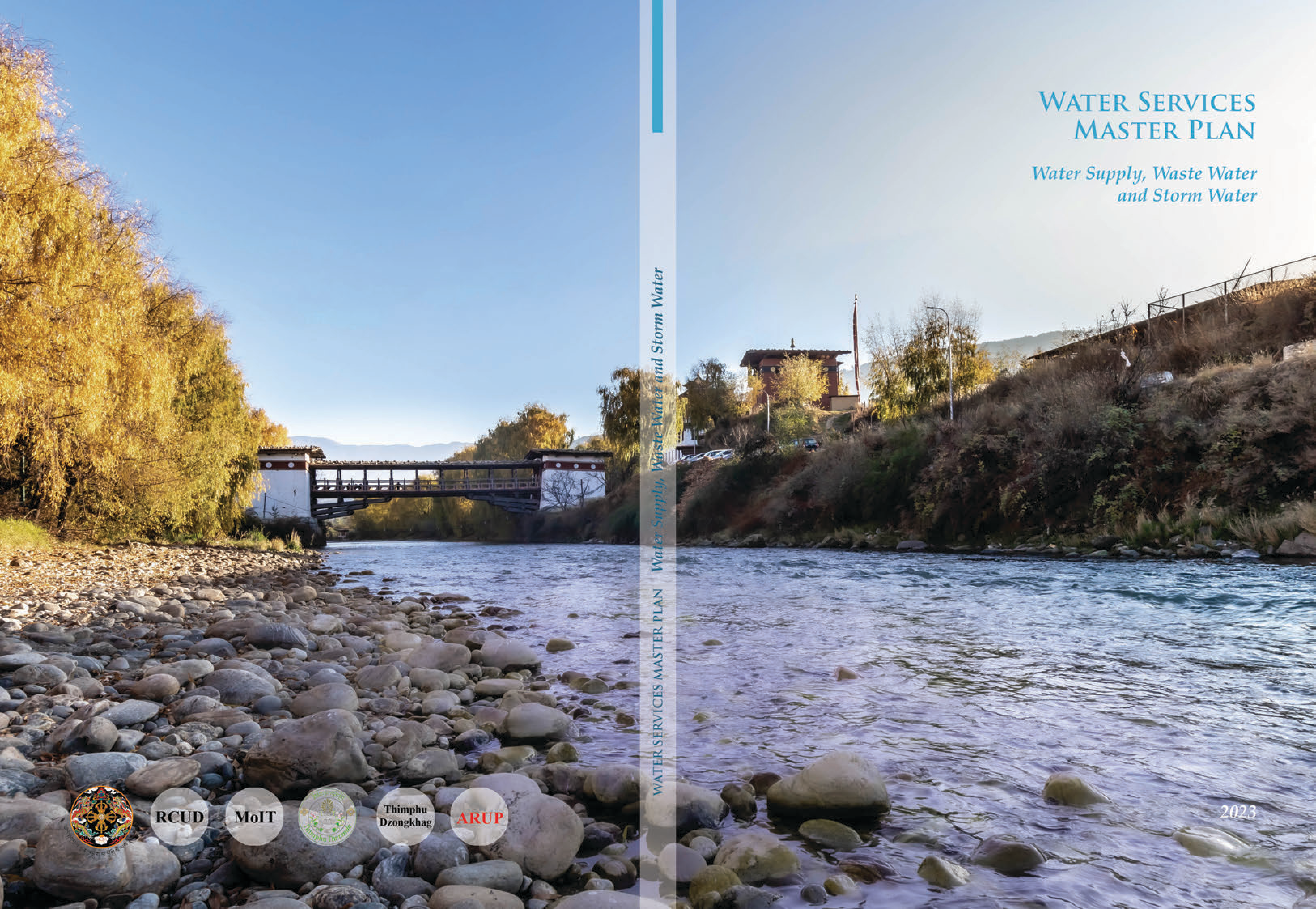
RCUD
MoIT
Thimphu Thromde
Thimphu Dzongkhag
ARUP
WATER SERVICES MASTER PLAN Water Supply, Waste Water and Storm Water
WATER SERVICES
MASTER PLAN
Water Supply, Waste Water
and Storm Water
2023

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Abbreviations

Abbreviation	Definition
BBF	BioBall Filter
BMC	Bulk Moulding Compounds
BOD	Biological Oxygen Demand
CAPEX	Capital Expenditures
CIRIA	Construction Industry Research and Information Association
The Client Team	Ministry of Works & Human Settlement; Thimphu Thromde; Royal Commission for Urban Development (RCUD)
CMIP6	Coupled Model Inter-comparison Project Phase 6
COD	Chemical Oxygen Demand
DWR	Drinking Water Regulations
DO	Dissolved oxygen
ECMWF	European Centre for Medium-Range Weather Forecasts
EU	European Union
FRP	Fibre Reinforced Plastic
FSM	Faecal Sludge Management
GIS	Geographic Information System
GLOF	Glacier Lake Outburst Floods
ICW	Integrated Constructed Wetlands
IFAS	Integrated Fixed Film Activated Sludge
IPCC	International Panel on Climate Change
lpcd	litres per capita per day
MBBR	Moving Bed Biofilm Reactor
min	minutes
mm	millimetre
m^3/h	cubic metres per hour
MLD	million litres per day
MLE	Modified Ludzack-Ettinger
MoIT	Ministry of Infrastructure and Transport
MRP	Molybdate Reactive Phosphorus
NBS	Nature Based Solutions
NRW	Non-revenue Water
OPEX	Operational Expenditures
PESTLE	political, economic, social, technological, legal and environmental

Abbreviation	Definition
PFD	Process flow diagram
PRV	Pressure reducing valve
PS	Pump stations
P&P	Prior & Partners
RCUD	Royal Commission for Urban Development
SBR	sequential batch reactor
SCADA	Supervisory Control and Data Acquisition
SMC	Sheet Moulding Compounds
SRT	solids retention time
SSP	Shared Socioeconomic Pathways
SuDS	Sustainable Urban Drainage Systems
TDH	Total dynamic head
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TSP	Thimphu Structure Plan
TSS	Total Suspended Solids
TT	Thimphu Thromde
WDM	Water Demand Management
WSP	Water Safety Plan
WTP	Water treatment plant
WWTP	Wastewater treatment plant

1. Introduction

1.1 Background

Arup prepared a Water Services Masterplan, in support of the Ministry of Infrastructure and Transport (MoIT) (formerly Ministry of Works and Human Settlement), Thimphu Thromde (TT) and the Royal Commission for Urban Development (RCUD) (the Client Team) in their review of the Thimphu Structure Plan (TSP). The aim of the project was to examine the infrastructure of the existing water supply, wastewater and stormwater systems and identify capital improvement projects required to service existing and future development within Thimphu. The Masterplan ran simultaneously with the TSP, providing inputs as required and to inform the TSP. The Masterplan provides the MoIT and RCUD with a list of recommended concept-level projects at a citywide scale.

1.2 Purpose

This report relates to Phase D of the Thimphu Water Services Masterplan "Optioneering and Strategy Design" as shown in Figure 1-1. The report builds on the works undertaken in previous phases, including:

- Further development of hydraulic models of the Water Supply and Wastewater networks.
- Appraises the strengths and weaknesses of the existing system, based on the data gathering and analysis carried out in Phase A and B.
- Based on available information, using quantified data or risk-based approach, and considering design vision, identify priority projects.
- Where required, make recommendations for improving system monitoring, to enable more specific planning of project interventions.

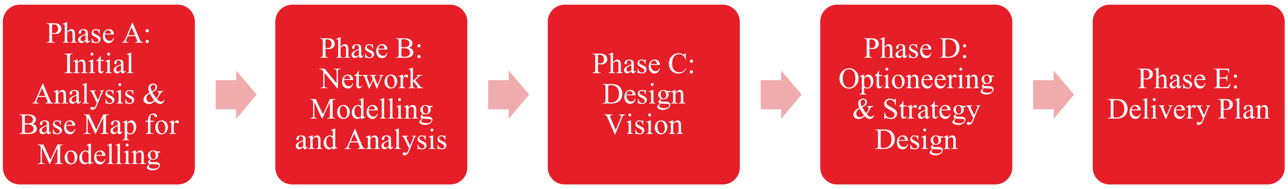


Figure 1-1: Project Phases

The output from Phase A *Initial Options Analysis: Constraints and Opportunities Report* was issued in November 2022. Unless otherwise noted, assumptions and outcomes from Phase A were carried through and used in Phase B *Water Supply, Wastewater and Stormwater Assessment,* which was issued in March 2023, and continue to be used in this Phase D.

1.3 Masterplan Objectives

The overarching strategy for Water Services in Thimphu is to provide a safe, equitable, reliable and resilient network which meets international Drinking Water Standards and protects natural watercourses. The Masterplan will support the growth of the city in line with the outcomes of the TSP and contribute to improved health and wellbeing of Thimphu and the surrounding environment.

The objectives of this Masterplan were developed as part of the TSP through a mix of international best practice, client ambition and consultation with stakeholders as relevant to the Thimphu context. These were further developed as part of this Masterplan.

The objectives of the water supply, wastewater and stormwater systems are outlined in Table 1.

Table 1: Key Objectives of the Masterplan

System	Objective
Water Supply	All residents within Thimphu will be served by a 24/7, high quality, safe and reliable water supply.
	Fair and efficient supply of water to all consumers within Thimphu Thromde (including domestic, non-domestic and commercial customers) and allow for growth of the city in accordance with the provisions of the TSP.
	Promote sustainable use of water to minimise the effect on the environment.
	The water supply infrastructure can deliver necessary flows and pressures throughout the city for firefighting purposes in line with the requirements of the Fire Department.
	The water supply network will be sensitive to the natural environment.
	The water supply system will be operated economically and efficiently.
	The water supply system will be resilient to shocks and stresses including climate change.
Wastewater	All residents within Thimphu will be connected to the municipal wastewater system.
	Wastewater in Thimphu will be managed in a manner that both protects the environment and minimises the risk to public health.
	Wastewater services shall be provided to international standards for all residents, businesses, schools and healthcare facilities in Thimphu and allow for growth of the city in accordance with the provisions of the TSP.
	All wastewater is treated prior to discharge to the environment.
	The wastewater system will be operated economically and efficiently.
Stormwater	Improve the water quality of stormwater run-off.
	Reduce stormwater run-off rates.
	Enhance amenity and biodiversity benefits of stormwater infrastructure.
	Improve the water quality of natural watercourses.
	Re-naturalise existing culverted streams.
General	Establish construction Quality Assurance / Quality Control standards for pipelaying.

2. Context

2.1 Location

Thimphu, the capital city of Bhutan, is located in Himalayas at an elevation of approximately 2,300 metres (m) above sea level. The city is located in the western central part of Bhutan, in the valley of the Wang Chhu, surrounded by steep mountains Figure 2-1.

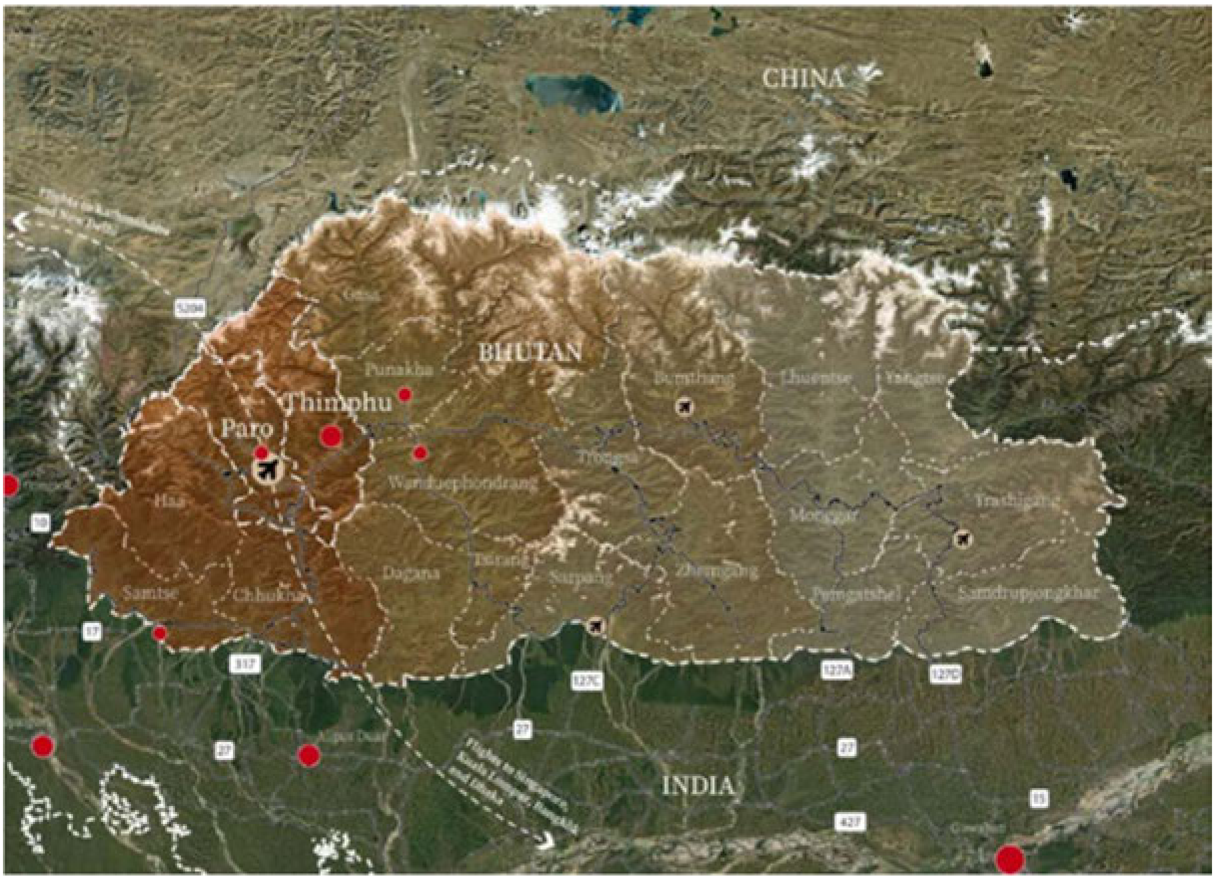


Figure 2-1: Map of Bhutan

2.2 Study Extents

The extent of this assessment is based on the boundary of Thimphu Structure Plan, an area of 65km², stretching from Dodena in the north to Namseling in the south, and up the tributary valleys of Kabesa, Dechencholing, Taba, Motihang, Maymaylakha and Royal Thimphu College. The study extents are depicted in Figure 2-2.

Figure 2-2: Study Extents

2.3 Thimphu Structure Plan

Thimphu's population has grown at a rapid pace over the past two decades through rural to urban migration. Thimphu's urban footprint has also significantly grown. Bhutan's urban population growth rate was the highest among the eight South Asian countries, at 5.7% per year from 2000-2010. Thimphu's urban population growth rate per year was high and is expected to remain high for the next two decades.

The proposed Thimphu Structure Plan (TSP) 2022 looks forward 25 years up to 2047. The TSP provides the strategic frameworks for how Thimphu should sustainably grow and develop in the future, through regeneration of existing urban areas and expansion of the city to the south.

The plan sets out limits to the city, whilst also identifying where and how urban development can be accommodated. This includes plans that establish land use across the city and associated policies that will guide development where these land uses apply. In addition, it sets out transport interventions and other forms of infrastructure to promote Gross National Happiness, support good quality of life and meet the needs of Thimphu's residents within the city's ecological limits.

2.4 Population Growth

Population growth in Thimphu was initially undertaken as part of the Thimphu-Paro Regional Strategy in July 2022. A bottom-up approach was used to determine the population uplift. This approach identified sites across the city that could accommodate urban growth and determining the carrying capacity of these sites through determination of measures such as:

- Proportion of the site available for development
- Building efficiency
- Land use
- Site density

The results of this assessment are shown in Figure 2-3.

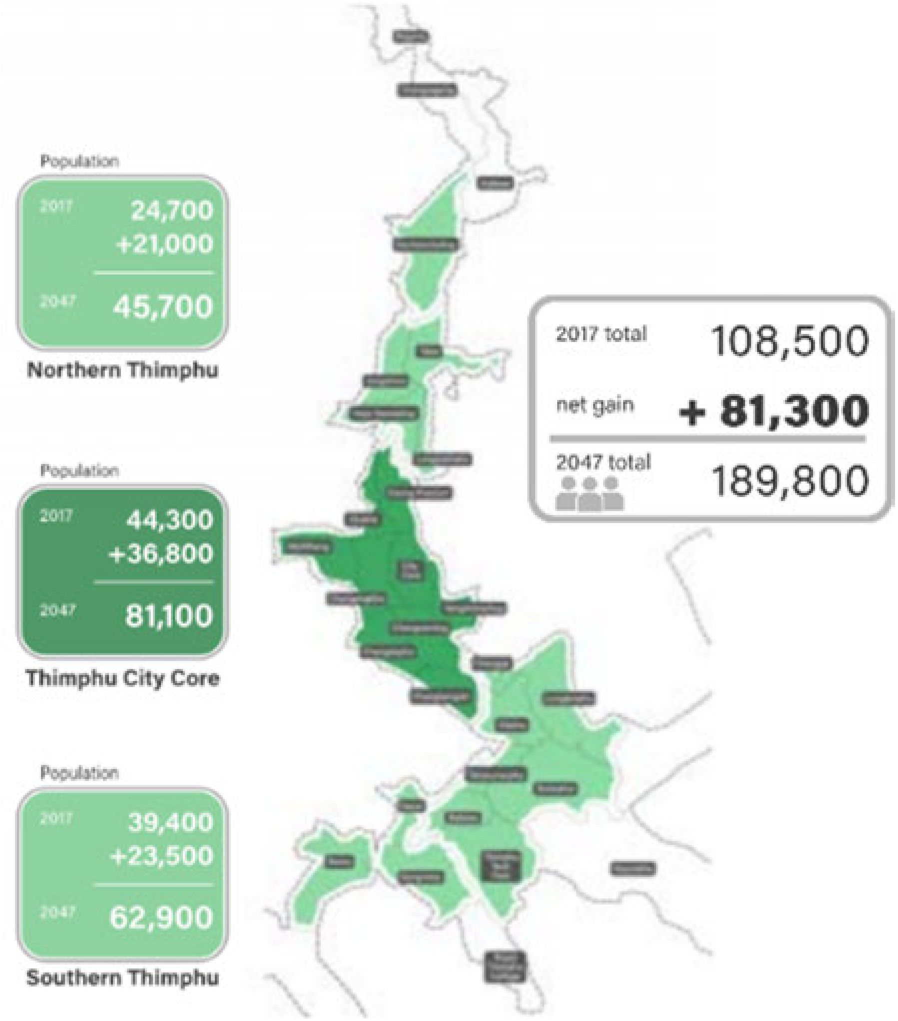


Figure 2-3: Population Growth as per Regional Strategy

Population distribution was further refined for Thimphu City as part of the TSP and as shown in Figure 2-4. This refinement focussed on an Urban Hierarchy, ensuring activity hubs are accessible and appropriately scaled to cater to the needs of population catchment sizes.

Rural local	2,000 people
Local	2,000-5,000 people
Neighbourhood	5,000-15,000 people
Sub-district	<50,000 people
City	>150,000 people

Figure 2-4: Urban Hierarchy Concept

The proposed population growth for each neighbourhood is shown in Table 2.

Table 2: Thimphu Population Distribution

Sub-districts	Neighbourhoods	People Existing 2017	People Net Gain 2047	People Total 2047
Northern Thimphu SD1	Dechencholing	6,490	6,668	13,158
	Taba	5,980	3,145	9,125
	Jungshina	4,730	4,601	9,331
	Langjophaka	2,500	1,297	3,797
	Hejo-Samtenling	5,010	5,361	10,371
Thimphu City Core SD2&3	Dzong Precinct	410	-	410
	Motihang	6,960	571	7,531
	Zilukha	2,590	375	2,965
	Changanakha	6,200	13,857	20,057
	City Core	5,760	7,122	12,882
	Changedaphu	3,580	1,189	4,769
	Changzamtog	13,290	10,543	23,833
	Changbangdu	3,540	1,410	4,950
	Yangchenphug	1,990	1,719	3,709
Southern Thimphu SD4	Changjiji	4,610	1,462	6,072
	Simtokha	3,630	1,322	4,952
	Lungtenphu	4,890	1,106	5,996
	Olakha	11,170	3,602	14,772
	Tshalumarphy	5,920	3,225	9,145
	Babesa	6,400	3,651	10,051
	Serbithang	1,120	192	1,312
	Rama	-	5,009	5,009
	Gangchey	100	-	100
	Debsi	1,600	3,889	5,489
	Ngabiphu			
Thimphu Thromde Total		108,470	81,316	189,786

Population growth will impact water and wastewater demand, but growth in specific areas will be constrained by the availability of water services. The long-term strategy will provide adequate water supply and wastewater drainage for all properties, however the programme for the upgrading of treatment plants, pipelines and storage reservoirs will depend on the phasing of this growth, ensuring that existing properties and customers are not negatively impacted by the additional demands.

2.5 Design Scenarios

The Masterplan examines the Water systems under three scenarios, current, mid-term (2032) and long-term (2047) in line with the TSP.

The current scenario represents the baseline condition. The current scenario includes population data from 2017, the per capita water consumption provided by Thimphu Thromde, non-revenue water audit data provided by Thimphu Thromde and assumptions around the percentage of water which is discharged to the wastewater system.

The future scenarios assessed include a mid-term 2032 scenario and a long-term 2047 scenario, in alignment with the TSP phasing and planning strategies.

Future population estimates and target consumption and leakage figures were applied. The current and two future scenarios were assessed in detail in the *Water Supply, Wastewater and Stormwater Assessment* to evaluate the operational performance of the existing and future water and wastewater systems.

3. Climate Change Resilience Assessment

A review was performed into areas of capital improvement opportunities previously identified to enhance water services across Thimphu, considering influences and impacts of climate change. A wider consideration of the city's catchment was taken into account considering climate change scenarios and temperature and precipitation trends. Refer to Appendix A for additional details on the Climate Change Resilience Assessment.

3.1 Overview

As Thimphu's population grows larger and more urbanised, resilient urban water management is critical to ensuring it is safe, healthy and prosperous development in the face of an unpredictable and changing climate. Water resilience describes the capacity of a city to function in the face of water-related stresses so that those living and working within the city can survive and thrive. In Thimphu, there is an increasing need for improved urban water management that ensures consistent, adequate and high-quality water services for all.

The Royal Government of Bhutan governs water supply, irrigation and flood management through four different ministries, as shown in Figure 3-1. In 2001, the Bhutan Water Partnership – a non-profit entity affiliated to the Global Water Partnership, was created to achieve the goals of Integrated Water Resource Management (IWRM) which incorporates water industry members beyond the four ministries (Royal Government of Bhutan, 2007). The 2011 Water Act and the 2014 Water Regulation Act govern the management of water resources and regulation of water prices respectively (National Environment Commission, 2014).

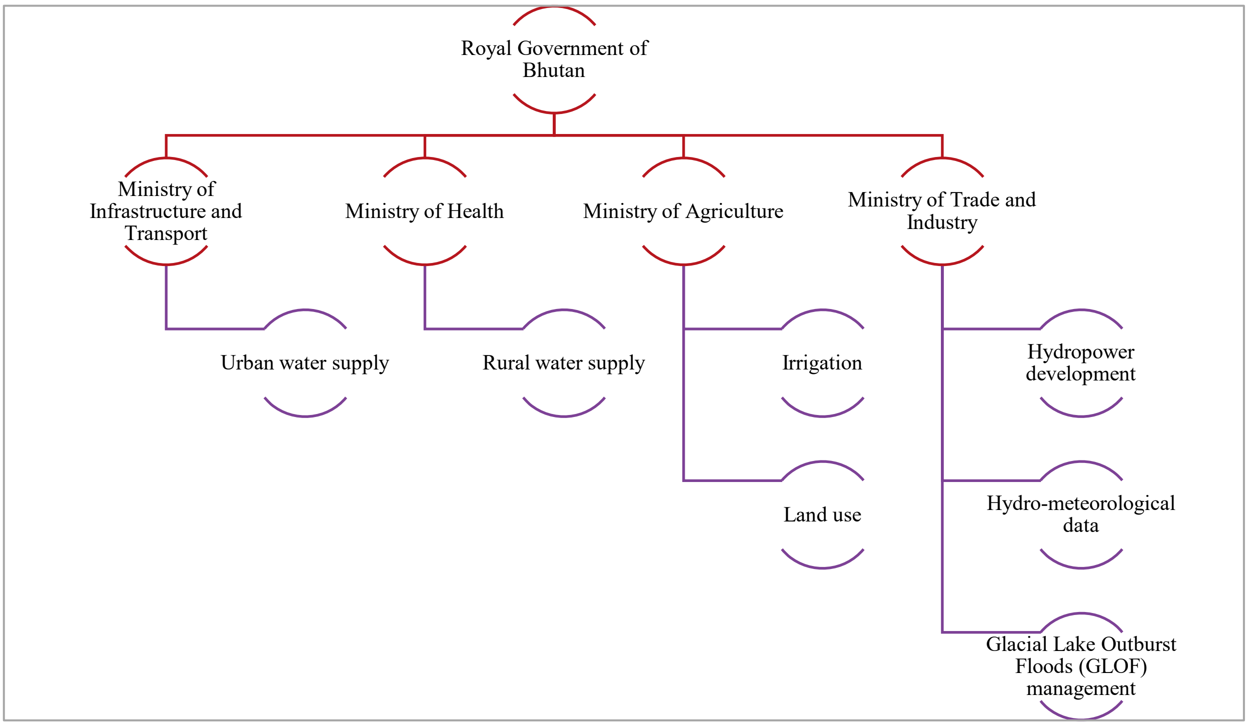


Figure 3-1: Water Governance in Bhutan

Most of the major rivers in Bhutan originate from glaciers and are recharged by watershed. River discharge results primarily from rainfall, supplemented by an estimated 2-12% glacial melt and another 2% from snow melt. The combined national outflow of the rivers is about 70,576 million m^3 (or 2,238m^3/s), which corresponds to a flow of 109,000m^3 per capita per year.

Bhutan experiences a monsoon-influenced humid tropical climate, dominated by seasonality in precipitation, with long periods of low rainfall followed by periods of intense rainfall (World Bank Group, 2021). Water shortages are prevalent in the country, where safe drinking water coverage is not universal and shortages are already present due to rainfall seasonality (Royal Government of Bhutan, 2007). In 2021 the annual rainfall was 1,685mm, with rainfall seasonality in this period.

Climate analysis of Bhutan and the Thimphu region by the International Panel on Climate Change (IPCC) and the World Bank suggest the following effects of climate change (World Bank Group, 2021):

- Warming of 3.9°C by the 2090s.
- Increase in the impact of flooding.
- Increase in the likelihood of heatwaves and droughts.
- Increased snowmelt with temperature rise leading to significant changes in river discharges and water resource availability.

Such changes in climate need to be considered in planning for future water supplies, such as current reliance on abstraction points which may become vulnerable to drier weather, limited storage capacities in the face of heightened monsoon seasons and operational water supply infrastructure to accommodate for the demand across the network.

3.2 Climate Trends for Thimphu

Climate projections for Bhutan are best explored through temperature and precipitation. Bhutan is set to experience more severe warming than the global average by the 2090s (World Bank Group, 2021).

The probability of heatwaves in Bhutan is set to increase from 2% currently to 20% by 2100 (World Bank Group, 2021), which is significant enough to exacerbate Bhutan's existing water system risks. Increased warming in Bhutan is set to cause glaciers in the country retreat, which would result significant reduction in available water resources in the region (World Bank Group, 2023).

Variation in rainfall and temperature are likely to significantly affect the water resources of the region and the water resource management. Studies conducted across the Masterplan show substantial seasonal changes in water flow levels for extended periods of the year that do not fully utilise water treatment plant (WTP) capacities. There is an anticipated change in seasonal precipitation trends, indicating a decrease in rainfall from September-February and increase in rainfall from March-August.

Key water resource features that will be affected by change in temperature and increased seasonality of rainfall and intensity include, but are not limited to:

- Management of water storage
- Flood risk management
- Distribution of potable water in periods of low precipitation
- Land use management- Nature-based Solutions (NBS) and Sustainable Urban Drainage Systems (SuDS)

These operational features will be affected at different levels by climate change. The resilience of these systems is explored further in Section 4.

3.3 Water Resources and Drought Risk Assessment

The security of water resources in dry conditions, considering annual variability, drought and climate change, is key to the urban water supply in Thimphu. Thimphu lies in the upper Wang Chhu basin, with the Wang Chhu itself being the primary watercourse through the city. The Wang Chhu has an annual total flow of 5,200Mm^3, which is 7.4% of the total run-off of Bhutan (National Environment Commission Royal Government of Bhutan, 2016).

The monsoon climate in Bhutan is characterised by low rainfall during the cooler winter months and much higher rainfall during the warmer summer months. This results in highly variable flows throughout the year, proving a challenge to water resources requirements of Thimphu. The months of December, January and February typically experience the lowest surface water flows. Snow and ice melt partially contributes to dry season flow, however the effect of this is limited due to reduced melting in winter temperatures, reduced precipitation and the lack of significant glaciers in the upper Wang Chhu catchment.

Little is known about groundwater in the Wang Chhu basin. There is limited groundwater exploitation in Thimphu, but the government generally discourages groundwater abstraction until aquifers are better understood (National Environment Commission Royal Government of Bhutan, 2016).

