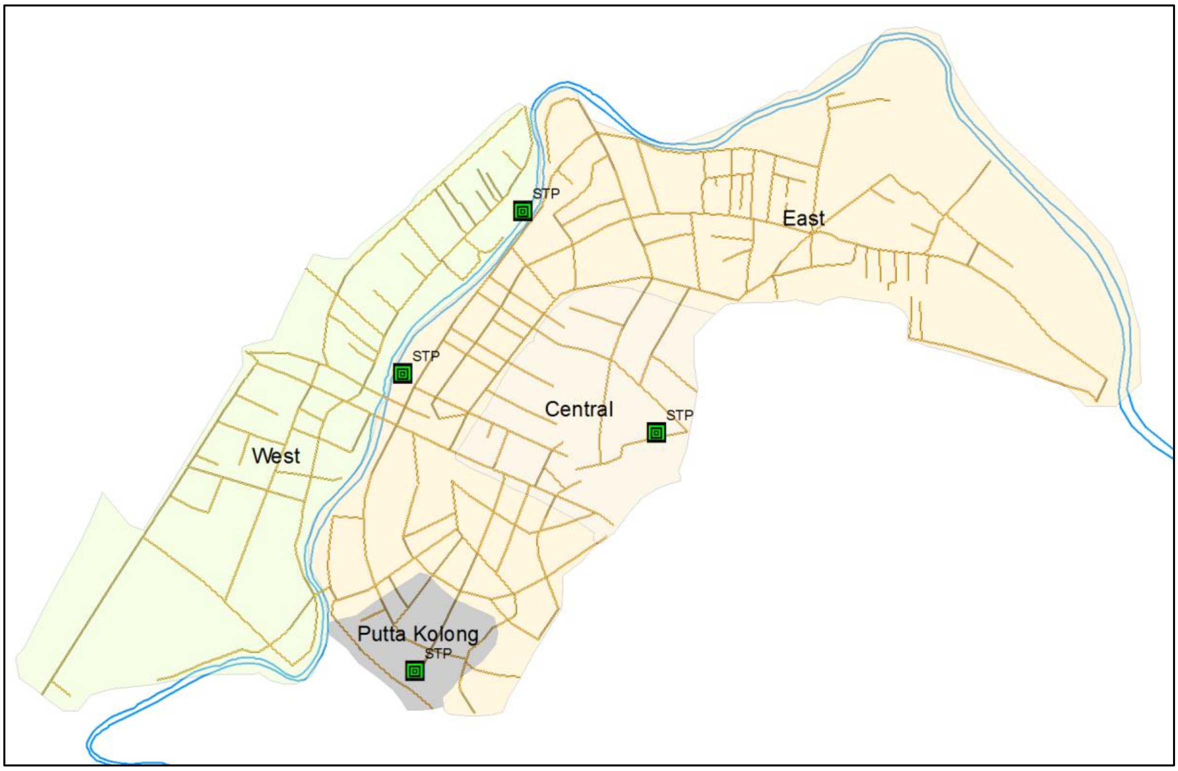
Pollution Control Board, Assam

Conservation of River Kolong, Nagaon

Preparation of Detailed Project Report

Project Feasibility Report for Sewerage Schemes

December 2013



Joint Venture of THE Louis Berger Group, INC
and DHI (India) Water & Environment Pvt. Ltd.

CONTENTS

FIGURES

TABLES

LIST OF KEY ABBREVIATIONS

BOD	:	Biological Oxygen Demand
CDM	:	Clean Development Mechanism
COD	:	Chemical Oxygen Demand
CPCB	:	Central Pollution Control Board
CPHEEO	:	Central Public Health Environmental Engineering Organisation
CSP	:	City Sanitation Plan
CWC	:	Central Water Commission
DA	:	Drainage Area
DBO	:	Design, Build & Operate
DO	:	Dissolved Oxygen
DPR	:	Detailed Project Report
FR	:	Feasibility Report
GIS	:	Geographical Information System
GL	:	Ground Level
GoI	:	Government of India
ICT	:	Information and communications technology
IEC	:	Information, Education & Communication
JNNURM	:	Jawahar Lal Nehru National Urban Renewable Mission
LPD	:	Litres Per Day
MLD	:	Million Litres per Day
MoEF	:	Ministry of Environment and Forests, Govt. of India
MSW	:	Municipal Solid Waste

NGRBA	:	National Ganga River Basin Authority
NMB	:	Nagaon Municipal Board
NMC	:	Nagaon Municipal Corporation
NRCD	:	National River Conservation Directorate
NRCP	:	National River Conservation Plan
O&M	:	Operation and Maintenance
PCBA	:	Pollution Control Board, Assam
PFR	:	Project Feasibility Report
PHE	:	Public Health Engineering
PMU	:	Project Management Unit
PS	:	Pumping Station
RFD	:	River Front Development
SPS	:	Sewage Pumping Station
SS	:	Suspended Solids
STP	:	Sewerage Treatment Plant
SWM	:	Solid Waste Management
TSS	:	Total Suspended Solids
ULB	:	Urban Local Bodies

Salient Features of the Project

Background and Objective

A study conducted by the Central Pollution Control Board (CPCB) identified the Kolong River (Kolong), a tributary of Brahmaputra River as one of 71 most polluted rivers in India. The Kolong originates from the Brahmaputra River in the Hatimura region of Jakhalabandha (Nagaon district, Assam), and after traversing approximately 250 kms through the districts of Nagaon, Morigaon and Kamrup, rejoins the Brahmaputra River at Kolongpar near Guwahati. The river flows through the heart of the Nagaon urban area and divides the town into two regions (Nagaon and Haiborgaon).

The Kolong River stretch which runs through the Nagaon town (Nagaon) is heavily polluted resulting in environmental degradation and continues to impact the health/hygiene of the inhabitants in the surrounding area. Therefore, the Pollution Control Board of Assam (PCBA) has commissioned preparation of this Detailed Project Report (DPR) for Kolong in accordance with the Ministry of Environment and Forests (MoEF), National River Conservation Directorate (NRCD) guidelines (NRCD, 2010).

The NRCD had earlier prescribed specific guidelines for the preparation of the Project Feasibility Report (PFR) and DPR under the National River Conservation Plan. Subsequent developments including the formulation of the March 2001 resolution by the National River Conservation Authority, lead to the issuance of new guidelines for the preparation of the DPR under the consolidated National River Conservation Plan and the National Lake Conservation Plan. The overall objective of the DPR is formulating a comprehensive and integrated river restoration plan for the Kolong in accordance with the 2010 NRCD guidelines.

Scope of the Work

Per the NRCD (2010) guidelines, the DPR will be prepared in a three-stage process related to sewerage schemes, namely:

- City Sanitation Plan (CSP).
- Project Feasibility Report (PFR) for sewerage schemes, which constitute this report.
- Detailed Project Report (DPR).

Executive Summary

The Nagaon stretch of Kolong suffers from environmental degradation and continues to impact the health/hygiene of the inhabitants in the surrounding area. Therefore, PCBA has assigned its highest priority to restoring the Kolong in accordance with the NRCD guidelines by adopting a series of integrated conservation measures. These measures include among others; waste water management; solid waste management; water resources management for hydraulic improvement of the river channel; provision of civil amenities along the river and around the area of influence; and, formulation of an awareness program among the affected communities and stakeholders to refrain from activities that degrade the condition of the river in any manner. The conservation measures will be analysed and documented in a DPR following NRCD (2010) guidelines. The DPR will thereafter serve as the primary guidance document for future river restoration measures.

The overall aim of the project is to revitalize the Kolong within the context of the continued urbanization of Nagaon by restoring it to its natural state, while allowing the river system to continue to support flood management, landscape development and recreational activities. In its current degraded state, the Kolong serves as an extended sewer canal running through the densest populated areas within Nagaon. The water quality of the river will be restored per NRCD guidelines by: restricting inflows of raw sewerage from residential/commercial establishments; limiting direct discharge from storm water drains along roads adjacent to the river; and preventing unabated dumping of solid waste by communities residing along the river. Measures will be adopted to augment inflow of clean water to improve river hydraulics and flood management controls, and to develop an integrated water resource management system to sustain optimum water levels required in the river during the dry winter months. The revitalization efforts will incorporate riverfront development to encourage public participation and ownership of the river. It is noted that this DPR is one of the several initiatives currently underway by the Government of Assam to improve the living conditions in Nagaon.

The DPR is being prepared by an experienced team of Indian and international professionals with a wide range of expertise in river restoration and wastewater management controls. In addition to collecting data and reviewing reports and documents of relevant programmes, consultations have been carried out with relevant Government agencies, municipalities, community members and other stakeholders. The DPR will also address diverse yet related issues such as environmental sustainability and dependency of local communities.

Per the NRCD (2010) guidelines, the DPR is being prepared in a three-stage process related to sewerage schemes, namely:

- City Sanitation Plan (CSP)
- Project Feasibility Report (PFR) for sewerage scheme
- Detailed Project Report (DPR).

Following the CSP, a Project Feasibility Report (PFR) of the sewerage works has been prepared. The PFR contains analysis of options considered for immediate actions as well as for mid- and long-term work plan. The sewerage scheme to be taken up during the project as part of the first phase is designed for the Kolong catchment areas (wards) directly discharging waste water to the river.

This PFR addresses the needs for providing an effective sewage collection, conveyance, treatment, and disposal system for Nagaon town to safeguard the River and also normal ecological system of the river Kolong. The proposed scheme has been formulated based on the latest version of National Ganga River Basin Authority (NGRBA) Guidelines issued by National River Conservation Directorate, Ministry of Environment and Forests, December 2010. Also, the criteria furnished in the ‘Manual on Sewerage & Sewage Treatment’ published by CPHEEO, Ministry of Urban Development, Government of India, has been used as necessary.

Adoption of a comprehensive system strategy is important in developing an effective sewerage system. The following system strategy has been formulated to provide the best engineering solution to the prevailing sanitation problem for the town.

- The current arrangement of wastewater collection will have to be modified after sewer lines are installed in the project area. Only the households need to be connected to proposed sewer lines either directly to manholes or through catch pits depending on the site conditions and space availability. This will ensure discharge of domestic wastewater flow (DWF) only into the sewer lines. Existing road side drains will be used exclusively to collect and convey storm water runoff (SWF). Connection of open drains to sewage collection network will be restricted and given only in cases where individual house connection is not possible due to space constraints. A suitable arrangement of such connection will be developed and proposed in the future.
- Wards directly overlooking the river Kolong would be taken up for providing sewage interception, collection, and diversion first. Subsequent areas would be covered and integrated with this centralized sewage collection system in the future.
- The proposed sewage collection system will include construction of house connections with an aim to intercept sewage at the very location of its generation. This would also avoid intermixing of sewage and storm water run-off. Though initially some intermixing of storm water is expected in view of any organized storm water management scheme for the town, it is expected that over time a storm water collection network would be installed rendering the now proposed system more efficient in collecting only the wastewater from households and other sources.
- The project area has narrow lanes (even < 2.5 m) with surface drains on either side. From the standpoint of feasibility of installation of sewer lines in these narrow lanes, the minimum road width where sewer line is proposed has been restricted to 2.5-3 m, i.e. the distance between the existing surface drains on either side. Also, to reduce the number of manholes in the streets, rider sewers may have to be laid along the length of main sewers. However, such a decision may be taken at the time of detail design depending on site conditions and feasibility of construction.
- In order to avoid duplication of pipeline, it has been proposed to pump wastewater from pumping station to the nearest gravity sewer as opposed to conveying the entire flow in a pressure conduit all the way to the next pumping station or treatment facility. This way, maximum efforts have been made to avoid installation of gravity sewer and pressure main along the same alignment, unless it was absolutely necessary over limited stretches.
- The options of a centralised treatment plat and a number of decentralized wastewater treatment plants were explored keeping in view the isolated nature of wards on either side of the town. However, due to unavailability of land for a centralised system, it has been proposed to construct four decentralised STPs at freely available lands along the river. Treated effluent with acceptable quality will be discharged into the river.

Check List for Feasibility Report

S. No.	NRCD Checklist Parameters*	Addressed		Reference in this PFR
		Yes	No	
1	Has the CSP been approved?			Under consideration
2	Has the problem of pollution with its causes been identified?	Y		Kindly refer section 1.1
3	Has the expected outcome been spelt out?	Y		Kindly refer Chapter 2
4	Has all available data relating to the city being necessary for FR and indicated in the Guidelines been collected?	Y		Kindly refer chapter1 and chapter 2and Map section
5	Have maps of the city been prepared?	Y		Kindly refer map Section 7
6	Has the present system of management of waste water and other works been studied?	Y		Kindly refer Chapter 2
7	Have area requiring up gradation of existing system of waste water management been identified?	NA		Not applicable
8	Have areas where sewers to be laid been identified?	Y		Kindly refer chapter 2
9	Have drainage areas and sewage districts been identified?	Y		Kindly refer chapter 2
10	Have alternative systems of waste water management been worked out?	Y		Kindly refer chapter 2
11	Has feasibility of options been worked out?	Y		Kindly refer chapter 2
12	Has life cycle costs of options been worked out?	Y		Kindly refer Chapter 2
13	Have alternative options been evaluated and the most cost effective and sustainable option selected?	Y		Kindly refer chapter 3
14	Has land requirement and its availability been examined?	Y		Kindly refer chapter 1 section1.1, Chapter 3
15	Has executive summary been prepared?	Y		Kindly refer page ix.
16	Executive Summary attached	Y		

* NRCD (2010), Chapter 20, Executive Summary and Check Lists for Feasibility Report of Sewerage Schemes.

1 About the Project Area

The authority for preparation of the project is:

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The project team for the CSP consists of The Louis Berger Group, Inc. in consortium with DHI (India) Water & Environment Pvt. Ltd.

1.1 Description of the Project Area

The Kolong River is a spill channel that diverts from the Brahmaputra River in the Hatimura region of Jakhalabandha (Nagaon district, Assam; Figure 1-1 and Figure 1-2).

The river is approximately 250 km long and flows through the Nagaon, Morigaon and Kamrup districts. It flows through the heart of the Nagaon urban area, where it divides the town into the two regions: Nagaon region and Haiborgaon region. The Kolong River re-joins the Brahmaputra River at Kolongpar near the town of Guwahati.

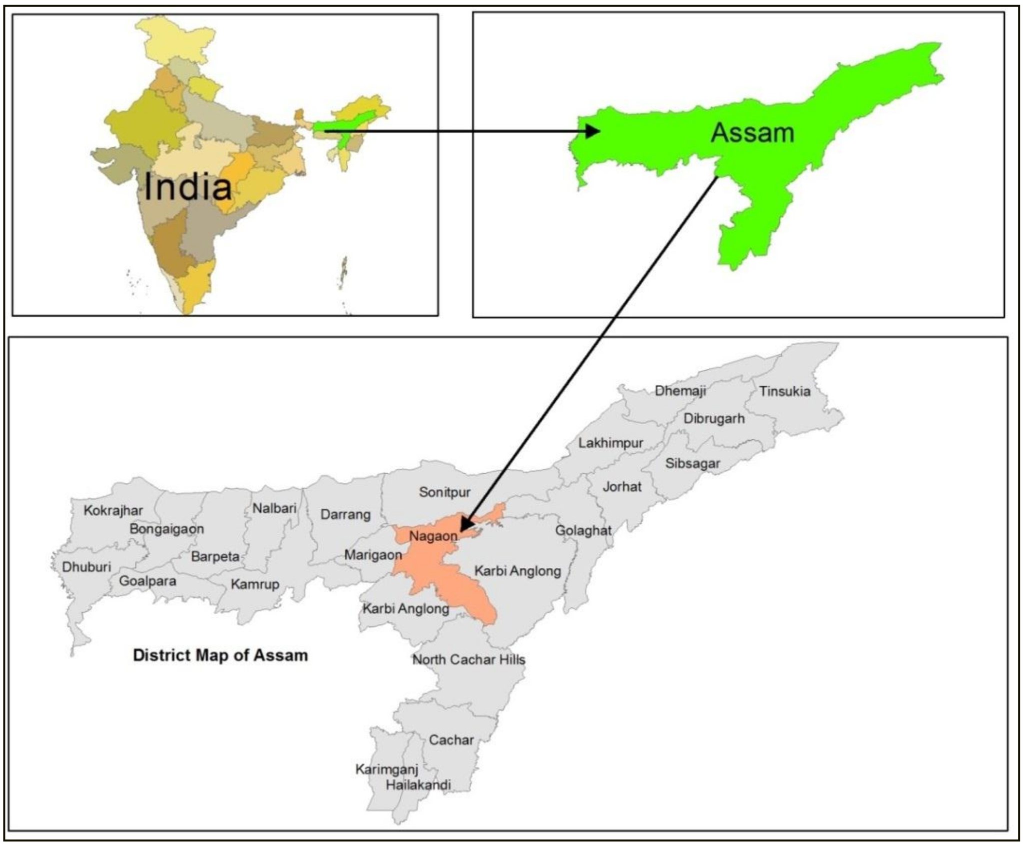

Figure 1-1: Study area.

In 1962, the Kolong River was closed by a dike at its upstream point of diversion from the Brahmaputra River. The dike was constructed by the State Flood Control Department to reduce flooding along the river during peak flow events. With the inflow from the Brahmaputra River blocked, the current sources of flow in the Kolong River are as follows:

- Storm water runoff from its catchment runoff;
- Baseflow from ground water seepage; and
- Waste water discharges from Nagaon town and various towns.

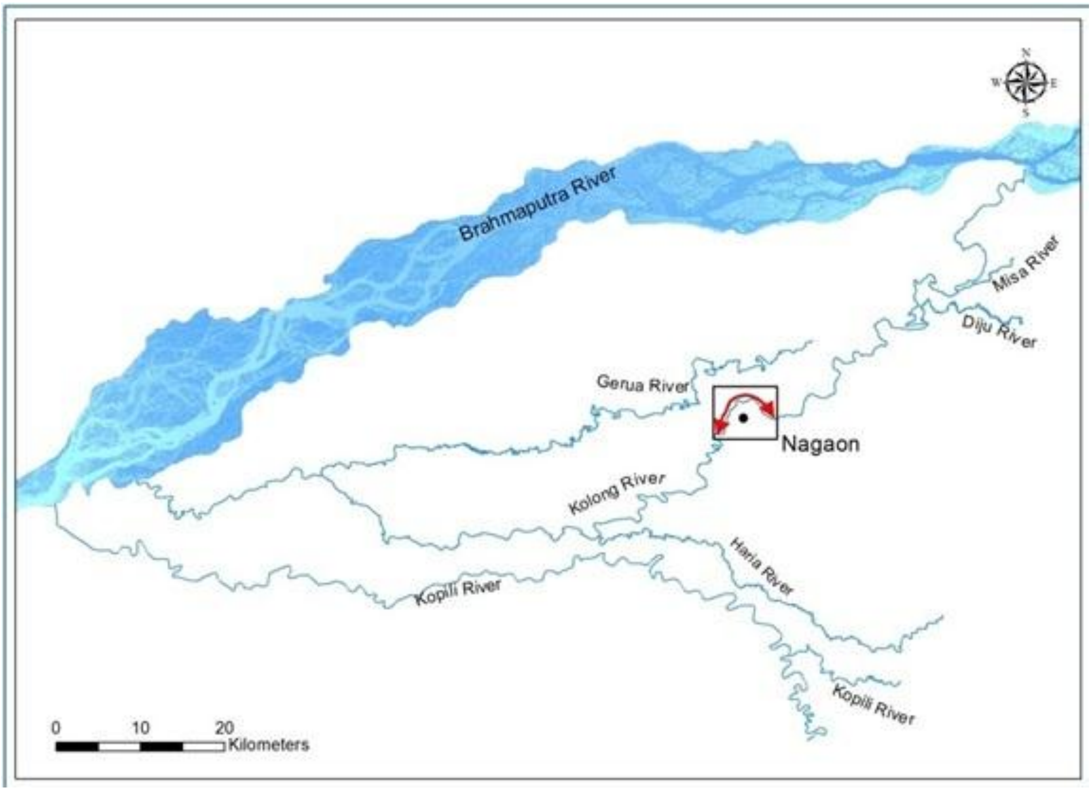

Figure 1-2: Kolong River basin. The polluted stretch in Nagaon town is marked.

The main contributors of pollutions to the Kolong River are:

- Misa River that carries organic loads and urban sewage from the Misa Township and tea gardens.
- Diju River that carries organic loads from tea gardens.
- Nagaon town that discharges large volumes of untreated sewage into the river.

The Haria and Gerua Rivers are tributaries that flow into the Kolong River. Since they carry a lower organic load, they reduce the contaminant concentrations in the Kolong River.

