PRELIMINARY DESIGN REPORT
BALLARI RECYCLED WATER TREATMENT PLANT

NITI AAYOG

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REPORT DETAILS

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Synopsis:

Project Deliverable No. 2: A Feasibility Study was completed in Sep 2019. This study aims to develop feasibility and concept for treatment options and configurations for Recycled Water Treatment Plant. It includes introduction and application of advanced recycled water treatment technology, advantages, disadvantages, preliminary sizing and costing implications. A high level and broad qualitative study of product recycled water is also carried out along with strategic discussion on the project delivery model. Following further technical and engineering design investigations a Preliminary Design Report has been prepared to outline the Pilot Project Reuse of Recycled Water in Karnataka. This Preliminary Design Report outlines the following key components of the proposed water recycling scheme:

- Process flow diagrams
- Estimates of electrical power and chemical consumptions
- Estimates of capital and operating costs

This report incorporates the key inputs received from officials of Ballari Municipal Corporation and Urban Development Department, Government of Karnataka, during the Workshop held from 5th to 7th Nov., 2019.

REVISION / CHECKING HISTORY

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Preface

Preface

The NITI Aayog has entered into a partnership with Temasek Foundation International (TFI), Singapore and Singapore Cooperation Enterprise (SCE), to facilitate the sharing of Singapore's experience in Water Recycling and Reuse under "Urban Management (Water Recycling and Reuse) Program in India – Phase 2 Collaboration with NITI Aayog" Program. As such, Singapore Cooperation Enterprise signed a Grant Agreement with the NITI Aayog. The programme will receive funding support from Temasek Foundation and will also be co-funded by the NITI Aayog.

The Singapore Cooperation Enterprise (SCE) is the lead agency that will aggregate a team of Singapore's water experts from the Public Utilities Board (PUB) as well as private sector water company JACOBS to jointly develop with the NITI Aayog, a water recycle and reuse strategy, concept plan, feasibility study, preliminary design, and Model Document to implement a Pilot Recycled Water Treatment Plant, over a series of capacity building workshops for the partnering Indian States officials.

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Executive Summary

Executive Summary

Water is among primary element for sustaining human life. Secure water supply and safe used water (used water) management provides a social, environmental and economic advantage to a city's communities and proactive businesses. As a city's water demand grows, resilient and efficient water and used water systems become crucial for continued growth, liveability and sustainability.

Ballari city is located 275 Km north of Bengaluru and has a population of about 4.1 lakhs as per 2011 census. The city is well known for its apparel cluster and has rich deposits of iron ore (1,032 MT). The city is also known for its dry weather and consecutive drought events, which had a debilitating effect on water availability for the city. In the period between 2001 to 2015, Ballari has witnessed 9 drought years[1].

Ballari receives its drinking water supply from the River Tungabhadra via two irrigation canals – Low Level Canal (LLC) and High Level Canal (HLC). Collectively, water through these two canals is supplied for 6 to 9 months. Water through these canals is also stored in an Impounding Reservoir (IR), to cater for water needs during remaining 3 to 6 months of non-supply period of HLC and LLC. Water is treated at two Water Treatment Plants (WTP) – Moka WTP (10 MLD) and Allipura WTP (40 MLD), and is supplied to the city via series of elevated Overhead Tanks (OHT). Water losses (physical and commercial) are reported at 50%, and a given water service zone in Ballari receives water once in five (05) days.

City's underground used water network has been developed in stages over last four decades. Ballari city's used water collection and conveyance system is divided in to four (04) zones. There are two Used Water Treatment Plant (UWTP) - 30 MLD capacity Ananthapur Road UWTP (receiving used water from Zone 3 and 4), and 15 MLD capacity Cowl Bazaar UWTP (receiving used water zone 1 and 2). Another 12 MLD capacity UWTP is under construction (Sequential Batch Reactor technology), and will receive used water from zones 1 and 2, which are currently undergoing construction of additional used water network to connect the newly formed and unconnected layouts.

Surface water is scarce in Ballari, and industries are typically dependent on groundwater for their water needs which is already over-exploited. Water has a high economic impact on Ballari's industrial area development. Ballari has more than 25 sponge iron units. Large industries include a thermal power plant and steel plant, along with two proposed steel plants. Karnataka Industrial Area Development Board (KIADB) has developed three industrial areas – Mundaragi (Phase I to IV), Sanklapura (Phase I, II) and Ananthapur Road Industrial Area, spread over 522 acres, which would need water for their sustainable development.

Existing urgent need of water to support industrial development is a major driver to develop alternate sources, such as recycled water, for Ballari. For last few years, Ballari Municipal Corporation has started selling secondary treated used water to industries and have list of identified industries that are potential customers.

This Preliminary Design Report (PDR) covers following aspects:

- Strategic goals, objectives and key challenges of implementing a viable water recycle and reuse scheme,
- Applicable international and Singapore's reuse quality standards for various applications of recycled water,

[1] Source: Proposal for Pilot Project Reuse of Recycled Water in Karnataka, Urban Development Department, Government of Karnataka.

- Applicable recycled water treatment and end use guidelines, influent and effluent water quality monitoring requirements, and target recycled water standards to produce water for non-potable industrial reuse,
- Scheme for existing 30 MLD Used Water Treatment Plant to meet CPCB revised guidelines and generation of recycled water, including operation and maintenance plan, delivery option analysis.

Treatment Scheme

As shown in the **Table ES 1** below, at present the two UWTP at Ballari are not meeting the CPCB treated effluent water quality standards (**Table ES 2**).

Table ES 1: Water quality results for existing UWTPs at Ballari

S No	Sample details	Date of sampling	Parameter	Prescribed standard	Result of analysis	
					Eastern outlet	Western outlet
1	30 MLD UWTP	23rd May, 2018	BOD (mg/L)	10	92	158
			COD (mg/L)	50	264	325
			Suspended solids (mg/L)	30	60	40
2	15 MLD UWTP	23rd May, 2018	BOD (mg/L)	10	44	83
			COD (mg/L)	50	183	237
			Suspended solids (mg/L)	30	40	60

Table ES 2: CPCB treated effluent discharge guidelines

Parameter	Unit	CPCB (2015)
pH	-	6.5 – 9.0
Biochemical Oxygen Demand (BOD_5)	mg/L	10
Chemical Oxygen Demand	mg/L	50
Total Suspended Solids	mg/L	20
Ammonium	mg/L	5
Total Kjeldahl Nitrogen	mg/L	10 (As TN)
Faecal Coliforms	MPN/100mL	100

*Note: Total Phosphorus (TP) is not stated. Discharge of treated used water to inland waterways or lakes with elevated TP can lead to water body eutrophication (nutrient enrichment) and algal blooms and excessive nuisance aquatic weed growths.

With used water most of the total phosphorus is in the PO43+ form. The rest, about 15% is in the form of poly P. Thus PO_4^{3+} is nearly the same as total P.

The commonly adopted standard in India for the PO_4^{3+} as P, is taken as less than or equal to 2 mg/L. In Australia, the concentration of total Phosphorus (as P) to prevent eutrophication of lakes is taken as less than 0.1 mg/L.

This note recommends a concentration of up to 1 mg/l for total Phosphorus (as P).

In order for the treated effluent comply with CPCB standards, and is fit as feed for producing recycled water for non-potable purposes, treatment process options that are technically and operationally proven, will be considered for this project, owing to following factors:

- Land availability,
- Capital cost,
- Operation and maintenance with OPEX,
- Energy consumption,
- Reliability, redundancy, robustness and resilience of the treatment process,
- Product water quality targets for indirect potable reuse including industrial reuse.

Process and Plant Options

Whilst there are a large number of process options which could be considered suitable for the purpose advanced water recycling, only process options which were technically and operationally proven were shortlisted and considered in the previous Feasibility Study and this Preliminary Design Report.

The treatment processes selected in the Feasibility Study have demonstrated and proven capability to produce treated water that meets or exceeds the guidelines for non-potable industrial reuse purpose. Membrane Bio Reactor (MBR) based Biological Nutrient Removal (BNR) process is preferred treatment process for this project.

The key reason for selecting the MBR based treatment train was the avoidance of multiple unit operations and process in the used water treatment plant. In the MBR plant, secondary and tertiary treatment is integrated, and there is no provision to bypass the secondary treated used water. The required degree of purification is achieved in a single window solution with minimal land requirement.

The analysis suggested that the costs for upgradation of the existing Ananthapur used water plant is expensive from capital as well as operational cost perspective. The existing infrastructure is aged and all major electromechanical components requires replacement with the new one. Surface aerators that are used in the existing used water treatment plant requires extensive electrical energy. With the limited side water depth in the lagoons, replacing of surface aerators with fine bubble diffuser was also analysed. Tank dimensions being large, retrievable fine bubble diffused aeration system was considered as an option. It requires additional civil works in the tanks to install, operate and maintain the aeration grid. Being the limited side water depth, fine bubble diffuser efficiency could not be utilised to its full potential and resulted into aeration blower of higher capacity, leading to higher electrical energy consumption. Apart from existing aeration tank, all other tanks requires new construction, namely secondary clarifiers, RAS sump and pumps, air blower room, tertiary treatment units, sludge dewatering units etc.

The Preliminary Design Report is based on the preferred treatment option of MBR based BNR process for the non-potable industrial reuse purpose. This being a reliable used water treatment process. Activated sludge treatment using Biological Nutrient Removal for nitrogen and phosphorus removal, and a membrane based solids separation (Membrane Bioreactor) instead of conventional gravity clarification, is envisaged. The Membrane Bioreactor also had the added advantage of producing a superior water quality to that possible with a gravity clarifier.

Figure ES 1: Process flow schematic

Figure ES 2: Solid handling schematic

Project Cost Estimate

The estimate project cost for the advanced used water treatment to generate treated water for industrial purposes is given in the **Table ES 3** and **Table ES 4**.

Table ES 3: Summary of Capital Cost (CAPEX)

Particulars	Cost (in Crores)
Civil works including piping, erection, testing and commissioning	₹ 33.00
Mechanical, Electrical and Instrumentation control and automation (MEICA) works including erection, testing and commissioning	₹ 57.60
Capital cost	₹ 90.60

Table ES 4: Summary of Annual Operational Cost (OPEX)

Particulars	Cost (in lakhs per month)
Labor cost	₹ 4.50
Chemical charges	₹ 5.30
Electricity charges	₹ 57.80
Maintenance charges	₹ 24.00
Sludge disposal cost	₹ 15.50
Total Operational cost	₹ 107.00

Recommendations

The following actions resulting from this Preliminary Design Report is recommended for adoption and implementation by Ballari Municipal Corporation (BMC) and KUWS&DB:

- It is recommended to upgrade the Anathapur 30 MLD UWTP using BNR based MBR treatment technology, and decommission the existing Aeration Lagoon based treatment plant,
- It is recommended that BMC engages with the industry representatives to discuss about the quality and quantity of recycled water that the project will generate, and create a robust industrial water demand requirements prior to commencing of project procurement,
- It is recommended that in the strong industrial backdrop of Ballari City, BMC explore the option for implementing this project on DBFOT model,

- It is recommended that BMC runs a holistic stakeholder participation and outreach program for engaging with stakeholders such as potential users, industry representatives, political leadership as well as senior technical and managerial leadership in GoK UDD, for garnering a holistic effort towards project implementation,
- It is recommended that BMC undertakes implementation of this project on Program Management Approach in order to ensure timely and high-quality delivery of project, and follows the best Operation and Maintenance Practices as provided in this report.

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ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ARWTP	Advanced Recycled Water Treatment Plant
BMC	Ballari Municipal Corporation
BDL	Below Detection Limit
BNR	Biological Nutrient Removal
BOD_5	Biochemical Oxygen Demand
CAPEX	Capital expenditure
CNG	Compressed Natural Gas
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
CPES	CH2M HILL's Parametric Cost Estimating System
CPHEEO	Central Public Health and Environmental Engineering Organization
DB	Design Build
DBB	Design Bid Build
DBFOT	Design Build Finance Operate & Transfer
DBO	Design Build Operate
DNA	Deoxyribonucleic acid
GoK	Government of Karnataka
HRT	Detention Time, Hours
INR	Indian Rupee(s)
KIADB	Karnataka Industrial Area Development Board
KSPCB	Karnataka State Pollution Control Board
KUWS&DB	Karnataka Urban Water Supply and Drainage Board
LSI	Langelier Saturation Index
MC	Maintenance Clean
MF	Microfiltration
MLD	Million Litres per Day
MLSS	Mixed Liquor Suspended Solids
MOC	Material of Construction
MPN	most probable number
NDWR	Non-Drinking Water Reuse
NITI	National Institution for Transforming India
NF	Nano-filtration

NPV	Net Present Value
NTU	Nephelometric Turbidity Unit
O&G	Oil and Grease
O&M	Operation and Maintenance
OPEX	Operational expenditure
P&ID	Process and Instrumentation Diagram(s)
PFD	Process Flow Diagram(s)
PPP	Public Private Partnership
PUB	Public Utilities Board
RCC	Reinforced Cement Concrete
RNA	Ribonucleic acid
RO	Reverse Osmosis
RWTP	Recycled Water Treatment Plant
SAMP	Sampling and Monitoring Program
SAR	Sodium Adsorption Ration
SCE	Singapore Cooperation Enterprise
SDI	Silt Density Index
STP	Sewage Treatment Plant
SWD	Side Water Depth
TDS	Total Dissolved Solids
TMP	Trans-Membrane Pressure
TSS	Total Suspended Solids
UF	Ultrafiltration
USD	United States Dollar(s)
USEPA	United States Environmental Protection Agency
UV	Ultraviolet
UWTP	Used Water Treatment Plant
VSS	Volatile Suspended Solids
WHO	World Health Organization
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant same as Sewage Treatment Plant or Used Water Treatment Plant

Background and Introduction

1 Background and Introduction

India is experiencing rapid urbanisation. The urban population has gone up from 29 crore in 2001 to 37.7 crore in 2011, and the number of town and cities has also risen from 5,161 to 7,935 during this period. At present, there are more than 8,000 cities and towns in India. Due to rapid urbanisation, water demand in urban areas is increasing rapidly. The water situation in metropolitan cities is particularly exacerbating, where the people in such cities face acute water shortage during summers. Changing climate and its impact on temporal and spatial variability of rainfall, is a further deterrent to timely and sufficient availability of water resources.

Government is putting concerted efforts in implementing rainwater harnessing schemes for groundwater improvement, however, there is an urgent need for water portfolio diversification through introducing alternate sustainable water sources. The recycle and reuse of water presents itself as a potential solution for ensuring assured water supply in the Cities, on a sustainable basis. Recycling and reuse has been widely practised in Singapore, where every drop of water is recycled for reuse. Such an approach not only reduces pressure on other water sources, but also offers a sustainable solution for water resources management.

The National Water Policy (2012)[2] of the Government of India proposed radical changes to the existing water policy, encouraging water reuse. It has also been observed that water is recognised as an economic good, over and above the pre-emptive need, i.e. the basic minimum quantity of water for essential health and hygiene and sustenance of ecology that would promote maximisation of value of water and its conservation and efficient use.

To benefit from Singapore's experience in sustainable urban management, NITI Aayog partnered with Singapore Government under "Urban Management Program in Indian – Phase 1" Program, with an objective to build capacity of technical and management leaders from Indian public utilities in water, wastewater and solid waste management. As part of the capacity building programme, two sets of strategic baseline framework documents were developed for Water & Wastewater Management and Solid Waste Management, for participating Indian States. The framework included general guidelines to address challenges and opportunities associated with Water & Wastewater Management and Solid Waste Management, generic enough for participating states to apply based on context and requirements.

Subsequently, NITI Aayog and Singapore Government have extended their collaboration to further deep dive capacity building in recycle and reuse under "Urban Management (Water Recycling and Reuse) Program in India – Phase 2" Programme.

Singapore is a pioneer in urban water cycle management and has successfully addressed water management challenges through technical ingenuity and strong public outreach efforts over the years. Singapore has set benchmark in successful implementation of large-scale water recycling projects, public education and participation, management and quality control systems and Public Private Partnerships (PPP) investments. Public Utility Board (National Water Agency of Singapore) through its highly successful NEWater programme supplies top quality recycled water for industrial as well as for indirect potable reuse purposes. Singapore has successfully been able to transform their urban waterscape over the last four decades, and their learnings can be adopted and contextualised for Indian scenario.

[2] http://mowr.gov.in/sites/default/files/NWP2012Eng6495132651_1.pdf

1.1 Program Objective

Under Phase 2 of this capacity building programme, following key objectives have been identified:

- Build capabilities of participants in recycling and reuse – infrastructure development, operation and management, Non-Revenue Water management, and used water management,
- Develop concept and feasibility study, preliminary design, development of delivery options and model documents for implementing a pilot recycled water treatment plant with desired water quality and safety guidelines,
- Develop understanding of the benefits and challenges towards adopting integrated wastewater management based on Singapore's experience, along with lessons learnt from Singapore towards development of policy frameworks and actions required to implement a successful water recycling strategy,
- Other objectives of this project include:
  - Achieve an in-depth understanding of the benefits and challenges of sustainable integrated recycle water management,
  - Identify policy action required to implement recycle and reuse strategies, and
  - Build capabilities of key officials through sharing of Singapore's lessons and experience in project implementation, including introduction to Public Private Partnership (PPP) based project delivery model,
  - Developing recycled water as part of sustainable and diverse water portfolio.

Further, the proposal submitted by Urban Development Department, GoK, for Ballari City is selected as the "Pilot Recycled Water Treatment Plant" project. It is envisaged that a successful water recycle and reuse program will assist in reducing the stress on freshwater sources, like surface water or groundwater, to meet non-potable water demand of industries in Ballari.

1.2 Program Scope

Scope of work for the program includes:

- Capacity building in Recycled & Reuse Water, Non-Revenue Water (NRW) Management, and Used Water Treatment through the sharing of the Singapore Experience:
  - Application of recycled and reuse water for non-potable purposes,
  - Sharing non-revenue water management experience and lessons learned from Singapore,
  - Knowledge sharing on various used water treatment technologies, key process equipment, and process elements for recycled water treatment,
  - Overview of used water management in Singapore,
  - Development of feasibility study for recycled water treatment plant:
  - Sharing applicable international and Singapore's reuse quality standards for recycled water applications,
  - Identification of applicable recycled and reuse water treatment and end use guidelines for Indian context, influent and effluent water quality monitoring requirements, and target recycled water standards to produce water for indirect potable reuse,
  - Introduction and application of advanced recycled and reuse water treatment technologies, identification and evaluation of various options for recycled and reuse water treatment, and review of their advantages and disadvantages,
- Development of preliminary design report:

- Identification of treatment plant design criteria, and development of preliminary design and configurations for pilot recycled water treatment plant,
- Health and Environmental aspects of Water Reuse including human health effects and water quality monitoring protocol,
- Sharing Singapore’s experience in stakeholder engagement for public acceptance of recycled water utilisation in indirect potable reuse,

- Development of Delivery Options and Model Documents for Project Implementation for Water Recycling Scheme:
    - Equipment specifications,
    - Identification of risks and mitigation strategy for implementing the water recycling scheme,
    - Strategy for operation and maintenance, and
    - Project delivery model - Discussion of potential options for project delivery models and development of recommendations for contract types (such as EPC/ DB/PPP etc).

1.3 Description of Treatment Scheme

The proposed project envisages to construct a new 30 MLD Anathapur recycle water treatment plant for supplying it to sponge iron units in Halkundi, Belagal, Veniveerapura belt, jeans washing units in Mundaragi Phase IV, and to upcoming industries in Kuduthini industrial area. Biological Nutrient Removal integrated with Membrane technology is recommended as it produces high quality treated water which can be directly used by the industrial units for most of their industrial applications.

1.3.1 Outcomes of Previous Feasibility Study Report

The feasibility study report issued in September 2019 covered the following aspects.

- Strategic goals, objectives and key challenges of implementing a viable water recycle and reuse scheme,
- Applicable international and Singapore's reuse quality standards for various applications of recycled water,
- Applicable recycled water treatment and end use guidelines, influent and effluent water quality monitoring requirements, and target recycled water standards to produce water for indirect potable reuse,
- Introduction and application of recycled water treatment technologies, identification and evaluation of various options for recycled water treatment, review of their advantages and disadvantages, etc.

The following actions resulting from this Feasibility Study were recommended:

- It is recommended that the production of treated recycled water is done without the generation of a salt or brine stream,
- It is recommended the product water be used for supply to industrial and commercial establishments,
- It is recommended that a detailed risk assessment for the total scheme be carried out at the stage of project implementation for the preferred process option,
- Conduct detailed and a fortnight long used water sampling and analysis on the Ananthapur Road (30 MLD) UWTP to further refine the preferred treatment scheme for the proposed plant upgrade and recycled water treatment plant,

- It is recommended that a public education outreach engagement and consultation programme be undertaken prior to tendering of this project,
- It is recommended the PPP project delivery model shall be explored for the implementation of this project.

1.4 About Preliminary Design Report (PDR)

This report provides a preliminary design of the preferred and recommended water recycling scheme for Anathapur 30 MLD UWTP, as identified in the Feasibility Study including further refinement of the project cost estimates. The Preliminary Design Report (PDR) takes into consideration the technical, commercial, social and environmental aspects for implementation of a water recycling project to supply Ballari City with treated recycled water for non-potable demand of industries.

Karnataka Urban Water Supply and Sewerage Board (KUWS & DB) is a state-level organisation responsible for water and sanitation services for all urban local bodies in the state of Karnataka. KUWS & DB which works under the authority of Urban Development Department (UDD), Government of Karnataka, along with Ballari Municipal Corporation, will be the agency responsible for implementing this pilot recycle and reuse project in Ballari.

This project serves the purpose of meeting successful water recycle and reuse program and will assist in reducing the stress on freshwater sources, like surface water or groundwater, to meet non-potable water demand of industries in Ballari.

The scope of the Preliminary Design Report is to provide further design of the selected treatment option recommended in the previous Feasibility Study. Major points of consideration within the scope of works for the Preliminary Design Report included the following:

- Consultation with Ballari Municipal Corporation to finalise the treatment option for an advanced recycled water scheme,
- Confirmation of the preferred option for used water treatment at Ballari,
- Design layouts of the wastewater treatment plants,
- Assessment of project delivery methods,
- Conclusions and recommendations for further future actions.