3.3.1 Supply Network Overview

The Thimphu water supply network abstracts from nine surface water sources at 12 intakes, feeding nine WTPs. The Thimphu water supply network capacity is 35.5 million litres per day (MLD), as defined by current maximum WTP output. The largest of these abstractions is 10MLD from the Wang Chhu at Dodena, approximately 20 km upstream of Thimphu centre. Another significant abstraction source is the Samtenling Stream (7.9MLD). Two intakes draw water from the Samtenling, the larger of which then feeds a run-of-the-river mini-hydropower station at Jungshina. The outflow of the power station is then treated at a WTP and enters the supply network. The remaining abstractions take place from smaller tributaries at higher elevations above the valley floor, where water cannot easily be pumped to. Additionally, there are three abstraction boreholes at depths of 32-53m below the surface feeding the Changbangdu WTP with a total capacity of 1.2MLD.

3.3.2 Drought Analysis

A simple low flow analysis was conducted using simulated data obtained from the Streamflow Prediction Tool for the Wang Chhu at Dodena and Samtenling Stream to provide an indication of the flow levels that could be experienced during severe drought events. The available data covered a 40-year period from 1980 to 2019. The lowest daily flows for each timeseries were ranked to obtain the return period and using this relationship, low flows with return periods of 100-years, 200-years and 500-years were extrapolated, as seen in Table 3. The analysis was performed on the raw daily data, rather than performing low-flow separation by each dry season.

Table 3: Summary Wang Chhu and Samtenling Stream Low Flows and Demand (MLD)

Source	Abstraction	100-Year Flow	200-Year Flow	500-Year Flow
Wang Chhu	10	157	154	149
Samtenling Stream	7.9	12.2	10.8	9.1

The Wang Chhu does not approach the current abstraction level of 10MLD, indicating a strong level of resilience to a 500-year drought event. The Samtenling Stream does approach the abstraction level of 7.9MLD at this level of severity. Additionally, the intake at the Samtenling Stream will not be 100% efficient in abstracting all available water, suggesting that the Samtenling Stream could present a drought-risk to water supply. Based on the IPCC data for Bhutan, these assessments do not incorporate the effects of climate change.

It is essential to acknowledge the significant uncertainty associated with these values. The estimated drought flows are subject to considerable uncertainty due to various factors, including the meteorological forecasting and routing models used in the Streamflow Prediction Tool as well as the extreme extrapolation to a 500-year event. Therefore, these values serve as indicators of potential drought flows rather than definitive values and provide context and need for more detailed drought risk assessments to be carried out.

The Wang Chhu Basin Management Plan (National Environment Commission Royal Government of Bhutan, 2016) has conducted some climate change analysis based on the RCP 4.5 and RCP 8.5 scenarios. These analyses indicate that historical flows of the Wang Chhu at the Lungtenphu gauging stations have dropped as low as $3.2m^3/s$. Climate change is expected to increase the frequency of flow reductions to this level, but not necessarily intensifying the severity of drought (National Environment Commission Royal Government of Bhutan, 2016).

There is no current consideration of ecological flow requirements as these assessments was not undertaken. The inclusion of ecological flow considerations would provide additional constraints on water abstraction.

3.4 Climate Risk Analysis: Water Sector

3.4.1 Approach

The climate risk methodology analyses the opportunities outlined in the *Initial Options Analysis: Constraints and Opportunities Report*. Climate change indicators were applied as a qualitative way of measuring change, which considers effects and impacts of climate change, adaptation and resilience. The opportunities considered were previously identified as bankable projects and programmes for the improvement of water services in Thimphu. The opportunities provided were summarised by water supply, wastewater and stormwater categories, which were established as either providing climate change resilience or not.

A climate change risk matrix (included in Appendix A) was developed to conduct a qualitative assessment of the water services opportunities in relation to their impacts by the effects of climate change. The opportunities related to operational issues were not taken into account.

3.4.2 Results and Analysis

The preliminary results from the climate resilience risk matrix are the results of the overall rating of each opportunity in response to the climate change indicators.

Climate Resilient Opportunities

The opportunities in Table 4 are classed as low-risk opportunities in relation to climate change uncertainty and impacts.

Table 4: Climate Resilient Opportunities

Category	Opportunity	Remarks
Water Supply	Water supply expansion	Mostly related to operational issues.
	Rationalising WTPs	Increase of abstraction and storage opportunities.
	Source monitoring	As a monitoring component to abstraction, this will provide information for future abstraction development.
	Upsize storage reservoirs	Mitigating flooding, can affect seasonality and inflow. More intense rain can be managed by greater storage, as can changing seasonality.
Wastewater	Implementation of greywater reuse	Diversifying water sources. Consideration of drier weather and demand reduction effect on greywater use.
Stormwater	Daylighting existing culverted streams	Such culverted streams reduce the flows of stormwater, reducing events of flooding and minimising impacts of flash flooding.
Stormwater	Reconnect greywater to wastewater network	
	First flush capture and treatment	As an additional source of water and water capture, this activity reduces reliability of water flowing through abstraction points but can be seen as a "nice to have". Diversification of water sources, capturing clean water.

Medium Risk Opportunities to Climate Change

The following opportunities in Table 5 are classed as medium-risk opportunities in relation to climate change uncertainty and impacts.

Table 5: Medium Risk Opportunities

Category	Opportunity	Remarks
Water Supply	Demand reduction	Climate change impacts have direct influence on behaviour and have been known through temperature and/or population increase/movements, to drive demand.
	Public awareness campaign	Communicating impacts of climate change to users and company, understanding of supply / demand effects.
Wastewater	Safe disposal of septic tank waste	Variations in temperature cause disruption in biological activity, increased population impacts on needs for septic tanks. Already, harmful pathogens are found in stormwater as a result of malfunctioning septic tank systems which services 25% of the current city.
	Monitoring of blockages	Key component to informing decisions and mitigating flooding events.
	New or upgrades to WWTP	Opportunity to maximise higher efficiencies, use of sludge, reducing energy usage. Additionally, current WWTPs do not contain biological nutrient removal system in the WWTPs to treat Molybdate Reactive Phosphorous (MRP) and ammonia. This can be harmful to surrounding ecosystems due to rapid algal growth, harming water quality, food resources, habitats and decreases in oxygen required for fish need to survive.
	Solid waste disposal and management	Variations in temperature cause disruption in biological activity, increased population impacts on needs for septic tanks. Safe management of solid waste required. High rainfall or seasonality – monsoon bursts can result in increased overflows, blockages and breakages.
	Sanitation public awareness campaign	Communicating impacts poor sanitation and building resilience from a human element. Heat and dry spells mean competing demand for water between sanitation use and irrigation, productive uses and drinking. Parts of the population still practice open defecation or pit toilets causing public and environmental public risks. Actions: Conduct hygiene promotion activities to encourage good hygiene practices when water is scarce and encourage and support the safe reuse and recycling of greywater, can improve on informed choices of processes around different technology options.
Stormwater	Flow monitoring of stormwater inflows	Accurate readings can inform varying flows and adverse effects on WWTPs and abstraction points.
	Coordination inclusion of SuDS and NBS	Land use has positive impacts on volume reduction.
	Stormwater Reuse	Diversification of water sources.
	Community awareness of stormwater management	Pro-active disaster risk management and resilience amongst communities.

High Climate Risk Opportunities

The following opportunities in Table 6 are classed as high-risk opportunities in relation to climate change uncertainty and impacts.

Table 6: High Risk Opportunities

Category	Opportunity	Remarks
Water Supply	New abstractions from tributaries	May be required to meet increases in demand, but climate change impacts may reduce abstraction availability or increase the drought risk associated with existing and new abstractions.

3.5 Climate Change Assessment Conclusions and Recommendations

Smaller water sources, such as Samtenling Stream, are more vulnerable to droughts and fluctuations in flow rates from changes in precipitation or snow melt. There is more security around larger watercourses, such as the Wang Chhu because the impacts from climate change are unlikely to reduce below the effective abstraction rate. The Wang Chhu as a water source is anticipated to have a reliable, sufficient supply in the long-term, although diversification of supply sources improves overall resilience of a system. To better understand this risk, continued monitoring and source inventory assessments are required to establish a baseline and evaluate trends. In the medium term, which is within the operational life of the WTPs, there is the potential for more vulnerable sources to drop below abstraction rates during severe drought, but this effect is not yet quantifiable without better data.

Thimphu and its surrounding areas water resources will face new, complex and pervasive challenges caused by population growth, socio-economic development and climate change. A multi-disciplinary approach is required; this can be effectively addressed through defined policies, public regulation, stakeholder participation and well-designed development programme with efficient management institutions. The following recommendations are made:

- Drive the development of drought management plans through which TT monitors various indicators of water availability and assesses the level of risk associated with all the abstractions. A relevant drought plan sets out drought onset monitoring, drought triggers and appropriate actions to be taken at each stage of a drought. At certain points, known as triggers, specific actions to manage water supplies and water demand are taken.
- Include improvement of rural supply as part of the city's urban plan. This will positively impact potable and stormwater as pipes in remote settlements are currently feeding off stormwater networks that are likely to be unreliable in the long term.
- More effective monitoring should include water quality checks for harmful pathogens such as E-coli in rivers where septic tanks and wastewater discharge. Increasing temperatures due to climate change are likely to improve the conditions for development of pathogens and could increase the period of time (season) during which they proliferate.
- Continued monitoring and learning as the frequency of droughts and floods become more prevalent. This requires proactivity and engagement to ensure lasting resilience.
- Work to provide greater visibility and understanding of climate change patterns and expected impacts, to mitigate the resulting linked water demand or usage patterns (usually increases).
- Strengthen partnerships and organisations such as the Bhutan Water Partnership, to become more effective in its roles and responsibilities, which could extend beyond infrastructure in the water sector.
- Diversification of supply sources (i.e., greywater, stormwater harvesting, supporting abstractions, etc.) should be ensured for the population reliant on this source. Data uncertainties notwithstanding, the Samtenling source potentially vulnerable to drought.
- Conduct an ecological assessment will be important to identify ecological low-flow requirements. There are currently no ecological flows available.
- Conduct a full source inventory assessment with recommendations for monitoring needs.

During implementation of the Water Services Masterplan, ensure that guidance provided in existing documents and national plans were incorporated for consistency, such as the National Water Supply

Strategy, Integrated Water Resources Management Plan and learnings from the National Rural Sanitation and Hygiene Programme for instance.

4. Water Supply Masterplan

This section focuses on the water supply system in Thimphu and is structured to discuss the appraisal and actions related to key areas of the water supply system. This section includes:

- Summary of existing system
- Objectives and strategies for the water supply system
- Design scenarios considered in the assessment
- Appraisal of the water supply trunk system and recommended actions
- Appraisal of the WTPs (existing and proposed) and recommended actions
- Other initiatives

4.1 Existing System

Access to clean water and sanitation is one of the 17 United Nations Sustainable Development Goals. There is currently inadequate water available to all residents in Thimphu and the supply is inconsistent and unreliable. The total current demand for potable water in Thimphu is approximately 30.6MLD. Approximately 85% of this water is provided by Thimphu Thromde and the remainder is provided by private or community supplies, which are not chlorinated and are therefore susceptible to contamination.

Based on discussions with MoIT and TT, most people on the municipal supply consume water directly from the tap. There were no major reports of contamination events in recent years. Chlorination contact time was identified as insufficient at some WTPs as part of the *Water Supply, Wastewater and Stormwater Assessment*, however residual chlorine levels still meet acceptable limits; therefore, there is no indication that there are issues regarding the safety of the water supply for human consumption. The Ministry of Health undertake regular sampling and testing of the water and there are no fundamental water quality issues. The Masterplan allows for all properties within TT to be supplied by the municipal network which would reduce this contamination risk.

Raw water is extracted and treated by nine WTPs with a combined design capacity of 39MLD. There are 49 storage reservoirs used to control the pressure and flow into different Demand Management Areas (DMAs) with a combined capacity of 10.5 million litres (ML).

There is good coverage of watermains throughout the city delivering potable water. A recent Water Loss Audit by Water Management International (September 2022) identified water losses of 47.5%-60.5% in the water supply network caused by leakage, high pipe burst rates, storage reservoir overflows and high system pressures. The water supply network is also unable to provide adequate firefighting capacity due to the lack of availability of water at certain times of the day, fire hydrants coverage and insufficient pipeline hydraulic capacity for the firefighting flow rates.

4.2 Water Supply Strategies

The water supply strategy aims to create opportunity through water systems which support sustainable growth within the city. This includes cultivating a balance between managing non-revenue water losses, such as leakage, and water demand to ensure adequate water for living while protecting natural water resources. A goal is to inspire the public to understand the water systems and how they can contribute to sustainable management of water in Thimphu.

The following strategies for the water supply system were developed through consultations with stakeholders to meet the objectives of the Masterplan. Table 7 shows the relationship between the different strategies and the objectives they help to achieve, as outlined in Section 1.3.

- Reduce potable water demand from 135 litres per capita per day (lpcd) to 100lpcd.
- Reduce Non-revenue Water (NRW) losses from >50% to <15%.
- Increase water storage from <12 hours to >48 hours to prevent a loss of supply during planned or unplanned interruptions.
- Operate the water supply network as a Smart water networks.
- Establish construction Quality Assurance / Quality Control standards for pipelaying to improve operations, maintenance and reduce water losses.
- Protect trunk mains from damage due to natural hazards to ensure the water supply is resilient through emergencies. Identifying routes prone to natural hazards (e.g., flooding, landslides) and diverting and protecting trunk lines which could be affected is essential to maintaining supplies.
- Adequately serve schools and health centres with a reliable water supply to minimise community health risks.
- Divert watermains currently laid through stormwater drains and bury under roads or footpaths.
- Potable water quality achieves European Union (EU) Drinking Water Regulations.
- Extend the existing watermain network to new neighbourhoods.
- Upgrades to existing watermains and network infrastructure to meet current and future demands.
- Upgrades to WTPs to meet current and future demands.

Table 7: Water Supply Objectives and Strategies Matrix

		Objectives				
		24/7, high quality, safe and reliable water supply.	Fair and efficient supply of water to all consumers.	Sustainable use of water.	Infrastructure suitable for firefighting purposes.	Sensitive to the natural environment.
Strategies	Reduce potable water demand		✓	✓		✓
	Reduce water losses	✓	✓	✓		✓
	Increase water storage	✓			✓	
	Smart water networks		✓	✓		
	Quality Assurance / Quality Control standards					
	Protect trunk mains from damage due to natural hazards	✓				
	Adequately serve schools and health centres	✓	✓			
	Divert existing watermains	✓				
	Potable water quality achieves EU Drinking Water Regulations (DWR)	✓				
	Extend the existing watermain network	✓	✓		✓	
	Network upgrades	✓			✓	
	WTP upgrades	✓			✓	

4.3 Design Scenarios

The design scenarios for the Masterplan are introduced in Section 2.5, with details pertaining to water supply summarised in Table 8 and Figure 4-1.

Table 8: Water Supply Assessment Scenarios

Population	Consumption (lpcd)	NRW
Current (2017)	135	45%
2032	120	30%
2047	100	15%

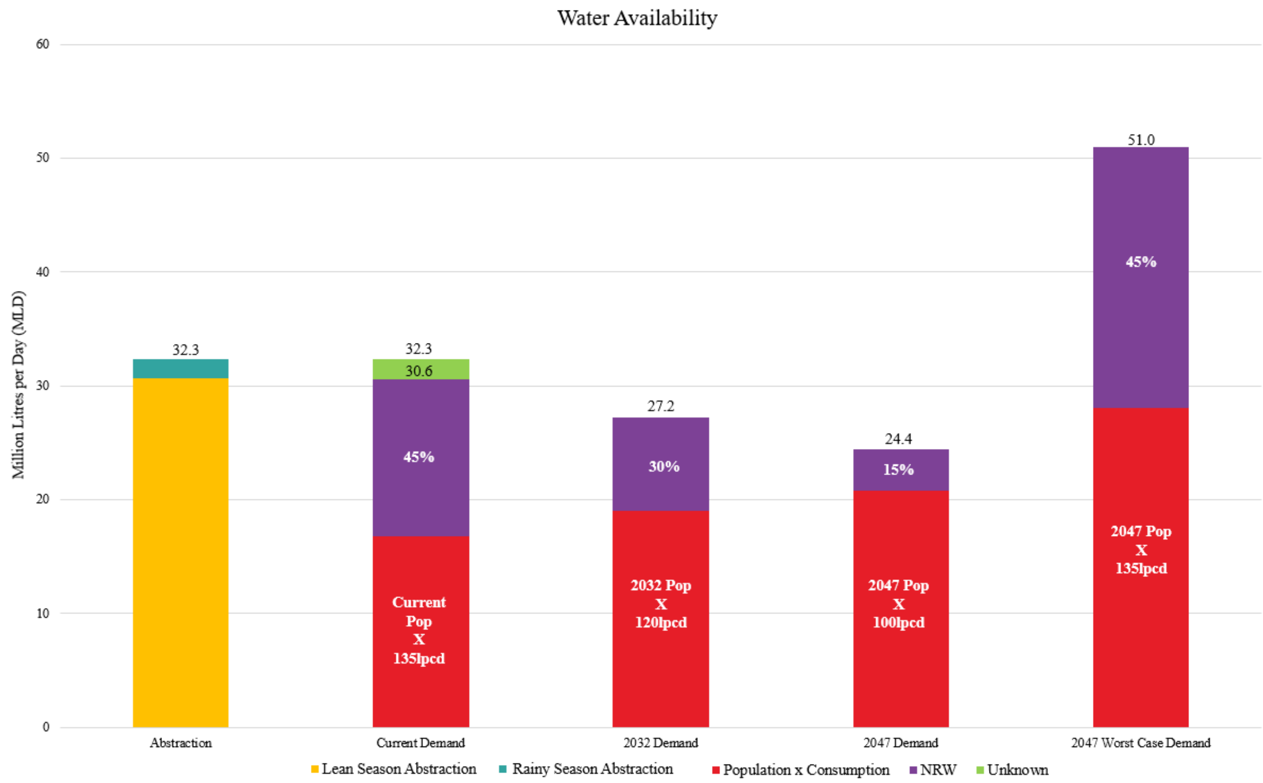


Figure 4-1: Water Availability Summary

A worst-case 2047 scenario, where consumption and NRW remained at their current levels with the 2047 population levels, was assessed in the *Water Supply, Wastewater and Stormwater Assessment*. This demand is considered unsustainable and would require significant upgrades to Water supply and Wastewater infrastructure. This Masterplan assumes that the NRW and demand management strategies proposed are implemented and that this worst-case scenario is therefore not applicable.

4.4 Water Supply Network

The existing water supply system includes WTPs, trunk mains (raw water, supply and distribution mains), storage reservoirs and local watermain networks within demand management areas (DMAs), as depicted in Figure 4-2. A hydraulic model was constructed in Bentley WaterCAD for the existing trunk main system to undertake a detailed assessment of the existing network. Refer to the *Water Supply Hydraulic Model Build Report* and *Water Supply, Wastewater and Stormwater Assessment* for details on the model build, assessment criteria, scenario details, results and limitations of the hydraulic models.

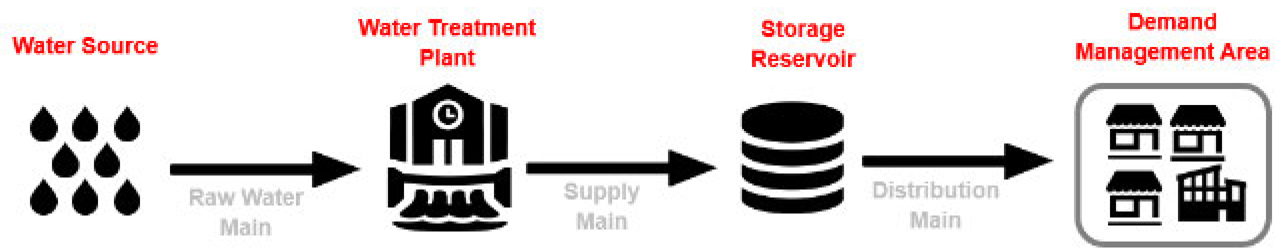


Figure 4-2: Mains Arrangement Showing Trunk Mains and Network Components

The hydraulic models were used to assess the existing operating performance of the water supply network as well projected future operating performances for the mid-term (2032) and long-term (2047) scenarios. The models have also been used to assist in developing solutions for improving the network operating performance both for the present and future operation. Detailed water supply maps can be found in Appendix B.

Due to limited availability of field data, the hydraulic models were not calibrated. Therefore, outputs from the models should be considered as high level requiring further work before investment decisions can be made, refer to Section 4.4.7.

4.4.1 Identified Network Deficiencies

Pressure within the network needs to be great enough to satisfy customer requirements; low pressure in the network may result in ground water seepage into the pipelines with potential contamination issues while significantly high pressure increases leakage rates, may cause bursts or damage to pipelines or plumbing, or wear and tear on fittings including customer apparatus. Pressure reducing valves (PRVs) release pressure from the system when the pressure level becomes too high for safe or efficient operations. To assess minimum and maximum pressure within each DMA, the models were extended from the trunk mains to include DMA network to the highest and lowest elevation properties, respectively. To assess pipelines hydraulic capacity, the main consideration was to keep flow velocity within the pipelines to an appropriate range.

4.4.1.1 Water Availability Assessment

The flow data received for *Water Supply, Wastewater and Stormwater Assessment* indicated that several WTPs receive a reduced flow during lean season. Therefore, a water availability assessment was performed to evaluate the available water yield from the supply sources for each WTP. To ensure consistency of supply to all residents, the flows from different WTP throughout the network were reportioned to accommodate the demand. A summary of the WTP, lean season availability, demand and reallocations to match demand and availability are included in Table 9. Refer to Section 3 for details on the Climate Change Assessment which evaluates the long-term water supply. The existing highest demand values are derived from applying the per capita demands against the population figures or projections; current demands or production at the WTPs may be higher due to inaccuracies in consumption, loss, or apportioning assumptions.

Table 9: Water Availability Assessment

WTP	Lean Season Availability (MLD)	Highest Demand Scenario	Existing Highest Demand (MLD)	Reallocated Highest Demand (MLD)	Summary of Reallocations
Chamgang Old	3.0	Current	6.2	2.6	Demand on WTP exceeded the available water supply, therefore reallocated demand from Bangdu Residents and Bangdu Area Left DMAs to Motihang WTP and Babesa Right, Above Old Highway and Babesa Left DMAs to Chamgang New WTP.
Jungshina	4.5 (assuming 3MLD from Taba as detailed in Section 4.4.2)	2032	2.6	2.6	With an additional supply from the Taba line (see below for details), there is an excess of available supply.
Motihang	7.5	Current	5.5	7.5	There is an excess of available supply. Therefore, reallocated demand from Bangdu Residents, Bangdu Area Left and Changzamtog DMAs to Motihang WTP.
Dechencholing	2.8 (assuming expansion)	2032	2.8	2.6	There is no excess water for distribution. Capable of supplying existing DMAs, plus the Community Supply (northern DMA), Dangrina Proposed and Pamtsho 2 DMAs. Reallocated Pamtsho 1 DMA demand to Taba WTP.
Boreholes	0.7	Current	1.9	0.7	Demand on WTP exceeds the available water supply, therefore reallocated demand above 0.7MLD supply to the Motihang WTP.

WTP	Lean Season Availability (MLD)	Highest Demand Scenario	Existing Highest Demand (MLD)	Reallocated Highest Demand (MLD)	Summary of Reallocations
Ngabirongchu	1.9	2047	1.9	1.9	There is sufficient water supply for the demands, except for Babesa Left DMA demands which were reallocated to Chamgang New WTP.
Taba	10.0	2032	7.3	7.5	There is an excess of available supply. Taba WTP to replace Dechencholing supply to Pamtsho 1 DMA.
Babena	1.0	Current	1.0	1.0	There is sufficient water supply for the demands and there is no excess water for distribution.
Chamgang New	3.5	Current	0.8	2.9	There is an excess of available supply. Chamgang New WTP to replace Chamgang Old WTP supply to Babesa Right, Above Old Highway and Babesa Left DMAs.

Figure 4-3 and a map in Appendix B depict the summary of the reallocated demand between the different WTP.

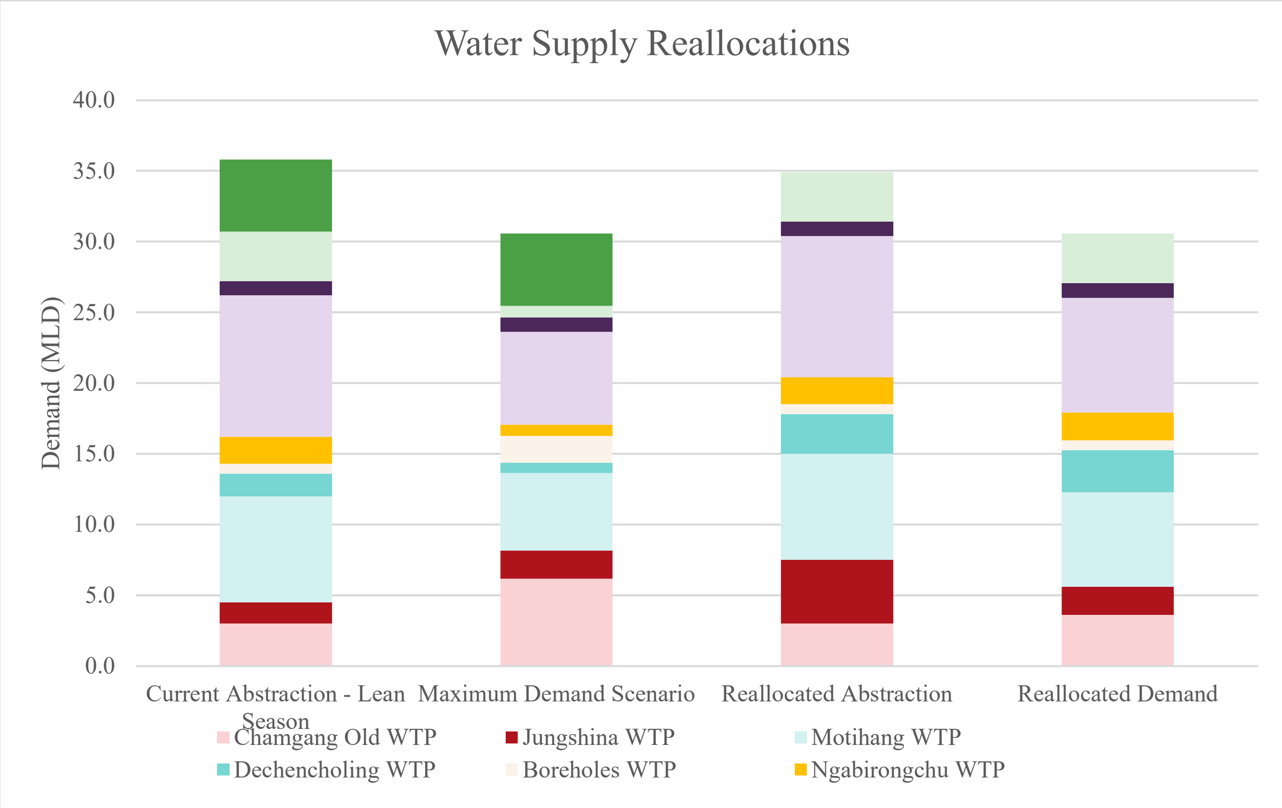


Figure 4-3: DMAs with Reallocated WTP Supply Source

4.4.1.2 Water Distribution Connectivity

To supplement the hydraulic modelling results, data sheets were prepared to summarise the information regarding each DMA and storage reservoir to assist in assessments of the operations and management of the network. The data sheets for the DMAs and storage reservoirs should be assessed together, with details about each component stated for ease of reference and include the details required for high-level network assessments. The data sheets in full are included in Appendix C. An example of the application for utilising the data sheets is detailed for the Above RICB DMA as shown in Table 10.

As identified in Figure 4-4, the hydraulic model outputs indicate that the pressure at the DMA inlet for Above RICB is greater than 100m and a PRV may be necessary to reduce the pressure to acceptable levels. The Above RICB DMA data sheet (presented in Table 10) states that 90% of properties in the DMA have an elevation of 2,300-2,500m, while only 10% of properties have an elevation above 2,500m. Therefore, the pressure management strategy for this DMA should consider differences for each of the groupings of property elevations. Kuengacholing Tanks 1 and 2 supply this DMA.

The Kuengacholing Tank 1 storage reservoir data sheet is presented in Table 11. The storage reservoir data sheet may be reviewed for details on how storage reservoirs are supplied, which is presented in the elevation profiles which depict the water supply (WTP), adjacent storage reservoirs and minimum and maximum property elevations per DMA. This hydraulic profile can be a useful tool in evaluating how DMAs are supplied and what potential connectivity options or re-zoning may be available as an alternative or to supplement a PRV.

The hydraulic model results in conjunction with these data sheets can provide a targeted approach for future studies and investment. The data sheet can assist in highlighting areas with the largest demands or properties which may be evaluated to improve operations and efficiencies through pressure or velocity management.