The dike along the Brahmaputra River has led to stagnation and degradation in the Kolong River in its upper catchment area (i.e., between the dike and the confluence with the Gerua River), a river stretch of nearly 197 km. In this stretch, the river is now choked with silt and water hyacinths, and its water is murky and polluted. The most polluted stretch of the river is located between its entrance into Nagaon town and its confluence with the Haria River.

The Kolong River flows through the heart of the Nagaon, Morigaon and Kamrup districts and transverses through densely populated residential, industrial and commercial areas. It carries a large portion of the municipal and other wastes from neighbouring communities and also serves as the natural drainage for storm water runoff.

The pollution caused by domestic and industrial waste poses a threat to the people along the river. The major focus of the restoration and conservation of the river is Nagaon town, the biggest polluter, and its immediate downstream stretch. Misa, Kaliabor, Puranigudam, Samaguri, Raha and Jamunamukh are also priority peripheral towns, where conservation works should to be taken up in the future.

1.1.1 Brief History of the Town

The present Nagaon district was once known as Khagarijan with its headquarter at Paranigudam. At that time there was a canal in the heart of the district. This canal was covered by reeds which were locally known as Khagari (hence the name Khagarijan).

During the reign of the Ahom King Pratap Sinha (1603 -1641 AD) the Kacharis attacked his kingdom and advanced as far as to Kaliabor. The people in the area between Kaliabor and Raha fled in panic. After expulsion of the Kacharis from the Ahom Kingdom, the king deputed an officer named Momai Tamuli Brabarua to reconstruct the area. Brabarua established new villages for the repatriated fugitives. The new settlements were called Nagaon, which stands for 'new village settlement', a name later given to the district.

1.1.2 Geographical Location

The Nagaon district in Assam is situated on the south bank of the Brahmaputra River (between 25º45' and 26º45' North and 91º50' and 93º20' East). It is bounded by six other districts (Figure 1-1). The Nagaon district covers an area of 4,002 km^2 making it one of the largest district in Assam.

1.1.3 Climate

The climate of the Nagaon district has the following characteristics:

- *Winter:* Dry and cool winter months with little rain and moderate winds from the east and north-east (north-east monsoon). Fog is a predominant feature of the weather condition during this season.
- *Pre-monsoon season:* The winter period is followed by the pre-monsoon season with thunderstorms from March to May.
- *Monsoon season:* Humid and hot conditions in summer months with the south-west monsoon and abundant rains.
- *Post-monsoon season:* This season lasts from October to November.

The average annual rainfall in the district was 1,788 mm between years 2000 and 2010 (Table 1-1; Figure 1-3). Annual rainfall in the district ranges from approximately 1,000 mm in the south to 2,000 mm in the north. About 68% of the annual rainfall amount falls in the period from June to September, with July being the rainiest month of the year. In the pre-monsoon months of April and May and the post-monsoon month of October, rainfall occurs mostly as thundershowers.

Table 1-1: Average annual rainfall (mm) in Nagaon.

Year	Average Annual Rainfall (mm)
2000	2,381
2001	1,556
2002	1,865
2003	2,064
2004	2,060
2005	2,778
2006	645
2007	1,620
2008	1,457
2009	1,017
2010	2,221
Average *(2000 to 2010)*	**1,788**

Source: Nagaon Water Resource Division, 2011

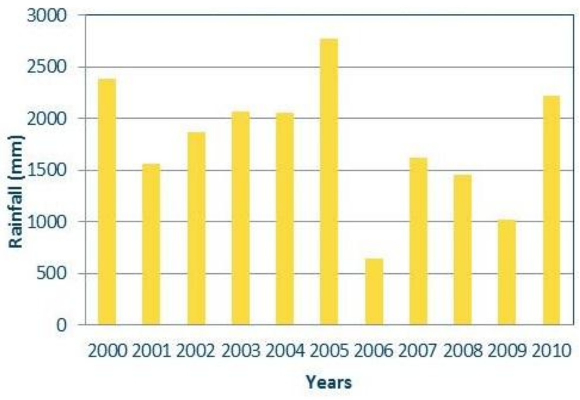

Figure 1-3: Average annual rainfall (mm) in the Nagaon district (data from Nagaon Water Resource Division, 2011).

Air temperatures are recorded at two meteorological observatories in the district, one at Lumding and the other at Chaparmukh. The record from Lumding covers a long period while that from Chapurmukh only covers a short period. In the five (5) years from 2009 to 2013, daily temperatures ranged from a maximum of 34°C in July-August to a minimum of 10°C in January (Table 1-2; Figure 1-4).

Table 1-2: Maximum and minimum monthly temperatures in the Nagaon district.

Month	Max Temperature (°C)	Min Temperature (°C)
January	23.2	10.3
February	27.7	13.6
March	30.8	16.8
April	31.0	20.3
May	32.7	22.8
June	33.5	25.3
July	33.6	25.6
August	33.6	25.5
September	33.5	24.8
October	32.5	21.9
November	28.6	16.7
December	25.3	13.3

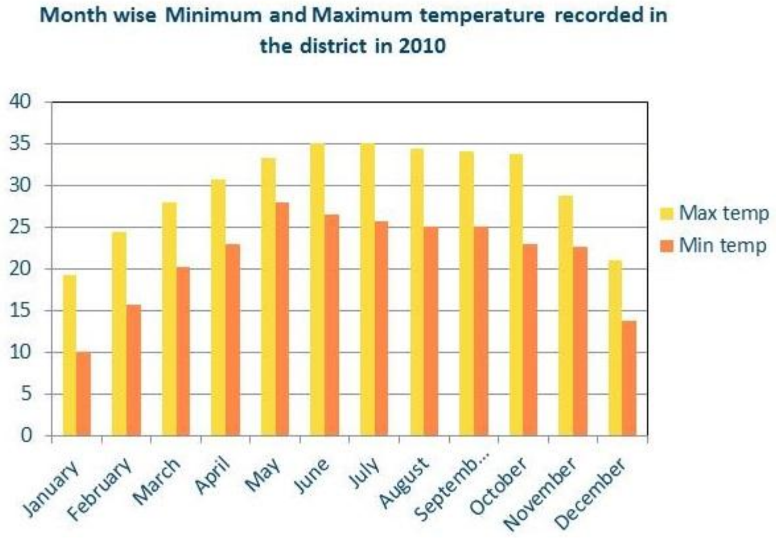

Figure 1-4: Maximum and minimum monthly temperatures in the Nagaon district in 2010 (data from Nagaon Water Resource Division, 2011).

1.1.4 Topography

The catchment area is bordered by the Meghalaya Hills to the southeast and the Brahmaputra River to the north (Figure 1-5). Due to the downwards areal slope from southeast to northwest, storm water from the wet Meghalaya Hills flows in a generally north-westerly direction towards the Brahmaputra River through numerous smaller rivers. However, much of the catchment area of the Kolong River in located in the low-gradient plain south of the Brahmaputra River in the northern part of Assam.

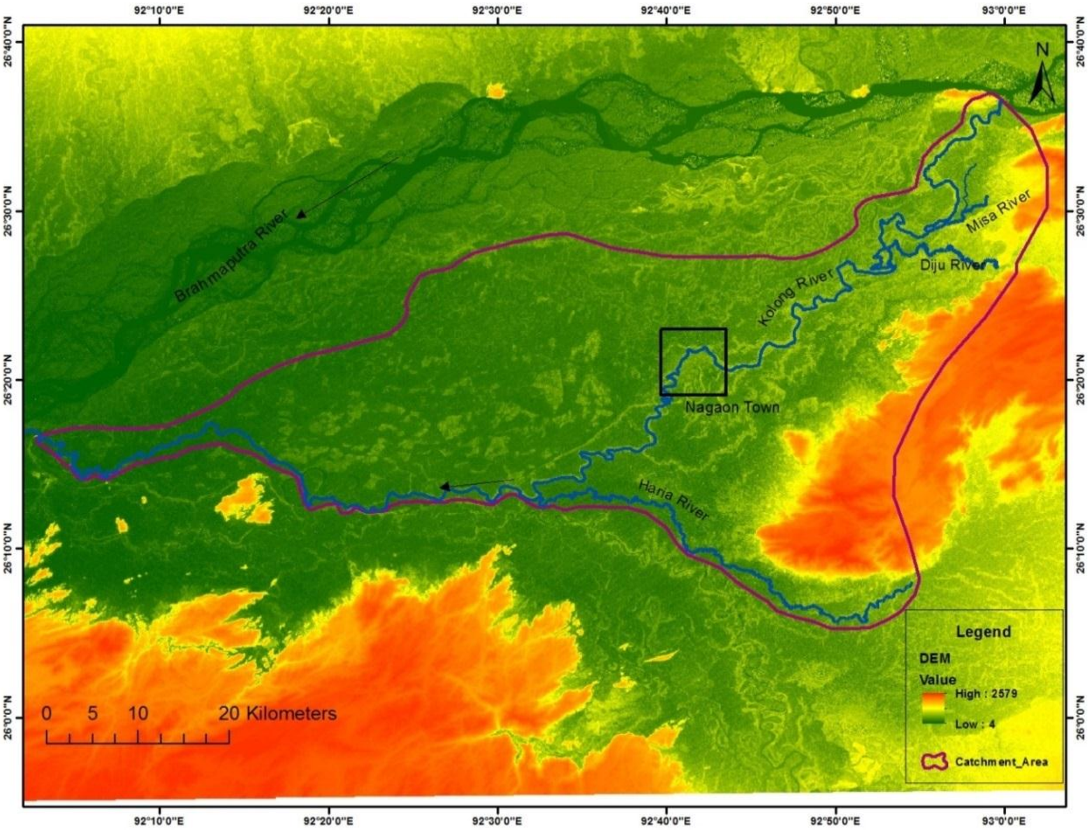

Figure 1-5: Topographic elevations (DEM) in the Kolong catchment area.

1.1.5 Drainage Channels

There is no well-connected drainage system in Nagaon town. Many of the open or closed-at-surface drains running along the side of the roads are either blocked or not linked up properly. That condition is one of the reasons for floods in the town particularly during the monsoon season. After heavy showers water-logged areas can be found in the town. The worst affected areas are:

- Part of Panigaon
- Hotelbari area
- Teliapatti
- Santipur
- Lakshminagar
- Islampatty
- Area opposite to Haibargaon railway station.

Table 1-3 lists the drains proposed to be improved by the State Government (PCBA, 2010).

Table 1-3: Drains to be improved (Source: Data from PCBA, 2010).

S.No.	Name of the drain	Length (m)	Width (m)	Drain type
1	NH-37	688	1.25	Type -1
2	Namghar Road	785	1.25	Type -1
3	Radhika Sati Road	688	1.25	Type -1
4	Rudraram Bora Road	1,313	1.25	Type -1
5	NH-37 (Dhing chariali to Kolong River	938	1.25	Type -1
6	Tarunram Phukam Road	1,250	1.25	Type -1
7	Laokhowa Road	1,875	1.25	Type -1
8	Madhav Dev road	2,063	1.25	Type -1
9	Mohichandra Bora Road	850	1.25	Type -1
10	Gunabhira, Bora Road	1,250	1.25	Type -1
11	NH-37 to Jail Road(Bara Bazar)	1,250	1.25	Type -1
12	Gurudwara Road	1,188	1.25	Type -1
13	Bimala Bora Road	1,750	1.25	Type -1
14	Masjid Road	1,000	1.25	Type -1
15	Kirtanghar Road	1,000	1.25	Type -1
16	Motiram Bora Road	937	1.25	Type -1
17	Milanpur Road	1,125	1.25	Type -1
18	Abad Nagar area road	1,938	1.25	Type -1
19	ITI Road	1,000	1.25	Type -1
20	RK Mission Road	1,681	1.25	Type -1
21	ADP Road	1,375	1.25	Type -1
22	Basanti Bora Road	2,250	1.25	Type -1
23	Railway open drain	813	1.50	Type -3
24	NH-37 (from ADP Road to Nagaon College junction)	1,250	1.25	Type -1
25	NH-37 Via Ghanashyam Bezbarua Rd. Manik Bezbarua Road to Kolong	1,750	1.50	Type -3
26	Amolapatty Rd to Kolong via Girls College Road	1,500	1.25	Type -1
27	Amolapatty Rd. to NH-37 via Stadium Road	1,375	1.4	Type -2
28	Chay Ali to Kolong via Amolapatty Rd. and Shankar Mandir Road	1,400	1.4	Type -2
29	Polytechnic Road to Kolong via Chay Ali	2,938	1.25	Type -1
30	NH-37 from Polytechnis to Panigaon Chariali	2,250	1.25	Type -1
31	Park Road	1,188	1.25	Type -1
32	Bara Bazar crossing N. Ahmed Road Thana Road and Azad Road	3,125	1.4	Type -2
33	Drain from N Ahmed to Mori Kolong	2,250	1.4	Type -2

1.1.6 Administrative Divisions

Nagaon district has 3 civil subdivisions, namely Nagaon, Kaliabor and Hojai (Table 1-4). It is divided into 10 revenue circles and 18 development blocks. The biggest of the seven communities in the district is Nagaon town with 126,115 inhabitants. There are 240 Gram

Panchayats inhabited by 1,375 villages. There are 21 police stations. The national highways NH-36 and NH-37 cross the district.

Table 1-4: Administrative divisions in the Nagaon district.

Type	Number
No. of Civil Subdivisions	3
No. of Towns/Cities	7
Revenue Circles	10
No. of Development Blocks	18
No. of Gram Panchayats	240
No. of inhabited Villages	1,375
No. of Community Information Centres	18
National highway passing through the district	NH-36 and NH-37

1.1.7 Commercial Aspects

Agriculture: Agriculture is the backbone of Assam's economy providing a livelihood to about 78% of its population. Agriculture is expected to remain the predominant economic activity for several decades to come. Due to the general characteristics of the soil, the district is best suited for cultivation of paddy rice. Besides paddy rice, maize, arahar, wheat, other cereals and small millets, rabi pulses, gram, jute, mesta, cotton, sugarcane, potato, sweet potato, banana etc. also grow in the district. Horticulture could be one of the strongest features of the economy of Nagaon district because of its congenial agro-climatic and soil conditions. The district has advantages in producing potato, banana, chillies, arecanut, coconut, etc.

Floods are a major impediment in the development of the agricultural sector. Credit flow has also been low. This aspect is now showing signs of improvement. Present marketing linkages in the sector are weak. The average land holding size is also low (0.9 hectare [ha]). Funding requirements need to be met under various governmental schemes and credit linkages from banks. An important component is the requirement of convergence of various agencies such the Irrigation Department, ASEB office, District Rural Development Agencies (DRDA), banks, etc.

Fisheries: Considering the fact that Assam gets a lot of rainfall and that fish is an integral part of the diet of the people of Assam, the state produces about 5.7% of the total freshwater fish production in India. The Nagaon district produces roughly 14,000 metric tons (MT) of fish in a year which is about 9% of the total production in the state. It is estimated that 95% of the population consumes fish; the total fish consumption is estimated to be about 23,000 MT in a year. Imported fish dominate the organised markets.

Nature has made the Nagaon district a congenial place for pisciculture. Beels, marshes, ponds, and around 150 natural fishes in the district paved the way for the pisciculture development. As the district also has an advantage of a high water table, it is not necessary to dig deep for water. There are a high number of unemployed youths in the district and it has been observed that most of them are active in fishery. In the past, fishing was not considered a respectable employment, but this perception has changed and the fishing sector is looked upon at as a decent livelihood option. However, absence of fishing on scientific/commercial principles is common, and the fishery sector in the district results only in low level of productivity. Concerted and coordinated efforts for organised pisciculture development would have a multiplying and accelerating effect not only in the district economy but the economy of the state as a whole.

1.1.8 Industrial Activities

Industry does not have a dominant role in the Nagaon district, which still depends mostly on agriculture. Existing industries include the following:

- Tea industry (largest industry)

- Handloom and handicrafts industries
- Forests and wood industry.

In addition, the following industrial projects are taken up in cooperative and state sectors:

- Assam Cooperative Jute Mill Ltd.
- Kampur Cooperative Sugar Mill
- Katimari Weaving Project
- Sack Craft paper project at Dhing.

These are all medium-scale industrial projects. Whereas the Jute Mill at Silghat is flourishing, the Kampur Sugar Mill has been struggling.

The handloom industry is the most important cottage industry in Assam with a glorious past. It is closely associated with art and culture of the society. Weaving is a traditional activity of the state. Weaving of fabrics is a way of livelihood for a large number of rural families and artisans. Looms are often found in rural households. However, weaving is only a part-time activity and not the primary bread-earning activity. As a result, the handloom industry has not yet been developed to its full potential. Jajori, located about 17 km from Nagaon town, is an important centre of handloom production. Famous for its Kacha pat products, there are approximately 6,705 weavers which include most of the local families. In addition, the government has established a handloom production centre at Jajori. The Nagaon district has a large potential by way of organising, modernisation, training and providing adequate marketing linkages, and it is proposed to use the Self-Help Group (SHG) method to develop its potential more fully.

Handicraft is also an important cottage and household industry, providing self-employment opportunities for the inhabitants in rural areas to supplement their earnings. The most important handicraft are: 1) kuhila craft; 2) pottery and terracotta; 3) jute, cane and bamboo products; and 4) rantholi jewellery.

The Nagaon district has potential for agro-based industries, including pisciculture and sericulture. Identified limitations for such industries are power shortages, seasonal floods, shortage of industrial labour, and lack of practical entrepreneurial motivation or experience.

1.1.9 Educational Activities

Types of educational institutions in the Nagaon district (based on the District Report) are shown in Table 1-5.

Table 1-5: Types of Institutions in Nagaon District.

Type of Institution	Government	Provincialized
Higher Secondary School	2	55
High School	1	139
Sanskrit Tol	--	5
Senior Madrassa	--	10
Title Madrassa	--	1
Junior College	--	1
College	--	15

The baseline survey for the district report was carried out in 30 sample villages. The survey showed that educational and schooling facilities for girls are much less common compared to the boys. Primary and middle schools exist for 3% of the girls for both types of schools, and for 23% and 14% of the boys, respectively. The same tendency exists for high and higher secondary education.

The survey also reveals that in all 30 sample villages at least one primary school is found within the village. More than 93% of the primary schools are located within 2 km. Although the distribution of primary schools in the rural area is satisfactory, more than 75% of the schools do not have a pucca structure. About 10% of them are semi-pucca, while the remaining buildings are kutcha normally with mud flooring and thatched roof.

There are approximately 15 degree colleges and one junior college in Nagaon district. Main educational institutions in the Nagaon district are listed below:

- Assam Agricultural University
- Homeopathic Medical College, Nagaon
- A.D.P. College (named after Anandaram Dhekial Phukan)
- Khagorijan College (named after the old administrative headquarter of the Nowgong District)
- Nowgong Law College

1.1.10 Cultural Activities

The Nagaon district has a rich cultural heritage:

- Place Bordowa, where the great Vaishnavite Saitn Mapurush Srimanta Shakardev was born, is situated just 18 km northwest from Nagaon town.
- There are two Satras (Vaishnavite monasteries) in Nagaon, one is Narowa Sattra and one is Salaguri Sattras.
- There is a mini museum in Narowa Sattras.
- There are numerous Namghars (worship places) but the main ones are Bharalli Namghar, situated in Hatbar. Subhagya Madhav, Dulal Madhav and Gopal Madhav are three ancient temples built during the reign of Ahom King Shiva Singh. People visit the Namghars regularly, particularly during the birth and death anniversaries of the Vainavite saints, and on occasions such as Janmastami, Bihu and Assamese New Year.

The colourful culture of Nagaon can be seen in its music and dance, art and craft forms, festivals, and food. Of the dances practised in Nagaon, Nagayan Ojhapali is most well-known.

Tourism attractions in the Nagaon district include the following:

- *Kaziranga National Park:* It is a world heritage site giving home to five big mammals: the great Indian one-horned rhinoceros, the royal Bengal tiger, the Asian elephant, the eastern swamp deer, and the Asiatic wild buffalo. Furthermore, it is the habitat of a sizeable population of other rare and endangered species. Every year thousands of tourists visit this park.
- *Lowkhowa Avayaranya:* The park is situated at Lowkhowa about 25 km from Nagaon town and covers an area of 70 km^2. The main attraction is its great Indian one-horned rhinoceros. Various species of birds and other animals like tiger, leopard, Asiatic buffalo, wild boar, civet cat, leopard cat, hog deer, are also found in Lawkhowa.
- *Samaguri Bill* (also known as Pokhi Tirtha): Situated about 16 km east of Nagaon town, the area has migrating birds from different places of the world in the winter season. The Rock Garden Amusement Park and Tanz Water Park, situated near Samaguri, are new attractions for the Nagaon public.
- *Subdivision towns* like Kaliabor (48 km east of Nagaon town) and Hojai (61 km from Nagaon town) are historic places. Hojai is renowned as the granary of Assam and the principal wholesale market for rice in Assam, though sugarcane, mustard, jute and

vegetables are also grown in abundance. Hojai is also the centre of the Agar perfume industry.

