No.

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
NATIONAL RIVER CONSERVATION DIRECTORATE (NRCD)
MINISTRY OF ENVIRONMENT AND FORESTS

THE STUDY
ON
WATER QUALITY MANAGEMENT PLAN
FOR
GANGA RIVER
IN
THE REPUBLIC OF INDIA

FINAL REPORT

VOLUME IV FEASIBILITY STUDY FOR PROJECT CITIES

VOLUME IV-1 FEASIBILITY STUDY FOR LUCKNOW CITY
PART I SEWERAGE SCHEME

JULY 2005

TOKYO ENGINEERING CONSULTANTS CO., LTD.
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FINAL REPORT
ON
WATER QUALITY MANAGEMENT PLAN FOR GANGA RIVER
JULY 2005

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ABBREVIATIONS

AD/MM	Average Day / Max Month
ADF	Average Daily Flow
ADWF	Average Dry Weather Flow
AIWSP	Advanced Integrated Wastewater Stabilization Ponds
AL	Aerated Lagoon
AS	Activated Sludge
ASR	Aquifer Storage and Recovery System
Avg	Average
AWT	Advanced Wastewater Treatment
BOD	Biochemical Oxygen Demand
CI	Cast Iron
CMS	Cubic Meter per Second
CO_2	Carbon Dioxide
CPCB	Central Pollution Control Board
CWR	Clear Water Reservoir
DLW	Diesel Locomotive Work
DO	Dissolved Oxygen
DPR	Detailed Project Report
ES	Equalization/Storage
FAB	Fluidised Aerated Bioreactor
F/S	Feasibility Study
FSA	Future Service Area
GAP	Ganga/Gomti Action Plan
GoAP	Gomti Action Plan
GIS	Geographical Information System
gpd	Grams per day
GOI	Government of India
GOJ	Government of Japan
GWI	Ground Water Infiltration
HDR	High-Density Residential
HP	Horse Power
I/I	Infiltration/Inflow
ISC	Indian Standard Code
JICA	Japan International Cooperation Agency
JS	Jal Sansthan
KVA	Kilo Volt Ampere
LDR	Low-Density Residential
lpcd	Litres per capita per day
lpm	Litres per minute
lps	Litres per second
MC	Municipal Corporation
MDR	Medium-Density Residential
mg/l	Milligrams per Litre
ML	Million Litres
mld	Million Litres per Day
MLSS	Mixed Liquid Suspended Solids
M/P	Master Plan
MPN	Most Probable Number per 100ml
MPS	Main Sewage Pumping Station
MPS	Meter per Second
MUD	Ministry of Urban Development
MoEF	Ministry of Environment and Forests
N/A	Not Available
NBC	National Building Code
NH_3-N	Ammonia-Nitrogen
NRCD	National River Conservation Directorate
NSA	Non Sewerage Area
O&M	Operations and Maintenance
PDWF	Peak Dry Weather Flow
PFR	Project Feasibility Report
PS	Pumping Station
PSC	Pre-Stressed Concrete
RAS	Return Activated Sludge
SMF	Sankat Mochan Foundation
SPS	Sewage Pumping Station
SS	Suspended Solids
SSO	Sanitary Sewer Overflow
STP	Sewage Treatment Plant
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
UASB	Up flow Anaerobic Sludge Blanket
UFW	Unaccounted for Water
UPJN	Uttar Pradesh Jal Nigam
UPPCB	Uttar Pradesh Pollution Control Board
USAID	United States Agency for International Development
UV	Ultra Violet
VCP	Vitrified Clay Pipe
WAS	Waste Activated Sludge
WRF	Water Reclamation Facility
WSP	Waste Stabilization Pond
WTP	Water Treatment Plant
YAP	Yamuna Action Plan

GLOSSARY OF TERMS

Aerated Lagoons*:* Like WSPs but with mechanical aeration. Oxygen requirement mostly from aeration and hence more complicated and higher O&M costs requires less land than WSP.

Activated-Sludge Process: A biological wastewater treatment process in which a mixture of wastewater and biologically enriched sludge is aerated to facilitate aerobic decomposition by microbes.

Advance Wastewater Treatment: Treatment process designed to remove pollutants that are not adequately removed by conventional secondary treatment processes.

Aeration: The addition of air or oxygen to water or wastewater, usually by mechanical means, to increase dissolved oxygen levels and maintain aerobic conditions.

Anaerobic Digestion: Sludge stabilization process in which the organic material in biological sludge is converted to methane and carbon dioxide in an airtight reactor.

Assimilative Capacity: The ability of a water body to received wastewater and toxic materials without deleterious effects on aquatic life or the humans who consume the water.

Average Daily Flow: The total flow past a physical point over a period of time divided by the number of days in that period.

Biochemical Oxygen Demand (BOD): A standard measure of wastewater strength that quantifies the oxygen consumed in a stated period of time, usually 5 days and at 20^{o}C.

Biological Process: The process by which the metabolic activities of bacteria and other micro organisms break down complex organic materials to simple, more stable substances.

Bio solids: Solid organic matter recovered from municipal wastewater treatment that can be beneficially used, especially as a fertilizer. *Bio solids* are solids that have been stabilized within the treatment process, whereas sludge has not.

Chlorination: The addition of chlorine to water or wastewater, usually for the purpose of disinfection.

Coliform Bacteria: Rod shaped bacteria from intestinal track of man used as an indication that pathogenic organisms may also be present.

Collection System: In wastewater, a system of conduits, generally underground pipes, that receives and conveys sanitary wastewater and/or storm water. In water supply, a system of conduits or canals used to capture a water supply and convey it to a common point.

Composting: Stabilization process relying on the aerobic decomposition of organic matter in sludge by bacteria and fungi.

Dechlorination: The partial or complete reduction of residual chlorine by any chemical or physical process.

Design Storm: The magnitude of a storm on which the design of a system and/or facility is based; usually expressed in terms of the probability of an occurrence over a period of years.

Diffused-Air Aeration: The introduction of compressed air to water by means of submerged diffusers or nozzles.

Digester*:* A tank or vessel used for sludge digestion.

Disinfection: The selective destruction of disease-causing microbes through the application of chemicals or energy.

Diurnal: A daily fluctuation in flow or composition that is of similar pattern from one 24-hour period to another.

Effluent: Partially or completely treated water or wastewater flowing out of a basin or treatment plant.

Fine-Bubble Aeration: Method of diffused aeration using fine bubbles to take advantage of their high surface areas to increase oxygen-transfer rate.

Fixed Film Process: Biological wastewater treatment process whereby the microbes responsible for conversion of the organic matter in wastewater are attached to an inert medium such as rock or plastic material. Also called *attached-growth process.*

Force Main: The pipeline through which flow is transported from a point of higher pressure to a point of lower pressure.

Friction Factor: A measure of the resistance to liquid flow that results from the wall roughness of a pipe or channel.

Gravity Thickening: A process that uses a sedimentation basin designed to operate at high solid loading rate, usually with vertical pickets mounted to revolving sludge scrapers to assist in releasing entrained water.

Grit Chamber: A settling chamber used to remove grit from organic solids through sedimentation or an air-induced spiral agitation.

Head Loss: The difference in water level between the upstream and downstream sides of a conduit or a treatment process attributed to friction losses.

Headworks: The initial structure and devices located at the receiving end of a water or wastewater treatment plant.

Infiltration: Water entering a sewer system through broken or defective sewer pipes, service connections, or manhole walls.

Influent: Water or wastewater flowing to a basin or treatment plant.

Invert: The lowest point of the internal surface of a drain, sewer, or channel at any cross section.

Land Application: The disposal of wastewater or municipal solids onto land under controlled conditions.

Lift Station: A chamber that contains pumps, valves, and electrical equipment necessary to pump water or wastewater.

Methane: A colourless, odourless combustible gas that is the principal by-product of anaerobic decomposition or organic matter in wastewater. Chemical formula is CH_4.

Mixed Liquor Suspended Solids (MLSS): Suspended solids in the mixture of wastewater and activated sludge undergoing aeration in the aeration basin.

Nitrification: Biological process in which ammonia is converted first to nitrite and then to nitrate.

Nutrient: Any substance that is assimilated by organisms to promote or facilitate their growth.

Pathogen: Highly infectious, disease-producing microbes commonly found in sanitary wastewater.

Peak Flow: Excessive flows experienced during hours of high demand; usually determined to be the highest 2-hour flow expected under any operational conditions.

Preliminary Treatment: Treatment steps including screening, grit removal, preparation, and/or flow equalization that prepare wastewater influent for further treatment.

Pump Station: (see lift station)

Primary Clarifier: Sedimentation basin that precedes secondary wastewater treatment.

Primary Treatment: Treatment steps including sedimentation and/or fine screening to produce an effluent suitable for biological treatment.

Rising Main : (see force main)

Reclaimed Wastewater: Wastewater treated to a level that allows its reuse for a beneficial purpose.

Return Activated Sludge (RAS): Settled activated sludge that is returned to mix with raw or primary settled wastewater.

Sanitary Sewer Overflow (SSO): Overloaded operating condition of a sanitary sewer that results from inflow/infiltration.

Screening: (1) A treatment process using a device with uniform openings to retain coarse solids. (2) A preliminary test method used to separate according to common characteristics.

Scum: Floatable materials found on the surface of primary and secondary clarifiers consisting of food wastes, grease, fats, paper, foam, and similar matter.

Secondary Clarifier: A clarifier following a secondary treatment process and designed for gravity removal of suspended matter.

Secondary Treatment: The treatment of wastewater through biological oxidation after primary treatment.

Sludge: Accumulated and concentrated solids generated within the wastewater treatment process that have not undergone a stabilization process.

Sludge Dewatering: The removal of a portion of the water contained in sludge by means of a filter press, centrifuge, or other mechanism.

Sludge Stabilization: A treatment process used to convert sludge to a stable product for ultimate disposal or use and to reduce pathogens to produce a less odorous product.

Suspended-Growth Process: Biological wastewater treatment process in which the microbes and substrate are maintained in suspension within the liquid.

Thickening: A procedure used to increase the solids content of sludge by removing a portion of the liquid.

Trickling Filters: Sewage passes down through a loose bed of stones, and the bacteria on the surface of the stones treats the sewage. An aerobic process in which bacteria take oxygen from the atmosphere (no external mechanical aeration). Has moving parts, which often break down.

Total Suspended Solids (TSS): The measure of particulate matter suspended in a sample of water or wastewater. After filtering a sample of a known volume, the filter is dried and weighed to determine the residue retained.

Waste Activated Sludge (WAS): Excess activated sludge that is discharged from an activated-sludge treatment process.

Wetlands Treatment: A wastewater treatment system using the aquatic root system of cattails, reeds, and similar plants to treat wastewater applied either above or below the soil surface.

Waste Stabilization Pond: Large surface area ponds that provide treatment essentially by action of sunlight, encouraging algal growth which provides the oxygen requirement for bacteria to oxidize the organic waste. Requires significant land area, but one of the few processes which is effective at treating pathogenic material. Natural process with no power/oxygen requirement. Often used to provide water of sufficient quality for irrigation, and very suited to hot, sunny climates.

UASB: Anaerobic process using blanket of bacteria to absorb polluting load. Suited to hot climates. Produces little sludge, no oxygen requirement or power requirement, but produces a poorer quality effluent than processes such as ASP. (NOTE: other anaerobic processes exist, but UASB is the most common at present).

Collection System Terminology

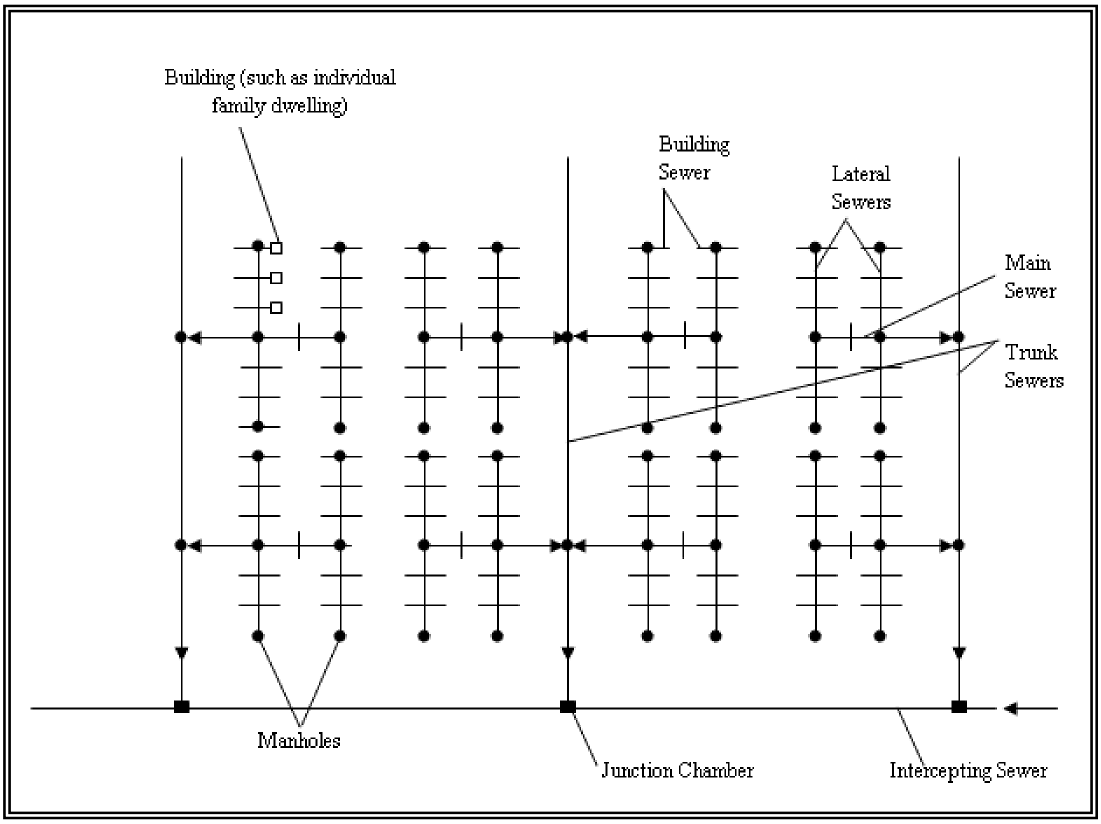
1. ***Interceptor Sewer:*** A sewer that receives flow from a number of other sewers or outlets for disposal or conveyance to a treatment plant.

2. ***Manhole:*** An opening in a vessel or sewer to permit human entry. Also called *manway.*

3. ***Trunk Sewer:*** Trunk sewers are large sewers that are used to convey wastewater from main sewers to treatment or other disposal facilities or to large intercepting sewers.

4. ***Main Sewer:*** Main sewers are used to convey wastewater from one or more lateral sewers to trunk sewers or to intercepting sewers.

5. ***Lateral Sewer:*** Lateral sewers form the first element of a wastewater collection system and are usually in streets or special easements. They are used to collect wastewater from one or more building sewers and convey it to a main sewers.



CHAPTER 1

INTRODUCTION

PART I SEWERAGE SCHEME

CHAPTER 1 INTRODUCTION

In response to a request from the Government of India, Japan International Corporation Agency (JICA) has undertaken "The Study on the Water Quality Management Plan for Ganga River in the Republic of India" by formulating JICA Study Team comprising of Tokyo Engineering Consultants Co., Ltd. in association with CTI Engineering International Co., Ltd. The Study started in February 2003 and has concluded in March 2005.

The objectives of the study are:

- To formulate the Master Plan for water quality management for Gomti River with the target year of 2030, focusing on Lucknow, Allahabad, Varanasi, and Kanpur
- To carry out Feasibility Study (F/S) for the priority projects identified in the Master Plan

The Master Plan for Lucknow has been prepared by the JICA Study Team and it encompasses the basic planning framework while identifying the priority projects for F/S.

1.1 PROJECT BACKGROUND

The consultancy services and survey activities for the F/S components were to be sub-contracted to a Local Consultant. Subsequently, JICA Study Team issued "Request for proposal" in the beginning of September 2004 to carry out the F/S comprising engineering services and the required survey activities for the priority projects for Lucknow city. In response to the Request for Proposal, MWH India Private Limited (MWH), Mumbai submitted their Technical and Financial Offer in the middle of September 2004 for the required services.

JICA Study Team, after scrutinising technical proposal of various local consultants, adjudged MWH technical proposal best and invited MWH for the discussions on their Technical and Financial Proposals in the end of September 2004. After the detailed discussions and the financial negotiations, Tokyo Engineering Consultants entered into an agreement with MWH India Pvt. Ltd, Mumbai to carry out the F/S for Lucknow in October 2004. JICA Study Team requested MWH for an early mobilisation of the team for preparation of F/S report for Lucknow, in turn MWH mobilised their team.

The scope of the F/S assignment includes engineering services along with the required survey activities i.e. topographical survey and geo-technical survey for Lucknow.

As a part of F/S, MWH has carried out the following activities for the JICA Study Team:

- Review/ collection of existing documents,
- Review of master planning framework and proposals,
- Assessing capacities of existing facilities,
- Evaluation of design alternatives and determination of planning framework for F/S,
- Detailed field survey for the F/S covering topographical survey and soil investigation,
- Preliminary design and cost estimation for priority project of sewerage scheme,
- Implementation planning and procurement of the machinery and materials,
- Organisation, operation & maintenance and human resource development plan,
- Environmental impact assessment, and
- Overall evaluation of the project for F/S

1.2 DELIVERABLES SUBMITTED

As per agreement, MWH prepared and submitted following reports during the assignment.

Table 1.1 List of Deliverables

Sr.	Deliverable	Details
1.	Inception report	Initial understanding of the project and detailed work plan based on the proposal
2.	Progress report	Brief explanation of the study progress
3.	Survey report	All the survey results as specified in the technical specifications for the survey work
4.	Draft feasibility report	All the study results
5.	Final feasibility report	All the study results including the comments of JICA Study Team on the draft report

MWH mobilised their team of experts, headed by Team Leader, at site to start the work and submitted Inception Report, Progress report, Survey report, and Draft Feasibility Report as per agreed schedule.

1.3 ABOUT THIS REPORT

This report, the Vol. IV-1 Part I of Sewerage Scheme of F/S Lucknow, titled “Final Feasibility Report”, under series of deliverables, provides details of scope of work, and the corresponding work carried out, covering review of collected data and Master Plan.

This report is divided into eleven Chapters describing the various components of this feasibility study.

The planning basis adopted for the feasibility study is explained in the second Chapter; similarly the design basis is presented in Chapter 3.

The preliminary design of the sewerage network is presented in Chapter 4. For the ease of the understanding the design sections of the report are structured district wise. Similarly, the preliminary design of the pumping station and sewage treatment plant are discussed in Chapters 5 and 6 respectively.

The rehabilitation of the Cis-Gomti trunk sewer is discussed in Chapter 7, while the augmentation / rehabilitation of old sewage pumping stations is discussed in Chapter 8.

The existing state of the institutions involved and the capacity building strategy of these institutions are discussed in Volume IV-1 Part IV of the F/S report, titled as “Institutional Development Programme”.

As a part of the study the impact of the feasibility components on the environment has been assessed and the same is presented in Chapter 9 of the report.

The implementation strategy for the feasibility components are discussed in Chapter 10, while the abstract of cost estimates are presented as concluding section of the report in Chapter 11.

CHAPTER 2

PLANNING BASIS

CHAPTER 2 PLANNING BASIS

As a first step of the feasibility study MWH collected various documents, from the JICA Study Team and reviewed all these documents to understand the existing situation. Based on this review and subsequent discussion with the concerned organisations, a planning basis has been formulated for the F/S. The formulated planning basis along with the understanding of the city and components of the F/S is presented in this section of the report.

2.1 REVIEW / COLLECTION OF EXISTING DOCUMENTS

The various documents, listed below, have been collected from the JICA Study Team along with the Master Plan, prepared by JICA Study Team.

- Influent and effluent wastewater characteristics for Daulatganj FAB treatment plant
- UPJN – Nala flow measurements 2003, and revised estimates for 2004, 2019, 2034.
- UPJN – Brief note on Pollution Control of Gomti River, March 2002.
- UPJN – Revised Project Feasibility Report (PFR) 2001-2002 for GAP II proposals
- UPJN – Gomti Action Plan Detailed Project Report (DPR), Sept. 2002

    - Vol. I – Gomti Action Plan – Phase II
    - Vol. II – Interception & Diversion of China Bazar Drain
    - Vol. III – Interception & Diversion of Laplace Drain
    - Vol. V – Interception & Diversion of La-Martiniere & Jiamau Drain
    - Vol. VI – Interception & Diversion of G.H. Canal Drain
    - Vol. VII – Interception & Diversion of Maheshganj Drain
    - Vol. VIII – Interception & Diversion of Rooppur Khadra Drain
    - Vol. X – Interception & Diversion of Daliganj No.1 Drain
    - Vol. XII – Interception & Diversion of Arts College Drain
    - Vol. XIII – Interception & Diversion of Hanuman Setu nala
    - Vol. XIV – Interception & Diversion of T.G.P.S Drain
    - Vol. XV – Remaining Part of Kukrail from Bypass to MPS at Guari Culvert
    - Vol. XXI – Main Sewage Pumping Station at Guari Culvert
    - Vol. XXII – 345 mld UASB STP at Kakraha
    - Vol. XXIII – Sewage Treatment Plant Waste Stabilization Pond at Kakraha
    - Vol. XXVI – Interception & Diversion of Kedarnath Drain

- UPJN "Feasibility Report & Forecast of Cost for Augmentation of Gomti River (by SS Feeder Canal) including proposal for III Water Works at Gomti Nagar, Lucknow" Estimate No.3/2002-2003
- Census data 2001 for wards administered by Lucknow Municipal Corporation
- Urban Environmental Services Master Plan for Lucknow (1996-2021):

    - Vol.1 – Urban Environmental Services Master Plan for Lucknow 1996-2021
    - Vol.2 – Engineering & Environmental Management Option Paper Appendices
    - Vol. 3 – Engineering Design, Costing and Supporting Data
    - Vol. 4 – Solid Waste Management
    - Vol. 5 – Infrastructure Deficiency Analysis
    - Vol. 6 – Water Quality Modelling

- Vol. 7 – Unaccounted for Water Operation and Maintenance of Sewerage & Drainage Systems Initial Environmental Screening

- Vol. 11 – Technical Papers

- Vol. 12 – Report on Economic Appraisal
- Vol. 13–Socio-Economic Segmentation in Lucknow, Population Projections and Household Service Arrangements, Summary of Findings from Study in Select Catchments

2.2 GENERAL ENVIRONMENT

The general environment of Lucknow city and the district is presented in this subsection.

2.2.1 Topography

Lucknow city is situated in the Gangetic plain on the bank of Gomti River. The topography of the city is slightly undulating. In general, city slopes towards east with lateral slope towards the Gomti River, which flows through the city from west to east. The area along the river on cis side is comparatively lower and congested than the trans side.