Table 10: DMA Data Sheet for Above RICB

Value	Result
DMA Name	Above RICB
Storage Reservoir Name	Kuengacholing Tank 1 Kuengacholing Tank 2
Storage Reservoir Volume (m^3)	320 320
Total Storage Reservoir Volume per DMA (m^3)	640.0
Top Water Level (m)	2592.5 2593.5
Supplying WTP	Motihang WTP
Common Supply Pipe Diameter (mm)	100
Number of Properties	124
Current Population	845
2032 Population	1504
2047 Population	2339
Current Zone Descriptor of Land Use	Low
2047 Zone Descriptor of Land Use	Low
Supply Times	Unknown
Property Level - Lowest Elevation (m)	2390
Property Level - Highest Elevation (m)	2540

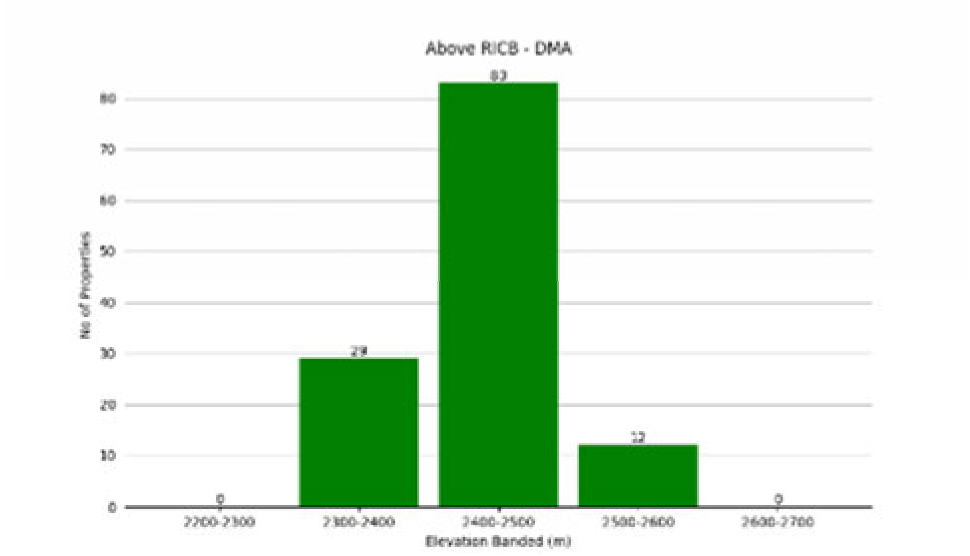
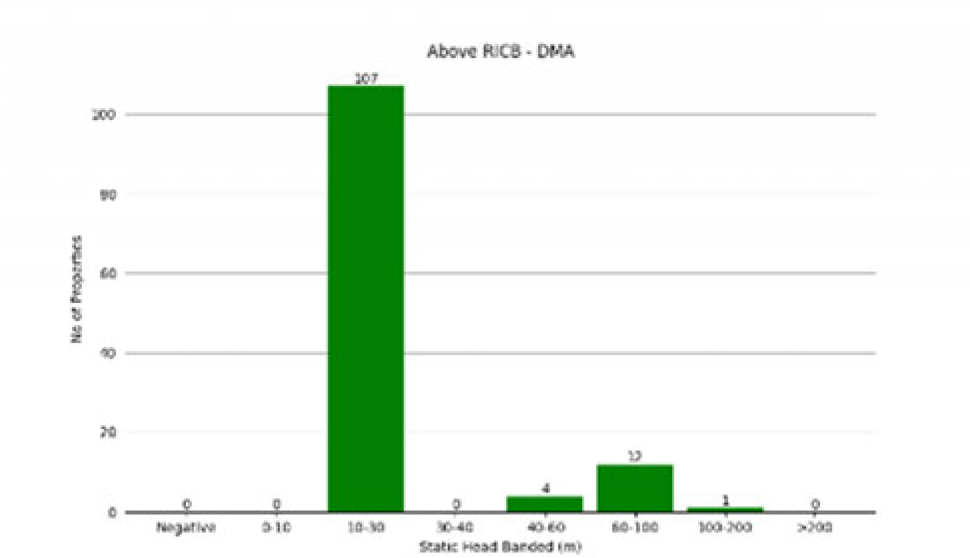
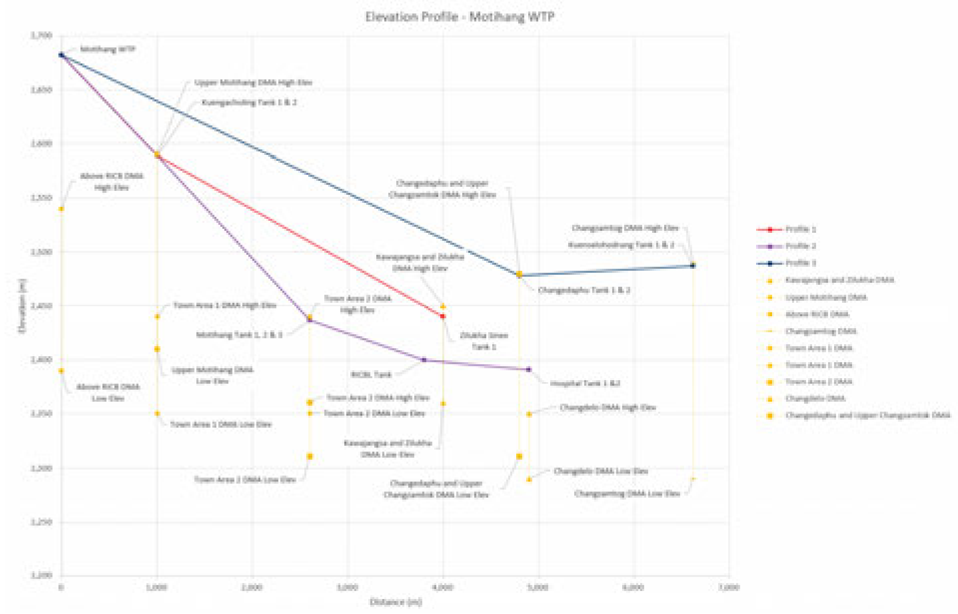
Value	Result
Property Level – Bell Curve by Elevation	
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	0.207
2032 Water Demand (MLD)	0.281
2047 Water Demand (MLD)	0.255
Required Storage Capacity for 24hours (m^3)	207
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	-433

Table 11: Storage Reservoir Data Sheet for Kuengacholing Tank 1

Value	Result
Storage Reservoir Name	Kuengacholing Tank 1
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	Kuengacholing Tank 2
Downstream DMA(s)	Upper Motihang Kawajangsa and Zilukha Town Area 1 Town Area 2
WTP Supplying Storage Reservoir	Motihang WTP
Hydraulic Profile Diagram	
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	100
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	80
Operations	8am-11am and 3pm-6pm
Top Water Elevation (m)	2592.5
Bottom Water Elevation (m)	2589
Storage Reservoir Volume (m^3)	320
Storage Reservoir Material	RCC_circular

4.4.1.3 Network Deficiencies – Pressure and Flow

The hydraulic modelling results of this assessment indicate that the pressure in the network is generally high with an average network pressure of approximately 84m. High pressure up to approximately 400m is recorded which will require further investigations to monitor pressure and confirm installation of PRVs. The locations of high pressure (>100m for the current scenario) and PRVs are depicted in Figure 4-4. Full results for pressure for the current and future scenarios are included in Appendix D.

The minimum average supply pressure within the existing network at DMA demand offtakes is estimated at 1.15m, downstream of the Zilukha Sintex Tank 2 compared to a minimum desirable pressure of 10m. Other DMA areas of low pressure in the current scenario are shown in Figure 4-4. There are also areas with results showing negative pressure which is an indication that the system in its current state will not be able to supply these areas and therefore pumping will be required at the locations depicted in Figure 4-4. Full results for velocities for the current and future scenarios are included in Appendix D.

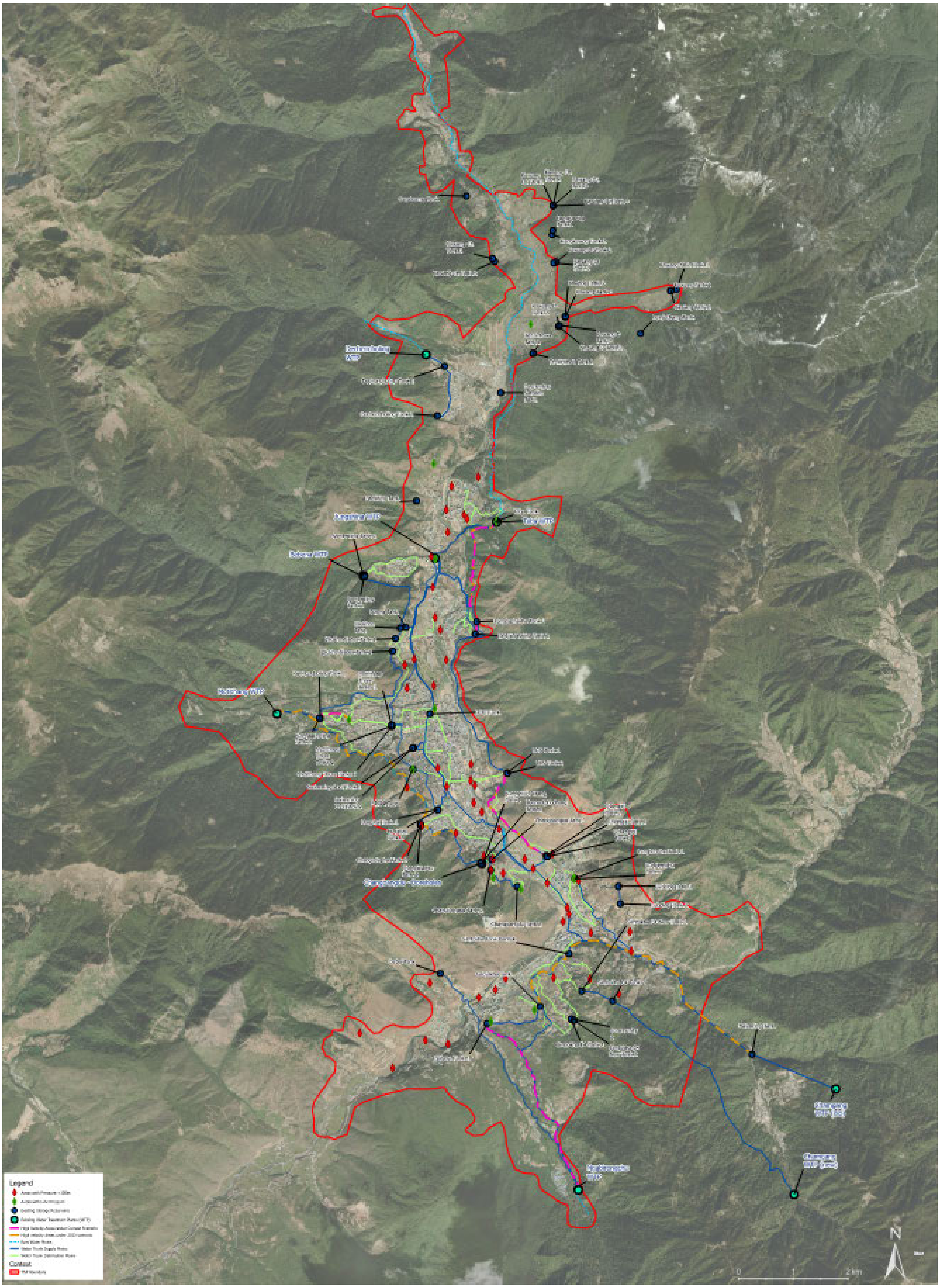


Figure 4-4: Identified Network Pressure Deficiencies, Velocity Deficiencies and Proposed Pumps and Valves

The trunk mains capacity was assessed using average pipeline velocities under the average flow conditions. A range of 0.5m/s to 1m/s was considered as desirable. Velocities below this range has the potential to impact on water quality due to water age while higher velocities have the potential remobilise sediments resulting in discolouration.

Pipelines with velocities greater than 3m/s in the current and 2032 scenario are depicted in Figure 4-4. Pipelines with these high velocities require further investigations through assessing flow meter recordings to confirm the velocity results and potential investment in pipe upsizing if confirmed. Full results for velocities for the current and future scenarios are included in Appendix D.

4.4.2 Upgrades to the Existing Network

Potential network improvements were identified to meet the design requirements, but these will require further detailed investigations before investment decisions should be made. There are potential improvements to reallocation of raw water, pressure management, flow control, network monitoring and firefighting capabilities. These are discussed in the sections below. A summary of the locations of the proposed upgrades on the existing network are shown in Figure 4-5.

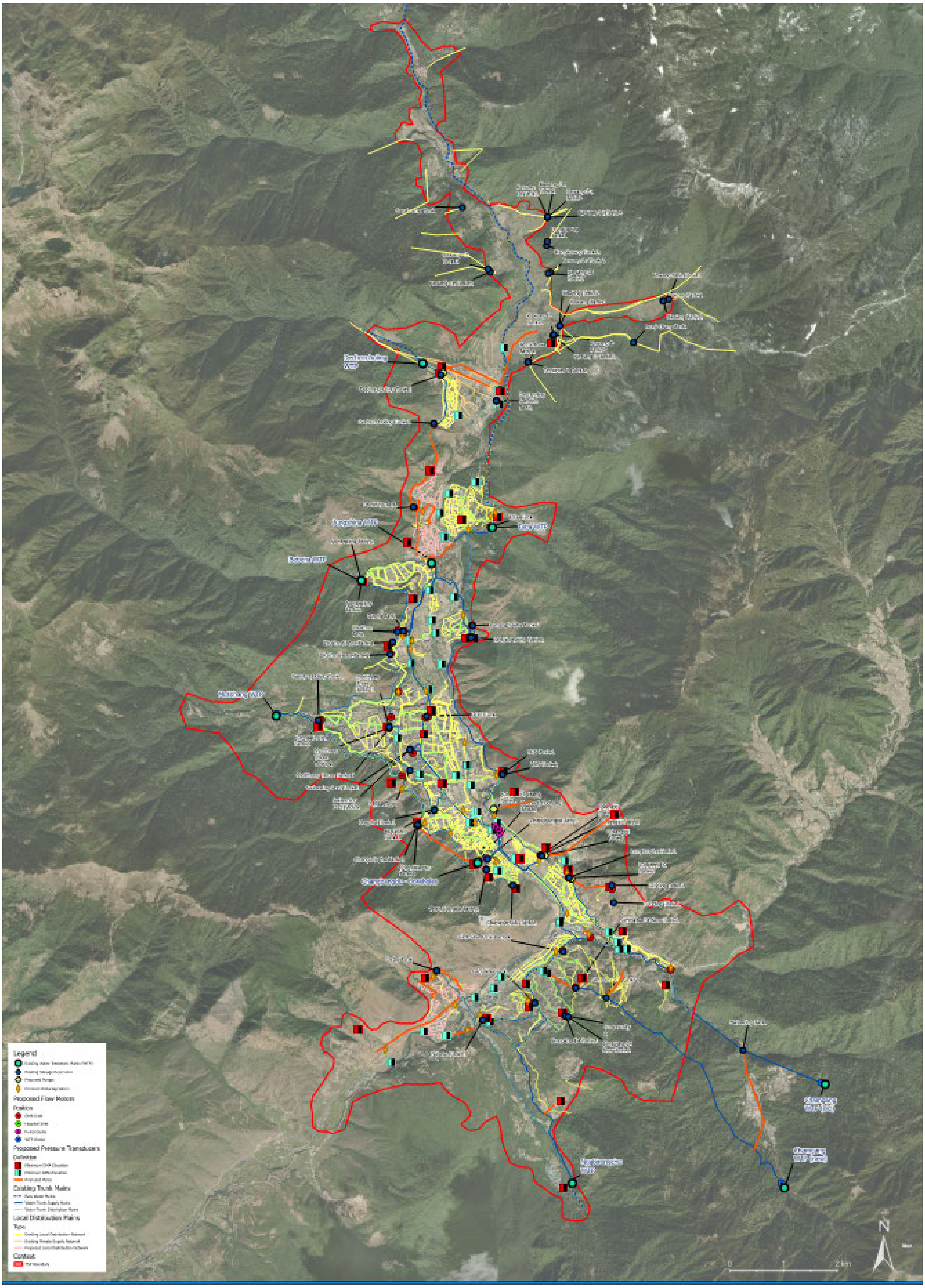


Figure 4-5: Upgrades to the Existing Network

Reallocation of Raw Water Supply to Jungshina WTP

The Jungshina WTP has a water supply deficit relative to the demand and hydraulic capacity of the WTP, which are intensified by competing other users such as agriculture. Raw water supply from the main which supplies Taba WTP could be rerouted to increase the availability of raw water to Jungshina WTP. As indicated by TT, the existing Taba WTP raw water trunk main has capacity for 13MLD, but Taba WTP only treats 10MLD. Therefore, the remaining 3MLD could be supplied to Jungshina WTP through a 150-millimetre (mm) diameter main, which runs from Taba WTP across the Wang Chhu, terminating by Jungshina WTP. Through extending this line approximately 600m to Jungshina WTP and reconfiguring the pipework at Taba WTP to divert 3MLD into this line, the availability of raw water to Jungshina WTP could be significantly increased particularly in the lean season. This opportunity is depicted in Figure 4-6.

Figure 4-6: Opportunity to Reroute Raw Water from Taba Raw Water Trunk Main to Jungshina WTP

Pressure Management

High Pressure

Pressure requirements vary and consideration needs to be given to the type of buildings supplied; for example, an area with tall buildings will require more pressure than areas with single story buildings. High pressure may also be required in a trunk main to meet pressure requirements further downstream; for example, where a trunk main is routed through a valley to a higher elevation downstream. Although the hydraulic model has identified locations of high pressure, it would be prudent to understand the pressure requirements for each DMA and building and where very high pressure is not required, pressure management with PRVs will be recommended. PRVs are designed to maintain a pre-set pressure in the trunk main downstream of the valve. Locations identified in the model with very high pressure (above 100m) are shown in Figure 4-4. The locations for installation of approximately 30 PRVs to mitigate the very high pressure are depicted in Figure 4-5. The PRV locations are subject to further investigations such as pressure testing.

There is not much difference in pressure between the current and future (2032 and 2047) operating scenarios and the PRV locations identified will be applicable to all scenarios.

Low Pressure
Areas with low or negative pressure were identified in the model and are included in Figure 4-4. The low pressure is largely due to high elevation of these areas and are an indication of high risk of loss of supply and in the case of negative pressure or insufficient capacity to supply these areas. To manage pressure, booster pump stations to increase the local pressure to sufficient levels will be required due to insufficient head to deliver water supply to these areas. To increase the head, pumping is required. Locations of proposed booster pump stations are depicted in Figure 4-5. Further investigations such as pressure testing is required to verify whether the areas experience low pressure and confirm booster pump station locations.

Network Monitoring
To ensure an uninterrupted water supply, constant network monitoring for flow, pressure, water quality and storage reservoir water levels are recommended.

Flow Meters

Flow meters should be installed for general flow measurement, leakage detection and customer charging. Limited information was provided on existing flow meters on the network, and it was reported by TT that many of these are defunct or are not collecting data. On this basis, flow meter installations are recommended at the following locations in the network, as depicted in Figure 4-5, for improved efficiency and management:

- At the outlet of WTPs, to measure outflow from the WTP and therefore production capacity.
- At the outlet of pumps, to record pumping rates and control pump operation.
- At the inlet to DMAs, to allow for local management of the supply area including leakage control.
- Customer meters for charging domestic, commercial and industrial supplies (not depicted due to quantity).

Consideration should be given to connecting the flow meters to a suitable telemetry system like Supervisory Control and Data Acquisition (SCADA) to allow for remote monitoring of flows and burst dictation.

Pressure Transducers
Pressure monitoring will be required for each pressure area of the network. This should be provided by use of pressure monitors (transducers) installed directly onto water trunk mains or fire hydrants. The pressure transducers should send a signal to a suitable telemetry system like SCADA. Pressure transducers should be installed at the maximum and minimum elevations within each DMA as depicted in Figure 4-5. There are insufficient fire hydrants in the network (refer to Cater for Firefighting Section for additional details), therefore new fire hydrants may be required to monitor pressure at the identified locations.

Quality Monitoring
Monitoring of chlorine residual is required to identify contamination in the water system downstream of the WTP and ensure that water remains safe for consumption. This can be achieved through regular sampling and testing, or online monitoring at key locations throughout the network. Online monitors linked to an alarm system can provide fast notification of a potential contamination event, minimising the risk to public health. Monitors are generally placed immediately downstream of storage reservoirs where water may have been stored for relatively long periods and residual chlorine is subject to decay.

Storage Reservoir Water Levels
Water levels in storage reservoirs should be recorded through level sensors. This water level data can assist with operation of the water supply network, providing warnings for low reservoir levels and enabling the operator to manage water distribution across the network in an effective and efficient manner.

The data can also be used to track filling and emptying rates of the storage reservoirs and sudden changes to normal operations.

Water Supply Storage

Water supply storage within the network is required to prevent a loss of supply during planned or unplanned interruptions. Typically, disruptions will only last a few hours, but major events such as earthquakes and landslides can impact supply while repairs are undertaken. The existing TT water supply system is providing approximately 10.5ML of storage which represents 8 hours of Thimphu’s daily water demand. International best practice is for water systems in hazard prone areas to provide at least 48 hours of storage, which is approximately 61ML of storage with current demands and 49ML with 2047 demands.

Future demand in 2047 is expected to be 24.4MLD, considering population growth, the expansion of the public network into areas on private or community supplies and the reduction in per capita water usage (refer to Section 4.4.6). A significant increase in storage volume is required to ensure reliability and resilience of the water supply.

Achieving the required storage volume for 48hours of supply should primarily be supplied in new strategic, consolidated storage reservoirs by the WTPs. Upgrades or upsizing of storage reservoirs throughout the network may also be provided. Strategic, centrally located, some consolidated locations with existing storage reservoirs which could be suitable for upgrade or upsizing include Motihang Three Tanks and the Swimming Pool Tanks. To further consolidate and size storage reservoirs, peak demands, fire flows and demand curves should be evaluated against the demand on each storage reservoir under current and future conditions.

To mitigate water quality issues, water circulation and water flow should be included in the design parameters. Disinfectant (chlorine) residual levels must also be maintained throughout the components of the system to ensure the water quality is free of pathogens or other contaminants. The residence time of water within storage reservoirs should be managed to minimise the age of water within the storage reservoirs.

Firefighting Capabilities

Having a sufficient and reliable supply of water for firefighting is crucial in ensuring the safety of people's lives and protecting property from the dangers of fire. Water is curtailed during certain periods of the days to different neighbourhoods to provide a more equitable supply to customers across the city. As a result, the fire department are unable to rely on the availability of water in any location in the event of a fire. Instead, water is tankered from dedicated fire storage reservoirs distributed across the city to the location of the fire.

A firefighting flow analysis was undertaken using the existing scenario hydraulic model. There was minimal information on existing fire hydrants in the Geographic Information System (GIS) files; the fire hydrant data provided includes the locations of 81 hydrants throughout the TSP study extents with no specifications stated. A high-level approach for firefighting flow analysis using the WaterCAD’s software capability was used in the analysis. This approach tests every pressure node in the model for capability to supply a pre-assigned firefighting demand while maintain pre-assigned pressure constraints at the node and elsewhere within the network. Details of how this analysis work are included in the *Water Supply Hydraulic Model Build Report*.

Using the above approach, the model was tested iteratively for reducing firefighting demands of 35L/s, 25L/s and 7L/s with pressure constraints of 10m and 5m at the operating node and elsewhere in the network, respectively. For all scenarios considered the hydraulic model was unable to run successfully indicating a high risk that the existing water supply network does not have sufficient hydraulic capacity to cater for firefighting demand. To mitigate against this risk, the following will be recommended:

- An inventory of all fire hydrants and updating of network records on location, nature and condition of each.
- Review of the fire hydrants coverage against prevailing standards or good practice.
- Design and upgrade of the firefighting system to prevailing or good practice standards. It should be noted here that some local pressure boosting may be required for the low pressure / high elevation areas of the network.

Fire hydrants are required for the Fire Department to abstract water from the network. All properties relying on public watermains for fire protection should be located within a maximum distance of a fire hydrant to ensure the Fire Department can connect a hose to it. This maximum distance can vary by jurisdiction but is typically between 45 and 90m (along the line of the hose). Hydrant spacing for Thimphu should be agreed with the Fire Department and installed as required to provide necessary coverage. Based on current information received, less than 1% of buildings are within 90m radius of an existing fire hydrant and less than 30% are within a 200m radius.

Protection of Water Mains

Trunk watermains convey water from intake structures to WTPs and from WTPs to storage reservoirs and are the key pipelines for providing potable water throughout the TSP study extents. Reliability and resilience of the water supply system is dependent on these strategic pipelines remaining operational at all times.

Many of these trunk mains pass through areas identified as landslide hazard zones and depicted in Figure 4-7 and summarised in Table 12. Trunk mains in landslide hazard zones are at higher risk of damage which could result in significant service interruptions. This risk is exaggerated where pipelines are located above ground where they also are exposed to impact damage. Further analysis is required to understand the extent of the risk, inform measures to reduce the risk of damage, or increase the resilience of the system through diversion or duplication along these routes.

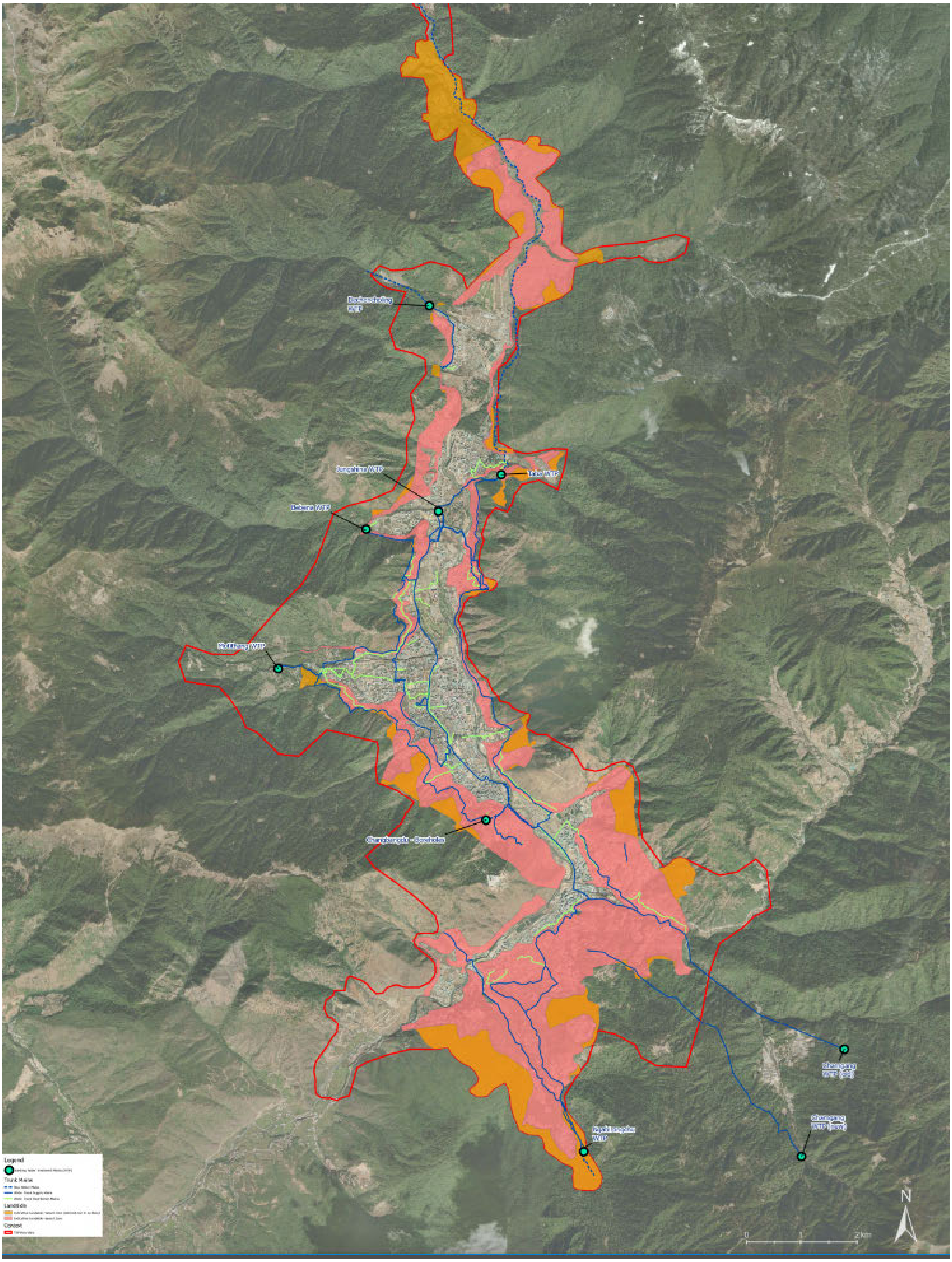


Figure 4-7: Water Mains Relative to Landslide Hazard Zones

Table 12: Length of Raw Water and Supply Main Network in Landslide Hazard Zones

Water Network	Length Outside Landslide Hazard Zone Included in Total Length Effected (km)	Estimated Total Length Effected (km)
Raw Water	3.1	9.6
Supply Main	12.0	57.5

Local distribution watermains are often laid in stormwater drains and culverts. This increases the risk of damage to the watermain from accidental impact by a vehicle, or longer-term deterioration from flowing water as well as risk of contamination. The presence of the watermain also reduces the conveyance capacity if the drain. Watermains located in these drains should be diverted into purpose-built trenches within the road reserve to ensure ease of access for operations and maintenance.

Flow Control

There is limited information on the locations and specifically the types of the valves in the system to consider the adequacy of these to the network operation. Assuming a worst-case scenario that records are not available, it is recommended that site investigations are undertaken to establish locations, nature and conditions of the existing valves and updating the network data to include results of these surveys.

4.4.3 Proposed Future Connections

Thimphu Thromde currently supplies approximately 85% of residents within the study extents. Private or community supplies provide water to the remaining residents. The private or community supplies are typically untreated and have water quality, availability and distribution issues. A key objective of this Masterplan is to provide safe, reliable drinking water to all residents within Thimphu Thromde, therefore strategies to connect to the following private or community supplied DMAs were evaluated and are summarised in Table 13 and presented in Figure 4-5. All DMAs are proposed to be connected by 2032, except for Rama which will be connected as part of the development of the Southern Extension which is considered by 2047 in the modelling. At the four locations where booster pumping was identified as required to enable supply to these proposed development areas, no further work was carried to design the booster pump stations.