1.5 Methodology

The following tasks have been completed during the preparation of Preliminary Design report to deliver the project objectives and scope of works:

- Task 1 – Assessment of options considered during the Feasibility Study Workshop, and site visits to as well as discussion with Ballari Municipal Corporation officials,
- Task 2 – Identify project objectives, scope and drivers
- Task 3 – Identify existing asset condition, standards, issues and risks
- Task 4 – Identify treatment plant sites and constraints
- Task 5 – Undertake preliminary engineering design including limited options identification and including cost estimates
- Task 6 – Options assessment and confirmation of the preferred option
- Task 7 – Preliminary design study reporting

- Task 8 – Workshop on the preliminary design report

1.6 Environmental Discharge Regulation

The Central Board in its 168th meeting held on 27.03.2015 resolved to notify the standards for treated used water. These standards for discharge of treated used water from UWTPs have also been endorsed in the Minister's Conference held during April 6-7, 2015 and 59th Conference of Chairman and Member Secretaries of Pollution Control Boards and Pollution Control Committees held on April 8, 2015, and are presented below in Table 1-1.

Table 1-1: CPCB standards for discharge of treated used water

S No.	Parameters	Parameters Limit (Standards for New STPs Design after Notification date)*
1	pH	6.5 – 9.0
2	BOD (mg/L)	Not more than 10
3	COD (mg/L)	Not more than 50
4	TSS (mg/L)	Not more than 20
5	NH_4- N (mg/L)	Not more than 5
6	N- total (mg/L)	Not more than 10
7	Fecal Coliform (MPN/100 ml)	Less than 100
Note: **These standards will be applicable for discharge in water resources as well as for land disposal. The standards for Fecal Coliform may not be applied for use of treated sewage in industrial purposes.** ***Achievements of Standards for existing STPs within 5 years from the date of notification.**		

Later, in October 2017, CPCB diluted the standards for BOD (<20 mg/L), TSS (<50 mg/L) and Faecal Coliform (<1000 MPN/100mL).

Recently, The National Green Tribunal (NGT) in its ruling dated 30/04/2019 has changed the effluent discharge standards for used water treatment plants in India. The NGT believes that partially treated wastewater is a major cause of pollution in the water bodies in urban areas as well as rivers. Further, NGT has also revised the standards for nutrients, phosphorous and nitrogen, as these are the major rate limiting elements essential for the growth of algae and other vegetation in water bodies leading to eutrophication of lake. The effluent discharge standards as required are in **Table 1-2**.

Table 1-2: NGT guidelines on water quality parameters of treated used water (April, 30th, 2019)

Sl No.	Parameters	Parameters Limit
1	pH	5.5 – 9.0
2	BOD (mg/L)	Not more than 10
3	COD (mg/L)	Not more than 50
4	TSS (mg/L)	Not more than 10
5	Total Nitrogen (mg/L)	Not more than 10
6	Total Phosphorus (mg/L)	Not more than 1
7	Fecal Coliform (MPN/100 ml)	Less than 100

The following **Table 1-3** presents the current output of treated used water at Anathapur UWTP, and it does not meets prescribed treatment standards by CPCB.

Table 1-3: Existing output from 30 MLD UWTP (Source: Ballari Municipal Corporation)

S No	Sample details	Date of sampling	Parameter	Prescribed standard	Result of analysis	
					Eastern outlet	Western outlet
1	30 MLD UWTP	23rd May, 2018	BOD (mg/L)	10	92	158
			COD (mg/L)	50	264	325
			Suspended solids (mg/L)	30	60	40
2	15 MLD UWTP	23rd May, 2018	BOD (mg/L)	10	44	83
			COD (mg/L)	50	183	237
			Suspended solids (mg/L)	30	40	60

Prior to selecting the most feasible techno-economic scheme for this plant, we looked at various option for rehabilitating, upgrading, and construction of new plant. Such optioneering is presented in the later section of the report. After detailed analysis, it is recommended that construction of a new UWTP will be most suitable option for following reasons:

- The analysis suggested that the costs for upgradation of the existing Ananthapur used water plant is expensive from capital as well as operational cost perspective,
  - The existing infrastructure is aged and all major electromechanical components requires replacement with the new one,
  - Surface aerators that are used in the existing used water treatment plant requires extensive electrical energy,
  - With the limited side water depth in the lagoons, replacing of surface aerators with fine bubble diffuser was also analysed, and given the large tank dimensions, retrievable fine bubble diffused aeration system was considered as an option.
  - It was found that this option requires additional civil works in the tanks to install, operate and maintain the aeration grid. Being the limited side water depth, fine bubble diffuser efficiency could not be utilised to its full potential and resulted into aeration blower of higher capacity, leading to higher electrical energy consumption.
  - Apart from existing aeration tank, all other tanks requires new construction, namely secondary clarifiers, RAS sump and pumps, air blower room, tertiary treatment units, sludge dewatering units etc.
  - With the high upgrade capital costs, the plant will need another upgrade in few years in the event of more stringent treated water quality standards,
  - Also, it will require for installing new treatment units for producing recycled water which will involve further capital expenditure, and a disjointed scheme,
- With such background, the technoeconomic analysis for creating a new used water treatment plant with advanced treatment process was found more suitable for following reasons:

- New plant with latest and advanced treatment technology will produce high quality water output, and therefore meeting the discharge standards as well as creating high quality water for industrial non-potable purposes,
- The plant can be delivered on Design Build and Operate scheme, and therefore ensuring that the desired maintenance as well as product water quality is achieved,
- With high quality water output, BMC can sell the water to industries and thereby omitting the need for retreatment by the industries – which industries such as Janaki Corporation are doing at a high cost.

1.7 Report Structure

The structure of this report is as follows:

- Executive Summary
- Section 1 – Project introduction, objectives, outcomes of Feasibility Study, scope of works, and statutory guidelines published by Government of India that are considered in preparation of the Preliminary Design Report,
- Section 2 – Provides project description and current demand of water for industrial purposes,
- Section 3 – Options development at the Feasibility Report stage
- Section 4 – Basis of Design outlines the key design basis including the relevant codes and standards, recycled water demand projections, wastewater characteristics and flows, water quality targets, treatment plant, residuals management and transfer system requirements
- Section 5 – Preliminary design of the new used water treatment plant at Anathapur (30 MLD), description of treatment plant's units,
- Section 6 – Concept design of electrical design, instrumentation and control details,
- Section 7 – Operation and maintenance plan for treatment plants, ancillary system and OH&S requirements,
- Section 8 – Financial assessment including basis of estimate, key assumptions for estimating the costs, total cost estimate for project, and operational costs,
- Section 9 – Delivery options analysis including DBFOT and recommendations for delivery options, and risk register,
- Section 10 – Conclusions and recommendations

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Project Description

2 Project Description

Following section presents a brief description about Ballari City as well as the proposed pilot project.

2.1 About Ballari City

Ballari city is located 275 Km north of Bengaluru at an elevation of 495 m and has a population of about 4.1 lakhs as per 2011 census, with approximately 82 km^2 of area within Ballari Municipal boundary. The city is well known for its apparel cluster and has rich deposits of iron ore (1,032 MT). Ballari has more than 25 sponge iron units. Large industries include a thermal power plant by KPTCL and Steel plant by Jindal South West (JSW Group). There are two proposed steel plants – by Arcellor Mittal and Uttam Galva. Karnataka Industrial Area Development Board (KIADB) has developed three industrial areas (IA) in the vicinity of Ballari city – Mundaragi (Phase I to IV), Sanklapura (Phase I, II) and Ananthapur Road IA, spread over 522 acres. KIADB is also developing a new industrial area in Kuduthini, 20 km to the West of Ballari city. Iron and Steel industry (with cogeneration power plant) and jeans washing units in Mundaragi Phase IV have large water demand.

The city is also known for its dry weather and consecutive drought events[3], which had a debilitating effect on water availability for the city.

2.2 Water and Used Water Infrastructure in Ballari

Following section presents the water and used water infrastructure for Ballari City.

2.2.1 Water Infrastructure

Ballari receives its drinking water supply from Tungabhadra River via two Canals – Low Level Canal (LLC) [supplying water to Ballari City for 6 to 9 months] and High Level Canal (HLC) [supplying water to Ballari City for 3 to 5 months].

Water supply scheme through Tungabhadra River to Ballari City via LLC and HLC is shown in the **Figure 2-1** below.

[3] Source: Proposal for Pilot Project Reuse of Recycled Water in Karnataka, Urban Development Department, Government of Karnataka.

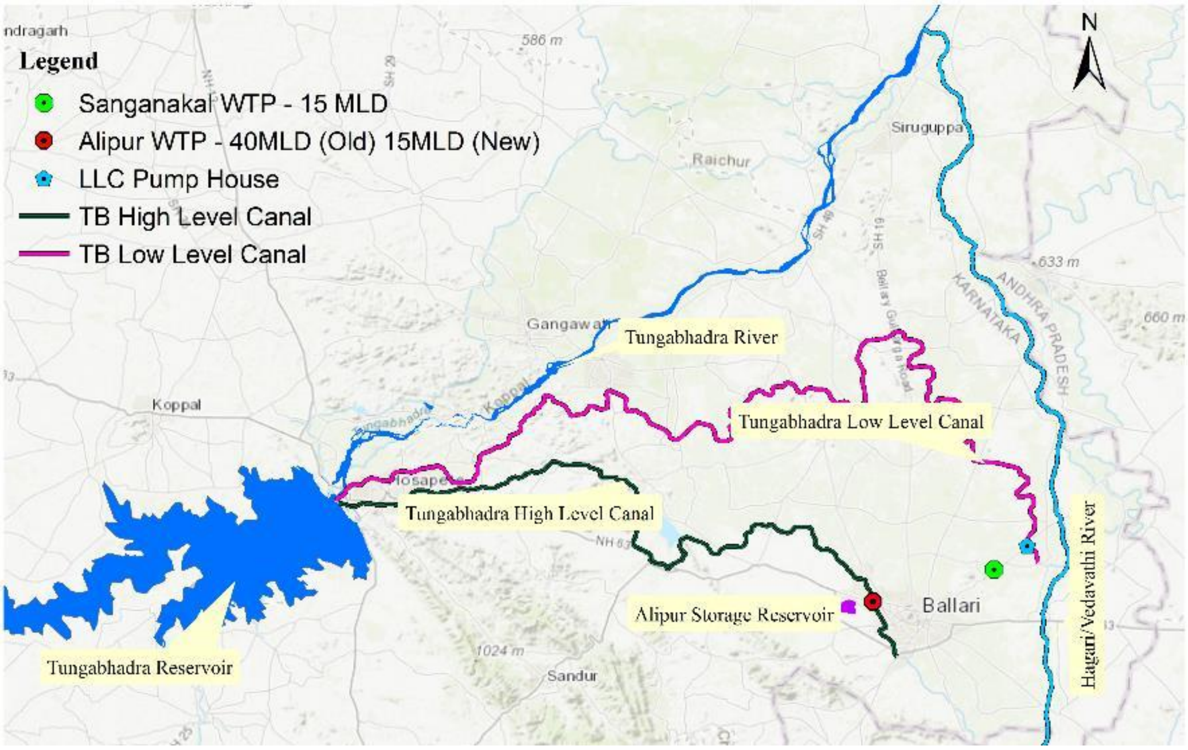

Figure 2-1: Ballari water supply scheme

Figure 2-2: Tungabhadra low level canal supplying drinking water to Ballari

Figure 2-2 above shows the Tungabhadra Low Level Canal. During the period of water supply in LLC, approximately 90 MLD of water is captured via an intake well from LLC, and is pumped through LLC Pump House to four (04) nos of WTPs. **Figure 2-3** shows the intake well at LLC, and **Figure 2-4** shows the LLC Pumphouse.

Figure 2-3: Intake well at LLC

Figure 2-4: LLC Pump house

Water from intake well is pumped to following WTPs:

- Allipura old WTP – 40 MLD [commissioned in 1975]

- Moka old WTP – 10 MLD [commissioned in 1992]
- Sangankal new WTP – 20 MLD
- Allipura new WTP – 15 MLD

Additional water from LLC is also stored in the Allipura Water Supply Impounding Reservoir of 12, 633 ML capacity, shown in **Figure 2-5.**

Figure 2-5: Allipura Impounding Water Supply Reservoir

All the four WTPs use conventional treatment, and the treated water is weekly checked from various location around Ballari City for drinking water quality compliance.

Typically, drinking water is supplied once in every five (05) days to each water service area.

2.2.2 Used Water Collection and Treatment Infrastructure

The underground used water collection and conveyance system for Ballari City has been developed over the period of last three decades, and currently has approximately 475 km of underground used water collection and conveyance network. The city is divided in to four (04) used water zones, namely Zone 1, 2, 3, and 4.

Used water collected from these zones is transported to following two Used Water Treatment Plants (UWTP), which are based on Facultative Aerated Lagoon technology for treating the used water:

Ananthapur Road UWTP – 30 MLD Capacity (average inflow 20 MLD, from Zones 3 and 4), (**Figure 2-6**)
Cowl Bazaar UWTP – 15 MLD Capacity (average inflow 9 MLD, from Zones 1 and 2) (**Figure 2-8**)

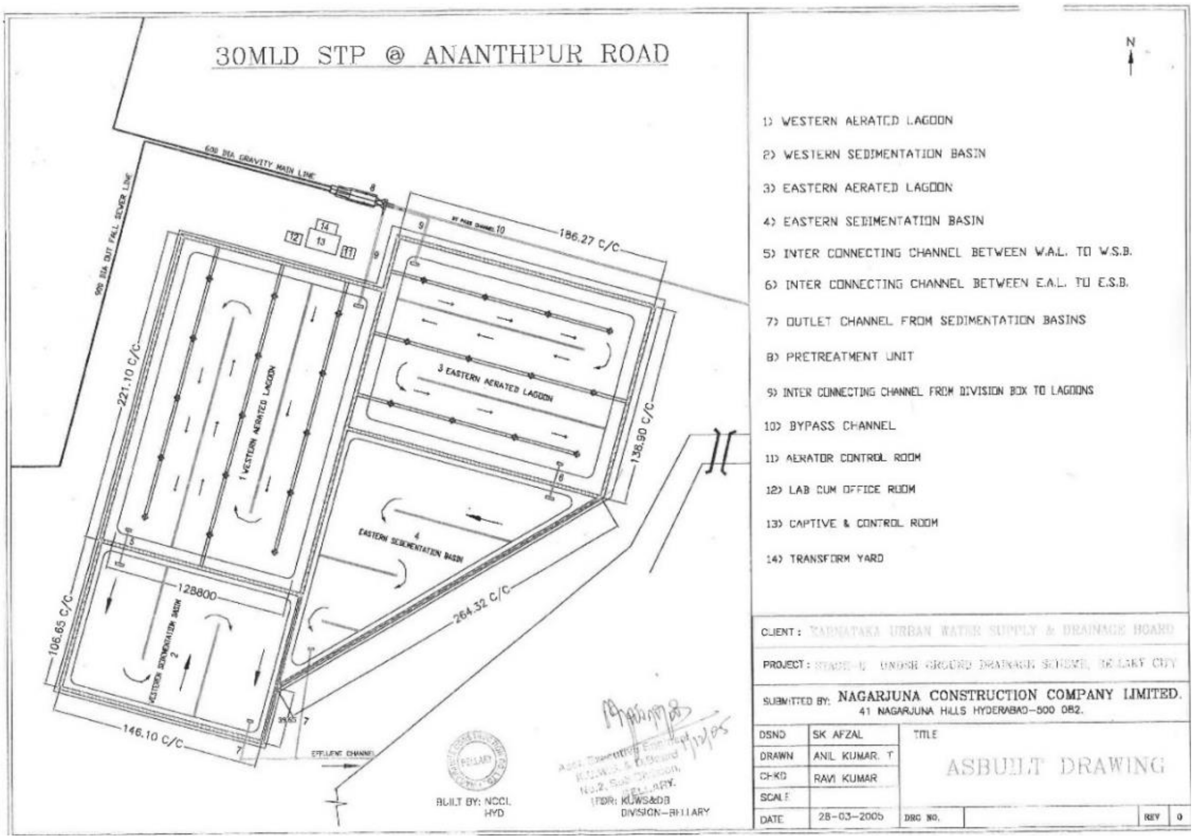

Figure 2-6: 30 MLD capacity Ananthapur Road UWTP Layout

Figure 2-7: Aerial image of 30 MLD capacity Ananthapur Road UWTP

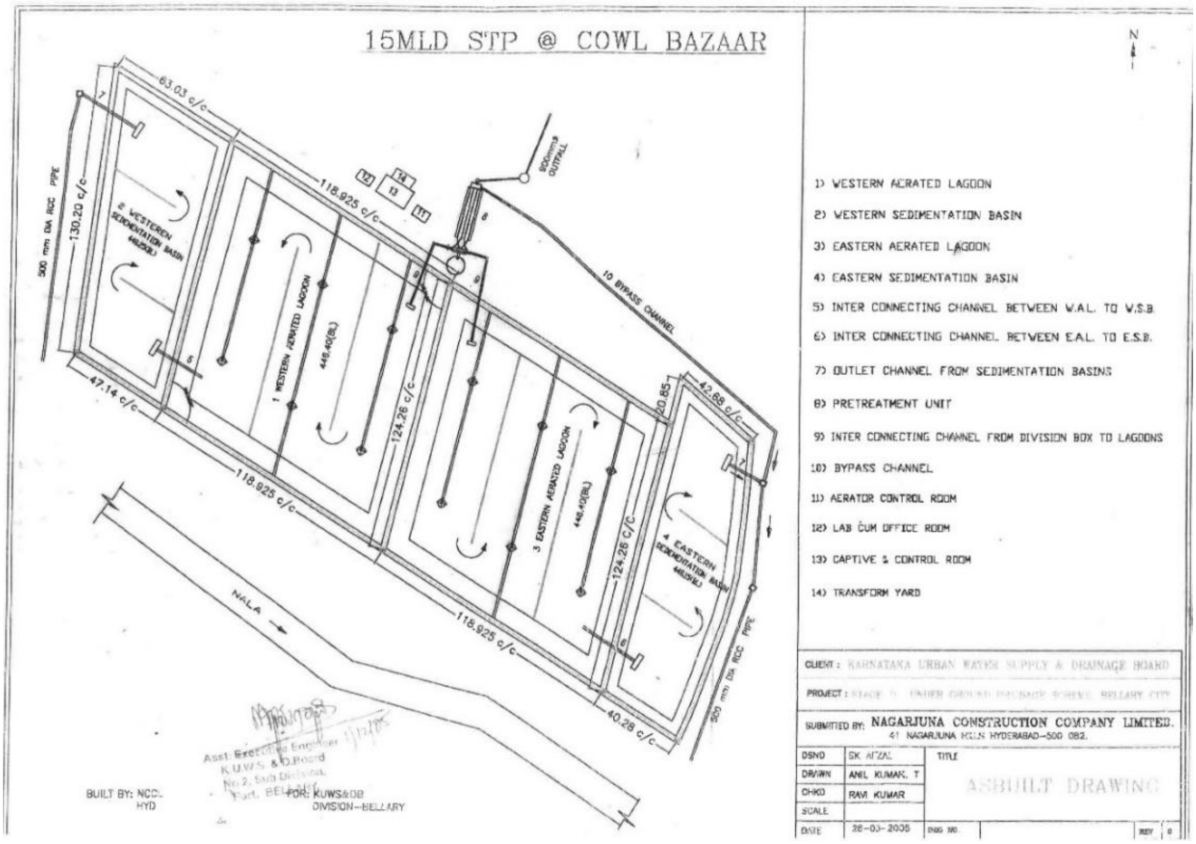

Figure 2-8: 15 MLD capacity Cowl Bazaar UWTP Layout

Figure 2-9: Aerial image of 15 MLD capacity Cowl Bazaar UWTP

Figure 2-10: 30 MLD capacity Ananthapur Road UWTP

Figure 2-11: 15 MLD capacity Cowl Bazaar UWTP

As per the water quality analysis performed for BOD, COD and Suspended Solids concentration in treated effluent from 30 MLD and 15 MLD UWTPs, the sample failed on all the three parameters. During discussion with Ballari Municipal officials, it was informed that the municipality is exploring the opportunity to upgrade/replace the existing UWTP for a better and technologically advanced treatment plant. Part of the used water currently being treated at the UWTPs, is supplied to industries, and remaining is discharged in the drain which runs through Ananthapur UWTP to Cowl Bazaar UWTP and meeting with Hagari River, which is a tributary to Tungabhadra River (**Figure 2-12**).

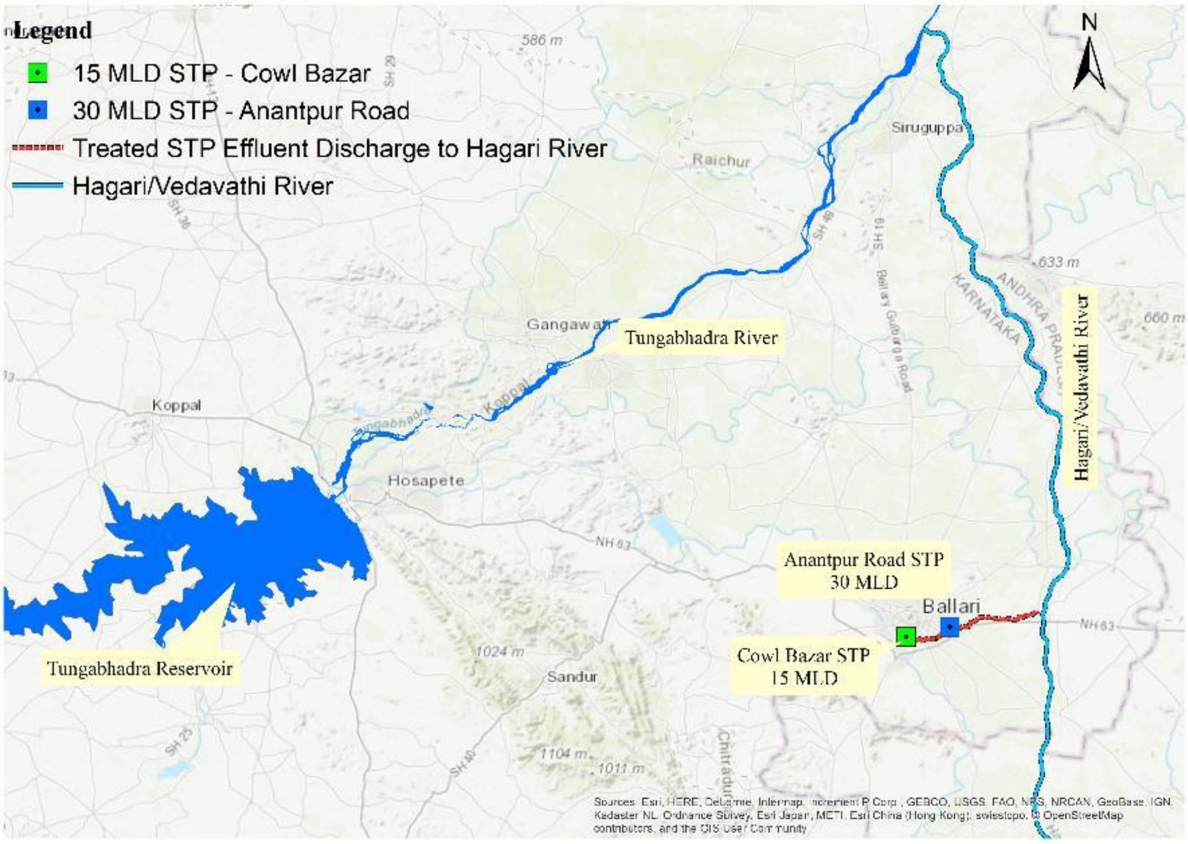

Figure 2-12: Used water treatment plants and existing scheme for disposing treated effluent

2.2.3 Existing Treatment Train Process Description for 30 MLD Ananthapur UWTP

The 30 MLD Ananthapur UWTP use Facultative Aerated Lagoon for used water treatment. The treatment process train is shown the below.