2.2.2 Geology

The nature of this Gangetic alluvium plain, essentially, consists of sand and sandy silt with occasional beds of clay and kankar. The entire district is covered with thick pile of quaternary sediments, overlaying the basement of Bundelkhand granitoides and sedimentary rocks. Terrace alluvium occurs as lenticular patches on either side of Gomti River with light khaki to brownish yellow in colour. These can be further classified into silt clay facies and sandy facies.
The soil is sedimentary in nature and contains transported alluvial sediments spread from the Shivalik Himalayas. The deposits dominantly belong to the Pleistocene period quaternary era. The alluvium thickness ranges between 300 to 400 m. The dominant rocks are sandstone, shale, limestone, etc. Seismically the district has not experienced any tremors of much significance in the past, however the entire district has been placed in zone of moderate intensity earthquake (Zone III).

2.2.3 Climate

The climate of the city is sub tropical with an average maximum and minimum temperature of the year are 32.2^{o}C and 16.7^{o}C, respectively. The city gets an annual average rainfall of the order of 1016 mm out of which about 90% of the rainfall occurs during the monsoon months from June to September. The average relative humidity varies from 29% in April to 95% in August.

2.2.4 Water Resources

Gomti River rises in the plains of north India. It originates from a natural impounding reservoir near a village Chanderpur in district Pilibhit in the state of Uttar Pradesh and merges with Ganga river near Audiar in district Ghazipur after it takes a course of 715 kms through 15 districts of the state. The river contributes about 15% flow to Ganga river and has an average dry weather flow of about 1500 mld, which can go upto as high as 55000 mld in monsoons and as low as 500 mld in summers. The river has an effective catchment area of 25,735 sq. kms.

In addition to the Gomti River, there is another river, Saryan that joins Gomti River at Bhatpur Ghat in district of Sitapur. This is a seasonal river originating from Sitapur district. In dry weather, it primarily carries the spent water and wastes from the inhabitants and industries located in Sitapur district.

Gomti River is the most important tributary of Ganga river. The main causes of pollution of Gomti River are:

- Discharge of the city’s untreated sewage into the river through different drains and nalas
- Discharge of industrial wastewater

It has been estimated that 364 mld of untreated sewage is discharged into the river in Lucknow.
Uttar Pradesh Pollution Control Board (UPPCB) is, regularly monitoring the water quality in the Gomti River, at six points, between Sitapur and Ghazipur. The salient features of the monitoring are as follows:

- It has been noted that the water quality of Gomti River at upstream of Sitapur, has improved marginally in 2004 as compared to the year 2001. The water quality at this point is suitable for drinking after purification.
- At Manjighat in Lucknow, it has been observed that the water quality has improved since 2001 and the water is suitable for drinking after necessary purification.
- At Lucknow Gaughat water intake works, the DO level has increased and the total coliforms have reduced in 2004 as compared to 2001. Since the water quality has improved at this point, it has been considered suitable for drinking after necessary treatment and purification.
- Significant improvement in the quality of water was not recorded, since 2001, in places downstream of Mohan Meakins.
- At Nishatganj bridge, upstream, it has been observed that there has been an increase in the DO level and reduction in total coliforms in 2003 as compared to year 2000. However, this water has been classified under Class D suitable for propagation of fisheries.
- At Gomti barrage, upstream, quality of the water has improved marginally in 2004 as compared to 2001. This water is classified under Class E, which is used for irrigation.
- At Gomti River downstream in Jaunpur and before its confluence with Ganga at Rajwari, the water has been found suitable for propagation of fisheries.

UPJN has installed hand pumps at various locations. In addition to this, local people have also installed hand pumps in their colonies. CPCB has conducted a zone based survey, with an objective of analyse and understand the groundwater quality, in 1996 and 2000. Some of the observations quoted in the CPCB report are presented below:

1. As water is drawn out from greater depth, the quality of water is conforming to the norms laid down for the coliform standards.
2. Fluoride concentrations were found below 1.0 mg/l in 6 out of the 20 samples in 1996 and 10 out of 17 samples in 2000. It is therefore not suitable for drinking particularly for children.
3. During 1996, it was found that concentration of chromium at all the locations is meeting the prescribed standards but in 2000, the same was exceeding at 6 locations.
4. Both during 1996 and 2000 surveys, it was found that the iron content exceeded the desirable limits at all the locations.
5. Copper and zinc concentration were meeting the desirable limits in both the surveys.
6. Lead and cadmium concentrations were not traceable in both the sample surveys.

2.3 PROJECT AREA

Lucknow city, capital of Uttar Pradesh, can be divided into two parts, one is the older habitations located in the central part of the city and the second is newer settlement, extending the boundary of the city. The older area, south of Gomti river, is densely populated and are characterized by pre-colonial settlement structures and ethos. The scope of F/S is limited to the city of Lucknow, corresponding to the sewerage system and related pollution abatement of Gomti river leading the improvement in the water quality in Ganga river.

The Ganga Action Plan (GAP) was a major initiative launched by the ministry of environment and forests, government of India to improve water quality in the Ganga river in the 1980s. Under the second phase, GAP–II, which targeted tributaries of the Ganga, UPJN has proposed sewerage works in Lucknow, to control pollution level in Gomti River through Gomti Action Plan, Phase I (GoAP-I).

Around 72 mld of the sewage entering into Gomti river was intercepted and diverted, out of which treatment facilities are constructed to treat around 60 % (42 mld), under the GoAP–I. In order to further reduce the pollution level in Gomti river, UPJN has prepared a Gomti Action Plan, Phase II (GoAP – II). Detail project reports were prepared, by UPJN, to intercept, divert and treat 370 mld sewage under the GoAP – II. Lists of sewerage schemes, pumping stations and STPs proposed in GoAP and in Lucknow M/P are presented in Tables 2.1, 2.2 and 2.3.

2.3.1 Sewerage Schemes

Table 2.1 Sewerage Schemes

Sr.	Sewer	Details	Current Condition	Proposal
1	Cis-Gomti trunk sewer	From Sarkata nala to Cis-Gomti pumping station	It is 40 years old and is damaged and choked at few locations. Also, substantial amount of silt has accumulated.	To conduct condition assessment and rehabilitation under phase-I, priority projects
2	Trans-Gomti trunk sewer (new)	Existing TGTS starts from Daliganj PS No.2 and terminates at TGPS	The existing trunk sewer is 40 years old and is damaged and choked almost throughout its stretch. Also, it does not have sufficient hydraulic carrying capacity.	To replace existing sewer from the junction of Mankameshwar temple road to TGPS under phase-I, priority projects
3	Cis-Gomti relief sewer	To relieve the excess sewage load from existing CGTS, a new trunk sewer is proposed from Medical university crossing to Martinpurwa pumping station		Proposed under phase-I, priority projects
4	Sultanpur road trunk sewer	A rising main is proposed from Martinpurwa pumping station to Dilkusha crossing on Sultanpur road. From here onwards, a gravity trunk sewer is proposed upto Mastemau STP		Proposed under phase-I, priority projects

2.3.2 Sewage Pumping Stations

Table 2.2 Sewage Pumping Stations

Sr.	Location	Capacity (mld)			Proposal
		2003	2015	2030	
1	Trans-Gomti	23.16	60	80	Rehabilitation/augmentation of pumping station under phase-I, priority projects
2	Cis-Gomti	46.14	50	55	Rehabilitation/augmentation of pumping station under phase-I, priority projects
3	Mahon Meakin	12.01	18.14	27.73	Sanctioned under GoAP-II
4	Kukrail No.1	72.49	179.11	233.71	Sanctioned under GoAP-II
5	Guari (Gomti nagar)	99.45	320.54	322.19	Sanctioned under GoAP-II
6	GH canal	73.96	93.92	124.68	Sanctioned under GoAP-II
7	Martinpurwa	-	80	250.00	Proposed under phase-I, priority projects
8	Luniapurwa	3.89	12.01	32.83	Proposed under M/P, phase-II
9	Kukrail No.2	13.39	27.48	58.75	Proposed under M/P, phase-II
10	Kukrail No.3	24.28	49.25	92.53	Proposed under M/P, phase-II

2.3.3 Sewage Treatment Plants

Table 2.3 Sewage Treatment Plants

Sr.	Location	Capacity (mld)			Proposal
		2003	2015	2030	
1	Daulatganj	42	56	56	Operational
2	LDA colony (Hardoi road)	-	10	14	Sanctioned by LDA
3	Kakraha	-	345	345	Sanctioned under GoAP-II
4	Mastemau	-	100	305	Proposed under phase-I, priority projects
5	Khwajapur (Alambagh)	-	-	135	

The execution of GoAP–II works will significantly reduce the, present, pollution in Gomti River subsequently in Ganga river. However, Lucknow city's population is projected to double from 2.5 million in 2003 to 5.4 million by 2030. At present, the total domestic wastewater load is about 365 mld against an installed treatment capacity of 42 mld. The amount of wastewater collected and diverted to treatment accounts just over 10% of the total quantity generated. Remaining wastewater is discharged to Gomti river. To cater to the needs of this growth a project "Integrated pollution abatement and river basin management for Ganga basin" aided by government of Japan was conceived. As stated earlier, the scope of this study is limited to the improvement in the sewerage system in the city of Lucknow.

2.4 POPULATION AND POPULATION PROJECTIONS

The infrastructure demand of a city is determined by the strategic and social consideration but often fallen short of the demands of the expanding city. To uphold such an eventuality, it is necessary to estimate the population of the city in the future.

Population projection forms an important part in infrastructure planning, which essentially makes provision of infrastructure in the city. JICA Study Team has carried out a detail ward-wise population projection. The population projection adopted in the Master Plan was reviewed for adoption of the same in the feasibility report. Some observations were made in the population projection and the same is presented below:

- The Master Plan states that Lucknow has a cultural heritage and attracts significant political and administrative importance. It also reads out that it has good regional and national connectivity encouraging commercial growth and trade activities, which continued to provide employment opportunities in the administrative, services, educational, and tourism sectors.
- More than 63 % of the wards have a growth rate of greater than 25 % and only 7 % of the wards grow at a rate of less than 5%.
- The growth rates by wards were estimated based on the analysis of the growth characteristics of each ward, dependent on its current density, road network, master-plan designation, and adjacent ward characteristics.

These observations were discussed with the JICA Study Team and it was mutually decided to adopt the population data provided by JICA Study Team for the F/S.

Table 2.4 District wise Population Projection

	Year of 2003	Year of 2015	Year of 2030
Municipality Area			
District I	162,178	221,243	323,766
District II	251,472	346,804	535,052
District III	819,532	1,107,512	1,593,952
District IV	1,132,207	1,372,696	1,720,206
Sub Total	2,365,389	3,048,255	4,172,976
Future Service Area			
District I	5,921	31,145	86,513
District II	29,901	137,987	328,343
District III	50,496	271,648	610,077
District IV	10,767	116,552	226,780
Sub Total	98,085	557,332	1,251,713
Total	2,463,474	3,605,587	5,424,689

2.5 EXISTING WATER SUPPLY SCHEMES

UPJN has formulated a Master Plan for augmenting water resources and improving water supply distribution to the year 2035. The plan is based on a per capita water demand of 150 lpcd + 15% UFW and the following populations and water demand estimates:

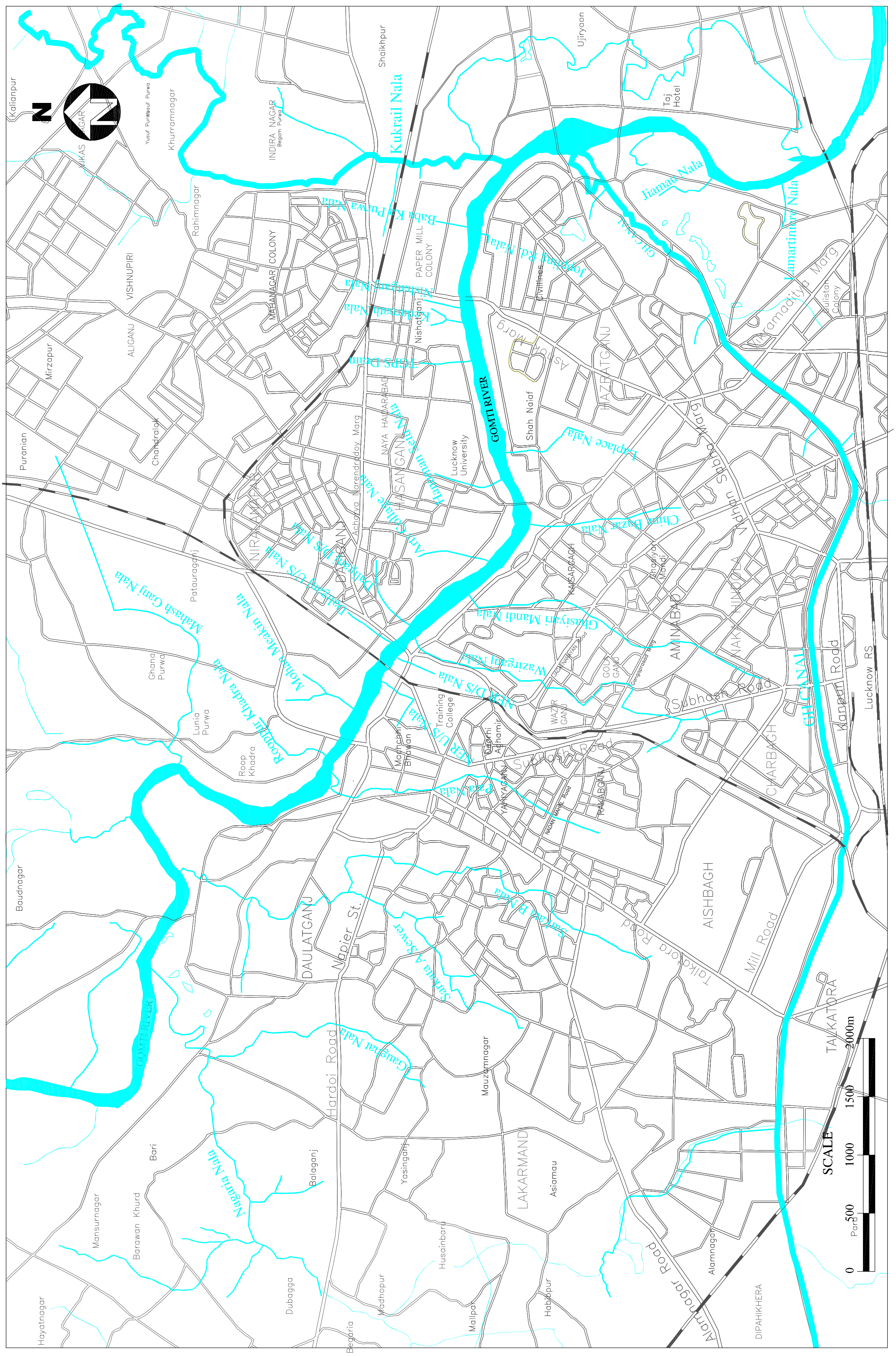
Table 2.5 Water Demand Estimates: UPJN

Year	2005	2020	2035
Population	2,598,000	3,859,000	5,363,000
Water demand (mld)	447	664	924

Based on the discussion with the JICA Study Team and UPJN officials it was finalized to adopt as per capita water supply rate of 150 lpcd + 15 % UFW for design of sewerage system.

2.6 EXISTING STORM WATER DRAINAGE SYSTEM

Lucknow city has fourteen nala/drains on the Cis-Gomti side and thirteen nala/drains on the Trans-Gomti side. Location of these nala/drains are shown in Figure 2.1, whereas the measured and projected flows in these nalas are presented in Table 2.6.



JICA JAPAN INTERNATIONAL COOPERATION AGENCY
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CTI CTI ENGINEERING INTERNATIONAL CO., LTD.

PROJECT	LOCATION	FIGURE 2.1
THE STUDY ON WATER QUALITY MANAGEMENT PLAN FOR GANGA RIVER IN THE REPUBLIC OF INDIA	LUCKNOW CITY	LOCATION MAP FOR NALAS

Table 2.6 Projected Flows in Nala

	Name of nala & Drain	Measured Discharge (mld)				Remarks
		Measured by UPJN		Measured by JICA Study Team		
		1993	2003	2004	2004	
Cis SIDE	Nagaria nala	-	10.10	-	-	Diverted and intercepted into STP under GoAP phase-I. .
	Gaughat nala	1.80	-	-	-	
	Sarkata nala	18.00	18.00	-	-	
	Pata nala	7.80	16.73	-	-	
	Ner u/s nala	0.50	-	0.00	-	
	Ner d/s nala	0.50	1.46	1.15	-	Intercepted into CGPS under GoAP phase-I.
	Wazirganj nala	43.00	14.00	-	10.80	
	Ghasiyari mandi nala	10.00	13.50	-	14.90	
	China bazar nala	2.00	2.94	3.15	4.10	
	Laplace nala	1.00	1.60	3.16	16.30	
	Jopling road nala	1.00	0.91	0.98	-	
	LaMarteniere nala	0.50	0.02	0.02	-	
	Jiamau nala	Running almost dry	0.29	0.14	-	
	G.H. canal	73.00	142.56	102.18	100.70	
TRANS SIDE	Mahesh ganj nala	Running almost dry	3.80	6.39	-	
	Rooppur khadra nala	0.50	1.20	0.95	-	
	Mohan Meakin	3.00	5.74	6.95	5.20	
	Daliganj u/s nala	8.00	7.37	6.35	-	
	Daliganj d/s nala	1.00	1.47	2.64	-	
	Arts college nala	0.50	1.73	1.58	-	
	Hanuman setu nala	0.50	6.28	4.09	-	
	TGPS Drain	1.00	1.66	0.27	-	
	Kedarnath nala	2.00	3.20	3.08	-	
	Nishatganj nala	1.00	1.66	1.39	-	
	Baba ka purwa nala	Running almost dry	0.12	0.09	-	
	Kukrail nala	29.00	97.75	85.71	73.10	
	Gomtinagar	18.00	-	-	3.70	

It was observed that these nala/drains carry significant amounts of wastewater to Gomti River. It was also ascertained that these drains are also a significant source of pollution during wet weather when cow dung and human waste that accumulates during the dry season are flushed away by runoff.

In order to have an estimate of the pollution load generated and discharged, the CPCB took up a comprehensive monitoring of all the incoming drains to the river, during the years 1996 and 2000. The results of the survey are summarized below:

1. During 1996, the BOD of water flowing in various drains, excluding drains carrying industrial wastewater, varied between 54 to 303 mg/l, whereas, during the year 2000, it was observed to be between 42 to 180 mg/l, excluding Jiamau and LaMarteniere drains.
2. The suspended solid concentration in 1996 was found to be between 125 to 852 mg/l, which was reduced to 55 to 449 mg/l in 2000.
3. The Sodium Absorption Ratio (SAR) of the sewage as measured during 1996 confirmed that it may be used for irrigation.
4. The presence of heavy metals like iron, lead and chromium are much on the higher side in the

drains of the Trans-Gomti side as compared to drains located in the Cis-Gomti side. Since most of the metal processing industries are located on Trans-Gomti side of the river, there is a possibility that metals in dissolved form are discharged into the drains along with the effluents.

UPJN also carried out investigations in the year 2003, and it has been found that drains discharge a total of 341 mld out of which 42 mld is already been diverted under GoAP-I and UPJN has proposed diverting the remaining nalas under GoAP-II. These nala-tapping arrangements are essential for intercepting wastewater during dry weather and reducing pollution loads, however some of the shortcomings of the present tapping arrangements are:

- Screens of these tapping/diversion arrangements are maintained manually, which leaves considerable hazardous on the facility.
- They allow a substantial quantity of silt and debris into the sewer system, which is detrimental to its life and proper function.
- They allow large quantities of storm water into the sewerage system which causes flooding and hydraulic overloads at treatment plants

Thus, it is recommended that each tapping point should be provided with proper screening and grit removal facilities to protect the collection system. Furthermore, each tapping point shall be provided with a system to regulate the inflow during wet weather. Five nalas/drains have already been diverted under GoAP-I and the remaining nalas/drains are proposed to be diverted under GoAP-II.

A relieving trunk sewer is proposed in order to maintain the hydraulic capacity of existing CGTS, which requires partial diversion of four nalas viz. Pata nala, Wazirganj Nala, Ghasiyarimandi nala and Katchehary nala. The alignment of relieving trunk sewer is planned in such a way that these nalas are intercepted and diverted on upstream of their terminal point thus reducing the load on existing CGTS. The reliving nalas/drains proposed to be diverted under the F/S are presented in Table 2.7.

Table 2.7 Nalas/Drains to be Diverted under the Feasibility Study

Name of Nala/Drain	Proposal
Pata nala	To be diverted into relief sewer (Partially)
Wazirganj nala	
Ghasiyari mandi nala	
Katchehary nala	
Mahesh ganj nala	To be diverted to the sanctioned Mohan Meakins PS
Rooppur khadra nala	
Mohan Meakin	
TGPS drain	Diversion is already sanctioned; discharge to be accommodated in proposed renovation of Trans-Gomti PS
Kedarnath nala	
Nishatganj nala	

2.7 EXISTING SEWAGE GENERATION

The sewerage system in Lucknow dates back to 1948, conceived through the sewerage master plan and completed in 1960's. As far as the sewerage system is considered, Lucknow city is been divided in to two parts, Cis-Gomti and Trans-Gomti. Two parallel trunk sewers, along the Gomti River, were laid on both the banks of the river viz. Cis-Gomti Trunk Sewer (CGTS) and Trans-Gomti Trunk Sewer (TGTS). Sewage generated in the city is conveyed to these two sewers through lateral intercepting sewers.

CGTS sewer starts from Sarkata nala in Husainabad near western gate of Chota Imambara and receives sewage from the following sewers:

- Sarkata - A
- Sarkata - B
- Pata
- Shahmina
- Wazirganj
- Katchehary
- Ghasiari Mandi
- Chamber lane
- Ashok Marg, and
- Wazir Hasan road

The sewer finally discharges the sewage to the pumping station, Cis-Gomti Pumping Station (CGPS). The total length of the trunk sewer is around 7.3 km and diameter gradually increases from 350 mm to 2100 mm.

The sewage from CGPS is presently pumped into Gomti River and UPJN has proposals to pump the sewage from CGPS to the rising main from Trans-Gomti Pumping Station (TGPS) by crossing the Gomti River through Nishatganj bridge. At present this rising main is defunct thus the sewage is pumped to Gomti River without any treatment.

TGTS starts from the Daliganj PS No. 2 drain and receives discharge from the following sewers

- Mohan Meakin
- Daliganj
- Mukarim Nagar
- Art College
- University

The discharge from TGTS is conveyed to Kukrail intermediate pumping station, which pumps it further to Guari MPS. It is further conveyed to STP at Kakraha before being discharged into Gomti River.

2.7.1 Sewerage Districts

The town has been divided into four sewerage districts, namely Districts I, II, III and IV. The different districts are described as below.