Table 13: Proposed Future Connections

DMA	Proposed WTP Supply	Network Modifications	Notes
Changiji 2	Taba	Connection from Changiji Tanks (2327mAOD) to the Changiji 2 DMA (2594mAOD).	Booster pumping required.
Community Supply	Dechencholing	Connection from Dechencholing Tank 1 (2522mAOD) to Community Supply DMA (2568mAOD).	Booster pumping required.
Dangrina Proposed	Dechencholing	Connection from Dechencholing Tank 1 (2522mAOD) to Dangrina Proposed DMA (2515mAOD).	Pressure from existing network may be sufficient. Additional investigations required.
Gangchey Nyezergang	Ngabirongchu	Connection to 250mm diameter (pipe diameter assumed) from Ngabirongchu WTP.	Pressure up to 404m, PRV required.
Lubding	Chamgang Old	Connection from Lungtenphu Tanks (2366mAOD) to Lubding DMA (2647mAOD).	Booster pumping required to supply storage reservoir. Additional investigations to considered alternative location for storage reservoir which may reduce pumping head.
Pamtsho 1	Dechencholing	Client provided proposed connection from the Dechencholing Tank 2 to Pamtsho Tank via a 200mm main.	Supply pressure at highest elevation circa -104m, booster pump station may be required. Additional investigations recommended.

DMA	Proposed WTP Supply	Network Modifications	Notes
Pamtsho 2	Dechencholing	Supply from Pamtsho Tank.	Supply pressure circa 106m. PRV will be required.
Rama (2047)	Ngabirongchu	Connection to 150mm diameter from Ngabirongchu WTP to Debsi Tank.	Supply pressure in the range 278m to 415m. PRV required.
Serbithang	Ngabirongchu	Connection to 100/150mm diameter (pipe diameter assumed) from Ngabirongchu WTP.	Supply pressure up to 280m, PRV required.
Workshop	Chamgang Old	Connection to 250mm diameter from Olakha 2 (tee from Break Pressure Tank downstream of Chamgang Old WTP) to Simtokha Tank Danak.	Supply pressure up to 187m, PRV required.
YHS 2	Taba	Connection to 100mm diameter from Taba WTP to Bhutan Hospital or 150mm diameter to Changiji Tanks.	Supply to high elevation properties circa -115m. Booster pumping required. Pressure to low elevation properties circa 125m. PRV required.

4.4.4 Future Scenarios

Future scenarios were evaluated for the mid-term (2032) and long-term (2047) timeframes in alignment with the TSP.

2032 Scenario

The baseline model for the existing network was modified to include projected future connections (Table 13) as well as changes in water demand. The network was also modified to allow for the rezoning of WTP supplies as informed by the WTP reallocation assessment in Section 4.4.1.1. In summary, the following changes were made to the baseline model:

- Addition of proposed future connections to DMAs currently supplied by community or private networks.
- Addition of 200mm diameter trunk main from Dangrina Tank 2 to Pamtsho Tank as advised by client to be a planned future installation.
- Reallocated supply to the Babesa Left DMA from Chamgang Old WTP to Chamgang New WTP, as detailed in the Availability Assessment in Section 4.4.1.1.
- Reallocated supply to Bangdu Residents and Bangdu Area (Left) from Chamgang Old WTP to Motihang WTP, as detailed in the Availability Assessment in Section 4.4.1.1.
- Connection between Chamgang New WTP and Chamgang Old WTP upstream of the Break Pressure Tank to allow for the reallocation of demand from Chamgang Old WTP to Chamgang New WTP. The route was assessed for hydraulic feasibility and further assessment is required to confirm the route from a topography and construction perspective.
- Updating demands to reflect change in water use and population growth.

The updated model was used to assess future performance for the 2032 operating scenario and results of the hydraulic assessments have not shown any significant differences in operating performances to those of the existing system. Results for pipeline velocities for the current and 2032 scenario are shown in Figure 4-4.

This could be an indication of the network robustness hydraulically of the existing trunk main system to accommodate the projected future demands without need for any major upgrades. Results for average pressure and velocity in the current and future scenarios are included in Appendix D.

2047 Scenario

Demands in the 2032 baseline model were updated to projected 2047 demands to create a model for this scenario. Results from running this model have not indicated any adverse impacts from changes in demand.

2047 Scenario - Chamgang Old WTP Decommissioned

The 2047 scenario was utilised as a baseline for this evaluation.

The Chamgang Old WTP currently has water supply availability issues which pose a risk to the water supply and are likely to worsen when considering the impacts of climate change on these smaller water sources (refer to Section 3 Climate Change Resilience Assessment for further details). Therefore, a future scenario where the Chamgang Old WTP is out of commission was assessed to evaluate the water supply availability and considerations for necessary infrastructure reconfiguration or routing to maintain the water supply under this condition.

Two aspects were considered in this assessment, resource availability and network hydraulic capacity. Regarding resource availability, the demand on Chamgang Old WTP is 2.6MLD, therefore the available excess supply from other WTP in the network was evaluated to cover this demand. An initial assessment to cover the demand based on water availability indicates that the demand could be reallocated to Chamgang New WTP and Taba WTP, which have excess capacity and water availability, as summarised in Table 14.

Table 14: Water Availability Assessment without Chamgang Old WTP

WTP	Lean Season Availability (MLD)	Demand on WTP (MLD)	Reallocated Demand on WTP (MLD)	Summary of Reallocations
Chamgang Old	None in this scenario	2.6	0	All 2.6MLD from Chamgang Old WTP reallocated to Taba WTP and Chamgang New WTP.
Ngabirongchu	1.9	1.9	1.9	No demand reallocations. However, the Rama DMA demand is 0.6MLD, therefore if this expansion does not occur 0.6MLD would be available from Ngabirongchu WTP.
Taba	10.0	7.5	9.5	There is an excess of available supply. Therefore reallocated 2.0MLD of demand currently supplied by Chamgang Old WTP to Taba WTP.
Chamgang New	3.5	2.9	3.5	There is an excess of available supply. Therefore reallocated 0.6MLD of demand currently supplied by Chamgang Old WTP to Chamgang New WTP.

A high-level hydraulic assessment indicated a potential solution for rezoning which involves reinforcement of sections of the trunk mains from Taba WTP to the YHS Tanks which are currently indicated as operating beyond their hydraulic capacity. Local connections to complete the rezoning will also be required. The proposed sections of trunk mains reinforcement are shown in Figure 4-8. These proposed mains reinforcements were not included in the model. Further detailed investigations will be required before this solution can be confirmed, which may include confirming the results of the model through pressure and flow monitoring and calibration, route assessment for the main and hydraulic assessments of the proposed route.

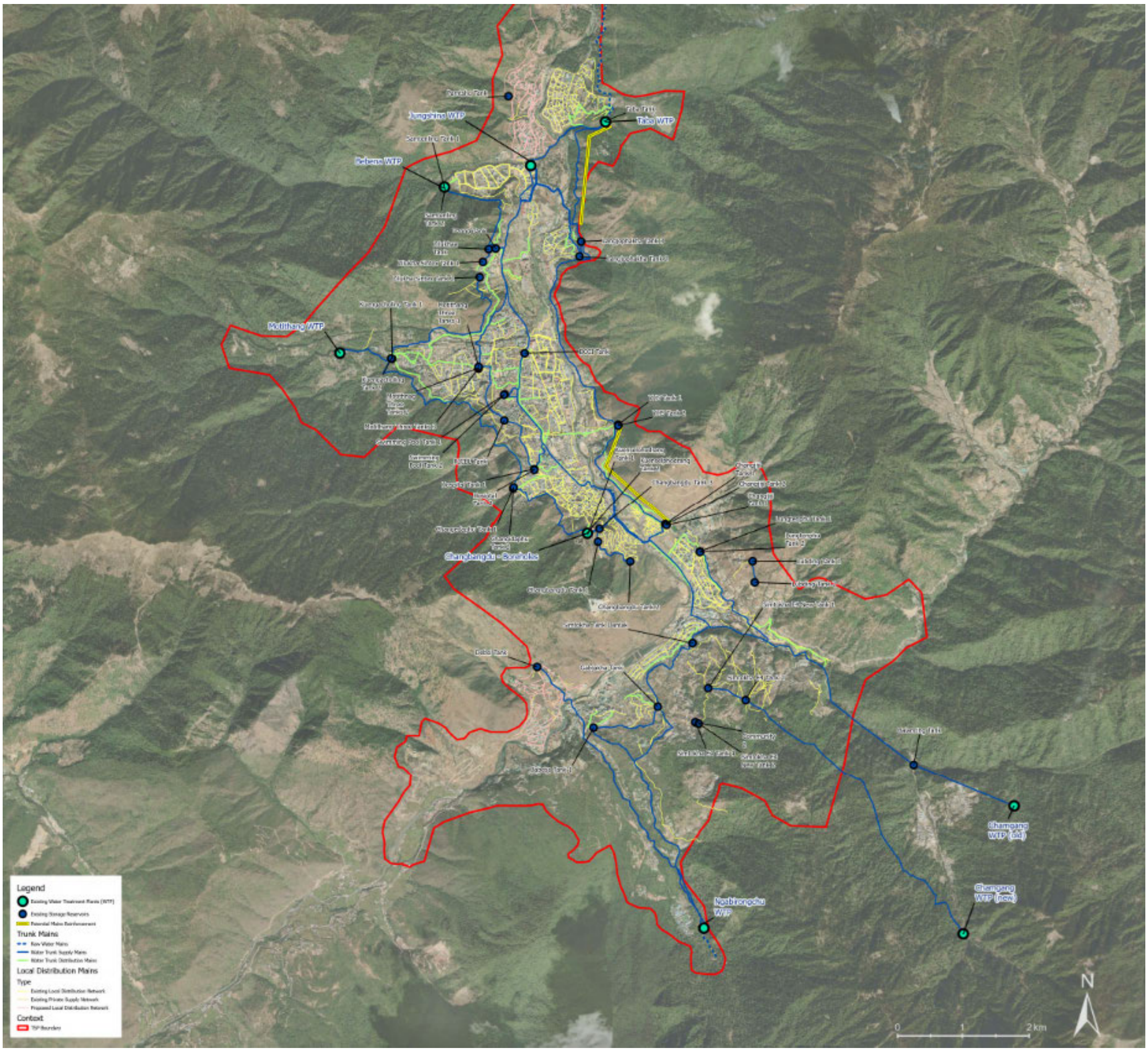


Figure 4-8: Potential Mains Reinforcement for Rezoning Chamgang Old WTP Demand to Taba WTP

4.4.5 Long-term Water Network Strategy

A high-level feasibility study for the route of a shared-utility corridor primarily between telecoms, electric and water utilities was performed for the TSP. The purpose of the utility corridor is to reduce issues with land procurement and aid in maintenance. The existing utility infrastructure was evaluated to prioritise a location and select a suitable route for all utilities. Figure 4-9 depicts two alternatives for the utility corridor.

The long-term water strategy looks beyond the TSP timeframe of 2047, where the aspiration is for water to be supplied from two WTP only, the new Begana WTP (20MLD), as identified by MoIT (*Feasibility Study of Begana Integrated Multipurpose Small Hydropower Project)* and Taba WTP (10MLD). The future operating scenario was assessed to evaluate whether a Begana-Rama trunk main within the utility corridor could supply all DMAs if all other WTPs are abandoned.

A high-level hydraulic assessment was undertaken of the strategic trunk main system utilising the utility corridor alignment. This assumed an upstream driving head equivalent to that existing in the Taba Tank (2532mAOD) with the flow rate progressively decreasing north to south to account for supply to upstream DMAs. Figure 4-9 depicts the flow breakdown by DMAs included in the assessment which is represented by the different colours.

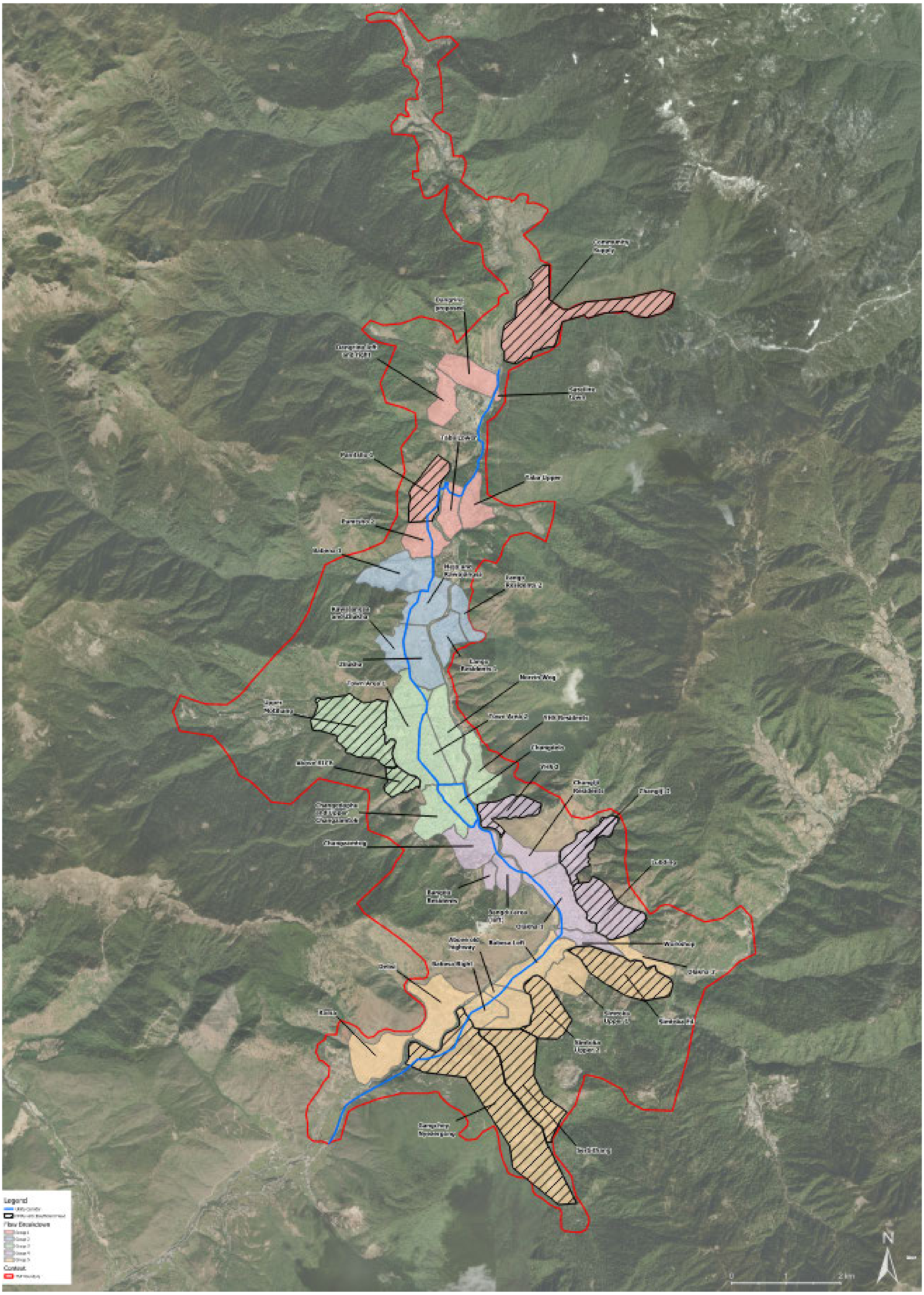


Figure 4-9: Utility Corridor with Flow Breakdown and DMAs with Insufficient Head from Begana-Rama Trunk Main

Based on this approach, it is not feasible to transfer treated water from the Begana WTP and Taba WTP to all DMAs using only a gravity-fed system installed within the utility corridor.

The DMAs depicted as hatched in Figure 4-9 and described in Table 15 have insufficient head to supply the highest elevation properties within these DMAs. The DMAs identified in Table 15 require further evaluation to determine the best suitable supply in the long-term water network strategy scenario. Potential supply opportunities for the DMAs with insufficient head from the Begana-Rama trunk main may include booster pumps to raise the available head (Option A) or consideration of maintaining the existing WTP which supplies the DMAs (Option B). The high-level hydraulic calculations and summary are included in Appendix E.

Table 15: Alternative Supplies to DMAs with Insufficient Head from the Begana-Rama Trunk Main

DMA	Alternative Supply to Begana-Rama Trunk Main		2047 Demand (MLD)
	Option A: Pumping Head Requirement (m)	Option B: Existing WTP Supply to DMA	
Above RICB	35	Motihang WTP	0.30
Changiji 2	90	Assume could maintain supply directly from Taba WTP through Changiji Tank 1, Changiji Tank 2, Changiji Thank 3 instead of from Begana-Rama trunk main	0.45
Community Supply	40	Dechencholing WTP (through Dechencholing Tank 1)	0.31
Gangchey Nyezergang	157	Ngabirongchu WTP	0.35
Lubding	126	Chamgang Old WTP (through Lungtenphu Tanks)	0.37
Pamtsho 1	34	Assume could maintain supply directly from Taba WTP or Dechencholing WTP through Pamtsho Tank instead of from Begana-Rama trunk main	0.57
Serbithang	146	Ngabirongchu WTP	0.10
Simtokha Upper 2	52	Chamgang New WTP (Simtokha E4 Tank 3)	0.20
Simtokha E4	8	Chamgang New WTP	0.24
Upper Motihang	82	Motihang WTP (through Kuengacholing Tank 1 & 2)	1.35
YHS 2	17	Assume could maintain supply directly from Taba WTP through Pamtsho Tank instead of from Begana-Rama trunk main	0.18

4.4.6 Water Management

The water supply strategy aims to create opportunity through water systems which support sustainable growth within the city. This includes cultivating a balance between managing non-revenue water losses, such as leakage, and water demand to ensure adequate water for living while protecting natural water resources. Water management strategies include reducing water usage through leakage and other non-revenue water reductions and reductions in per capita consumption were evaluated.

Reduction in Non-revenue Water

Water Loss Audits recently undertaken in Thimphu show losses in the network of over 50% which arise from leakage, illegal connections and metering inaccuracies.

This is significantly higher than internationally accepted rates (typically <20%). The current losses are the primary contributor to water shortages for customers as the existing water sources and WTPs have capacity to deliver current water demands.

Reducing water losses has considerable benefits for the operation of the water system, including cost savings, improved system integrity and preventing third party property damage. Reducing water losses result in the need for less water to be abstracted from rivers and streams which reduces the environmental impact of water abstraction, particularly during low flow periods. Operational costs at WTPs will reduce due to reduced flows and operating times. Further operational cost savings will be achieved where water is pumped through the network. Capital expenditure savings will be achieved as upgrades to water supply infrastructure (WTPs, reservoirs, pipelines) will be less substantial or not required at all to meet current demand.

It is generally accepted that it is not economically viable to completely eliminate water losses from the system, although improvements in metering technologies are continuing to help lower water loss targets. Water utilities being able to demonstrate a reduction in water losses is also essential for successfully promoting customers to reduce their potable demand.

World Bank Group and Water Management International have prepared the *Bhutan Water Status Assessment Report (2023)* and *Draft Roadmap to NRW Management (25 January 2023).* The roadmap provides a set of strategies and actions targeting NRW reduction. These include capacity building, institutional strengthening, reducing commercial losses and reducing real losses. Many of the recommendations of this roadmap align with those in this Masterplan. In particular the requirements for new SCADA systems to monitor flow and pressure throughout the network is essential to calibrate the hydraulic model and improve the reliability of the results, which can help identify areas with high leakage or bursts, to confirm areas which require investment prior to committing major capital expenditure. Reducing losses is also fundamental to the proposed design criteria associated with water demand calculations throughout the water supply system.

Close coordination between the outcomes from this Masterplan and the Roadmap implementation is required to maintain consistency and efficiency of future work.

Water Demand Management

Water Demand Management (WDM) is a strategy for managing water resources, which focuses on reducing water demand by encouraging efficient usage. This is achieved by offering targeted incentives that promote fair and sustainable water usage.

Current water usage (excluding losses) is 135lpcd, as provided by TT at the 17 October 2022 Standard Workshops and detailed in the *Initial Options Analysis – Constraints and Opportunities* Report. As availability and reliability of potable water is improved, there is a high potential for increases in water usage. Although water consumption in many developed cities is >150lpcd, reducing this value is a key strategy for water utilities worldwide. The World Business Council for Sustainable Development, World Economic Forum and 2030 Water Resources Group have launched the 50L Home Coalition to reform domestic urban water management with an aim of reducing consumption to 50lpcd.

WDM is a multi-pronged approach considering social, economic, technical and environmental factors. Measures which will contribute to WDM include:

- Water saving devices (low-flush toilets, low flow shower heads and low-flow taps)
- Water efficient landscape design
- Efficient irrigation practices, including rainwater harvesting
- Water reuse
- Pressure management
- Smart metering
- Tariff systems

In addition, a strong consistent, education message is required to underpin all other WDM activities. New building standards, education programmes and technical infrastructure solutions need to be developed and implemented to reduce water consumption throughout Thimphu.

4.4.7 Recommendations on Hydraulic Model Further Developments

This study has successfully created a “digital twin” hydraulic model for the trunk main system including all DMA supplies and critical pressure points within the DMAs. Although the model can be used straight away as a high-level decision-making tool and for assessing operational performance, additional work will be required to further develop the model and increase the level of confidence in the outputs from the tool. The following next steps are recommended:

- The model was constructed based on Arup's best interpretation of the water supply network arrangement and connectivity from the GIS files and TT schematics provided. The client should review the model and combined schematic for network arrangement and connectivity and identify any anomalies to be addressed in the next revision of the model.
- The specialist modelling software, Bentley's WaterCAD, was utilised to construct the water supply hydraulic model. Export files will be provided to the client in the EPANET software format, which is a free software to download. It is recommended that the client appoint a dedicated holder of the master files to avoid unauthorised changes to the files which may be difficult to be accounted. Any changes to the master copy are to be logged and an appropriate version control applied. If training and upskilling in the use of the software is required, Arup would be able to assist MoIT with this process.
- A number of assumptions were made to fill in data gaps. These are recorded in the Assumptions Register (Appendix to the *Water Supply Hydraulic Model Build Report)*, in the hydraulic model metadata and in the GIS shapefile metadata. MoIT should review these assumptions and where information is available, identify these to be addressed in the next revision of the model.
- Hydraulic model calibration is a critical step in any hydraulic model process and it involves adjusting the hydraulic model to match field data. This process was not completed due to the absence of adequate field data. Future flow and pressure monitoring will be required to inform the model calibration. Flow monitoring should be prioritised at outlets of all WTPs and storage reservoirs and at the inlets to DMAs. Pressure monitoring should be prioritised at the pressure critical points identified in Section 4.4.2 and GIS files.
- Flow and pressure monitoring could be collected via temporary installations which are deployed for a limited time to capture model calibration data, via permanent installations connected to a telemetry system such as SCADA or a combination of the two.
- Further development of the hydraulic model from Steady State to Extended Period Simulation is recommended. To achieve this, more detailed demand studies will be required to develop demand profiles to understand any daily and seasonal variations in water use.

4.5 Water Treatment Plants

There are nine existing or proposed WTPs operated by Thimphu Thromde (refer to Section 4.4). These supply approximately 85% of the population within the TSP study extents, the remainder supplied by private or community supplies. The WTPs were assessed in the *Water Supply, Wastewater and Stormwater Assessment* regarding their current conditions, if the systems are hydraulically stressed and if the systems are able to cater current and future (2032 and 2047) scenarios of water demand. Based on the Assessment, operational best practices, SCADA upgrades and WTP components upgrades were identified. Justifications are provided in deciding to proceed or not with these upgrades as well as the required monitoring to ensure treatment performance is achieved and to highlight the risks associated.

4.5.1 Upgrades to Existing WTPs

The hydraulic assessment (from the *Water Supply, Wastewater and Stormwater Assessment)* indicated any required upgrades for each WTP. These upgrades were further evaluated holistically considering the lean season availability of the water source for each WTP (refer to Section 4.4.1.1), the proposed highest demand scenario as well as the current operational performance of the WTP.

In addition, the performance review workshop held on 5 May 2023 informed the appraisal. Therefore, some upgrades, as discussed in the following subsections, were not pursued when the hydraulic capacity was limited.

4.5.1.1 SCADA Upgrades

Based on the assessment, the following issues are generally common to most WTPs:

- Flow meters are either defunct or not provided.

- Online water quality meters are not installed.
- There is no SCADA monitoring for parameters nor SCADA control of pumps.

Developing a comprehensive SCADA strategy and plan, along with appropriate training and recruitment for SCADA operation, and establishing SCADA monitoring stations can greatly enhance the efficiency, safety and reliability of WTP operations. SCADA plays a vital role in the safe operation of WTPs and serves as a critical component in meeting water objectives. By implementing a SCADA system, WTPs gain real-time monitoring and control capabilities over various processes and equipment within the WTP. This enables operators to remotely monitor and control the operation of pumps, valves, chemical dosing systems and other critical components, ensuring optimal performance and responsiveness to changing conditions.

SCADA systems can enhance operational efficiency by automating routine tasks, optimizing resource allocation, and streamlining workflow processes. This leads to cost savings, improved energy efficiency and optimised chemical usage, ultimately contributing to sustainable water management practices.

Therefore, the following upgrades are recommended for all the WTPs as applicable. Figure 4-10 shows a general concept for SCADA upgrades. Not all controls are applicable to all WTPs, for example, some WTPs do not have raw water storage pumps.

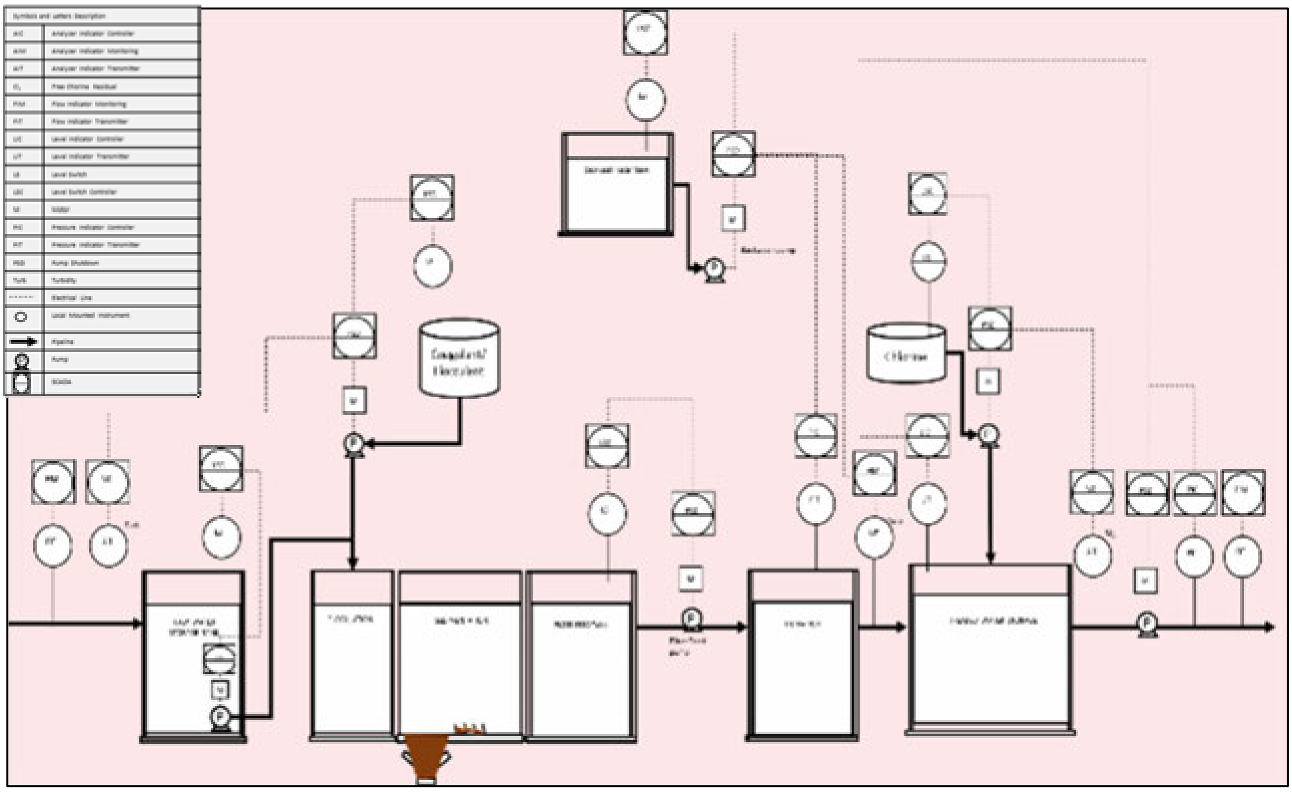


Figure 4-10: General Concept for SCADA Upgrades

All online meters and operation of pumps are recommended to be included in the SCADA system to allow operators to monitor each WTP and control pumps, as well as to monitor flows entering and leaving the WTP which can assist in calculating losses. These upgrades would require assessment of the existing electrical system load capacity of the WTPs to confirm adequacy. The following SCADA upgrades are suggested:

- Install online meters such as inlet and outlet flow meters, inlet and outlet turbidity meters, free chlorine residual meters and filter pressure meters.
- Install other online water quality meters and corresponding SCADA monitoring as needed based on the variability of values for the parameters of concern identified from the raw water quality monitoring as mentioned in Section 4.5.3.