Process units – 30 MLD Ananthapur

30 MLD Capacity	
Location	Ananthapur Road
Primary Treatment	
Inlet chamber	Type: RCC
	Size: 4.45m x 4.80m x 0.55m
	MLD: 2.35 FB
	Penstock gates: 2 numbers
Spin chamber	Type: Automatic
	Automatic Motor Capacity: 1.5 HP
Grit chamber	Type: RCC

30 MLD Capacity	
	Length: 18.00m
	Width: 3.00m
	Depth: 1.87m + 0.5 MFB
Division box	Type: RCC
	Size: 1.60m x 6.20m x 0.80m + 0.50m (free board)
	Penstock gates: 2 numbers
Inlet channel type	Mechanical
	Length: 80 m
	Width: 1.2 m
	Depth: 1.45 m + 0.6m (free board)
Secondary Treatment Plant:	
Aerated lagoon details	Number of ponds: 2 (east / west)
	Measurement –Eastern: 140.00m x 186.00m x 3.5m +0.5m (free board)
	Measurement –Western: 221.00m x 128.80 x 3.5m +0.5m (free board)
Number of aerators	12.5 HP – 15 numbers (western)
	15 HP – 12 HP (eastern)
Sedimentation Basin Details	Number of Sedimentation Ponds: 2 (east / west)
	Measurement – Eastern 69, 192 m^2+ 0.60 FB
	Measurement – Pond 2: 221.00m x 128.80m x 1.65m + 0.60m (free board)
Outlet channel details:	Type: Machinery/Mechanical
	126m x 0.75m x 1.15m

2.2.4 Water Quality Analysis of Anathapur 30 MLD UWTP

Ballari Municipal Corporation conducted grab sampling at 6 hours interval for 24 hours (a total of 4 samples) at eastern and western outlets of Anathapur UWTP. The water quality analysis was performed following APHA 22nd Edition, and 44 parameters were tested. The outcomes of analysis and its comparison with CPCB prescribed guidelines is presented in the **Table 2-3** below.

Table 2-1: Comparison of treated effluent from Anathapur UWTP with CPCB and NGT Standards

S No.	Parameters	Parameters Limit (Standards for New STPs Design after Notification date)*	NGT prescribed standards (Published 30th April, 2019)	Ananthapur	
				Influent	Treated effluent
1	pH	6.5 – 9.0	5.5 – 9.0	7.1	7.7
2	BOD (mg/L)	Not more than 10	Not more than 10	622	83

S No.	Parameters	Parameters Limit (Standards for New STPs Design after Notification date)*	NGT prescribed standards (Published 30th April, 2019)	Ananthapur	
				Influent	Treated effluent
3	COD (mg/L)	Not more than 50	Not more than 50	1710	551
4	TSS (mg/L)	Not more than 20	Not more than 10	393	77.5
5	NH_4- N (mg/L)	Not more than 5	Not more than 5	21.5	7.9
6	N- total (mg/L)	Not more than 10	Not more than 10	41	16
7	Fecal Coliform (MPN/100 ml)	Less than 100	Less than 100	>161	>161
8	Total Phosphorus (mg/L)		Less than 1	3.9	2.3

The following **Table 2-2** presents range for key parameters of raw and treated used water for Anathapur 30 MLD UWTP.

Table 2-2: Key parameters of raw and treated used water for Anathapur 30 MLD UWTP

S No.	Parameters	Parameters Limit (Standards for New STPs Design after Notification date)*	NGT prescribed standards (Published 30th April, 2019)	Treated effluent					
				Min	Max	Avg	Min	Max	Avg
1	Total Suspended Solids	6.5 – 9.0	5.5 – 9.0	340.00	460.00	393.75	55.00	110.00	77.50
2	BOD_5	Not more than 10	Not more than 10	560.00	690.00	622.75	60.00	160.00	83.13
3	COD	Not more than 50	Not more than 50	1580.00	1860.00	1707.50	510.00	580.00	551.63
4	Ammonia (NH•4 ·N)	Not more than 20	Not more than 10	20.14	23.00	21.54	4.38	10.30	7.97
5	Nitrate (NO3-N)	Not more than 5	Not more than 5	17.10	28.00	23.73	15.80	21.00	18.01
6	Nitrite (NO2-N)	Not more than 10	Not more than 10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
7	Total Nitrogen	Less than 100	Less than 100	38.00	44.00	41.00	12.00	18.00	15.88
8	Total		Less than 1	3.62	4.36	3.93	2.11	2.86	2.33

S No.	Parameters	Parameters Limit (Standards for New STPs Design after Notification date)*	NGT prescribed standards (Published 30th April, 2019)	Treated effluent					
				Min	Max	Avg	Min	Max	Avg
	Phosphorus (as PO4)								

Source: Water quality sampling performed by Ballari Municipal Corporation

2.2.5 Current Utilisation of Secondary Treated Used Water

For Ananthapur UWTP, Ballari Municipal Corporation has got in to a contract with Janaki Corporation Limited for purchasing a minimum binding quantity of 3 MLD of treated effluent at Rs. 4.01 per kL. In case if Janaki Corporation uses more than 3 MLD of treated effluent, a cost of Rs. 4.01 per kL is levied. The cost of infrastructure for transporting the treated water from Ananthapur UWTP to Janaki Corporation premises, including pump house and pipelines, is borne by the Janaki Corporation.

Figure 2-13: Pump infrastructure supplying treated used water from Ananthapur UWTP to Janaki Corporation

Figure 2-14: Discussion with Ballari Municipal Officers at inlet to Janaki Corporation

2.2.6 Pumping Infrastructure

Once the treated used water from Ananthapur UWTP reaches Janaki Corporation, this water is again treated at the UWTP installed within Janaki Corporation premises.

The treated water at Janaki Corporation UWTP is used for following purposes:

- As feed water to boilers for steam production,
- Steam condensation and recirculation for cooling tower at power plants,
- For heat exchange in pellet and sponge iron plants,
- Irrigation and construction works.

The existing treatment process at Janaki Mills 5 MLD UWTP is shown in **Figure 2-15** below.

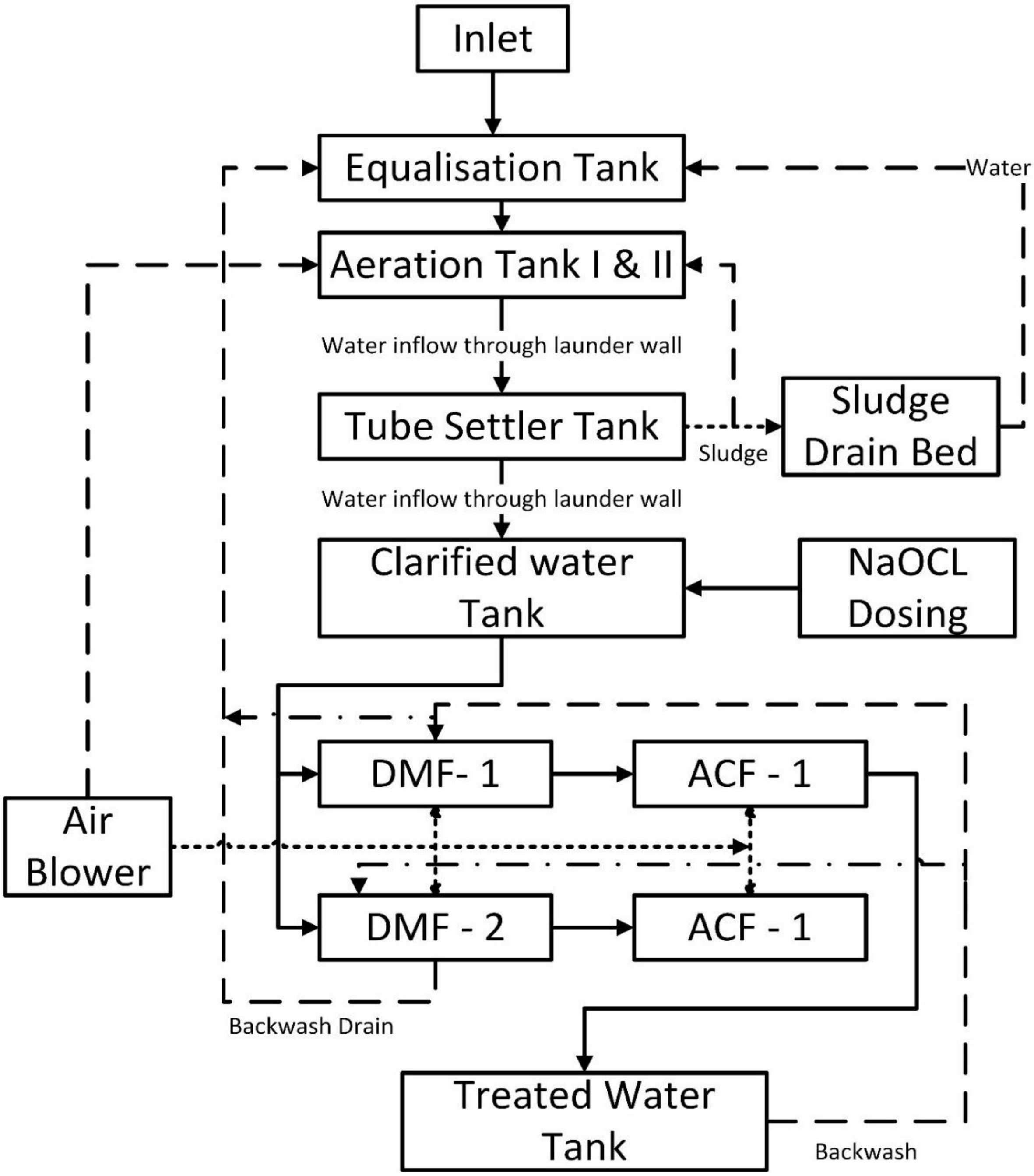

Figure 2-15: Existing treatment process ta Janaki Mill UWTP

2.2.7 Identified Recycled Water Demand Centre

In Ballari, sponge iron clusters are located in Belagal, Halakundi, and Veniveerapura. Sponge iron industries use water for the cooling towers and power plants. During water demand survey, 19 sponge iron units have expressed interest in using treated wastewater. Of these, only one unit has a cogeneration power plant. Remaining industries have not invested in a co-generation power plant due to water shortages. At present, all the industrial units use water from private bore wells and purchase water tankers that are sourced through groundwater. Jeans washing cluster in Mundaragi Phase IV industrial area has 53 jeans washing units. These industrial units require about 100,000 litres water per day, and receive their water through private water tankers (Sourced through groundwater from nearby villages). About 25 of these units have an ETP within premises, but none of these ETPs are operational. Upcoming industrial projects such as the Kuduthini Industrial Area and Uttam Galva Steel Plant will significantly add to the future demand of water. The estimated water demand in Kuduthini industrial area is about 07 MLD, while that of steel plants such as Uttam Galva is about another 07 MLD, totalling it to close to 15 MLD.

The water demand of existing sponge units in Ballari is presented in **Table 2-3**.

Table 2-3: List of iron sponge units in Ballari and their water demand

Name of the sponge iron unit	Water demand (MLD)
Mahamanav Ispat	0.125
Sapthagiri Sponge	0.05
Bhuwalka Steel	0.2
Suvan Steel	0.2
Pragati Ferro Steel	0.2
Hindustan Metals	0.25
Sree Giritej Iron and Steel	0.05
Jairaj Ispat	0.3
Balaji Premium Steel	0.25
Bellary Ispat	0.25
Yeshashvi Steel	0.125
Rangineni Steel	0.1
Supra Steel	0.15
Sree Venkateshwara Sponge	0.15
Popuri Steel	0.1
VKRP	3
Rayen Steel	0.25
Agarwal Sponge and Energy	3
Pavman Ispat	0.075
Total	8.825

Source: Proposal for Pilot Project Reuse of Recycled Water in Karnataka, Urban Development Department, Government of Karnataka.

Recycled Water Scheme – Feasibility Development

3 Recycled Water Scheme – Feasibility Development

Development of options for recycled water scheme was outlined in the Feasibility Study, and are briefly presented in the section below.

3.1 Used Water Treatment Site

Based on the consultations with the officials of Ballari City Corporation (BCC) and KUWS & DB, it was decided that the proposed RWTP to be situated in the premises of existing Ananthapur Road UWTP. This land parcel is owned by BCC. Further, it was also decided to use membrane-based treatment technology with UV disinfection in the proposed RWTP.

Reassessment and Selection of the Preferred Option

A technical discussion was held between the design team and KUWS & DB in the month of April 2019. During this discussion, a variety of options were considered based on the following criteria:

- Availability of sites
- Reliability and robustness of treatment technology
- Public perception and acceptance
- Future expansion capacity of plant CAPEX and OPEX costs

Following sections detail the re-evaluation work and selection of preferred option for the advanced recycled water scheme for Ballari.

3.1.1 Option 1 — Upgrade Treatment Process (retrofit) at both Existing UWTPs

This option will have following features:

- Produces secondary treated effluent better than existing quality and meets CPCB standards,
- Utilises existing infrastructure with additional cost for reactors and clarifiers,
- Does not use multi-barrier treatment, unfit for human contact,
- Proper O&M is critical for this option as higher O&M cost for treatment plant at two locations.

Treatment units in this option are as in **Figure 3-1**.

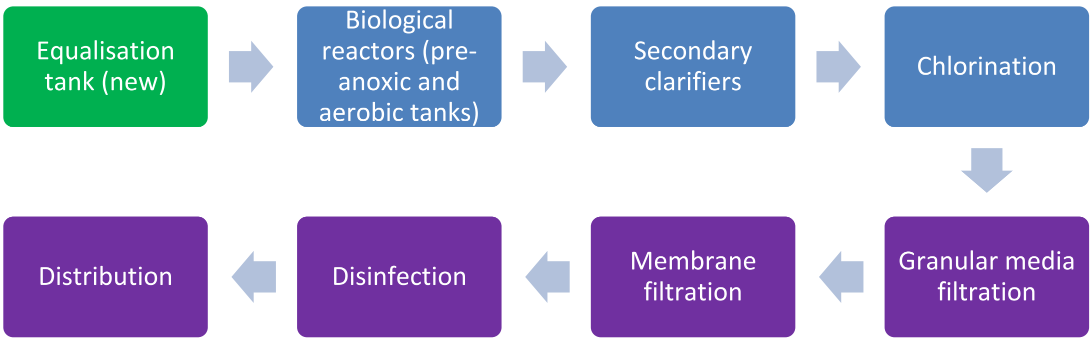

Figure 3-1: Treatment train for Option 1

3.1.1.1 Option 1a: Upgrade Existing Treatment Process, Standalone RWTP

The challenges and opportunities for Option 1a are listed below.

Table 3-1: Challenges and opportunities - Option 1a

Challenges	Opportunities
• Upfront capital cost investments, • O&M costs at two locations, • May require an external O&M contractor, • Less reliable RWTP influent quality, plant operation, and hence recycled water quality	• CPCB compliant treated secondary effluent, • Minimize UWTP modifications • Separate delivery models possible for RWTP

The schematic and bird's eye view on terrain of Option 1a are presented in **Figure 3-2** and **Figure 3-3** respectively.

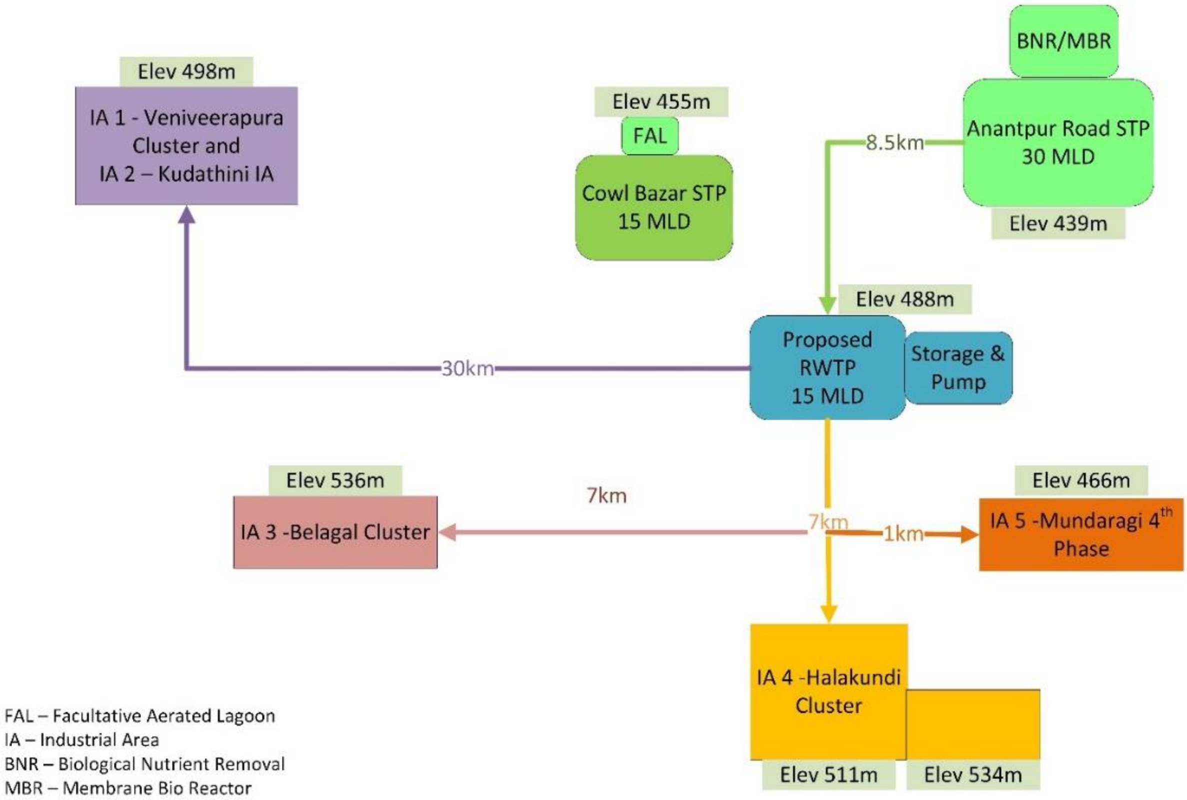

Figure 3-2: Schematic for Option 1a

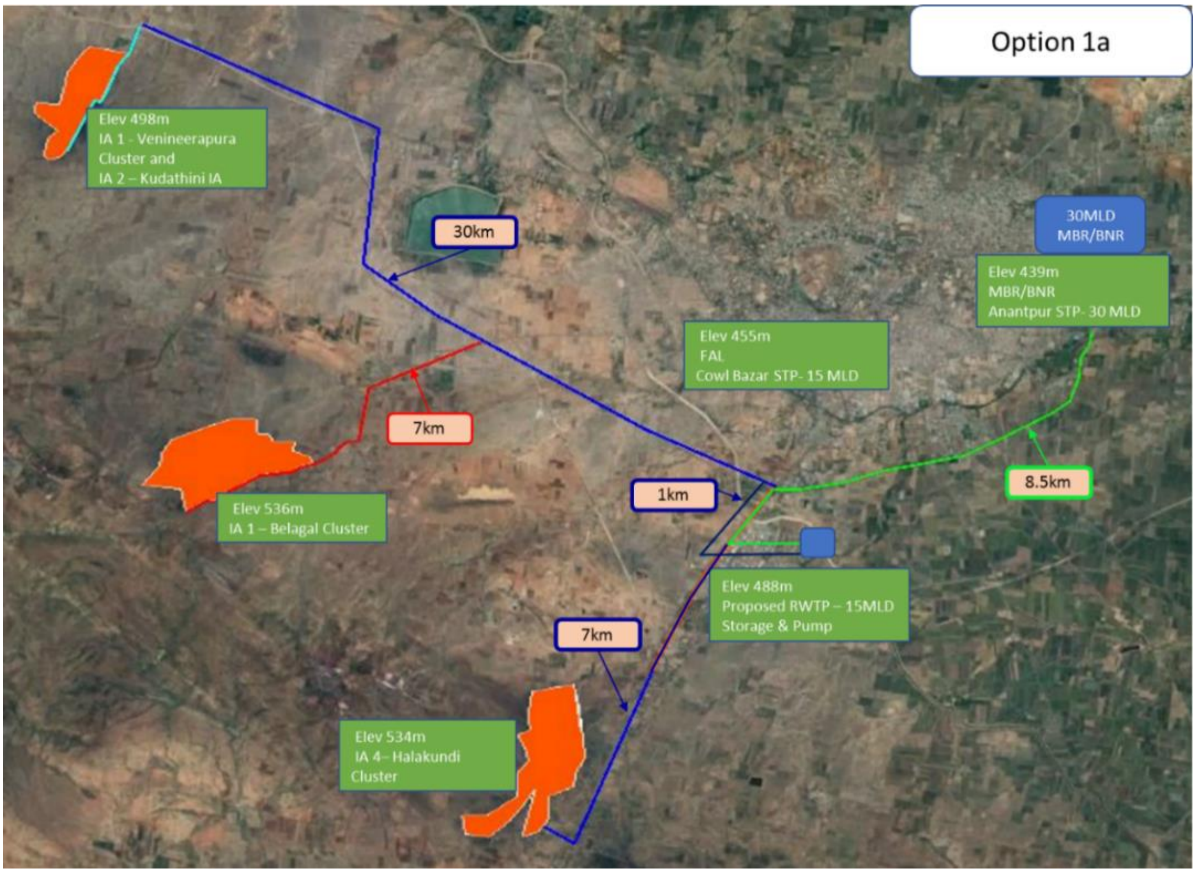

Figure 3-3: Aerial view of Option 1a

3.1.1.2 Option 1b: Upgrade existing treatment process, co-located RWTP at Ananthapur

Option 1b recommends upgrading the existing 30 MLD Ananthapur UWTP so that the treated effluent meets CPCB requirements and co-locate ARWTP at 30 MLD Ananthapur UWTP site.