- *Silghat:* Situated at almost 50 km from Nagaon is a vital and picturesque river port lying on the south bank of the Brahmaputra River. Pre-communication links of central Assam across the Brahmaputra River are maintained through this port town. Besides playing host to the Assam Cooperative Jute mill, Silghat also has several temples to enthral visitors. A big Samantagiri hillock draws big crowds from everywhere.
- *Jugijan:* Situated at about 6 km from Hojai, it has become well-known after the recent discovery of remnants of a fort and three stone temples decorated with carvings and base-reliefs.
- *Kamakhya Temple:* The famous Kamakhya temple is situated in Silghat on the bank of Brahmaputra River. The Ashok Astami Melas is held every year at the Kamakhya temple.
- *Waterfalls* like Akashiganaga (located near Doboka, 34 km to the south-east of Nagaon town) and Champawati Kunda (located in Chapanala) are famous falls, and favourites for many picknickers.
- Other places like Ranthaliu village, located 4 km west of Nagaon town, is famous for its gold-plated traditional ornaments. Jamnunamukh, located 35 km from Nagaon town is also famous for its earthen wares.

1.1.11 Religious Activities

The population in the Nagaon district has the following religions, as per the District Report (2010) that was based on a total of 900 sample households in 30 villages:

- Muslim: 54.6%
- Hindu: 45.2%
- Christian: 0.2%

Of the total sample households, 11.8% were from Scheduled Caste (SC), 3.9% from Scheduled Tribe (ST), and 21.6% from Other Backward Caste (OBC). The Muslim and Christian households represent general caste.

1.1.12 Socio-Economic Status

As described in section 0, agriculture is the backbone of Nagaon’s economy and more than 78% of its working population derives their livelihood from agriculture. Fishing is another common economic activity in the district.

People of Nagaon are in many ways still living the traditional Indian way. People help each other during the time of family function, family crisis and also during festivals, like bihu and puja. The community feeling is strong. In the namghars, most time of the year, people offer Prasad on the occasion of death anniversaries, birthdays and any other important dates of family members and also during Assamese New Year and during the month of Bhadra.

1.1.13 Town Management

The Nagaon Municipal Board is responsible for town management. The Chairman of the Nagaon Municipal Board (NMB) is the head of the town and District Magistrate has the full responsibility for the district. Disasters are managed by the district Disaster Management Authority (Table 1-6).

1.1.14 Land Cost in and around the Town

Land cost at Nagaon vary by location, but typical cost for 1 katta is from 6-7 lakhs INR and up to 1 crore INR (1 katta is equal to 2,880 square feet).

1.1.15 City Development Plan

A development plan for Nagaon town is not available.

Table 1-6: Disaster Management Authority.

S.No.	Designation	Status
1	Deputy Commissioner, Nagaon	Chairperson
2	Chairperson, Zilla Parishad, Nagaon	Co-chairperson
4	Superintendent of Police, Nagaon	Member
5	Jt. Director, Health Services, Nagaon	Member
6	Executive Engineer, PWD (R) Nagaon State Road Division, Nagaon	Member
7	Executive Engineer, PWD (R), Nagaon Rural Road Division, Nagaon	Member
8	Executive Engineer, Nagaon Water Resources Division, Nagaon	Member
9	Executive Engineer, Irrigation, Nagaon Division, Nagaon	Member
10	Executive Engineer, PWD (R), Building Division, Nagaon	Member
11	Executive Engineer, PHE, Dhing, Nagaon	Member
12	Executive Engineer, NH-37, Nagaon	Member
13	Executive Engineer, PHE, Nagaon	Member
14	Executive Engineer, (PWD) Electrical Division, Nagaon	Member
15	Executive Engineer PWD, Kaliabor Rural Road Division, Jakhalabandha, Nagaon	Member

1.2 Population within the Project Area

According to census data, the population of Nagaon town has grown by 30% in 20 years, from 93,350 in year 1991 to 1,21,628 in year 2011 (Table 1-7). The sex ratio between males and females is near even. The most recent literacy rate was recorded with 74%.

Table 1-7: Demographic details of Nagaon town.

Area	Year	Population	Sex Ratio (females per 1000 males)	Literacy Rate (%)
Nagaon town	1991	93,350	929	55
	2001	1,07,667	944	62
	2011	1,21,628	962	74

Source: Census of India

1.2.1 Ward Wise Population

The ward wise population of the Nagaon town is presented in Table 1-8. Population and number of households were obtained from census data of years 2001 and 2011.

The population in some of the wards increased in this time periods, while the population in other wards decreased. Wards 20, 23 and 27 are the most developed wards in the town.

1.2.2 Slum Wise Population of the last 5 Decades

As per the 2011 census, the total slum population in Nagaon town was 18,110 which decreased by almost 50% compared to the 2001 census data. One of the reasons for the decrease in the slum population may be economic growth of the people. Sanitation facilities in slum areas consist mostly of community toilets, which are connected to a septic tank and soak pit. The condition of these community toilets is very bad.

Table 1-8: Ward wise population of Nagaon Municipal area (Source: Census of India).

Ward No	2001		2011	
	Households	Total Population	Household	Total Population
1	350	2,085	350	1,705
2	838	4,591	974	4,587
3	686	3,143	1,035	4,151
4	497	2,728	510	2,725
5	922	4,351	1,038	4,456
6	1,331	6,704	1,565	6,873
7	679	2,931	748	3,022
8	829	3,811	970	3,858
9	565	2,565	583	2,429
10	389	1,883	449	1,831
11	1,009	5,109	1,108	4,989
12	926	4,963	1,138	4,991
13	373	2,118	487	2,327
14	654	3,311	706	3,117
15	451	3,489	567	2,641
16	757	3,417	861	3,563
17	938	4,690	1,013	4,583
18	1,000	5,262	1,199	5,414
19	581	2,751	815	3,377
20	2,513	12,524	3,221	15,240
21	407	2,196	561	2,564
22	930	4,504	1,200	5,149
23	918	4,201	1,753	7,308
24	1,010	5,605	1,335	6,485
25	677	3,643	1,207	5,336
26	962	5,092	1,090	5,001
27			608	2,917
28			229	989
Total	**21,243**	**1,07,667**	**27,320**	**1,21,628**

1.2.3 Population Projections as per the City Master Plan

Presently there is no City Master Plan for the Nagaon town. The base data used for population projection were obtained from the Census of India, with detailed summaries for urban area population and municipal ward for 2001 and the 2011. These data provided the numeric basis for benchmarking of the actual population and its decadal growth for the past decades.

Different population projection methods (i.e., arithmetic, incremental increase, geometric, and exponential methods) were used to calculate future population growth. As different methods result in different projections, the averages of all methods were considered for the CSP population projection. Projected populations by different methods are presented in Table 1-9 and Figure 1-6.

Table 1-9: Population Projection by Different Methods.

Year	1971	1991	2001	2011	2014	2024	2034	2044
	Past Census Data				Future projections			
Arithmetical	56,537	93,350	1,08,786	1,21,628	1,26,296	1,41,858	1,57,419	1,72,981
Geometric					1,23,930	1,29,471	1,37,819	1,46,705
Incremental					1,40,145	1,61,482	1,86,067	2,14,395
Exponential					1,29,679	1,60,566	1,98,810	2,46,163
Average					**1,30,013**	**1,48,344**	**1,70,029**	**1,95,061**

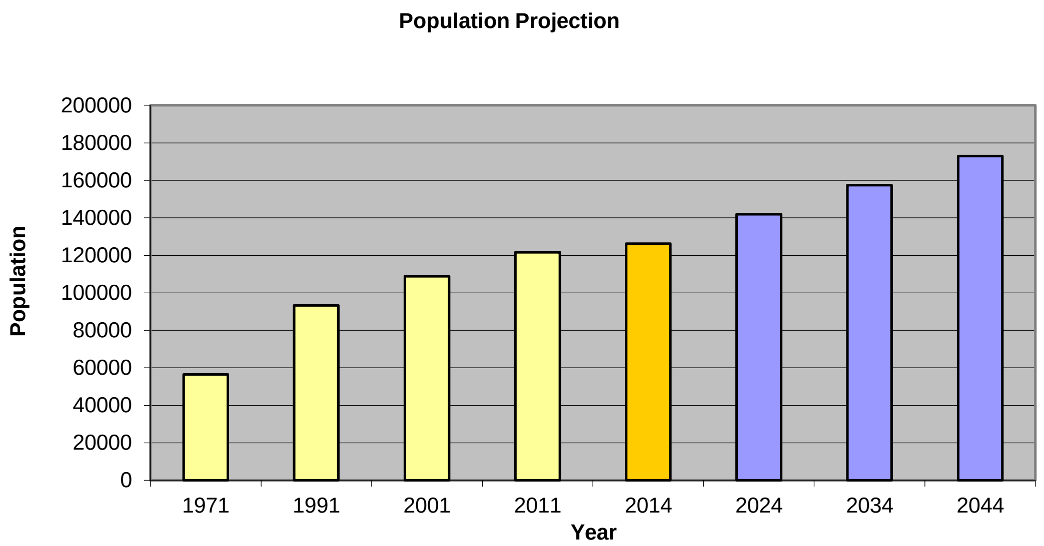

Figure 1-6: Population projection of Nagaon Town.

On average, the population is expected to grow from approximately 1,22,000 in year 2011 to 1,95,000 by year 2044, an increase by 60% over the next 33 years. These growth rates will form the basis of river restoration design efforts.

1.3 Status of Water Supply

Water supply to Nagaon town is the responsibility of the Nagaon Municipal Corporation, but presently the responsibility is held by the Public Health Engineering Department. People of Nagaon get water through various sources, including piped water supply, dug wells, hand pumps, tube and bore wells, and springs.

The piped water supply scheme was initiated in 1981. At the completion of the scheme, 4,477 households were covered by a tap connection, and 16 community taps were installed in 26 wards of the town. Ground water is pumped from six Deep Tube Wells (DTW; extending to depth of 30 to 50 m) with the help of 12.5HP submersible pumps to a treatment plant. The treated water is then stored in three underground reservoirs with capacities of 2.25 million liters (ML), 1.75 ML and 1.25 ML. Water is then pumped to three Elevated Service Reservoirs (ESR) with capacities of 1.8 ML, 1.2 ML and 0.9 ML (Figure 1-7) from where the water is supplied to the consumers through the distribution network. Water is supplied for only one hour in the morning.



Figure 1-7: Elevated service reservoirs in Zones 1, 2 and 3.

Presently, only 20% of the population is supplied by treated water through the distribution network. The remaining 80% of the population uses different water sources (Figure 1-8) primarily from the ground. Most of the houses in the outskirts have either tube or bore wells. The health hazard of using ground water is high because of elevated arsenic concentration in several locations as well as contamination from overflowing septic tanks and soak pits. Some village households use ponds as well to meet certain types of water supply needs.

Figure 1-8: Example of water contamination by septic tank and water pump placed side by side by side.

1.3.1 Actual Water Supply from Different Sources

As stated above, Nagaon town gets its potable water almost exclusively from the ground. Details of the various sources are listed in Table 1-10 and Figure 1-9. About 77% of the household in Nagaon town use hand pumps, tube and bore wells as the ground water table is high (3 to 4 m below the surface).

Table 1-10: Water Supply by Source.

S. No.	Source	No. of Households	Population	Percentage
1	Tap water	6,394	27,273	22.40
2	Wells (open + closed)	108	461	0.38
3	Hand pumps	19,153	81,695	67.20
4	Tube wells / Bore wells	2,778	11,849	9.70
5	Other (springs, etc.)	82	488	0.29
	Total	**28,515**	**1,21,766**	**100.00**

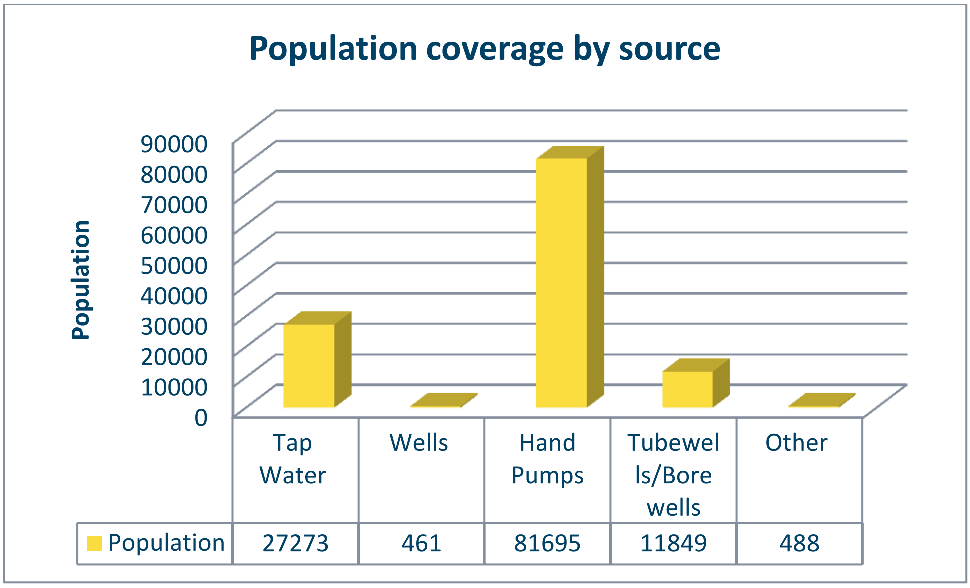

Figure 1-9: Population coverage by source (Source: Census 2011).

1.3.2 Proposal for Augmentation of Water Supply System

Presently there are no proposals for the augmentation of the water supply for Nagaon town. As the town has a perennial source of water (the Kolong River) it is advisable to use the river for water supply to the extent possible rather than ground water. In addition, ground water contains elevated iron concentrations in most parts of the town and elevated arsenic concentrations in some parts of the town. It is also a prerequisite as per the Central Public Health and Environmental Engineering Organisation (CPHEEO) manual to have a piped water supply system before a separate sewerage system can be proposed for the whole town. It is proposed that a DPR should be prepared to implement a water supply scheme by the NMB.

1.4 Status of Existing Waste Water Disposal Works

1.4.1 Existing Work

Presently, there is no existing sewerage collection system or treatment plant in Nagaon town. As per the information received from Nagaon Municipal Board, 85-90% of the inhabitants use a septic tank with soak pits for the sewerage disposal. Water from the soak pits contaminates the ground water and creates human health problems. The remaining 10-15% of inhabitants discharges their sewage directly in the river as most of them reside along the river.

Waste water from kitchens and washrooms are discharged into open drains in front of the houses, which are directly discharged into the river without any treatment. These open drains are a major contributor to the pollution in the river. Some of the overflows of the septic tanks are also connected to these open drains, further contributing to the pollution of the river.

The river is also a significant cultural aspect to the town, and is used by the population for washing, bathing, and fishing. It is imperative that a method of sewage collection and treatment be implemented to reduce pollution and improve the water quality of the Kolong River and reduce existing health risks.

Figure 1-10: Sewerage discharges along Kolong River.

1.4.2 Work under Execution

The amount of water supplied to Nagaon residents is less than 135 lpcd, which is the standard prescribed in the Central Public Health and Environmental Engineering Organisation (CPHOO) manual. Considering that only 22% of the population of Nagaon receives 50-60 lpcd of piped water supply, there will not be sufficient sewage generation in the town for a sewage treatment plant (STP). Presently there are no works proposed for the sewerage system for the Nagaon town. As there is no existing sewerage system in place, new house construction plans require septic tanks within the premises of the house for construction approval. The size of the septic tank depends on the number of family members in the house.

1.4.3 Work Sanctioned but not yet started

As stated, there are no existing sewerage system works in the Nagaon town. However, a tender has been called for construction of road side drainage. As per the information provided by the NMB the process of awarding the drainage construction work is in progress. The work on open drains has been sanctioned but not yet started.

1.5 Status of Pollution of the River

1.5.1 Number and Details of Drainage Channel

There is no well-connected drainage system in Nagaon town, resulting in occasional flooding particularly in the monsoon season. Drains along the side of roads exist in some areas but may be blocked or not linked up properly. Flooding is of particular concern in the following areas:

- Part of Panigaon
- Hotelbar area
- Teliapatti
- Santipur
- Lakshminagar
- Islampatty
- Area opposite to the Haibargaon railway station.

In recent times, improvement schemes for the drains have been proposed by the state government with possible assistance from the Government of India. A road side drainage improvement project has been sanctioned by the NMB but has not yet started.

1.5.2 Waste Water Flow Carried by Drains

At present the Nagaon town does not have an integrated sewerage system. The only collection and treatment process being followed is the use of septic tanks. Therefore, part of the waste water generated in the town is being disposed of into the rivers without any treatment.

The waste water volume discharged into the Kolong River is based on the following assumptions:

- Estimated number of inhabitants contributing to waste water discharging into the river. The estimation is carried out as follows. On the basis of the town's topography a delineation of the town is made. On the basis of this delineation the areal percentage of each ward contributing to the discharge is determined. The number of people living in each ward is known. And hence the number of people in each ward contributing to the discharge in the Kolong River can be found simply by multiplying the percentage and the number of people in the ward.
- Daily contribution of 108 lcpd, calculated as follows: 0.8 x 135 lcpd.

Accordingly, the total waste water generation is as follows:

- Point West Nagaon: 17,00,000 liters per day (l/d)
- Internal Pond: 8,00,000 l/d
- Puta Kolong: 4,00,000 l/d
- Point East Nagaon: 17,50,000 l/d

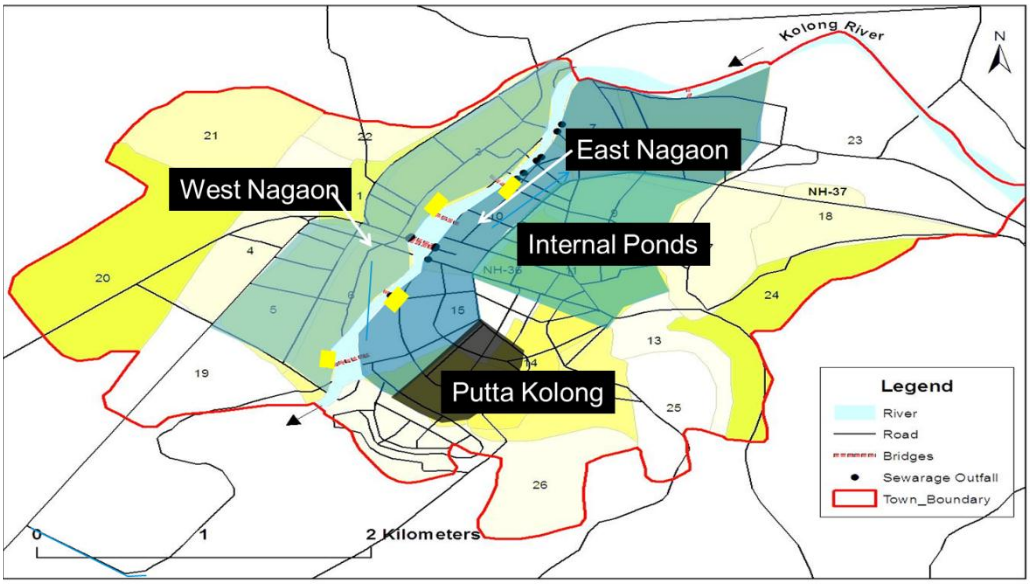

Figure 1-11: Map showing the four (4) areas.

As the town along Kolong River grows and develops, including the water supply system, the waste water flow carried by drains to the Kolong River will increase.

1.5.3 Measurement of Flows in Drains along with Copies of Test Report

The drains inside Nagaon town discharging into the Kolong River were visited and inspected numerous times during the execution of the present project. During each visit the discharge from the drains were either measured by simple floater methods or estimated from the water depth. The estimates were used to evaluate the numbers provided in Section 1.5.2. The evaluation proved that the numbers presented in Section 1.5.2 are reasonable.