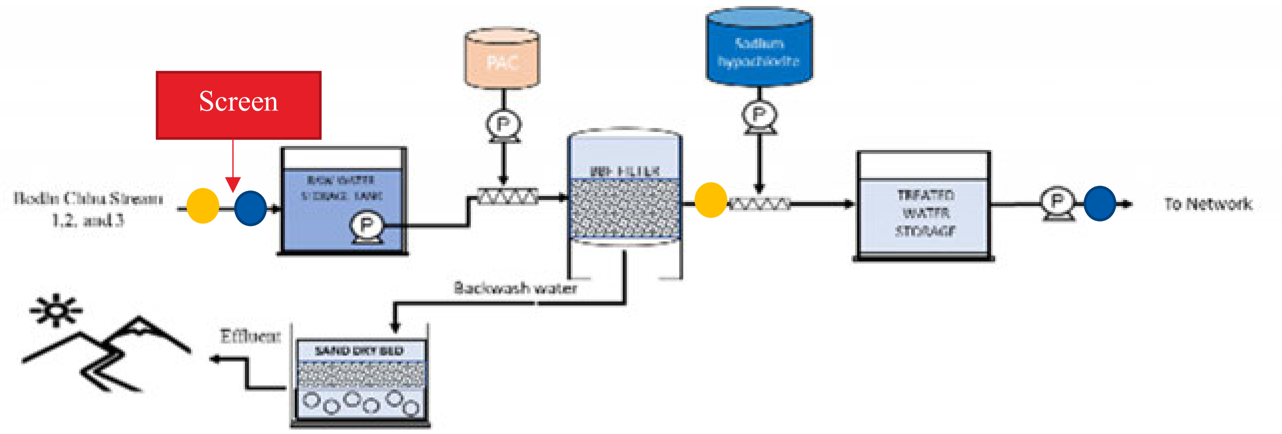
- Provide automatic control programs of chemical dosing pumps in proportion to turbidity and free chlorine residual. This automatic control may require a change of dosing pumps from fixed speed to variable frequency drive pumps and installation of tank level switches.
- Provide automatic control programs for raw water pumps, distribution pumps, backwash water pumps, dosing pumps and filter feed pumps based on storage tank levels. This may also require installation of storage tank level switches or transmitters.
- Provide automatic control programs for distribution pumps from Jungshina WTP to run based on network pressure.
- Provide automatic control programs for backwashing operation regimes based on the filter pressure, turbidity and backwashing duration and frequency.
- Provide all run and stop status of pumps in SCADA.

4.5.1.2 Chamgang Old WTP

A summary of major and minor component recommendations for Chamgang Old WTP are presented in Table 16. Figure 4-11 depicts the recommendations and quality monitoring locations and parameters.

Table 16: Chamgang Old WTP Upgrades and Monitoring

Upgrades/Monitoring	WTP Components	Basis
Major		
None		
Minor		
Monitor turbidity to check BioBall Filter (BBF) performance especially at higher flows.		Highest demand is 2.6MLD. Four BBF units (no standby) can treat 3MLD.
Install screen on the intake structure.		Prevent frequent blockages that affect the production capacity.



Legend:	
●	Turbidity Meter
●	Flow Meter

Figure 4-11: Chamgang Old WTPs Recommendations

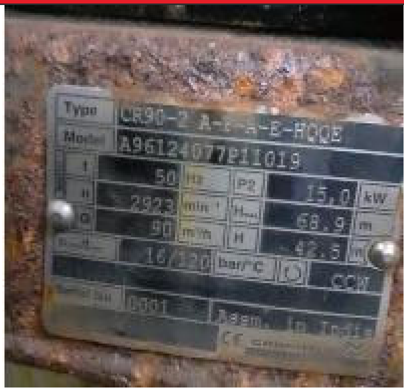
Based on a water demand of 2.6MLD and performance review with TT, no upgrades to the BBFs are proposed. The hydraulic assessment indicated that the combined capacity of the four filters can meet the proposed demand 2.6MLD, but there would be no standby BBF. TT also confirmed the filters function well up to 6.5MLD. Based on the data provided, the WTP is not experiencing much high turbidity, but the data is also limited to confirm the variability in turbidity and performance especially during higher flows and turbidity. Therefore, close monitoring should be undertaken to ensure the filters continue to meet treatment requirements, particularly during periods of greater flow and turbidity through the WTP.

4.5.1.3 Jungshina WTP

A summary of major and minor component recommendations for Jungshina WTP are presented in Table 17.

Table 17: Jungshina WTP Upgrades and Monitoring

Upgrades/Monitoring	WTP Components	Basis
Major		
None		
Minor		
Check condition of pumps. Repair any leakages in the WTP.	 High Pressure Pumps	Design life was reached.

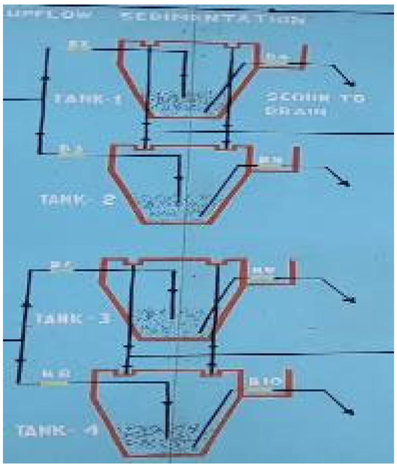
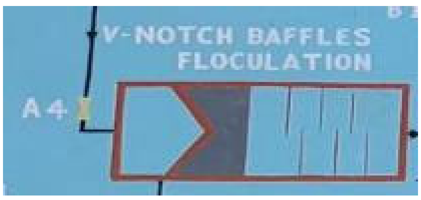
Upgrades/Monitoring	WTP Components	Basis
	 Medium Pressure Pumps Booster Pumps (no picture available)	

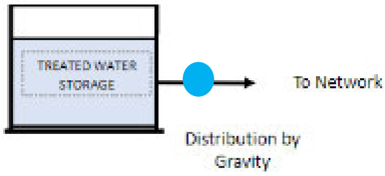
Based on a water demand of 2.6MLD and performance review with TT, no upgrades to any of the WTP components are proposed. The hydraulic assessment indicated that the capacity of the WTP is sufficient to cater this demand. Water supply intake upgrades for the Jungshina WTP source are not required because the additional alternate water source is from the Taba water supply (refer to Section 4.4.1.1 for details of Reallocation of Raw Water Supply to Jungshina WTP). TT also confirmed that there are no operational issues encountered with the WTP.

4.5.1.4 Motihang WTP

A summary of major and minor component recommendations for Motihang WTP are presented in Table 18.

Table 18: Motihang WTP Upgrades and Monitoring

Upgrades/Monitoring	WTP Components	Basis
Major		
Retrofit sedimentation tank with lamella.		To meet current flows of 10MLD at higher turbidity and meet turbidity standards.
Minor		
Check flocculation tanks size if retention time is met at 40 minutes (min) for 10MLD current flow. If this retention time is not met, reduce production flow during high turbidity.		To meet current flows of 10MLD at higher turbidity and meet turbidity standards.

Upgrades/Monitoring	WTP Components	Basis
Monitor free chlorine residual at treated water storage tank outlet.		To ensure water quality meets standards.
Inspect structures and renew as needed.		WTP has already reached its design life and has been running beyond the assessed capacity.

The hydraulic assessment indicated that the treated water storage tank is undersized based on chlorine contact time (12min vs the minimum 30min), however the treated water quality data provided meets the free chlorine residual standards. Therefore, only close monitoring of free chlorine residual levels is required at this stage to confirm that the WTP is providing suitable free chlorine residual levels.

In addition, the WTP is currently treating up to 10MLD and the WTP is not able to meet water quality standards and this high production rate. If the WTP continues to operate above the assessed level of 7.5MLD, then the sedimentation tanks are required to be retrofitted with lamella. In addition, the flocculation tank sizes need to be checked for whether the required retention time of 40min is met.

4.5.1.5 Dechencholing WTP

A summary of major and minor component recommendations for Dechencholing WTP are presented in Table 19.

Table 19: Dechencholing WTP Upgrades and Monitoring

Upgrades/Monitoring	Basis
For Existing WTP	
Investigate the root cause of frequent blockage or malfunctioning of flow meters	To better inform the future upgrades or necessary modifications. Although based on the flow monitoring records, one probable reason for the meter malfunction may be due to freezing during winter.
For New WTP (1.4MLD)	
Review the design of all WTP components to meet 1.4MLD and provide two trains of treatment	Existing WTP components are slightly undersized and no level of redundancy.

Based on a water demand of 2.6MLD, the proposed WTP expansion of 1.4MLD (which is under tender) combined with the current WTP of 1.4MLD will be able to meet this demand. Currently, the existing WTP is typically running at 2.5MLD and the WTP does not meet water quality standards. The hydraulic assessment indicated that the WTP components were only slightly undersized to accommodate 1.4MLD. Therefore, capacity upgrades should be incorporated into the proposed WTP expansion rather than upgrading the existing WTP.

4.5.1.6 Ngabirongchu WTP

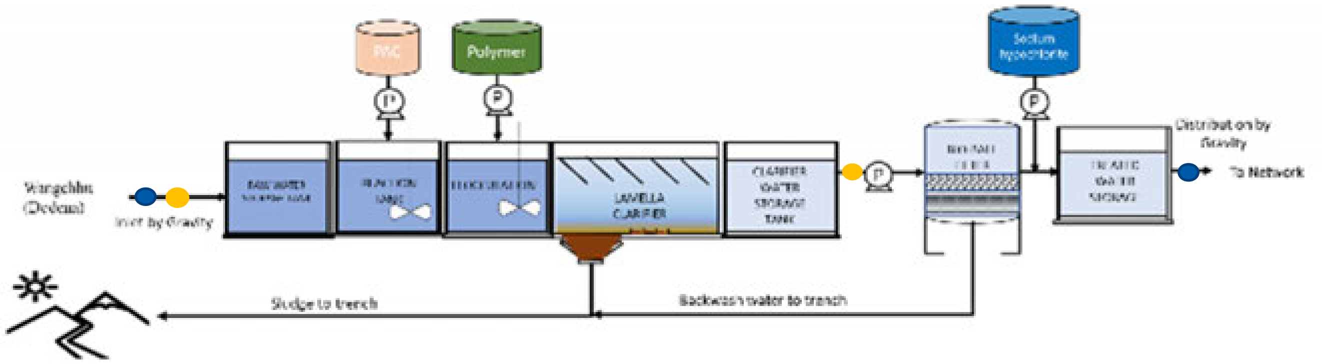
Based on a water demand of 1.9MLD, the hydraulic assessment indicated that the biofilters are slightly undersized compared to this future demand. The WTP is new and there is no water quality data available to check the WTP performance. Therefore, no upgrades are proposed at this stage. Water quality monitoring should be monitored continuously to better evaluate the performance of the WTP.

4.5.1.7 Taba WTP

A summary of major and minor component recommendations for Taba WTP are presented in Table 20. Figure 4-12 depicts the recommendations and quality monitoring locations and parameters.

Table 20: Taba WTP Upgrades and Monitoring

Upgrades/Monitoring	WTP Components	Basis
Major		
Upgrade BBFs to 7.5MLD.		To meet future demand of 7.5MLD and to meet water quality standards.
Minor		
Continue monitoring the turbidity at raw water and the quality of water after the lamella clarifier.	N/A	To ensure the flocculation tank and lamella clarifier continue to meet the required treatment performance.
Reduce production flow at high turbidity.	N/A	To meet turbidity standards.
Investigate the root cause of frequent disconnection or damage at intake structures.	N/A	To inform the necessary modifications or upgrades in the future.



Legend:

Turbidity Meter

Flow Meter

Figure 4-12: Taba WTP Monitoring

Based on a water demand of 7.5MLD, the hydraulic assessment indicated that the BBFs are undersized and will not be able to meet this demand. In addition, the water quality does not meet the standards when raw water enters the WTP at high turbidity. Therefore, the BBFs are recommended to be upgraded to a hydraulic capacity of 7.5MLD. The flocculation tanks and lamella clarifiers are sized at 8MLD, therefore no upgrades for these components are proposed.

4.5.1.8 Babena WTP

A summary of major and minor component recommendations for Babena WTP are presented in Table 21.

Table 21: Babena WTP Upgrades and Monitoring

Upgrades and Monitoring	Basis
Major	
None	

Upgrades and Monitoring	Basis
Minor	
Check for flocculation tank, coagulant/flocculant dosing tanks and pumps and chlorination. Install the systems as necessary.	Necessary WTP components to meet the required treatment standards.
Confirm filter size.	Significantly oversized.
Confirm sedimentation tank size.	Slightly undersized.

The future demand is 1MLD and the WTP is not yet operational. TT provided drawings for the sedimentation tank and rapid sand filter. It is not clear whether the flocculation tank and corresponding coagulant/flocculant dosing tanks and pumps and chlorination are installed. Therefore, prior to operation of this WTP, it is recommended to confirm the existence of these components to ensure water quality standards can be met.

4.5.1.9 Changbangdu (Boreholes)

The future demand is 0.7MLD. Treatment at the Boreholes WTP is only chlorination, and no water quality data was provided. Therefore, water quality testing should be undertaken to verify water quality and inform any additional treatment requirements.

4.5.1.10 Chamgang New WTP

The future demand is 2.9MLD. Chamgang New WTP is not yet operational, and no information was provided to assess the hydraulic capacity limitations. Therefore, no upgrades are identified at this stage. Water quality testing should be undertaken to verify water quality and inform any additional treatment requirements.

4.5.2 New WTPs

4.5.2.1 Begana

The MOIT provided the *Feasibility Study of Begana Integrated Multipurpose Small Hydropower Project* on 29 March 2023. The feasibility study evaluated a 20MLD Begana WTP downstream of a hydropower facility to augment the water supply to TT. The Begana site is proposed as a water source because of its reliability and resilience. Section 4.4.5 discusses the Begana-Rama utility corridor and trunk main which was assessed as the conveyance route for the water supply from the Begana site.

4.5.2.2 Taba

TT has also indicated their plans to build another 5MLD WTP at Taba, however, as discussed in Section 4.4, this is not necessary based on the demand and is therefore not considered in the Masterplan.

4.5.2.3 Dechencholing

The proposed 1.4MLD Dechencholing WTP is required and recommended to meet future demands.

4.5.3 Operation and Maintenance

The following operational best practices are recommended to all the WTPs as a minimum to ensure continuity of services and compliance with standards:

Testing

- Limited water quality data is provided for all WTPs. Therefore, it is recommended to perform raw water quality tests for each of water sources for all parameters listed in Tables A, B and C of the 2014 EU DWR in accordance with the frequency stipulated in Part 2 of the same standard. This data can be utilised to determine other parameters of concern and ensure that existing facilities are still relevant. This data can also support in determining whether other treatment is required. This data will serve as baseline information for each raw water source quality.

- Develop a sampling plan and testing procedure for internal and third-party laboratory testing and analysis for all parameters required in Table 5 and 6 of 2016 Bhutan Drinking Water Quality Standards as a minimum. This plan shall be updated later based on the results of the raw water quality monitoring mentioned above.
- Conduct jar testing to determine the optimum type and dose of coagulant, flocculant, pH, turbidity, solids removal, sludge volume produced and others. Based on this jar testing, establish a dosing matrix for the coagulant and flocculant concentration versus raw water turbidity. This will form as the operator's basis on the amount of these chemicals to dose in proportion to the raw water turbidity. In the future, when the automatic dosing of chemicals is to be implemented, this dosing matrix can inform the program logic control required. This operational practice will ensure the right condition is provided with the current water quality and ensures turbidity standards will be met.

Operations

- Establish a Water Safety Plan (WSP) based on World Health Organization standards or based on nationally approved WSP guidance. WSP is a comprehensive risk assessment and risk management approach that encompasses all steps in drinking water supply chain, i.e., from catchment to consumer, ensuring safe drinking water supply at consumer taps. The WSP should address normal operating conditions as well as incident or emergency situations. It must also include provisions for review and revision so that the plan remains current and accurate.
- Develop Operation and Maintenance Manuals for pumps, instruments and other equipment to ensure proper and safe operation and continuity of services. The manual should also cover inspection and maintenance schedules and programs for equipment considering the design life of each equipment. The operation should also include any remedial actions required in case of any exceedances on water quality standards.
- Regularly inspect all filter media for levels or volume adequacy. Filter media can get carried over during air scouring and backwashing and its amount are reduced over time. Filter media needs to be topped-up annually.
- Either provide an individual sludge treatment facility for all WTPs (except for Chamgang Old WTP and Jungshina WTP have sludge drying beds and sludge lagoons, respectively) or provide a centralised sludge treatment facility or sludge drying bed for WTPs serving north, south and central Thimphu. All other WTPs, besides Chamgang Old WTP and Jungshina WTP, dispose of sludge directly to streams or rivers. If a centralised sludge treatment facility is provided, it should treat all sludge from sedimentation tanks, backwash water from filters and any water used to clean tanks. If individual sludge treatment facilities are to be provided, supernatant can be recycled back to the inlet of the WTP to increase recovery and prevent water wastage as this is a potential resource that can be treated. The effluent from the sludge drying bed of Chamgang Old WTP and overflow of sludge lagoon of Jungshina WTP can also be recycled back to its respective WTP inlet.

Staffing

- Employ a WTP manager, chemist or chemical technician, and process engineer so the WTPs will have relevant technical skills required to operate the WTP efficiently. WTP operation involves process performance analysis, equipment operation and maintenance, and water quality analysis. These personnel may be responsible for multiple WTPs.

4.6 Water Supply Assumptions, Validation and Risks

The preparation of the Water Supply Masterplan involved numerous assumptions particularly in relation to wastewater flows and to a lesser extent network infrastructure. In light of the limited field data available for validation and the assumptions made during the development of the hydraulic model for the water supply network, it is essential to acknowledge the potential risks associated with implementing the proposed recommendations without validating these assumptions. The accuracy and reliability of the model results are contingent upon the accuracy of the assumptions made. Relying solely on uncalibrated model results introduces uncertainties and compromises the confidence in the correctness of all recommended improvement works.

Implementing the recommendations without proper validation may lead to unforeseen discrepancies between the model predictions and the actual behaviour of the water supply system.

This study created a "digital twin" hydraulic model for the trunk main system within the limits of the data available, which can be used as a high-level decision-making tool and for assessing operational performance. Additional work will be required to further develop the model and increase the level of confidence in the outputs from the tool.

Recommendations given on the key steps to improve the model and refine modelling outputs include a review of system arrangement and connectivity, review of assumptions to fill data gaps, model calibration with flow and pressure monitoring data, and further development from Steady State to Extended Period Simulation.

There are several risks associated with implementing the recommendations in this Masterplan without proper validation. These include:

- Inaccurate performance predictions
- Suboptimal or ineffective improvements that fail to address issues within the network
- Inefficient resource and investment allocation
- Increased public health and environmental risks
- Public and stakeholder dissatisfaction if the recommended improvement works do not deliver on the expected outcomes

Therefore, it is strongly advised to prioritise efforts towards data collection and validation to enhance the accuracy and reliability of the hydraulic model, enabling more informed decision-making and reducing the potential risks associated with unvalidated assumptions.

4.7 Water Supply Masterplan Summary

Within the timeframe of this Masterplan, the water availability assessment and treatment capacity at the WTPs indicate that there is sufficient water supply in the system to accommodate current and future water demands. This assumes that the non-revenue water reduction strategies suggested within this Masterplan, the *Bhutan Water Status Assessment Report (2023)* and the *Draft Roadmap to NRW Management (25 January 2023)* are implemented in conjunction with water demand management.

The modelling demonstrated that for the life of the Masterplan the water supply network is robust hydraulically for the existing trunk main system to accommodate the projected future demands without need for any major upgrades. Upgrades due to poor pipe condition may be required but were not examined as part of this Masterplan.

Table 22 shows a summary of the proposed water supply works and how they contribute to achieving the objectives of the Water Supply Masterplan. Note that these works are based on several assumptions which should be validated before committing to any major capital expenditure.

Table 22: Water Supply Masterplan Summary

		Objectives				
		24/7, high quality, safe and reliable water supply.	Fair and efficient supply of water to all consumers.	Sustainable use of water.	Infrastructure suitable for firefighting purposes.	Sensitive to the natural environment.
Proposed Works	Reducing NRW losses, particularly leakage, is essential for supporting sustainable growth within the city and ensuring there is adequate water for living while protecting natural water resources. The *Draft Roadmap to NRW Management* outlines the steps to implement to reduce NRW losses.	✓	✓	✓		✓
	Network extension to DMAs currently supplied by community or private networks to allow for all properties within TT to be supplied by the municipal network which would reduce contamination risk from community supplies which are untreated and improve reliability of supply. Four booster pump stations are likely to be required to distribute water to the highest elevations of each DMA. For other DMAs, PRVs are recommended to ensure adequate pressure in the local watermain network.	✓	✓			
	Network reconfiguration between Taba and Jungshina WTPs through the extension of an existing 150mm diameter spare watermain coming from Taba WTP to Jungshina WTP, approximately 600m, to enable an additional 3MLD to be treated during periods of low supply from the current Jungshina source (mini-Hydro).	✓	✓			
	Network reconfiguration to balance the demand from seven DMAs with the lean season availability of water from their respective WTPs. These include Pamtsho 1, Babesa Right, Above Old Highway, Babesa Left, Bangdu Residents and Bangdu Area Left and Changzamtog.	✓	✓	✓	✓	
	Flow meters should be installed for general flow measurement, leakage detection and customer charging. Indicative locations for 52 flow meters were identified. Pressure monitoring will be required for each pressure area of the network. Indicative locations for 84 pressure transducers were identified.	✓	✓	✓		
	SCADA upgrades proposed throughout the system include: Online meters and pump controls at WTPs Chlorine residual monitoring at storage reservoirs Water level monitoring at storage reservoirs	✓				
	Establish a WSP to ensure safe drinking water supply at consumer taps. The WSP should address normal operating conditions as well as incident or emergency situations.	✓				
	The planned 1.4 MLD upgrade by TT at Dechencholing WTP is required. Additional capacity or construction of new WTPs are not considered necessary up to 2047, assuming Water Demand Management and NRW objectives are achieved.	✓	✓	✓		
	Various upgrades at existing WTPs were identified to ensure each WTP can meet the required Drinking Water Standards for the proposed water demand. Upgrades to primary components include: Taba WTP – BioBall Filters Motihang WTP – Lamella to sedimentation tanks	✓				
	Upgrades to storage reservoirs include upsizing, consolidation and strategic storage to ensure 48hours of storage is provided. Datasheets for each individual storage reservoir were developed. These should be used in conjunction with Extended Period Simulations using the hydraulic model to identify under-	✓			✓	

		Objectives				
		24/7, high quality, safe and reliable water supply.	Fair and efficient supply of water to all consumers.	Sustainable use of water.	Infrastructure suitable for firefighting purposes.	Sensitive to the natural environment.
	capacity storage reservoirs. Clusters of storage reservoirs can then be examined to determine preferred locations for capacity upgrades and strategic level storage reservoirs.					
	A new trunk line running the length of the city from Begana to Rama was assessed with respect to a potential new abstraction from the Wang Chhu and WTP replacing all other WTPs (except Taba WTP) to provide a more resilient long term water supply for Thimphu. This solution is not considered necessary during the timeframe of this Masterplan (2047). The results show it is feasible to supply the majority of the city by these two sources, although some pumping may be required to reach some higher elevations.	✓	✓	✓	✓	✓

5. Wastewater Masterplan

This section focuses on the wastewater system in Thimphu and is structured to discuss the appraisal and actions related to key areas of the wastewater system. This section includes:

- Summary of existing system
- Objectives and strategies for the wastewater system
- Design scenarios considered in the assessment
- Appraisal of the wastewater trunk system and recommended actions
- Appraisal of the WWTPs (existing and proposed) and recommended actions
- Separation of the wastewater and stormwater system
- Other initiatives

5.1 Existing System

Wastewater in Thimphu is conveyed to one of seven WWTPs, treated by private on-site septic tanks, or discharged untreated to stormwater drains. The WWTPs have a combined design capacity of 17MLD, however the actual capacity is often reduced due to operational issues (Refer to the *Water Supply, Wastewater and Stormwater Assessment*). Except in areas served by Babesa WWTP and Lungtenzampa WWTP, only blackwater is discharged to the public wastewater mains due to capacity issues at the other WWTPs. Greywater is discharged to the stormwater system in these catchments.

There is good coverage of existing wastewater mains serving the city to collect wastewater from existing properties and the network is continually being expanded. Detailed wastewater supply maps can be found in Appendix F. Stormwater inflow exists within the wastewater network. Sludge at the WWTPs is poorly managed; most WWTPs have no adequate sludge treatment, and the resulting product is disposed unsafely to the environment.

The existing wastewater system is nearing capacity. The overall combined capacity of the WWTPs will be insufficient to cater future flows (24MLD). Wastewater overflows are occurring at WWTPs and wastewater mains surcharge during high flows, resulting in raw sewage on the streets.

5.2 Wastewater Strategies

The wastewater strategies focus on improving the reliability and efficiency of the overall wastewater system by meeting the current, medium-term (2032) and long-term future (2047) demand in the wastewater trunk networks and the WWTPs. Table 23 shows the relationship between the different strategies and the objectives they help to achieve, as outlined in Section 1.3. The following strategies for the wastewater system were developed through consultations with stakeholders to meet the objectives of the Masterplan:

- Upgrade existing WWTPs to be able to meet the current demand.
- Centralise treatment works into two larger WWTPs to meet the future demand (one WWTP for the north and one for the south).
- Develop a new wastewater trunk main to serve the new WWTP in the north which makes use of the existing wastewater system, where applicable, which typically follows proposed greenways.
- Reduce the volume of wastewater being produced by costumers through Water Demand Management (refer to Section 4.4.6).
- Identify and disconnect sources of stormwater inflow entering the wastewater network.
- Reduce the number of blockages in the systems due to solid waste dumping.
- Greywater to be collected by the wastewater treatment network and treated at the WWTPs.
- Establish a sludge management plan for all WWTPs that includes safe collection, treatment and disposal and/or reuse of the sludge.
- Install SCADA systems throughout the network to better monitor flows which will assist Operation and Maintenance of assets and inform future design considerations.
- Extend the existing wastewater network to new neighbourhoods.
- Upgrades to existing wastewater mains and network infrastructure to meet current and future demands.
- Identify opportunities for wastewater reuse, reducing demand on freshwater sources particularly for irrigation.
- Identify alternative manhole covers with zero scrap value to reduce theft risk.

Table 23: Wastewater Objectives and Strategies Matrix

Strategies		Objectives: Protect the environment and public health.	Objectives: Wastewater services shall be provided for all residents.	Objectives: All wastewater is treated prior to discharge.	Objectives: System operated economically and efficiently.
Strategies	Upgrade existing WWTPs	✓	✓	✓	✓
	Centralise WWTPs				✓
	New wastewater trunk main to serve the new WWTP				✓
	Reduce the volume of wastewater produced	✓			✓
	Reduce stormwater inflow	✓			✓
	Reduce the number of blockages caused by dumping	✓			
	Greywater to be collected by and treated at the WWTPs	✓		✓	
	Establish sludge management plan	✓			
	Install SCADA systems				✓
	Extend the existing wastewater network		✓		
	Network upgrades	✓	✓		
	Wastewater reuse	✓			
	Alternative manhole covers	✓			✓

5.3 Design Scenarios

The following scenarios were simulated in the hydraulic model and used to inform upgrades to WWTPs:

- Reduced Demand and Infiltration and Inflow in 2032 (Scenario 2B)
- Reduced Demand and Infiltration and Inflow in 2047 (Scenario 3B)
- High Infiltration and Inflow in 2047 (Scenario 3C)

The flow estimates per WWTP are presented in Table 24.

Table 24: Flow Estimates per WWTP

WWTP	Design Capacity (MLD)	2032 Flow - Scenario 2B (MLD)	2047 Flow - Scenario 3B (MLD)	2047 Flow - Scenario 3C (MLD)
Dechencholing	0.75	1.20	1.53	2.41
Taba	1.0	1.36	1.56	2.46
Jungshina	1.0	1.22	1.52	2.61
Hejo (not included in the initial report)	0.1	0.35	0.41	0.65
Langjophakha	0.6	0.34	0.40	0.63

WWTP	Design Capacity (MLD)	2032 Flow - Scenario 2B (MLD)	2047 Flow - Scenario 3B (MLD)	2047 Flow - Scenario 3C (MLD)
Lungtenzampa	2.0	1.25	1.29	2.04
Babesa	12.0	13.37	15.23	24.03
Total	**17.35**	**18.74**	**21.53**	**34.18**

Design scenarios allow for 100% of greywater and blackwater to be collected and treated. Refer to the *Water Supply, Wastewater and Stormwater Assessment* for details on the assumptions on the population, sewage generation and infiltration.

5.4 Wastewater Trunk Main Network

Sections of the existing wastewater trunk mains appear to be under capacity for the current, 2032 and/or 2047 design scenarios based on the hydraulic modelling undertaken (refer to the *Water Supply, Wastewater and Stormwater Assessment*). This section outlines the upgrades required to prevent the system from surcharging during design events. It also includes details of new trunk mains required to serve new catchments and WWTPs.

Works are prioritised into Phase 1 (based on 2032 flows) and Phase 2 (2047 flows). However, significant flow monitoring and manhole surveying is required to verify the assumptions made in the hydraulic model prior to undertaking major capital improvement works (refer to the *Water Supply, Wastewater and Stormwater Assessment*).

Results of Scenario 3C with the upgraded wastewater network is also assessed to provide information for TT on the problematic areas that can be expected during extreme storm events.

5.4.1 Extension to the Existing Network to New Areas

The wastewater network should be extended to serve areas within the Thimphu Thromde boundary that are not served by the existing public wastewater network. Table 25 and Figure 5-1 show the details of the wastewater network and WWTP expansion.