District I	Western part of city. The sewage generated from this district drains into existing FAB technology Daulatganj STP.
District II	Southern part of city, south of Sharda Canal. The sewage generated from this district will be treated in the proposed Khwajapur STP.
District III	City core, Trans Gomti area. The sewage generated from this district will drain into sanctioned Guari MPS for treatment in the sanctioned Kakraha STP. And Kakraha STP will also receive a part of wastewater from District IV via existing Cis side interceptor sewer and Cis will be Gomti Pumping Station until year 2015.
District IV	City core, Cis Gomti area. A part of sewage generated from this district will be intercepted by proposed relief trunk sewer to discharge into proposed Martin Purwa MPS and then to proposed Mastemau STP.

2.7.2 Sewerage Zones

The Sewerage Master Plan divides the municipal corporation of Lucknow into eight major drainage catchments. These are described in Section 5.5.1 of the Sewerage Master Plan. The districts have been divided into Sewerage Zones, which are shown in Table 2.8 and in Figure 2.2.

Table 2.8 Sewerage Zones

Sewerages District III: Area on the trans side of Gomti River which is divided into seven zones.	
Zone A	Mohan Meakin area conveying sewage to sanctioned Mohan Meakin PS
Zone B	Trans core area conveying sewage to existing TGPS
Zone C	Luniapurwa area conveying sewage to proposed Luniapurwa PS
Zone D	Hasanganj area conveying sewage to proposed Daliganj PS No.2
Zone E	Vikas nagar area conveying sewage to proposed Kukrail PS No.3
Zone F	Left bank side of Kukrail nala conveying sewage to sanctioned Kukrail PS No.1
Zone G	Gomti nagar area conveying sewage to sanctioned Guari PS
Sewerage District IV: Area on the cis side of Gomti River including the old city area with old sewerage network. This district expanses upto Sarda nagar canal towards south and the municipal boundary towards east. This district is divided into four zones.	
Zone H	Core area of city along Gomti River conveying sewage to CGPS
Zone I	The core city area is proposed to be served by Cis-Gomti relief sewer
Zone J	GH canal area conveying sewage to the sanctioned GH canal PS
Zone K	Arjunganj and Telibag area is proposed to be served by new proposed sewer

2.7.3 Sewage Generation

Master Plan, prepared by JICA, reveals that the per capita sewage generated is calculated by using the proposed per capita water supply rates as basis and the same is presented in Table 2.9. This calculation is based on different water supply rates prevailing in core area and no-core area. Core area is defined as the central part of the city where any new development due to population growth is not possible. The remaining developing part of the city is considered as non-core area.

Table 2.9 Per Capita Wastewater Generation Rates

Core area	2003	2015	2030
Per capita water consumption (lpcd)	283	230	173.5
Return factor	0.70	0.75	0.80
Per capita wastewater discharge (lpcd)	198	172.5	139
+10% infiltration allowance	218 (say 220)	190	153 (say 155)

Non core Areas	2003	2015	2030
Per capita water consumption (lpcd)	147	161	173.5
Return factor	0.70	0.75	0.80
Per capita wastewater discharge (lpcd)	103	121	139
+10% infiltration allowance	113 (say 115)	133 (say 135)	153 (say 155)

Source: JICA Study Team

The JICA study has adopted the return factors, mentioned in the above table, which are provided in the "Manual on Sewerage and Sewage Treatment" published by CPHEEO, Ministry of Urban Development and Poverty Alleviation, December 1993. Thus the same values have been adopted for this F/S report.

2.8 PRIORITY PROJECTS (COMPONENT AND DISTRICT WISE)

As an initial part of the project, JICA Study Team started their study in February 2003 to prepare a Master Plan for water quality management for Ganga river for a design target year of 2030 for Lucknow city. Another important focus of the JICA Study Team was to identify priority projects to undertake the F/S. The methodology of the study has been to determine the least cost approach in meeting Lucknow City's sewerage and pollution control needs. This involves the consideration of existing infrastructure and proposal of UPJN for GoAP-II, alternative service coverage, alternative technologies, and alternative wastewater treatment and disposal methods.

With this concept, JICA Study Team identified the priority projects that should be implemented as soon as possible to reduce the pollution in Gomti River and appointed MWH for carrying out the F/S of the same. The description of the various components, district-wise, of the F/S is presented in Table 2.10.

Table 2.10 Components of Feasibility Study

Sewage District	Component	Description	Design and details presented in
District III	Sewer (New)	Proposed rising main from Mohan Meakin PS to Mankameshwar temple road and a gravity sewer from Mankameshwar temple road to TGPS	Chapter 4
	Sewer (Old)	Replacement of Trans-Gomti trunk sewer	Chapter 4
	Pumping Station (Old)	Renovation of Trans-Gomti pumping station (TGPS)	Chapter 8
District IV	Sewer (New)	Proposed Cis-Gomti relief sewer from Medical university crossing to Martinpurwa PS	Chapter 4
		Proposed rising main from Martinpurwa PS to Dilkusha crossing	Chapter 5
		Proposed Sultanpur road sewer from Dilkusha crossing to Mastemau STP	Chapter 4
	Sewer (Old)	Partial rehabilitation of Cis-Gomti trunk sewer	Chapter 7
	Pumping Station (New)	Proposed Martinpurwa PS	Chapter 5
		Rehabilitation of Cis-Gomti pumping station (CGPS)	Chapter 8
	STP (New)	Proposed Mastemau STP	Chapter 6

CHAPTER 3

DESIGN BASIS FOR FEASIBILITY REPORT

CHAPTER 3 DESIGN BASIS FOR FEASIBILITY REPORT

3.1 INTRODUCTION

MWH has received and studied the Sewerage Master Plan of Lucknow city, which is prepared by JICA Study Team. MWH has also studied and reviewed PFRs and DPRs prepared by UPJN, LNN, LJS for the city of Lucknow, which are relevant to this project.

MWH has specific comments and suggestions for further improvements in the design of specific project components, which are presented in the relevant sections of this report. The details on design basis developed by MWH for assessing the feasibility of the various components are presented in this section. The design basis has been developed based on the current practices and past performance of the relevant components in the region, guidelines provided in Manual on Sewerage and Sewage Treatment Plants prepared by CPHEEO and the guidelines prepared by National River Conservation Directorate (NRCD).

3.2 DESIGN YEARS

In the Master Plan, design years for various schemes, are considered as per the agreement between Govt. of India and the Govt. of Japan. The Sewerage Master Plan has been prepared for the year 2030 with phased implementation occurring in 5-year intervals.

As stated earlier, Master Plan has identified a set of priority projects, which are proposed to be executed within five years after the adoption of Master Plan. Following design years have been adopted in line with the agreement between the two Governments and the provisions in Master Plan.

- For all gravity sewer lines, the design year adopted is year 2030.
- For all pumping stations, civil structures are designed to satisfy the requirements of year 2030 whereas the installation of electrical, mechanical, instrumentation, automation and rising mains are designed for their requirements of year 2015.
- For all sewage treatment plants, civil structures, mechanical, electrical, instrumentation, automation works are designed for year 2015 whereas land shall be acquired for the capacities to be designed for year 2030.

3.3 DESIGN BASIS FOR SEWERAGE NETWORK

The design basis of sewerage network adopted in this Feasibility Study is described in this section.

3.3.1 Hydraulics of Sewers

For design purposes, the flow of sewage in pipes is presumed to be steady and uniform flow. The most popular equation for calculating the velocity and head loss for flow conditions in gravity sewers is Manning formula, which is used in this feasibility study for designs of gravity sewers.

$$V = \frac{1}{n} \text{ x } R^{2/3} \text{ x } S^{1/2}$$

$$Q = A \text{ x } V$$

Where V = Velocity, m/s
n = Manning's coefficient of roughness of the pipe
(0.013 for design purpose, 0.015 for old sewers for RCC pipes)

R = Hydraulic radius of pipe, m

S = Slope of the energy gradient line
Q = Flow rate, m^3/s
A = Cross sectional area, m^2

(1) Peak Factors

Based on the recommended values of peak factor as per CPHEEO's Manual on Sewerage and Sewage Treatment, the peak factors adopted for contributory populations of drainage area are given in Table 3.1. Depending on the contributory population, the peak factor changes - it being higher for less population and low for high population.

Table 3.1 Peak Factors Considered for Sewerage Design

Contributory Population	Peak Factor as per CPHEEO Manual
Up to 20,000	3.00
20,000 - 50,000	2.50
50,000 - 750,000	2.25
Above 750,000	2.00

(2) Depth of Flow

The sewerage system for the ultimate design year has been designed to utilise 80% of the full bore of the pipe at peak flows. It is proposed to select an optimum size of sewer considering that the pipes will utilise less than 80% of the full bore in the design year and will also achieve self-cleansing in early years. This will result in cost savings and also help in achieving the reduced operation and maintenance.

(3) Velocities

It is necessary to size the sewer to have adequate capacity to carry peak flow at the end of design period, so as to avoid steeper gradients and deeper excavations. It is desirable to design sewers for higher velocities wherever possible. This is done on the assumption that although silting might occur at minimum flow, the silt would be flushed out during the peak flows. However, the problem of silting may have to be faced in the early years, where the depth of flow during early years is only a small fraction of the full depth. Similarly, upper reaches of laterals pose a problem as they flow only partly full even at the ultimate design flow because of the necessity of adopting the prescribed minimum size of sewer. In such situations, flushing arrangements may be provided in the initial years. The sewerage system has been designed for a minimum velocity of 0.8 m/sec. for design flow i.e. peak flow at design horizon.

(4) Sizing of Pipes and Slopes

The size of pipes and slope is calculated for contributory population based on the contributory area of the individual administrative wards and the projected population of the respective administrative wards for the design horizon year 2030. The pipe diameter is selected by considering (d/D) ratio of 0.8 (80% bore utilisation). The corresponding flattest slope is provided so as to achieve the minimum required self-cleaning velocity with an aim to minimise sewer depth thus ensuring reduced cost. In cases where (i) the topography does not permit to have the calculated gradient for full bore utilisation and/or (ii) the proposed sewer is to be connected to an existing line, which is at a shallow depth, a higher size pipe is selected to match the crown of connecting sewers.

(5) Minimum Pipe Size

The interceptor sewers and secondary sewers have been designed considering the minimum size of sewer as 500 mm and 300 mm respectively.

(6) Minimum Depth of Cover

The minimum depth of cover of 1.5m has been considered. The actual depth of cover may vary, as most of the sewers are planned on proposed roads. While finalising the depth of initial manhole, care shall be taken so that the secondary sewer lines, when laid, shall be connected to these priority main intercepting sewers.

(7) Maximum Depth of Sewer

The sewerage system has been designed such that the maximum cover of sewer will be about 10 meters below ground level. In many areas construction of sewers below 10 meters becomes very difficult. This shall increase the cost of construction and maintenance. Hence as per the prevailing practice it is proposed to lift the sewage by the proposition of a sewage pumping station once the sewer depth reaches around 10 meters.

3.3.2 Sewer Appurtenances

(1) Manholes

Standard circular manholes have been recommended for pipe diameter up to 1200-mm. However, rectangular manholes should be provided for shallow depths. General arrangement drawing is presented in drawing no. LKO-TYP-1 “Typical Details of Ordinary Manholes and Vent Shafts.

(2) Scraper Manholes

For sewers of diameter 600 mm and above, scraper manholes shall be provided at major junctions and at an interval of every 150 m. Scraper manhole openings will range from 900 to 1200 mm size to permit lowering of sewer cleaning equipment. It is very important to construct scraper manholes as the sewers are designed to serve for long term, which shall run with quite less flow during the initial years resulting into silting.

(3) Drop Arrangement

The drop arrangement consists of a pipe that drops the invert of the incoming sewer to that of the main sewer in the manhole. The diameter of the drop pipe should be at least as large as the incoming pipe. Theoretically, drop arrangements are provided where the drop of an incoming sewer in manhole exceeds 600 mm. Drop arrangements are provided in manhole for the following reasons:

- To convey the sewage to bottom of the manhole without splashing
- To minimise the scouring action of the sewage falling from a height on the cement concrete floor of the manhole
- For the safety of the personnel who enter the manhole

(4) Receiving Manhole at Pressure line Discharge

A 2 m x 2 m receiving sump with a PVC splash pad is proposed for chamber-type manhole into which pressure line is discharged prior to joining the gravity sewer.

(5) Vent Shafts

Ventilation shafts will be provided at the head end of every sewer and along the sewers at about 150-m interval as well as at junctions. General arrangement drawing for the typical vent shaft is presented in drawing no. LKO-TYP-1 “Typical Details of Ordinary Manholes and Vent Shafts.

(6) Pipe selection

The materials used extensively for sewerage in most Indian cities are glazed stoneware / vitrified clay and reinforced concrete pipes for gravity sewers whereas cast iron / ductile iron pipes are employed for rising / force mains of pumping stations. Concrete pipes conforming to IS :458-1988 of appropriate strength with proper anti-corrosive lining may even last for about 50-60 years. Considering the capital cost, durability and availability of the pipes, RCC pipes, preferably, NP_3/NP_4 class as per IS:458-1988, have been proposed. Concrete pipes are usually S/S type RCC sewer pipe.

The class of concrete pipes is decided on the basis of analysis of design loads likely to be imposed upon on the sewer depending upon its depth.

3.3.3 Structural Design of Buried Sewers

Any sewer line buried into the ground should have adequate strength to withstand the stresses imposed not only by the internal pressure but more importantly, by the stresses induced by external loads. There are two types of external loads, one is due to the backfill material known as backfill load and other is due to superimposed loads. Besides these external loads, the sewer line is also subjected to the load of water in the pipeline, especially during surcharge conditions.

(1) Load on Conduit due to Backfill

The load on a buried conduit is equal to the weight of the prism of earth directly over the conduit plus the frictional shearing forces transferred to the prism by the adjacent prism of earth. The most widely used method for determining the vertical load due to backfill on buried conduit is Martson’s formula, the general form of which is

$$W = C.w.B^2$$

where,

- W: Vertical load in kg per meter length acting on the conduit due to gravity loads
- w: Unit weight of earth, kg/m^3
- B: Width of trench or conduit depending upon type of installation condition, m
- C: Dimensionless coefficient that measures the effect of ratio of height of fill to width of trench or conduit

The value of C for various types of installation and depending on the height / width ratio is given in the Manual of Sewerage and Sewage Treatment. The C-value for 'ordinary maximum for clay' has been considered for design purposes.

The unit weight of earth varies from 1600 kg/m^3 for dry sand to 2100 kg/m^3 for saturated clay.

(2) Load on Conduit due to Superimposed Load

Superimposed loads may be either concentrated or distributed loads. The formula for load due to concentrated load such as truck wheel is given by Boussinesq’s formula

$$W_{sc} = C_s(PF/L)$$

where,

- Wsc: load on the conduit, kg/m
- P: concentrated load acting on the surface, kg
- F: impact factor (1.0 for air field runways, 1.5 for highway traffic and air taxi ways,

1.75 for railway traffic) and

Cs: load coefficient which is a function of Bc/2H and L/2H, where
H: the height of the top of conduit to ground surface, m
Bc: the outside width of conduit, m and
L: effective length of the conduit to which the load is transmitted, m.

For distributed superimposed loads, the formula for the conduit is given by

WSD = CS.P.F.BC
where,

Wsd: load on conduit, kg/m
P: intensity of distributed load, kg/m^2
F: impact factor
Bc: width of conduit, m
Cs: load coefficient, a function of D/2H and L/2H
H: height of the top of conduit to the ground surface, m and D and L are width and length respectively of the area over which the distributed load acts, in meters.

For class AA IRC loading in the critical case of 6.25 tonnes wheel load, the intensity of distributed load with wheel area 300mm x 150mm is given by P = 6.25/(0.3x0.15) T/m^2.

(3) Supporting Strength of Rigid Conduit

The ability of a conduit to resist safely the earth load depends on its inherent strength as well as the distribution of vertical load, bedding reaction and on the lateral pressure acting against the sides of the conduit. The inherent strength of a rigid conduit is usually expressed in terms of the three edge bearing test results, the condition of which are however different from the field load conditions. For strength calculations of NP class precast RCC pipes, IS:458-1988 is used.

(4) Field Supporting Strength

The field supporting strength of a rigid conduit is the maximum load per unit length, which the pipe will support while retaining complete serviceability when installed under specified conditions of bedding and backfilling. The field supporting strength however does not include any factor of safety. The ratio of the strength of a pipe under any stated condition of loading and bedding to its strength measured by the three edge-bearing test is called the load factor. The load factor does not contain a factor of safety. Load factors have been determined experimentally and analytically for the commonly used construction condition for both trench and embankment conduits.

The basic design relationships between the different design elements are:

Safe supporting strength,

W = Field supporting strength/Factor of safety
= (Load factor x three edge bearing strength)/Factor of safety
A factor of safety of at least 1.5 should be applied to the specified minimum three edge bearing strength to determine the working strength for all the rigid conduits. The class of bedding considered is B type, whose load factor as per the CPHEEO Manual is 1.9.

Based on the above consideration, a general guide for selecting the class of pipe from 200 to 600-mm diameter is given in Table 3.2. However, in our case we have carried out the structural designs for all pipes above 300mm.

Table 3.2 Guideline for Selection of Pipe Class for Sewers with B-class Bedding

Diameter	NP2	NP3	NP4
200	1.2 to 7.0 m	-	-
250	1.2 to 7.0 m	-	-
300	1.2 to 4.2 m	4.2 to 6.0 m	6.0 to 10.0 m
350	1.2 to 2.7 m	2.7 to 3.5 m	3.5 to 10.0 m
400	1.2 to 2.7 m	2.7 to 3.5 m	3.5 to 10.0 m
450	1.2 to 2.7 m	2.7 to 3.5 m	3.5 to 9.5 m
500	-	1.5 to 3.5 m	3.5 to 8.5 m
600	-	1.5 to 3.5 m	3.5 to 7.5 m

Note: For larger diameters of 700-mm and above, pipe class cannot be generalised and has to be calculated on a case-to-case basis.

3.3.4 Type of Bedding

The type of bedding provided for pipes will be selected from granular bedding, concrete (M20) cradle bedding or concrete encasement (M20) and the choice will depend on the depth at which the sewer is laid, three edge bearing strength of pipes used, load due to backfill and superimposed vehicular traffic loads. Technical suitability of such bedding, as per the guidelines of CPHEEO, is studied and adopted as found acceptable.

3.3.5 Force Main

Sewage may have to be carried to higher elevations through force main. The size of the main should be determined by taking into account the initial cost of pipeline and cost of operation of pumping for different sizes. The size of pressure main has been calculated for velocity of 1.1 to 1.5 m/sec for design peak flows with a maximum velocity upto 2.0 m/sec.

Losses in valves, fittings, etc. are dependent upon the velocity head $v^2/2g$. Loss in bends, elbows depend upon the ratio of absolute friction factor to pipe diameter, besides the velocity head. Loss due to sudden enlargement depends upon the ratio of diameters.

Each individual case needs to be studied from various aspects such as operation of pumps, the specified limits, availability of land required for duplicating the main in future, etc.

CI pipes conforming to IS:1536-1989 and DI pipes as per IS: 8329-1994 are corrosion resistant with an expected life of about 100 years. CI pipes will be jointed either by rubber gaskets suitable tyton joints or by lead joint.

3.4 DESIGN BASIS OF SEWAGE PUMPING STATIONS

3.4.1 Design Approach

The design and selection of pumps for a sewage pumping station involves a multi-disciplinary team of experts who have to work out every detail of the civil, mechanical and electrical aspects in order to obtain a satisfactory design and operation of the pumping station. Different types of pumps have their own purposes and characteristics. There are a series of decisions that have to be taken while selecting and designing the pumps. The various factors considered while designing the pumping station are:

- Determine location and purpose
- Determine the required discharge (average and peak flows)

- Determine the required lift or pressure increase, including the variations therein, as well as the transport distance
- Determine the type of liquid
- Determine in and outflow conditions, etc.

The outline of design procedure can be best laid out in the following Figure 3.1

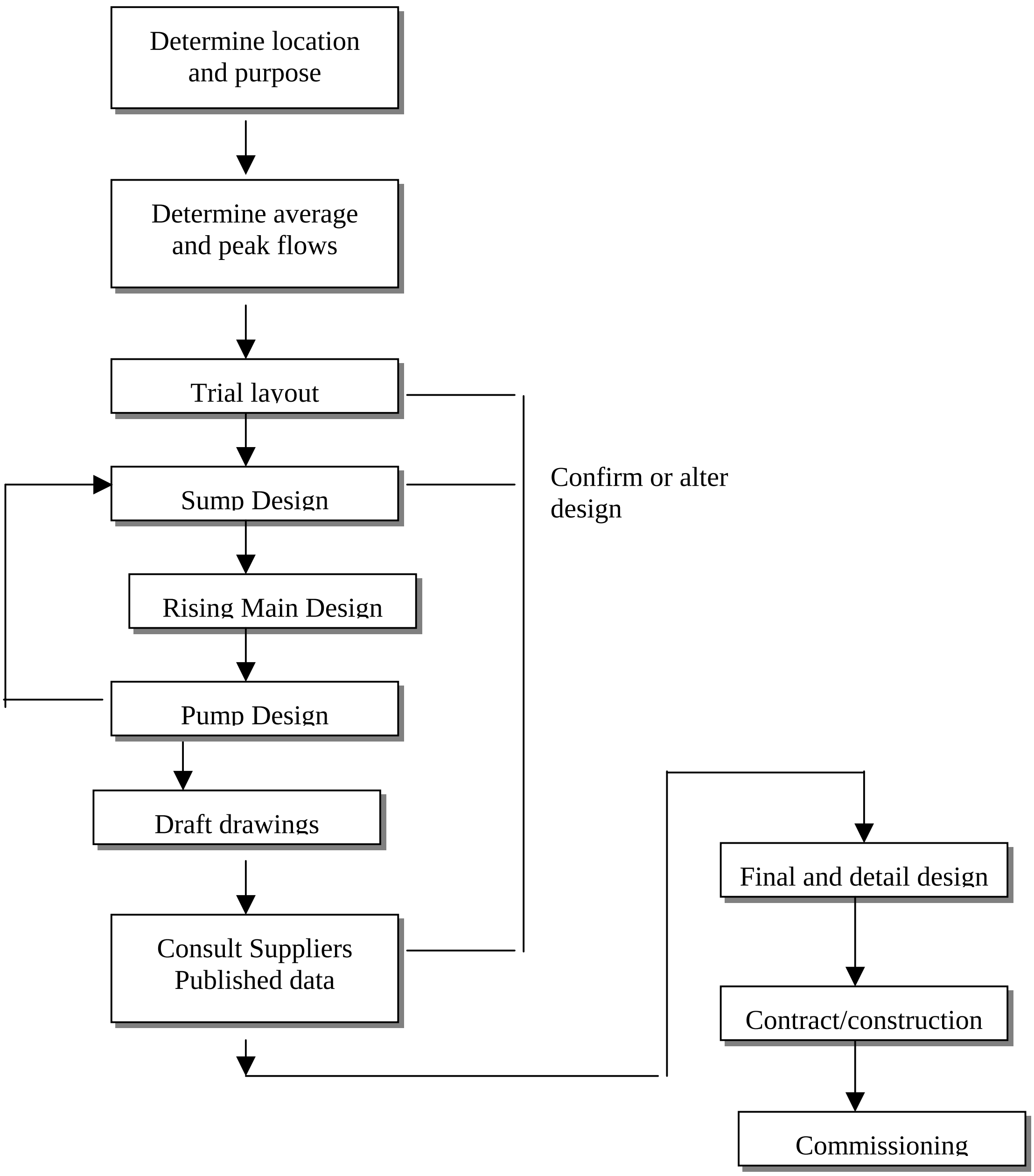


Figure 3.1 Pumping Station Design Procedure

(1) Location

Pumping stations are normally located at the lowest point of the area they are intended to serve. They will frequently, therefore be found alongside the watercourses that drain the area as they are at the natural lowest level.