1.5.4 Waste Water Characteristics of Different Drains

The sources that have been identified include the following:

- *Domestic sewage:* Raw domestic sewage and partially treated sewerage in the form of septic tank effluent drains are directly connected to the storm water drainage system. The direct sewage discharges contribute heavy organic loads which affect water quality and include bacteria, viruses, and other pollutants which are harmful to human and ecological health. Similarly the septic tank effluent contributes organic loads but at a much lower magnitude.
- *Municipal solid waste (MSW):* MSW (i.e., garbage) is routinely dumped in town streets and along the banks of the Kolong River. At numerous locations along the river bank, MSW is strewn about in thin, non-contiguous layers, but in many locations, thicker, contiguous fills exist on the river banks and lie in contact with the flowing water. In many cases, metal, wood, and food wastes appear to be scavenged by local populations, dogs, and other animals, and the resulting mixture is dominated by plastic wastes. As these wastes slowly degrade, they release toxic pollution to the water.
- *Storm water:* Storm water is directly discharged to the Kolong River via the surface drainage system, and also as overland surface runoff. In both cases, this storm water carries solids and pollution from the town streets into the river, In addition to domestic sewage, this runoff likely includes particulates from combustion of diesel fuel and other petroleum fuels, pollution from MSW, oils and greases from pavement areas, abraded asphalt particulate, animal wastes, agricultural, and other pollution sources.
- *Industrial pollution:* Industrial pollution sources may include automotive maintenance areas, fuelling stations, and other industries indigenous to the area. These pollution sources can be directly discharged to the drainage system, can flow overland, or can infiltrate groundwater which ultimately discharges to the Kolong River.
- *Atmospheric deposition:* The air quality in Nagaon town is affected by sources such as the combustion of petrochemicals for transportation, energy, and industrial purpose and regional air quality pollution. Particulates which contains toxic combustion by-products and heavy metals such as mercury settle and dissolve into the town's waterways.

Due to the density of the residential population in Nagaon, it is believe that the most significant source of pollution to the Kolong River is the direct discharge of domestic sewage. Given the prevalence and magnitude of the problem, MSW dumping may also be a significant source. It is likely that the pollution loads from storm water, industry, and atmospheric deposition are less significant, but there has been little study done to confirm this assertion.

1.5.5 Measurement of Waste Water Characteristics along with Copies of Test Reports

The water quality measurements are collected and analysed by:

Environmental Research & Evaluation Centre (EREC)
MPG Complex, R-2
Rupnagar, Guwahati
Assam
781032
India
Home-page: www.erec.in

EREC is a certified laboratory to collect and analyse water quality samples.

The water samples were collected at five locations on three consecutive days (Figure 1-12):

- Upstream at the confluence with Misa River (river water)
- Upstream of Nagaon town (river water)
- Inside Nagaon town in the drain at the ATP bridge (drain water)
- Inside Nagaon town in the drain at the jail (drain water)
- Downstream of Nagaon town (river water).

NRCD water quality limits for effluent discharge into rivers are presented in Table 1-11.

Table 1-11: Effluent limits prescribed by NRCD (see Table 4.7 in NRCD).

Parameter	Unit	Limits
pH	--	From 5.5 to 9.0
BOD	mg/l	< 20
TSS	mg/l	< 30
Faecal coliform	MPN/100ml	Desirable – < 1,000 Permissible – < 10,000

As part of the present project, water samples were collected from two drains inside Nagaon town. The laboratory results are shown in Appendix A. The results confirm that the waste water characteristics correspond to domestic waste water with high pollution levels.

The waste water discharging from Nagaon town into the Kolong River does not adhere to present rules. The waste water is more polluted than allowed. Actions are required to lower the pollution of the Kolong River and improve the environmental conditions of the water body.

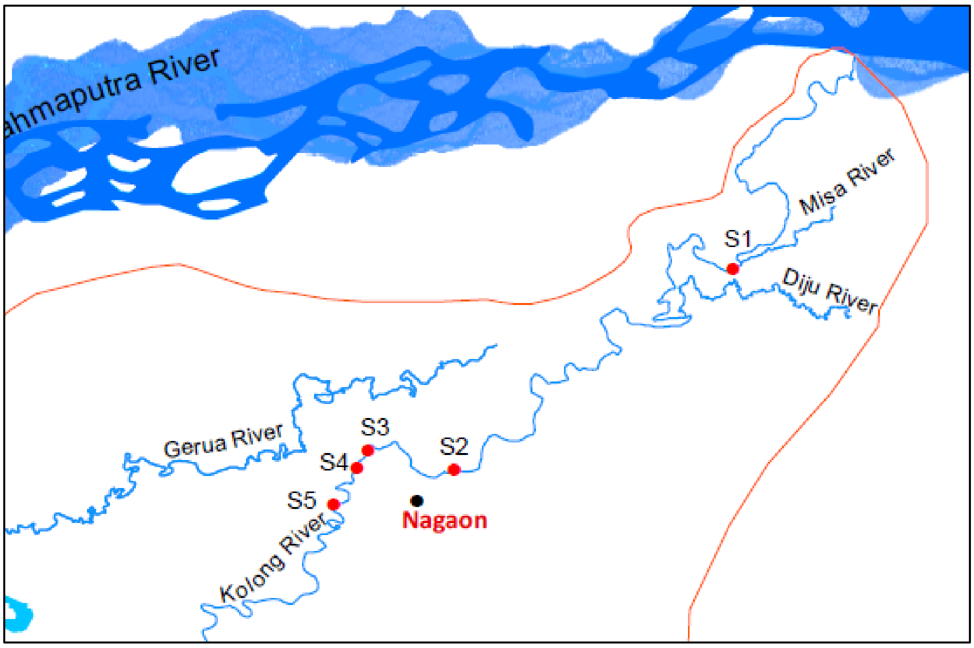

Figure 1-12: Locations of water samples.

1.5.6 Water Quality of the River U/S, D/S and at Outfall of Drain discharging into River

The following description is based on historical water quality measurements. Some of them can be found in Appendix C, D and E.

Based on the measurement in PCBA (1993) which has the most details inside the town it is found:

- The water quality levels do not vary much through the town (some more comments on this issue is given below).
- pH, BOD and DO levels are all higher during the pre-monsoon season than during the monsoon season as expected.
- Faecal coliform levels are generally lower during the pre-monsoon season than during the monsoon season.
- pH, BOD and DO levels satisfy the limits in NRCD guide (see section 1.5.9).
- Faecal coliform levels are higher than the desired limit and close to the permissible limit (see section 1.5.9).

The measurements show that the water quality levels do not change much throughout the town. Of course if and when samples are taken too close to the source the values can be high, but it is considered to be erroneous data (one such case is identified in the data). The downstream water quality samples should not be collected closer to the drain than about 10 times the width of the river to ensure that the sewerage is mixed over the river cross-section (else the data are meaningless as it will be an undefined mixture of drainage and river water).

No signs are found in the historical measurements that indicate that the water quality of the Kolong River has improved since the detailed measurements were collected in year 1993. On the other hand, it is found that the situation has most probably deteriorated and that the river today is more polluted than ever before.

The historical water quality data shows that the river is polluted with faecal coliform bacteria and does not adhere to the NRCD guideline. Actions are required to clean up the Kolong River for the benefit of the town's inhabitants and well as the ecosystems in the river.

1.5.7 Measurement of the Quality of River Water along with copies of Test Report

Details on water samples collected can be found in Section 1.5.5. The actual water quality data can be found in Appendix A.

Based on the collected and analysed water samples from the Kolong River and analysed as part of the present project it is found:

- pH and DO levels satisfy the limits in NRCD guideline (see section 1.5.9).
- BOD levels do <u>not satisfy</u> the limit in the NRCD guideline and faecal coliform levels are higher than the desired limit and close to the permissible limit (see section 1.5.9).

The water quality data obtained in the present project shows that the Kolong River is polluted with faecal coliform bacteria inside Nagaon town and does not adhere to the NRCD rules.

1.5.8 Methodology followed for Flow Measurement and Quality Characteristics

The laboratory methodology is shown in Appendix B.

1.5.9 Water Quality Standards of River Water Quality

NRCD specifies the following limits for water quality for rivers if used for bathing:

Table 1-12: NRCD water quality limits for rivers (designated best use bathing) (see Tables 2.3 and 4.5 in NRCD).

Parameter	Unit	Limits
pH	---	From 6.5 to 8.5
BOD	mg/l	< 3
DO	mg/l	> 5
Faecal coliforms	MPN/100ml	Desirable – < 500 Permissible – < 2,500

For propagation of wildlife and fisheries, the following additional limits apply:

- DO > 4 mg/l
- Free ammonia (as N) < 1.2 mg/l.

1.6 Justification of the Project for Pollution abatement of the River

As stated in Section 1.3.2, the Central Pollution Control Board found that the Kolong River is among the most polluted rivers in India, and the NRCD (2010) guidelines considered the Kolong River as one of the rivers for conservation. The water quality measurement collected and analysed as part of the present project confirm the high degree of pollution. Hence, the pollution abatement is justified.

2 Approach and Sewerage Districts

2.1 Approach

This section describes the basic input used for providing an effective sewage collection, conveyance, treatment, and disposal system for Nagaon town to safeguard the River and also normal ecological system of the river Kolong. The proposed scheme has been formulated based on the latest version of National Ganga River Basin Authority (NGRBA) Guidelines issued by National River Conservation Directorate, Ministry of Environment and Forests, December 2010. Also, the criteria furnished in the 'Manual on Sewerage & Sewage Treatment' published by CPHEEO, Ministry of Urban Development, Government of India, has been used as necessary.

Adoption of a comprehensive system strategy is important in developing an effective sewerage system. The following system strategy has been formulated to provide the best engineering solution to the prevailing sanitation problem for the town.

- The current arrangement of wastewater collection will have to be modified after sewer lines are installed in the project area. Only the households need to be connected to proposed sewer lines either directly to manholes or through catch pits depending on the site conditions and space availability. This will ensure discharge of domestic wastewater flow (DWF) only into the sewer lines. Existing road side drains will be used exclusively to collect and convey storm water runoff (SWF). Connection of open drains to sewage collection network will be restricted and given only in cases where individual house connection is not possible due to space constraints. A suitable arrangement of such connection will be developed and proposed in the future.
- Wards directly overlooking the river Kolong would be taken up for providing sewage interception, collection, and diversion first. Subsequent areas would be covered and integrated with this centralized sewage collection system in the future.
- The proposed sewage collection system will include construction of house connections with an aim to intercept sewage at the very location of its generation. This would also avoid intermixing of sewage and storm water run-off. Though initially some intermixing of storm water is expected in view of any organized storm water management scheme for the town, it is expected that over time a storm water collection network would be installed rendering the now proposed system more efficient in collecting only the wastewater from households and other sources.
- The project area has narrow lanes (even < 2.5 m) with surface drains on either side. From the standpoint of feasibility of installation of sewer lines in these narrow lanes, the minimum road width where sewer line is proposed has been restricted to 2.5-3 m, i.e. the distance between the existing surface drains on either side. Also, to reduce the number of manholes in the streets, rider sewers may have to be laid along the length of main sewers. However, such a decision may be taken at the time of detail design depending on site conditions and feasibility of construction.
- In order to avoid duplication of pipeline, it has been proposed to pump wastewater from pumping station to the nearest gravity sewer as opposed to conveying the entire flow in a pressure conduit all the way to the next pumping station or treatment facility. This way, maximum efforts have been made to avoid installation of gravity sewer and pressure main along the same alignment, unless it was absolutely necessary over limited stretches.
- The options for decentralized wastewater treatment were explored keeping in view the isolated nature of wards on either side of the town. The space might be available at selected locations for construction of a sewage pumping station and treatment facility on a segregated basis. However, availability of land and location of nearest discharge location within town boundary (for treated effluent) might be two deterrent factors. Even if a treatment plant had been proposed here, the treated effluent would have to be

conveyed by pressure conduit to a suitable discharge location. It also seems preferable to avoid multiple operating points for management of its wastewater treatment system for a small town like this one. Hence, in order to reduce operating point of the scheme and also capital cost of installation of treatment facility, a centralized approach has been adopted.

- The maximum depth of invert of proposed sewer line will be restricted to 4 m, and at certain places this can be up to 5 m, if absolutely necessary. The sewer invert will never be proposed at a depth more than 5 m as the water table is very high in Nagaon city. This is suggested in view of town setting, advanced technique employing deep sewer construction does not seem to be either feasible or preferable. Narrow street/lanes in wards, to negotiate acute space constraints, avoid damage to the foundation of existing building due to sewer installation, and ensure feasibility of excavation of trenches for sewer construction, also support this concept.
- Generally, roads having ≤ 5 m width (distance between the property lines on either side) will be provided with sewer line in the centre. House connections will be given to these lines from either side of existing road. For any existing road > 5 m wide, sewer line will be laid along one particular flank of the road preferably outside the black top road surface, provided space is available.
- The manholes will be constructed in brick masonry having rectangular in shape with access shaft to reduce cost and facilitate relatively easy and quick construction. Size of manhole will vary according to their depth of invert, which will be decided at the time of detail design.
- There might be a few critical manholes that will receive discharge from pressure mains. These manholes will serve as collection manholes and velocity/energy dissipation locations for incoming flow. Such manholes will be built in reinforced concrete of suitable grade to avoid any erosion/abrasion effect inflicted by the continuous inflow of wastewater discharged under pressure. Apart from being manholes, these structures will also serve as energy dissipation locations to ensure smooth gravity flow on the downstream sewer.
- Maintenance of sewer against possible silt accumulation and other repair works are mandatory. For sewer cleaning works, suitable equipment (both for trunk sewer and branch sewer) will have to be procured under this project and such provision has been kept in the estimates.

A few critical elements in framing the proposed scheme have been identified that would involve permissions and approval from other agencies. These are acquisition of land for construction of proposed sewage pumping station and treatment plant, alignment of pressure main along existing roads, laying of sewers, thrust boring for underpass crossing, etc. These will be addressed individually on approval of the scheme.

2.1.1 Design Criteria

Formulation of the sewerage collection, treatment and disposal scheme will be framed by following the guidelines given in the Manual of Sewerage and Sewage Treatment (Second Edition), Ministry of Urban Development, 1993. It is a normal engineering practice followed by all engineering consultants and government authorities across India to comply with the recommendations of this Sewerage Manual in designing and detailing of sewerage systems. Apart from this, a number of design criteria, were taken from the recently revised “Guidelines for Preparation of Project Reports under National River Conservation Plan and National Ganga River Basin Authority” (December 2010), issued by Ministry of Environment & Forest, Government of India. After completion of field surveys, remaining data collection and a study of existing field conditions, certain design parameters and considerations may require revision in order to suit specific project requirements.

2.1.1.1 System configuration

Separate sanitary and storm sewers are expected for any underground drainage system. The main advantages of separate system are protection of water-courses from pollution and exclusion of storm runoff from treatment system with a significant saving in construction and operation cost. At times, however, for older communities where the existing road widths are very narrow, combined sewers are frequently encountered and providing separate systems is found to be extremely difficult and costly. Under the present study, the proposed system is provided and designed exclusively to convey the wastewater generated and accordingly the design norms have been formulated.

There is considerable stretches of existing surface drains in Project Area. These drains will be used for disposal of storm runoff with suitable expansion and augmentation to be planned at a later date. It is conceived that sewers from individual premises will discharge to a master pit/collection pit within its property boundary. This master/collection pit will be connected with manholes to be built under this project.

Configuration of proposed system will comprise of house connection, wastewater collection system, sewage pumping station(s) at strategic locations for conveyance of wastewater to treatment facility, wastewater treatment, and final disposal to natural water body. Efforts will be made to plan and design the collection network in a cost-effective way with an aim to reduce the number of pumping stations. Whenever the depth of manhole exceeds a stipulated depth, sewage pumping stations will be provided.

The collected sewage will be treated in proposed sewage treatment facility and disposed off to inland surface water. Reuse of treated sewage will be decided as suitable.

2.1.1.2 Wastewater Generation Rate

Design of sewerage system is based on flow or the volume of the waste water generated. With respect to flow, peak flow rates must be known in order to decide the hydraulic capacities of sewers, dimensioning of pumping station(s), sizing of sewage treatment plant(s), and effluent disposal facilities. Three important components, namely domestic sewage, industrial wastewater (if applicable), and ground water infiltration have been considered for estimation of expected flow of wastewater. This is referred to as Dry Weather Flow (DWF) and will determine the normal loading on the above components impacting the hydraulic capacity required for sewers, pumping stations and force mains.

Per capita sewage generation as per the CPHEEO Sewerage manual is given as 80% of the per capita water supply. Per capita sewage flows are conventionally determined from a study of existing per capita rate of water supply and population served in case no wastewater flow monitoring data from the contribution area is available. In absence of any such flow monitoring data, future wastewater flow will be estimated by per capita rate of sewage generation.

The existing water supply scenario in Nagaon town is expected to improve after implementation of any future piped water supply scheme for the area. Since the concerned authority does not have any immediate plan for any major augmentation of water supply in the area, current supply rate has been considered for estimation of wastewater flow over the design years. However, suitable provision for future augmentation in water supply has been considered. Based on these considerations on the perspective of present and future water demand, the following assumptions have been made.

- Water demand for population covered with piped water supply system is @ 135 lpcd considering fully developed water supply system in the area.
- Water demand for remaining population not covered by piped supply at present will be covered in future by the above rate,

- The above supply rate includes other demand, i.e. possible Institutional Commercial & Industrial (ICI) demand for Nagaon city.

When a water supply system is implemented the sewerage generation per capita will be:

Table 2-1: Calculation of per Capita Sewage Generation.

S. No.	Description	Demand (lpcd)
1	Net per capita water demand for Nagaon	135.00
2	Add 10% for ICI demand[1] @ 10%	13.50
2	Add ground water infiltration @ 5%	6.75
	Sub Total	**155.25**
3	Considering 80% for sewage generation	124.20
	USE	**125.00**

As the town grows and develops, including the water supply system, the total waste water generation will increase.

2.1.1.3 Groundwater Infiltration

As the project area is situated in close proximity of the banks of river Kolong, the water table in the city is as high as 10-15ft. In view of possibility of infiltration of ground water in sewers, it will be proposed to adopt strict quality control measures for selecting material and workmanship during execution. The amount of groundwater infiltration in sewers will largely depend on the following factors,

- Depth of sewer line and position of existing groundwater table,
- Material and type of joints for sewer pipes used, and
- Workmanship of sewer installation work.

CPHEEO Manual suggests a range of 500 to 5,000 litres per km of sewer line per day (l/km/d) as possible infiltration depending on situation. Considering high groundwater table in the project area, 5% of ultimate peak sewage flow will be considered as contribution from groundwater infiltration. For the ultimate design year, it amounts to about 2200 l/km/d. This looks reasonable and in line with the provisions in the Manual.

2.1.1.4 Depth of Flow

The maximum depth of flow in sewer will be taken as 0.8 or 80% of the conduit diameter for all sizes of sewers. In other words, maximum value of “d/D” ratio will be taken as 0.8 (where “d” is depth of flow in sewer and “D” is inside diameter of sewer) at peak design flow. Sewer design will be done with this maximum depth of flow and corresponding value of “q/Q” ratio (where “q” is peak design flow and “Q” is discharge at full depth).

This maximum depth of flow in sewers is restricted to keep some extra provision in design and provide adequate ventilation inside sewers to avoid crown corrosion. But, if the same criterion of 80% maximum depth is used for the smaller diameter sewers, this might not be fulfilling the basic objective for keeping this extra provision. In other words, the space left over 150 mm, 200 mm, 250 mm, and 300 mm diameter conduits, considering 80% depth of flow are 30 mm, 40 mm, 50 mm, and 60 mm respectively. It seems that such minimal space over the maximum water surface in sewers is not sufficient to provide proper ventilation. Hence, restricting the maximum depth of flow in conduits ≤ 300 mm to 50% depth might have been useful and ensured ample space for ventilation with conservative design practice. However, in line with the provisions kept in the Manual, the 80% maximum depth criterion has been used.

2.1.1.5 Peak Factor

Flow of wastewater would vary depending on the size of contributing population and over a day. Hydraulic design of sewer needs to take care of such variation in wastewater flow for adequate hydraulic design of sewers. The ratio of peak to average daily flow (peak factor, PF) is as given by the Gifft Equation (for population more than 500) is as below,

$$PF = \frac{5}{P^{0.167}} \qquad \text{Eqn. 1}$$

Where P is population in 1,000 people

An approximation of this formula in calculating peak factors for various population figures is given in CPHEEO Manual. The design flow in a sewer is the average dry weather flow multiplied by this peak factor plus infiltration. Peak factor for any sewer will be calculated by the number of contributing population adopting the peak factors as given below.

Table 2-2: Peak factors for various population figures.