Table 25: Extension to the Existing Network

Area	WWTP Catchment	Connection Point to Existing Network	New Trunk Main Diameter (mm)	Length (m)
Kabesa	Dechencholing WWTP	Dechencholing WWTP	160	1,500
Royal Bhutan Army	Babesa WWTP	SNMH4755	250	500
Depsi	Babesa WWTP	SNMH2664	100 (force main)	1,500

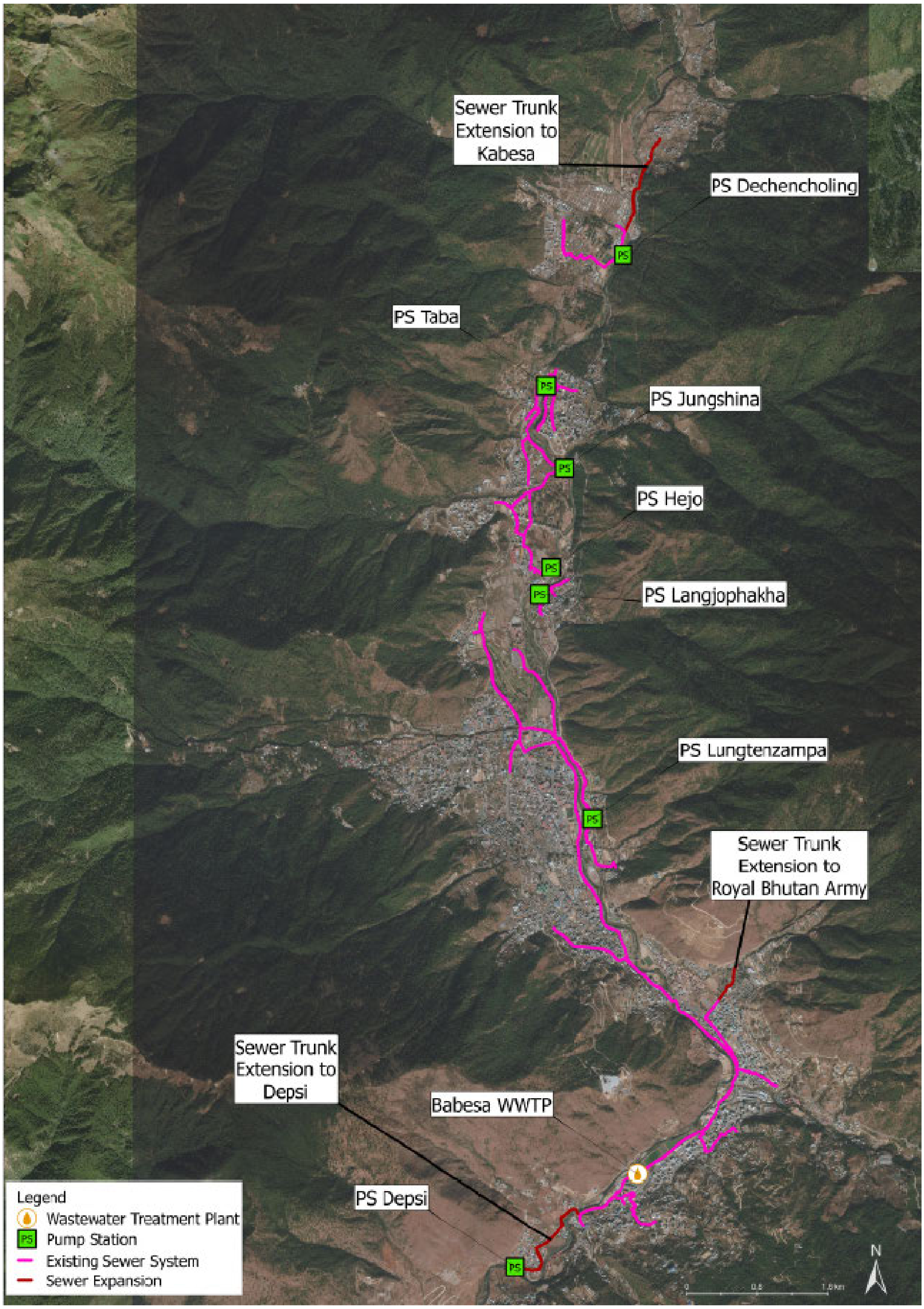


Figure 5-1: Extension to Existing Wastewater Network

Rama, which is located at the southernmost catchment, is not included in the expansion as it is understood that there will be a separate WWTP to serve the region.

5.4.2 Proposed Wastewater Trunk Main

A new wastewater trunk main is required to convey wastewater to the proposed Northern WWTP (Refer to Section 5.5.3). The *Wastewater Network Hydraulic Model Build Report* describes the process undertaken to identify the preferred route in detail. Based on discussions with TT and MoIT and a Political, Economic, Social, Technical, Legal and Environmental (PESTLE) Analysis, a preferred route option was selected which became the basis of the hydraulic model developed. This route proposes additional wastewater trunk mains and adapting a centralised wastewater network system each for a northern Hejo WWTP at and a southern Babesa WWTP. For river crossings, the preferred solution is to use a bridge crossing instead of inverted siphons. However, site specific evaluation at each location should be considered in future design stages, such as considering flood levels, ground conditions, costs and other factors.

The proposed route is depicted in Figure 5-2. The proposed wastewater trunk mains are underneath both greenways and existing roads while leveraging on the gravity system. The proposed new pipe length is approximately 5.4km and there are four river crossings. This option reduces the geohazard risks between Dechencholing WWTP and Taba WWTP and considers a shorter traverse of river crossings. This option yields the shortest route amongst all the options.

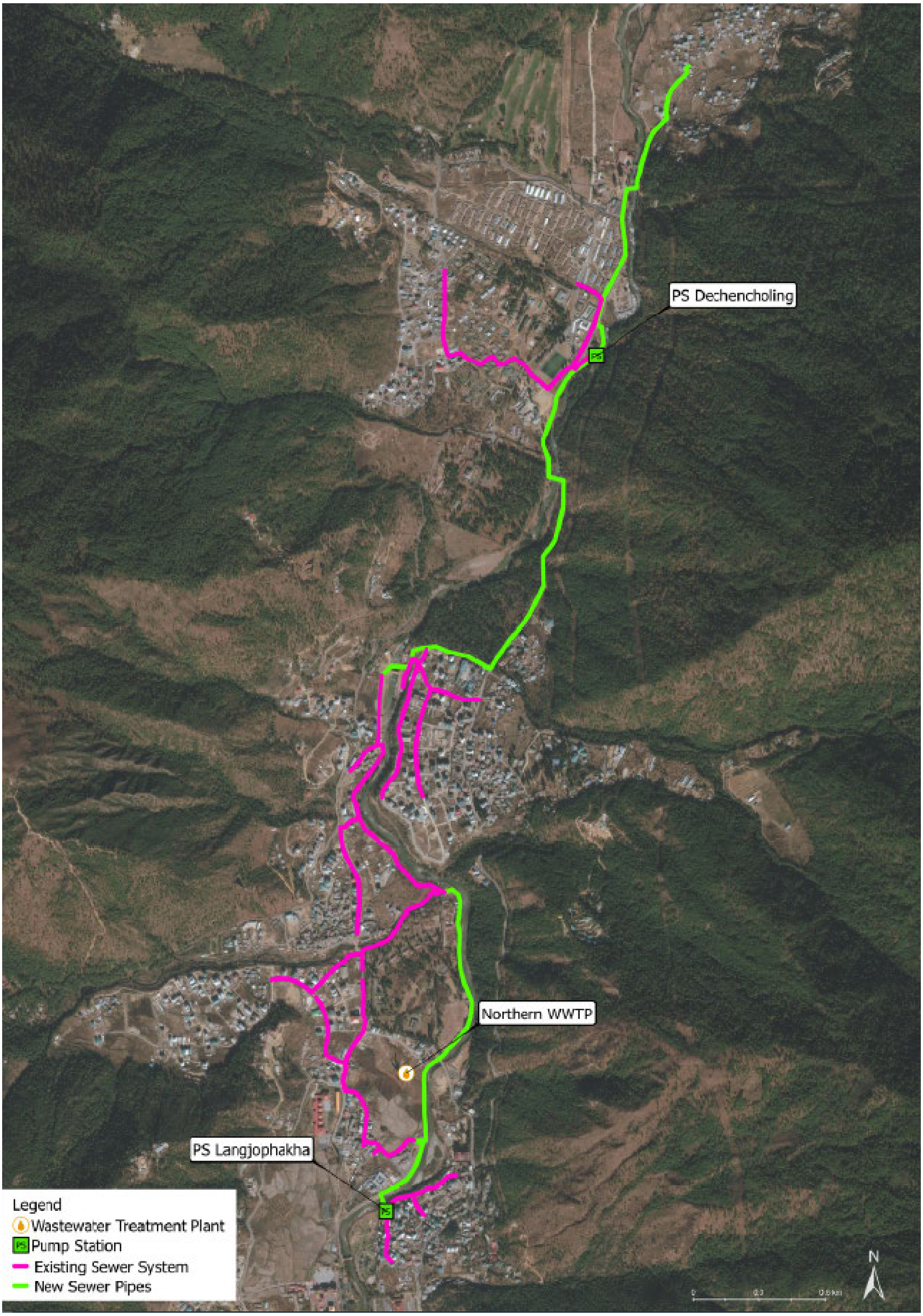


Figure 5-2: Proposed Wastewater Main Route

5.4.3 Upgrades to the Existing Wastewater Network

The existing wastewater mains proposed to be upsized are shown in Figure 5-3 and listed in Table 26.

Table 26: Network Upgrades for Phase 1 (Scenario 2B)

Location for Wastewater Main Upgrades	Length (m)	Existing Diameter (mm)	Minimum Proposed Diameter (mm)
PHASE 1			
Jungzhi Lam Northeast, Jungzhi Wom Zur Lam, Jungshina influent	650	400	500, 600
Hejo influent	200	160	200
Doebum Lam, Nordzin Lam, Kashing Lam Se, Yarden Lam, Chogyal Lam	1,150	250	350
Chogyal Lam, Chang Lam Southern, Chang Lam Se	1,900	315	500
Unnamed road beside Babesa-Thimphu Expressway, Wangchhu Lam, Doebum Lam, Babesa-Thimphu Expressway	1,800	500	600
PHASE 2			
Dechencholing influent	60	200	300
Mapho Lam-5	500	250	300

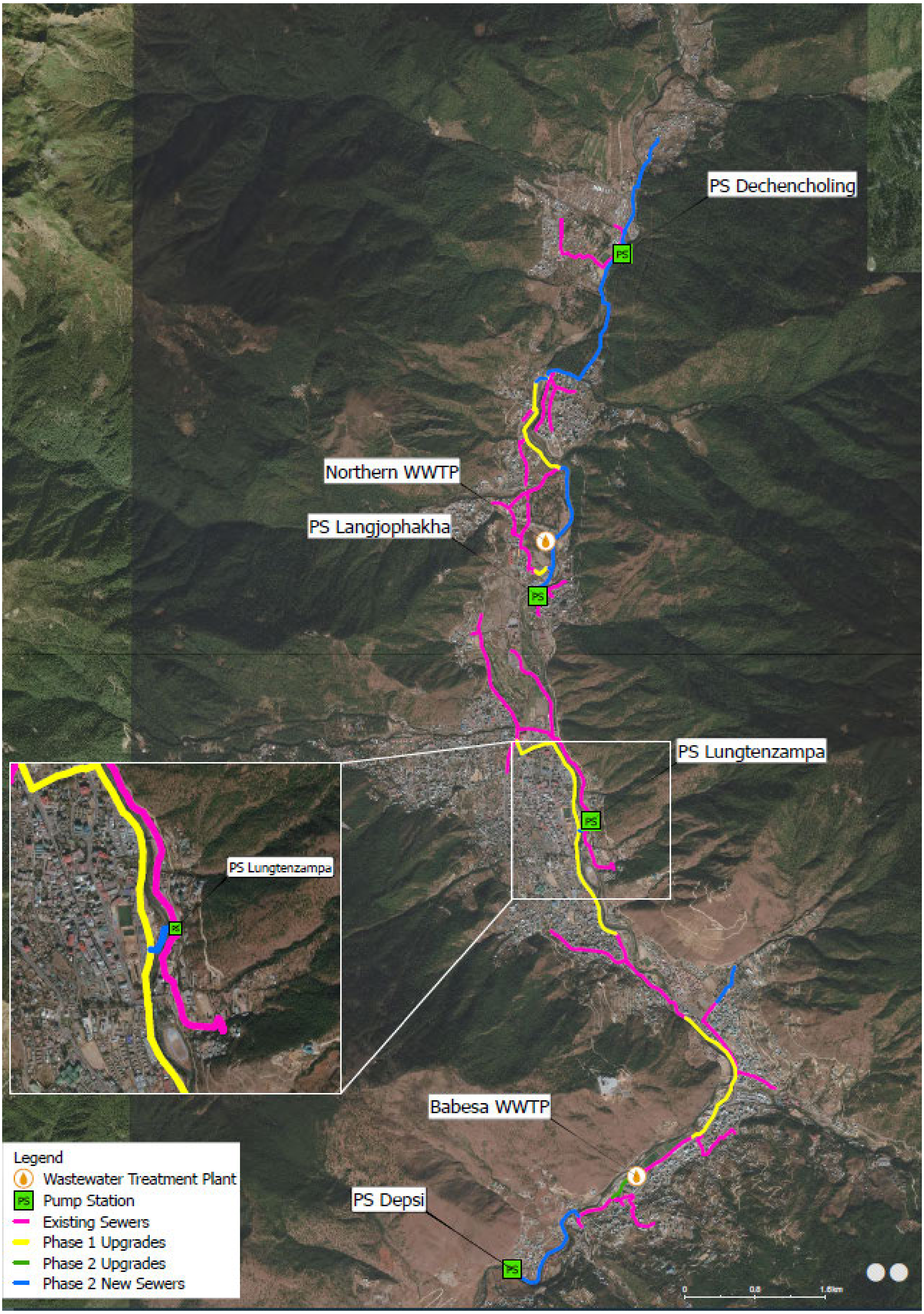


Figure 5-3: Wastewater Network Phasing

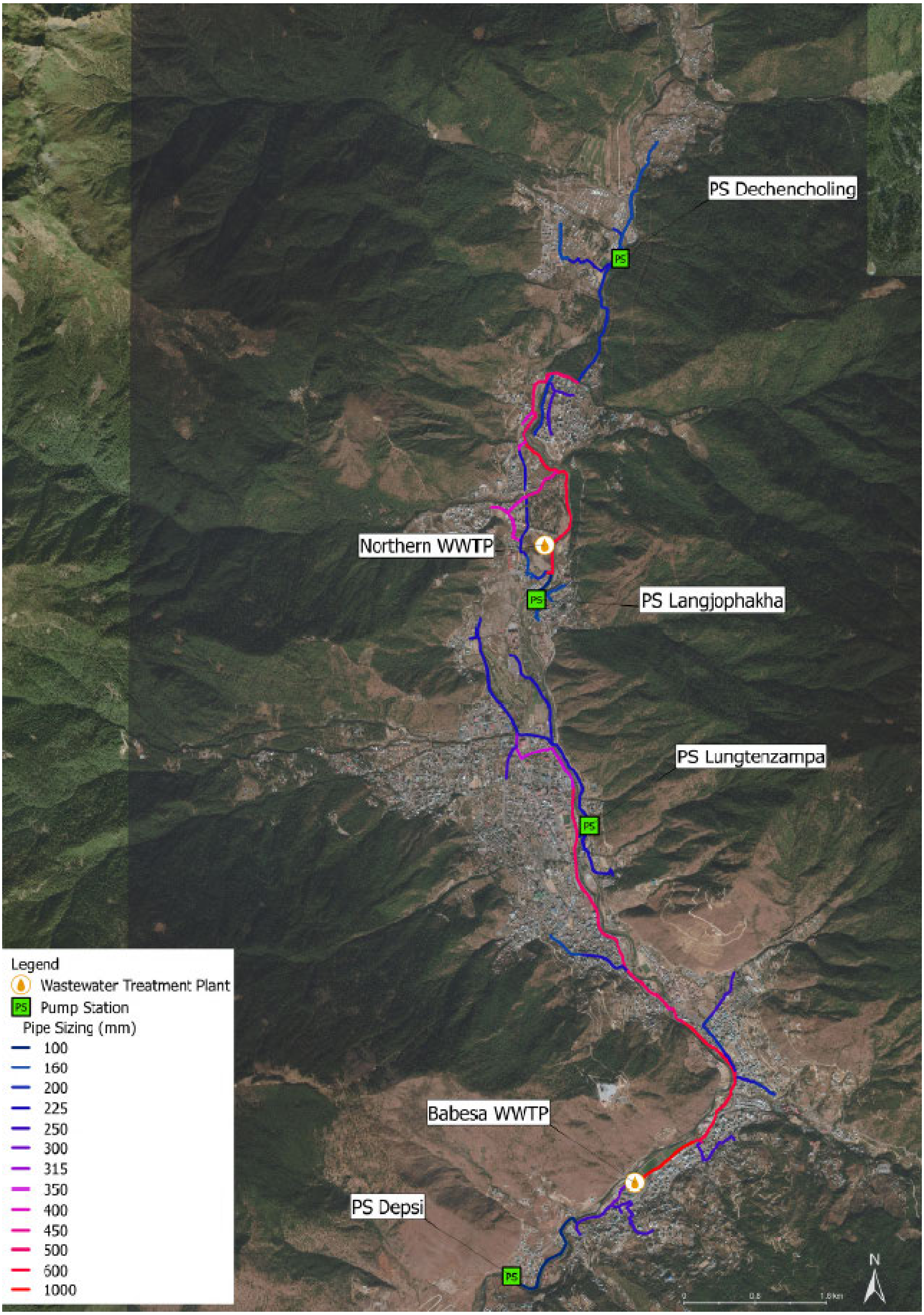


Figure 5-4: Wastewater Network Sizing for Design Year 2047

In general, wastewater networks use Pump Stations (PS) to convey wastewater flow from lower elevations to higher elevations. For the Thimphu wastewater network, PS are introduced at strategic locations of the existing network to promote centralising the existing wastewater system. Some of the existing WWTPs will be converted to pump stations in Phase 2. The design flow (Scenario 3B) and its total dynamic head (TDH) are shown in Table 27.

Table 27: Proposed Pump Station Details

Pump Station	Design Flow (lps)	TDH (m)
PS-Depsi	7.1	34
PS-Lungtenzampa	48.7	7
PS-Langjophaka	15.5	21
PS-Dechencholing	60.7	57

5.4.4 High Flow Scenario Check

Scenario 3C is also simulated to check areas in which wastewater mains will surcharge under high flows beyond the design scenario to identify higher risk surcharge areas. Locations of these pipes are summarised in Table 28 and in Figure 5-5.

Table 28: Scenario 3C Results Using Preferred Option

Location of Surcharging Pipes on 3C	Length (m)
Doebum Lam North	130
Dechencholing Influent	60
Lhadrong Lam	370
Unnamed Road near Babesa Thimphu Expressway	2,450
Unnamed Road near Khamtoe Lam	1,320
Zeri Lam	410
Mapho Lam-5	30

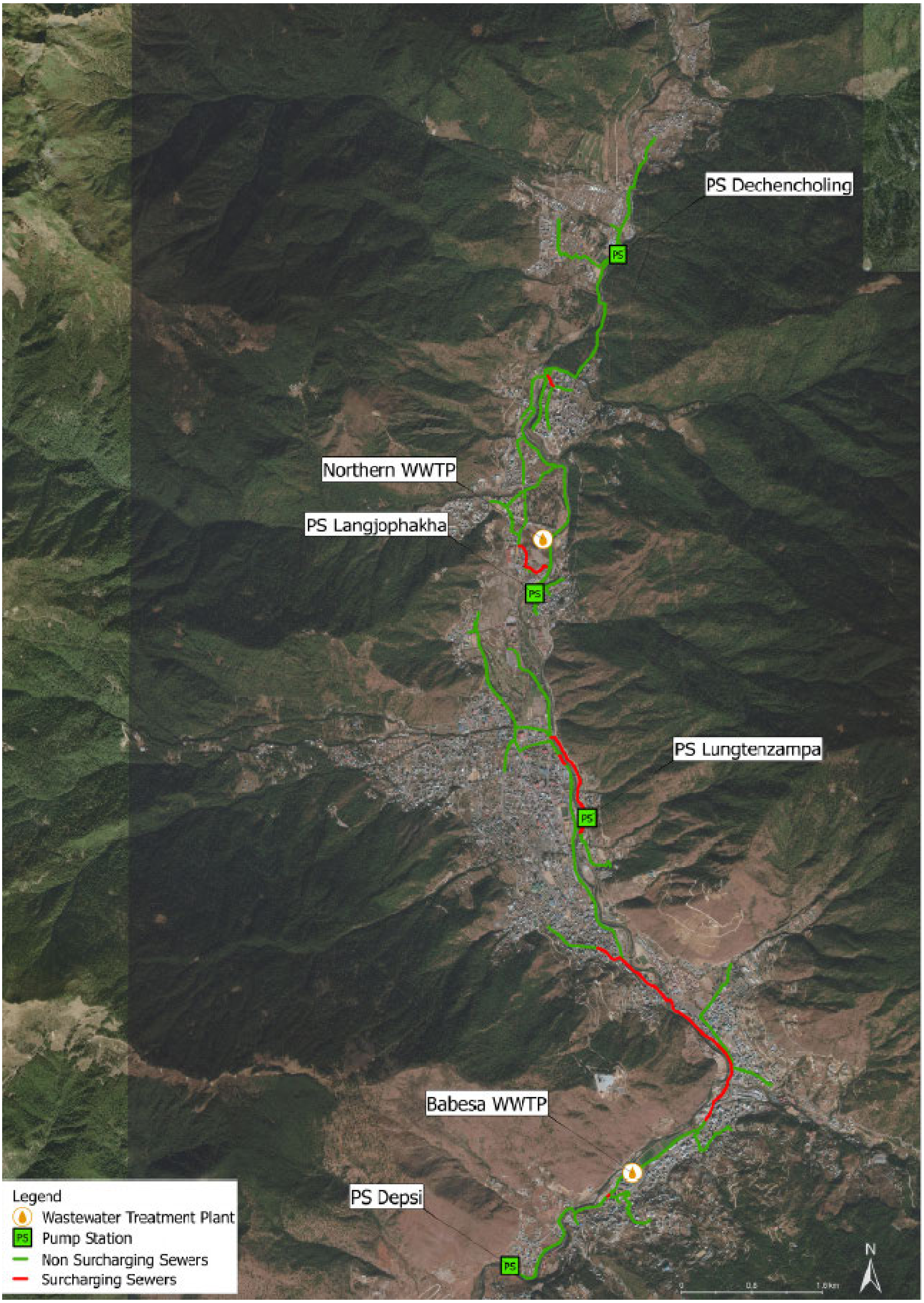


Figure 5-5: High Flow Scenario Check

5.5 Wastewater Treatment Plants

Thimphu has eight WWTPs and six of them are operated by TT which treat the wastewater generated from approximately 85% of the population. All six WWTPs were hydraulically and biologically assessed to determine whether the systems were able to cater future flows. Table 29 summarises the existing and proposed WWTPs.

Following the assessment of the existing WWTPs (Phase B) and stakeholder workshops (Phase C), it is proposed to centralise wastewater treatment for the northern suburbs. This will involve construction of a new WWTP and decommission the existing WWTPs namely Dechencholing, Taba, Jungshina, Hejo, Langjophakha and Lungtenzampa. Babesa WWTP will be retained and continue to operate and serve the central and southern areas of Thimphu.

Table 29: Existing and Proposed WWTP

Existing TT WWTPs	Capacity (MLD)	Proposed WWTPs	Proposed Capacity (MLD)
Dechencholing	0.75	Hejo: New WWTP Northern Extension	6.0
Taba	1.0		
Jungshina	1.0		
Langjophakha	0.6		
Hejo	0.1		
Lungtenzampa	2.0	Upgraded Babesa	18.0
Babesa	12.0		
-		Rama: New WWTP Southern Extension	1.0

5.5.1 Upgrades to Existing WWTPs

Based on the current capacity and design life of the existing WWTPs, it is proposed to keep the existing WWTP operating until 2032 to maximise value from the existing infrastructure. This timeframe also allows for improvement in the monitoring and management of the existing system, optimisation of the design for interventions, and time to construct the new WWTP.

All the upgrades listed for the five WWTPs which will be decommissioned are the most significant items which are necessary to run and cater the 2032 flow. Upgrades listed for Babesa WWTP are necessary to run and cater for the 2032 and 2047 flows.

5.5.1.1 Dechencholing WWTP

A summary of major recommended actions and further upgrades for Dechencholing WWTP are presented in Figure 5-6 and Table 30. Other minor upgrades are shown in Appendix G.

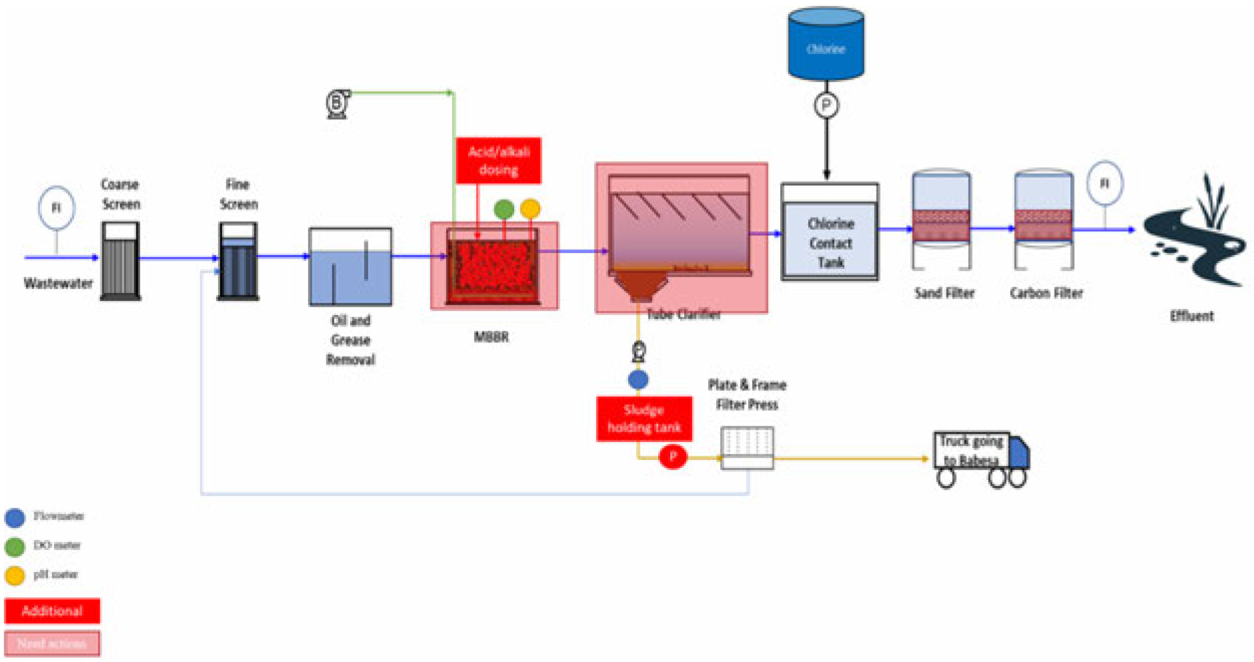


Figure 5-6: Dechencholing WWTP Process Flow Diagram (PFD) Recommended Upgrades

Table 30: Dechencholing WWTP Recommended Upgrades

Issues Identified	Recommended Actions	Further Upgrades
WWTP is not functional due to multiple mechanical failures and equipment that will reach their design life in 2027	Assess all equipment, auxiliaries, pipelines and cables that are not functioning as per specification	Refurbish or replace equipment to ensure compliance to design capacity
Clogged diffusers which reached their design life in 2017	Replace the diffusers	-
Insufficient quantities or worn-out Moving Bed Biofilm Reactor (MBBR) media	Assess the condition of MBBR media	Wash the media and replenish up to the design volume
Insufficient capacity of the MBBR	Investigate the performance in terms of Biological Oxygen Demand (BOD) removal while operating conditions of Dissolved Oxygen (DO) and pH are maintained and provide an alkali/acid dosing	Provide additional media or increase the air flow or add a unit of MBBR
Insufficient capacity of TUBEdek Settler	Investigate the influent and effluent Total Suspended Solids (TSS)	Change the configuration of settler (such as the slope) to increase the settling area or provide an additional unit
Missing and exhausted filter media	Check the size of the filter vessels and plan how to fill these with media	Fill the filter vessels with media or replace the whole unit if vessel has insufficient capacity
No historical data for all parameters required in influent and effluent	Develop a sampling plan and testing procedure for internal and third-party laboratory testing and analysis for all required parameters to ensure compliance and identify influent quality	Establish the influent characteristics to use as a basis in constructing future centralised WWTP
No sludge holding tank	Check if there is one sludge holding tank on site and if its capacity is sufficient to handle the sludge while the plate and frame filter press is running	Provide sludge holding tank

5.5.1.2 Taba WWTP

A summary of major recommended actions and further upgrades for Taba WWTP are presented in Figure 5-7 and Table 31. Other minor upgrades are in Appendix G.