Proper location of the pumping station requires a comprehensive study of the area to be served to ensure that the entire area can be adequately drained. Special considerations have to be given in undeveloped or developing areas to the probable future growth, as the location of the pumping station will, in many cases, be determined by the future overall development of the area. The site should also be aesthetically satisfactory. The pumping station shall be located and constructed in such a manner that it will not be flooded at any time. The station should be easily accessible under all weather conditions.

(2) Determination of Flows

Having decided the location of the pumping station, its purpose and the contributory area, the next stage is to calculate average and peak flows for the present day and a point in the future at a set "design horizon'. Whilst in the structural sense, concrete structures are designed for 30-50 years, they are normally sized to deal with the peak flow at a 30 year horizon.

(3) Layout

The layout of pumping stations will primarily depend upon the local conditions. In general, it can be said that the layout of a pumping station is logic fit of all functions of the station, with sufficient room to move between machinery for erection and maintenance purposes, but without unnecessary empty spaces either in horizontal plane or in vertical plane. In principle, flow lines shall be as short as possible and no unnecessary bends shall be present in the piping.

Spaces are required for the following units.

- Inlet chamber
- Screen chamber
- Main collection sump
- Valve chamber/ dry well
- Transformer station
- Electrical panel room
- DG set room
- Operations office

Two type of pump house layout is considered based on type of pumps:

- Dry well and wet well for horizontal centrifugal pumps
- Wet well and valve chamber for submersible pumps

All spaces should be well lighted. Also, outside lighting may be required. Proper railings are required along stairs or on platforms. Sufficient space shall be available for future expansion of the station.

(4) Design of Pumping Station

Pump sizing is carried out with reference to manufacturer's catalogues, as these are the most reliable guides.

Sump Design

a) Wet Well

Capacity of wet well sump is decided based on CPHEEO manual and NRCD guidelines depending on the selection of either submersible or horizontal centrifugal type of pumps. The well must be self-cleansing and hence benching is provided on the floor of the sump.

b) Dry Well / Valve Chamber

Sizing of dry well (for horizontal centrifugal pumps) or valve chamber (for submergible pumps) has been designed considering common header diameter, fittings, valves, working space and operating space.

(5) Rising Main Design

The concept of rising main design is to meet following criteria:

- the main must be self cleaning with minimum flows
- velocities shall not be excessive at design peak flows
- Techno-economic diameter of rising main is calculated considering capitalised cost of pumps and rising main for 15 years

3.4.2 Design Criteria for Sewage Pumping Stations

(1) Design Year

For the design of civil structures	2030
For the design of mechanical and electrical items	2015
For the design of rising main	2015

(2) Wet well Capacity

Detention time of wet well at peak flow — 5 minutes for horizontal centrifugal pumps
3.75 minutes for submersible pumps

(3) Dry Well/ Valve Chamber Size

Based on number of pumps and clear spacing requirement for pumps, pumps dimension, valves, fittings and working space requirement.

(4) Rising Main

The pump capacity together with rising main diameter shall be calculated considering pump cost, rising main cost and annual operation & maintenance cost. Lesser diameter rising main may be cheaper in initial cost but the operation cost may be high due to increased pump head.

The most economical size of the rising main should be selected after analysing following factors:

- The different diameter of pipes for different head losses, which can be considered for the quantity of sewage, intended to be transported
- The design period and the quantum of flow to be carried out for design period
- The pipe and its relative cost including cost of laying and jointing
- The cost of pump and its installation against the various diameters of pipes
- The annual and capitalised cost of electric charges

- Minimum required velocity (self cleansing) in pipe line shall be 0.6 m/sec during non-peak condition
- Maximum allowable velocity in pipe line shall not be more than 2.0 m/sec

(5) Pumps

Number of pumps for small capacity pumping stations

i) When rising main is long	a) 3 nos. pumps of half-peak flow
	b) 2 nos. pumps of non-peak flow
ii) When rising main is short	a) 5 nos. pumps of one-fourth peak flow

Number of pumps for large capacity pumping stations

Equal capacity pumps (6 to 8) + 50% standby on peak flow

Above criteria is basic NRCD guideline for selection of number of pumps. However, the final decision on pump configuration is taken based on availability of pump capacity in market.

Moreover, a technical evaluation of various types of pumps has been done and the same is presented in Appendix A3.1. Based on the technical evaluation, considering advantages, disadvantages, and also the past experiences of UPJN officials on existing installations, it was decided and recommended that for the various sewage pumping stations in Lucknow, submersible pumps shall be opted only upto 150 HP capacity and horizontal centrifugal pumps shall be opted for higher (>150 HP) capacities.

Pump capacity and power charges

Pump capacity in kW	9.81 * H * Q/ (Ep * Em)
where,	H = working pressure, m
	Q = pump discharge, m3/sec
	Ep = pump efficiency
	Em = motor efficiency
Electrical power charges	Rs. 3.25 per unit
Capitalised energy charges	CC = CR *{ [1 – (1+r) ^ (-n)]/ r }
where,	CR = annual energy charges
	n = period in years = 15 or 30
	r = rate of interest = 10% or 5%
	For n = 15 & r = 10%; CC = 7.61 CR and
	For n = 30 & r = 5%; CC = 15.37 CR

(6) Screens and Screen Channel

Screening of incoming sewage is required for the removal of large floating materials, which can damage the pumps. This will be carried out in two stages, viz. 40 mm opening manually cleaned bar screen followed by a 20 mm opening mechanically cleaned bar screen.

Standby units	100 %
Stage - I	
Clear spacing between screen bars	40 mm
Thickness of screen bar	10 mm
Type of working screens	Manual screen

Stage - II

Clear spacing between screen bars	20 mm
Thickness of screen bar	10 mm
Type of working screens	Mechanical screen
Type of standby screen	Manual screen
Minimum approach velocity @ avg. flow	0.3 m/sec
Minimum velocity through screens	0.6 m/sec
Maximum velocity through screens	1.2 m/sec

(7) Electrical Load capacity

Main transformer and other electrical equipments are designed for peak flow electrical load requirement.

(8) Standby Power Supply Source

In case of electrical power failure at pumping station, diesel generator sets are proposed for peak load. Also, an auto changeover arrangement has been proposed for switching between grid power and DG power.

3.5 DESIGN BASIS FOR SEWAGE TREATMENT PLANTS

3.5.1 Criteria for Selection of STP Site

One of the basic design concepts required to be studied for the design of sewerage system is whether centralized or de-centralized sewage treatment plants is suitable. The main criteria governing the choice for the location of STP site are,

- Topography of the contributing area (sewerage zone)
- Usage of existing sewerage system
- Proximity to the discharge point for the treated sewage
- Location of discharge of the treated sewage from intake of water works
- Availability and accessibility of site for the STP
- Location of the selected site for STP vis-à-vis the city
- Availability of other utilities like power, roads, communications etc.
- Capitalized operation and maintenance costs

Topography of the contributing area (sewerage zone)

The city of Lucknow is divided into various sewerage districts considering topography and natural drainage system. These sewerage zones are marked on the base map and are presented in the drawing no. LKO-BASE MAP-1.

Usage of existing sewerage system

The existing sewerage system consists of the CGTS on the Cis-Gomti side and TGTS on the other side of the river. Sewage flowing through the existing CGTS is proposed to be diverted to Trans-Gomti area and planned to be treated at the proposed sewage treatment plant at Kakraha (345 mld capacity) till year 2015 and thereafter it will be diverted to Mastemau STP. Sewage flowing through TGTS will also be conveyed to Kakraha STP. Construction of 345 mld capacity STP at Kakraha is a sanctioned project. Feasibility report is prepared considering the sanctioned projects, which are either under execution or completed.

A sewage treatment plant is proposed to be constructed at Mastemau to treat the sewage generated in Cis-Gomti area. However, sewage from the existing CGTS and GH canal will be conveyed to proposed STP at Kakraha in the phase-I. After 2015, flows from the catchment of GH canal and CGTS will also be diverted to the proposed STP at Mastemau.

Proximity to the discharge point for the treated sewage

It is necessary to locate the proposed plant at a suitable site from where the treated sewage can be safely discharged. The treated sewage from the Mastemau STP is proposed to be used for irrigation in the surrounding areas. When there is no demand for water on the irrigation fields the same shall be disposed off in the river.

Location of discharge of the treated sewage from intake of water works

It is very essential that the location of discharge point of treated sewage into receiving body is on the downstream side of the water intake points for water supply system. The discharge point envisaged for the proposed STP is far away from the raw water intake points and on the downstream side of the city.

Availability and accessibility of site for the STP

It is essential to have proper access roads to the STP location. The site identified for the proposed Mastemau STP is close to the Sultanpur road and the site is connected to this road by the village road. The existing landuse of the city makes it necessary to locate the proposed STP at the outskirts.

Availability of other utilities like power, roads, communications etc.

The STP site proposed under the master plan is easily approachable being close to the Sultanpur road. The site is located close to an existing road network, which ensures that other utilities such as power, communication facilities can be made available easily.

Capitalised Operation and Maintenance costs

Looking at the existing sewerage facilities, all the above factors which have influence on the selection of STP location do not have any adverse impact on the capital costs as well as on the operation & maintenance costs and the existing facilities will be utilised to fullest possible extent.

After these detailed discussions it is found that the location of STP at Mastemau is most suitable.

3.5.2 Raw Sewage Characteristics Considered for Design Purpose

Raw sewage characteristics differ from one situation to another depending on the level of sanitation, water usage, return factor, type of collection system, retention time in conveying system and infiltration. UPJN and JICA Study Team have collected a limited number of grab samples for a limited period of time (about 4 weeks). The BOD concentration in various nalas varied from 75 to 154 mg/l.

The catchment area of Cis Gomti relief sewer which will bring sewage to the proposed STP at Mastemau is densely populated and has over 60% sewer coverage area. The relief sewer will intercept sewage flowing through the existing sewerage system in this area along with China bazar nala sewer, Pata nala sewer, Wazirganj nala sewer, Katchehary road sewer apart from the nala tapings. The sewage which is flowing through these sewers is expected to be having higher concentration than that flowing through the nalas presently. The water supply rate considered in the Master Plan at user end is also on much higher side hence actual characteristics of the sewage are expected to be medium to strong strength.

Based on these facts the wastewater characteristics adopted for design of the proposed STP at

Mastemau are presented in the Table 3.3.

Table 3.3 Raw Sewage Characteristics Considered for Design Purpose

Sr.	Parameter	Average Value
1.	Minimum temperature, ^oC	20
2.	pH	6.0 - 8.5
3.	Biochemical oxygen demand (BOD_5), mg/l	250
4.	Total suspended solids, mg/l	500
5.	Faecal coliform count, MPN/100ml	2×10^7

3.5.3 Discharge Standards

The sewage treatment plant shall be designed to achieve treated wastewater of equal or better quality as mention in the Table 3.4 hereunder.

Table 3.4 Treated Wastewater Quality

Sr.	Parameter	Value (Irrigation Field/River)
1.	pH	5.5 – 9.0
2.	Biochemical oxygen demand, mg/l	≤ 30
3.	Total suspended solids, mg/l	≤ 50
4.	Faecal coliform count, MPN/100ml	Desired $\leq$1,000 Permissible $\leq$10,000

NRCD has conveyed the recommendations of the expert committee through their letter no DO. No. A-33013/1/99-NRCD dated 5th October 1999, suggesting that the maximum permissible value for faecal coliform in treated water should not exceed 10,000 MPN per 100 ml sample irrespective of its mode of disposal in river or its use for irrigation to grow either restricted or unrestricted crops. However, the STP is designed to meet the discharge guideline of NRCD for less than 1,000 MPN/100 ml sample. It is also mentioned in NRCD guidelines that BOD and TSS concentration less than 30 mg/l and 50 mg/l respectively.

3.5.4 Approach for Selection of Sewage Treatment Schemes

(1) Power Supply Situations in India and in Uttar Pradesh

UP has currently possesses power generation capacity of 4,693 MW: 4,192 MW by thermal generation and 501 MW by hydraulic power. In addition, UP has a share of 2,855 MW in central sector generation in the northern region. The peak power demand for 2004-2005 was 7,877 MW out of which 5,268 MW could be met, indicating the peak power shortage was 21 %. The shortage is expected to decrease to 5 % by various measures described below. When the new projects such as Rihand II, Tehri, Dhauliganga and Unchatar III are commissioned, some 3,200 MW capacity will be added.

Beside the new installation of power plants, four measures have been taken to enhance power supply in UP: renovation and modernisation of existing plants, more effective transmission and distribution network, organisational reforms and introduction of non conventional energy sources.

<u>Renovation and modernisation of existing plants</u>

Unit new installation cost is said to be Rs. 4 crore/MW, while the unit cost to renovate and modernize old power plants is said to be Rs. 0.5 – 1.5 crore/MW, which implies that renovation and modernisation is more cost effective depending upon how long the plants have been operated and how they are maintained. Some of the old plants were already renovated and some others are expected to follow them.

<u>More effective transmission and distribution network</u>

The transmission and distribution losses in UP were 35% in 2003, the highest in India. The losses are attributed to inadequate investment, metering inefficiencies and theft. To solve the problems, the investment will concentrate on highly densely networks leading to quick and visible results, 100% feeder metering and as well as consumer metering are targeted, and transformation capacity will be enhanced.

(2) Approach for Selection of Sewage Treatment Schemes

The requirements of a feasible sewage treatment system are as following:

- Simple to construct and operate,
- Ability to handle strong sewage within short detention time,
- Minimum capital and operation cost,
- Possibility of cost recovery,
- Minimum land requirement,
- Ability to treat up to the prescribed discharge standards,
- Minimum odour, flies and other nuisance, and
- General acceptance to the people in the vicinity of the STP.

3.5.5 Treatment Options for Use of Treated Water for Irrigation Purpose

The techno-economic treatment option should take into consideration the site-specific constraints and the inlet characteristics of the sewage. Further, for a city like Lucknow which is fast growing resulting into huge quantity of sewage being generated every day with high organic load, the treatment option should not be separately looked into without considering the land costs.

Following four options have been evaluated for finalising the sewage treatment scheme:

a) Alternative 1: Waste stabilisation pond system consisting of anaerobic pond followed by facultative pond and further followed by maturation pond,
b) Alternative 2: Activated sludge process with chlorination system,
c) Alternative 3: Upflow anaerobic sludge blanket (UASB) Process followed by aerated lagoon with chlorination system,
d) Alternative 4: Aerated lagoon followed by maturation ponds with chlorination system,

Alternative 1: Waste Stabilisation Pond System of Anaerobic Pond + Facultative + Maturation Pond

Stabilisation ponds are open, flow through earthen basins specially designed and constructed to treat sewage and biodegradable industrial wastewater. Stabilisation ponds provide long detention periods extending to several days. In ponds the organic waste is stabilised through symbiotic relationship between the algae and bacteria. Oxygen is provided by photosynthesis of algae or by mechanical aeration in some cases.

The treatment process will consist of inlet chamber, screen channel, and an anaerobic pond having hydraulic retention time of 2 days. The facultative pond having a detention time of 16 days will follow the anaerobic pond. Subsequent to the facultative pond, there shall be maturation ponds having detention time of 1 day. The waste stabilisation ponds are designed for ambient temperature of 20 degree Celsius.

Table 3.5 Design Parameters for Waste Stabilisation Pond System

Sr.	Unit	Detention time (day)	Depth (m)
1	Anaerobic lagoon	2	3.0
2	Facultative pond	16	2.0
3	Maturation pond	1	1.2

The schematic flow diagram of this alternative is presented in the Figure 3.2.

Alternative 2: Activated Sludge Process with Chlorination System

An activated sludge process (ASP) is a type of aerobic suspended growth system. The ASP plant essentially consists of the following:

- Primary treatment consisting of screening and grit removal,
- Primary clarifier for settling of suspended solids,
- Aeration tank containing microorganisms in suspension in which biological degradation of organic matter takes place aerobically,
- Activated sludge recirculation system to maintain the sufficient microorganisms in aeration tank,
- Excess sludge wasting and disposal facilities,
- Aeration system to transfer oxygen, and
- Secondary clarifier for settling of suspended solids,
- Thickener to thicken activated sludge,
- Digester for sludge digestion,
- Gasholder for gas storage resulting from sludge digestion,
- Chlorination system for disinfecting treated sewage.

Table 3.6 Design Parameters for ASP with Chlorination System

Sr.	Parameters	Value	Unit
1.	Inlet Chamber		
	Hydraulic retention time (minimum)	30	sec
2.	Fine Screen Channel		
	Clear opening through screen	6	mm
	Minimum approach velocity at average flow	0.3	m/sec
	Minimum velocity through screen at peak flow	0.6	m/sec
	Maximum velocity through screen at peak flow	1.2	m/sec
3.	Grit Chamber		
	Particle size	0.15	mm
	Specific gravity of grit at 20^{o} C	2.65	
	Efficiency	75	%
4.	Primary Clarifier		
	Surface overflow rate at average flow	35	cum/sqm/day
	Detention time	2.05	hours
5.	Aeration Tank		
	F/M	0.30	
	MLSS	2500	mg/l
	MLVSS/MLSS	0.8	
	O_2 provided	1.2	Kg O2/kg BOD removed
6.	Secondary Clarifier		
	Surface overflow rate at average flow	25	cum/sqm/day
	Detention time	3.07	hours
7.	Chlorine Mixing Tank		
	Detention time	2	mins
8.	Chlorine Contact Tank		
	Detention time	30	mins
9.	Sludge Thickener		
	Rate of solids surface loading	50	kg/sqm/day
10.	Primary Sludge Digester		
	SRT	15	days
	Ratio of diameter to depth	3.74	
11.	Secondary Sludge Digester		
	SRT	10	days
	Ratio of diameter to depth	3.75	
12.	Gas Holder		
	Detention time	6	hours
	Pressure	0.03	kg/sqcm

This alternative consists of the following treatment units:

- Inlet chamber,
- Fine screen channel,
- Grit chamber,
- Primary clarifier,
- Aeration tank,
- Secondary clarifier,
- Chlorination system,
- Sludge pumping station,
- Filtrate pumping station,
- Sludge thickener,
- Sludge digester,

- Gasholder and
- Sludge drying beds.

Raw sewage will be received in the inlet chamber and then passed to the screen channel and subsequently to the grit chamber. In screen channel floating matters are trapped and removed whereas in grit chamber, grit is removed. After screening and grit removal the wastewater is taken into a primary clarifier. This is provided for the removal of suspended matter before taking wastewater for further biological treatment. The sludge generated as a result of primary settling is taken for thickening and subsequently for digestion. A sludge digester and pumps are provided for this purpose.

After primary settlement of the suspended matter, the wastewater is taken to aeration tank containing microorganisms in suspension in which the biological degradation takes place. Further, a secondary clarifier is provided to separate the activated sludge. A part of the incoming flow is re-circulated upstream of the aeration tank. A tapping is provided on this line to lead the excess sludge to the sludge sump.

A two-stage digestion system is provided for sludge digestion. The detention time in the digester is about 20 days. Mixers are provided to operate in a completely mixed regime in the digester. It is proposed to use sludge drying beds for sludge dewatering prior to sludge disposal.

The schematic flow diagram of this alternative is presented in the Figure 3.3.

Alternative 3: UASB Process followed by Aerated Lagoon with Chlorination

The UASB process followed by aerated lagoon with chlorination essentially consist of the following:

- Primary treatment consisting of screening and grit removal,
- UASB reactor for anaerobic degradation of sewage,
- Aerated lagoon having aeration system to transfer oxygen,
- Chlorination system for further reduction of faecal coliform and disinfecting treated sewage.
- Gasholder for gas storage and gas utilisation system, and
- UASB sludge wasting and dewatering facilities,

Table 3.7 Design Parameters for UASB followed by AL with Chlorination

Sr.	Parameter	Value	Unit
Average flow		1.157	cum/sec
Peak factor		2.0	
Peak flow		2.315	cum/sec
Sewage Treatment Plant:			
1.	Inlet Chamber		
	Hydraulic retention time (minimum)	30	sec
2.	Fine Screen Channel		
	Clear opening through screen	6	mm
	Minimum approach velocity at average flow	0.3	m/sec
	Minimum velocity through screen at peak flow	0.6	m/sec
	Maximum velocity through screen at peak flow	1.2	m/sec
3.	Grit Chamber		
	Particle size	0.15	mm
	Specific gravity of grit at 20^{o} C	2.65	
	Efficiency	75	%
4.	UASB Reactor		
	Solids retention time, SRT	38	days
	Sludge bed concentration	65.0	kg TSS/cum
	Maximum sludge bed height	90.0	% of Ht to gas collector
	Average upflow velocity	0.5	m/hr
	Maximum upflow velocity	1.0	m/hr
	Average aperture velocity	2.5	m/hr
	Maximum aperture velocity	5.0	m/hr
	Angle of gas collector	50.0	degree
	Settling zone surface percentage	> 75.0	% of total surface area
	Settling zone detention time (minimum)	1	hr
	Feed inlet point distance (maximum)	2.0	m
	Overlap	0.15	m
5.	Aerated lagoon		
	Aeration zone		
	Detention time	0.5	day
	Depth	3.0	m
	Quiescent zone		
	Detention time	1.0	day
	Depth	1.5	m
	Sludge depth	0.3	m
6.	Chlorine Mix Tank		
	Detention time	2	min
7.	Chlorine Contact Tank		
	Detention time	30	min
8.	Gasholder		
	Detention time	6.0	hr
	Pressure	0.03	kg/sq.cm

The treatment process will consist of the following treatment units:

- Inlet chamber,
- Fine screen channel,
- Grit chamber,
- UASB reactors
- Aerated lagoon,

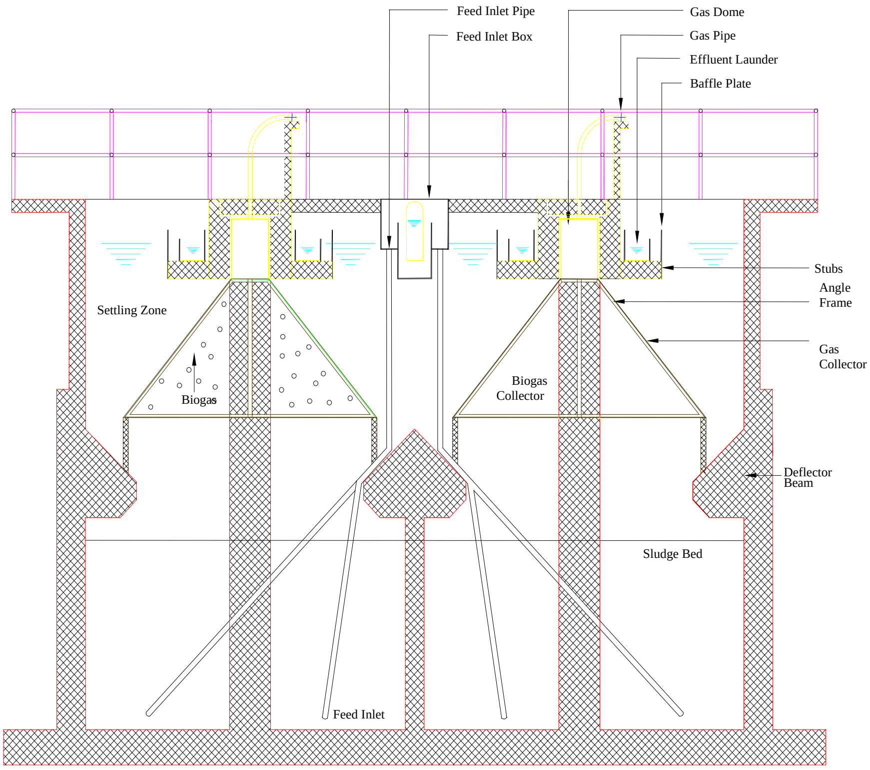
- Chlorination system,
- Sludge pumping station,
- Filtrate pumping station,
- Gas utilisation system, and
- Sludge drying beds.