Population	Peak factor
For population ≤ 20,000	3.00
For population > 20,000 and ≤ 50,000	2.50
For population > 50,000 and ≤ 7,50,000	2.25
For population > 7,50,000	2.00

Source: CPHEEO Manual

2.1.1.6 Hydraulic Design Formula

Manning's formulae for open channel flow inside circular conduits is used for hydraulic design of sewers, as given below:

$$V = \frac{1}{n}(3.968x10^{-3})D^{2/3}S^{1/2} \qquad \text{Eqn. 2}$$

and

$$Q = \frac{1}{n}(3.118x10^{-6})D^{2/3}S^{1/2} \qquad \text{Eqn. 3}$$

Where, V is velocity in m/s, n is Manning's coefficient of roughness, D is inside diameter of pipe in mm, S is slope or hydraulic gradient, and Q is discharge in l/s. The value of Manning's roughness coefficient to be adopted in the design is 0.011 for spun RCC pipes with socket and spigot joints (and 0.011 for uPVC sewers, if used).

2.1.1.7 Flow Velocity and Gradient

Domestic wastewater contains significant amount of organic and inorganic solids in floating or suspended forms. If velocity of flow in the sewer is low, these solids might be deposited at the invert of the conduit and cause obstruction to free flow of sewage. Hence, it is necessary to maintain the self-cleansing velocity at least once in a day during peak flow conditions at all sections of the sewerage system.

Sewers will be designed for a self-cleansing velocity of 0.6 m/s at peak design flow in immediate phase. Considering the limited gradient available in the project area and to restrict the invert of sewers to a certain depth for practical reasons, it might not be possible to maintain self-cleansing velocity in initial stretches (mostly laterals) of sewers during the early years. To overcome this problem, these stretches need to be flushed intermittently. However, trunk sewers will be designed to maintain self-cleansing velocity even for peak design flow in immediate phase.

2.1.1.8 Maximum Depth to Invert

Maximum depth of invert of a sewer line will be dictated by practical and economic considerations. The choice will normally be between having a deep sewer and providing a sewerage pumping station. The suggested criterion is that sewerage pumping station should only be proposed when absolutely necessary to restrict the depth of invert of sewers to a specified value. Maximum depth of sewer invert is restricted to 4.5 m for the Nagaon city sewerage system also because of high water table in the city.

2.1.1.9 Minimum Cover and Sewer Protection

Sewers should always be laid at depths which will serve not only all existing properties but also any future properties within its service area. Normal current practice is to have at least 0.9 m cover above the top of the sewer, however at times this might be reduced by providing extra protection to the sewer. It should be noted that the depth of a sewer is the distance between the top of the barrel and ground level.

However, applying this criterion to initial lengths of sewer will lead to unnecessarily deep sewers, and the cost of providing protection to initial lengths of shallow sewer can be saved by reduction in depth of all subsequent sewers. A shallow sewer at a depth of 0.6 m, with adequate protection by proper concrete encasement, is considered acceptable, economically justified and is not technically detrimental. Minimum cover to sewers will be as follows,

Without protection	0.9 m
With protection (concrete encasement)	0.6 m
Under existing services	as recommended by concerned service authority

2.1.1.10 Minimum Pipe Diameter

Regular and periodic blockage of smaller sewers is common due to mishandling by the public and insufficient sewer cleaning. In view of this, it is advisable to stipulate a minimum diameter of 200 mm for public sewers. However, The Design Manual recommends that the minimum diameter of conduit should be 150 mm except for hilly areas where it can be reduced to 100 mm where there are high slopes. In line with this, minimum size of sewer is adopted as 150 mm. It needs to be pointed out that this size does not apply to house/property connections. The suggested minimum size for such connection is 100 mm diameter, which can be increased appropriately depending on its size.

2.1.1.11 Sewer Transition

Hydraulic design of sewers will adopt a criterion of matching the soffit levels of incoming and outgoing pipes wherever there will be a transition of sewer from smaller diameter to larger diameter. The soffit level is the crown in the inside of circular sewer. This will ensure better hydraulics for the sewer as opposed to matching the full flow depth (i.e. 80%) of upstream and downstream sewers.

2.1.1.12 Material of Sewer Line

There are various pipe materials available for application in wastewater collection systems and each of these materials has a unique characteristic used under different conditions. Pipe material selection considerations include trench conditions (soil conditions), corrosion potential of ground, temperature variations, safety requirements, and cost. Key pipe characteristics are corrosion resistance (both interior and exterior), the scouring factor, leak tightness, jointing method and hydraulic characteristics. Pipe manufacturers follow requirements set by the Indian

Standards or applicable International Standards for specific pipe materials. Specification standards cover the manufacture of pipes and specify parameters such as internal diameter, loadings classes, and wall thickness. The methods of pipe construction vary greatly with the pipe materials.

Some new pipe materials and construction methods use the basic materials of concrete pipes with modifications (e.g. linings). Other pipe manufacturing methods use newly developed resins which offer improvements in strength, flexibility, ease of laying and jointing, and resistance to certain chemicals. Construction methods may also allow for field modifications to adapt to unique conditions (i.e., river crossings, rocky trenches, etc.) or may allow for special, custom ordered diameters and lengths.

The applicability of different pipe materials might vary with each site and system requirements. The selected pipe material must be compatible with the chemistry between soil and groundwater. The pipe material also should be compatible with the soil structure and topography of the site, which affects the pipe location and depth, supports for the pipe fill material, and required strength of pipe material. A summary of various factors to be considered for determining the type of best pipe material is given below (not necessarily in order of priority),

- Expected overburden, dynamic, and static loading on pipe,
- Lengths of pipe available, joining materials and installation equipment required,
- Time taken and ease of laying,
- Soil properties and chemistry, location of water table, stability,
- Chemical and physical properties of the wastewater and its corrosion potential,
- Joint tightness and level of craftsmanship required,
- Size range requirements, availability,
- Compatibility with existing system,
- Manholes, pits, sumps, and other required structures to be connected,
- Maintenance requirements, durability, and space required for installation.

However, the prioritization of criteria for selection of pipe material varies from one project to another and ultimately dictates the selection. Under the present scenario, the following criteria have been classified as the most critical ones,

- Time of construction of sewer network should be as less as possible since the areas are extremely congested and at places just have enough space for laying of sewers. But these areas cannot be closed down during sewer laying for a very long period as this will interfere with the regular use of these rods/streets causing difficulty to the stakeholders. So, it would be better if pipes to be used here are laid easily without requiring high craftsmanship and as quickly as possible.
- Pipes should be strong enough to take on the overburden pressure as it is expected that the depth of excavation can be as high as 5 to 6 m. Depths of pipe installation are optimized to balance between the quantity of earth cutting and segregation of sewerage zones (also called sewerage districts) to provide pumping stations.
- The water table in the site is very near to surface and this should be taken into consideration while selecting the material to ensure stability of pipes and the joints. Differential settlements at pipe joints can result in leakage causing groundwater contamination and are very difficult to pinpoint, even if repair is undertaken.
- Lastly, cost of pipe used in sewage collection network forms a significant portion of the cost of total sewerage scheme and this has to be kept in view. Even a small difference in per unit length of pipe cost can ultimately prove to be a significant percentage of total project cost.

The most common material being used for sewer network all over India is Reinforced Cement Concrete (RCC) pipe of classes NP3 and NP4. Apart from RCC, other pipe materials considered for application under this project are ductile iron (DI), un-plasticized poly-vinyl chloride (uPVC), vitrified clay or stoneware (SW), and high density poly-ethylene (HDPE). Glass reinforced plastic (GRP) pipes are yet to enter the Indian market for application in new sewerage line and have not been considered here.

A comparative statement of advantages and disadvantages of various pipe materials is given in Table 2-3.

Table 2-3: Advantages and Disadvantages of Various Pipe Materials.

SN	Material/Ref. IS Codes	Advantages	Disadvantages
1	Ductile Iron/ IS 8329:2000.	Good corrosion resistance when cement mortar lining is used. High impact resistance. Ease in laying.	Costly.
2	Reinforced Cement Concrete/ IS 458:2003.	Widespread availability. High strength. Corrosion resistance when coated or lined or better quality cement is used.	Heavy. Requires careful installation to avoid cracking. Susceptible to attack by H2S and acids when pipes are not coated.
3	Vitrified Clay/Stoneware/ IS 651: 2007.	Very resistant to acids and most chemicals. Easy in handling and installation.	Short length and more joints make it prone to infiltration and costly to install. Joints are susceptible to chemical attack. Brittle (may crack) and requires careful installation. Available only up to a certain size.
4	Un-Plasticized poly-Vinyl Chloride/ IS 4985:2000. High Density Poly-Ethylene/ IS 4985:2000.	Very lightweight, easy to install and flexible. Economical and good corrosion resistance. Smooth surface reduces friction losses. Long pipe sections reduce infiltration potential.	Susceptible to chemical attack, particularly by solvents. Pipe must be restrained from floating in the presence of groundwater. Strength affected by sunlight unless UV protected. Requires special bedding which can very well offset the cost difference. Available only over a particular range of diameters.

Apart from the above, a tentative cost comparison for various pipe materials have been prepared out by working out per unit cost of pipeline with collecting rates from the market/ manufactures, using applicable schedule of rates for other items like laying and jointing, bedding, etc.

Costs for piping comparisons should include both the costs of the materials as well as the construction costs. The pipe cost is usually given in Rs. per unit length, traditionally in Rs. per running m (Rs/m), plus the costs of placing, laying, and jointing. Construction costs will depend on the type of excavation, special field equipment requirements, and an allowance for in-field adjustments to the system. Sanitary sewer construction costs will depend on several variables, such as depth of installation, type of soil, loading conditions, type of bedding provided, site clearing costs, and other factors.

On careful review of the qualitative and quantitative comparison of various materials, it is recommended that RCC pipes will be primarily used for sewage collection system. However, keeping in mind that the project area has less space at some places and the streets where sewer lines and house connections are to be laid are very narrow, in some case narrower than even 3.5 m. It is suggested to use uPVC pipe of 110 to 315 mm outer diameter to hasten the process of providing individual house connections and relative flexibility of laying in difficult field conditions.

RCC pipe has been used for sewers for a long time primarily due to its inherent strength and relatively low cost when compared to other products. The pipe can now be made in several joint configurations and can also be lined with PVC and other materials for protection against crown corrosion. The pipe can be designed on the basis of allowable stresses resulting from overburden pressure and laying conditions. It is important that the design of pipeline is done with the best approach to suit the anticipated design conditions.

Concrete pipe designed and manufactured properly can deliver excellent service for the conveyance of domestic wastewater. However, the converse is also true, i.e. pipe manufactured poorly or based on improper design criteria can lead to poor service life. Today, concrete pipe is expected to function properly in the field if strict adherence to specifications and plant quality control/quality assurance are maintained. The referenced specification dictates minimum reinforcement steel requirements that can be expected to deliver the stated design conditions of superimposed load or allowable stresses resulting from earth cover or internal pressure.

RCC is a high-density, wet-cast pipe meeting the requirements of IS 458 specifications. This pipe is designed as a rigid pipe, meaning that it is designed to carry construction, earth, and traffic loads without significant cracking, or deflection of the barrel. RCC pipe is designed to deliver an agreed upon level of performance at a specified design. The measure of performance is the formation of a 0.01-inch crack for a length of 12 inches pursuant to IS standards.

Over the years, the pipe manufacturing technology has been improved in terms of producing more durable RCC pipes. This has been done both in terms using better material of construction and also protective linings for pipes. These are discussed categorically to select and recommend the best quality of RCC pipe for the project.

There are generally three types of lining that are used to prevent sulfuric acid attack on the interior of the concrete pipe (known as crown corrosion). This attack is due to sulfides escaping the sewage as hydrogen sulfide gas and then reforming as sulfuric acid through bacterial action at the crown of the pipe. The degree of this problem is dependent on the amount of hydrogen sulfide forming in the sewage flows, amount of hydrogen sulfide released, and temperatures necessary to support sulfuric acid formation. In a tropical country like India, formation and release of hydrogen sulfide may very well be correlated to the high reaction kinetics inflicted by conducive sewage temperature and crown corrosion remains a persistent problem in sewers. With the availability of linings today and their reasonable cost, it is prudent to recommend linings to protect the pipe material from crown corrosion and extend its service life.

Plastic Lining – PVC lining is physically bonded into the concrete pipe interior with “T” shaped PVC corrugations to prevent crown erosion. This lining is placed into the interior of the form during the manufacture of the pipe and cast into the interior wall of the pipe. Sometimes, the amount of T-Lock placed into the pipe is limited to the top 90 degrees of the crown of the pipe. However, due to noted sulphide attack in large, low-flowing sewers, the degree of coverage has gradually increased to where it is now standard practice to provide the lining over the entire inside surface of the sewer pipe. The lining in each section of the pipe is welded to the lining in the next joint in the field. This process requires the use of high-quality equipment by well-trained plastic welders to ensure that good seals are obtained. Full-time inspection and PVC weld testing are required with most contractors to obtain high quality PVC lining and are an important part of the construction quality control program. Such pipes are now available in India.

Such plastic lining provides protection of the interior of the pipe from acid attack and crown corrosion throughout the pipe barrel. The cost for the lining system is reasonable and this is easily field repairable. However, such lining requires field PVC welding of the lapped joints at each joint of pipe and low quality PVC welding has resulted in acid attack under the liner in warm sluggish sewer systems. Also, high level of inspection of the welds is required to ensure sound installation.

Cured-in-Place Fiberglass Liner - The lining can also be provided by placing a glass-resin-impregnated flexible felt tube inside the pipeline. Availability of this lining is limited in India and is not considered for further consideration.

Sprayed on Protective Coatings - This method includes spraying high build epoxy, two part epoxy, or cementious epoxy coatings onto the interior surface of the RCC pipe. Due to the costs, application issues, and historical performance these systems are not recommended for lining the pipe barrel and are not further considered.

Bitumen Lining – To protect the inside surface of the pipe from the reaction of a variety of sulphates which can attack the concrete directly, bituminous coating, whether asphaltic or coal tar, is applied to protect the structure against such attack. This can be field applied, yet careful supervision is required to ensure quality of application.

RCC Pipe with Sulphate Resistant Cement - Use of pipes manufactured with high density sulphur resistant cement is only recommended. These pipes are made of slag cement that contains fewer calcareous (CaOH2) particles than pipes made of ordinary portland cement. These particles react with the sulphuric acid (produced by oxidation of hydrogen sulphide) generated inside the sewer environment and cause crown corrosion. If this particular cement is used, lifetime of concrete sewers can be enhanced beyond the anticipated design life of 30 years. RCC pipes are also manufactured with sulphate resistant cement when the soil contains sulphur and other corrosive substances.

Jointing – The types of concrete pipe joints are evaluated for this project, single gasket concrete joint with projected socket, double gasket concrete joint with projected socket, and embedded steel joint rings with smooth or projected socket. However, considering the ease of laying and other factors, only single gasket joint is recommended. To test the joint two inflatable bladders, or temporary bulkheads, one located on each side of the joint are installed and the area between the bladders pressurized. For smaller sewers, the entire installed length may be subjected to an overall leakage-performance installation test. The advantages of this type of joint are, these are easy to install, standard joint used in concrete pipe industry, long-term history of success, competitive cost. Disadvantages associated with single gasket joints include, manufacturing joint sockets within standard roundness tolerances has been a problem for some manufacturers and difficulty in testing each joint.

Inspection of Manufacture and Installation - To help ensure proper manufacture of concrete pipe, inspection services should be provided at the manufacturing plant for a project of this magnitude. To ensure proper placement of the rigid pipe, proper placement of bedding at trench bottom and compaction of backfill are very important. To ensure proper support, the bottom of the trench should be provided with stipulated granular or PCC bedding of adequate dimensions in the trench following pipe placement. The remainder of the bedding should be placed and compacted in lifts to provide additional support and to prevent trench settlement. It follows that the class bedding achieved at the jobsite must be at least equal to or exceeds the class bedding used in design.

2.1.1.13 Structural Design of Sewer

Structural design of sewers is important to ensure that these buried pipelines can structurally withstand the overburden pressure and superimposed load to which they are likely to be subjected. For gravity sewer lines, internal pressure is not significant. At greater depths, these pipes will be provided with proper bedding which will also be feasible to install under difficult site conditions. Properly compacted backfill plays a critical role in dispersion of superimposed loading.

The computation of loads on buried pipelines and calculation of safe load for a particular diameter of pipeline installed at certain depth underground has been established by Marston and others, and such methods are summarised in the Sewerage Manual. A safety factor of 1.5 has been applied and the loading conditions are adopted on the basis of these lines being laid below roads with heavy traffic as per recommendations in the Manual. Keeping in view the practicability of providing bedding for sewer lines in limited space, only granular and PCC beddings are proposed, as applicable and to be decided by the supervising engineer during actual laying of pipelines. In order to avoid differential/ordinary settlement and soil movement around sewers, strict adherence to suggested bedding has to be ensured during construction. The RCC pipes used will be of socket and spigot type with push-on rubber ring joints.

2.1.1.14 Manhole

Manholes have been proposed based on the following criteria and other salient features. These will be constructed in brick masonry to reduce cost of the project. No use of precast or fabricated manholes have been considered.

Location

Manholes are located based on the criteria as given below,

- At changes of slopes in sewer pipeline.
- At change in direction.
- At sewer junctions and probable house connections.
- At change in sewer diameter.
- At termination of sewer.
- At any designated special location as envisaged by planning.

Spacing

The spacing of sewers is dependent on the type of maintenance envisaged. Such spacing varies depending on whether sewers can be physically entered for inspection or maintenance or not. The sewers that would be installed in the project area are expected to be less than 1,100 mm hence these can be categorized as “non-man entry” sewers. A spacing of 30 m has been stipulated by the Manual for non-man entry sewers which is mainly based of the type of cleaning apparatus or procedure intended to be used. Manholes will primarily be located following the criteria given above. On continuous stretch, the spacing provided will be 30 m.

Size of Manhole

The size of manholes is related to its invert level (i.e. depth of manhole) and size of outgoing sewer. Manholes will be rectangular to facilitate ease of construction, time of installation, and future maintenance. Based on structural requirements to ensure appropriate design of manhole, the criteria given in Table 3 will be used. Deeper manholes will be provided with suitable access shafts. Manholes will be provided with RCPC covers and frame and polypropylene steps for accessing the sewers.

Manhole Levels

In paved areas, cover level of manholes will match with the final paved level, and in open and unpaved areas cover level will be 50 mm above the ground level. Also, the invert of manhole will be finished with a difference of 0.025 m or 25 mm below the proposed invert of the outgoing pipe.

Sewer Ventilation

Vent shafts are normally provided for venting off the gas generated inside sewer lines and as per requirement, practicability of construction, etc. Ventilation pipe is recommended for every house connections. In case of trunk sewers, such provision may be kept as suitable without causing any obstruction to other services.

Table 2-4: Manhole types and size.

SN	Manhole		Size, L x B (m x m)	Max. diameter of Outgoing Sewer (mm)
	Type	Depth of Invert, m		
1	M1	1.5 ≤	0.9 x 0.9	400
2	M2	> 1.5, 2.5 ≤	1.2 x 0.9	500
3	M3		1.2 x 1.2	800
4	M4		1.2 x 1.5	1000
5	M5	> 2.5, 4.0 ≤	1.4 x 1.2	800
6	M6		1.4 x 1.5	1200
7	M7	> 4.0, 6.5 ≤	1.4 x 0.9	600
8	M8		1.4 x 1.2	800
9	M9		1.4 x 1.5	1200

2.1.1.15 Sewer Crossing

Gravity trunk sewers and pressure mains are expected to cross beneath roads and railway tracks. At major road, railway, drainage crossings, pipes will have to be protected by concrete encasement or sleeve pipes. Sewers are not to be laid above water supply pipelines. When laid under water supply lines, there should be at least 0.5 m clear distance between the two pipes. If required, pipelines may have to be installed by trenchless technology (i.e. thrust boring) to cross important utility lines. The cost of utility shifting (e.g. water, drains, electric, telephone, optical fibre cable, etc.) needs to be added to cost of sewer pipe laying at specific locations.

2.1.1.16 Sewage Pumping Station

Sewage pumping station will be provided only when the depth of excavation for laying sewers exceeds a certain limit. In the present case, this depth has been stipulated at 4.5 m. pumping station will also be required to pump sewage from a lower level to a higher elevation, where gravity conveyance of sewage to a terminal location (i.e. treatment plant) is not feasible. A few relevant features of the proposed sewage pumping station are given here.

Sewage pumping stations normally forms a weak point in the entire sewerage system due to lack of adequate maintenance. Hence, the effort will be made to reduce their number as much as practicable. On a different aspect, other environmental impacts are expected due to possible odour/noise problem, silt/sludge removal, etc.