The challenges and opportunities associated with Option 1b are shown in **Table 3-2**.

Table 3-2: Challenges and opportunities - Option 1b

Challenges	Opportunities
• May require an external O&M contractor, • Operation of integrated treatment process	• Relatively lower land and capital costs, • Lower O&M costs due to co-location, • CPCB compliant treated effluent, • More reliable RWTP influent quality and plant operation, superior quality recycled water production,

The schematic and bird's eye view on terrain of Option 1b are presented in **Figure 3-4** and **Figure 3-5** respectively.

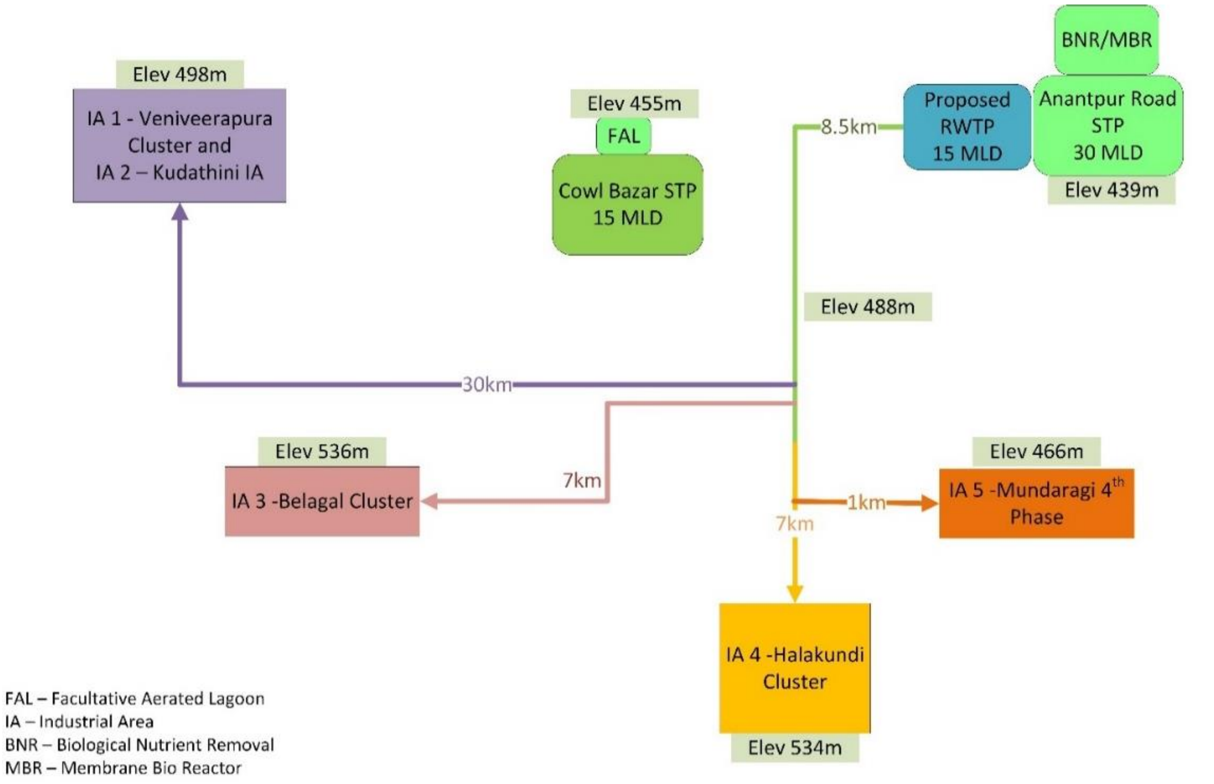

Figure 3-4: Schematic for Option 1b

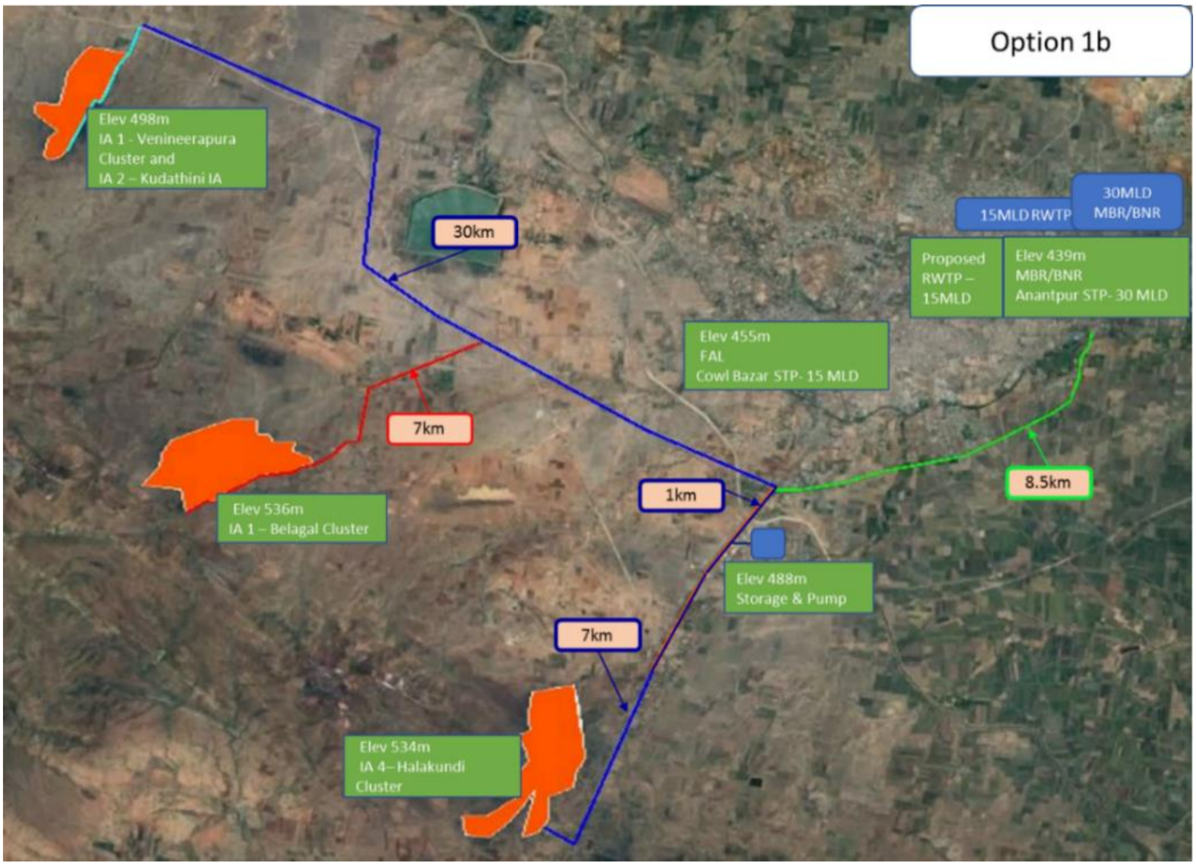

Figure 3-5: Aerial view of Option 1b

3.1.2 Option 2 — Construct New UWTP and Standalone RWTP

Option 2 recommends decommissioning the existing 30 MLD Ananthapur UWTP, and construct a new one of the same capacity. The ARWTP will be located close to Mundaragi 4th Phase Industrial area (at the same location identified under KUWS&DB proposal).

Option 2 will have following features:

- Produces high quality treated effluent and meets CPCB standards,
- Utilises existing land with additional cost for reactors and membrane,
  - Higher cost than Option 1
- Does not use multi-barrier treatment, unfit for human contact,
- Proper O&M is critical for this option as higher O&M cost for treatment plant at two locations.

Treatment units in this option are as in **Figure 3-6**.

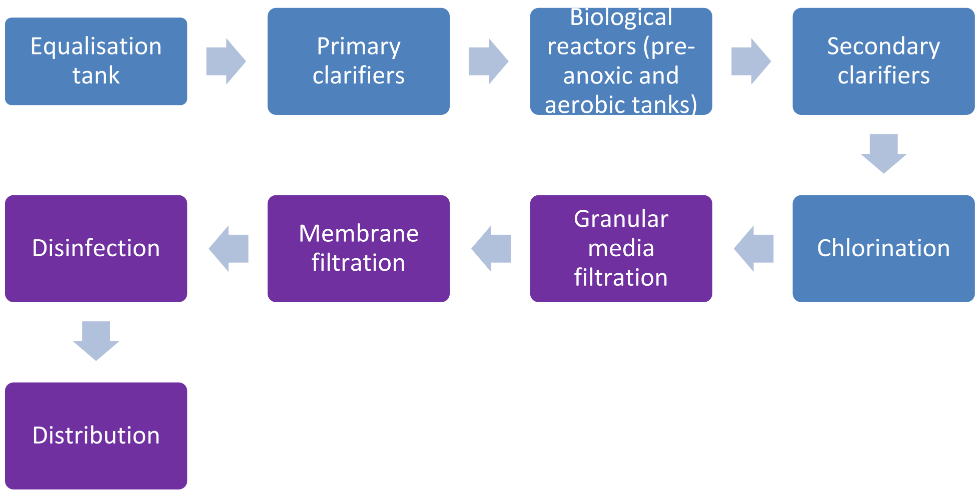

Figure 3-6: Treatment chain for Option 2

The challenges and opportunities for Option 2 are listed in the **Table 3-3** below.

Table 3-3: Challenges and opportunities - Option 2

Challenges	Opportunities
• Upfront higher capital cost investments, • O&M costs at two locations, • May require an external O&M contractor,	• Leveraging latest treatment technology, • Surpassing CPCB treated secondary effluent, • High quality recycled water production, • Higher industrial uptake leading to improved revenue generation through proper pricing.

The schematic and bird's eye view on terrain of Option 2 are presented in **Figure 3-7** and **Figure 3-8** respectively.

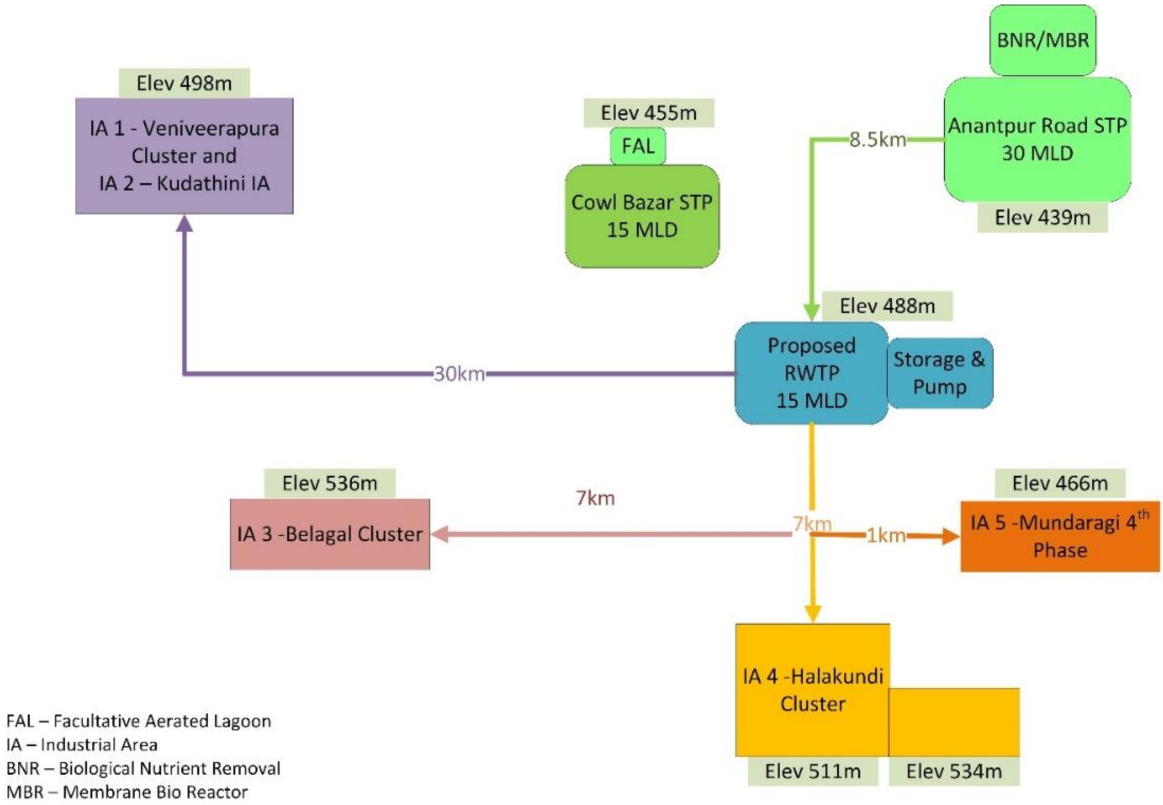

Figure 3-7: Schematic for Option 2

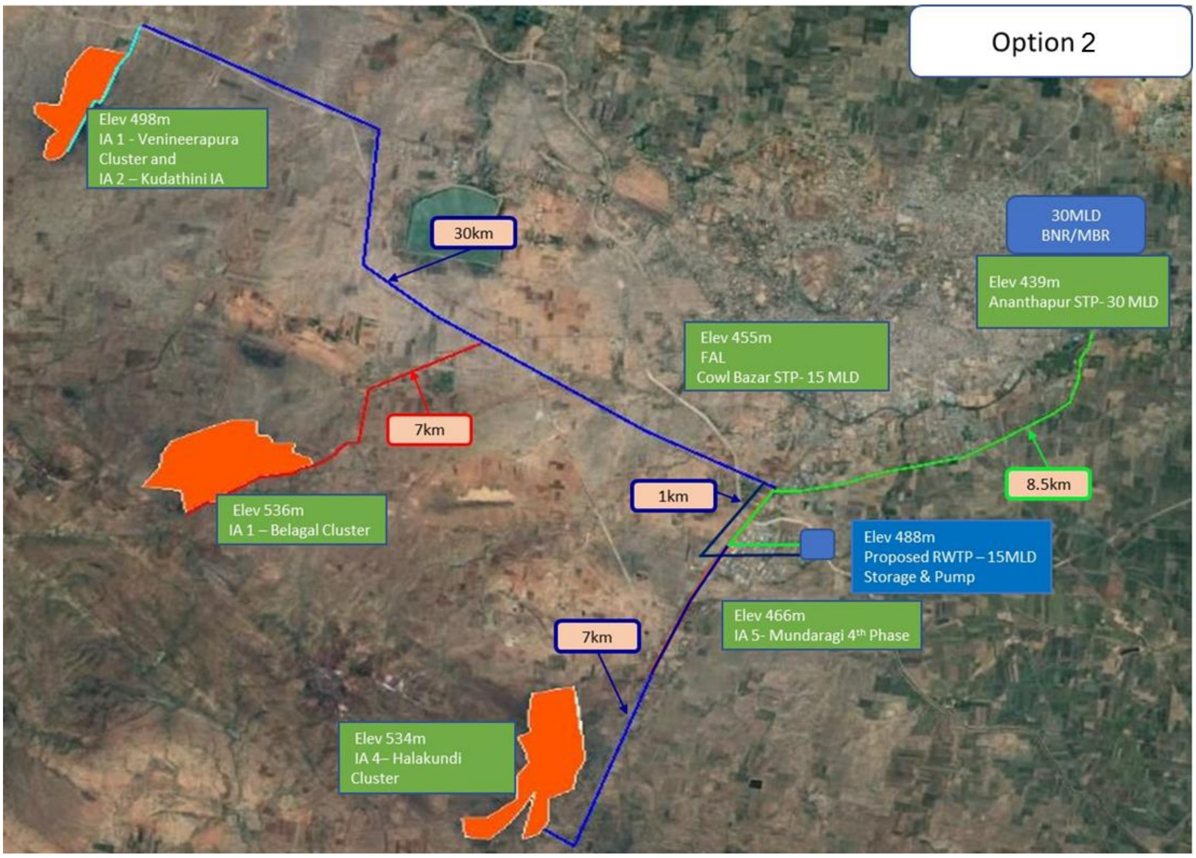

Figure 3-8: Aerial view of Option 2

3.1.3 Option 3 — Construct New UWTP and RWTP at Anantapur Road

Option 2 will have following features:

- Produces high quality treated effluent and meets CPCB standards,
- Lower capital cost as compared to Option 2,
- Does not use multi-barrier treatment, unfit for human contact,
- Lower O&M cost as compared to Option 2, better suited scheme for recycled water production and distribution.

Treatment units in this option are as in **Figure 3-9.**

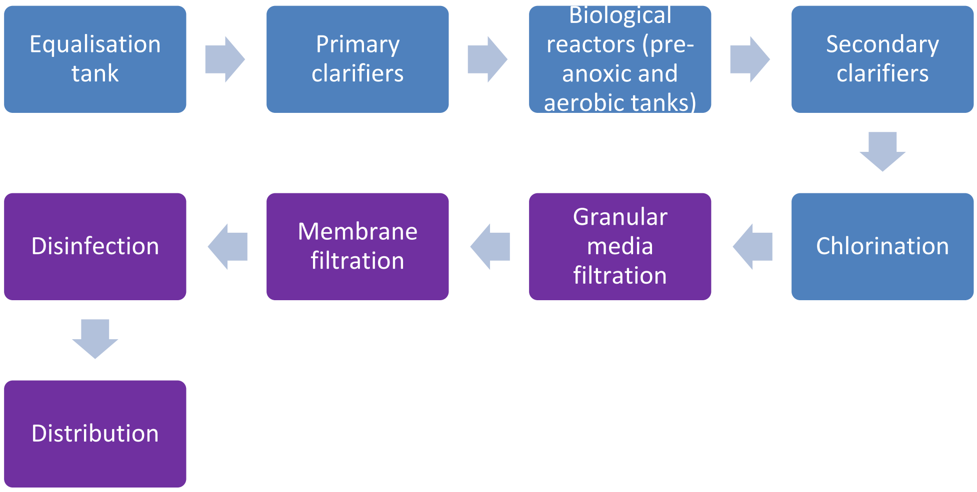

Figure 3-9: Treatment chain for Option 3

Option 3 recommends decommissioning the new construction of 30 MLD Ananthapur UWTP, and co-locate ARWTP at 30 MLD Ananthapur UWTP site.

The challenges and opportunities associated with Option 3 are shown in the **Table 3-4** below.

Table 3-4: Challenges and opportunities associated with Option 3

Challenges	Opportunities
• Upfront higher capital cost investments, • O&M costs at two locations, • May require an external O&M contractor,	• Leveraging latest treatment technology, • Surpassing CPCB treated secondary effluent, • High quality recycled water production, • Higher industrial uptake leading to improved revenue generation through proper pricing.

The schematic and bird's eye view on terrain of Option 3 are presented in **Figure 3-10** and **Figure 3-11** respectively.

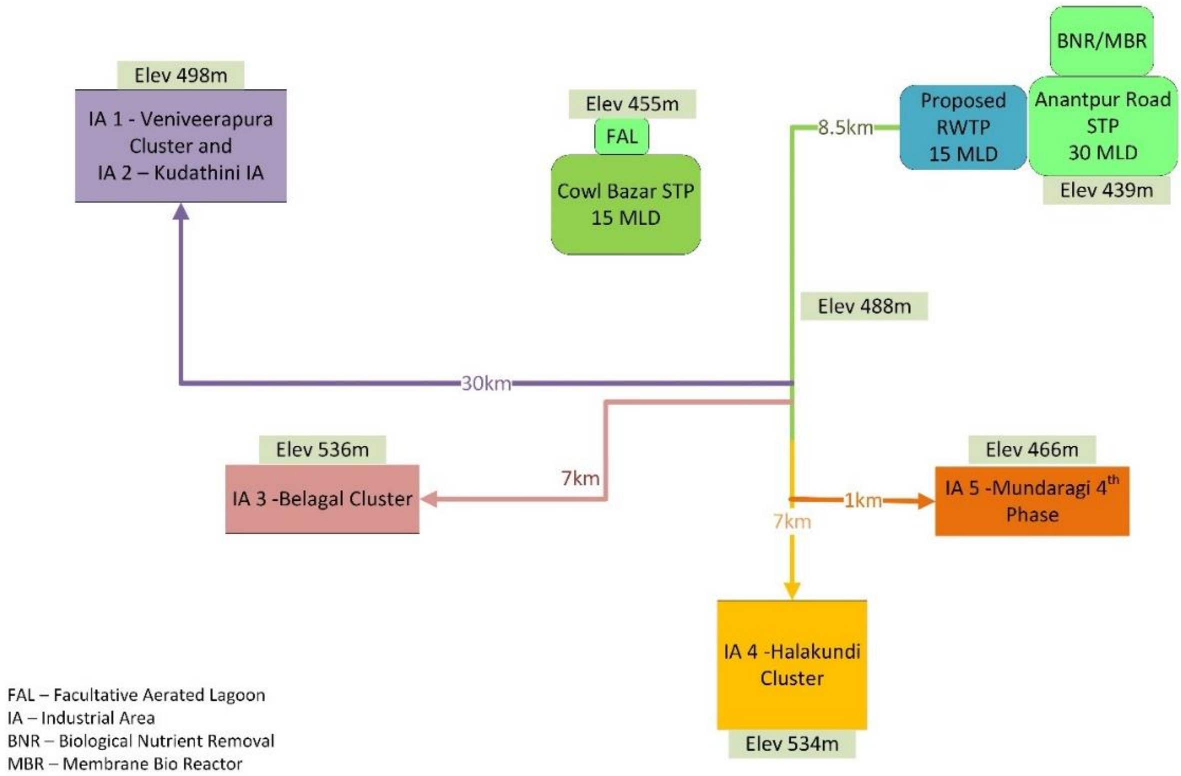

Figure 3-10: Schematic for Option 3

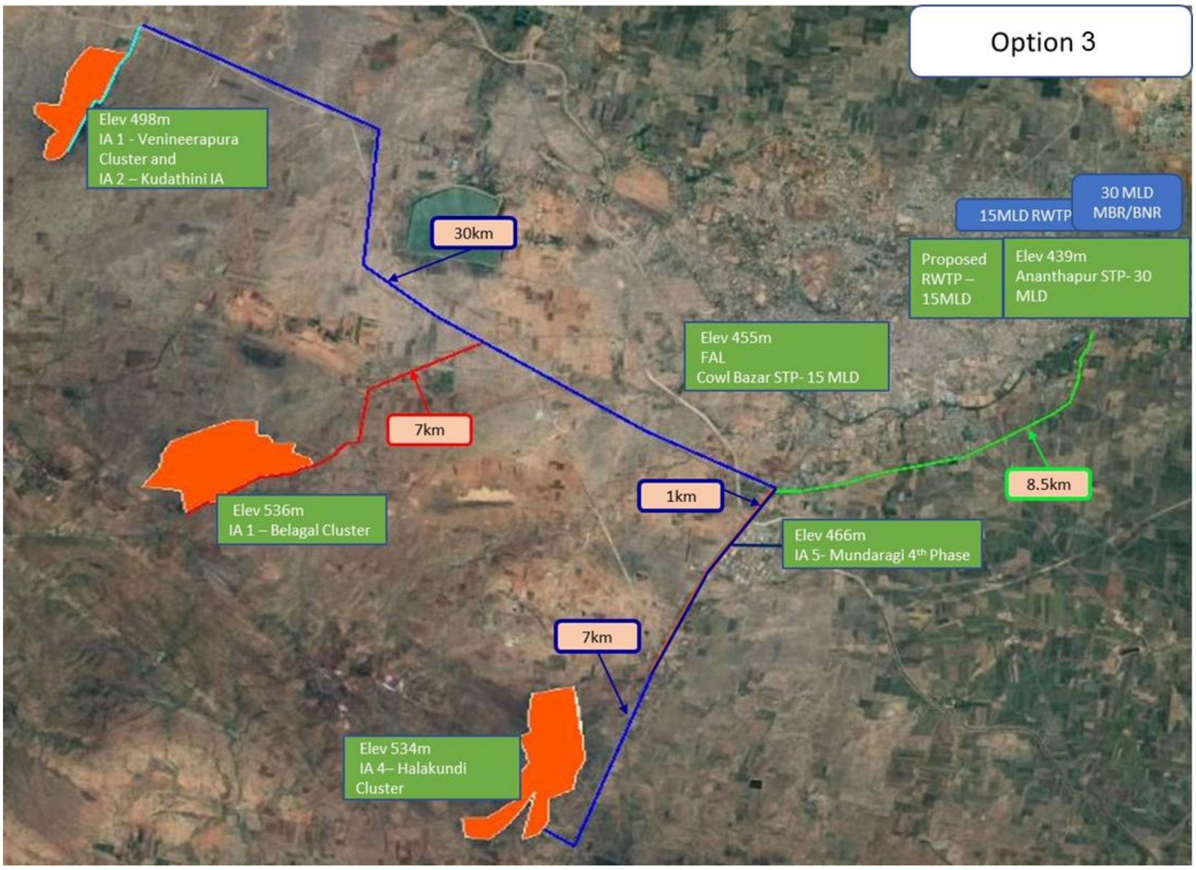

Figure 3-11: Aerial view of Option 3

3.1.4 Option 4 – Construction of An Advanced New UWTP

The fourth option included creation of an advanced UWTP, which can serve following purposes:

- New plant with latest and advanced treatment technology will produce high quality water output, and therefore meeting the discharge standards as well as creating high quality water for industrial non-potable purposes,
- Deliver the plant on Design Build and Operate scheme, and therefore ensuring that the desired maintenance as well as product water quality is achieved,
- With high quality water output, BMC can sell the water to industries and thereby omitting the need for retreatment by the industries – which industries such as Janaki Corporation are doing at a high cost.
- In case, the industries demand high grade water that can be used for industrial applications such as in boilers, further advanced treatment units can be added for bacteria removal and water softening.