UASB Technology

The development of the UASB reactor dates back from early 1970's. Pre-sedimentation, anaerobic wastewater treatment and final sedimentation including sludge stabilisation are essentially combined in one reactor making it most attractive high-rate wastewater treatment alternative. It produces high value by-products viz.

- Treated wastewater usable for gardening purpose or for pisci-culture after a simple post treatment,
- Methane enriched biogas having high calorific value is converted into a usable energy resource like heat energy, electricity etc., and
- Mineralised excess sludge produced in UASB reactor for its usage as manure for agricultural purpose.

UASB initially was developed for the anaerobic treatment of industrial wastewater with a moderate to high COD and BOD concentrations. The basic idea is flocculent or granular sludge developed in the reactor depending on the wastewater characteristics and operational parameters will tend to settle under gravity when applying moderate upward velocities in the reactor. In this way no separate sedimentation basin is necessary. Anaerobic bacteria are developed in the reactor and are kept in the biological reaction compartment for sufficient time. Organic compounds present in the wastewater are absorbed or adsorbed on the sludge particles in the reaction zone during its passage through the sludge bed. Thereafter, organic compounds get anaerobically biodegraded converting it into methane-enriched biogas and a small part into the new bacterial mass. Biogas consists of methane CH_4, carbon dioxide CO_2, hydrogen H, hydrogen sulphide H_2S and traces of ammonia NH_3 and nitrogen N_2. This biogas can be used as energy source and for this reason, is collected in gas collectors.



A typical cross section of UASB Reactor

A gas, liquid and solids separator (GLSS) is provided below the gas collectors in order to provide an opportunity to the sludge particles to which biogas bubbles are attached to lose biogas and settle back into the reaction compartment. In between two gas collectors a settling zone is provided where virtually no gas bubbles are present in the liquid. The sludge particles carried with the wastewater flow are settled in the settling zone and slide down into the biological reaction zone. Wastewater enters the UASB reactor from the bottom and travels through the reactor in the upward direction. In order to ensure sufficient contact between the incoming wastewater and the anaerobic bacterial mass present in the reactor, the wastewater is fed uniformly all over the bottom of the reactor. Further mixing in the reaction zone is achieved by the production of the biogas travelling in the upward direction, settling velocity of the sludge particles and the density currents in the sludge mass.

With proper seed material available at the time of start-up of the UASB reactor, the microbial population is developed within three months period. Proper care is taken while designing the UASB reactor to absorb estimated shock loads in terms of hydraulic and organic contents in the wastewater.

The reactor is having the following zones:

- Gas collection zone
- Clarification zone
- Sludge blanket zone

Effluent from UASB reactor will not meet the discharge standards for BOD and TSS, hence, further treatment is required. Therefore, post treatment in the form of AL is provided to meet these standards.

Aerated lagoons are generally provided in the form of simple earthen basins with inlet at one end and outlet at the other to enable the wastewater to flow through while aeration is usually provided by mechanical means to stabilise the organic matter. The major difference between activated sludge systems and aerated lagoons is that in the latter, settling tanks and sludge recirculation is absent.

Aerated lagoons can be categorised into two types depending on how the microbial mass of solids in the system is handled. Aerated lagoons are those in which some solids may leave with the effluent stream and some settle down in the lagoon since aeration power input is just enough for oxygenation and not for keeping all solids in suspension. As the lower part of such lagoons may be anoxic and anaerobic while the upper layers are aerobic, the term facultative is used.

Aerobic lagoons, on the other hand, are fully aerobic from top to bottom as the aeration power input is sufficiently high to keep all the solids in suspension besides meeting the oxygenation needs of the system. No settlement occurs in such lagoons and under equilibrium conditions the new (microbial) solids produced in the system equal the solids leaving the system. Thus, the solids concentration in the effluent is relatively high and some further treatment is generally provided after such lagoons. If the effluent is settled and the sludge recycled, the aerobic lagoon, in fact, becomes an activated sludge or extended aeration type lagoon.

Facultative type aerated lagoons have been more commonly used the world over because of their simplicity in operation and minimum need of machinery. They are often referred to simply as ‘aerated lagoons’. Their original use came as a means of upgrading overloaded oxidation ponds in some countries without adding to the land requirement. In fact, much less land is required compared to oxidation ponds.

Moreover, chlorination is carried out for disinfecting the wastewater to meet discharge guideline for faecal coliform as per the latest NRCD norms. Disinfection refers to the selective destruction of diseases-causing organisms. Diseases caused by waterborne bacteria include typhoid, cholera, paratyphoid, and bacillary dysentery; diseases caused by waterborne viruses include poliomyelitis and infectious hepatitis. At present, the most common method of disinfecting wastewater is by the addition of chlorine.

The schematic flow diagram of this alternative is presented in the Figure 3.4.

Alternative 4: Aerated Lagoon followed by Maturation Pond with Chlorination

Aerated lagoons are generally provided in the form of simple earthen basins with inlet at one end and outlet at the other to enable the wastewater to flow through while aeration is usually provided by mechanical means to stabilise the organic matter. The major difference between activated sludge systems and aerated lagoons is that in the latter, settling tanks and sludge recirculation is absent.

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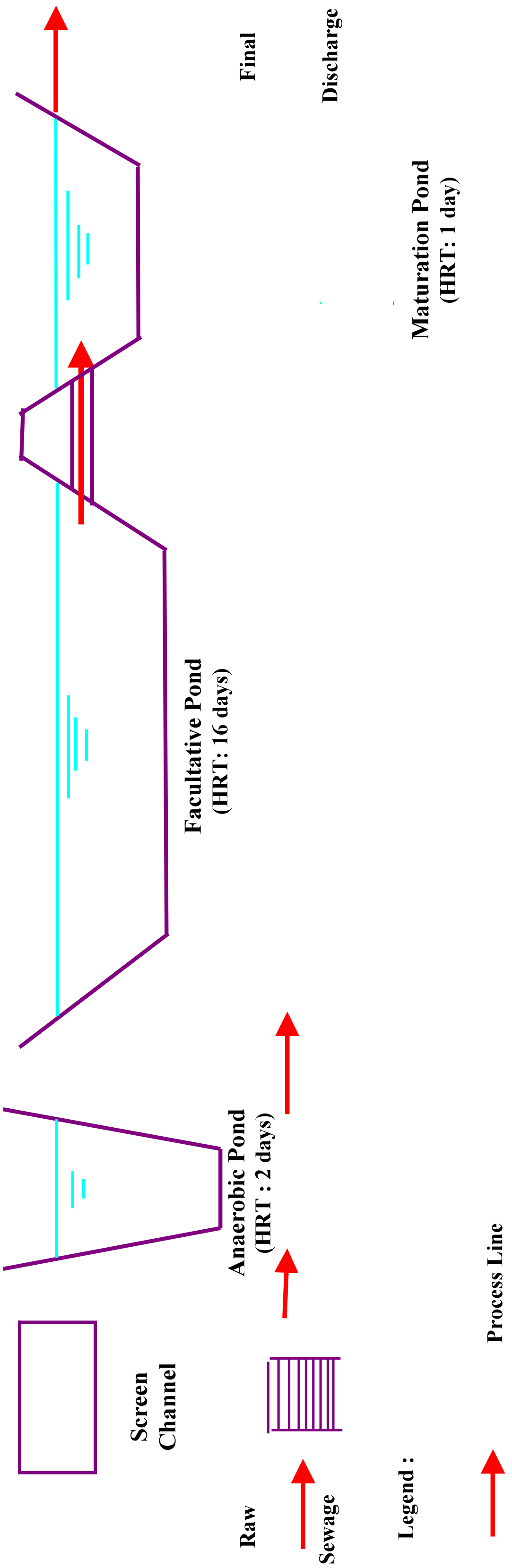
A maturation pond is shallow earthen pond, which is provided for polishing of effluent from aerated lagoons. This is an aerobic pond as the depth of this pond is restricted to 1.2 m. In maturation pond, BOD and suspended solids are further reduced, aerobically, to meet the wastewater discharge standards.

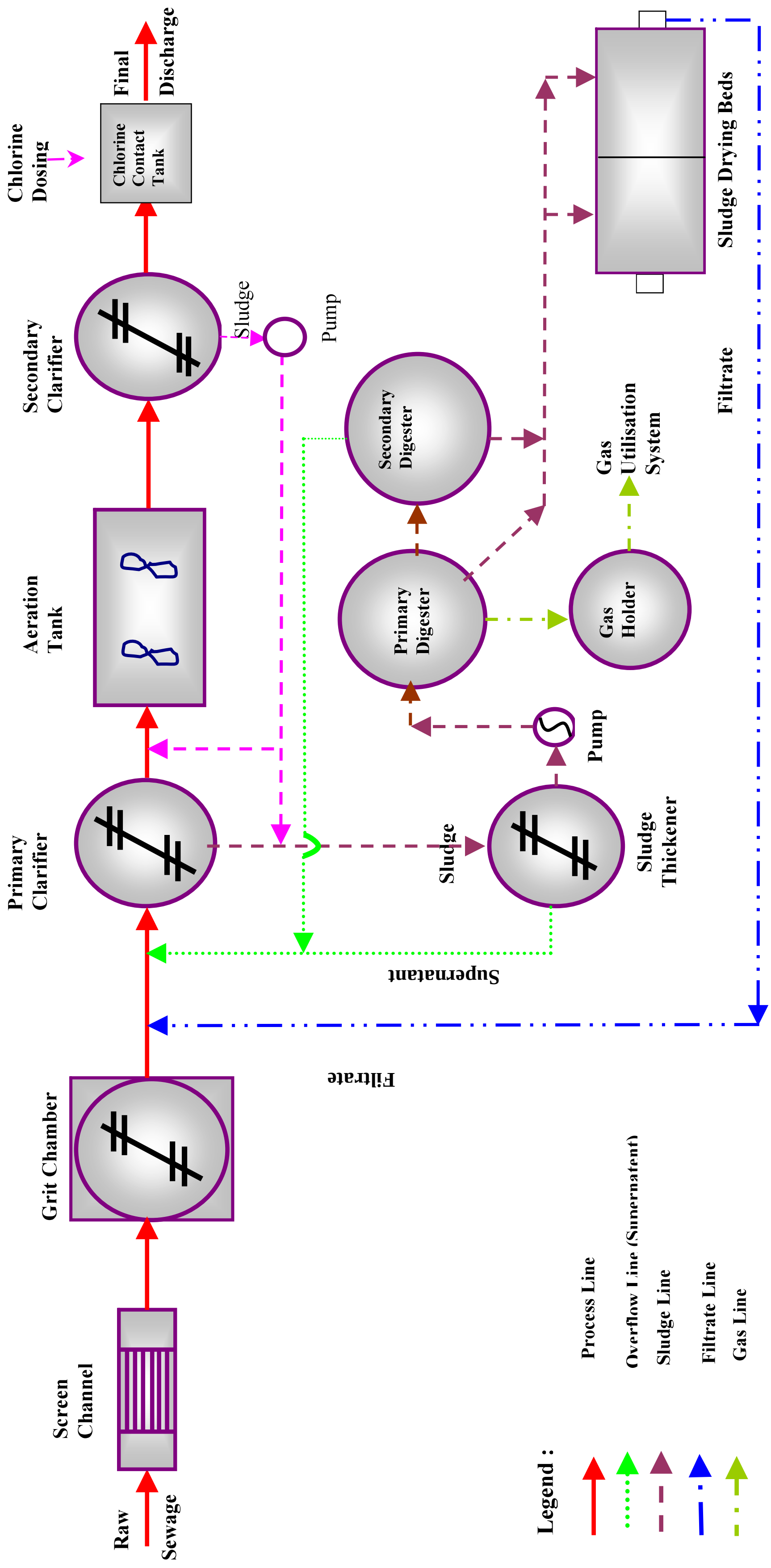
Table 3.8 Design Parameters for AL Followed by Maturation Pond with Chlorination

Sr.	Parameters	Value	Unit
1.	Inlet Chamber		
	Hydraulic retention time (minimum)	30	sec
2.	Fine Screen Channel		
	Clear opening through screen	6	mm
	Minimum approach velocity at average flow	0.3	m/sec
	Minimum velocity through screen at peak flow	0.6	m/sec
	Maximum velocity through screen at peak flow	1.2	m/sec
3.	Grit Chamber		
	Particle size	0.15	mm
	Specific gravity of grit at 20^{o} C	2.65	
	Efficiency	75	%
4.	Aerated lagoon		
	Temperature	20	^{o}C
	HRT	6	days
	D/UL	1.0	
	Minimum power required	0.75	W/cum
	Detention time in settling zone	12.86	hours
5.	Maturation Pond		
	Detention time	2.0	days
6.	Chlorine Mixing Tank		
	Detention time	2	mins
7.	Chlorine Contact Tank		
	Detention time	30	mins

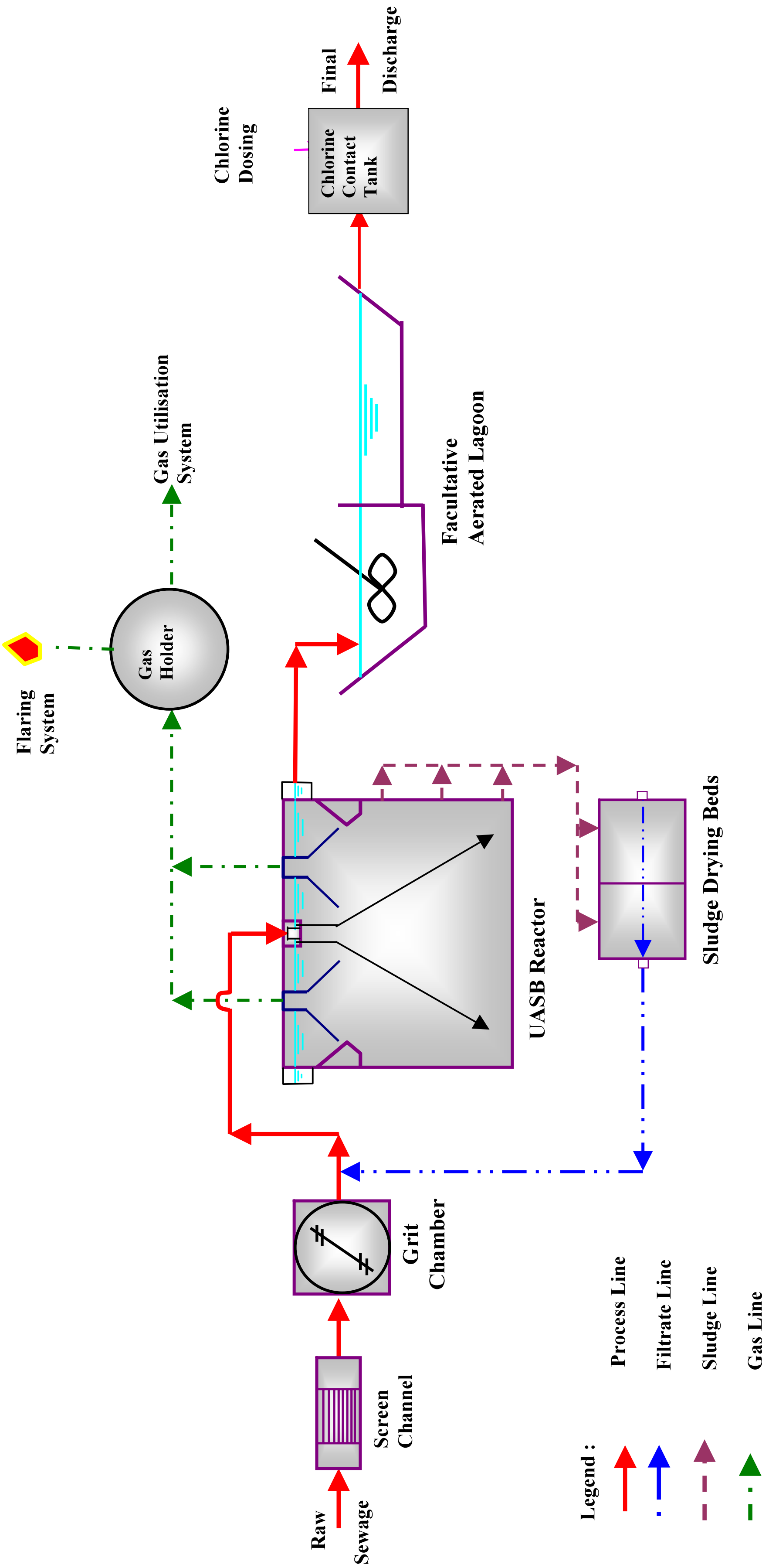
The schematic flow diagram of this alternative is presented in the Figure 3.5.



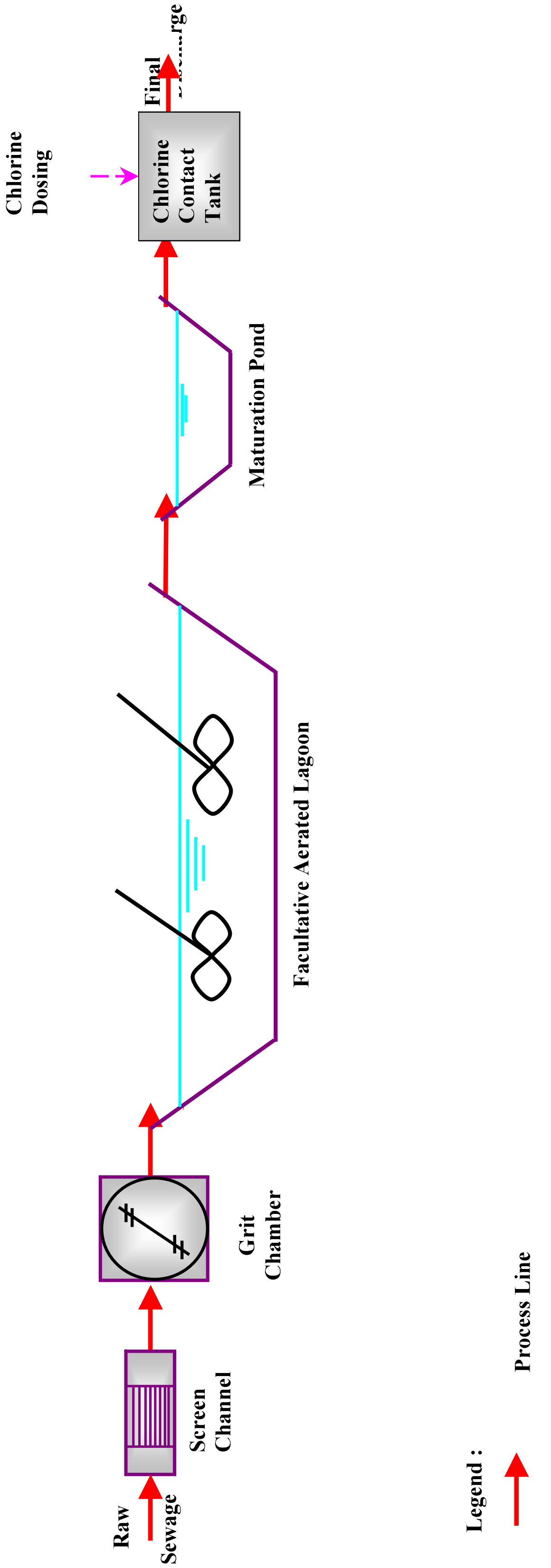
Firgure 3.2 Schematic Flow Diagram of Waste Stabilisation Pond System



Firgure 3.3 Schematic Flow Diagram of Activated Sludge Process



Firgure 3.4 Schematic Flow Diagram of UASB Process + Aerated Lagoon



Firgure 3.5 Schematic Flow Diagram of Aerated Lagoon + Maturation Ponds

3.5.6 Evaluation of Treatment Scheme Alternatives

As discussed, four treatment alternatives have been considered for the proposed 100 mld capacity, in phase I, sewage treatment plant at Mastemau. The cost comparison for the treatment alternatives is presented in Table 3.9.