Inlet Structure

Sewage pumping station will be provided with exclusive inlet arrangement. The inlet will comprise two parallel and separate channels, one with a manual bar screen and the other with mechanical bar screen. The size of opening of screen will be 25 mm to safeguard the pumps against possible abrasion and clogging caused by larger particles. Sluice gates will be provided at upstream and downstream ends of each channel for isolation and maintenance. Such an arrangement is proposed to ensure system flexibility in case any of the bar screen requires cleaning/maintenance, the other can cater the entire estimated flow to the pumping station.

Wet Well

The wet well will be suitably sized to cater for any combination of wastewater inflow and pumping. The capacity of wet well is related to the maximum level of water in the sump and minimum pump suction level. The wet well will be suitably dimensioned to ensure running of minimum capacity pump for at least 5 minutes and maximum retention of sewage for a period of 30 minutes.

Pumping Arrangement

To ensure simple operational procedure and keeping in view the capacity of each pumping station, non-clog and wear-resistant submersible sewage pumps are proposed. These pumps will be installed in the wet well of the sewage sump and capable to handle solids of 100 mm spherical size and operate near to their duty points as given by the manufacturer. The design criteria for selecting the size of sewage pumps as recommended is given below,

Table 2-5: Recommended Capacity of Sewage Pumps.

SN	Criteria	Capacity	No.	Total No.
A	As per Recommendation of Sewerage Manual			
1	Smaller capacity pumping station	1 DWF 2 DWF 3 DWF	1 1 1	3
2	Larger capacity pumping station	0.5 DWF 1 DWF 3 DWF	2 2 1	5
B	As per Recommendation of NRCD Guidelines			
1	When rising main is long	0.5 Peak flow Non-peak flow pumps	2 2	4
2	When rising main is short	0.25 Peak flow 0.25 Peak flow	5 1	6 (1 stand by)

Duty conditions and capacity of individual sewage pump will be selected depending on projected sewage flow in two phases. Diesel generator sets will be provided at each pumping station location, if sufficient space is available, to insulate its operation from power failure. These stations will be well-ventilated to ensure there is accumulation of gases inside the stations which can seriously compromise the working condition and prove to be extremely detrimental to operators' health.

Pumping Main

Pumping main from sewage pumping station will be of ductile iron (DI). The hydraulic design of pipelines is given by the Hazen-Williams formula as below:

$$Q = 1.292(10^{-5})Cd^{2.63}S^{0.54} \quad \text{Eqn. 4}$$

$$V = 4.567(10^{-3})Cd^{0.63}S^{0.54} \quad \text{Eqn. 5}$$

Where, Q is discharge in m3/hr, V is velocity of flow in m/s, d is the diameter of pipe in mm, C is the Hazen-Williams Co-efficient, S is the slope of hydraulic gradient in m/m. Hazen-Williams Coefficient ('C' value) of 140 is adopted for design purpose for cement mortar lined DI pipes. The minimum diameter of pumping main has been restricted to 150 mm so that there is no clogging problem. Minimum velocity of flow in pipe will be 0.6 m/s to avoid settlement of solids inside the conduit and maximum velocity will be 3 m/s.

The pumping main will be laid with a clear cover of 1 m, with necessary sluice, washout, and air valves for maintenance (suitable to use for sewage). The pumping can discharge sewage to treatment plant, receiving sewage pumping station, or manhole. The discharge head of pumping main will be suitably dampened to reduce turbulence and corrosion of civil structure. These discharge locations will be well-ventilated to avoid accumulation of undesirable gases.

Pump Operation Philosophy

The control philosophy of pumping operation will be dictated by the prevailing water level in wet well. The detention volume refers to the storage volume between the High Water Level (HWL) and Low Water Level (LWL) of wet well used for formulation of this operational strategy of pumps. Accordingly, sizing of the well will be finalized based on (a) plan area of the well as per the space requirements for installation of pumps and (b) proposal for level controlled operation of the pumps.

For monitoring the levels ultrasonic level sensors and level controllers will be provided with a display unit inside the pump house. Operation of the pumps will be controlled by signals from the level controllers. Sensitivity of ultrasonic level sensors available in the market is generally within the range of 0.1 to 0.2 percent of the measuring range. Considering average depth of wet well as 6 m, the sensitivity comes to about 1 cm. Based on the above, the cut in/cut off levels of the pumps will be devised. The proposed logic for determining progressive intermediate cut in/cut off levels of pumps, depending on inflow to the well, is described below:

- Each pump will start at a pre-determined level L1 and stop at a pre-determined low cut-off level (LCL).
- Different levels will be decided on the basis of incoming flow, wet well size and respective pump capacities so that each pump runs for at least 5 minutes.
- In case any pump fails to start as per the above sequence, the next pump shall be automatically introduced.
- No pump shall be in operation below low cut-off level (LCL) to prevent dry running of pumps.
- There shall be manual override to auto-operation of the pumps.
- Automatic pump selector for periodically changing selection of equal capacity pumps with manual override will be provided for uniform distribution of running time between various pumps.

2.1.1.17 Sewer Warning Tape

Sewer line is suggested to be laid with warning/caution tape. Such tape will be installed precisely following the alignment of sewer line at about 0.3 m above it. This tape will be required to identify the underlying sewer in case of any emergency or unplanned excavation undertaken at a later stage. This caution tape will be of green colour with “sewer” written on it and a metallic strip. The metallic strip is necessary to identify the alignment and depth of sewer in case GIS mapping of this utility is intended in future. Such provision will help future identification of sewers and help in management of assets created under the project.

2.1.2 Design Periods

Designing a suitable and adequate sewage collection system for collecting domestic wastewater generated by population and likely ground water infiltration are the main component of an organized sewerage system. Sewerage system are designed keeping in mind the financial viability of the project and can be achieved by considering the future population of 30 years, which is the general practice in India. In case of Kolong city also the design period will be for 30 years, starting from year 2014. A design period of 30 years is also recommended by the “Manual for Sewerage and Sewerage Treatment” for all types of sewers and its components. The design life of mechanical components like pumping machinery, equipment, etc. are generally taken as 15 years after which these are expected to be suitably replaced in phased manner depending on the condition of the equipment.

As per the NRCD Guidelines, “base year” should be taken as year of expected commissioning of the project and for design of its various components. Consideration the size of the town; the design and tendering of the scheme should be completed by year 2014, and “base year” for the system implementation should be taken as 2015. Accordingly, the ultimate design horizon for the sewerage system is taken as 2044. The design life of electro-mechanical components to be installed in sewage pumping station(s) and treatment plant(s) is considered as 15 years, i.e., these will be replaced around year 2030 depending on the condition of these assets. Correspondingly, year 2030 has henceforth been referred to as “intermediate stage” and 2044 as “ultimate/final stage”. Design periods for various components are summarized in Table 2-6 below.

Table 2-6: Design Year for Components.

SN	Component	Design Year (from base year)	Remarks
1	Sewerage System	30	As per NRCD guidelines and CPHEEO Sewerage Manual
2	Sewage pumping station (Civil)	30	Economical to invest in civil works for full design period of 30 yrs.
3	Sewage pumping station (Electro-Mechanical)	15	Economical to invest in a phase-wise manner
4	Pumping main	30	As per NRCD guidelines and CPHEEO Sewerage Manual
5	Sewage treatment plant	15	Design period of 30 years phased out in two phases of 15 yr. each
6	Land for Sewerage Treatment Plant	30	For additional treatment plant(s) if phased out or done on modular basis

Source: *Analysis*

2.1.3 Population Projections

The population projections are presented in Section 0.

The ward wise population projections will be done based on considering the overall growth of 60% in the whole town of Nagaon and equitable distribution of the growth of Nagaon city.

2.1.4 Norms of Rate of Water Supply

According to the guidelines of Government of India, and as per the Manual on Water Supply and Treatment by CPHEEO, which are applicable all over the country, following water supply rates are to be adopted:

Table 2-7: Recommended per capita Water Supply levels for designing Schemes.

SN	Classification of cities	Recommended Max Water Supply Levels (LPCD)
1	Cities provided with piped water supply but without sewerage system	70
2	Cities provided with piped water supply where sewerage system is existing/ contemplated	135
3	Metropolitan and Mega cities provided with piped water supply where sewerage system is existing/ contemplated	150

As the city of Nagaon gets water from different sources like piped water supply, hand pumps, bore wells etc. it is assumed that the existing water supply to the city is not more than 70 lpcd, although there is no official records available with Nagaon municipal board regarding the average water supply to the households as 77% households use hand pumps for their daily need of water supply. For the consideration of this project it is assumed that piped water supply scheme will be implemented with average water supply of 135 lpcd as recommended by CPHEEO manual.

2.1.5 Interception Factor (IF)

Interception Factor (IF) for the scheme has been adopted to ensure complete capture of domestic wastewater or Septage from falling into river Kolong and diverting the same to the treatment facility which will be either centralised or decentralised as proposed for adequate treatment before disposal. The adopted system strategy has been explained in Section 2.1 of this report, to frame an engineering solution to the prevailing sanitation problem of the catchment area.

2.1.6 Plans for Renovation, up gradation and Augmentation

In absence of existing sewerage system, there are no plans for renovation, up-gradation and augmentation of the sewerage system in Nagaon city. The proposal for implementation of new sewerage system has been worked out in this project for Nagaon city, which is the most important aspect of this project. The strategy adopted for the design of new sewerage system for the city of Nagaon has already been elaborated in Section 2.1 of this report.

2.2 Drainage Areas

2.2.1 Description

At present there is no clear division of drainage areas in Nagaon city. Drainage is present on both sides of the roads on almost 90% of the roads. Total approximate length of the drains in Nagaon city is 265 km. Recently Nagaon municipal board has issued a tender for construction of additional 18km of drainage network along the roads in new developed areas. The process of allocation of the work is in progress and will be completed by December 2013. The drains are open type and made of bricks, which make them vulnerable to the clogging as the households throw their garbage in open drains.

2.2.2 Details

There is no well-connected drainage system in Nagaon town. Many of the open or closed-at-surface drains running along the side of the roads are either blocked or not linked up properly. That condition is one of the reasons for floods in the town particularly during the monsoon season. After heavy showers water-logged areas can be found in the town. The worst affected areas are:

- Part of Panigaon
- Hotelbari area
- Teliapatti
- Santipur
- Lakshminagar
- Islampatty
- Area opposite to Haibargaon railway station.

Table 1-3 lists the drains proposed to be improved by the State Government (PCBA, 2010).

2.2.3 Population Projections of each Drainage Area for Design Years

Since there are no well-defined drainage areas in Nagaon city, the population projection for the drainage area is considered same as that of the ward wise population projection for sewerage network, which is explained in Section 2.2.5 of this report.

2.2.4 Actual Water Supply from Different Sources

The actual water supply from different sources is outlined in Section 1.3.1.

Ground water is the major source of water supply to the Nagaon town and therefore it is important to stop the contamination of the ground water. Untreated discharge of waste water from septic tank into the ground, and also into the river, is contaminating the ground water and creating health hazards for the people of Nagaon.

2.2.5 Projected Waste Water Flows

Nagaon city has been divided into four sewerage district zones as West, East, Central and Putta Kolong sewerage zones. The division of these zones was done based on the topography and geographic features, ridge lines, alignment of drains, major roads, national highway and the ward boundaries. Number of wards considered in west zone is ward number 1,3,5,6 and 19, for East zone ward number is 7, 8,10,14,15 and 23, for central zone ward number is 9 and 11 whereas for Putta Kolong ward number is 16.

Projection of waste water flows is done by multiplying the projected population by per capita sewage generation. Calculation of per capita sewage generation is as shown in the following table.

Table 2-8: Calculation of per Capita Sewage Generation.

S. No.	Description	Demand (lpcd)
1	Net per capita water demand for Nagaon	135.00
2	Add 10% for ICI demand[1] @ 10%	13.50
2	Add ground water infiltration @ 5%	6.75
	Sub Total	**155.25**
3	Considering 80% for sewage generation	124.20
	Say	**125.00**

Source: Analysis

Following table shows the total waste water generation within the catchment area and also by the sewerage district zones. Details regarding the number of wards in each sewerage zone are assumed, whereas number of household in each ward, population in each ward is collected from census 2011 data. Population projection is done and is then multiplied with per capita sewage generation to get the total expected waste water generation from each zone and for the complete catchment area.

Table 2-9: Projected waste water generation.

Sewerage Districts	Ward no	No. of House hold	Population	Projected Population (1.6X) 2044	Total Expected Sewage 2044 (lpcd)	Expected Sewage Discharge (lpcd)
West	1	350	1,705	2728	341000	4112400
	3	1,035	4,151	6642	830200	
	5	1,038	4,456	7130	891200	
	6	1,565	6,873	10997	1374600	
	19	813	3,377	5403	675400	
Central	9	583	2,429	3886	485800	1483600
	11	1,108	4,989	7982	997800	
Putta Kolong	16	861	3,563	5701	712600	712600
East	7	748	3,022	4835	604400	4355400
	8	970	3,858	6173	771600	
	10	449	1,831	2930	366200	
	14	706	3,117	4987	623400	
	15	567	2,641	4226	528200	
	23	1753	7,308	11693	1461600	
					Total	**10664000**
					Say Total (MLD)	**11**

Source: Analysis

From the above table it can be seen that total waste water generated from all the catchment area is approximately 11mld, where west zone is contributing approximately 4.2MLD, East zone contributing approximately 4.4 MLD and remaining contribution is from central and Putta Kolong sewerage zones.

2.3 Decentralized Option

2.3.1 Possible Numbers of Sewerage Districts

Sewerage districts considered for this project are the wards which are contributing directly to the pollution of Kolong River. The wards are ward number 1, 3, 5, 6, 7, 8, 10, 15, 19, and 23. These wards are basically divided in four sewerage districts for the Nagaon town; these are West district, East District, Central district and Putta Kolong district.

The boundary of the west district is considered up to state highway no 3, which is also a ridge line as per the topography of the Nagaon town. Area between Kolong River and state highway number 3 is considered as West sewerage district and is extended towards the city boundary towards north along State highway number 3 going towards Palasoni village. East sewerage district is bound between Kolong River, National Highway 36 passing through the city and BM road towards north of the city. National highway 36 also acts as a ridge where there is slope on either side of highway. Central sewerage district is a low lying area on the right side of National highway number 36. Households staying in the area surrounded by Putta Kolong are considered as a separate sewerage district.

While formulating the sewerage districts an attempt is made to avoid long sewers, as sewers will not be required to be laid at depth greater than 4.5 meters and also intermediate pumping stations could be avoided or reduced.

2.3.2 Population Projections of Each District in Design Years

As mentioned above the section the entire catchment area is divided into four sewerage districts. Details of population projection in these sewerage districts are as follows:

Table 2-10: Population projection in Sewerage districts of Nagaon city.

Sewerage Districts	Ward No	No. of Household	Total Population	Projected Population (1.6X) 2044
West	0001	350	1,705	2728
	0003	1,035	4,151	6642
	0005	1,038	4,456	7130
	0006	1,565	6,873	10997
	0019	815	3,377	5403
Central	0009	583	2,429	3886
	0011	1,108	4,989	7982
Putta Kolong	0016	861	3,563	5701
East	0007	748	3,022	4835
	0008	970	3,858	6173
	0010	449	1,831	2930
	0014	706	3,117	4987
	0015	567	2,641	4226
	0023	1753	7,308	11693
		Total Population	**53,320**	**85313**

It can be seen that there is an increase of about 31993 people which is more than 60% in next 30 years. Although there is a trend of shifting of households from the core area of the town to outskirts for population projection equal distribution is considered.

2.3.3 Projected Waste Water Flows in each District in Design years

This is already being explained in detail in section 2.2.5 of this report. Total waste water generated in west, east, central and Putta Kolong is 4.11mld, 4.35mld, 1.48mld and 0.72mld respectively. Total waste water generated in the catchment area would be approximately 11mld, which will be for the year 2044. For the decentralised option, four STPs of 4.5mld,4.5mld,1.5mld and 1mld needs to be installed in each West, East, central and Putta Kolong area of Nagaon city respectively.

2.3.4 Length of Sewer Lines and Capacity of SPS, STPs in each District

Total length of the sewer in the entire four sewerage districts will be 84km, which will include the length of sewer required to tap the individual connection and connecting it to the sewer network and also the small lanes which are required to be connected. The sewerage district wise length of the sewer network and capacity of STP in each district is as shown in the following table:

Table 2-11: Length of sewer.

SN	Name of the District	Length of sewer network	Capacity of STP
1	West	43.00 km	4.5 MLD
2	Central	6.50 km	1.5 MLD
3	Putta Kolong	2.00 km	1.0 MLD
4	East	32.50 km	4.5 MLD
Total	All	84.00 km	10.50 MLD say 11 MLD

Source: Analysis

The length of sewer network includes the individual connections to sewer line, trunk and sub trunk sewer, branch and lateral sewer lines in all the four sewerage districts. Length of trunk/sub trunk, branch and lateral and individual sewer connection line will be worked out in Detail Project Report.

2.3.5 Availability of Land for various Components in each District

Sewerage network is laid on the road side on publicly owned land; hence no land is required to be acquired for sewer. However, land is required for intermediate pumping stations and decentralised sewerage treatment plants in each district. Generally an area of about 20 sq. meters is required for a sewerage pumping station and an area of about 200 sq. meters per MLD is required to put the decentralized treatment plants. Figure 2-1 shows the proposed sewerage network with the decentralized STPs option.

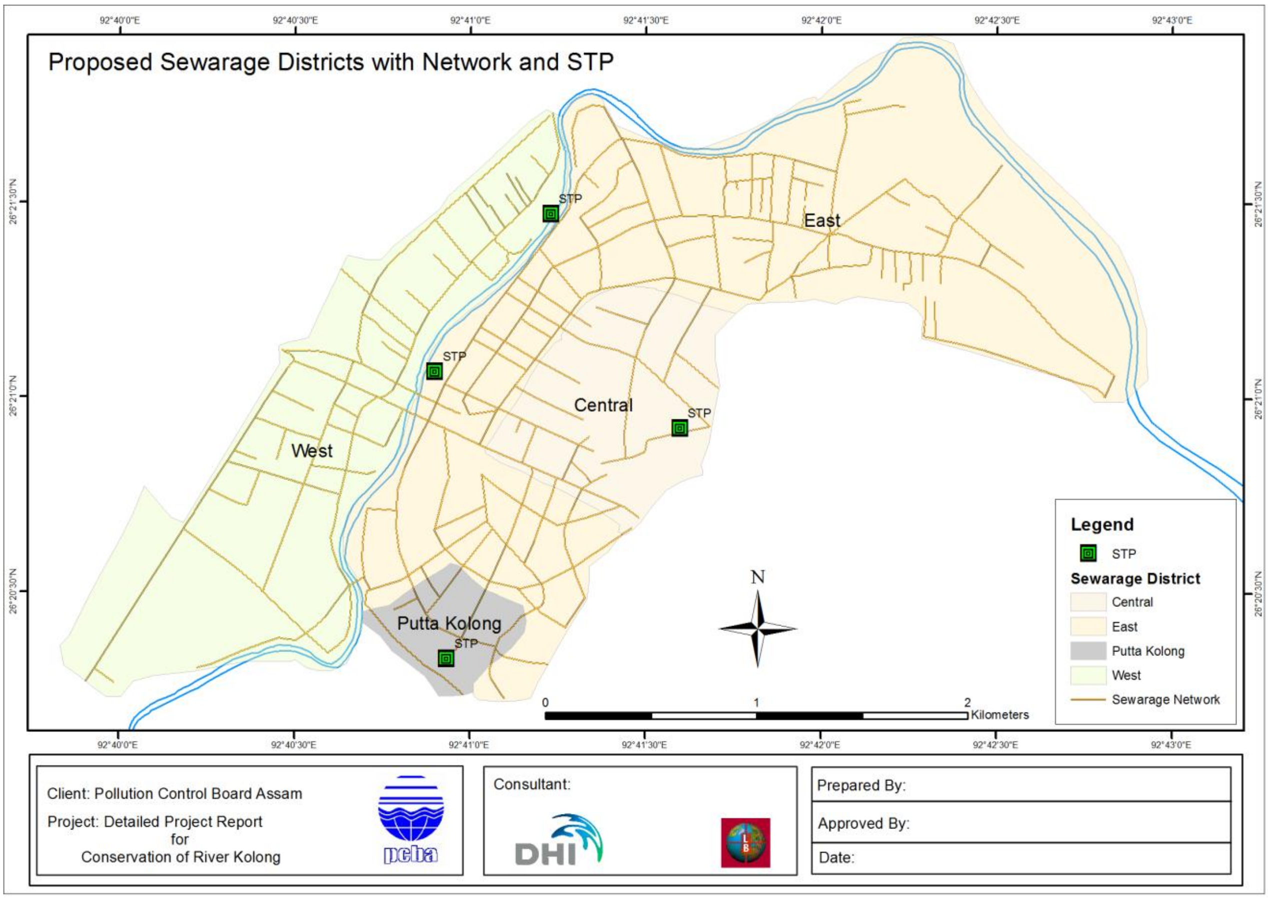

Figure 2-1 Sewerage network with decentralized STPS

2.3.6 Cost of STP including O&M

Table 2-12 Cost of the Proposed STPs

S.No.	Item	Qty	Unit	Rate	Amount
1	Decentralised STPs including supply of compact biporeactor units, installation, contractors' fees all complete				
	2 Nos., 5 MLD Modular STP	10	MLD	2,37,30,000	23,73,00,000
	1 MLD Modular STP	1	MLD	2,37,30,000	237,30,000
	1 MLD Modular STP	1	MLD	2,37,30,000	237,30,000
	Total				28,47,60,000
	Contingencies			5%	1,42,38,000
2	O&M costs @Rs. 4000/MLD/Day for 5 years adjusted to escalation	1	LS	18,06,75,000	18,06,75,000
	Grand TOTAL				47**,96,73,000**

2.3.7 Cost of proposed sewer network including O&M costs

Table 2-13 Cost of the proposed sewer network including O&M.