3.2 Selected Preferred Option

Based on the assessment of the four options, the further techno-economic analysis was done between Option 1 b and Option 4, and Option 4 was found more suitable.

The development of Preliminary Design for Option 4 is presented in the subsequent sections.

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Basis of Design

4 Basis of Design

Following section presents the key aspects that will form the basis of design. It includes applicable policies, codes and standards for recycled water treatment and utilisation, availability, quality and existing treatment scheme of used water,

4.1 Policies, Codes and Standards for Recycled Water Utilisation

Existing policies, codes and standards for recycled water treatment and utilisation are provided in this section.

4.1.1 Existing Policy for Reuse in India

Historically, India has limited national policy governing reuse of treated used water. The Environment (Protection) Rules 1986, developed under the Environment (Protection) Act 1906 (Government of India), specifies water quality standards for discharges, including use of treated water for irrigation. Regulation on the use of treated used water for other activities is absent from the document.

However, there has been a push for reuse in more recent years, on both regional and local (building or development level) scale. The National Urban Sanitation Policy 2008 endorses recycling and reuse but abstains from specifying obligations. The National Water Policy 2012 also encourages recycling and reuse of water after treatment but does not outline specific requirements.

More recently in April 2015, CPCB issued a directive to promote non-drinking reuse together with revised treated used water standards. The directive states that:

"secondary treated sewage should be mandatorily sold for use for non-potable purposes such as industrial process, railways & bus cleaning, flushing of toilets through dual piping, horticulture and irrigation."

"No potable water to be allowed for such [above] activities."

"dual piping system should be enforced in new housing construction for use of treated sewage for flushing purposes."

4.1.2 Central Pollution Control Board direction for treatment and utilisation of treated used water

The Central Board in its 168th meeting held on 27.03.2015 resolved to notify the standards for treated used water. These standards for discharge of treated used water from UWTPs have also been endorsed in the Minister's Conference held during April 6-7, 2015 and 59th Conference of Chairman and Member Secretaries of Pollution Control Boards and Pollution Control Committees held on April 8, 2015, and are presented below in **Table 4-1**.

Table 4-1: CPCB standards for discharge of treated used water

S No.	Parameters	Parameters Limit (Standards for New STPs Design after Notification date)*
1	pH	6.5 – 9.0
2	BOD (mg/L)	Not more than 10
3	COD (mg/L)	Not more than 50
4	TSS (mg/L)	Not more than 20
5	NH_4- N (mg/L)	Not more than 5

S No.	Parameters	Parameters Limit (Standards for New STPs Design after Notification date)*
6	N- total (mg/L)	Not more than 10
7	Fecal Coliform (MPN/100 ml)	Less than 100

Note:

These standards will be applicable for discharge in water resources as well as for land disposal. The standards for Fecal Coliform may not be applied for use of treated sewage in industrial purposes.

***Achievements of Standards for existing STPs within 5 years from the date of notification.**

4.1.3 Urban Waste Water Reuse Policy of Government of Karnataka (GoK)

The Government of Karnataka (GoK) approved the Urban Waste Water Reuse Policy in the year 2017 with an overall goal to establish an enabling environment for the reuse of municipal used water to maximise efficient resource use, protect the environment, address water scarcity, and enhance economic output. This policy focuses on the reuse of treated used water and the associated implications on sustainable sanitation and water resources availability, and considers integrated approach to urban water management emphasising on circular water economy.

This policy envisages to achieve the vision of accelerated adoption of circular economy across major towns and cities of Karnataka with respect to used water treatment and reuse through the targets listed below:

- By 2020, 10 major cities[4] have adopted used water reuse principles and developed firm plans, to be increased to [100% of all major cities/towns by 2030].
- By 2020, 20% of all secondary treated used water is targeted for reuse across the state, in accordance with regulatory standards; to be increased to 50% by 2030, subject to responsible ecological return flow provisions approved under Integrated Urban Water Management Plans[5].

This policy applies to all Class I and Class II urban centres in Karnataka and focuses largely on recycling after used water conveyance through sewer networks and treatment at sewage treatment plants. Separate guidance may be developed for smaller cities and towns that may have alternative used water conveyance and treatment systems in place (ex: faecal sludge management systems).

This policy has suggested minimum water quality criteria for reuse of treated used water for the following broad sectors as shown in Table 4-2.

A detailed note on Waste Water Reuse Policy of Government Karnataka in presented in **Appendix A**.

Table 4-2: Suggested minimum water quality criteria for different sectors

Suggested minimum water quality criteria for agriculture reuse

Parameter	Unit	Value
Intestinal nematodes	No./liter	<1
Faecal coliforms	MPN/100	Nil (for crop eaten raw) & <230/100 ml (for crops eaten

[4] Class I and II cities, corresponding presently to 67 cities and town in Karnataka

[5] This provision accounts for the hydrological principle of return flows, whereby users of treated wastewaters are themselves new generators of wastewater; and whereby net withdrawal of the urban hydrological cycle is limited to evapotranspiration, embedded water in products, and/or lost return flows.

Parameter	Unit	Value
	ml	cooked or non-edible crops
pH		6 – 9
Source: Chapter 7, Part A of CPHEEO 2013 Manual on Sewerage and Sewage Treatment		

Typical water quality requirements for industrial reuse

Constituent (mg/L)	Boiler Feed	Pulp and Paper	Textiles	Petroleum and Coal	Cooling Water*
Calcium	0.01 – 0.4	20	-	75	100
Iron	0.05 – 1.0	0.3 – 1.0	0.3 – 1.0	1	-
Manganese	0.01 – 0.3	0.05 – 0.5	0.01 – 0.05	-	-
Alkalinity as CaCO3	40 – 350	100	-	125	-
Chloride	-	200 – 1000	-	300	100
TDS	200 – 700	-	100	1000	-
Hardness as CaCO3	0.07 – 350	100	25	350	-
Ammonium - N	0.1	-	-	-	1 – 3
Phosphate – P	-	-	-	-	0.6
Silica	0.7 – 30	50	-	-	20
Colour (Hazen)	-	10 - 30	5	-	-
Calcium	0.01 – 0.4	20	-	75	100
Source: Guidance Note for Municipal Used water Reuse and Reclamation in India, JICA 2013 CPHEOO Manual (Part A Chapter 7) discusses cooling tower water and boiler water in some details					

Suggested minimum *water quality for environmental/recreational reuse*

Parameter	Unit	Value
BOD_5		≤ 10
TSS	mg/L	<5
Faecal coliforms	MPN/100 ml	Nil
pH		6.5 – 8.3
Total Kjeldahl Nitrogen (as N)		<5 for impoundments, <10 for horticulture/golf course
Dissolved Phosphorous (as P)		1
Colour (Hazen)		Non-detect
Source: Chapter 7, Part A of the CPHEEO 2013 Manual on Sewerage and Sewage Treatment		

4.1.4 Recycled Water Transfer System

Currently, there are no Indian standards or codes exist for a recycled water transfer system. It is anticipated that the same codes as a water transfer/reticulation system can be applicable for a recycled water transfer system.

4.1.5 Residuals (bio-solids) Management

Biosolids are produced during the treatment of used water. They contain organic matter and plant nutrients and hence provide a useful soil conditioner and medium grade fertiliser.

However, untreated used water sludge may also contain pathogens (capable of causing disease in humans and animals), microorganisms such as bacteria, viruses, helminths (parasitic worm-like invertebrates), protozoa (small single celled animals including amoebae, ciliates and flagellants) and fungi. These organisms must either be destroyed by treatment or managed through controls on recycling. In addition, biosolids may contain various levels of chemical contaminants including metals from domestic and industrial sources.

In recent years, new treatment methods and technologies have improved the quality of generated biosolids. At the same time, there is growing awareness of the value of this product and increasing demand for its use. Biosolids contain a wide range of essential nutrients that are beneficial for plant growth. These include nutrients, nitrogen and phosphorus, and the trace elements calcium, magnesium, potassium, sodium, manganese, copper, zinc, molybdenum, boron and others. However, it should also be noted that the trend towards improvement in treated used water quality by removal of nutrients via chemical means has the potential to adversely affect biosolids quality by increasing iron or aluminium and associated trace contaminant content.

In India, no guidelines currently exist for the management of biosolids. In several international countries, the USA and Australia for example, the first step in biosolids management is the classification of biosolids according to stabilisation status (including pathogen reduction, vector attraction controls and chemical contaminant levels). Typically, where a sludge or biosolids product does not meet a reuse classification and is to be disposed by landfill, it is classified according to leachate status.

Further safeguards are typically provided by:

- The regulatory pathway determining how the biosolids may be used, dependent on the biosolids classification,
- Limitations on biosolids application rates,
- Monitoring of soil contaminant levels before application,
- Ceiling concentrations for soil contaminant levels,
- Dilution by incorporation into soil, and
- Monitoring of groundwater before application.

4.1.5.1 Classification and use of biosolids

International guidelines on biosolids management require a level of biosolids treatment to reduce the concentrations of pathogens and contaminants depending on the proposed use of the resource. In Australia, the classification system contains seven categories of biosolids related to recycling or disposal:

- All land application uses, including residential,

- Agriculture - biosolids suitable for land used for the grazing of cattle, crops consumed raw, crops consumed cooked or processed,
- Institutional landscaping: recreational - biosolids suitable for urban land application (such as parks and racecourses),
- Institutional landscaping: non-recreational,
- Forestry, land rehabilitation,
- Municipal landfill, and
- Controlled landfill or thermal processing.

To achieve a classification, the biosolids should comply with:

- The specified stabilisation grade (which includes pathogen reduction and vector attraction controls), and
- Chemical contaminant level limits.

4.1.5.2 Biosolids disposal options

Since the method of biosolids treatment will be dictated by the chosen disposal route, the available biosolids disposal options will drive the overall biosolids management strategy. Biosolids disposal options are subject to the following considerations:

- Practicability and reliability,
- Security and sustainability,
- Environmental impact,
- Public acceptance,
- Timelines and,
- Economics.

The following final disposal options for treated biosolids were assessed, including:

- Landfill,
- Land application, e.g. agriculture, forestry, horticulture,
- Thermal oxidation with energy recovery (mono- or co-incineration),
- Combustion/ Co-processing (supplementary fuel/ raw material in industry),

The advantages and disadvantages of the most common biosolids disposal techniques are summarised in **Table 4-3.**

Table 4-3: Advantages and disadvantages of biosolids disposal techniques

Disposal Technique	Advantages	Disadvantages
Landfill	• Little monitoring required • Simple solution • Continuous outlet • Can generate energy from landfill gas	• Not environmentally sustainable • Requires good physical quality • Requires landfill capacity • Health and safety concerns

Disposal Technique	Advantages	Disadvantages
Land application • Agriculture • Forestry • Horticulture • Land reclamation	• Considered best practice environmental option • Low CAPEX and OPEX • Environmentally sustainable route • Benefits both biosolids producer and user	• Logistically and administratively complex • Requires strict monitoring and control • Requires additional biosolids treatment • Seasonal demand (storage implications)
Thermal oxidation with energy recovery (mono- or co-incineration)	• Largest volume reduction • Destruction of pathogens, toxic organic compounds • Uses calorific value of biosolids • Continuous outlet (no seasonal/ weather impacts)	• High CAPEX and OPEX • Nutrients not recycled • Complicated process – requires skilled operators • Residuals (air emissions and ash) require careful handling • Potential public aversion over health concerns
Combustion/ Co-processing (supplementary fuel/ raw material in industry)	• Complete destruction of biosolids • Uses calorific value of biosolids • Continuous outlet	• High CAPEX and OPEX* • Requires the appropriate industry to use the biosolids as a secondary fuel/ raw material.
*Achieving a biosolids product of sufficient quality for this use may require additional treatment (e.g. biosolids drying to achieve 90%DS), increasing both CAPEX and OPEX		

4.2 Used Water Quantity and Quality Assessment

This section presents the used water quantity and quality at Ananthapur and Cowl Bazaar UWTP.

4.2.1 Used Water Quantity Assessment

Ballari City has two used water treatment plants – 30 MLD on Ananthapur Road and 15 MLD at Cowl Bazaar, with two wet wells at Raghavendra Colony and Mahalaxmi Timber that were commissioned in 2004. Another 6 wet wells (six different places in the city) were commissioned in 2012; one at Ballarappa Colony was commissioned in 2014; and two at Azad Nagar and Gonal were commissioned 2017.

On average, Ananthapur UWTP receives around 21 MLD of used water, whereas Cowl Bazaar UWTP receives 9 MLD of water.

4.2.2 Treated Used Water Quality Assessment

Both the UWTPs use facultative aerated lagoon (FAL) technology for used water treatment. The aeration is achieved using surface aerators, and aerated effluent is stored in sedimentation tanks, prior to disposal in open drain at downstream.

Following Table 4-4 presents the treated effluent water quality results, and results shows that the treated water did not comply with prescribed limits for BOD, COD and suspended solids.

During discussion with Ballari Municipal Corporation officials, it was learned that the aerators in the

UWTPs have not been functioning and also the ponds have not been de-sludged. This could be a potential reason for high BOD, COD and SS in treated effluent.

Table 4-4: Water quality results for treated used water at 30 MLD and 15 MLD UWTPs

S No	Sample details	Date of sampling	Parameter	Prescribed standard	Result of analysis	
					Eastern outlet	Western outlet
1	30 MLD UWTP	23rd May, 2018	BOD (mg/L)	10	92	158
			COD (mg/L)	50	264	325
			Suspended solids (mg/L)	30	60	40
2	15 MLD UWTP	23rd May, 2018	BOD (mg/L)	10	44	83
			COD (mg/L)	50	183	237
			Suspended solids (mg/L)	30	40	60

Source: Ballari Municipal Corporation

Table 4-5: Effluent discharge standards for sewage treatment plants

Parameter	Unit	Revised CPCB Discharge Standards (Discharge in Water Resources & Land Disposal) for New STPs*	Old CPCB Discharge Standards (Inland Surface Water)
pH	Units	6.5 – 9.0	5.5 – 9.0
BOD	mg/L	≤10	30
COD	mg/L	≤50	250
TSS	mg/L	≤20	100
NH_4 – N	mg/L	≤5	50
N – total	mg/L	≤10	
Faecal Coliform	MPN/100ml	<100	

Source: Directions under Section 18 (1) (b) of the Water (Prevention and Control of Pollution) Act, 1974 regarding treatment and utilization of sewage. Notification dated: 21 April, 2015.

One of the key objectives of CPCB to have these guidelines was to facilitate recycled water production and utilisation.

4.3 Used Water Flows

At present, the Ananthapur UWTP is receiving an average of 21 MLD of inflow and Cowl Bazaar UWTP is receiving 9 MLD of inflow.

4.4 Product Recycled Water Quality Guidelines – Indirect Drinking Reuse (IDR)

Recycled water utilisation for indirect reuse does technically entails to produce water that meets safe drinking water standards, however, it is a prudent approach to reduce public health risks. Recycled water treatment can be employed to provide multiple barriers for removal of pathogens and trace organic contaminants.

In India, and internationally there are no agreed guidelines or standards for IDR. As such an amalgam of WHO, USEPA, Australian Recycled Water Guidelines and Australian Water Quality Guidelines for Fresh and Marine Waters has been adopted in defining the target treated recycled water quality. Table 4-6 gives a summary of the water quality targets for recycled water.

Table 4-6: Treated Recycled Water Quality Targets (Adapted from WHO, USEPA, Australian Recycled Water Guidelines, California Recycled Water Standard & ANZECC Guidelines for Freshwater)

Parameters	Units	Adopted Value	Reason
Alkalinity (as $CaCO_3$)	mg/L	None	Not a health-based target
Aluminium	mg/L	None	Not a health-based target
Ammonia (as N)	mg/L	<1.0	Environmental objective
Bacteria	organism/100 mL	>8.1 log reduction	Pathogen log reduction target based on Campylobacter
Escherichia Coli (E. coli)	cfu/100ml	<1.0	Health-based target
Boron	mg/L	2.4	Health-based target
Calcium	mg/L	None	Not a health-based target
Chloride	mg/L	None	Not a health-based target
Copper	mg/L	2	Health-based target
Fluoride	mg/L	1.5	Health-based target
Iron	mg/L	<0.3	For aesthetics & control of biofilm growth
Langelier Saturation Index (LSI)		None	Not a health-based target
Magnesium	mg/L	None	Not a health-based target
Manganese	mg/L	<0.1	For aesthetics & control of biofilms
Nitrate (as N)	mg/L	<10	Environmental target for control of nuisance plant growth; For irrigation
pH	mg/L	7.0 to 8.5	Corrosion control & environmental target
Total Phosphorus (as P)	mg/L	<0.2	Environmental target for control of nuisance plant growth
Potassium	mg/L	0.5 to 15	Health-based target
Protozoa	Log reduction	>8 log reduction	Pathogen log reduction target based on

Parameters	Units	Adopted Value	Reason
			Cryptosporidium
SAR		None	Not a health-based target
Sodium	mg/L	None	Not a health-based target
Total Dissolved Solids (TDS)	mg/L	None <500	Not a health-based target for WHO or USEPA India drinking water guideline
Total Organic Carbon (TOC)	mg/L	<0.5	Control biofilm growths & absence of trace organic compounds
Total Nitrogen	mg/L (N)	<10	Control biofilm growths & environmental target for control of nuisance plant growth
TSS	mg/L	See turbidity	
Turbidity	NTU	<0.3 prior to disinfection	WHO and USEPA pathogen control
Viruses	Log reduction	>9.5 log reduction	Pathogen log reduction target. Human health protection or drinking
Water Hardness (as CaCO3)	mg/L	None	Not a health-based target
Zinc	mg/L	None	Not a health-based target
Total Residual Chlorine	mg/L	<5	Health-based target
Total Trihalomethanes Ratio		<1.0	Health-based target
Barium	mg/L	<1.3	Health-based target

4.5 Environmental Targets for Recycled Water Utilisation

For recycled water, there is an absence of guidelines for designated of recycled water. Environmental water quality objectives for recycled water are shown in Table 4-6.

The State of Queensland in Australia has developed comprehensive water reuse guidelines (Queensland Government Environmental Protection Agency, 2005). The Queensland guidelines identify five levels of water quality for reuse applications varying from irrigation of non-food crops to applications involving potential for direct human contact. As with California regulations, emphasis is placed on microbiological characteristics and turbidity. Physical and chemical characteristics such as pH, free chlorine, total dissolved solids (TDS) and electrical conductivity (EC) are also included. While several technologies applicable for treating used water to reuse standards are described in the Queensland guidelines, the California standards do not specify prescriptions for specific processes trains or technologies required to produce treated effluent that satisfies the five levels of recycled water quality identified in the guidelines.

Table 4-7 summarizes the quality requirements for Class A+ recycled water which is the highest level and is considered suitable for "dual reticulation to households and industry for toilet flushing, garden irrigation, washing of cars, houses and hard surfaces and many industrial purposes (suitably determined in a case-by-case basis)".

Table 4-8 summarizes the recommended water quality specifications for Classes A through D recycled water.

Table 4-9 summarizes typical recycle water uses and the corresponding recommended class of recycled water appropriate to each use.