Table 3.9 Cost Comparison of Treatment Alternatives for 100 mld STP

Sr.	Units	Alternative 1 : Waste Stabilisation Ponds	Alternative 2 : Activated Sludge Process + Chlorination	Alternative 3: UASB + Aerated Lagoon + Chlorination	Alternative 4: Aerated Lagoon + Maturation Pond + Chlorination
I	Qualitative Factors				
a.	Location of land	At Mastemau, south-east of Lucknow	At Mastemau, south-east of Lucknow	At Mastemau, south-east of Lucknow	At Mastemau, south-east of Lucknow
b.	Is land available at existing site for 305 mld STP?	No	Yes	Yes	No
c.	Ease of operation	Comparatively easy	Moderate	Moderate	Moderate
d.	Possibility of biogas production?	No	Yes	Yes	No
e.	Possibility of sludge production?	No	Yes	Yes	No
f.	Treated sewage characteristics: • BOD, mg/l • TSS, mg/l • Faecal coliform, MPN/100ml[4]	<30 <50 <1,000	<30 <50 <1,000	<30 <50 <1,000	<30 <50 <1,000
g.	Likely problem areas • Odour • Seasonal variability • Ground water pollution • Mosquito nuisance potential	High Maximum High High	Moderate Minimum Minimum Moderate	Localized Minimum Moderate Minimal	High Maximum High High
h.	Potential for meeting WHO bacteriological guidelines for irrigation	Suitable for unrestricted irrigation	Suitable for unrestricted irrigation	Suitable for unrestricted irrigation	Suitable for unrestricted irrigation
II	Quantitative Factors				
A.	Cost (Rs.)				
1.	Capital cost				
	Civil cost	384,721,919	268,795,688	235,032,725	170,143,408
	Mechanical cost	7,314,000	73,383,763	27,764,505	58,944,000
	Electrical & instrumentation cost	6,680,496	44,081,060	33,650,403	32,974,220
	Total Civil, E & M Cost	398,716,415	386,260,511	296,447,633	262,061,628
2.	STP utilities	16,790,000	15,765,000	14,580,000	15,340,000
3.	Total Capital Cost (Rs.)	415,506,415	402,025,511	311,027,633	277,401,628
B.	Land Requirement				
	Area required for 100 mld, ha	101.21	20.24	20.00	55.87
	Land cost (Rs.) (@Rs. 2,476,000 per ha)	250,607,287	50,121,457	49,520,000	138,335,223
C.	O & M cost per annum				
1.	Operation Cost				
a.	Manpower	3,247,200	7,611,600	7,611,600	4,570,000
b.	Power	574,740	21,865,788	4,055,544	19,952,964
c.	Chemicals	-	1,488,000	1,488,000	1,488,000
2.	Maintenance Cost				
a.	Civil	1,923,610	5,375,914	1,175,164	3,402,869
b.	Mechanical and electrical & instrumentation	279,890	3,523,945	1,228,299	2,757,547
3.	Total O & M Cost	6,025,440	39,865,247	8,556,607	32,172,180
D.	Summary Cost Analysis				
	Total capital cost including land cost	666,113,702	452,146,968	360,547,633	415,736,851
	O & M cost per year	6,025,440	39,865,247	8,556,607	32,172,180
	Resource recovery*	-	7,780,000	8,720,000	-
	Capitalized Cost (1)	758,739,484	945,375,857	358,035,882	910,302,112
	Ranking	II	IV	I	III
	Capitalized Cost (2)	711,943,678	696,189,908	359,304,853	660,441,010
	Ranking	IV	III	I	II

Note:
+ Source: Finance & Revenue Dept., Govt. of Uttar Pradesh
(1) : Capitalised Cost calculated for 30 years at interest rate of 5%
(2) : Capitalised Cost calculated for 15 years at interest rate of 10%
** : Cost recovered through Resource Recovery is not considered while working out the Capitalised Cost.*

(1) Discussion on the Treatment Options

Each treatment alternative has some positive and some negative aspects to it. These are discussed below with reference to certain key factors.

Process Performance

The treatment schemes proposed under the four alternatives are suitable and technically viable to meet the NRCD guidelines for treated sewage discharge. All the treatment schemes are time tested proven treatment schemes.

Inference

All four treatment processes satisfy the process performance criteria as these will meet the discharge standards as stipulated by NRCD for land irrigation as well as for river discharge.

Seasonal Variability

As regards coliform removal, the performance of the ponds considered in the Alternatives nos. 1 & 4 will be reduced substantially in the winter months due to low temperatures. While in summer months, coliform removal will improve but effluent BOD will increase owing to algae in the effluent. This effect will not be so pronounced in the alternative of UASB followed by aerated lagoon owing to the dampening effect of the UASB. The third alternative will be least affected by seasonal variations.

Inference

The third alternative namely, UASB followed by aerated lagoon with chlorination, is the most suitable treatment process from the seasonal variability aspect as it is least affected by the temperature variations.

Environmental Impact

Ground Water

There is a possibility of ground water contamination in case of first and fourth alternatives due to seepage from the holding area of the ponds although as a precaution all the ponds are proposed to be lined at considerable cost. This possibility is minimum in case of alternative no. 2 as well as alternative no. 3. Since, the aerated lagoon has the least detention time and therefore, least contact surface with the soil. The aerated lagoon will also be lined

Mosquito

Mosquito breeding in the pond is generally caused due to weed growth and marginal vegetation in badly maintained ponds. Fly breeding may be another problem if the ponds are not maintained well. Hence, this problem can occur only in badly maintained ponds, which are more likely, in large size ponds as in alternative nos. 1 & 4.

Odour

In summer months, blue green algae may grow vigorously in the pond, giving rise to floating mats of algae. The algae in the mats may then die and give rise to odours. Some odorous sulphides may also be generated in warmer months. Due to mechanical aeration in the second and third alternatives, odour problem is not foreseen, which could occur in the other alternatives nos. 1 and 4. The UASB may at worst give a slight localised odour problem

Inference

The third alternative of UASB followed by aerated lagoon with chlorination is the most suitable treatment process as it has minimal adverse environmental impact on the population. No odour and mosquito problem is envisaged due to aeration. In comparison to the other alternatives, the holding area of the aerated lagoon, which will also be lined, is very small and there is a minimal possibility of ground water contamination due to seepage.

Land Availability

The available land of 110 hectares is adequate for the alternatives nos. 2, 3 & 4. The land requirement for the alternative no. 1 is higher and found substantially more than the available land.

Inference

The alternative nos. 2, 3 & 4 are feasible treatment process from the land availability viewpoint. However, the land requirement is least in case of alternative nos. 2 & 3.

Resource Recovery

The treatment alternative nos. 2 & 3 only offer the avenue for resource recovery from the sewage treatment. The by-products of ASP and UASB system are biogas and excess sludge. The biogas formed can be utilized as an energy source and the sludge as manure. The operation & maintenance cost can be partly recovered from the sale of these products. This benefit is available with both the second and third treatment alternatives. The other two alternatives do not offer any resource recovery.

Inference

The second and third alternatives are equally beneficial from the resource recovery viewpoint as both generate biogas and sludge, which can partly reduce the operating costs.

Capitalised Costs

The capitalized cost of the treatment alternatives is based on capital cost, O&M cost as well as resource recovery. The costs are annualised for 15 years at an interest rate of 10% and also for 30 years at an interest rate of 5%.

Inference

The third alternative is the least from the capitalised cost viewpoint as it has the lowest present worth in comparison to the other three treatment alternatives.

Recommendation

It can finally be concluded that “Alternative 3: UASB followed by Aerated Lagoon with Chlorination System” is best suited for the proposed 100 mld capacity STP at Mastemau. The process will comply with the all the relevant discharge standards as well as being the most economically viable.

CHAPTER 4

PRELIMINARY DESIGN OF SEWERAGE NETWORK

CHAPTER 4 PRELIMINARY DESIGN OF SEWERAGE NETWORK

Main intercepting sewers are proposed in sewerage Districts III and IV in Master Plan under priority projects. In this section, designs of these sewers are presented.

4.1 SEWERAGE DISTRICT III

The sewerage District III is on the left bank of Gomti River called Trans-Gomti side.

The district is sub-divided into seven separate sewerage zones, each sewerage zone having its gravity sewers and an independent pumping station as follows:

- Zone A: Mohan Meakin area conveying sewage to sanctioned Mohan Meakin PS
- Zone B: Trans core area conveying sewage to existing TGPS
- Zone C: Luniapurwa area conveying sewage to proposed Luniapurwa PS
- Zone D: Hasanganj area conveying sewage to proposed Kukrail No. 2 PS
- Zone E: Vikas nagar area conveying sewage to proposed Kukrail No. 3 PS
- Zone F: Kukrail nala left bank side area conveying sewage to sanctioned Kukrail No. 1 PS
- Zone G: Gomti nagar area conveying sewage to sanctioned Guari MPS

Priority projects defined under Master Plan for this sewerage District III include,

- Rising main from Mohan Meakin PS to Mankameshwar temple road
- Rehabilitation of Trans-Gomti pumping station (TGPS)

Designs and cost estimates of the proposed new gravity sewer i.e. Trans-Gomti trunk sewer (new) instead of the rising main upto TGPS is presented in this section whereas other proposed components of rising main and rehabilitation of pumping station are presented in relevant sections of the report.

While designing these proposed priority projects, all the sanctioned projects under this district are considered.

4.1.1 Review / Collection of Existing Documents

MWH has reviewed following documents while designing the proposed Trans-Gomti trunk sewer (new)

- UPJN-Nala flow measurements 2003, 2004
- UPJN- Revised Project Feasibility Report (PFR) 2001-2002 for GAP II proposals
- UPJN-Gomti Action Plan Detailed Project Report (DPR), Sept 2002
- Census data 2001 for wards administered by Lucknow Municipal Corporation
- Urban Environmental Services Master Plan for Lucknow (1996-2021)
- Sewerage Master Plan for Lucknow prepared by JICA Study Team

4.1.2 Need of Trans-Gomti Trunk Sewer (New)

Trunk sewer investigation of existing Trans-Gomti sewer was carried out and its alignment and levels were studied. The following observations were made during the survey:

- Sewer has been out of use for almost five years, which has resulted in choking of sewer at various locations.
- A part of the sewer, between Chatrasangh Bhawan (Students Union Building) near Hanuman Setu and Colvin Talukedars College is not traceable as new residential colonies have

developed in this area and many new houses are built over the existing alignment.

- The tail end of this sewer falls within the boundary of Colvin Talukedars College. Maintenance inside the college is difficult as the entry is restricted due to security reasons.
- Also, the existing sewer does not have sufficient sewage carrying capacity.

Based on the above, rehabilitation of this sewer line is not found to be a cost effective measure and, hence, it was decided to replace the existing sewer with a new sewer

4.1.3 Master Plan Provisions

According to the master plan, a rising main is proposed from the Mohan Meakin pumping station to the TGPS. Also, Master Plan has proposed the rehabilitation of existing TGTS.

4.1.4 Survey Works Executed

MWH has carried out following survey works on this alignment

- Reconnaissance survey
- Topographical survey

(1) Reconnaissance Survey

A reconnaissance survey was conducted with the JICA Study Team and UPJN officials on October 2004.

(2) Topographical Survey

Topographical survey to ascertain the physical features and ground/ road levels is carried out and is used for design purpose.

4.1.5 Replacement of TGTS

Based on the above observation made during the trunk sewer investigation of existing TGTS, rehabilitation of this sewer line is not found to be a cost effective measure and, hence, it was decided to replace this sewer with a new gravity sewer viz. Trans-Gomti trunk sewer (new), which will start from Mankameshwar temple road to Trans-Gomti pumping station.

Moreover, a rising main is proposed to convey the sewage from Mohan Meakin PS to Mankameshwar temple road where it will discharge its flow into the TGTS (new). The alignment of TGTS (new) will start from Mankameshwar temple road and will terminate at TGPS. In addition to the flow from Mohan Meakin pumping station, it will also carry the flow from the catchment area of the sewer zone B of District III. The combined flow of the Daliganj No. 1 PS and Daliganj No. 2 PS are also proposed to be discharged into the newly proposed Trunk Sewer.

The proposal of rising main in the Master Plan is modified due to the following reasons

a) As per Master Plan, the existing TGTS was proposed to be rehabilitated. However, during the F/S, this proposal was modified due to the reasons specified in Section 4.1.2.
b) To reduce the power cost, length of rising main from Mohan Meakin PS has been reduced and the flow has been accommodate in the new TGTS, which is a gravity sewer.

TGPS, after its rehabilitation will receive flow from TGTS (new) and also from Nishatganj nala, Kedarnath nala and TGPS nala.

4.1.6 Trenchless Options for Trunk Sewer

The selection of a trenchless option for the construction of a part of the proposed Rising main and TGTS (new) will avoid much of the disruption associated with traditional open cut construction. Trenchless construction involves access to the construction works at discrete points along the pipeline route rather than the disruption of a continuous corridor along the route with the requirement for temporary reinstatement and pavement patching. Site management of trenchless process involves the delivery of essential materials to these discrete intervention points in a timely fashion as opposed to the stringing out along the route of pipe and pipe bedding materials. Similarly, the removal of spoil material can be managed in a timely fashion with the attendant avoidance of disruption. However, it should be mentioned here that site management is the key to successful trenchless construction; a poorly organised site and bad practice can be immensely disruptive and damaging to the public interest causing damage to the perception of the implementing authority in a magnitude not dissimilar to open cut construction.

The proposed trunk sewer involves both trenched and trenchless components; the section identified for trenchless construction, presented in Table 4.1, is ideally suited being a deep sewer 3-10m to invert, located under a busy road where trenched construction would be enormously disruptive. The trenched component is also deep where connecting to the trenchless section; special measures should be taken here and for most of the trenched reaches to use modern practice of closed sheeting or trench boxes to minimize trench width and ensure worker safety.

Table 4.1 Trenchless Stretches

Sr.	Name of the stretch	Chainage (meter)	Length (meter)	Diameter (mm)	Physical Condition
Trans-Gomti trunk sewer (new)/Rising Main					
1	Railway under bridge (RM)	0650 - 0750	100	700	Heavy traffic and narrow road
2	Faizabad road crossing (RM)	0750 - 0900	150	700	Heavy traffic and narrow road
3	University road crossing TGTS (new)	3350 - 3450	100	1400	Heavy traffic

(1) Abstract of Cost Estimates for Trenchless Stretches

The Indian society of trenchless technology publishes a schedule of rates for carrying out laying of pipes by trenchless method. The rate for micro-tunnelling in soft soil is Rs. 73,000/m for the size range 600 – 900 mm diameter, Rs. 80,500/m for the size range 900 –1200 mm and Rs. 88,000/m for the size range 1200 – 1500 mm. These figures suggest a projection range up to 2400 mm of about Rs. 110,500/m. However, these schedules are for guidance only and the rates are not based on actual implementation in India. There is very limited experience of these techniques in India.

Such information available through experience from similar works carried out by contractors viz. AJECT, Michigan Engineers and Cherrington. AJECT have undertaken micro-tunnelling works in Mumbai, approximately of 4 km of trenchless work is carried out with at an average price of Rs. 80,000/m plus Rs. 11,000 for pipes. Michigan has undertaken another project with Iseki Uncle Mole in Calcutta and using soft soil auger bores. Cherrington have installed 900 mm steel pipe in soft soil as sewer for Delhi Jal Board at approximately Rs. 55,000/m.

Based on this unit cost, the total cost for trenchless technology has been estimated and the same is presented in Table 4.2.

Table 4.2 Abstract of Cost Estimates for Trenchless Sections of Rising Main & TGTS (new)

Sr.	Name of the stretch	Chainage (meter)	Length (meter)	Diameter (mm)	Rate (Rs./m)	Amount (Rs.)
Cis-Gomti relief sewer						
1	Railway under bridge (RM)	0650 - 0750	100	700	73,000	7,300,000
2	Faizabad road crossing (RM)	0750 - 0900	150	700	73,000	10,950,000
3	University road crossing (TGTS new)	3350 - 3450	100	1400	88,000	8,800,000
	Total					27,050,000

A detailed methodology on laying of sewers using trenchless technology is presented in Appendix A4.1.

4.1.7 Design Engineering Works

Design and cost estimates for proposed TGTS (new), are presented in the following sections.

(1) Design Population and Flows

Ward-wise population figures, finalised under Master Plan, are considered for design of the gravity sewer lines. Based on the topography of the project area and the surveys conducted, the alignment of the gravity sewer line has been finalised. Nodal populations contributing to the flows on the nodes are derived considering the catchment areas considered in the Master Plan and the general topography.
A summary table presenting the contributing population for year 2015 and 2030 along with the sewage conveyed is presented in Table 4.3.

Table 4.3 Catchment Details of TGTS (new)

Gravity Sewer	Year 2015		Year 2030	
	Population Covered	Average Flow (mld)	Population Covered	Average Flow (mld)
Trans-Gomti trunk sewer (new)	192,860	32.1	293,260	45.50

(2) Design of Trans-Gomti Trunk Sewer (new)

Design of the TGTS (new) is presented in Table 4.5.

Catchment area of the TGTS (new) is presented in drawing no. LKO-CA-TG. The sewer line is designed for year 2030.

Table 4.4 Details of Pipe Requirement in Sewerage District III

Diameter (mm)	Length (m)
TGTS (new)	
1300 NP_3 class	875
1400 NP_3 class	1,900
1600 NP_3 class	450
Total length	3,225

Table 4.5 Hydraulic Design of TGTS (new)

Sr No	From	To	Popln_Line	Popln_Branch	Nodal Popln	Cumulative Population	Nodal Flow	Cumulative Nodal Flow	Peak Factor	Peak Flow	Dia Recomended	Slope	Qa/Qf	d/D
							M^3/sec	M^3/sec		M^3/sec	mm	1 in		
1	TG_N1	TG_N2	1852	221701	223553	223553	0.401	0.401	2.25	0.9024	1300	1600	0.75	0.72
2	TG_N2	TG_N3	2351		2351	225904	0.004	0.405	2.25	0.9119	1300	1600	0.75	0.72
3	TG_N3	TG_N4	2076	14772	16848	242752	0.030	0.435	2.25	0.9799	1300	1600	0.81	0.76
4	TG_N4	TG_N5	2735		2735	245487	0.005	0.440	2.25	0.9909	1400	1800	0.71	0.70
5	TG_N5	TG_N6	7233		7233	252720	0.013	0.453	2.25	1.0201	1400	1800	0.73	0.71
6	TG_N6	TG_N7	5708		5708	258428	0.010	0.464	2.25	1.0431	1400	1800	0.75	0.72
7	TG_N7	TG_N8	1017	17630	18647	277075	0.033	0.497	2.25	1.1184	1400	1800	0.80	0.76
8	TG_N8	TG_N9	996		996	278071	0.002	0.499	2.25	1.1224	1400	1800	0.81	0.76
9	TG_N9	TG_N10	2623	7297	9920	287991	0.018	0.517	2.25	1.1625	1600	2150	0.64	0.65
10	TG_N10	TG_PS	5271		5271	293262	0.009	0.526	2.25	1.1837	1600	2150	0.65	0.66

4.1.8 Cost Estimates

Cost estimate of TGTS (new) are presented in Table 4.6.

Table 4.6 Cost Estimate of TGTS (new)

Sr.	Items	Units	Rate (Rs.)	Quantity	Amount (Rs.)
1	Excavation				
(a)	Excavation for depth up to 1.5 m below G.L for laying Sewer manholes ordinary soil (earth, sand loam and clay) including cutting of joints pits ramming dressing) levelling, refilling of trenches in 20 cm layer watering and ramming the same including removal of surplus earth or other dismantled material upto a distance of 50 m. from the centre of trenches.				
	(a) 0 to 1.5 m depth	cum	61	12,757	778,177
	(b) 1.5 to 3 m depth	cum	75	11,596	869,700
	(c) 3 to 4.5 m depth	cum	93	9,704	902,472
	(d) 4 .5to 6 m depth	cum	107	6,773	724,711
	(e) 6.0 to 7.5 m depth	cum	140	5,598	783,720
	(f) 7.5m to 9.0 m depth	cum	184	1,900	349,600
	(g) 9.0m to 10.5 m depth	cum	240	1,021	245,040
(b)	Same as item 1a but excavation in soil mixed with kankar and boulders				
	(a) 0 to 1.5 m depth	cum	294	3,190	937,860
	(b) 1.5 to 3 m depth	cum	338	2,899	979,862
	(c) 3 to 4.5 m depth	cum	393	2,426	953,418
	(d) 4 .5to 6 m depth	cum	452	1,694	765,688
	(e) 6.0 to 7.5 m depth	cum	541	1,400	757,400
	(f) 7.5m to 9.0 m depth	cum	663	475	314,925
	(g) 9.0m to 10.5 m depth	cum	813	256	208,128
2	Shuttering				
(a)	Provide and fix close timbering in trenches for the depth up to 3 m o 3m below G.L consisting of 40 mm thick approved country wood plank for polling board 125 x 75 mm Indian Sal wood walers and 100 mm dia sal wood ballies for shutting at 1.50m C/C including removal after laying of sewers (both sides of trenches) will be taken as one side for the purpose of payment and measurement i.e. area equals to Length x depth of trenches, Dismantled, timbering material will be the property of the Contractor. Details of cost for 30 m and 3 m deep trench i.e. 90 Sq M (M2) area of timbering				
	0 to 3 m	sqm	176	4,838	851,488
	3 to 6 m	sqm	224	3,717	832,608
(b)	Same as item no.1 but timbering left in trenches (unused timbering) 0 to 3 m				
	6 to 9 m	sqm	1,392	1,144	1,592,448
	9 to 12 m	sqm	1,600	169	270,400
(c)	Same as item no.1 but timbering left in trenches (used timbering) 0 to 3 m				
	6 to 9 m	sqm	584	763	445,592
	9 to 12 m	sqm	670	113	75,710
3	Supply of following sizes of RCC spigotted and socketed non pressure pipes				
	(m) 1300 mm dia in 1.25 m length	m	5,191	875	4,542,125
	(n) 1400 mm dia in 1.25 m length	m	5,927	1,900	11,261,300

Sr.	Items	Units	Rate (Rs.)	Quantity	Amount (Rs.)
	(o) 1600 mm dia in 1.25 m length	m	7,652	450	3,443,400
4	Laying Jointing of RCC Hume pipe				
	Carting following sizes of R.C.C Hume pipe (NP3 Class Socket /spigoted rubber ring jointed and specials from store to the work lowering the same in to the trenches in depth upto 1.5m below G.L true to alignment including excavation of earth below G.L invert level of pipe, cost of all jointing material, testing etc, complete but excluding excavation and refilling of trenches from ground level to the invert level of pipe. (300 mm dia)				
	Rate per meter at different Depth				
	1300 mm dia pipe	m			
	(b) 1.5 - 3.00 m		1,485	875	1,299,375
	1400 mm dia pipe	m			
	(c) 3.0 - 4.50 m		1,771	60	106,260
	(d) 4.5 - 6.0 m		1,891	60	113,460
	(e) 6.0 - 7.5 m		2,061	1,345	2,772,045
	(f) 7.5 - 9.0 m		2,289	240	549,360
	(g) 9.0 - 10.50m		2,563	195	499,785
	1600 mm dia pipe				
	(e) 6.0 - 7.5 m		2,484	380	943,920
	(f) 7.5 - 9.0 m		2,760	70	193,200
5a	Sand filling				
	Sand filling including supply of all materials labour T & P etc required for proper completion of work rate as per building schedule (below ground level)	cum			
	(b) 3.0 m to 4.5 m	cum	218	874	190,532
	(c) 4.50 m to 6.0 m	cum	232	118	27,376
	(d) 6.0 m to 7.5 m	cum	253	118	29,854
	(e) 7.5 m to 9.0 m	cum	281	118	33,158
	(f) 9.0 m- 10.50m	cum	315	118	37,170
5b	PCC				
	Cement concrete work in bedding with cement, coarse sand and 20 mm gauge approved stone ballast (1:2:4) including supply of all materials, labour, T & P etc, required for the proper completion of work. (below ground level)	cum			
	(d) 6.0 m to 7.5 m	cum	3,264	1,081	3,528,384
	(e) 7.5 m to 9.0 m	cum	3,626	73	264,698
6	RCC	cum	3,989	305	1,216,645
7	Constructing Vent shafts	Nos.	16,000	7	112,000
6	Construction of Scrapper manhole 2.43x1.53				
	up to depth 4.57m	Nos.	80,318	25	2,007,950
	upto depth 9.14m	m	14,189	59	837,151
	upto depth 14.0 m	m	22,040	3	66,120
9	Construction of Manhole dia 1.82m				
	upto depth 2.28m (type C1)	Nos.	26,914	24	645,936
	upto depth 5.03m (type C2)	m	8,715	39	339,885
10	Construction of Manhole dia 2.43x1.53				
	upto depth 4.57m (type C1)	Nos.	68,200	62	4,228,400
	upto depth 9.14m (type C2)	m	15,539	203	3,154,417
	upto depth 14.00 m (type C3)	m	22,136	9	199,224
11	Road restoration				
	Dismantling of tar road for laying sewer including shorting out and stacking serviceable materials and disposal of unserviceable materials upto distance of 60 m and its rein statement after filling and proper compaction	sqm	1,250	11,149	13,936,250

Sr.	Items	Units	Rate (Rs.)	Quantity	Amount (Rs.)
	of trenches.				
12	Shifting of Electric and telephone cables				
	Provision for shifting and reinstatement of electric and telephone cable etc. during excavation and laying of sewer lines	LS			250,000
13	Shifting of Temporary water supply lines				
	Provision for temporary shifting of existing sewers and water supply falling in the alignment of conveying main during excavation and the restoring utilities/ services to its original condition	LS			250,000
14	Provision for laying of sewer by trenchless technology	As per Table 4.2			27,050,000
	Total cost				97,768,327 **(97,768,000)**

4.2 SEWERAGE DISTRICT IV

The sewerage District IV is on the right bank of Gomti River, which is called Cis-Gomti side and includes the old city core area with an old sewerage network. The area extends upto Sarda Canal on south and the Municipal boundary on the east. The district is sub-divided into four separate sewerage zones, each sewerage zone having its gravity sewers and an independent pumping station as follows:

- Zone H: The core city area along the Gomti River conveying sewage to existing CGPS
- Zone I: The core city area is proposed to be conveyed by new Cis-Gomti Relief Sewer
- Zone J: GH canal area conveying sewage to sanctioned GH canal pumping station
- Zone K: Arjunganj-Telibagh area where sewage will be conveyed by new proposed sewer.

