It is situated 1km away from the main stream of Yamuna but still in its Basin & was a part of the flood plain during some 30-40 years back. DDA acquired land in 2001-2002 and planned biodiversity park in 2003. The area is low lying used to get seasonally flooded and long spell of standing water has turned soil more saline.(pH=8.9). As a process plants which can grow well in sodic soil were planted to remove excessive salt from the soil to prepare the land for further plantation.

6.2.3 Thematic development

The idea behind the development of park was to bring back the flora and thus fauna, which was being lost in hundred years. An extensive study of the forest communities along the Yamuna river basin was conducted including field survey and field tests.

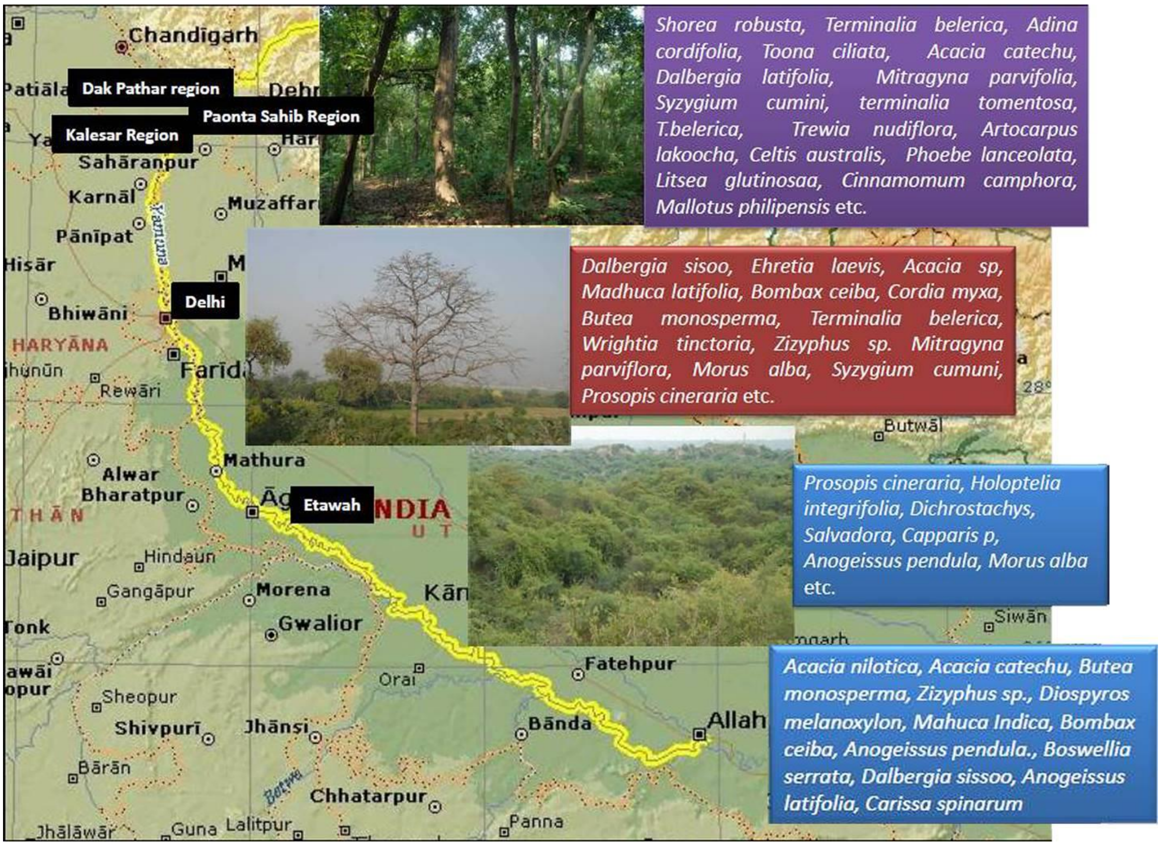


Figure 42 : Yamuna Basin having widely Diverse Flora
Source: Floodplain restoration: *Principles and Practices,* Dr. Faiyaz A. Khudsar

After analysing the results of survey and studies, a planting strategy was being evolved. It has covered all the species and plant communities along the Yamuna river basin. This also includes some species of middle to lower Himalayan regions of Yamuna river basin.