Table 4-7: Recommended Water Quality Specifications for Queensland Class A+ Recycled Water (Queensland Government Environmental Protection Agency, 2005)

Item	Requirement
Treatment Objective Starting with Raw Used Water (If measured from settled, primary screened sewage, a 0.5 log reduction credit can be applied for bacteria and protozoa and 0.1 log credit for viruses.)	Six log reductions of viruses (bacteriophage as indicator) Five log reductions of bacteria (E. Coli as indicator) Five log reductions of protozoan parasites (Clostridium perfringens as indicator) For irrigation applications, compliance with trigger values for irrigation waters in Chapter 4 of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality
Microbiological Criteria	E. Coli <1 CFU per 100 mL (median); <10 CFU per 100 mL (95 %'ile) Clostridium perfringens <1 CFU per 100 mL (median); <10 CFU per 100 mL (95 %'ile) F-RNA bacteriophage <1 PFU per 100 mL (median); <10 PFU per 100 mL (95 %'ile) Somatic coliphage < 1 PFU per 100 mL (median); <10 PFU per 100 mL (95 %'ile)
Physical & Chemical Criteria	Turbidity <2 NTU (95 %'ile), 5 NTU (maximum) For dual reticulation systems, free chlorine residual 0.2 to 0.5 mg/L on delivery to customer. For other Class A+ uses, the need for a chlorine residual should be determined as part of 5-17 the risk assessment. pH 6.0 to 8.5 (if disinfection relies predominantly on chlorine, but not chlorine dioxide) or 6.0 to 9.2 if other disinfection systems are used. For sustainable irrigation, salinity should be kept as low as possible, e.g. if TDS >1,000 mg/L or EC >1,600 µS/cm, a salinity reduction program should be implemented. Any other physical or chemical criteria that the risk assessment phase of a Recycled Water Management Plan has identified as representing a risk to soil, crop or human health.

Table 4-8: Recommended Water Quality Specifications for Queensland Class A through D Recycled Water (Queensland Government Environmental Protection Agency, 2005)

Class	E. Coli (median) CFU / 100 mL	BOD_5 (median)	Turbidity (95 %'ile/ max) NTU	TSS (median) mg/L	TDS or EC (medians) mg/L or µS/cm	pH
A	<10	20	2/5	5	1,000 or 1,600	6.0 to 8.5
B	<100	20	-	30	1,000 or 1,600	6.0 to 8.5
C	<1,000	20	-	30	1,000 or 1,600	6.0 to 8.5
D	<10,000	20	-	-	1,000 or 1,600	6.0 to 8.5

Table 4-9: Recommended Recycled Water Classes for Various Uses (Queensland Government Environmental Protection Agency, 2005)

Recycled Water Class	Recycled Water Use
A+	• Dual reticulation to households and industry for toilet flushing, garden irrigation, washing of cars, houses and hard surfaces and many industrial purposes (suitability determined on a case-by-case basis • Irrigation of field crops (fruits & vegetables), including root crops, eaten raw or with minimal processing • Retail nurseries irrigating ready to eat crops • Industrial uses such as open systems (potential for high human contact) such as a carwash or quarry where aerosol generation is constant • Fire fighting
A	• Above ground open space irrigation with uncontrolled public access of public open spaces and golf courses • Retail nurseries irrigating non-food crops • Various industrial open systems with potential for occasional human contact but with safeguards in place • Fountains and water features with no primary or secondary contact recreation
B	• Irrigating pasture/fodder for dairy animals without a withholding period Wash-down of hard surfaces in agricultural industries
C	• Irrigating pasture/fodder for dairy animals with a withholding period of 5 days • Irrigating pasture/fodder for non-dairy grazing animals except pigs with a withholding period of 4 hours • Irrigation of "no public access" areas • Various industrial closed systems with low potential for human contact • Water features for amenity purposes only and with controlled access • Natural or artificial wetlands
D	• Irrigation of non-food crops such as silviculture, turf, cotton, wholesale nurseries with controlled access and other safeguards to protect the health of workers or neighbours

4.6 Assumptions and Limitations

There is very little precedence of advanced recycled water treatment plants -built for reuse applications in India. For this Feasibility Study, some key assumptions were made during the design and cost estimation phases. Such assumptions were based on similar overseas examples and experience acquired through delivering similar projects.

A project risk register needs to be compiled for this project and it is recommended that future project implementation stages for this project comprehensively review, evaluate and address each of the project risks identified for this project. The key areas of assumptions and limitations for the Feasibility Study are listed below:

- Limited water quality and quantity data. It is further assumed that RWTP will receive water quality that complies to CPCB – 2015 treated effluent standards,
- Planning level engineering design,
- Planning level cost estimates,
- Cost and available capacity of the power supply to the proposed site,
- Legal, land and property acquiring costs,
- Environmental, heritage and planning approvals for the proposed pipeline,
- No investigation of geotechnical aspects for the site or pipeline.

Preliminary Design Development

5 Preliminary Design Development

Used water treatment is an important component of the overall treatment process as it has a strong bearing on the overall effectiveness of advanced water treatment processes. A balance between economic and technical aspects is essential for achieving the project objectives.

The Preliminary Design Report is based on the preferred treatment option of MBR based BNR process for the non-potable industrial reuse purpose. This being a reliable used water treatment process. Activated sludge treatment using Biological Nutrient Removal for nitrogen and phosphorus removal, and a membrane based solids separation (Membrane Bioreactor) instead of conventional gravity clarification, is envisaged. The Membrane Bioreactor also had the added advantage of producing a superior water quality to that possible with a gravity clarifier.

Figure 5-1: Process flow schematic

Figure 5-2: Solid handling schematic

5.1 Inlet Works

The inlet works include the first set of unit processes in the WWTP that perform preliminary treatment of the incoming raw used water flow to remove large or coarse materials and grit. This reduces operational and maintenance issues such as excessive wear/abrasion, siltation and interference with mechanical equipment in downstream process units.

5.1.1 Fine Screening

The fine screening system should be complete with the fine screens, screenings washing/dewatering equipment and a system to convey dewatered screenings to a storage bin. The size and shape of the screen openings should be selected by the future construction contractor to suit the equipment being supplied. The maximum screen opening size should not exceed 6 mm in order to protect downstream equipment. Another set of 2 mm opening size MBR fine screens will be provided upstream of the MBR tank to protect the membrane equipment.

Table 5-1 presents a summary of the design criteria for the inlet screens.

Table 5-1: Inlet screens design parameters

Parameter	Value
Average Flow	30 MLD
Inlet Screen Max Opening Size	6 mm, mechanical screen
Number of Inlet Screens	2
MBR Fine Screens (Opening Size)	2 mm, punched plate

Parameter	Value
MBR Fine Screens (Number)	2
Configuration	1 duty; 1 standby

5.1.2 Grit Removal

Grit includes sand, gravel, cinder or other heavy and non-putrescible solid materials that are "heavier" (higher specific gravity) than the organic biodegradable solids in the used water. Removal of grit prevents unnecessary abrasion and wear of mechanical equipment, grit deposition in pipelines and channels, and accumulation of grit in the digesters and aeration basins. The grit system should include grit removal, classification, and washing equipment and dumpster/tote.

The used water flow is conveyed by channel from each of the fine screens to vortex-type grit removal basin. The underflow grit slurry from each basin is pumped to grit separator-classifier systems for dewatering. The dewatered, classified grit will be dropped into dumpster/tote and avoid conveyor if possible, finally will be disposed offsite.

A summary of the design criteria for the grit removal system is given in **Table 5-2**.

Table 5-2: Grit removal design parameters

Parameter	Value
Average Flow	30 MLD
Removal Efficiency	95% of 0.20 mm 75% of 0.15 mm
Number of Units	2
Configuration	1 duty 1 standby

5.2 Biological Nutrient Removal (BNR) with Membrane Bioreactor (MBR)

Biological Nutrient Removal is a common process requirement due to the water quality targets for the final product water. Biological Nutrient Removal processes remove organic material from the used water through a series of reactions such as hydrolysis, oxidation, cellular incorporation, and solid-liquid separation. The BNR consists of a series of interconnected cells within the treatment tank.

After the biological nutrient removal process, flow containing suspended biomass (mixed liquor) is passed into a final membrane tank. Here the solids-liquid separation is achieved using membrane separation technology. The integrated treatment process consisting of both the biological nutrient removal tanks and the membrane tanks is called the membrane bioreactor (MBR).

5.2.1 Function

The BNR system will be designed to serve several key functions which include the following:

- Removal of soluble and particulate biodegradable organic components through consumption by biomass microbial population. The microbes are then separated by the membranes and either recirculated to achieve rapid treatment by increasing the population of microbes in the anoxic and aerobic tanks or wasted from the system.
- Nitrification of influent ammonia and organic nitrogen to nitrate and the subsequent denitrification of the nitrate to nitrogen gas. This results in an effluent low in nitrogen that will achieve water quality goals of the project.

The water quality performance targets for the BNR+MBR process unit is summarised in **Table 5-3**.

Table 5-3: Water quality criteria for BNR + MBR permeate

Parameter	Value
Total Nitrogen	Less than 10 mg/L as N
Total Phosphorous	Less than 1 mg/L as P

5.2.2 BNR Design

As the effluent quality targets of this project are stringent due to the intended non-potable reuse for industrial units, the treatment process selected needs to be robust for both the used water treatment processes as well as the advanced treatment process.

The influent used water has average BOD levels of about 300 mg/L, which is indicative of a strong used water. The main impact this has on treatment is that it is likely that there is sufficient carbon source especially for the heterogeneous bacteria involved in the de-nitrification process required to reduce total nitrogen in the effluent. Considering the characteristics of the influent used water, the Bioreactor contains design features to provide for enhanced biological nutrient removal, namely additional de-nitrification through a first anoxic zone.

The design criteria for the bioreactor treatment process unit is summarised in **Table 5-4**.

Table 5-4: BNR design parameters

Parameter	Estimate quantity
Configuration	2 trains
Required Anoxic Bioreactor Volume	1600 m3
Number of Bioreactor Lanes	2 lanes
Lane Dimensions	11.1 m x 10 m x 7.77.11 m (W x L x H)
Maximum Liquid Depth (at full equalisation level)	7.2 m
Freeboard	0.5 m
Number of Anoxic Mixers	2 per train, total 4
Mixer Type	Submersible mixer
Mixer Power	9.4 kW
Configuration	2 trains
Required Aerobic Bioreactor volume	6400 m3
Lane Dimensions	25 m x 19 m x 7.7 m (W x L x H)
Maximum Liquid Depth (at full equalisation level)	6.8 m
Freeboard	0.9 m
Number of Aerobic Aeration Blowers	2 duty 1 standby
Blower Power, each	226 kW
Bioreactor Recirculation Flow (RAS) cum Nitrified Recycle (NRCY)	120,000 m3/d

Parameter	Estimate quantity
Number of Recirculation Pumps	1 pump per train
Recirculation Pump Power, each	65 kW

5.2.3 Aeration

Of the total bioreactor volume, the aerobic zones equate to 80% by volume inclusive of membrane zone). Aeration is carried out in two aeration cells, per train, with a controlled air supply to develop the required microbial population for removal of organics and nitrification of ammonia and organic nitrogen. Air is supplied by blowers fitted with variable speed drives to control aeration input. The dissolved oxygen concentration in each of the aeration cells will be monitored by dissolved oxygen probes. The air supply to each cell will then be controlled by an actuated valve based on the dissolved oxygen reading.

5.2.4 Flow recirculation

Internal recirculation is provided to achieve the required de-nitrification within the anoxic cells. A relatively high internal recirculation rate of three to four times of plant flow is provided to permit low nitrogen concentrations to be achieved and to recover more of the alkalinity consumed by the nitrification process. This nitrified recycle flow can controlled either through the use of a nitrate analyzer signal at the end of the primary anoxic zones or flow paced off of the influent flow measurement signal. In addition, recirculation capacity of up to three to four times of plant flow is provided to bring flow from the membrane tanks back to the front of the aerobic zone in order to maintain biomass concentrations. This recirculation flow can be flow-paced.

5.2.5 Nitrogen removal

The proposed design layout consists of a tank with baffle walls to create cells in series with anoxic and aerobic zones. The anoxic zone is for de-nitrification followed by an aerobic zone for nitrification and final oxidation of organic matter. To maximise the amount of de-nitrification, the anoxic zone precedes the aerobic zone so that it receives the untreated used water, which has the highest concentration of BOD. However, due to the low BOD expected from the influent used water. In addition, methanol dosing can also be used at pre anoxic zones to provide a supplemental external carbon source. This is optional to bring total nitrates and total phosphorous of the effluent down to target levels before going to the advanced treatment processes. Air blowers would be used to create aerobic conditions in the aerobic cells.

5.2.6 BNR system description

For this project, a BNR using a Ludzack Ettinger process integrated with Membrane technology configuration (for low total nitrogen, alkalinity and oxygen recovery) is selected.

In a Ludzack Ettinger configuration, the influent used water is fed to anoxic zone which is followed by aerobic zone. The process relies on the nitrate formed by aerobic zone being returned via the RAS to the anoxic zone. Typically, the RAS ratio is half to one times the influent used water flow. Because the only nitrate fed to the anoxic zone is that in the RAS, and RAS flow is limited, denitrification is greatly limited by the RAS recycle ratio.

This process is integrated with MBR technology. It is the usual feature of the MBR technology that RAS ratio is three to four times of the influent used water. Hence, almost all the nitrate formed in the aerobic zone returns to the anoxic zone, and denitrification is enhanced greatly. This configuration can easily meet a common effluent standard of < 10 mg/l total nitrogen.

A step-by-step description of the flow path follows:

- Feedwater (from preliminary treatment) is conveyed via pipe to Pre-Anoxic Tank. The pre-anoxic zone is intended to provide an environment for denitrification to take place, so only horizontal propeller mixers or platform mounted submerged turbine mixers will be provided to keep biomass in suspension. Flow and scum will overflow from the Anoxic Tanks to the Aerobic Tanks,
- Return Activated Sludge (RAS) also enters the Pre- Anoxic Tank , from the Membrane Tank. This recycle is set at a high-rate, to accommodate maximum nitrogen removal and oxygen and alkalinity recovery,
- The influent used water and RAS flows are mixed under anoxic conditions and an appropriate residence time. Anoxic Tank contains submersible mixers to mix and keep the biomass in suspension,
- The denitrified mixed liquor flow (i.e. mixed liquor) out of Anoxic Tank enters Aeration tank. Sufficient residence time is provided and air is diffused at the bottom of the tank through fine bubble diffused aeration system,
- After an appropriate residence time in the aerobic zone, the mixed liquor overflows out of the bioreactor into the membrane tanks,
- The membranes are placed in separate tanks to allow for cleaning and maintenance to be undertaken without impacting on plant throughput. Air is applied below the membranes to provide scouring and reduce fouling,
- Permeate pumps draw clear effluent (permeate) through the membranes by applying a suction (vacuum) pressure,
- The excess sludge generated is wasted to the sludge treatment process.

5.2.7 Membrane system description

The MBR tank block will be constructed from reinforced concrete. The overall structure will be rectangular layout configuration.

The membrane tank sizes should be reconfirmed during future design phases according to the supplier proprietary designs for the membrane units. The membrane system would be procured as a package system and would generally include the following:

- Membrane modules (hollow fibre),
- Membrane supporting mechanism,
- Associated pumps, blowers, valves and controls,
- Ancillary system equipment to provide operating and cleaning resources.

The design criteria for the membrane system is summarised in **Table 5-5**.

Table 5-5: MBR design parameters

Parameter	Estimate quantity
System Capacity	30 MLD, peak flow of 67.5 MLD
Membrane Trains	5 Trains
Membrane Area per Train	10,000 m^2
Design Flux	25 lmh

Parameter	Estimate quantity
Flow per Train	6 MLD
Number of Permeate Pumps	5 duty 3 standby
Permeate Pump Power, each	40 kW
Permeate Pump Motor Rating	90% efficiency
Membrane Tanks	5
Membrane Tank Dimension (estimated)	3 m x 15.2 m x 4.0 m (W x L x H)
Approximate Liquid Depth	2.7 m
Design Membrane Air Flow	10 Nm^3/hr air rate per module*
Scour Air Blowers	3 duty; 1 standby
Mixed Liquor Recirculation Pumps	5 duty; 1 standby
Mixed Liquor Recirculation Pump Power	65 kW

5.2.8 Maintaining Membrane Performance

During operation, the membranes remove the solids in the mixed liquor, some of it forming a compressible filter cake on the membrane surface. The filter cake forms a filter in itself and so adds to the filtration performance of the unit but at the same time increasing the head loss or pressure drop across the membrane, commonly known as the Trans-Membrane Pressure (TMP). This filter cake must be controlled to maintain a reasonable pressure drop or TMP across the membrane wall during filtration.

The minimisation of the fouling layer or filter cake is controlled by three procedures:

- Relaxation (temporary ceasing of filtration)
- The Maintenance Clean (MC)
- The Clean-In-Place (CIP) or Recovery Clean

Filtration rates are principally maintained by the relaxation step; however, a small residual of foulant is retained on the membrane surface and accumulates over time. This is reflected by a slow increase in membrane resistance to flow. To remove these foulants, chemical cleaning is carried out, namely the Maintenance Clean and the Recovery Clean. These three preventative cleaning processes vary depending on the vendor and selected technology.

5.2.9 Sludge Wasting

The biological treatment system grows biomass that must be partially wasted to prevent over-accumulation. A controlled rate of wastage is carried out from the membrane tank. This waste activated sludge is conveyed to the sludge treatment trains for further processing.

The potential exists to develop a growth of filamentous foaming bacteria within the bioreactor. This will separate out as a foam layer on the surface of the membrane tanks. With appropriately designed and operated waste activated sludge draw off systems, this foam layer can be drawn off with the waste activated sludge and removed from the system.

5.3 Sludge Treatment

Dewatering is a procedure to increase the solids content of sludge by removing a portion of the liquid fraction of the sludge. Dewatering helps to reduce the volume of the sludge. As waste activated sludge with 1% of solids content gets dewatered to 20% solids content, it would reduce the sludge volume by up to twenty-fold. This makes the final sludge product much easier to transport and dispose of by reducing total volume. A belt filter press is used for dewatering sludge here.

The WAS pumps would deliver waste sludge to the WAS holding tanks before feeding to the belt filter press. An appropriate mixing system would be provided for each holding tank. Wasted sludge then flows by pump to belt filter press. A polymer system would be provided to add polymer solution to the sludge feed line to improve dewatering performance. Dewatered sludge would be dropped into container trucks to take off-site. Centrate from the belt filter press would flow by gravity to upstream of the MBR tanks for treatment.

The design criteria for both the belt filter press and the sludge holding tank are summarised in **Table 5-6** and **Table 5-7** respectively.

Table 5-6: WAS holding tank design parameters

Parameter	Estimate quantity
Total Tank Volume	500 m^3
Number of Units	1 (with two equal compartments)
Sidewater Depth	5.0 m
Type of Aeration/Mixing System	Jet Mixing Pumps
Estimated Blower Motor Size	126 kW

Table 5-7: Belt filter press design parameters

Parameter	Estimate quantity
Number of Units	2 duty; 1 standby
Effective belt area per unit	9.5 m^2
Solids Loading Rate	16.8 $kg/hr/m^2$
Capacity per Unit	16 m^3/hr
Estimated BFP Power Rating	13 kW
Type of Feed Sludge Pumps	Progressing Cavity
Number of Feed Sludge Pump Units	2 duty, 1 standby
Sludge cake conveyance method	Belt conveyor
Dewatered sludge concentration	20%

5.4 Chemical Dosing

Several chemicals are required as part of the system either as part of the water treatment process (i.e. enhance removals or for disinfection) others are for membrane (MBR) cleaning. The chemicals included as part of the system include cleaning chemicals:

- Sodium Hypochlorite
- Citric Acid

The membrane cleaning chemicals may vary depending on the actual membrane selected for this purpose. The assumptions used to develop this functional design are presented in **Table 5-8**, are consistent with the most common immersed hollow fibre membrane products used in India.

Table 5-8: CIP cleaning requirements

Parameter	Estimate quantity	Frequency	Concentration
MBR	Sodium Hypochlorite	Weekly	200 mg/L
	Sodium Hypochlorite	Once every 6 months	1,000 mg/L
	Citric Acid	Once every 6 months	20,000 mg/L

5.5 Treated Effluent Transfer Pipeline and Transfer Pumping Station

The system is designed considering two possible option as follows-

- **Option 1:** 2 stage pumping
    - It includes transmission line of 700 mm DI K9 from UWTP to intermediate storage reservoir at 488m elevation.

From intermediate storage reservoir, two separate transmission lines are considered.

- To Belagal & Venineerapura
- To Halakundi

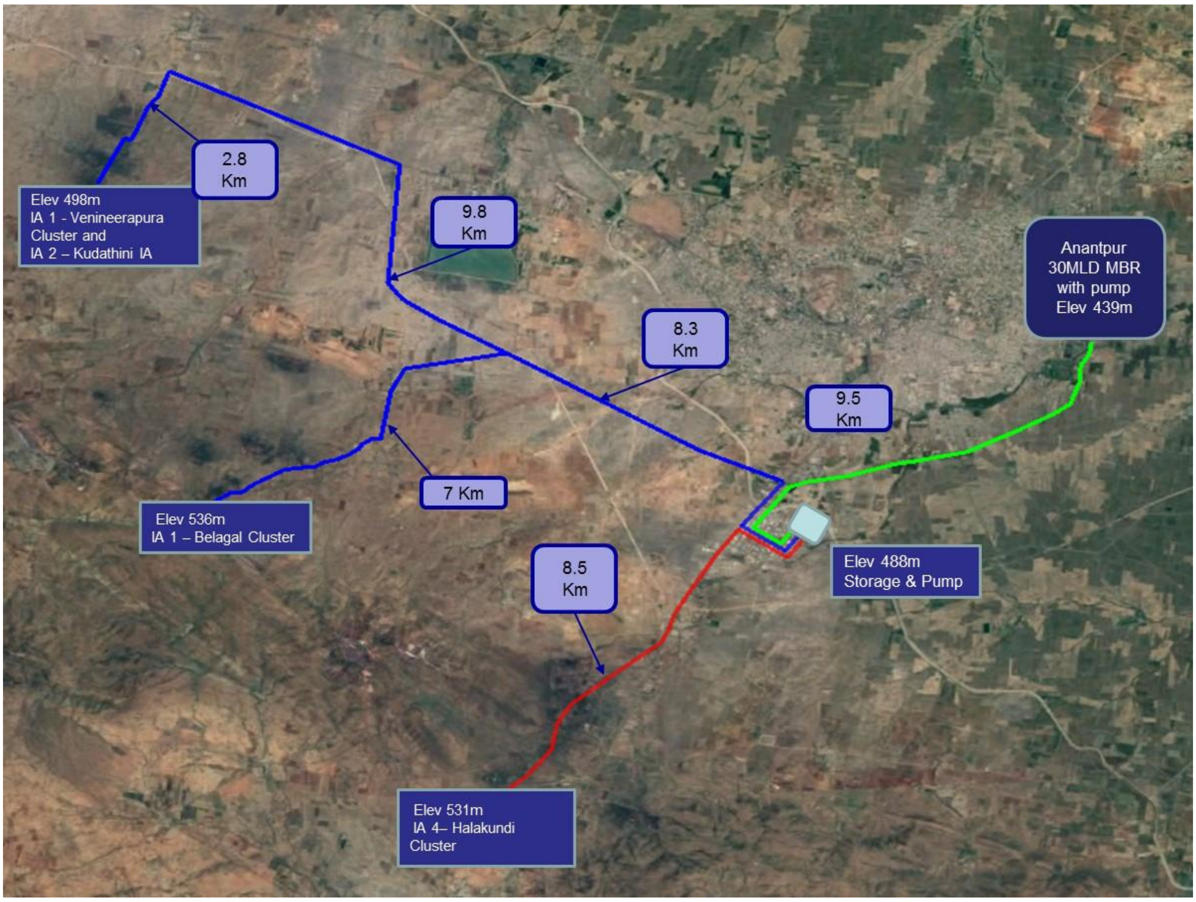

Figure 5-3: Option 1 - Two stage pumping

Description of pump infrastructure for Option 1 is provided in the **Table 5-9** below.