Priority projects defined under Master Plan for this sewerage District IV include,

a) Rehabilitation of existing old Cis-Gomti trunk sewer
b) Provision of Cis-Gomti relief sewer
c) Pumping station at Martinpurwa
d) Conveyance main from Martinpurwa pumping station to Mastemau STP on Sultanpur road
e) Terminal sewage pumping station and STP at Mastemau

Designs and cost estimates of the proposed new gravity sewer i.e. Cis-Gomti relief sewer and conveyance main from Martinpurwa to Mastemau STP are presented in this section whereas other components including Rehabilitation of existing sewers, pumping stations and STP are presented in relevant sections of the report.

While designing these proposed priority projects, all the sanctioned projects under this district are considered.

4.2.1 Review / Collection of Existing Documents

MWH has reviewed following documents while designing the proposed Cis-Gomti relief sewer

- UPJN-Nala flow measurements 2003, 2004
- UPJN- Revised Project Feasibility Report (PFR) 2001-2002 for GoAP II proposals
- UPJN-Gomti Action Plan Detailed Project Report (DPR), Sept 2002
- Census data 2001 for wards administered by Lucknow Municipal Corporation
- Urban Environmental Services Master Plan for Lucknow (1996-2021)
- Sewerage Master Plan for Lucknow prepared by JICA Study Team

4.2.2 Need of Cis-Gomti Relief Sewer

The hydraulic capacity of the existing Cis-Gomti trunk sewer (CGTS) is found less than the required capacity to carry sewage generated in the core city area. It is proposed to reduce the sewage load from the existing CGTS and to lay another interceptor sewer viz. Cis-Gomti Relief Sewer (CGRS). It is not feasible to lay this relief sewer on the same route of CGTS so a new route is proposed which is on the upstream side of the intercepted nalas on CGTS. Detailed investigation and rehabilitation works are proposed for the existing CGTS and are presented in the relevant section of this report.

The proposed CGRS will convey sewage generated in zone I of sewerage District IV. Also, the following nalas are intercepted and diverted to CGRS before their termination point. However the d/s side of the interception & diversion of these nalas will continue to flow into the existing CGTS.

- Pata nala
- Wazirganj nala
- Ghasiyari mandi nala

The sewage will be conveyed to the proposed new Martinpurwa pumping station from where it will be conveyed to the proposed Mastemau STP.

4.2.3 Need of Sultanpur Road Trunk Sewer

A rising main from Martinpurwa pumping station is proposed upto Dilkusha crossing on Sultanpur road. The sewage from Dilkusha crossing is conveyed to Mastemau STP through proposed gravity sewer on Sultanpur road. The gravity sewer will also collect sewage from Arjunganj and its nearby villages and convey the same to Mastemau STP.

4.2.4 Master Plan Provisions

The provision made in the feasibility report is in line with the Master Plan provisions except that rerouting is proposed in certain stretches of Cis-Gomti relief sewer.

4.2.5 Survey Works Executed

MWH has carried out following survey works on this alignment

- Reconnaissance survey
- Topographical survey
- Geo technical survey

(1) Reconnaissance Survey of Cis-Gomti Relief Sewer

Reconnaissance survey along the proposed alignment was carried out, starting from the Medical university crossing to the proposed location of Martinpurwa pumping station. Some of the important location along the proposed alignment include Medical university crossing, Medical university gate, Jagat narain road, Nagar Nigam office, Capital cinema, GPO, Hazrat ganj crossing (Allahabad Bank), Park road, Zoo boundary, GH canal crossing and golf club.

At Sarkata Nala B, LNN has plans to construct a desilting facility. Feasibility of tapping this nala and to convey sewage flowing through this nala to the proposed Cis-Gomti Relief Sewer was examined. It was found that the provision of tapping this nala on the downstream exists and the intercepted sewage from this nala is conveyed to the existing STP at Daulatganj. It was also found that intercepting this nala at the starting point of the proposed relief sewer would also necessitate the additional pumping station resulting in higher capital and operation and maintenance costs.

The proposed alignment of the relief sewer runs through various congested stretches where laying of sewer may only be possible with trenchless method. Laying of sewer with trenchless method is proposed at the following locations.

a) Medical university crossing
b) Medical university gate
c) Rail under bridge near city station
d) Kaisarbag bus station crossing
e) Kaisarbag crossing
f) Lalbag crossing
g) Hazratganj crossing
h) Park road and
i) GH canal

(2) Reconnaissance Survey of Sultanpur Road Trunk Sewer

Reconnaissance survey was carried out from Martinpurwa pumping station upto Mastemau STP. During the survey, it was found that the rising main may be necessary upto Dilkusha crossing and thereafter a gravity sewer can be proposed. At two locations, this sewer needs to cross natural depressions (nala crossings) wherein steel bridges need to be proposed. Also, laying of rising main/sewer by trenchless method is proposed at two location viz. railway crossing near Martinpurwa and another railway crossing near Mohanganj village.

(3) Topographical Survey

Topographical survey on this alignment was carried out from Medical university crossing to the proposed Martinpurwa pumping station and from thereafter upto the proposed STP site at Mastemau.

(4) Geotechnical Survey

Eight boreholes of 10 m depth have been bored in this alignment to create the geo technical data for design purpose. The details of the geo technical data have been submitted in the geo technical report.

4.2.6 Evaluation of Alternatives and Selection of Scheme

The feasibility of interception of dry weather flow of Sarkata nala and diverting it into the relief sewer was evaluated and was found infeasible due to requirement of additional pumping station for which sufficient space is not available. Therefore, it was decided to start the alignment of relief sewer from Medical university crossing where the flow from next nala, which is Pata nala, can be intercepted.

Possibility of diverting sewage from CGTS to Cis-Gomti relief sewer by gravity was also evaluated, which was found feasible. However, the option of diverting the flow to existing CGPS was selected as the proposal of augmentation of CGPS and diverting this flow to proposed STP at Kakraha has been sanctioned and is under process of implementation.

4.2.7 Trenchless Options for Trunk Sewer

On relief trunk sewer, following stretches are identified where laying of sewer will be carried out by trenchless method.

Table 4.7 Trenchless Stretches on Relief Trunk Sewer

Sr.	Name of the stretch	Chainage (meter)	Length (meter)	Diameter (mm)	Physical Condition
Cis-Gomti relief sewer					
1	Pata Nala Junction	0 – 30	30	1200	Heavy traffic
2	Medical university crossing	250 – 350	100	1200	Heavy traffic
3	Rail under bridge	800 – 1,100	300	1400	Heavy traffic and narrow road
4	Kaisarbag bus station crossing	2,650 – 2,750	100	1800	Heavy traffic
5	Kaisarbag crossing	3,100 – 3,300	200	1800	Heavy traffic
6	Lalbag junction	3,800 – 3,950	150	1800	Heavy traffic
7	Hazratganj junction – part 1	4,300 – 4,700	400	1800	Heavy traffic
8	Hazratganj junction – part 2	4,900 – 5,350	450	2200	Heavy traffic and narrow road
9	GH canal	5,350 – 5,500	150	2200	Canal crossing
Rising main from Martinpurwa PS to Dilkusha Crossing					
10	Railway crossing near Martinpurwa	7,150 – 7,300	150	1200	Railway line crossing
Sultanpur road trunk sewer					
11	Railway crossing in Sultanpur road	9,650 – 9,750	100	2400	Railway line crossing

(1) Abstract of Cost Estimates for Trenchless Stretches

The Indian society of trenchless technology publishes a schedule of rates for carrying out laying of pipes by trenchless method. The rate for micro-tunnelling in soft soil is Rs. 73,000/m for the size range 600 – 900 mm diameter, Rs. 80,500/m for the size range 900 –1200 mm and Rs. 88,000/m for the size range 1200 – 1500 mm. These figures suggest a projection range up to 2400 mm of about Rs. 110,500/m. However, these schedules are for guidance only and the rates are not based on actual implementation in India. There is very limited experience of these techniques in India.

Such information available through experience from similar works carried out by contractors viz. AJECT, Michigan Engineers and Cherrington. AJECT have undertaken micro-tunnelling works in Mumbai, approximately of 4 km of trenchless work is carried out with at an average price of Rs. 80,000/m plus Rs. 11,000 for pipes. Michigan has undertaken another project with Iseki Uncle Mole in Calcutta and using soft soil auger bores. Cherrington have installed 900 mm steel pipe in soft soil as sewer for Delhi Jal Board at approximately Rs. 55,000/m.

Based on this unit cost, the total cost for trenchless technology has been estimated and the same is presented in Table 4.8.

Table 4.8 Abstract of Cost Estimates for Trenchless Sections of Relief Trunk Sewer

Sr.	Name of the stretch	Chainage (m)	Length (m)	Diameter (mm)	Rate (Rs./m)	Amount (Rs.)
Cis-Gomti relief sewer						
1	Pata Nala Junction	0 –30	30	1200	80,500	2,415,000
2	Medical university crossing	050 – 050	100	1200	80,500	8,050,000
3	Rail Under Bridge	000 – 1100	300	1400	96,800	29,040,000
4	Kaisarbag bus station crossing	2,650 – 2,750	100	1800	107,800	10,780,000
5	Kaisarbag crossing	3,100 – 3,300	200	1800	107,800	21,560,000
6	Lalbag junction	3,800 – 3,950	150	1800	107,800	16,170,000
7	Hazratganj junction – part 1	4,300 – 4,700	400	1800	107,800	43,120,000
8	Hazratganj junction – part 2	4,900 – 5,350	450	2200	116,050	52,222,500
9	GH canal	5,350 – 5,500	150	2200	116,050	17,407,500
Total						200,765,000
Rising main from Martinpurwa PS to Dilkusha Crossing						
10	Railway crossing near Martinpurwa	7,150 – 7,300	150	1200	80,500	12,075,000
Sultanpur road trunk sewer						
11	Railway crossing in Sultanpur Road	9,650 – 9,750	1080	2400	121,550	12,155,000

A detailed methodology on laying of sewers using trenchless technology is presented in Appendix A4.1.

4.2.8 Design Engineering Works

Designs of Cis-Gomti relief sewer and the conveyance main from Martinpurwa pumping station are presented under this section, which fall in sewerage District IV.

(1) Design Population and Flows

Ward wise population figures finalised under Master Plan are considered for design of the gravity sewer lines. Based on the topography of the project area and the surveys conducted, the alignment of the gravity sewer line has been finalised. Nodal populations contributing to the flows on the nodes are derived considering the catchment areas considered in the Master Plan and the general topography. A summary table presenting the contributing population for year 2015 and 2030 along with the sewage conveyed is presented in Table 4.9.

Table 4.9 Catchment Details of Cis-Gomti Relief Sewer and Sultanpur Road Trunk Sewer

Gravity Sewer	Year 2015		Year 2030	
	Population Covered	Average Flow (mld)	Population Covered	Average Flow (mld)
Cis-Gomti relief sewer	417,685	77.4	796,961	123.5
Conveyance main from Martinpurwa PS to Mastemau STP (Sultanpur road trunk sewer)	472,144	87.3	891,259	138.2

(2) Design of Cis-Gomti Relief Sewer

Design of the CGRS is presented in Table 4.10.

Catchment area of the CGRS sewer is presented in Drawing No.LKO-CA-RTS. The sewer line is designed for year 2030 for which flow from the catchment area of CGTS is also considered. The design has been checked for flows in year 2015 for which flow from CGTS is not considered, as the flow of CGTS shall be diverted to the Kakraha STP as per the sanctioned projects of UPJN and provisions in Master Plan.

Provision of trenchless technology is made at few locations where open cut excavation is found not feasible. These locations where trenchless technology is provided are presented in drawing No.LKO-TT-1.

(3) Designs of the Sultanpur Road Trunk Sewer

Design of the Sultanpur road trunk sewer is presented in Table 4.11.

The capacity of proposed pumping has been determined from the flows reaching pumping station through CGRS. A rising main is proposed from the pumping station up to Sultanpur road (Dilkusha crossing) then gravity main is proposed up to terminal pumping station at Mastemau STP site.

Provision of steel bridges is made at two locations for crossing of culverts on the Sultanpur road.

In feasibility study stage (for year 2015), the conveyance main from Sultanpur Road Trunk Sewer has been designed for the catchment area of Cis Gomti Relief Trunk Sewer and for the flow diverted from LaMarteniere Nala, which amounts to around 138 mld. For the year 2030, the flow from this PS is expected to be around 250 mld, for which a parallel sewer has been proposed. Furthermore, an option of laying a single sewer was evaluated and it is found that it is not possible to achieve the self-cleansing velocity during the period 2015.

Table 4.10 Hydraulic Design CGRS

Sr No	From	To	Popln_ Line	Popln_B ranch	Nodal Popln	Cumulative Population	Nodal Flow	Cumulative Nodal Flow	Peak Factor	Peak Flow	Dia Recomended	Slope	Qa/Qf	d/D	v/V
							M3/sec	M3/sec		M3/sec	mm	1 in			
1	RTS_N1	RTS_N2	2693	37731	40424	40424	0.073	0.073	2.50	0.181	700	800	0.55	0.59	0.88
2	RTS_N2	RTS_N3	5249	0	5249	45673	0.009	0.082	2.50	0.205	700	800	0.62	0.64	0.92
3	RTS_N3	RTS_N4	318	0	318	45991	0.001	0.083	2.50	0.206	700	800	0.63	0.64	0.92
4	RTS_N4	RTS_N5	614	100686	101300	147291	0.182	0.264	2.25	0.595	1200	1800	0.65	0.65	0.92
5	RTS_N5	RTS_N6	567	8389	8956	156247	0.016	0.280	2.25	0.631	1200	1800	0.68	0.68	0.94
6	RTS_N6	RTS_N7	809	1989	2798	159045	0.005	0.285	2.25	0.642	1400	2000	0.49	0.55	0.85
7	RTS_N7	RTS_N8	380	1167	1547	160592	0.003	0.288	2.25	0.648	1400	2000	0.49	0.55	0.85
8	RTS_N8	RTS_N9	157	0	157	160749	0.000	0.288	2.25	0.649	1400	2000	0.49	0.55	0.85
9	RTS_N9	RTS_N10	157	7241	7398	168147	0.013	0.302	2.25	0.679	1400	2000	0.51	0.57	0.87
10	RTS_N10	RTS_N11	1742	5772	7514	175661	0.013	0.315	2.25	0.709	1400	2000	0.54	0.58	0.88
11	RTS_N11	RTS_N12	2183	79871	82054	257715	0.147	0.462	2.25	1.040	1800	2500	0.45	0.53	0.84
12	RTS_N12	RTS_N13	485	8644	9129	266844	0.016	0.479	2.25	1.077	1800	2500	0.47	0.54	0.84
13	RTS_N13	RTS_N14	259	1217	1476	268320	0.003	0.481	2.25	1.083	1800	2500	0.47	0.54	0.84
14	RTS_N14	RTS_N15	207	0	207	268527	0.000	0.482	2.25	1.084	1800	2500	0.47	0.54	0.84
15	RTS_N15	RTS_N16	570	33018	33588	302115	0.060	0.542	2.25	1.219	1800	2500	0.53	0.58	0.88
16	RTS_N16	RTS_N17	128	15897	16025	318140	0.029	0.571	2.25	1.284	1800	2500	0.56	0.60	0.89
17	RTS_N17	RTS_N18	994	18294	19288	337428	0.035	0.605	2.25	1.362	1800	2500	0.59	0.62	0.90
18	RTS_N18	RTS_N19	577	4720	5297	342725	0.010	0.615	2.25	1.383	1800	2500	0.60	0.62	0.90
19	RTS_N19	RTS_N20	801	2532	3333	346058	0.006	0.621	2.25	1.397	1800	2500	0.61	0.63	0.91
20	RTS_N20	RTS_N21	102	2266	2368	348426	0.004	0.625	2.25	1.406	1800	2500	0.61	0.63	0.91
21	RTS_N21	RTS_N22	293	0	293	348719	0.001	0.626	2.25	1.408	1800	2500	0.61	0.63	0.91
22	RTS_N22	RTS_N23	91	293	384	349103	0.001	0.626	2.25	1.409	1800	2500	0.61	0.63	0.91
23	RTS_N23	RTS_N24	229	10065	10294	359397	0.018	0.645	2.25	1.451	1800	2500	0.63	0.64	0.92
24	RTS_N24	RTS_N25	1648	405739	407387	766784	0.731	1.376	2.00	2.751	2200	3000	0.77	0.73	0.97
25	RTS_N25	RTS_N26	0	15050	15050	781834	0.027	1.403	2.00	2.805	2200	3000	0.78	0.74	0.97
26	RTS_N26	RTS_N27	0	0	0	781834	0.000	1.403	2.00	2.805	2200	3000	0.78	0.74	0.97
27	RTS_N27	RTS_N28	0	0	0	781834	0.000	1.403	2.00	2.805	2200	3000	0.78	0.74	0.97
28	RTS_N28	RTS_N29	0	0	0	781834	0.000	1.403	2.00	2.805	2200	3000	0.78	0.74	0.97
29	RTS_N29	RTS_N30	338	7635	7973	789807	0.014	1.417	2.00	2.834	2200	3000	0.79	0.74	0.97
30	RTS_N30	RTS_N31	173	426	599	790406	0.001	1.418	2.00	2.836	2200	3000	0.79	0.75	0.98
31	RTS_N31	RTS_N32	995	5274	6269	796675	0.011	1.429	2.00	2.858	2200	3000	0.80	0.75	0.98
32	RTS_N32	RTS_PS	286	0	286	796961	0.001	1.430	2.00	2.859	2200	3000	0.80	0.75	0.98

Table 4.11 Hydraulic Desing of Sultanpur Road Trunk Sewer

From	To	Popln_Line	Popln_Branch	Nodal Popln	Cumulative Population	Sewage Collection Demand	Nodal Flow	Nodal Flow	Cumulative Nodal Flow	Peak Factor	Peak Flow	Dia Recomended	Slope	Qa/Qf
						LPCD	LPD	M3/sec	M3/sec		M3/sec	mm	1 in	
STS_N1	STS_N2	0	796961	796961	796961	155	123528955	1.430	1.430	2.00	2.859	2400	3000	0.63
STS_N2	STS_N3	9409	0	9409	806370	155	1458395	0.017	1.447	2.00	2.893	2400	3000	0.64
STS_N3	STS_N4	0	0	0	806370	155	0	0.000	1.447	2.00	2.893	2400	3000	0.64
STS_N4	STS_N5	0	0	0	806370	155	0	0.000	1.447	2.00	2.893	2400	3000	0.64
STS_N5	STS_N6	0	0	0	806370	155	0	0.000	1.447	2.00	2.893	2400	3000	0.64
STS_N6	STS_N7	84889	0	84889	891259	155	13157795	0.152	1.599	2.00	3.198	2400	3000	0.71
STS_N7	STS_N8	0	0	0	891259	155	0	0.000	1.599	2.00	3.198	2400	3000	0.71
STS_N8	STS_N9	0	0	0	891259	155	0	0.000	1.599	2.00	3.198	2400	3000	0.71
STS_N9	STS_N10	0	0	0	891259	155	0	0.000	1.599	2.00	3.198	2400	3000	0.71
STS_N10	STS_N11	0	0	0	891259	155	0	0.000	1.599	2.00	3.198	2400	3000	0.71
STS_N11	STS_N12	0	0	0	891259	155	0	0.000	1.599	2.00	3.198	2400	3000	0.71
STS_N12	STS_N13	0	0	0	891259	155	0	0.000	1.599	2.00	3.198	2400	3000	0.71
STS_N13	STS_N14	0	0	0	891259	155	0	0.000	1.599	2.00	3.198	2400	3000	0.71
STS_N14	STS_N15	0	0	0	891259	155	0	0.000	1.599	2.00	3.198	2400	3000	0.71
STS_N15	STS_PS	0	0	0	891259	155	0	0.000	1.599	2.00	3.198	2400	3000	0.71

Table 4.12 Details of Pipe Requirement for Cis-Gomti Relief Sewer and Sultanpur Road Trunk Sewer

Diameter (mm)	Length of Pipe (meter)	
	NP3	NP4
CGRS		
1200	650	-
1400	1,250	-
1800	-	2,750
2200	-	2,300
Sultanpur road gravity sewer		
2400	-	7,450
Total length	1,900	13,500

(4) Abstract of Cost Estimates of Cis-Gomti Relief Sewer

The abstract of cost estimates of Cis-Gomti Relief Sewer is presented in Table 4.13.