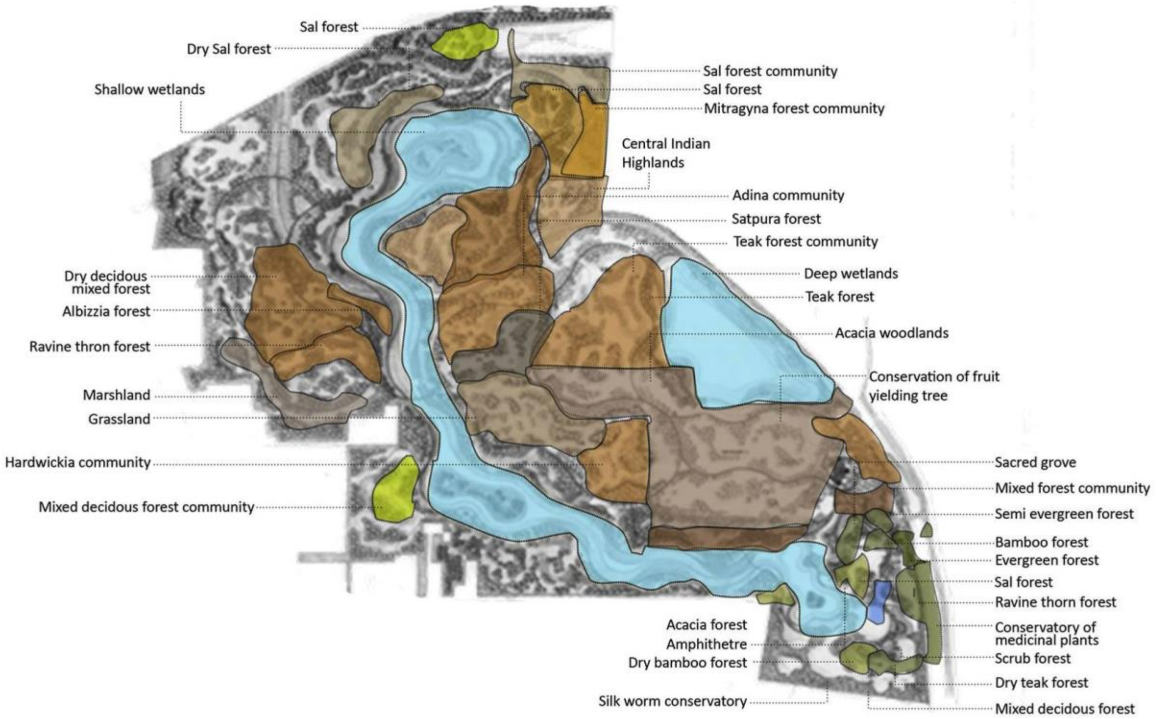


Figure 43 : Different Forest and Wetland Communities
Source: Delhi Development Authority in collaboration with Delhi University

6.2.4 Constructed wetland

To deal with localized flooding, terrain was modified by creating wasteland and marshes. Mounds were created for leaching soil of excess salt and make niches for biodiversity. To reduce water percolation the beds of wetlands were layered with clay soil, which helped a lot in holding water for wetlands.

Figure 44: Development of grassland along the stream
Source: Floodplain restoration: *Principles and Practices,* Dr. Faiyaz A. Khudsar

Biological inputs were applied for improving habitat quality. Leguminous species and some other characteristic grass were introduced.

6.2.5 End results

The Yamuna Biodiversity park witnesses following in addition to variety of forest communities and wetland species

- The butterfly conservatory harbours about 55 species of bufferflies on some 100 host plants of both larvae and adult moths.
- An Herbal Garden contains 350 species of medicinal plants that are used in home remedies, Ayurvedic and Unnani preparations and health foods.
- A fruit yielding plant conservatory supports 150 cultivars of 50 native fruit yielding species.
- The mammals that were seen about 150 years ago have returned back to the terrestrial communities. These include Wild boars, Civet cat, Jungle cat, Porcupine and Indian hare

Species Groups	Year		
	2002	2007	2014
Terrestrial Plants	90	656	874
Aquatic Plants	2	76	99
Avifauna	37	168	196
Invertebrates	39	122	380

Species Groups	Year		
	2002	2007	2014
Herpetofauna	3	16	18
Mammals	4	17	18
Fishes	0	12	18

Figure 45 : Biodiversity Profile of YBP
Source: Floodplain restoration: *Principles and Practices,* Dr. Faiyaz A. Khudsar

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8. Design proposals