Table 5-9: Pumping infrastructure - Option 1

Location	Duty flow of feed pumps (m3/hr)	Duty head of feed pumps (m)	No of pumps	Pump type	Estimate pump power (kW)
At UWTP	936	64	3 (2W + 1S)	Horizontal split casing end suction	242
To Belegal and Kudithini	624	78	3 (2W + 1S)		196
To Halakundi	312	60	3 (2W + 1S)		76

Option 2

- Direct pumping from UTP is considered to the industrial clusters,
- It includes Single Stage pumping with pump head of 123 m.

Figure 5-4 shows options 2.

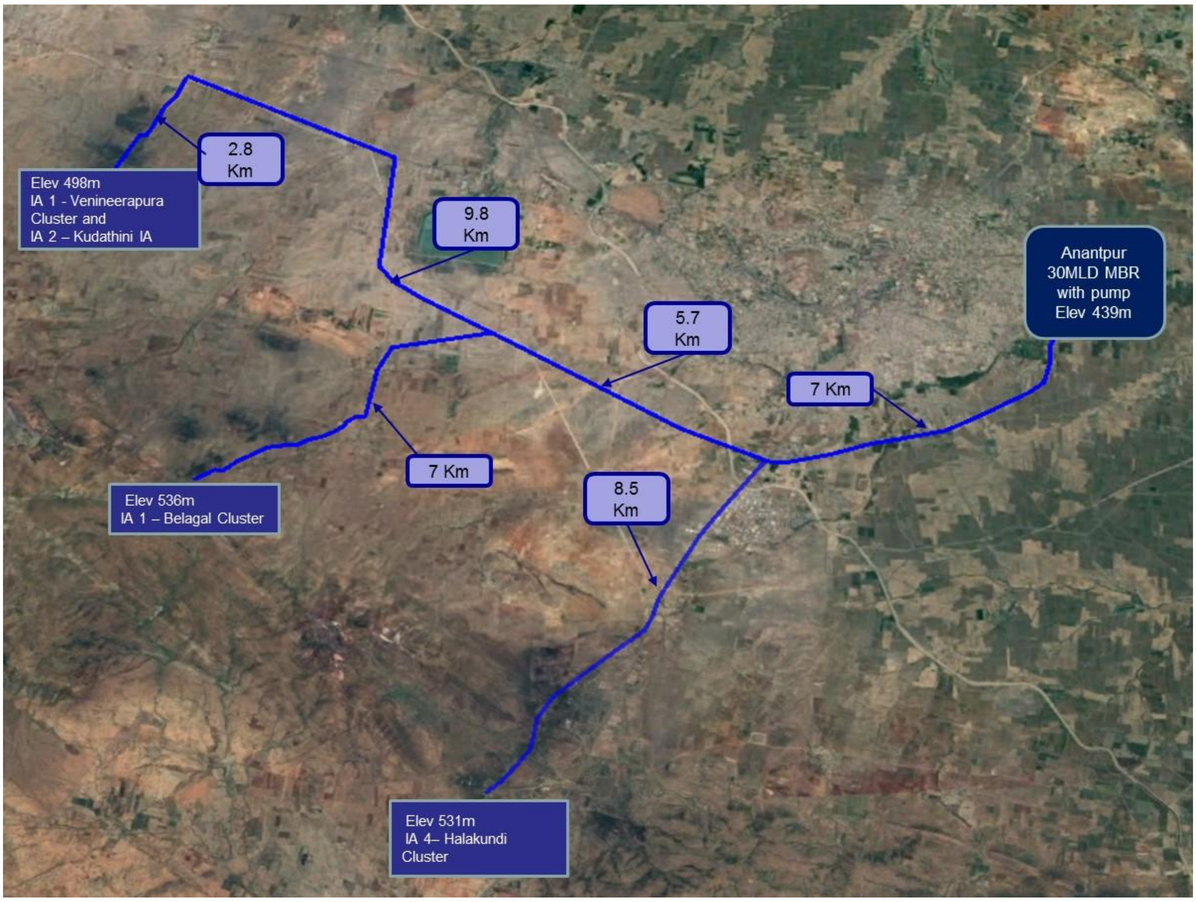

Figure 5-4: Single stage pumping - Option 2

Description of pump infrastructure for Option 2 is provided in the **Table 5-10** below.

Table 5-10: Pumping infrastructure - Option 2

Location	Duty flow of feed pumps (m3/hr)	Duty head of feed pumps (m)	No of pumps	Pump type	Estimate pump power (kW)
At UWTP	935	130	3 (2W + 1S)	Horizontal split casing end suction	491

Electrical Instrumentation, Monitoring and Control

6 Electrical Instrumentation, Monitoring and Control

All Electrical, Instrumentation and Control work are to be carried out in accordance with local statutory requirements and standards. This section highlights key areas for the design of the electrical, instrumentation, monitoring and control systems.

6.1 Electrical Design

The electrical design has been based on relevant standards and codes of practice.

6.1.1 Main Power Supply

Based on initial load and maximum demand estimates, the proposed treatment plant has a total installed power consumption of 25 MW.

For the treatment plant, 11KV power supply needs to be secured from the local distribution network. An enclosure will be provided for the power company's transformer and switchgear.

Pits and in-ground conduits shall be provided to take the mains power to the MCC. All field wiring shall be run in conduits or appropriate cable trays with segregation of power and instrument cables.

6.1.2 Switch Room

An indoor-type switchboard will be provided in a dedicated switch room to terminate the mains supply and distribute it to the various plant loads through a Motor Control Centre (MCC) located within. The switchboard enclosure will be of mild steel with anti-corrosive painting. The enclosure rating will be IP54. Separate compartments will be made for each motor starter, auxiliary supply distribution board, the PLC & SCADA equipment and the energy metering equipment.

6.1.3 Standby Power

The need for standby generation of electrical power should be assessed during later detailed design phases.

For the purposes of this study, a generator connection panel will be provided outside the switch room along with a hardstand area adjacent to the switch room building for an emergency generator with integral double-skin fuel tank. The generator would be automatically connected to the MCC with interlocked air circuit breakers. During detailed design and following a HAZOP, the sizing for back-up power supply to keep the plant operational during mains power supply failure will be further assessed.

For the control and instrument equipment an Uninterruptible Power Supply (UPS) with a two hour battery back-up will be provided.

6.1.4 Motor Starters

Variable Speed Drives are provided for Nitrified recycle pumps, Mixed liquor recycle pumps, Aeration blowers and MBR Filtrate pumps. Air-cooling/conditioning will be provided to ventilate the hot air produced by the electrical equipment. The motor isolator and the supply contactor will be housed in each starter compartment. Motors will be installed with adjacent Local Control Station for testing after maintenance, and local stopping. Power cables on variable speed drives shall be shielded.

6.1.5 Motor Protection

Motors will have overload, short circuit and single-phase protection provided by the motor starter. Motors rated 11kV and above will have embedded winding temperature detectors.

All submersible pump motors will have seal leak detectors factory-built into the pumps with their monitoring/control units supplied loose to be installed and connected in the starter compartments.

6.2 Control an Instrumentation

The control system will include:

- Instrumentation required for operating the plant and monitoring essential process variables (e.g. flows, levels, pressure etc) and measurement of water quality.
- Automated PLC and SCADA system to provide automatic and local control, monitoring, indication and operator interface.

6.2.1 Common Control

In general, these types of plants typically have a high level of automation and require very little operator intervention on a regular basis. Routine operator duties involve checking the levels of tanks, laboratory testing and trending of operational data to project and plan future maintenance requirements. There are also intermittent activities such as membrane cleaning and routine maintenance of process equipment (e.g. replacement of media) that requires a high level of operator intervention to complete.

The plant is controlled from a central SCADA terminal located in the control room with telemetry for remote monitoring and control. Major process units such as the membrane units are likely to be supplied with a standalone PLC controller. A separate dual redundant PLC will also provide control to smaller ancillary plant items and coordinate/communicate between process units to allow the plant to function as an integrated unit.

The plant control set points are managed via the SCADA interface and whilst most set points would be established during the initial stages of plant testing and commissioning most of the control set points are operator adjustable to allow the required level of operational flexibility.

Most tanks and storages will have level instrumentation. There are several key functions of the level instrumentation including:

- Continuously measure and transmit the level of fluid in the tank
- High and low cut-out levels – These levels trigger the system to undertake the necessary corrective actions to prevent equipment damage and shutdown upstream processes to prevent overflow (e.g. a low level in a tank will shut down a pump to prevent equipment damage)
- High and low level alerts – These are simply warning levels which trigger an alarm that needs some form of operator intervention. These alerts are queues for the operator to investigate a potential problem with the system.

6.2.2 PLC and SCADA

A main plant Programmable Logic Controller (PLC) and a Supervisory Control and Data Acquisition (SCADA) system will be provided for monitoring and control of the treatment plant. The main PLC will have a local rack with various PLC modules such as power supply, processor, Input/Output modules, etc. Input/Output signals from plant equipment and instruments will be hard-wired to the PLC panel. The PLC will be supplied complete with all ancillaries such as terminal blocks, fuses, etc mounted in control panels. PLC and SCADA software will be provided as part of a package and will be configured for the purpose. The radio antenna at the Treatment Facility will receive signals from the pump station antenna and convey them to the SCADA Human Machine Interface (HMI). The SCADA chosen will be compatible with radio communication.

A UPS will provide sufficient power to keep the PLC alive and make the plant safe in the event of a power failure. The plant PLC will be provided with a hot standby back-up redundant PLC, depending on operations and manning philosophy.

6.2.3 Field Instruments

All field instruments will be chosen to suit the process involved and will be from reputed manufacturers. Instrument makes such as Endress & Hauser, ABB etc are commonly used in waste water applications.

6.2.4 Motor Control

Motors will be automatically controlled by process requirements, via PLC. In a duty/standby pair if the duty machine does not start or fails, the standby machine will take over. Run/Stop/Speed control will be conveyed from the PLC to the starter via hard wiring. The treatment plant HMI will have overriding manual control, for the all motor drives.

Control via a local push buttons will be provided for testing purposes. A local control panel with the control pushbuttons and a lockable isolator will be provided within 1 metre of each motor drive. A changeover switch will be provided on each starter for selecting between local and automatic control.

6.2.5 Treatment Plant Monitoring

The following parameters will be monitored from the treatment plant HMI:-

- Flow - influent, mixed liquor recycle, waste activated sludge, plant effluent
- Levels - all process tanks, upstream and downstream of the influent screens (in case of blockage)
- Dissolved oxygen in bioreactor
- Nutrients - NO_3, NH_3, TP
- Switchboard incomer current
- Motor current (motors 11kW and above)
- Motor speed (variable speed motors)
- Analogue and digital instrument outputs;
- Equipment status

The following alarm signals will also be monitored from the HMI:

- Power supply failed
- Motor tripped (each motor)
- VSD fault (each VSD)
- Instrument faults
- All process alarms
- Control system fault
- Control system communication fault
- UPS fault
- Intruder alarm

6.2.6 Raw Used Water Pump Station Control

Level switches must be installed in the raw used water pump station (by others), membrane bioreactor and pre-treatment unit to stop further discharges to these areas and ensure no spillage of sewage.

The diversion chamber before the fine screens is the treatment plant interface point that receives sewage transferred from the raw used water pump station (by others). The level in the pump station is controlled by the level in the gravity drain from which it is pumping. It is intended that the pump station will always be full when there is flow in the gravity drain. Excess flow will overflow the pump station and return to the gravity system bypassing the extraction point.

The operation of the raw used water pumps will be governed by the level in the bioreactor. The target will be to maintain a minimum level in the bioreactor. The speed of the pumps will increase as the level decreases and decrease as the level increases. A backup level indicator will override the pump operation in the event of a low level in the pump station. A magnetic flow meter is used to continuously measure the flow to the treatment plant.

Operation & Maintenance Plan

7 Operation & Maintenance Plan

The operation and maintenance of the plant is critical given the intended end use of the product water. The following section outlines the key areas for the effective operations and maintenance of an advanced water recycling treatment plant.

7.1 Operability of Plant

The plant will have a high level automation and require very little operator intervention on a regular basis.

The treatment process relies on a number of chemicals that are generally either delivered in a bulk by tankers, transported to the site in containers or generated on-site. The refill frequency of the chemicals would be at least 14 days in general. This may need to be reconsidered for the Indian context during the next design phase for this project. The roads must be designed to allow tankers to access the site and allow through traffic around the site.

Selected mechanical equipment is also located close to the roadways to allow access by maintenance personnel. The roads are designed with the intent that a maintenance vehicle equipped with a lifting device can access major items of mechanical equipment. In general, sufficient standby equipment has been provided to allow maintenance to be carried out during hours when the plant is manned. Regular maintenance at the site is likely to occur on a monthly basis however most items of equipment require attention no more than every six to twelve months.

7.2 Ancillary System

All necessary services to make a fully operable plant are to be included in the scope of works. These services include the following items:

- Plant drain system, including wet well and pumps
- Plant water system for spray water and washdown, with mechanical strainer and provision for disinfection
- Compressed air systems
- Chemical storage, chemical delivery, waste chemical neutralisation, storage bunding, safety showers, tanks, etc.
- Site works & services, including process and service pipe work, drainage, sewers within the plant, underground piping and electrical conduits and pits.
- Conduits and pits to take the incoming power supply from the site boundary
- Equipment identification and pipe markings to clearly identify all components for installation, operation and maintenance purposes
- Sampling points for each unit process, including automated refrigerated sampling units for influent and effluent
- Platforms, stairs, handrails and supports to allow safe access to all equipment and instrumentation requiring inspection, maintenance or calibration

7.3 OH&S Requirement

An Occupational Health and Safety management system is needed to promote a proactive, repeatable, continually improving Health, Safety, and Environment (HS&E) program. The proposed methodology for ensuring safety is described for each phase of the project is given in this next section.

7.3.1 Design Phase

The project design methodology addresses the elimination, substitution and minimisation of hazards as part of the design review process. Considering health and safety hazards at this stage maximises opportunity for use of the hierarchy-of-controls approach to safety management in all parts of the project: construction, commissioning, operation and maintenance for the life of the facility.

7.3.2 Construction Phase

The construction contractor's project-specific safety plan is the controlling document which establishes the system for managing OH&S in detail for this stage. The construction phase risk assessment process needs to include a two-part process and involves the supervisors and the work crew to ensure consultation and cooperation in the execution of the required controls.

The first part is a job safety analysis (JSA) to identify the hazards associated with each step in the activity, identify control methods and nominate the person responsible for implementation.

The second part of the process involves developing the work practices and documenting the required training/qualifications, codes, legislation or standards applicable. It also requires detailing the plant and equipment (including personal protective equipment) required, equipment maintenance or checks necessary and certificates or approvals required. This forms the safe work method statement for the activity.

Achieving effective implementation of the controls identified requires the establishment of a safety culture and positive safety behaviours from the outset of the project. The Project Safety Plan needs to address the creation of this proactive culture to enable effective execution.

7.3.3 Testing and Commissioning Phase

Commissioning requires approved procedures based on input from vendors, designers and construction residual risks. The risk identification and assessment of safety hazards needs to be included in the development and approval of these commissioning procedures.

7.3.4 Operation & Maintenance Phase

As the construction contractor will be responsible for commissioning as well as subsequent Operation and Maintenance, safety procedures and controls are developed for this operation and maintenance period based on results of the testing and commissioning phase.

7.4 Recommended Operation and Maintenance Procedure

Based on the critique of existing operations and maintenance practices, a number of improvements to Ballari Municipal Corporation (BMC) existing practices are recommended. These recommendations are outlined in the following subsections.

7.4.1 General Safety Requirements - Good Practice

In line with BMC's commitment to ensure the safety and health of all staff, customers and stakeholders, it is essential that good practice safety procedures are adopted. These procedures can be categorised into those related to policy, design, construction, and operations and maintenance, each of which is addressed in the following subsections.

Safety policy

BMC shall ensure that all staff are aware of and commit to BMC's health and safety principle, set down in a clear policy. This shall include requirements to:

- Always work safely, in accordance with specific standard operating procedures (SOPs) and maintenance procedures that must be developed for all tasks,
- Seek to mitigate hazards by following the hierarchy of controls (**Figure 7-1**),
- Always report unsafe work conditions and actions, and
- Always report health, safety or environment incidents, including near misses (near misses are unplanned events that did not result in injury, illness or damage but had the potential to do so).

BMC shall ensure that all staff and contractors are trained in its health and safety policy, including how to report incidents and near misses, and to whom.

BMC shall also monitor, track and report on the number of recorded health, safety and environment incidents and near misses, including responses taken. This shall apply to all BMC operations, including those undertaken by third parties.

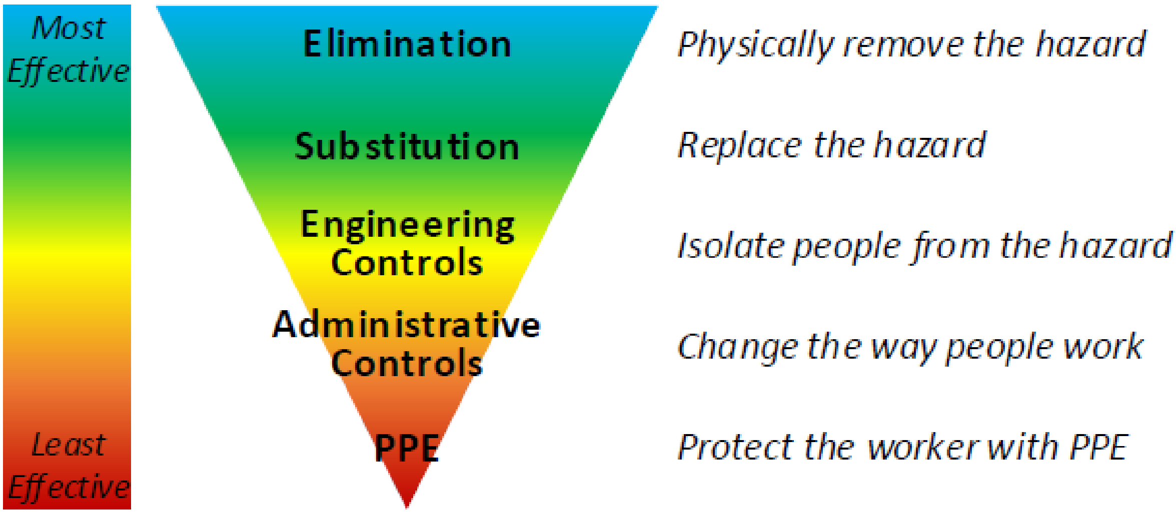

Figure 7-1: Hierarchy of Controls

Safety in design

Safety in design is an ethos that ensures an efficient and effective design by avoiding creating risks to the environment or to personnel safety that may otherwise result through poor design. The approach requires:

- Early and continued consideration of safety during all aspects of the design phase,
- Periodic design reviews and hazard and operability studies (HAZOPs), including subsequent design amendments to address observations made, and
- Continual review of the implications of particular design aspects on the ability of staff to conduct safe operations and maintenance.

Safety in construction

The management of health and safety during construction requires the comprehensive preparation and implementation of occupational health and safety management documents.

These documents must be constantly and progressively updated, submitted and complied with as the construction project is delivered.

As a minimum, the occupational health and safety management documents shall include:

- A clear policy statement with safety as the number one priority,
- References to applicable standards, laws and regulations,
- General safety and health procedures and Safe Work Method Statements (such as confined space, lock-out-tag-out, housekeeping, working at heights - see Section 7.4.2),
- A Permit-to-Work system that requires certain procedures to be completed before particular work activities are authorised. Activities requiring a Permit-to-Work should include but not be limited to:
    - Confined space working,
    - Excavation,
    - Electrical work,
    - Hot works,
    - Lifting,
    - Scaffolding, and
    - Chemical handling,
- Safety training – covering for example basic safety training, first aid training, confined space training,
- Safety rules and regulations – such as to provide safety helmets, safety shoes/boots, goggles and protective vests,
- Industrial safety (such as noise protection and respiratory protection),
- Promoting a safety ethos – to enhance personnel safety awareness, attitudes and behaviour on safety, and also as a commitment to advancing safety culture,
- Safety inspections,
- Incident investigation and analysis, reporting and record keeping,
- Hazard analysis,
- Emergency planning (including training and dry runs),
- Safety audits, and
- Safety key performance indicators.

Safety in operations and maintenance

It was observed during site visits to several BMC facilities that standardised best practice safety procedures were not in place. The procedures outlined in in this section of the Master Plan must be adopted as a priority.

It is critical that the following three overarching rules for a safe operations and maintenance are implemented:

- **Rule 1 – General:** Adherence to minimum personal protective equipment (PPE) requirements (safety helmet, safety boots, high visibility day/night safety vest, safety gloves, ear defenders and eye protection).
- **Rule 2 – Operation:** All operations shall be in line with SOPs, and any required asset training defined by these SOPs.

- **Rule 3 – Maintenance:** All maintenance activities shall be in line with maintenance procedures.

SOPs and maintenance procedures shall be an important component of the overarching operations and maintenance manual for each facility.

7.4.2 Specific Safety Procedure - Good Practice

Safety requirements shall apply to all works and it is the responsibility of the contractor and/or BMC to ensure the safety of all persons on the site in question, and the general public.