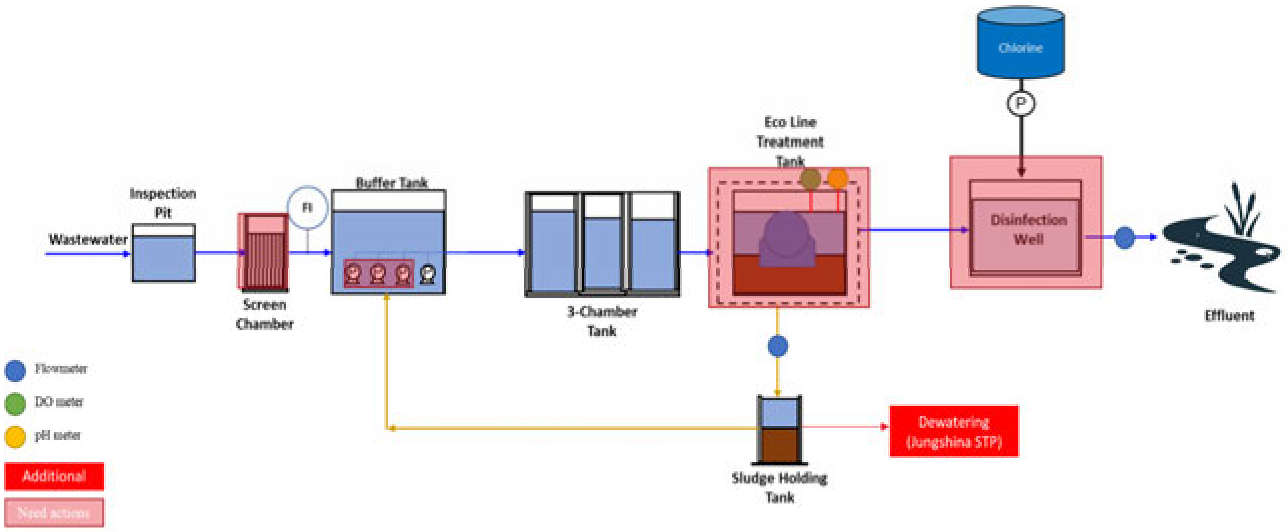


Figure 5-7: Taba WWTP PFD Recommended Upgrades

Table 31: Taba WWTP Recommended Upgrades

Issues Identified	Recommended Actions	Further Upgrades
Hydraulically overloaded screens	Evaluate the solids removal efficiency of the screens and check if the solids are accumulated on the chambers	Provide additional unit
75% of pumps are not working	Conduct full maintenance and troubleshooting and assess if equipment condition is acceptable for operation	Replace the damaged pumps with the capacity that can cater for 2032 flow
Insufficient design capacity of eco-line by 136%	Assess the BOD removal performance while operating conditions of DO and pH are maintained	Provide alkali/acid dosing or increase the air flow or add another train of eco-line
Insufficient disinfection well	Investigate the faecal coliform of the effluent to determine if it is meeting the standard	Increase the chlorine dosage or add another tank with sufficient capacity to have enough contact time
No historical data for all parameters required in influent and effluent	Develop a sampling plan and testing procedure for internal and third-party laboratory testing and analysis for all required parameters to ensure compliance and identify its influent quality	Establish the influent characteristics to use as a basis in constructing future centralised WWTP
No sludge treatment	Check the dewatering unit of Jungshina WWTP to determine if there is excess capacity	Transfer the sludge to Jungshina WWTP or provide dewatering unit to Taba WWTP if that is not possible

5.5.1.3 Jungshina WWTP

A summary of major recommended actions and further upgrades for Jungshina WWTP are presented in Table 32. Other minor upgrades are in Appendix G.

Table 32: Jungshina WWTP Recommended Upgrades

Issues Identified	Recommended Actions	Further Upgrades
Insufficient capacity of Sequential Batch Reactor (SBR)	Assess the BOD removal performance while operating conditions of DO and pH are maintained	Adjust the operation by modifying intercycle phase duration or replace the activated sludge into granular

Issues Identified	Recommended Actions	Further Upgrades
	Check the auxiliaries if it is sufficient to increase the flow	sludge or provide additional unit of SBR

5.5.1.4 Langjophakha WWTP

A summary of major recommended actions and further upgrades for Langjophakha WWTP are presented in Figure 5-8 and Table 33. Other minor upgrades are in Appendix G.

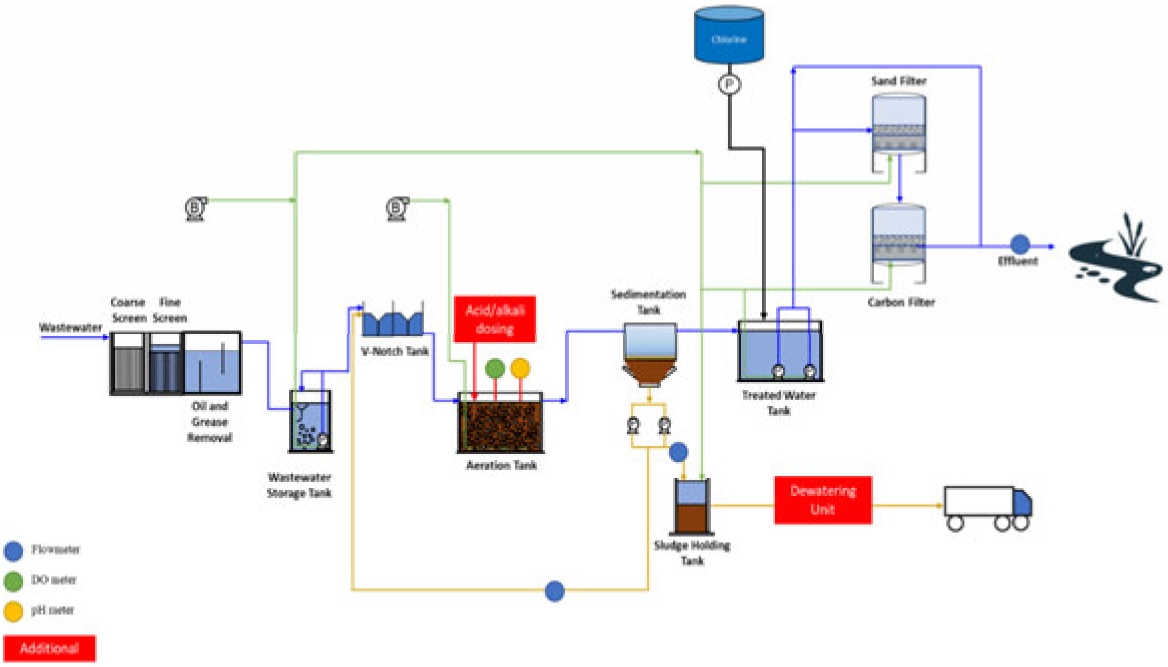


Figure 5-8: Langjophakha WWTP PFD Recommended Upgrades

Table 33: Langjophakha WWTP Recommended Upgrades

Issues Identified	Recommended Actions	Further Upgrades
Other components of WWTP which were not assessed like blowers, pumps and filters may not be capable to handle the 2032 flow	Assess all equipment, auxiliaries, pipelines and cables that are not functioning as per specification	Refurbish or replace equipment to ensure compliance to 2023 flow
No historical data for all parameters required in influent and effluent	Develop a sampling plan and testing procedure for internal and third-party laboratory testing and analysis for all required parameters to ensure compliance and identify its influent quality	Establish the influent characteristics to use as a basis in constructing future centralised WWTP
No sludge treatment	Provide a dewatering unit	-

5.5.1.5 Lungtenzampa WWTP

A summary of major recommended actions and further upgrades for Lungtenzampa WWTP are presented in Figure 5-9 and Table 34. Other minor upgrades are in Appendix G.

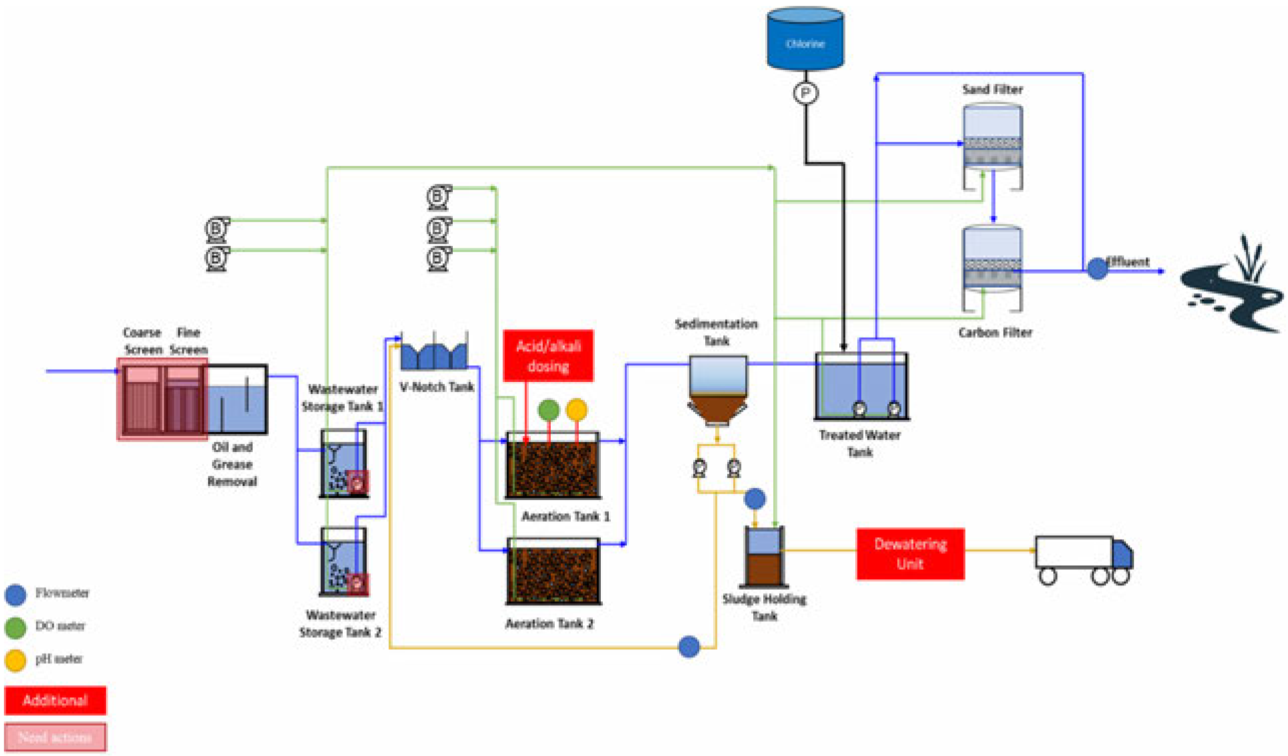


Figure 5-9: Lungtenzampa WWTP PFD Recommended Upgrades

Table 34: Lungtenzampa WWTP Recommended Upgrades

Issues Identified	Recommended Actions	Further Upgrades
Leaking pumps	Conduct full maintenance troubleshooting and assess if equipment condition is acceptable for operation	Refurbish or replace equipment to ensure compliance to 2032 flow
Hydraulically overloaded screens	Evaluate the solids removal efficiency of the screens and check if the solids are accumulated on the chambers that could cause overflowing overflow pipe	Provide additional unit
Review functionality of other equipment	Assess all equipment, auxiliaries, pipelines and cables that are not functioning as per specification or which are clogged	Refurbish or replace equipment to ensure compliance to 2032 flow
Possible clogging of diffusers in wastewater storage tanks and aeration tanks	Check the performance during the operation	Replace the diffusers
No historical data for all parameters required in influent and effluent	Develop a sampling plan and testing procedure for internal and third-party laboratory testing and analysis for all required parameters to ensure compliance and identify its influent quality	Establish the influent characteristics to use as a basis in constructing future centralised WWTP
No sludge treatment	Provide a dewatering unit	

5.5.1.6 Babesa WWTP

A summary of major recommended actions and further upgrades for Babesa WWTP are presented in Figure 5-10 and Table 35. Other minor upgrades are in Appendix G.

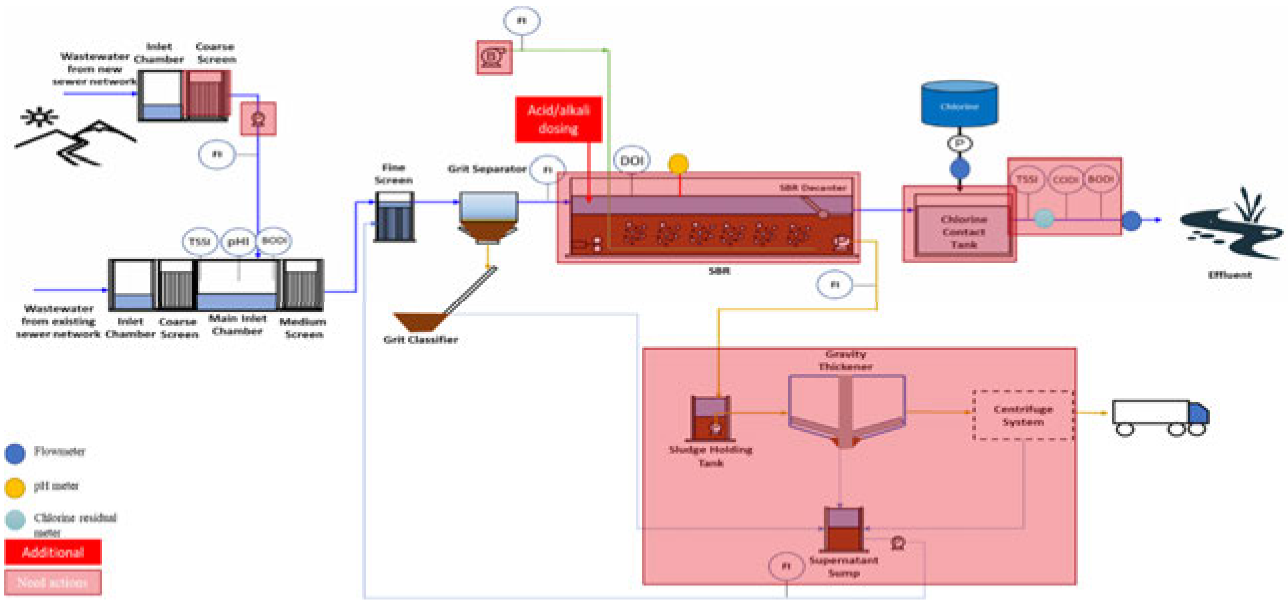


Figure 5-10: Babesa WWTP PFD Recommended Upgrades

Table 35: Babesa WWTP Recommended Upgrades

Issues Identified	Recommended Actions	Further Upgrades
Outside coarse screen may be insufficient in receiving the wastewater from new wastewater main One of the coarse screens is not functional	Prepare a service report for the defective coarse screen Validate actual flow measures coming from the new wastewater main and evaluate with the existing capacity of the coarse screens Evaluate the solids removal efficiency of the screens and check if the solids are accumulated on the chambers	Refurbish or replace the coarse screen and provide additional chamber of coarse screens
Possible insufficient capacity of wastewater pumps	Identify the flow going from the new wastewater main	Provide additional unit or replace the pumps with higher capacity
Insufficient capacity of SBR when 1 unit is down with 2032 flow Insufficient by 11% with 2047 flow even if all units are running	Assess the BOD removal performance while operating conditions of DO and pH are maintained Check the auxiliaries if it is sufficient to increase the flow	Adjust the operation by modifying intercycle phase duration or replace the activated sludge into granular sludge or provide additional unit of SBR
Possible insufficient capacity of aeration blower when 1 unit is down with 2032 flow Insufficient by 11% with 2047 flow even if all units are running	Validate the flow of assumed capacity of each blower is 740 cubic metres per hour (m^3/hr)	Provide additional unit
Insufficient contact time in chlorine tank Possible short circuiting happens in a Treated Water Tank	Investigate the faecal coliform of the effluent to determine if it is meeting the standard	Increase the chlorine dosage or add another tank with sufficient capacity to have enough contact time
Possible insufficient capacity of sludge holding tank	Identify the flow of the waste activated sludge and assess if the tank has sufficient capacity to handle the sludge when the sludge treatment is in downtime	Provide additional sludge holding tank or provide additional unit of the downstream equipment like thickener and dewatering unit
Insufficient capacity of Gravity Sludge Thickener and possible the Centrifuge System	Check the water content of thickened and dewatered sludge	Provide additional polymer dosing or provide additional unit of thickener and dewatering unit

Issues Identified	Recommended Actions	Further Upgrades
No historical data for all parameters required in influent and effluent	Develop a sampling plan and testing procedure for internal and third-party laboratory testing and analysis for all required parameters to ensure compliance and identify its influent quality.	-

5.5.2 WWTP Technologies Assessment

An assessment of conventional biological treatments was performed to understand what treatment technologies would be more suitable to the proposed new WWTPs. Table 36 provides a summary of the advantages and disadvantages of each technology and the suitability of each. A more detailed comparison assessment can be found in Appendix H.

Table 36: First Stage of Screening Options for New WWTP

Treatment Technology	Description	Advantages	Disadvantages	Suitability
Membrane Bio-reactor	Suspended growth process with membrane filtration	<6mg/L Total Nitrogen (TN) effluent is achievable Smallest area requirement Suitable for cold weather but potential issues may arise Identified existing WWTPs with low capacity	Requires dedicated personnel with technical skills to operate and maintain the system especially on maintaining the membranes Possible highest Capital Expenditures (CAPEX) and Operational Expenditures (OPEX) in all technologies	Less Suitable
Modified Ludzack-Ettinger (MLE)	Suspended growth process	<10mg/L TN effluent is achievable Slightly higher area requirement Suitable for cold weather but potential issues may arise Identified existing WWTPs with low capacity Easy to operate and maintain requiring minimal personnel to manage the WWTP and this is the technology used in Langjophakha WWTP and Lungtenzampa WWTP Low CAPEX and OPEX		Preferred Option
Oxidation Ditch	Suspended growth with longer solids retention time (SRTs)	<5mg/L TN is achievable Suitable for cold weather but potential issues may arise Suitable for low capacity Easy to operate and maintain	Largest area requirement Higher CAPEX and OPEX than MLE	Not Suitable
SBR	Batch suspended growth process	5-8mg/L TN effluent is achievable Can be configured for both nitrification and denitrification processes Small area requirement depending on depth Suitable for cold weather but potential issues may arise Identified existing WWTPs with low capacity Low OPEX	Generally requires dedicated personnel to operate and maintain the WWTP but this technology is already existing in Babesa WWTP; therefore, TT is familiar with this technology Higher CAPEX than MLE	Preferred Option
Step-feed Reactor	Plug flow of suspended growth	<5mg/L TN effluent is achievable Small area requirement Suitable for cold weather but potential issues may arise Suitable for low capacity Low OPEX	Requires dedicated personnel to operate and maintain the WWTP because flow needs to be distributed in each train Slightly higher CAPEX than MLE	Less Suitable
Aerobic Granular Sludge	Granular activated sludge	Similar or better effluent quality than other biological nutrient removal technologies	Must be protected against sunlight, wind and rain (especially against freezing in cold climates)	Preferred Option

Treatment Technology	Description	Advantages	Disadvantages	Suitability
		Can be configured for both nitrification and denitrification process Small area requirement Suitable for cold weather but potential issues may arise Suitable for low capacity Low OPEX	Higher CAPEX than MLE	
Integrated Fixed Film Activated Sludge (IFAS)	Suspended growth reactor with attached growth media	Nitrifying bacteria can grow on the IFAS media to provide nitrification despite the limited SRT in the suspended growth process. Suitable for cold weather but potential issues may arise Suitable for low capacity	Slightly large area requirement Require dedicated personnel to operate and maintain the WWTP Higher CAPEX than MLE	Less Suitable
Biological Aerated Filter or Submerged Aerated Filter	Attached growth process with fixed bed filter	Can be configured for both nitrification and denitrification processes Depending on the application of air within the filter, BOD removal and nitrification removal efficiency of ⩾85% Small area requirement Suitable for cold weather but potential issues may arise Suitable for low capacity Lower OPEX than MLE	Require specialist expertise to operate and maintain the WWTP Higher CAPEX than MLE	Less Suitable
Fixed Bed Biofilm Reactor	Attached growth process with fixed bed biofilm	Can achieve effluent ammonia-nitrogen concentration of 0.5mg/L Small area requirement Suitable for cold weather but potential issues may arise Suitable for low capacity Lower OPEX than MLE	Require dedicated personnel to operate and maintain the WWTP Higher CAPEX MLE	Less Suitable
MBBR	Attached growth process with moving bed biofilm	Effluent total nitrogen <10mg/L Small area requirement Suitable for cold weather but potential issues may arise Suitable for low capacity Lower OPEX than MLE	Generally requires dedicated personnel to operate and maintain the WWTP, but this technology already exists in Dechencholing WWTP; therefore, TT is familiar with this technology Higher CAPEX MLE	Preferred Option
Rotating Media Reactor	Attached growth process with circular disk on horizontal shaft	Both aerobic nitrifying bacteria and anaerobic denitrifying bacteria can simultaneously live in the attached biofilm Small area requirement Identified existing WWTPs with low capacity	Protection of the system in a cold climate is difficult Requires dedicated personnel to operate and maintain the WWTP	Less Suitable

Treatment Technology	Description	Advantages	Disadvantages	Suitability
		Lower OPEX than MLE	Higher CAPEX than MLE	
Trickling Filter	Attached growth process with fixed bed filter	Suitable for cold weather but potential issues may arise Identified existing WWTPs with low capacity	Applications include combined BOD removal and nitrification, however, difficult to accomplish biological nitrogen and phosphorus removal compared to single-sludge biological nutrient removal suspended growth designs Large area requirement Require dedicated personnel to operate and maintain the WWTP	Not Suitable

5.5.3 New WWTPs

As highlighted in Section 5.2, one of the main strategies for wastewater in Thimphu is to centralise treatment works into two larger WWTPs to improve the efficiency of operations and maintenance. A new WWTP would serve the northern suburbs and an upgraded Babesa WWTP would cater for the southern suburbs. In addition, with the development of Rama and Depsi as part of the southern extension a new treatment facility was considered to minimise pumping.

5.5.3.1 Proposed Northern Extension WWTP – Hejo

5.5.3.1.1 Site Identification for New Hejo WWTP

In collaboration with Thimphu Thromde and Prior & Partners (P&P), Hejo was identified as the preferred location for a new 6MLD WWTP that will serve the northern suburbs. The new WWTP will cater the areas currently covered by Dechencholing, Taba, Jungshina, Hejo and Langjophaka WWTPs.

Preliminary WWTP sizing was undertaken which indicated a site of 6,000m² is required. Several locations were assessed for the new Hejo WWTPFigure 5-11: and Plot C depicted in Figure 5-11 was identified as the preferred location. This site allows for the most efficient integration with other land uses in the area, set back from Tashichho Dzong and the Royal Estate, and reduces the requirement from pumping from the northern trunk main. Prevailing wind direction should be considered to minimise odour concerns for down-wind populations.

Figure 5-11: Location Assessed for the New Hejo WWTP

5.5.3.1.2 Treatment Technology Selection for New Hejo WWTP

For the new Hejo WWTP, the use of NBS was explored as a treatment solution. Common NBS solutions (i.e., integrated constructed wetlands, horizontal / vertical flow wetlands, reed beds) as well as other innovative technologies (i.e., algae treatment in enclosed photobioreactors, phragmifiltre reed beds) were assessed; however, no feasible solution was found which could cater for the design population, available space and which could meet the treatment standards.

The amount of space required by NBS to treat the future flow was the main constraint. Maintaining available landscape for recreational use is a main driver in this area and the use of NBS is not fully justified due to the mentioned constraints. For a 6MLD capacity WWTP, the disposal of a final effluent that meet the discharge limits for Wang Chhu to maintain a good status could not be guaranteed.

The NBS solutions in Table 37 were assessed based on the following assumptions:

- Population Equivalent: 60,000 PE
- Average Inlet Flow: 70L/s
- Peak Inlet Flow: 132L/s
- Inlet Loading Chemical Oxygen Demand (COD): 1,150mg/L
- Inlet Loading BOD: 400mg/L
- Inlet Loading TSS: 216mg/L
- Inlet Loading Total Kjeldahl Nitrogen (TKN): 48mg/L
- Inlet Loading PO4-P: 6.7mg/L
- Inlet Water Temperature: 15°C

Table 37: Assessment of NBS

NBS	Considerations
Integrated Constructed Wetlands (ICW)	Requires approximately 1,200,000m^2 total area for ICW. Space for access and embankments was not included in the assessment. The space on-site (100,000m^2) is not sufficient for the ICW to achieve the required effluent quality standards.
Algae Treatment in Enclosed Photobioreactor	Requires approximately 90,000m^2 total area for photobioreactors. The available space on-site (100,000m^2) is sufficient, however this option requires careful high maintenance and operation at the facility. In addition, a significant portion of the available land is within the flood zone of the Wang Chhu which will be at risk of reduced or unpredictable treatment efficiency. Typically, this option is recommended for smaller flows and might not achieve the required effluent quality standards.
Hybrid Solution: Traditional Pre- treatment and NBS for Secondary and Tertiary Treatment	The space on-site (100,000m^2) is considered to be sufficient (high area of land is still required), however a significant portion of the available land is within the flood zone of the Wang Chhu which will be at risk of reduced or unpredictable treatment efficiency. The overall WWTP would govern the landscape design for this proposed Parkland area, which is culturally sensitive due to the current location of the crematorium and proximity to Tashichho Dzong. This is therefore not a preferred option.

It is preferred to use conventional treatment to treat the flow, suit the available space and achieve the required quality. Section 5.6.2 provides an assessment of WWTP technologies and highlights four preferred options. Appendix H provides a deeper assessment of these four options, with weighted score selection criteria. The key points to consider for treatment selection are highlighted in Table 38. This deeper assessment pays particular attention to Thimphu Thromde experience and capacity to operate and maintain the WWTPs, the proven reliability of each treatment in the region and the regional availability of the required equipment.

Table 38: Preferred Technologies for New Hejo WWTP

Technologies	Key Points	Suitability
Modified Ludzack-Ettinger (MLE)	Existing treatment in Lungtenzampa WWTP and Langjophakha WWTP; therefore, TT is familiar with this technology in terms of operation and maintenance with > 5 years of experience, and it needs minimal supervision. Easy to construct and land area requirement is approximately 4,800m^2. All materials like equipment or chemical needs for this treatment could be sourced locally or in India.	Preferred Option

Technologies	Key Points	Suitability
	Track record for proven and solid performance in this region and climate but could be upset during load/flow variations; therefore, requires an equalization tank.	
SBR	Existing in Babesa WWTP and Jungshina WWTP; therefore, TT is familiar with this technology in terms of operation and maintenance with < 5 years of experience, but it may require dedicated personnel to operate and maintain the WWTP. Easy to construct if the depth of the reactor is not too high and land area requirement is approximately 4,400m^2. All materials like equipment and chemical needs for this treatment could be sourced locally or in India. Track record for proven and solid performance in this region and climate but could be upset during load/flow variations; therefore, requires an equalization tank.	Suitable
Aerobic Granular Sludge	TT has no experience regarding the operation of this type of process facility and it may require dedicated personnel to operate and maintain the WWTP. Granular sludge may need to be outsourced to other countries like China. Easy to construct if the depth of the reactor is not too high and land area requirement is approximately 4,400m^2. Adaptable in flow/load variations and with a track record for proven and solid performance in China and in this climate. Lower carbon footprint, less waste sludge produced and fewer chemicals needed.	Suitable
MBBR	Existing in Dechencholing WWTP; therefore, TT is familiar with this technology in terms of operation and maintenance with > 5 years of experience, but it may require dedicated personnel to operate and maintain the WWTP. Easy to construct and land area requirement is approximately 4,500m^2. All materials like equipment and chemicals needed for this could be sourced locally or in India. Track record for proven and solid performance in this region and climate and adaptable in flow/load variations.	Preferred Option

5.5.3.1.3 Requirements for New Hejo WWTP

The new Hejo WWTP should meet the following requirements:

- Design to treat wastewater in compliance to the Standard Workshops which was identified on 17 October 2022 and stipulated in the *Initial Options Analysis – Constraints and Opportunities* Report.
- Have the following facilities and WWTP components which cover all civil, process, mechanical, electrical and control engineering needs:
  - Equipped with preliminary treatment (i.e., screenings, screenings handling, oil/grease and grit removal, equalization tank) to remove all the solids and other components that can affect the downstream equipment and processes.
  - Ensure there is treatment for biological organic matter, biological nutrient removal (i.e., ammonia and MRP) and disinfection.
  - Faecal sludge management processes in place as described in Section 5.7.1.
  - Chemical dosing systems and storage facilities.
  - Minimise or control the odour and noise emitted in operating the WWTP.

- Monitoring and instrumentation that shall include, but is not be limited to: flow meters, pressure measuring devices, water level sensors, pH meters, DO meters, ORP meters, Mixed Liquor Suspended Solid concentration sensors, on-line ammonia, phosphate and turbidity/TSS analysers. Signals and status from these instruments shall be displayed in SCADA system.

- Sampling plan and testing procedure for internal and third-party laboratory testing and analysis to ensure quality standards are met.

- Operation and maintenance manual that comprises, but is not limited to: detailed design criteria, standard procedures for operation and maintenance of each equipment/process, control philosophy, emergency plan, preventive maintenance schedule, health and safety measures, quality monitoring plan, inventory, proper handling, and storing and disposal of chemicals.

- Available WWTP manager, process engineers and mechanical engineers in the WWTP for troubleshooting and to ensure the WWTP is adequately maintained for continuous operation and compliant with required specifications, latest legislations and standards.

5.5.3.2 Proposed Southern Extension WWTP – Rama

5.5.3.2.1 Site Identification for New Rama WWTP

The proposed southern extension of the city into Rama will require a new wastewater system for this unserved area. As Rama is a lower elevation than the existing Babesa WWTP, a new pump station and rising main would be required to convey wastewater from Rama to Babesa WWTP. To reduce operating costs associated with pumping, a new WWTP is proposed at the southern end of Rama as shown in Figure 5-12.

Figure 5-12: Proposed Location for Rama Wastewater Treatment Facility

5.5.3.2.2 Treatment Technology Selection for New Rama WWTP

The use of NBS was explored (**Table 39**) for the new Rama WWTP that would cater the new developments in Rama and Debsi. The space was not a significant constraint in this site, with 110,000m^2 of land available for a 1MLD WWTP. The low design capacity of this WWTP makes it more suitable to NBS compared to Hejo. NBS typically have low Nitrogen and Phosphorus removal rates and therefore a waste assimilative capacity assessment of the Wang Chhu would be required to confirm final effluent quality would not result in excessive negative effects on the river.

Table 39: Assessment of NBS for New WWTP

NBS	Considerations	Suitability
Integrated Constructed Wetlands	140,000m^2 required – not enough space available	Not Suitable
Reed Beds	70,000m^2 required	Suitable
Vertical / Horizontal Wetlands	21,000m^2 required	Suitable

5.5.3.2.3 Requirements for New Rama WWTP

The requirements for the new Rama WWTP would be similar to the requirements in Section 5.5.3.1.3.