S.No.	Item	Qty	Unit	Rate	Amount
1	Trunk Mains	32000	m	1550	4,96,00,000
2	Laterals	54600	m	9300	50,77,80,000
3	Pumping Mains	8400	m	6200	5,20,80,000
4	Pumping Stations	20	No	20,00,000	4,00,00,000
5	Utility Relocations	11940	m	7625	9,10,42,500
6	Subtotal				74,05,02,500
7	Contingencies			5%	3,70,25,125
10	Total				77,75,27,625
11	O&M for 5 years @ 5 % (per year) of the total capital cost , adjusted to escalation				11,66,29,144
12	Grand TOTAL				89,41,50,765

2.4 Centralised Option

2.4.1 Capacity of STP

For catchment area of Kolong River, if the centralised STP is to be constructed then the total capacity of the STP will be 11MLD, calculations of which are explained in the earlier sections of this report. Considering an option of Moving Bed Biofilm Reactor (MBBR) process technology for the treatment of sewage, which requires less amount of space for installation and is having very high discharge standards of treatment. The capacity of the treatment plant is for the projected population for year 2044 for the catchment area only. All other computations are similar to the decentralised option except that the sewage will be transported to a centralized treatment plant as shown in Figure 2-2.

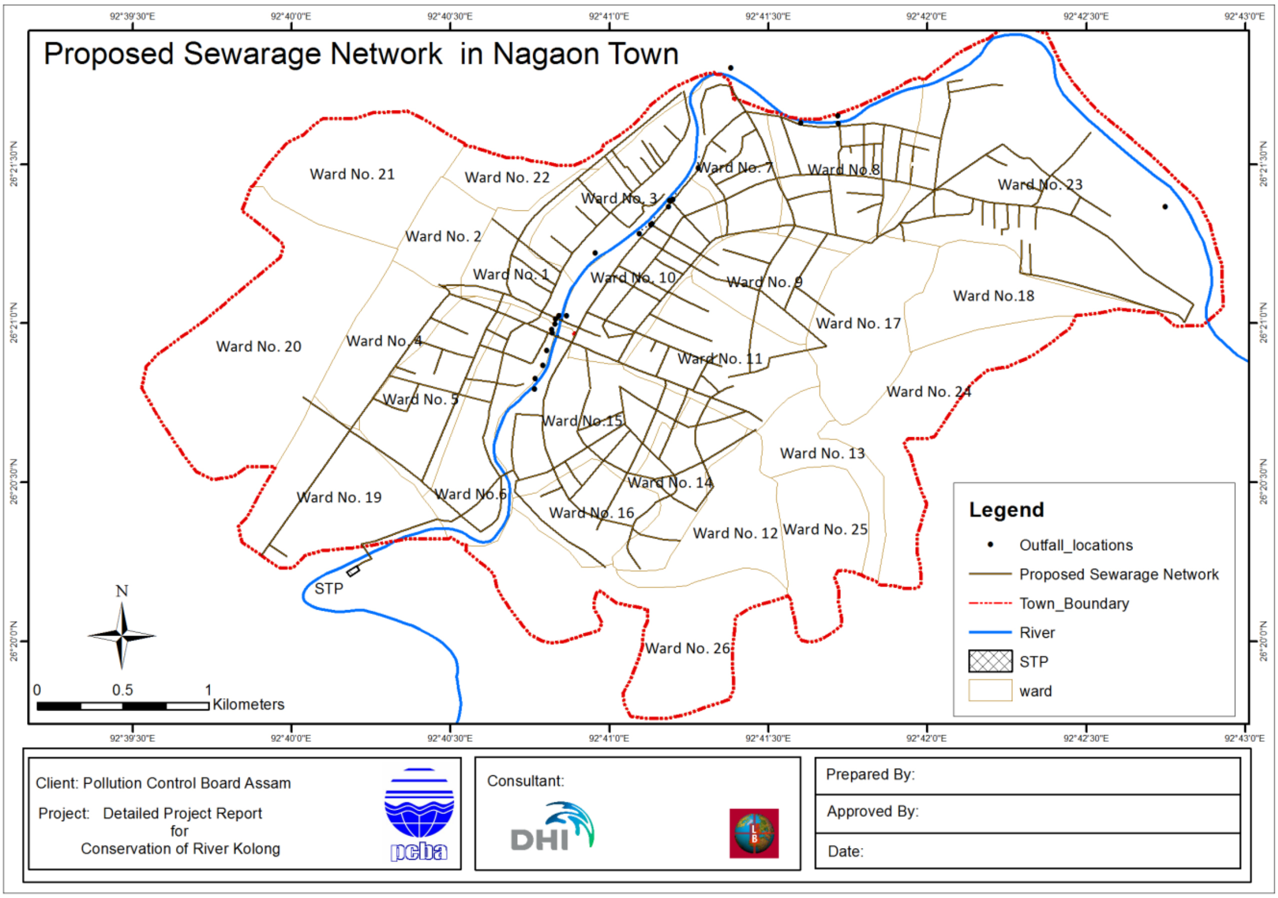

Figure 2-2 Sewer Network with a Centralized STP

2.4.2 Cost of Centralized STP

Table 2-14 Cost of Centralized STP

S.No.	Item	Qty	Unit	Rate	Amount
1	Centralised STPs including supply of components, installation all complete with contractors' fees				
	One 11 MLD Plant	11	MLD	2,50,00,000	27,50,50,000
	Total				27,50,50,000
	Contingencies			5%	1,37,50,000
2	O&M costs for 5 years @ Rs. 4000/ MLD/day adjusted to escalation	1	LS	18,06,75,000	18,06,75,000
	Grand TOTAL				46,94,25,000

2.4.3 Life Cycle Cost of STP

Table 2-15 Life cycle cost analysis for centralized STP.

Parameters	MBBR
Capital Cost	275
LA Cost	45.00
Total Capital Cost	320.00
Annual O&M Cost	24.60
Annual Resource Recovery	0.01
Annual Costs(O&M-Resource recovery)	24.59
Total Life Cycle Cost (30 Years)	**1057.60**
Net Present Value @ 12% Discount	476.20
Capital Recovery Factor, CRF (12% intrest Rate & 30 years repayment period)	0.13
Annual Capital Investment Recovery Requirement	43.01
Annual O&M Recovery Requirement	24.59
Annual Investment+ Annual O&M costs	67.59

Per MLD, Amount in Hundred Thousand INR

2.4.4 Anticipated Numbers of SPS

Depending on the topography and geographical features of the Nagaon town, anticipated number of sewage pumping stations are 15-20 numbers, however exact number of sewage pumping stations will be calculated in Detail Project Report. The reasons for high number of sewage pumping station is the distance from the source to the treatment plant, water table in Nagaon city is very high (15-20 ft) and also the land availability for the treatment plant, which is considered at outskirts of the city.

2.4.5 Land Required for Various Components

Land required for setting up the MBBR STP technology as per the Final Compendium of Sewerage Treatment Technologies published by National Conservation Directorate, Ministry of Environment and Forest, Government of India, 2009, is in the range of 0.15 to 0.25 ha per mld of installed capacity. Taking average of about 0.20 ha per mld, total land requirement for setting up 11mld treatment plant would be 2.2 ha. The average land required for sewage pumping station is 20 sq. meter. Land requirement for each component will be detailed out in Detail Project Report.

2.4.6 Land Available for Various Components

The proposed land for the 11 MLD STP is available on government land area.

2.4.7 Land Cost in and near the Town

Land cost at Nagaon vary by location, but typical cost for 1 katta is from 6-7 lakhs INR and up to 1 crore INR (1 katta is equal to 2,880 square feet).

2.4.8 Cost of proposed sewer network including O&M costs

Table 2-16 Cost of proposed Sewer network including O&M

S.No.	Item	Qty	Unit	Rate	Amount
1	Trunk Mains	32000	m	1550	4,96,00,000
2	Laterals	54600	m	9300	50,77,80,000
3	Pumping Mains	8400	m	6200	5,20,80,000
4	Pumping Stations	20	No	20,00,000	4,00,00,000
5	Utility Relocations	11940	m	7625	9,10,42,500
6	Additional trunk line to centralized STP	5000	m	1550	77,50,000
6	Subtotal				74,82,02,500
7	Contingencies			5%	3,74,12,625
10	Total				78,56,65,125
11	O&M for 5 years @ 5 % (per year) of the total capital cost , adjusted to escalation				11,78,49,769
12	Grand TOTAL				90,35,14,894

3 Option Adopted

3.1 Cost comparison

Table 3-1 Comparison of Centralized and decentralized options of STPs

	Centralized	Decentralised STP
Cost of STPS	46,94,25,000	47,96,73,000
Cost of sewer network	90,35,14,894	89,41,50,765
Total	137,29,39,894	137,38,23,765

Table 3-1 shows that the total costs of STPs and sewerage network for the two options is similar. However, in case of the decentralized option, land requirement is small pieces of land along the river banks, which is freely available. For the centralized option, since there is no free land available, the cost of land acquisition prohibits the adoption of this option. Therefore a decentralized option of STPs has been adopted.

3.2 Finally deciding number of Districts and Justification

After the detailed investigation and analysis of population data, various discharges, four sewerage districts could be finalized. Justification of sewerage districts are following:

- Highly concentration of wards in these districts.
- Population concentration is high.
- Contributing waste water and solid waste in the Kolong River.
- Topography of these districts.

3.3 Brief Description of Each District, Works Proposed and Cost

The division of these zones was done based on the topography and geographic features, ridge lines, alignment of drains, major roads, national highway and the ward boundaries. Number of wards considered in west zone is ward number 1,3,5,6 and 19, for East zone ward number is 7, 8,10,14,15 and 23, for central zone ward number is 9 and 11 whereas for Putta Kolong ward number is 16 (Figure 2-1). Brief discussion on sewerage district already given in section 2.3.

Cost of the proposed decentralized system given in section 2.4.2 and section 2.4.8.

3.4 Impact of the Proposed Works on the Health of the River

The effect of raw and treated sewage discharged from street in river can have a significant localised impact on the river environment. It can be disturb the water health means BOD will be increase. Potential impacts of sewage on human health and aesthetic issues in the vicinity of popular bathing ghats.

Biochemical Oxygen Demand - when human waste, Commercial waste and is discharged into the river, bacteria feed on the organic matter within the sewage. As the organic substances are decomposed by the bacteria, dissolved oxygen in the water is consumed. If large quantities of waste are discharged into the water the bacteria's biochemical oxygen demand (BOD) can seriously deplete dissolved oxygen levels in the water.

The reduction in dissolved oxygen levels can have serious consequences for fish and other flora and fauna, which depend upon oxygen for survival. High levels of BOD resulting from waste discharge are a particular problem in low flushing areas where water circulates only slowly. However, it should be noted that there are many other significant sources of high BOD including decaying plants and animal wastes.

Nutrient Enrichment - human waste discharges contain phosphorus and nitrogen in varying quantities. Phosphorous and nitrogen are nutrients which are essential for plant growth. However, when present in the water in excessive quantities these nutrients can trigger algal 'blooms' which reduce light penetration through the water column. Populations of submerged aquatic vegetation or macrophytes which rely on light transmission for survival can be seriously affected by such blooms. As the algae die, the process of decomposition also increases BOD in a similar way to that of sewage decomposition.

It used to be said that "the solution to pollution is dilution." When small amounts of sewage are discharged into a flowing body of water, a natural process of stream self-purification occurs. However, densely populated communities generate such large quantities of sewage that dilution alone does not prevent pollution. Instead of discharging sewage directly into a nearby body of water, it's better to let it pass through a combination of physical, biological, and chemical processes that remove some or most of the pollutants. This takes place in sewage treatment plants.

Sewage treatment plants neutralize and deactivate the chemicals found in the sewage water. They work by relying on the bacteria that is found in our colons, which eat away the nitrates, phosphates and organic matter that is found in sewage. These plants can be expensive to build and operate for many governments, but there are cheaper alternative which rely on nature to do most of the work. This is done by rebuilding or restoring wetlands, because the plants and bacteria found in the wetlands will do the same thing that bacteria in standard sewage treatment plants do. This helps the environment in two ways: restoring river, wetlands and treating human waste water before it pollutes the natural waterways.

Dredging activities in certain stretches will improve the flow in the downstream and flood management.

4 Institutional Arrangements

Many times there is an overlap in the roles of several bodies with the result that the efficiency with which the function should be performed suffers. The state Government needs to resolve such overlaps. The role of each institution involved needs to be very clearly specified. As the Kolong River flows through diverse landscape, catering to various needs, multiple agencies can be having different roles in its management. That is why, an umbrella organization with core overall responsibility coordinating with all such bodies listed below will be necessary to avoid overlap or any conflict of interest.

- Pollution Control Board of Assam
- Nagaon Municipal Board
- Public Health Engineering Department, Assam
- Town and Country Planning Department, Assam
- Water Resources Department, Assam

The institutions that are involved in the conservation programme of the Kolong River and the towns on its bank suffer from certain weaknesses that need to be overcome. Major among them are:

- Lack of adequate and trained manpower
- Lack of sufficient technical knowledge and awareness
- Lack of decision making capacity
- Lack of tools and utilities
- Lack of coordination between concerned departments
- Absence of an established institutional mechanism

It is expected that with the formation of a dedicated agency with adequate devolution of power, most of the above shortcomings can be addressed.

4.1 Project management Unit

For the implementation of the project, a Project Management Unit (PMU) will be established under PCBA, which will take care of funds related to the project and manage the planning and implementation of the project. PMU will ensure a clear allocation of funds for the management of the activities related to the project and will orient the internal organization towards an integrated functioning of the project. Such board form of management will ensure a clear cut budget and allocation of expenditures, allows better management of tasks and integrated planning, execution and maintenance of the project. PMU will also coordinate with all the departments connected with the project and the general stakeholders. PMU will be supported by a Project Management Consultant (PMC) during the project implementation period. Capacity building needs of PMU include, but not limited to the following:

- Administrative: Administrative capacity building would focus on strengthening of administrative functioning of the project and also to ensure accountability and transparency.
- Legal: Legal capacity building initiative would include adherence to all regulations pertaining to river water pollution.
- Project management: For the Successful project management, manpower skills would be enhanced through sufficient and relevant training, and sufficient physical and financial resources would be generated during the course of the project to deal with all the aspects mentioned above in all the phases of the project.

- Human resources: Human resources are increasingly recognized as a key asset of any successful and visionary project plan. Poorly trained human resources leads to poor performance and functioning of the project and will lead to ill management and poor quality in performance. Human Resources Development will deal with appropriate skill development in the organizations involved in the planning, design and management of the project. The main activities are listed below

4.2 Training needs Assessment

Human resources and related training needs are different for different fields. For example, for a sewerage system, there is the necessity of identifying the manpower training needs in managing the sewerage plants, power stations, in monitoring water quality and maintenance of equipment. Skilled manpower is needed, particularly for maintenance of developed works, equipment and manning of the sewerage and pumping stations. For the handling of various instruments, special training is needed as good handling of the machine increases their lifespan; moreover, regular wear and tear of the machinery can be rectified and repaired by the project manpower if they are trained appropriately. This will go a long way in reducing unnecessary overhead costs.

Presently, different organizations viz. PHED, AUWS&SB and NMB are responsible in different areas of Nagaon city for the issues related to Sewerage. Though most of the employees of the existing organizations are qualified by education required for the O & M of the Sewerage system, they are not trained to handle and properly operate and maintain, the latest equipment of drain cleaning. They are not aware of preventive maintenance, resulting in reoccurrence of flooding in same place during monsoon. Training on Concept of separate sewerage system and its merits and demerits is required.

Recruitment of trained engineering personnel for management of sewerage works is an important issue confronting the organizations in Assam. Special efforts to impart in-service training or continuing professional education should go along with employment of such personnel. In view of the rapidly changing pace of technology, engineers need to get updated periodically about newly incorporated instruments and technologies through training and workshops. Enhancement of knowledge, both operational and theoretical will help in running such services smoothly.

Training employees at different levels is recognized as an essential aspect in any public utility agency. However, training cannot end with just one course. To be effective, it has to be a continuous process. In Nagaon, due to lack of sufficient training of field staff, maintenance personnel and engineers, public utility systems like the NMB do not function satisfactorily. It is therefore necessary to provide intensive training to the operation staff which may include:

- Dealing with public and stakeholders
- Importance of proper and efficient sewerage
- Importance of proper and efficient sewerage system
- Advanced training of handling instruments and other accessories required for maintenance work
- Training on maintenance of instruments and works
- Emergency restoration work after flooding and choking of drains
- Efficiency in record keeping
- Other

The outcome of the training will include

- Increased efficiency with advanced knowledge
- Organizational uplifting including economics
- Improvement in quality of Sewerage system;
- Improved public relations; and
- Improved public health conditions due to superior quality and efficient maintenance by trained O & M staff

The following training needs have been identified for the operational staff

- Basic principle of Sewerage, catchment areas, runoff etc.
- Basic Knowledge in the working of Sewerage cleaning equipment's.
- Reasons of blockage of drains
- Reasons of Flooding & Flood mitigation methods
- Preventive maintenance of electrical and mechanical equipment
- Attending to minor repairs, major repairs – procedure to be followed
- Log books – maintenance & upkeep of records
- Importance of keeping good health and hygiene
- Management crises in the operation & Maintenance

Local agencies are capable for providing technical training for operational staff. Some of them are:

- Industrial Institute of Technology, Guwahati – This organization can conduct training for field staff
- Government Engineering College, Guwahati conduct can short term courses for Sewerage
- Institution of Engineers (India), Guwahati Center, can also conduct training course for O & M for field staff
- The Indian Institute of Technology, Guwahati
- State Resource Centre, Department of Public Health and Engineering, Guwahati
- Staff College

These Institutions, which have an interest in the subject, may be asked to develop training modules required for specific needs of the project. They should be involved on a long-term basis so that they develop expertise in all the aspects of this programme. They should be involved in various aspects and activities of the programme.

4.3 Training Programmes

Code	Training module	Organisations	Staff
T-1	Concepts and advances in river restoration and conservation	PCBA, NMB, MOEF	Senior administrative officials
T-2	Effluent monitoring & management (enforcement)	PCBA, PHED	Senior technical and managerial staff
T-3	Operation and maintenance of STPs, Pumps	PCBA, NMB, PHED	Technical operational staff
T-4	Maintenance of sewerage network including structures	PCBA, NMB	Technical operational staff
T-4	River monitoring and operation of water augmentation structures	WRD, PCBA	Technical staff
T-5	Maintenance of river front works	PCBA, private sector	Managerial and maintenance staff
T-6	Public awareness and educational programmes	PCBA, NMB, NOGs, civil society members	All levels
T-7	Project Management	PCBA, GMDA, GMC	Administrative and managerial officials
T-8	Exposure, knowledge enhancement	PCBA, NMB	Attending national & international seminars & conferences

5 Environmental Impact Assessment

A concept plan for an EIA pertaining to the construction of sanitation facilities proposed in this Feasibility Report is delineated as under. The major works which are expected to have an appreciable level of environmental impacts are construction and operation of sewage collection network, pumping stations, and sewage treatment plant. The various types of impacts at different levels of implementation of the scheme (during construction and operation) are mentioned here. Some mitigation measures have also been suggested. Minor impacts during the design phase of the scheme have been neglected.