Table 4.13 Abstract of Cost Estimates of Cis-Gomti Relief Sewer

Sr.	Items	Units	Rate (Rs.)	Quantity	Amount (Rs.)
1	Excavation				
(a)	Excavation for depth up to 1.5 m below G.L for laying Sewer manholes ordinary soil (earth, sand loam and clay) including cutting of joints pits ramming dressing) levelling, refilling of trenches in 20 cm layer watering and ramming the same including removal of surplus earth or other dismantled material upto a distance of 50 m. from the centre of trenches.				
	(a) 0 to 1.5 m depth	cum	61	33,539	2,045,879
	(b) 1.5 to 3 m depth	cum	75	31,037	2,327,775
	(c) 3 to 4.5 m depth	cum	93	28,535	2,653,755
	(d) 4 .5to 6 m depth	cum	107	25,694	2,749,258
	(e) 6.0 to 7.5 m depth	cum	140	19,063	2,668,820
	(f) 7.5m to 9.0 m depth	cum	184	11,104	2,043,136
	(g) 9.0m to 10.5 m depth	cum	240	3,332	799,680
	(h) 10.5m to 12.00 m depth	cum	312	602	187,824
(b)	Same as item 1a but excavation in soil mixed with kankar and boulders				
	(a) 0 to 1.5 m depth	cum	294	8,385	2,465,190
	(b) 1.5 to 3 m depth	cum	338	7,760	2,622,880
	(c) 3 to 4.5 m depth	cum	393	7,134	2,803,662
	(d) 4 .5to 6 m depth	cum	452	6,424	2,903,648
	(e) 6.0 to 7.5 m depth	cum	541	4,766	2,578,406
	(f) 7.5m to 9.0 m depth	cum	663	2,776	1,840,488
	(g) 9.0m to 10.5 m depth	cum	813	833	677,229
	(h) 10.5m to 12.00 m depth	cum	996	151	150,396
2	Shuttering				
(a)	Provide and fix close timbering in trenches for the depth up to 3 m, 3m below G.L consisting of 40 mm thick approved country wood plank for polling board 125 x 75 mm Indian Sal wood walers and 100 mm dia sal wood ballies for shutting at 1.50m C/C including removal after laying of sewers (both sides of trenches) will be taken as one side for the purpose of payment and measurement i.e. area equals to Length x depth of trenches, Dismantled, timbering material will be the property of the Contractor. Details of cost for 30 m and 3 m deep trench i.e. 90 Sq M (M2) area of timbering				
	0 to 3 m	sqm	176	20,850	3,669,600
	3 to 6 m	sqm	224	20,649	4,625,376

Sr.	Items	Units	Rate (Rs.)	Quantity	Amount (Rs.)
(b)	Same as item no.1 but timbering left in trenches (unused timbering) 0 to 3 m				
	6 to 9 m	sqm	1,392	7,887	10,978,704
	9 to 12 m	sqm	1,600	1,161	1,857,600
(c)	Same as item no.1 but timbering left in trenches (used timbering) 0 to 3 m				
	6 to 9 m	sqm	584	5,258	3,070,672
	9 to 12 m	sqm	670	774	518,580
3	Supply of following sizes of RCC spigotted and socketed non pressure pipes				
	(a) 1200 mm dia in 1.25 m length	m	4,508	650	2,930,200
	(b) 1400 mm dia in 1.25 m length	m	5,927	1,250	7,408,750
	(c) 1800 mm dia in 1.25 m length	m	10,035	2,750	27,596,250
	(d) 2200 mm dia in 1.25 m length	m	16,045	2,300	36,903,500
4	Laying Jointing of RCC Hume pipe				
	Carting following sizes of R.C.C Hume pipe (NP3 Class Socket /spigoted rubber ring jointed and specials from store to the work lowering the same in to the trenches in depth upto 1.5m below G.L true to alignment including excavation of earth below G.L invert level of pipe, cost of all jointing material, testing etc, complete but excluding excavation and refilling of trenches from ground level to the invert level of pipe.				
	Rate per meter at different Depth				
	1200 mm dia pipe				
	(a) 7.5 - 9.0 m	m	1,805	300	541,500
	(b) 9.0 - 10.50m	m	2,022	300	606,600
	(c) 10.50- 12.0 m	m	2,285	50	114,250
	1400 mm dia pipe				
	(a) 4.5 - 6.0 m	m	1,891	140	264,740
	(b) 6.0 - 7.5 m	m	2,061	375	772,875
	(c) 7.5 - 9.0 m	m	2,289	435	995,715
	(d) 9.0 - 10.50m	m	2,563	300	768,900
	1800 mm dia pipe			-	-
	(a) 4.5 - 6.0 m	m	2,723	1,025	2,791,075
	(b) 6.0 - 7.5 m	m	2,967	450	1,335,150
	(c) 7.5 - 9.0 m	m	3,296	1,100	3,625,600
	(d) 9.0 - 10.50m	m	3,691	175	645,925
	2200 mm dia pipe				
	(a) 4.5 - 6.0 m	m	3,764	650	2,446,600
	(b) 6.0 - 7.5 m	m	4,101	500	2,050,500
	(c) 7.5 - 9.0 m	m	4,556	1,100	5,011,600
	(d) 9.0 - 10.50m	m	5,101	25	127,525
	(e) 10.50- 12.0 m	m	5,767	25	144,175
5a	Sand filling				
	Sand filling including supply of all materials labour T & P etc required for proper completion of work Rate as per building schedule				
	(a) 3.0 m to 4.5 m BGL	cum	217	40	8,680
	(b) 4.50 m to 6.0 m BGL	cum	232	2,566	595,312
	(c) 6.0 m to 7.5 m BGL	cum	253	373	94,369
5b	PCC				
	Cement concrete work in bedding with cement, coarse sand and 20 mm gauge approved stone ballast (1:2:4) including supply of all materials, labour, T & P etc, required for the proper completion of work (below ground level).				
	(a) 3.0 m to 4.5 m	cum	2,805	41	115,005

Sr.	Items	Units	Rate (Rs.)	Quantity	Amount (Rs.)
	(b) 4.50 m to 6.0 m	cum	2,996	1,224	3,667,104
	(c) 6.0 m to 7.5 m	cum	3,264	1,193	3,893,952
	(d) 7.5 m to 9.0 m	cum	3,626	1,382	5,011,132
	(e) 9.0 m- 10.50m	cum	4,060	403	1,636,180
6	RCC (M20)	cum	3,989	2,130	8,496,570
7	Constructing Vent shafts	Nos.	16,000	14	224,000
8	Construction of Scrapper manhole 2.43x1.53				
	up to depth 4.57m	Nos.	80,318	58	4,658,444
	upto depth 9.14m	m	14,189	185	2,624,965
	upto depth 14.0 m	m	22,040	13	286,520
9	Construction of Manhole dia 1.82m			-	-
	upto depth 2.28m (type C1)	Nos.	26,914	17	457,538
	upto depth 5.03m (type C2)	m	8,715	47	409,605
	upto depth 9.14m (type C3)	m	11,668	70	816,760
	upto depth 14.0m (type C3)	m	16,500	28	462,000
10	Construction of Manhole dia 2.43x1.53				
	upto depth 4.57m (type D1)	Nos.	68,200	166	11,321,200
	upto depth 9.14m (type D2)	m	15,539	510	7,924,890
	upto depth 14.00 m(type D3)	m	22,136	13	287,768
11	Road restoration				
	Dismantling of tar road for laying sewer including shorting out and stacking serviceable materials and disposal of unserviceable materials upto distance of 60 m and its rein statement after filling and proper compaction of trenches. Based on the nagar Mahapalika, P.W.D, VNS	sqm	1,250	28,844	36,055,000
12	Shifting of Electric and telephone cables				
	Provision for shifting and reinstatement of electric and telephone cable etc. during excavation and laying of sewer lines	LS			500,000
13	Shifting of Temporary water supply lines				
	Provision for temporary shifting of existing sewers and water supply falling in the alignment of conveying main during excavation and the restoring utilities/ services to its original condition	LS			500,000
14	Provision for laying of sewer by trenchless technology	As per Table 4.8			200,765,000
	Total cost				444,132,425 **(444,132,000)**

(5) Abstract of Cost Estimates: Sultanpur Road Trunk Sewer

The abstract of cost estimates of Sultanpur Road Trunk Sewer is presented in Table 4.14.

Table 4.14 Abstract of Cost Estimates of Sultanpur Road Trunk Sewer

Sr.	Items	Units	Rate (Rs.)	Quantity	Amount (Rs.)
1	Excavation				
(a)	Excavation for depth up to 1.5 m below G.L for laying Sewer manholes ordinary soil (earth, sand loam and clay) including cutting of joints pits ramming dressing) levelling, refilling of trenches in 20 cm layer watering and ramming the same including removal of surplus earth or other dismantled material upto a distance of 50 m. from the centre of trenches.				
	(a) 0 to 1.5 m depth	cum	61	42,730	2,606,530
	(b) 1.5 to 3 m depth	cum	75	40,048	3,003,600
	(c) 3 to 4.5 m depth	cum	93	37,366	3,475,038
	(d) 4 .5to 6 m depth	cum	107	34,552	3,697,064
	(e) 6.0 to 7.5 m depth	cum	140	25,891	3,624,740
	(f) 7.5m to 9.0 m depth	cum	184	17,833	3,281,272
	(g) 9.0m to 10.5 m depth	cum	240	8,867	2,128,080

Sr.	Items	Units	Rate (Rs.)	Quantity	Amount (Rs.)
	(h) 10.5m to 12.00 m depth	cum	312	5,794	1,807,728
	(i) 12.0m to 13.5 m depth	cum	406	4,445	1,804,670
	(j) 13.5m to 15.00 m depth	cum	528	524	276,672
(b)	Same as item 1a but excavation in soil mixed with kankar and boulders				
	(a) 0 to 1.5 m depth	cum	294	10,683	3,140,802
	(b) 1.5 to 3 m depth	cum	338	10,012	3,384,056
	(c) 3 to 4.5 m depth	cum	393	9,342	3,671,406
	(d) 4 .5to 6 m depth	cum	452	8,638	3,904,376
	(e) 6.0 to 7.5 m depth	cum	541	6,473	3,501,893
	(f) 7.5m to 9.0 m depth	cum	663	4,459	2,956,317
	(g) 9.0m to 10.5 m depth	cum	813	2,217	1,802,421
	(h) 10.5m to 12.00 m depth	cum	996	1,449	1,443,204
	(i) 12.0m to 13.5 m depth	cum	1,006	1,112	1,118,672
	(j) 13.5m to 15.00 m depth	cum	1,016	131	133,096
2	Shuttering				
(a)	Provide and fix close timbering in trenches for the depth up to 3 m o 3m below G.L consisting of 40 mm thick approved country wood plank for polling board 125 x 75 mm Indian Sal wood walers and 100 mm dia sal wood ballies for shutting at 1.50m C/C including removal after laying of sewers (both sides of trenches) will be taken as one side for the purpose of payment and measurement i.e. area equals Length x depth of trenches, Dismantled, timbering material will be the property of the Contractor. Details of cost for 30 m and 3 m deep trench i.e. 90 Sq M (M2) area of timbering				
	0 to 3 m	sqm	176	11,175	1,966,800
	3 to 6 m	sqm	224	11,148	2,497,152
(b)	Same as item no.1 but timbering left in trenches (unused timbering) 0 to 3 m				
	6 to 9 m	sqm	1,392	4,426	6,160,992
	9 to 12 m	sqm	1,600	1,509	2,414,400
	12 to 15 m	sqm	1,840	560	1,030,400
(c)	Same as item no.1 but timbering left in trenches (used timbering) 0 to 3 m				
	6 to 9 m	sqm	584	2,951	1,723,384
	9 to 12 m	sqm	670	1,006	674,020
	12 to 15 m	sqm	770	373	287,210
3	Supply of following sizes of RCC spigotted and socketed non pressure pipes				
	2400 mm dia in 1.25 m length (NP4)	m	19,500	7,450	145,275,000
4	Laying Jointing of RCC Hume pipe				
	Carting following sizes of R.C.C Hume pipe (NP4 Class Socket /spigoted rubber ring jointed and specials from store to the work lowering the same in to the trenches in depth upto 1.5m below G.L true to alignment including excavation of earth below G.L invert level of pipe, cost of all jointing material, testing etc, complete but excluding excavation and refilling of trenches from ground level to the invert level of pipe. (300 mm dia)				
	2400 mm dia pipe				
	(a) 4.5 - 6.0 m	m	4,363	1,790	7,809,770
	(b) 6.0 - 7.5 m	m	4,753	1,520	7,224,560
	(c) 7.5 - 9.0 m	m	5,281	2,350	12,410,350
	(d) 9.0 - 10.50m	m	5,913	930	5,499,090
	(e) 10.50- 12.0 m	m	6,685	790	5,281,150
	(f) 12.0m - 13.5 m	m	7,226	70	505,820
5	Sand filling				
	Sand filling including supply of all materials labour T & P etc required for proper completion of work. Rate as per building schedule (depth below ground level)	cum			-
	(a) 4.50 m to 6.0 m	cum	232	573	132,936

Sr.	Items	Units	Rate (Rs.)	Quantity	Amount (Rs.)
	(b) 6.0 m to 7.5 m	cum	253	573	144,969
	(c) 7.5 m to 9.0 m	cum	281	2,159	606,679
	(d) 9.0 m- 10.50m	cum	315	2,423	763,245
	(e) 10.50m- 12.0 m	cum	356	3,348	1,191,888
	(f) 12.0m - 13.5 m	cum	384	837	321,408
6	PCC				
	Cement concrete work in bedding with cement, coarse sand and 20 mm gauge approved stone ballast (1:2:4) including supply of all materials, labour, T & P etc, required for the proper completion of work. (depth below ground level)	cum			-
	(a) 4.50 m to 6.0 m	cum	2,996	2,267	6,791,932
	(b) 6.0 m to 7.5 m	cum	3,264	782	2,552,448
	(c) 7.5 m to 9.0 m	cum	3,626	470	1,704,220
7	RCC M20	cum	3,989	14,522	57,928,258
8	Constructing Vent shafts	Nos.	16,000	15	240,000
9	Construction of Scrapper manhole 2.43x1.53				
	up to depth 4.57m	Nos.	80,318	55	4,417,490
	upto depth 9.14m	m	14,189	182	2,582,398
	upto depth 14.0 m	m	22,040	50	1,102,000
10	Construction of Manhole dia 2.43x1.53				
	upto depth 4.57m (type D1)	Nos.	68,200	199	13,571,800
	upto depth 9.14m (type D2)	m	15,539	661	10,271,279
	upto depth 14.00 m(type D3)	m	22,136	186	4,117,296
11	Road restoration				
	Dismantling of tar road for laying sewer including shorting out and stacking serviceable materials and disposal of unserviceable materials upto distance of 60 m and its rein statement after filling and proper compaction of trenches.	sqm	1,250	36,690	45,862,500
12	Shifting of Electric and telephone cables				
	Provision for shifting and reinstatement of electric and telephone cable etc. during excavation and laying of sewer lines	LS			250,000
13	Shifting of Temporary water supply lines				
	Provision for temporary shifting of existing sewers and water supply falling in the alignment of conveying main during excavation and the restoring utilities/ services to its original condition	LS			250,000
14	Provision for Bridge construction for Nala crossing				
	First nala crossing (6m Span)	LS			400,000
	Second Nala crossing (30m Span)	LS			3,000,000
15	Provision for laying of sewer by trenchless technology				
	2400 mm	As per Table 4.8			12,155,000
	Total cost				421,879,481 **(421,879,000)**

4.3 OPERATION & MAINTENANCE ASPECTS

4.3.1 Operational Aspects

(1) General

Quality operation and maintenance of sewerage system consists of the optimum use of labour, equipment and material to keep the system in good condition, so that it can accomplish efficiently its intended purpose of collection and conveyance of sewage to the treatment plant.

Provisions made in this report are only for the components covered under F/S. Sufficient services are available for existing facilities.

(2) Types of Maintenance

There are two types of maintenance of a sewerage system - preventive and emergency. It is necessary that preventive or routine maintenance be carried out to prevent any breakdown of the system and to avoid emergency operations to deal with clogged sewer lines or over flowing manholes or backing up of sewage into a house or structural failure of the system. Preventive maintenance is more economical and provides for reliability in operations of the sewer facilities. Emergency repairs, which would be very rare if proper maintenance is carried out will also have to be provided for proper inspection and preventive maintenance is a necessity.

(3) Operation and Maintenance of Sewerage System

The organisation responsible for the maintenance of the sewerage system will vary with the size and type of the sewerage system and the relative age of the system. The larger the municipality, the larger and more complexes will be its maintenance organisation. The size of the organisation will vary from a couple of employees to several hundred regular employees. The primary effort of the staff is to maintain sewers free flowing and unobstructed.

The sewer system with its components properly designed and installed is handed over to the person in charge of maintenance who assumes the responsibility to make it function satisfactorily for the benefit of the community. One should have sufficient experience in the design and construction of the system to enable him to perform his task efficiently with an understanding and appreciation of the problems that may arise during maintenance. One has not only to be a technical man but has also to deal with human relations in order to be successful in his work. In service training shall be imparted to the maintenance personnel to improve upon the methods adopted based on the latest trends. Failure to develop a better understanding of human relations and also lack of development of the concept of service to the community generally results in the maintenance part becoming unpopular. The public is also to be made aware of do's and don'ts to help in keeping the sewers free flowing and unobstructed.

(4) General Practice

General practice used for cleaning of sewers depends upon the diameter of sewer. The methods suggested are as follows.

Small diameters (150 mm to 400 mm): Jetting machines are used to clean these small diameter pipes.
Larger diameters (400 mm to1100 mm): Bucket cleaning equipment is used.

Larger diameters (Above 1100 mm): Manual desilting of sewers is practiced.

(5) Manual Cleaning

In manual cleaning method, the silt is collected manually from manholes and large sewers where man-entry is possible. This is however a very slow and risky operation. Proper artificial ventilation and adequate safety precautions are required before the men enter the sewers. The depth of most of the sewers is considerable in some cases, the velocity can also be expected to be low leading to generation of gases. All personnel entering the manhole should have proper safety equipment. There should be forced ventilation by using air blowers on manholes upstream of the concerned length. All such personnel should use safety harness fastened at the other end and another crewmember should monitor crew who has entered the manhole.

(6) Passing Rope Knots and Discs through Sewers

In this method of sewer cleaning, solid split bamboos are passed through sewers from one manhole to the other to create a link. Ropes are attached to this link and a rope link is created between two manholes. A wooden disc with rubber gasket ring or a series of knots of rope are formed and pulled through the sewer to and fro. The inside of the sewer (sewer fabric) gets scrubbed due to this procedure and dislocates the encrusted silt. The freed silt flows away downstream and in this way the sewer can be cleaned from upstream to downstream. This method is labour intensive and hence expensive. Further, such vigorous scrubbing sometimes breaks the joints and damages the sewer fabric. This method is therefore, no longer adopted in modern sewer maintenance practices.

(7) Utilising Bucket Cleaning Equipment

In the method of utilising the bucket cleaning equipment, two winches are installed on two manholes. A rope link is established. A bucket is attached to the rope and pulled from one end to the other. The silt deposited in the sewer is collected in the bucket and is taken out from a manhole. This method can also cause damage to manholes and sewer fabric due to heavy pulling.

(8) Utilising Jetting and Suction Equipment

Jetting and suction equipment is mounted on a truck chassis. Water is stored in a tank (usually 6000 l capacity) mounted on the truck. This water is jetted in the sewer line using a high-pressure pump and a nozzle system. Fine jets with high velocity are generated. On the forward and the backward pass of the jet, the deposited silt is loosened and is washed down and is collected in the downstream manhole. From this manhole, it is sucked out in a slurry form to a silt tank mounted on the chassis. Various sizes of jets and suction can be used to clean various diameter sewers. The Indian equipment available is usually effective for sewer up to 300mm diameter and can be used up to 450mm diameter with some modifications. For larger diameter sewers, imported heavy-duty suction and jetting machines can be used. In the latest sewer maintenance programmes, these machines are preferred by all.

4.3.2 Utilities Requirement

(1) Manpower Requirement

Component wise O & M cost is as given below
Total length = approx. 30 kms in phase I

Sewer cleaning once in two years, 300 days in a year, the number of labourers required is given below in Table 4.15. Sewer cleaning has to be taken up every two years due to the following reasons.

- Non-availability of a separate storm water drainage system
- Abundance of plastic bags and small sachets in the sewage

Table 4.15 Labour Force Estimated for Sewerage System

Description	Quantity	Unit
Total length of proposed sewer lines in phase-I	30	km
No. of working days in a year	300	Nos.
Length to be covered in a day	100	m
Length that can be cleaned per day by a team of 10 labourers	50	m
No of gangs required	2	Nos.
Per gang members	10	Nos.

Manpower requirement is worked out and presented in Table 4.16. The figures mentioned below are based on personnel deployment of maintenance crews in other large Indian cities.

Table 4.16 Manpower Cost

Designation	No.	Rate (Rs./Year)	Amount (Rs.)
Executive engineer exclusive for the maintenance of the sewerage system	0.5	500,000	250,000
Assistant engineers per sewerage zone	2	300,000	600,000
Junior engineers (two per sewerage zone)	4	225,000	900,000
Supervisors (one per labour gang as per table above)	2	100,000	200,000
Mechanics (one per administrative zone)	1	125,000	125,000
Labours	20	75,000	1,500,000
Total manpower cost			3,575,000

4.3.3 Equipment Cost

A number of equipment would be required for the maintenance of the sewerage system. These would be as per Table 4.17 as listed below.

Table 4.17 Capital Costs of Maintenance Equipment

Sr.	Equipment	Nos.	Unit	Rate /unit	Amount
1	Jetting machines	2	Nos.	4,000,000	8,000,000
2	Tankers with suction machine	2	Nos.	2,500,000	5,000,000
3	Trolley mounted diesel engine and non clog sewage pump sets with all accessories like delivery pipe, suction pipe sluice valve, non return valve etc.	2	Nos.	300,000	600,000
4	Air blower	2	Nos.	300,000	600,000
5	Maintenance van or equivalent	2	Nos.	750,000	1,550,000
6	Other operation equipment as per manual		Nos.	200,000	200,000
Total					15,950,000

4.3.4 Operation and Maintenance costs of equipment used for O and M

For the equipment that is specifically bought for the operation and maintenance of the sewerage system, facility for the operation and maintenance would either have to be created in form of garages or existing garages of the UPJN / municipal corporation would be used. In the present case we recommend that existing facilities be used. Also existing personnel be used for the maintenance of these equipments also.

(1) Maintenance Cost

However, the actual costs of operation and maintenance of the plants and equipment would have expenditure, which has been provided for here.

Capital cost of equipment	Rs. 15,950,000	
Considering life as 15 years		
Rate of maintenance considered @ 5%	Rs. 15,950,000 x 5% =	Rs. 7,97,500
	Say	Rs. 8,00,000

4.3.5 Summary Operation and Maintenance Cost

Table 4.18 Summary Operation and Maintenance Cost

Sr.	Particulars	Amount (Rupees/year)
1	Manpower cost	3,575,000
2	Consumables	300,000
3	Maintenance cost	8,00,000
	Total	4,675,000

4.4 ABSTRACT OF CAPITAL COSTS FOR NEW SEWERS

Table 4.19 Abstract of Capital Costs for New Sewers

Sr.	Particulars	Amount (Rupees)
1	Trans-Gomti trunk sewer (new)	97,768,000
2	Cis-Gomti relief sewer	444,132,000
3	Sultanpur road trunk sewer	421,879,000
	Total	963,779,000000