Based on the safety procedures commonplace in other countries, the following t procedures are considered critical for BMC.

Confined space entry

A confined space is a space which has limited or restricted access for entry or exit and is not designed for continuous occupancy. Confined spaces include but are not limited to tanks, vessels, silos, hoppers, storage bins, tunnels, pits, manholes, pipelines, shafts, pressure vessels and ductwork.

Incidents related to working in a confined space can result in fatality (due to lack of oxygen, airborne contaminants, flooding, smoke for example) and as such, it is essential that BMC implements a confined space procedure. A means of defining and designating confined spaces is also necessary.

Entering used water pipes

IS 11972:1987 (and reaffirmed in 2002), defines safety precautions to be taken when entering a used water system. Similarly, the National Human Rights Commission has published guidelines (2012) defining safety norms for persons working in or around used water systems.

At a minimum, BMC shall ensure compliance with these guidelines. In addition, it shall implement additional controls to address specific hazards. This approach has been adopted by other Indian utilities (Delhi Jal Board for example). Additional measures shall include:

- Ensuring that appropriate signage and railings are provided around manholes before work starts,
- Ensuring that manhole covers are opened and ventilated for an appropriate period of time before entry is permitted,
- Ensuring that a standby person and evacuation procedures are in place before entry,
- Testing for the presence of toxic gas before entry and during occupancy of confined space,
- All PPE including breathing equipment must be worn at all times, and
- Time within the confined space shall be minimised and regular breaks provided.

These procedures are equally applicable to confined space working at UWTPs, such as cleaning of sludge tanks.

Handling of chlorine gas

Chlorine is the most widely used disinfectant in UWTPs around the world. Chlorine, in both gas and liquid forms, is a toxic substance that can burn moist body surfaces such as the eyes, nose, throat, lungs, and wet skin because it forms harmful acids when it reacts with moisture.

Chlorine gas is easily liquefied under pressure and has a disagreeable, sharp, pungent, penetrating odour.

BMC shall prepare written safety procedures to address the following aspects of chlorine use:

- Container storage, handling, repair and disposal,

- Cylinder change,
- Leak detection and control,
- Lone working,
- Respirator use,
- Maintenance of chlorine handling equipment, and
- PPE – eye, skin and respiratory protection is particularly critical.

Emergency procedures shall also be documented and practiced, and emergency equipment that includes eye wash and shower facilities, first aid kits and container repair kits must be provided.

Lock-Out-Tag-Out

The purpose of a Lock-Our-Tag-Out (LOTO) procedure is to define processes and protocols that provide protection and effective isolation from hazardous energy, and also to provide guidance and implementation of safe work procedures. Effective adoption of LOTO procedures prevents uncontrolled release of energy causing harm to personnel, equipment and the environment.

A LOTO procedure shall be used for equipment isolation, and shall also be implemented during construction and commissioning work. All personnel responsible for work areas shall be trained in the LOTO procedure before they are allowed to work on energised equipment.

Working at heights

Personnel or objects falling from height have the potential to cause serious harm and fatality. Even a fall from a relatively low height can cause serious injury and as such, any activity requiring working at height must be controlled. Falls may occur as a result of poor/inappropriate access, inadequate edge protection, poorly maintained access equipment, adverse weather conditions, or from objects in storage being poorly secured.

As an example of a general rule, for working at heights in Australia, specific control measures are required where there is a risk of a fall of 2m or more. Maintenance procedures must also acknowledge and manage the risks and hazards associated with working at heights.

Financial Assessment

8 Financial Assessment

This section outlines the basis of capital and operating costs for a 30 MLD used water treatment plant, to produced highly purified water suitable for non-potable reuse purpose.

The accuracy of the cost estimate is commensurate with the detail provided to develop the design for this study. The design is a preliminary conceptual design undertaken without detailed understanding of the water quality, geotechnical and other issues. The estimate would therefore be expected to have an accuracy of about ±30% and will change once more detailed information is available.

8.1 Basis of Estimate

This section outlines the basis of the cost estimate and includes the methodology for developing the cost estimate including:

- The techniques used to obtain budget pricing for the capital cost estimates
- The methodologies used in calculating the indirect cost estimates
- The cost estimate was developed using budget prices from suppliers for process equipment, piping, chemicals and other miscellaneous items
- Cost estimates, technologies, labour rates and equipment rates used on local projects of similar nature

Capital and operations and maintenance cost estimates were based on the conceptual design, preliminary drawings and equipment lists.

Indirect costs such as approvals, engineering, commissioning and start-up have been estimated as a percentage of the total construction cost estimates.

8.2 Key Estimating Assumptions

The indirect, direct and operations and maintenance costs were derived from underlying assumptions stated below:

- Being a concept design or planning level estimate, subjected to standards limits of accuracy, capital cost contingency allowance of 30% has been applied
- Overhead costs were assumed at 4% of the total direct costs
- Profit costs were assumed at 6% of the total direct costs
- Mobilisation, Bonds and Insurance costs were assumed at 1.5% of the total direct costs
- Engineering and Project Management costs were assumed at 4% of the total direct cost
- Services During Construction (SDC), Commissioning and Start-up have been considered as a part of Project Management cost
- Both capital and operating costs were based on the assumption that the plant will be programmed for construction commencement by end-2020. Labour requirements for operation’s management are assumed as an Administrative Assistant and Office Manager at 20 hours a week and Office Manager at 40 hours a week
- Labour costs assumed two treatment plant operators working at 40 hours a week, with one operator in attendance 24 hours per day, 7 days per week
- Spare parts included in cost estimate for major process equipment

- Electricity cost assumed at INR 8.0/kWh
- Chemical costs and doses were provided by suppliers
- Land acquisition costs are to be decided by BMC and are not included in this estimate

8.3 Project Cost Estimate

A summary of the Capital and Operational cost estimates are provided in this section.

8.3.1 Summary of Capital and Operational Cost

The following **Table 8-1** and **Table 8-2** presents capital cost for upgrade option.

Table 8-1: Capital cost for construction of new 30 MLD MBR plant

Particulars	Cost (in Crores)
Civil works including piping, erection, testing and commissioning	₹ 33.00
Mechanical, Electrical and Instrumentation control and automation (MEICA) works including erection, testing and commissioning	₹ 57.60
Capital cost	₹ 90.60

Table 8-2: Operational cost for construction of new 30 MLD MBR plant

Particulars	Cost (in lakhs per month)
Labor cost	₹ 4.50
Chemical charges	₹ 5.30
Electricity charges	₹ 57.80
Maintenance charges	₹ 24.00
Sludge disposal cost	₹ 15.50
Total Operational cost	₹ 107.00

8.4 Assumptions and Limitations of Cost Estimates

As there is no large- scale MBR based plants in India, there were several constraints on obtaining cost from local suppliers. Hence, some of the key factors considered in costing are based on similar overseas plants and data available from vendors/equipment suppliers.

Other assumptions and limitations of the feasibility study that can have bearing on the project cost are given as follows:

- Limited water quality data – The raw sewage characteristics are based on limited sampling regime hence the plant design parameters may vary after extensive testing spread spanning across a year.
- Limited engineering design – The objective and scope of project appropriated only high level design during the study. No major project specific engineering problems and their mitigation have been considered during the study.
- Subsoil (Geotechnical) Conditions – Good subsoil conditions warranting any special soil treatment or foundation design has been envisaged for this project.
- Power supply – It has been assumed that BMC would be able to obtain reliable power source and required amount of uninterrupted power for the project.
- Land costs – It is assumed that encumbrance free land at no cost would be available for this

project.

- Pipeline route – The pipeline routing, design, engineering and laying execution has been considered without any issues like right of way, litigations, traffic issues, soil conditions etc.
- Raw used water availability – It has been assumed that the sewage would be available in required quantity within the acceptable range as indicated elsewhere in this report.

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Delivery Option Analysis

9 Delivery Option Analysis

Infrastructure provisioning is complex and has many delivery options. Each delivery model ranging from the conventional to the more nuanced has its relative strength and disadvantages. For the purpose of this exercise few of the traditional and established models have been considered and compared in the context of a hybrid – public, private partnership (PPP) model.

Traditional models discussed as follows:

- Design Bid Build (DBB)
- Design Build (DB)
- Design Build Operate (DBO)
- Design Build Finance Operate & Transfer (DBFOT)

9.1 Design Bid Build

This model is ideally suited where there is sufficient time and desire to complete design documentation prior to tendering. This model also attracts a large pool of potential Tenderers giving rise to increased competition. Given the design certainty there is greater scope for competitive price. That said, there is little incentive or need for innovation from the contractor. Since the scope is generally well defined there is little likelihood of scope creep or wholesale change to requirements. The contract value is set before construction commences.

This model is ideally suited where there are high levels of certainty with regard to cost and quality and the project risks are well defined, clearly understood and easily allocated to the appropriate party. High level of BMC involvement and control will be required during the design phase and a clear cut division is present between design and construction.

While freezing up design well in advance provides some level of cost certainty and control for BMC there are a number of issues that need managing:

- Separate design and construction mean no single point of responsibility for the project.
- Potential claims and delays due to design deficiencies and separation of design from construction
- Minimal opportunity for innovation input from the contractor
- Retains the risk of constructability of design, fitness for purpose and overall design
- Potential lack of focus on life-cycle costs and considerations

9.2 Design Build

This delivery model is ideally suited where BMC's requirements are tightly specified before tender and do not change after that. The decision to award a Design Build contract generally stems from the desire to reduce the overall project cost by giving the contractor the opportunity to contribute construction experience into the design resulting in innovation and efficiencies. Furthermore, through a single point of accountability, the contractor is better placed to manage design risks and will be in a position to take on fixed price contract. While the Contractor normally warrant the design including "fitness for purpose", generally the following issues needs to be managed:

- Longer tender periods are needed to allow Tenderers to assess design risk
- BMC may pay a premium to transfer design risks and also retains whole-of-life asset risk
- Will likely lose focus on life-cycle costs considerations and

- May be liable for time and cost overruns through claims from the contractors

9.3 Design Build Operate

In this delivery model, the contractor also has ongoing maintenance obligations in addition to design and construction. While the features of Design Build delivery model are retained, through "operate" there is an added transfer of life-cycle risk to the contractor, which encourages design efficiency and quality construction and finishes to reduce long-term costs. As discussed above, this model is ideal where there is an opportunity to bundle services / maintenances and thereby create whole-of-life efficiencies.

DBO delivery option is suitable where there is a need to outsource asset management activities and BMC wishes to encourage and or reward the contractor to incorporate reliability and maintainability into the design. That said, there are still a number of issues that needs to be managed during the delivery phase. Some of them are:

- Longer tender period needed for Tenderers to assess design and maintenance risks
- BMC may pay a premium to transfer design and maintenance risks
- Success relies on well-defined functional and service specifications
- A large number of stakeholder resources may be required if multiple concept designs are being developed
- Changes to design may require contract negotiations
- Ability to make variations needs to be addressed in the contract
- Higher agency tendering costs and resourcing costs that need to be offset against potential cost savings and efficiencies

9.4 Design Build Finance Operate and Transfer

Design Build Finance Operate and Transfer (DBFOT), or PPP refers to long-term partnering relationships between the public and private sector to deliver services. It is an approach that Government has adopted to increase private sector involvement in the delivery of public services. A well - structured and implemented PPP can improve value for money in infrastructure provision. It provides a framework to appropriately allocate risk, harvest benefits from whole of life costing, creates opportunities for innovation by specifying outputs in a contract rather than prescribing inputs and enhance asset utilisation as private parties are motivated to use a single facility to support multiple revenue streams thus reducing the cost of any particular service from the facility. Overall it should allow BMC to acquire services at the most cost-effective basis, rather than directly owning and operating assets.

That said, to be successful, the project must be built upon a diagnostic that provides a realistic assessment of the current constraints. Project appraisal typically involves assessing the project against the following four criteria:

- Feasibility and economic viability
- Commercial viability
- Value for money and
- Fiscal responsibility

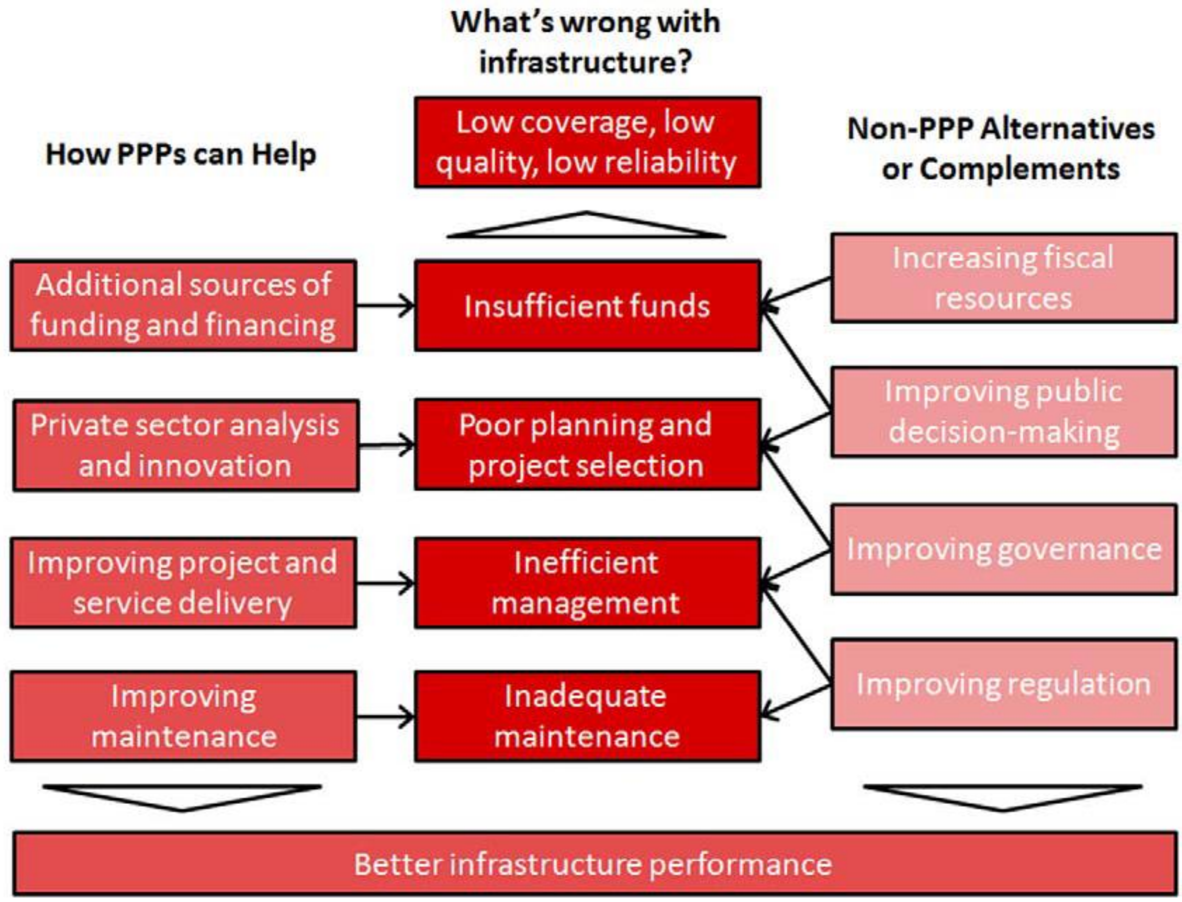

Figure 9-1: PPP delivery models provide better infrastructure performance

Source: World Bank

All of the above, require careful consideration of the Technical issues, legal, regulatory and policy frameworks, Institutional and Capacity status surrounding the project.

9.4.1 Feasibility and Economic Viability

The intent here is to determine whether the underlying project makes sense, irrespective of implementation as a PPP or through traditional public sector procurement. This requires confirming that Ballari Recycle and Reuse Plant is central to policy priorities and overall infrastructure plans. It then involves carrying out feasibility studies to ensure the project is possible and economic appraisal to check the cost-benefit is justified

9.4.1.1 Commercial Viability

This determines whether the project is likely to be able to attract good-quality sponsors and lenders by providing robust and reasonable financial returns. Normally preliminary market sounding sessions are carried out to prepare potential bidders ahead of the procurement. This will also help BMC to assess the likely reaction of the market to the proposed PPP procurement and BMC's preliminary thinking on the salient aspects of the PPP contract. This will help BMC to gauge the potential level of bidding interest and also the valid concerns which the industry may have on the draft PPP structure.

9.4.1.2 Value for Money

The purpose of this criterion is to assess whether developing the project as the proposed PPP can be expected to best achieve value for money, compared to other traditional options after considering that the risks have been allocated optimally.

9.4.1.3 Fiscal Responsibility

Last but not least is the Fiscal responsibility assessment which determines whether the project's overall revenue requirements are within the capacity of users, BMC or both, to pay for the infrastructure service. This involves checking the fiscal cost of the project – both in terms of regular payments, and fiscal risk and establishing whether this can be accommodated within prudent budget and other fiscal constraints.

9.5 Delivery Option Recommendation

Based on the above comparison and assessment, the Design Build Finance Operate and Transfer (DBFOT) or PPP, is the recommended for advanced recycled water project.

According to The National Water Policy 2012, private sector participation should be encouraged in planning, development and management of water resources projects for diverse uses, wherever feasible. Draft National Water policy released earlier this year by the Ministry of Water Resources states that the service provider role of the state has to be gradually shifted to that of a regulator and water-related services should be transferred to community and / or private sector with appropriate PPP models.

Government of India's draft National PPP Policy sets several objectives for PPPs:

- Harnessing private sector efficiencies in asset creation, maintenance and service delivery
- Providing focus on life cycle approach for development of a project, involving asset creation and maintenance over its life cycle
- Creating opportunities to bring in innovation and technological improvements
- Enabling affordable and improved services to the users in a responsible and sustainable manner

PPP allows the public sector to get better value for money in the delivery of public services. Moreover, by switching its role from a provider to a buyer of services, the Government can focus on its core responsibilities of policy-making and regulation. Through close partnership with the private sector, efficiency gains and other benefits can be reaped.

With significant growth projections in municipal water demand from 2010 to 2025, the need for increased investment infrastructure will only be on the rise. PPPs can help increase the funding available for infrastructure, that is, bring in more revenue to pay for infrastructure services over time. Further accessing finance through a PPP can help BMC with additional source of funding because the capital cost of the project is spread over its lifetime through availability payments rather than incurred upfront.

In order for the projects to be commercially viable contractual arrangement needs to be balanced, clear and respected by both parties. In addition, the legal and regulatory framework needs to be empowered for allocating appropriate risks to the parties. The project should be both economically viable for the public sector and financially viable for the private sector. This means that BMC, which is in charge of setting the water tariffs, needs to set realistic performance indicators, pragmatic time frames and balanced water tariff to ensure affordable service for all and adequate revenues to cover project costs. Further details of this delivery option will be developed in a separate report.

Conclusions and Recommendtaions

10 Conclusions and Recommendations

A preferred option for supplying water demand of industrial units in Ballari city in a sustainable way using recycled water has been identified and recommended. Using a systematic approach that balances the technical, economic and social aspects of such a project has been investigated and a preliminary design completed.

10.1 Selection of Preferred Option

The Preliminary Design Report is based on the preferred treatment option of MBR based BNR process for the non-potable industrial reuse purpose. This being a reliable used water treatment process. Activated sludge treatment using Biological Nutrient Removal for nitrogen and phosphorus removal, and a membrane based solids separation (Membrane Bioreactor) instead of conventional gravity clarification, is envisaged. The Membrane Bioreactor also had the added advantage of producing a superior water quality to that possible with a gravity clarifier.

Figure 10-1: Process flow schematic

Figure 10-2: Solid handling schematic

This scheme has the following merits:

- New plant with latest and advanced treatment technology will produce high quality water output, and therefore meeting the discharge standards as well as creating high quality water for industrial non-potable purposes,
- A proven and well-known multi-barrier treatment approach that will produce a reliable and consistent water for supplying it to industrial areas in Ballari,
- The plant can be delivered on Design Build and Operate scheme, and therefore ensuring that the desired maintenance as well as product water quality is achieved,
- With high quality water output, BMC can sell the water to industries and thereby omitting the need for retreatment by the industries - which industries such as Janaki Corporation are doing at a high cost,
- Avoidance of overly complex or duplicated treatment processes and infrastructure and therefore unnecessary costs,
- Simplicity in operations and maintenance

10.2 Project Cost Estimate

The following **Table 10-1** and **Table 10-2** presents capital cost for upgrade option.

Table 10-1: Capital cost for construction of new 30 MLD MBR plant

Particulars	Cost (in Crores)
Civil works including piping, erection, testing and commissioning	₹ 33.00
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Table 10-2: Operational cost for construction of new 30 MLD MBR plant

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Maintenance charges	₹ 24.00
Sludge disposal cost	₹ 15.50
Total Operational cost	₹ 107.00

10.3 Public Acceptance

For a strong project acceptance, it is recommended that BMC undertake following initiatives:

- **Internal Organisation for Reuse**: The first priority of Outreach Plan is developing a communication strategy to build consensus and alignment within BMC and then carrying out short-term, mid-term, and long-term activities to build trust in BMC, describe water reuse as a key component of a sustainable and reliable water supply, and implement a successful water recycle project,
- **Immediate Actions**: Promote Internal Stakeholder Alignment through Creation of a Dedicated Communications Department
- **Development of an Effective Terminology**: The Communications Department should target to develop terminology guidelines to promote positive communication. This work should include development of a water glossary to be used in development of communication materials. The glossary should use layperson-friendly non-highly-technical terms but explain water science, water treatment, and the water cycle clearly and accurately.

10.4 Recommendations

The following actions resulting from this Preliminary Design Report is recommended for adoption and implementation by Ballari Municipal Corporation (BMC) and KUWS&DB:

- It is recommended to upgrade the Anathapur 30 MLD UWTP using BNR based MBR treatment technology, and decommission the existing Aeration Lagoon based treatment plant,
- It is recommended that BMC engages with the industry representatives to discuss about the quality and quantity of recycled water that the project will generate, and create a robust industrial water demand requirements prior to commencing of project procurement,
- It is recommended that in the strong industrial backdrop of Ballari City, BMC explore the option for implementing this project on DBFOT model,
- It is recommended that BMC runs a holistic stakeholder participation and outreach program for engaging with stakeholders such as potential users, industry representatives, political leadership

as well as senior technical and managerial leadership in GoK UDD, for garnering a holistic effort towards project implementation,

- It is recommended that BMC undertakes implementation of this project on Program Management Approach in order to ensure timely and high quality delivery of project, and follows the best Operation and Maintenance Practices as provided in this report.

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