5.1 Sewerage Network

5.1.1 Construction Phase Impacts

Most of the construction phase potential impacts will be temporary, in the nature of inconveniences to the citizens using the same space for their day-to-day activities, and will eventually withdraw once the construction phase is over. Despite this, the construction stage impacts as identified below need to be addressed and mitigated. Identified types of impact and their tentative mitigation are given as below, which will be further reviewed and elaborated in the DPR stage.

a) Erosion Prevention – Excavations for laying sewerage collection network needs to be scheduled in such a way that large volume of soil should not remain stacked at site for considerable time especially during the monsoon.

b) Prevention of dust nuisance – Fugitive dust generation from exposed construction surfaces during dry/windy periods is to be suppressed by light spraying of water or by other suitable means.

c) Disposal of soil – Major quantity of excavated soil and road crust will be used to fill-up the excavations after pipelines are laid.

d) Emission and noise from plying vehicles and noise from construction activities – All construction vehicles are to be properly maintained and should have valid 'Pollution under Control Certificate'. Noisy construction activities should be carried out only during normal working hours and local residents are to be advised in advance of any unusual or unavoidable noise.

e) Relocation of utility services – Some inconveniences to public, such as temporary dislocation of civic amenities like water supply, drainage and sewerage, electricity, telephone and cable TV connection may be caused for relocation and/or replacement of these facilities.

f) Prevention of dust and noise during material handling operation – Dust and noise producing activities such as stone crushing, bitumen and cement batching plant etc. are to be located downwind and away from habitation settlement wherever practicable.

g) Prevention of soil, ground and/or surface water contamination – Silt after dewatering is to be immediately disposed in approved disposal site.

h) Prevention of waterlogging/ flooding – Dewatering during trenching and water testing of new lines are to be regulated in a manner so that it does not lead to waterlogging of the nearby areas.

i) Road safety and traffic management during construction – Since many roads in the project area are not wide enough; there may be some traffic congestion during the construction phase. In the narrow sections of road, construction activities may cause traffic disruption. A traffic management plan has to be prepared and approved by the ULB.

j) Prevention of accidents and damage to property – All necessary precautions has to be taken to prevent accidents and/or damage to property. Unforeseen accidents could result in personal injury and/or damage to private or public property.

k) Health and safety of work force – All occupational and health and safety requirements for work force has to be adhered to. Facilities of periodic health check-up of workers must be available free of cost.

l) Environmental health and safety at construction camp sites and construction work sites – Camps/ work sites are to be located so that they do not interfere with the existing drainage system. Camps/ work sites should have a suitable drainage outlet, if required.

m) Prevention of impacts on places of cultural importance – Routing of sewers should avoid places of cultural importance including shrines, temples, maazars, mosques etc. to the extent feasible. Safe access to these places has to be maintained.

n) Social impacts – Since it is not be feasible to provide complete sewerage coverage in all the areas under the project, it might result in some discontent from public residing in the areas which will not be covered by the project. Consultation with elected representatives, public relations and awareness building exercises including information disclosure through several known means has to be carried out by the project to address this issue.

5.1.2 Operational Phase Impacts

During the operational phase the environmental impacts are expected to be mostly positive. Provision of complete sewerage system under this project would minimize wastewater stagnation and waterborne disease propagation in the service area and ensure better sanitation practices. This is expected to lead to abatement of nuisance and public health hazard in the service areas, for instance, improved sanitary conditions is expected to result in reduction in incidence of parasitic infections, hepatitis and various gastrointestinal diseases including cholera and typhoid which occurs either through direct contact with fecal material or contamination of water supply and food.

Other potential adverse impacts during the operational phase are identified, along with their mitigation measures, as follows:

a) Due to lack of control there may be discharge of hazardous industrial effluents from existing industries. Regulatory activities being carried out by the Assam Pollution Control Board (APCB), such as strict enforcement of treatment regulations of existing industrial discharge and regular monitoring activities carried out by the APCB would ensure that untreated or inadequately treated effluent from any industry is not discharged into the proposed sewer system.

b) There is a potential health hazard to workers engaged in sewer maintenance works. These workers are likely to be exposed to toxic gases and hazardous materials present in the sewage and are likely to contract communicable diseases from exposure to pathogens present in the sewage.

c) There can be some stretches where there will be difficulty in achieving self-cleansing velocity during operational stage. To minimize the siltation problem, the operating agency should undertake continual and routine maintenance of the system.

d) Lack of proper operation and maintenance of the system could cause overflow of sewage, which would be a nuisance and health hazard to public.

5.2 Pumping Stations

In general, potential adverse environmental impacts from this sub-component are likely to arise from: (a) augmentation/renovation of existing pumps (if any); (b) civil construction of new pumping stations; (c) disposal of silt, soil and debris due to the construction of inlet and outlet channels and other civil works of the pump houses; and (d) safety, security and occupational hazards during construction and operation phases.

5.2.1 Construction Phase Impacts

Construction activities will inflict short-term minor adverse impacts on soil, surface water, air, noise, ecology of the area and quality of life values of nearby habitants and work force. In order to mitigate these impacts, construction phase activities related to earth work has to be scheduled in the dry season so that chances of flooding, inundation, waterlogging and surface erosion become minimal. Exposed construction sites have to be adequately covered to reduce erosion, surface runoff, air pollution, and construction spoils has to be suitably disposed of.

5.2.2 Operation Phase Impacts

Overall operation phase impact is expected to be positive as the proposed pumps have been designed to transmit DWF to next pumping station or STP and will significantly reduce the inadequacy of sanitation facility in the service area. Siltation of the pump houses is a potential impact, which may be mitigated by adequate operation and maintenance of the pumps with regular desiltation.

5.3 Sewage Treatment Plant

5.3.1 Design Phase Impacts

The proposed STP is expected to be located in relatively low land. Adequate drainage provisions has to be made in the design of the STPs to avoid flooding during incidence of rain. In addition, the following features have to be built into the STP designs, for both new STPs and the STP upgrades, in order to minimize adverse impacts on the environment:

a) Provision of adequate capacity in the canals to receive the expected treated water discharge,

b) Proper choice of specification of the pump(s) from the point of view of design capacity and operation at low noise level,

c) Proper design of the pump house so as to contain noise within the pump house,

d) Provision of a peripheral green belt, and

e) Provision of 15-20% open space within the complex to improve scenic quality of the STP area.

5.3.2 Construction Phase Impacts

There may be minor air pollution from dust generation during construction of new STP. Excavations during the construction phase may produce surplus earth and spoil material and these are to be disposed in the designated areas. In order to mitigate these impacts, the following measures are to be adopted:

a) Provision of fencing around the construction site with GI sheets all around to prevent encroachment and to ensure community safety,

b) Use of construction machineries to the extent practicable so as to limit deployment of labourers and avoid accident,

c) Provision of safety training to the construction laborers and ensuring the provision and use of adequate protection gears for their safety,

d) Storage of excavated earth separately for future use in greenbelt development and landscaping,

e) Step cutting of earth or timber/metal shoring to be provided during deep excavation to protect against earth sliding,

f) Settlement of construction wastewater carrying suspended solids like earth, cement and sand in a brickwork basin; decanted water may then be let into public drains,

g) Avoidance of night time work; if at all needed, safety provisions and proper lighting arrangements are to be provided, and no noise generating construction activity is to be undertaken,

h) Storage of all construction materials within the fenced area and absolutely not on public thoroughfare,

i) Dispose of all construction debris and wastes in the low lying areas, and

j) Spraying of water to prevent dust generation as and when required.

5.3.3 Operation Phase Impacts

Noise due to operation of the pumps and moving systems is being confined to the plants. The noise level of the equipment should meet the standard from occupational health point of view (with 85 dBA at a distance of 1.5m from the source). The discharge flow quantity from the STPs has been accommodated in the designed capacity of the receiving canals. Therefore over bank flooding of the canals due to increased discharge is not expected.

During the operation stage, continuous attention has to be paid for maintenance of the environmental improvement brought about by implementation of the sub-components. The STP site should remain all the time neat and clean i.e. with the highest order of housekeeping. Adequate operation of the outlet pump(s) is to be ensured so that there is no overflow of untreated or partially treated wastewater from the STP. In case of failure of the pump(s) or prolonged power cut alternative arrangement of power has to be made.

Noise from the operation of the outlet pumps and other moving parts is not expected to add significantly to the ambient noise level if appropriate maintenance of the pumps and regular checking are carried out. Each individual operator may use ear plugs for which provisions will be made.

Special provisions of fresh water must be made to treat operators affected by accidental spillage from chlorinator plant. Sewage water should not be touched by the operators. Adequate soap and detergent are to be kept for washing of hands.

STP may cause bad odour principally by the release of H2S formed by limited anaerobic reduction of sulphate by sulphate reducing bacteria. Recommended design loading should not be exceeded and sulphate (SO4) concentration in the raw wastewater should not be allowed to exceed 300 mg/litre so that only odourless HS is produced instead of H2S by the reduction process if at all formed. ‘No smoking’ signboard will be prominently displayed and carriage of match box or lighter should be prohibited to prevent fire hazard in case bio-gas (methane) is generated.

6 Cost Estimates and Resource Requirement

6.1 Abstract of Cost Estimates for Each Component of Works

Table 6-1 Cost Estimate of Sewerage Network

S.No.	Item	Qty	Unit	Rate	Amount
1	Trunk Mains	32000	m	1550	4,96,00,000
2	Laterals	54600	m	9300	50,77,80,000
3	Pumping Mains	8400	m	6200	5,20,80,000
4	Pumping Stations	20	No	20,00,000	4,00,00,000
5	Utility Relocations	11940	m	7625	9,10,42,500
6	Subtotal				74,05,02,500
7	Contingencies			5%	3,70,25,125
10	Total				77,75,27,625
11	O&M for 5 years @ 5 % (per year) of the total capital cost , adjusted to escalation				11,66,29,144
12	Grand TOTAL				**89,41,50,765**

Table 6-2 Cost Estimate of STPs

S.No.	Item	Qty	Unit	Rate	Amount
1	Decentralised STPs including supply of compact biporeactor units, installation, contractors' fees all complete				
	2 Nos., 5 MLD Modular STP	10	MLD	2,37,30,000	23,73,00,000
	1 MLD Modular STP	1	MLD	2,37,30,000	237,30,000
	1 MLD Modular STP	1	MLD	2,37,30,000	237,30,000
	Total				28,47,60,000
	Contingencies			5%	1,42,38,000
2	O&M costs @Rs. 4000/MLD/Day for 5 years adjusted to escalation	1	LS	18,06,75,000	18,06,75,000
	Grand TOTAL				**47,96,73,000**

7 Maps

Maps created for this PFR are summarized in Table 7-1.

Table 7-1: List of maps.

S.No.	Maps	Description
1	India	States of India, with Assam highlighted as the project location.
2	Assam	District map of Assam; it includes the Nagaon district where the Kolong River passes through and where the river is most polluted.
3	Map of Kolong River Basin	Kolong River and its tributaries. Also marks the location where the river flows through the Nagaon district.
4	Satellite image of the area	Satellite image (AWiFS) of the area.
5	Ward map of Nagaon	Municipal Wards, Slums and Roads
6	Digital Elevation Model	Digital Elevation Model (DEM) of Kolong river basin including Kopili, Digaru, Jamuna and Digaru rivers.
7	Sewerage Outfall Map	Municipal wards, sewerage outfall, water bodies.
8	Solid Waste Map	Municipal Wards, Soild Waste Dumping Sites and with water bodies in Nagaon town.
9	Bathing Ghat	Municipal Ward, Water Body with Bathing ghat in Nagaon Town.
10	Dredging Stretch	Municipal Ward, Kolong River with Dredging stretches
11	Sampling Location	Kolong river basin and Sapling location.
12	Sewerage Network	Map include proposed Sewerage network with ward boundaries
13	Proposed Work	All the proposed work in Nagaon (River Front Development, Low Cost Sanitation and Crematoria)
14	sewerage District	Map including proposed Sewerage districts with location of STP.

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Appendix A: Water Quality Data (Present project)

Appendix B: Water Quality Methodology (Present project)

Appendix C: Water Quality Data (PCBA, 2013)

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Table 3. Water Quality of Kolong river at Morigaon (During the period from 2008 to 2013)

Parameters	Month & Year of collection					
	April, 08	April, 09	April, 10	April, 11	April, 12	April, 13
a. Physical Parameters:						
pH	7.6	7.5	6.8	7.2	6.5	7.4
Turbidity (NTU)	13.2	1.5	5.2	11.9	16	16.5
Conductance (µmho/cm)	106	101	84	94	116	134
b. Organic Parameters:						
DO (mg/L)	8.3	9.5	7.1	7.4	7.5	9.4
COD (mg/L)	16.5	6.3	3.3	9.4	4.6	5.9
BOD (mg/L)	3.3	1.1	1.0	2.2	1.2	2.3
c. Major Mineral Parameters:						
Chloride as Cl (mg/L)	28	16	8	8	10	6
PO_4 as P (mg/L)	10	0.1	8.3	0.1	4.4	4.3
Sulphate as SO_4 (mg/L)	34	21.7	27	3.8	26.5	35.7
d. Other Inorganic parameters:						
T. ALKALINITY (mg/L)	42	48	38	48	32	40
T. Hard ness as $CaCO_3$ (mg/L)	38	46	50	54	42	50
Calcium as $CaCO_3$ (mg/L)	28	36	32	34	30	36
Magnesium as $CaCO_3$ (mg/L)	10	10	18	20	12	14
NITRATE-N (mg/L)	0.2	0.1	0.1	0.1	0.1	0.44
Total Dissolved Solid (TDS) (mg/L)	76	74	62	48	82	92
Total Fixed Solid (TFS) (mg/L)	37	35	28	20	38	26
Total Suspended Solid (TSS) (mg/L)	29	12	13	34	10	12
Sodium (mg/L)	7.7	6.2	1.6	3.9	5.7	1.4
Potassium (mg/L)	1.7	2.5	1.3	1.6	2.6	0.6
Fluoride (mg/L)	0.57	0.55	0.53	0.32	0.41	0.34
e. Trace Metals:						
Zinc as Zn (µg/L)	51	86	324	27	390	46
Copper as Cu (µg/L)	3.9	6	27	1	13	BDL
Lead as Pb (µg/L)	1	10	15	1	10	BDL
Cadmium as Cd (µg/L)	3	3	BDL	1	3	BDL
Nickel as Ni (µg/L)	8	11.9	45	20	19	BDL
Chromium as Cr (T) (µg/L)	7.9	50	18	1	7	BDL
Arsenic as As (µg/L)	1.6	0.5	0.8	1	1.7	1.7
Mercury as Hg (µg/L)	BDL	BDL	BDL	BDL	BDL	BDL
Total Iron (µg/L)	180	80	1200	280	260	400
f. Bacteriological Parameters:						
Total Coliform (MPN/100ml)	700	910	360	Nil	360	1500
Faecal Coliform (MPN/100ml)	Nil	Nil	Nil	Nil	Nil	Nil

BDL : BELOW DETECTABLE LIMIT

Table 4. Water Quality of Down stream of Kolong river at Anandaram Dhekial Phukan Bridge, Nagaon (During the period from 2008 to 2013)

Parameters	Month & Year of collection					
	April, 08	April, 09	April, 10	April, 11	April, 12	April, 13
a. Physical Parameters:						
pH	7.2	7.3	6.9	6.7	6.5	7.2
Turbidity (NTU)	5.8	8.1	110	8.6	6.2	3.8
Conductance (μmho/cm)	189	184	77	99	128	234
b. Organic Parameters:						
DO (mg/L)	8	7.4	5.4	7.2	7.1	3.4
COD (mg/L)	9	14.6	10.4	4.6	3.1	11.8
BOD (mg/L)	2.6	3.5	2.7	1.9	0.9	3.2
c. Major Mineral Parameters:						
Chloride as Cl (mg/L)	14	26	14	12	10	12
PO_4 as P (mg/L)	8.5	6.9	4.1	1.3	4.7	4.5
Sulphate as SO_4 (mg/L)	22.2	6.7	10.4	6.5	2.1	7.6
d. Other Inorganic parameters:						
T. ALKALINITY (mg/L)	76	96	42	58	2.2	122
T. Hard ness as $CaCO_3$ (mg/L)	68	94	42	52	62	106
Calcium as $CaCO_3$ (mg/L)	56	56	34	34	40	92
Magnesium as $CaCO_3$ (mg/L)	12	38	8	18	22	14
NITRATE-N (mg/L)	0.1	0.1	0.1	0.1	0.1	0.96
Total Dissolved Solid (TDS) (mg/L)	132	128	48	66	88	156
Total Fixed Solid (TFS) (mg/L)	49	52	22	30	40	42
Total Suspended Solid(TSS) (mg/L)	24	18	11	23	14	16
Sodium (mg/L)	6.7	7.9	3.1	4.6	4.3	8.5
Potassium (mg/L)	1.6	2	2.5	2.6	2.9	0.7
Fluoride (mg/L)	0.63	0.83	0.73	0.53	0.41	0.38
e. Trace Metals:						
Zinc as Zn (μg/L)	45.5	74	56	69	..	..
Copper as Cu (μg/L)	3.9	13	37	150	..	..
Lead as Pb (μg/L)	6	10	31	10	..	..
Cadmium as Cd (μg/L)	3	2.6	1	2	..	..
Nickel as Ni (μg/L)	9.4	9.2	54	20	..	..
Chromium as Cr (T) (μg/L)	7.9	10.1	29	31	..	..
Arsenic as As (μg/L)	5.3	3.9	2.2	3.2	..	..
Mercury as Hg (μg/L)	BDL	BDL	BDL	BDL	..	..
Total Iron (μg/L)	240	120	180	400	..	..
f. Bacteriological Parameters:						
Total Coliform (MPN/100ml)	2200	700	910	360	910	1500
Faecal Coliform (MPN/100ml)	1100	300	Nil	Nil	300	Nil

BDL : BELOW DETECTABLE LIMIT
.. : Analysis Not Done.

Appendix D: Water Quality Data (Khan & Arup, 2012)

Table - 1 : Site wise observed values of different water quality parameters of Kolong River

Parameters	**Site-I**		**Site-II**	
	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
pH	7.9-8.2	7.1-8.0	8.2-8.6	6.5-7.1
Total Suspended Solids (mg/L)	185-495	70-212	200-540	50-160
Turbidity NTU	1.2-79.5	17.9-80.6	28.6-85.6	80.5-110.7
Conductivity m.mhos.cm-1	426-449	412-429	496-546	479-531
Total hardness (mg/l)	178-189	156-162	180-196	128-145
D.O.(mg/l)	7.0-7.5	7.6-8.5	7.0-7.3	7.1-7.9
B.O.D.(mg/l)	7.1-7.9	5.1-5.7	5.5-6.4	5.1-5.6
C.O.D (mg/l)	431-450	412-429	509-541	490-506
Chloride (mg/l)	150-161	178-187	180-214	206-213

Appendix E: Water Quality Data (PCBA, 2010)

Table 3-7 (a): Water quality data analysed in Kolong River

River	Sampling point	Temp^r	pH	TDS	EC	DO	BOD_5	Turbidity	Hardness	Cl	PO_4
Kolong	Kajalimukh (Gobordhan)	28.9	7.4	90	97.30	6.6	1.1	284	44	7	0.125
Kolong	Boha	28.8	7.2	70	80.70	7.4	1.1	30	32	0.5	0.03
Kolong	Nagaon	29.4	7.4	110	119.40	6.8	1.4	25	64	15.5	0.053
Kolong	Dimoruguri	27.7	7.2	100	104.90	5.9	0.9	10	58	10	0.047
Kapili	Dharamtul	27.4	7.5	80	84.70	7.4	1.5	8	38	1.5	0.032

Table 3-8 (b): Water quality data analysed in Kolong River

River	Sampling point	SiO_2	Ca	Mg	Na	HCO_3	NH_3	SO_4	K	NO_3	Total Chlorine	Free Chlorine	Fe
Kolong	Kajalimukh (Gobordhan)	22.3	3.72	8.4	7.64	36	0.09	17.00	2.61	0.059	0.1	0.07	0.05
Kolong	Boha	19.5	2.92	6.0	4.76	32	0.07	21.00	1.84	0.009	0.02	0.02	0.15
Kolong	Nagaon	31.6	3.91	13.2	6.51	66	0.06	10.00	2.37	0.103	0.06	0.04	0.15
Kolong	Dimoruguri	29.3	2.87	12.4	4.7	64	0.05	10.00	1.93	0.054	0.13	0.01	-
Kapili	Dharamtul	17.6	2.26	7.9	5.39	32	0.06	21.00	1.97	0.01	0.15	0.15	-