5.6 Wastewater and Stormwater Separation Strategy

5.6.1 Strategy Overview

Separation of wastewater and stormwater is a key strategy for this Water Services Masterplan. There is a significant amount of stormwater flow entering the wastewater network and greywater is commonly connected to the stormwater network which results in WWTPs operating over capacity and wastewater being discharged untreated to the environment.

This Wastewater Masterplan focuses on blackwater and greywater management but the assessment recognises that the system is integrated. The integrated system includes planned enhancement and maintenance of wastewater, greywater and stormwater systems within the local (property level), network (street scale and wastewater trunk mains) and treatment level (sub-catchment and catchment level).

5.6.2 Wastewater Separation Strategy

To achieve the Wastewater Masterplan vision and manage the wastewater system in a manner that both protects the environment and minimises the risk to public health, different sources of wastewater pollution must be identified. Figure 5-13 illustrates these sources, their potential impact and how effective the current wastewater network is at managing them. To achieve the goals of the Masterplan, the scope and ambition of the wastewater separation strategy is also depicted.

Figure 5-13: Wastewater Separation Strategy

Existing WWTPs are generally not testing for coliforms and do not treat for MRP or ammonia; however, testing of these parameters is included in the proposed WWTP upgrades outlined in Section 5.5.

Strategic Target for Network Separation

The targets for wastewater and stormwater network separation are as follows, and as illustrated in Figure 5-13 and set out in Section 1.3:

- Full basic treatment of all black wastewater in both dry weather conditions and during general storm events. This will largely be achieved by ensuring WWTPs have adequate capacity (refer to Section 5.5.) and will include building better storm resilience by removing storm inflow and infiltration from the wastewater network.
- Full basic treatment of all grey wastewater in both dry weather conditions and during general storm events. This will be achieved by collecting all greywater within the wastewater network, ensuring sufficient capacity at WWTPs and by building better storm resilience. This will provide a direct river health benefit and also increase capacity in stormwater systems.
- Improve the storm network resilience to storm events in accordance with the Integrated Stormwater Management Plan.
- The long-term objectives to further improve river health could include biological nutrient removal systems at WWTPs to treat MRP and ammonia pollution present in black and grey wastewater, as well as integration of green infrastructure into the stormwater network to treat certain pollutants from stormwater discharges as outlined in Section 5.5 and Section 6 and the *Green Infrastructure and Open Spaces Masterplan* proposed as part of the TSP.

5.6.3 Wastewater Separation Delivery Plan

A five-phase delivery plan to achieve a separate and resilient wastewater network is illustrated in Figure 5-14. Each phase will include a series of actions and workshops as summarised in the following sections.

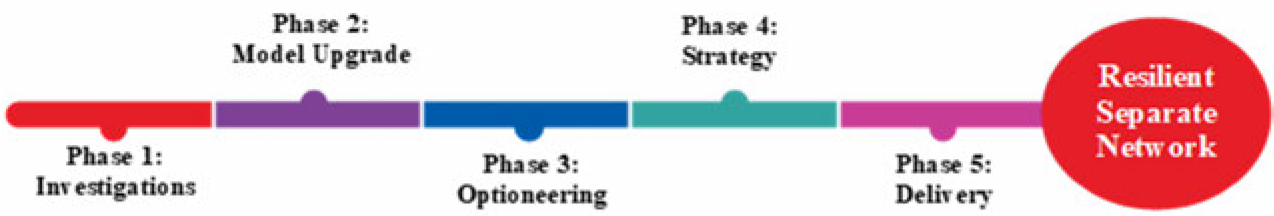


Figure 5-14: Wastewater Separation Delivery Plan

Phase 1: Investigations

Investigations form the foundation for understanding how water is managed through the catchment (wastewater, greywater and stormwater). Investigations will be designed around determining a robust root cause, further detailed development and improvement of the hydraulic model and a view to the options/strategy. Key actions will include, but are not limited to:

- Agree on a vision for the city. This will set the priorities, key outcomes, actions and outputs, key stakeholders and help focus effort for Phase 1. This work is already largely completed as part of this Masterplan and TSP. Priorities to be determined based on growth areas and existing network capacity issues.
- Conduct key surveys within priority sub-catchment(s). These can be scoped and delivered at sub-catchment scale; an example is given for the Dechencholing catchment below.
- Main output will be to provide base data for proposed model upgrades in Phase 2.

Phase 2: Model Upgrade

A robust hydraulic model will enable an evidence-based strategy and optimal solutions. This will need to include wastewater, greywater and stormwater systems and their interconnections. Key actions will include, but are not limited to:

- Integrate the existing wastewater and stormwater hydraulic models for Thimphu. This tool will underpin strategy and longer-term catchment operation, therefore local teams must be equipped to manage and enhance the model.
- Model enhancement using survey data. Model to be updated based on Phase 1 surveys. This work will complement the requirements for calibrating and validating assumptions made in preparation of the existing hydraulic model (Refer to *Wastewater Modelling and Trunk Capacity Assessment Report*).
- Model verification based on flow survey, long term telemetry (where exists) plus other evidence (e.g., reported flooding incidents, pollution hotspots, community data, evidence collected for the Integrated Stormwater Management Plan)
- Root cause and impact analysis on people and community, river health and nature.

Phase 3: Optioneering

Utilise the hydraulic model developed in Phase 2 to assess future scenarios. This can include building in various growth, deterioration, water use and climate scenarios. Key actions will include, but are not limited to:

- Re-affirm strategies and outcomes and classify them in short-term, medium-term and long-term targets.
- Long-list of intervention options. This will include quick wins (e.g., local plumbing interventions), through to strategic options (e.g., wastewater trunk main enhancement, WWTP upsizing or consolidation) covering wastewater, greywater and stormwater.
- Include a total value assessment (multiple capitals).
- Client workshops and community workshops, where appropriate.
- Optimise the best combinations of interventions for an integrated catchment approach. This should consider all water challenges in Thimphu including water supply.

Phase 4: Strategy

This includes the process of converting the preferred Phase 3 solution into a viable delivery strategy. Key actions will include, but are not limited to:

- Hierarchy of options and needs between wastewater, greywater and stormwater.
- Optimised network enhancement.
- Stakeholder consultations.
- Adaptive pathway plan.
- Business case and funding.
- Water stewardship and governance.

Phase 5: Delivery

This is a short-term, medium-term and long-term adaptive delivery plan for the wastewater and stormwater separation strategy. Taking an adaptive approach will help Thimphu respond to changes in the catchment, communities and local climate.

5.6.4 Phase 1 in Focus: Investigation Details

In this section some detail is provided for Phase 1 because this work is largely included as part of this Masterplan and TSP. Survey types were reviewed based on United Kingdom best practice, with a sub-catchment shown to illustrate how to plan the investigations.

Information Required

Different types of survey required during the investigation stage are described in Table 40 along with an indicative cost, timescale and difficulty. Some of this data has already been collected as part of this Masterplan and Integrated Stormwater Management Plan, but it is incomplete across the entire catchment. An example of Phase 1 implementation for Dechencholing is provided in Appendix I.

Table 40: Survey Types for Investigation Stage

Survey Type	Time	Cost	Skill	Benefits	Basic Drainage Plan	Strategic Plan	River Health Plan
Connectivity	Low	Low	Low	Information on wastewater connectivity (i.e., properties discharge what waste to what system) and identifies misconnections.	✓	✓	✓
Drainage Area Survey	Low	Low	Low	Information on stormwater connectivity and identifies misconnections.	✓	✓	✓
Manhole Survey	Low	Low	Low	Data on levels, and pipe and chamber size to inform network capacity and model hydraulics.	✓	✓	✓
Asset Survey (e.g., Pump Station)	Low	Low	Medium	Information of size and operation of specific assets (e.g., tanks, pumping stations, storm overflows). Required for model.	✓	✓	✓
Closed Circuit Television	Low	High	High	Information on connectivity, levels, size and state of infrastructure.		✓	✓
Flow Survey	High	High	High	Information for flows through a pipe against a specific time. Used for model verification. Typically monitor for 12 weeks to capture rainfall events, likely need 2 seasons of data.		✓	✓
Invertebrate Surveys	Low	Low	Medium	Data on invertebrate health at different points in a river system. Can inform on impact of different types of discharges in a river.			✓
Water Quality Sampling	High	Medium	High	Data on pollutant concentrations at different points or times in a river system. Can inform the impact of different types of discharges in a river.			✓

Scale:

Time	Cost*	Skill
1-5 days	£0.2k	Simple
1-4 weeks	£1-2k	Detailed measurements required
4-25 weeks	>£2k	Specific technology required

*cost "per survey" e.g., 100 number/ manhole surveys would cost £20,000. All costs based on United Kingdom rates, require local ratification.

Considering Root Cause and Options at the Same Time

During successful investigations there will be opportunities to explore the viability of certain option types. Several of these were assessed as part of the *Wastewater Modelling and Trunk Capacity Assessment Report* and recommendations were carried through into strategies and initiatives within this Masterplan. During Phase 1, these potential solutions should continue be explored in further detail to help inform investigations where reasonable to do so. The continued investigations include the following:

- Utilise previous greywater to wastewater connections.
- Greywater re-use at the property level.
- Rainwater harvesting to reduce storm inflows.
- Capacity restrictions and opportunities in wastewater network for greywater connections.
- Key opportunities to retrofit green infrastructure to treat and reduce peak storm inflows.
- Opportunity to reduce wider catchment run-off through land management and natural flood management techniques.

During the Phase 1 surveys is should be possible to include catchment walkovers to appraise the potential of such options at an early stage, whilst appreciating the final solutions will only be borne through the full five phase process.

5.7 Other Wastewater Initiatives

5.7.1 Faecal Sludge Management Plan

Currently, there is no regulation or national environmental policy for the disposal of sludge. The current practices applied pose a risk to the environment and public health due to the pollutants existing in untreated sludge. The sludge management practices per WWTP are detailed in Table 41.

Table 41: Sludge Management Practices per WWTP

WWTP	Existing Management Practice	Disposal
Dechencholing	Dewatering	Dispose to Babesa WWTP
Langjophakha	No treatment	Dispose to landfill
Lungtenzampa	No treatment	Dispose to landfill
Taba	Not treatment	Unknown
Jungshina	Dewatering	Unknown
Babesa	Thickening and dewatering	Unknown

For detailed information on the current management of faecal sludge refer to the *Water Supply, Wastewater and Stormwater Assessment.*

5.7.1.1 Faecal Sludge Management (FSM) Approach

Three different approaches (Table 42) can be assessed to establish a Faecal Sludge Management plan for Thimphu:

- Decentralised: each WWTP fully treats and disposed sludge.
- Centralised: the sludge from each WWTP is collected and transferred to a centralised site to be treated.
- Hybrid: the sludge is partially treated (thickened and/or dewatered) at each WWTP and transferred to a common site to be stabilised for disposal or further processed for reuse.

Table 42: FSM Approach for 2032 Scenario

FSM Approach		Considerations
Decentralised	Economic	High CAPEX. The existing sludge treatment of each WWTP has thickening and/or dewatering system or no treatment at all. Equipment for stabilization to reduce the pathogen of sludge cake for all WWTPs will be required. The cost will depend on the treatment technologies used.

FSM Approach		Considerations
		Potentially high OPEX. Skilled workers needed at the six WWTPs.
	Environmental and Social	Dechencholing WWTP and Langjophaka WWTP have limited space to implement further treatment and are nearby a school and residential areas, respectively.
		Odour control would be necessary at each WWTP.
	Technical	This approach does not align with TSP strategy of consolidating WWTPs.
Centralised	Economic	Potentially high CAPEX to build a centralised WWTP and established the transport system for the sludge.
		High OPEX. Small number of skilled workers needed at the WWTP in comparison to a decentralised solution, but the sludge will need to be transported from the existing WWTPs to the centralised site. OPEX will be depending on the treatment technology used.
	Environmental and Social	Significant space required. A strategic location that would suit the transportation of the sludge from all WWTPs would be required, ideally in an area that is not around residential areas or any social infrastructure.
		Opportunity to produce a reusable product from sludge.
	Technical	This option is aligned with the potential long-term plan for 2047 where there will only be two main WWTPs.
		Complexity will depend on treatment technology used and how the sludge is transported from the WWTPs. Transport of the sludge could be done through routinary collection by transport trucks or through a pipeline network and pumping system (which would require additional works). Lungtenzampa WWTP is below the ground floor level of the street which could potentially be an issue when hauling the sludge.
Hybrid	Economic	Potentially high CAPEX needed to build a common site to process the sludge and establish the transport system for the sludge. Some works in the existing WWTPs will be needed to thicken and/or dewater the sludge due to limited frequency of collection and transport. However, existing dewatering technologies in the WWTPs would be used.
		Potential medium OPEX. Small number of skilled workers needed at the WWTP in comparison to a decentralised solution, but need to transport the dewatered sludge from the WWTPs.
	Environmental and Social	Less space required than with a centralised system as sludge has been dewatered/thickened. Stabilisation could be implemented at Babesa WWTP for the part of the WWTP that has sludge treatment.
		Odour control would be necessary for each WWTP.
		Opportunity to produce a reusable product from sludge.
	Technical	This option is aligned with the potential long-term plan for 2047 where there will only be two main WWTPs.
		Transport of the sludge could be done through trucks since the sludge would be previously thickened and/or dewatered.

A hybrid approach could provide a suitable solution to address the current sludge management needs, but could also be adapted in the future when the WWTPs are consolidated. This is presented in Figure 5-15. The sludge generated in Dechencholing, Jungshina and Babesa WWTPs could be dewatered using the existing systems in place. Additional dewatering units could be added to Langjophaka and Lungtenzampa WWTPs to dewater the sludge before transferring it to Babesa WWTP for further stabilisation and process. Before adding a dewatering system to Taba WWTP, the transfer of sludge from this WWTP to Jungshina WWTP should be explored to minimise the addition of equipment.

For an assessment of treatment technologies to treat the sludge from thickening to dewatering refer to the *Water Supply, Wastewater and Stormwater Assessment, Appendix A*.

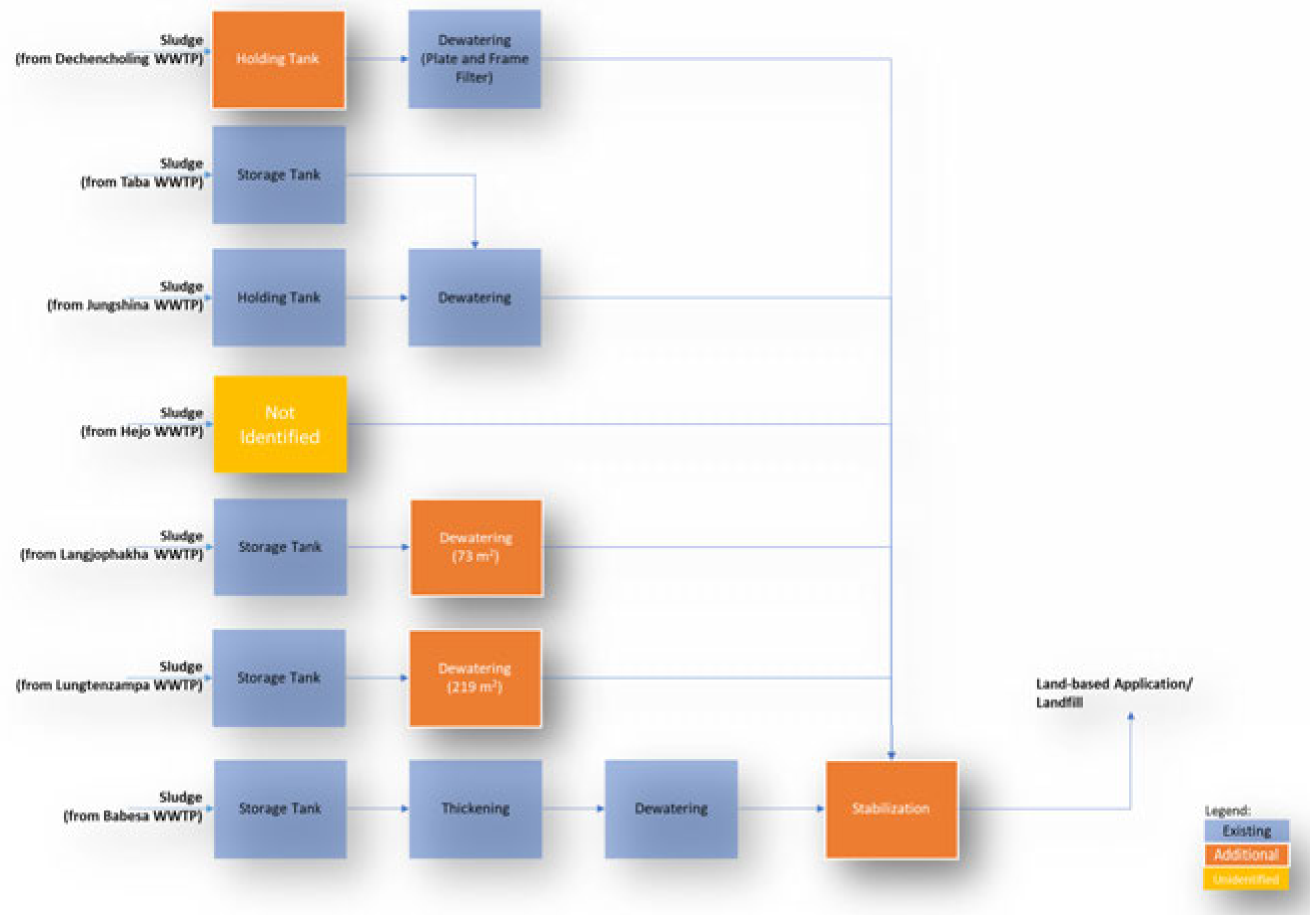


Figure 5-15: FSM Hybrid Approach for Thimphu

For the 2047 scenario, Babesa WWTP could continue dewatering and stabilising sludge. Some of the dewatering equipment from other WWTPs could be utilised and updated to accommodate the new sludge capacity required. For the sludge generated in the new Hejo WWTP, further assessment is needed to determine if the option to transfer the dewatered sludge to Babesa WWTP is preferrable over establishing a second sludge treatment system at the new site. Table 43 shows initial considerations to take into account.

Table 43: FSM Approach for 2047 Scenario

FSM Approach	Considerations
Two Stabilisation Systems at Babesa WWTP and New Hejo WWTP	The sludge quality from New Hejo WWTP and Babesa WWTP would be different. However, this is not a critical issue as some of the reuse product of sludge can be utilised as a fertiliser for non-food crops.
	Requires additional CAPEX but fewer transportation costs.
	Increases the amount of land required for the New Hejo WWTP.
	The effectiveness of the stabilization process could be affected by the limited amount of sludge to be treated, particularly with flow variations. Modular systems should be considered to prevent this.
	Requires additional odour control measures for the New Hejo WWTP to avoid disturbance of surrounding inhabited areas.
One Stabilisation System at Babesa WWTP	Requires high OPEX in terms of transportation costs from the northern suburbs.
	Sludge transportation to Babesa WWTP would need to be considered. Additional elements to New Hejo WWTP may be necessary to hold dewatered sludge to avoid frequent transport.
	High storage area may be required for the total dewatered sludge from Babesa WWTP and New Hejo WWTP.

5.7.1.2 Safe Disposal and Reuse Options for Faecal Sludge

The sludge generated in WWTPs is not treated to a stage that is pathogen free and can be safely disposed of in the environment. The sludge is not processed to be reused, but this is something that could be assessed as part of the FSM strategy for the city. The most common reuse and disposal options for faecal sludge were assessed in Table 44.

Table 44: Safe Disposal and Reuse Options

Options	Key Points	Suitability
Land-based Application (i.e., Fertiliser through composting)	Relatively simple process Can run in low capacity Less CAPEX/OPEX Less energy required as compared to other options Public acceptance needed to use with food agriculture and crops Possible odour emissions during the process and storage	Preferred Option
Energy (i.e., Anaerobic Digestion)	Requires highly skilled operator Requires high organic loads of sludge which is uncommon in domestic wastewater High production cost but a high profit Smaller carbon footprint since the produced energy can minimise the fossil energy Emission to air of by-product CO_2	Not Suitable
Building Material (i.e., Pyrolysis, Gasification, or Any Advanced Thermal Oxidation Process)	Requires producing sludge ash through incineration that can be combined with cement, but is not suitable for low sludge generation Requires highly skilled manpower High production cost Requires high temperature and pressure; therefore requires high energy Emission of particles, greenhouse gases and flue gases	Not Suitable
Sanitary Landfill	Requires landfill area No value obtained from the output Possible odour emissions	Suitable

The estimated areas shown in Table 45 could be needed for treatment if the sludge is to be utilised for land-based application. To adapt the process from 2032 to 2047, a modular composting system could be used. There are currently some suppliers in India that provide modular systems.

Table 45: Additional Areas Required for Land-based Sludge Application, Depending on Selected Approach

Scenario	WWTP	Estimation of Additional Areas Required
2032 – Hybrid Approach	Babesa	Area for stabilization: 465m^2
	Langjophakha	Area for dewatering: 73m^2
	Lungtenzampa	Area for dewatering: 219m^2
2047 – Two Stabilisation Systems	New Hejo	Area for thickening and dewatering: 239m^2 Area for stabilization: 134m^2
	Babesa	Additional area for thickening and dewatering: 365m^2 Area for stabilization: 440m^2
2047 – One Stabilisation System at Babesa	New Hejo	Area for thickening and dewatering: 239m^2
	Babesa	Additional area for thickening and dewatering: 365m^2 Area for stabilization: 574m^2

5.7.1.3 Next Steps to Select FSM Strategy

Before deciding the best strategy to implement a safe and reliable FSM system, the following aspects would need to be considered:

- Quality and quantity of the sludge to be treated
- Space available to use at each site
- Strategic location of potential site
- Transport infrastructure available to transport sludge and the associated costs
- Available budget for investment costs and operational costs
- Manpower skills
- Weather conditions
- Understand community acceptance for reuse and marketability of the final product
- Existing legal frameworks that have possible effects in choosing the processes to be used
- Potential collaboration with other solid waste strategies

5.7.2 Manhole Covers

There are approximately 5,200 manholes for wastewater. The total number of manholes is higher in the city if we consider cover for stormwater drains and other existing covers for other utilities. Manhole covers theft for scrap iron was highlighted as an issue that poses a safety risk to the citizens (pedestrians and drivers) and may put pressure on the maintenance budget for the network.

To address the issue of manhole covers theft, zero scrap value manhole covers could be used in new developments and areas of the wastewater network with high rates of manhole cover theft. Composite manhole covers, as an alternative to traditional covers, are used in different countries where manhole theft is an issue with apparently positive results (such as in China, India). Figure 5-16 depicts examples of these alternative manhole covers. Table 46 summarises characteristics of composite manhole covers.

Figure 5-16: FRP Manhole Covers from Chinese Manufacturers

Table 46: Characteristics of Composite Manhole Covers

Characteristics of Composite Manhole Covers
Zero scrap value
Weigh less than traditional covers reducing health and safety risks to workers who handle them
Strong locking mechanisms that secure the covers in place
Tight fitting manhole lids which can reduce inflow and infiltration
Long-lasting and not affected by corrosions
Non-conductive
Allow radio frequency signals from Automatic Meter Reading systems and telemetry systems to pass through

Composite manhole covers can be made of different materials. Currently, there are three main types of composite manhole covers in the market, as summarised in Table 47. Among the three, Fibre Reinforced Plastic (FRP) composite manholes can reach higher load-bearing capacity.

Table 47: Types of Composite Manhole Covers

Composite Manholes	Composition	Advantages	Disadvantages
Fibre Reinforced Plastic	Made of unsaturated polyester resin, glass fibre, quartz and different types of additives.	Good surface. Wear-resistant and have a very high load-bearing capacity.	Fast but complex manufacturing process.
Bulk Moulding Compounds (BMC)	Made of unsaturated polyester resins, glass fibres, calcium carbonate, trays and steel rods.	Simple and inexpensive manufacturing process. Smooth surface and uniform colour similar to plastic.	Low load ability. Susceptible to friction.
Sheet Moulding Compounds (SMC)	Made of unsaturated polyester resins, glass fibres, calcium carbonate, trays and a few additives.	Better load carrying capacity than BMC.	Manufacturing process more complex and expensive than BMC. Susceptible to friction.

To decide which composite manhole option is better for the different areas of Thimphu, the following factors need to be considered:

- Available suppliers: there are FRP manhole suppliers in India.
- Load bearing capacity required in different areas of application: pedestrian areas, driveways, main roads and heavy-duty areas.
- Cover size, type of cover (solid top or recessed) and type of seal required.
- Desired appearance.

In addition to using composite manholes covers, supplementary measures could be taken to reduce thefts, such as:

- Engage with local scraps shops, setting up procedures which can help identify and report thefts.
- Place locks in the traditional manhole covers.
- Awareness campaigns of the public risks of removing manholes covers.

Engagement with scrap shops is the most cost-effective method of reducing manhole cover thefts. Procedures which include customer identification for manhole cover scrappage and delayed payments will help deter thefts at significantly lower costs than replacement of covers.

5.7.3 Solid Waste Entry

Blockages in the wastewater network are an issue throughout the city. Different types of complementary measures could be taken to prevent frequent blockages that affect the operation and maintenance of the system, as summarised in Table 48. The most sustainable and less intrusive approach is to combine behavioural change campaigns for the population with adequate provision of solid waste management and regular monitoring of the network to identify and promptly address blockages.

Other infrastructure measures could be taken; however, they would be more intrusive and less likely to succeed than behavioural change and solid waste management. For example, interception chambers that capture solids could be added to the network. This measure would require significant investment and regular maintenance.

Physical measures could be also taken at property level to prevent the entrance of solids to the wastewater system. Wastewater from new developments could be passed through septic tanks, interceptors chamber, or screens, which would allow unwanted solids to settle to the bottom preventing them to enter the wastewater network. This type of measure would require maintenance to remove the sludge and unwanted solids from the chamber.

The responsible entity for doing the maintenance would need to be agreed between the municipality and the property owners.

Table 48: Solid Waste Entry Interventions

Type of Interventions	Key points	Suitability
Behavioural Change Campaigns	Long term sustainable if well developed and implemented. Opportunity to understand challenges and needs of the citizens. Change will not be seen immediately. Need adequate solid waste management to be successful.	Preferred Option
Solid Waste Management	Long term sustainable if well developed and implemented. Change will not be seen immediately. Need behavioural change campaigns to be successful.	Preferred Option
Regular Monitoring of the Network through SCADA	Requires construction works. It is a complementary measure. It will not solve the problem of blockages but support the effective maintenance of the network.	Less Suitable
Interceptor Chambers	Requires significant construction works. Required regular maintenance. Can provide immediate solution but will not be sustainable without behaviour change.	Less Suitable
Wastewater screens	Located at pumps stations. Required regular maintenance. Mechanical cleaning needed in locations with no permanent on-site technician. Can provide immediate solution but will not be sustainable without behaviour change.	Less Suitable
Septic Tanks in New Developments	Required regular maintenance from property owners. Can provide immediate solution but will not be sustainable without behaviour change. No aligned with the objectives of the Wastewater Masterplan of reducing septic tanks in town.	Not Suitable

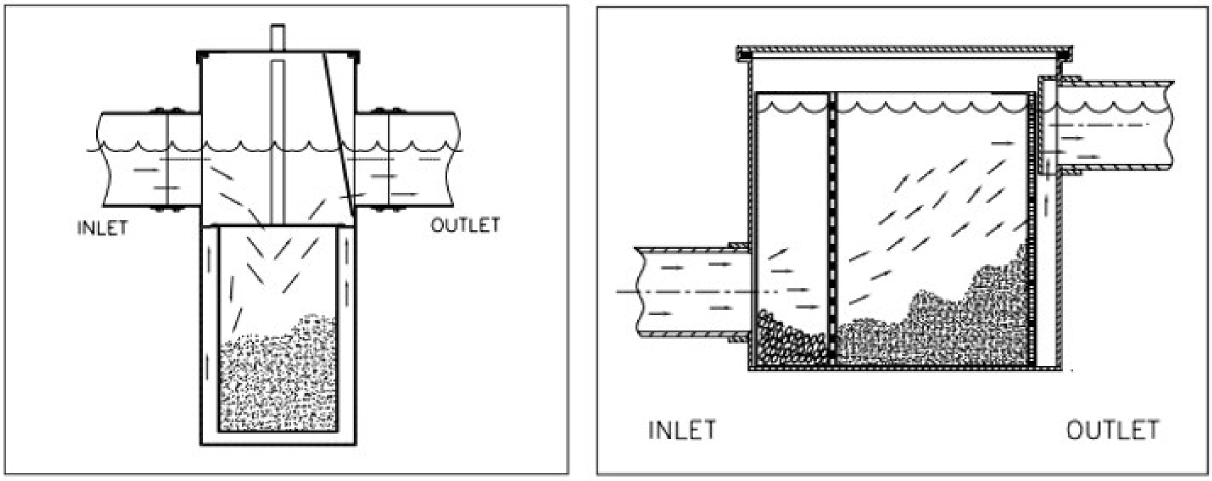


Figure 5-17: Example Diagrams of Interceptor Chambers (Source: Zurn)

Figure 5-18: Example Wastewater Screen (Source: JWC Environmental)

Behavioural Change Campaigns

Behavioural change campaigns should be developed to raise awareness among the population on the importance of adequate solid waste disposal and on how disruption on the wastewater network operation affects the citizens and pose a risk to the public health. These campaigns could include communication materials to discourage solid waste disposal in toilets and drains and promote the use of solid waste points in the neighbourhoods. Community groups should also be engaged in the campaign to promote good practices and encourage behaviour change through Champions across the community.

Provision of Solid Waste Management

Solid waste disposal areas should be available in each neighbourhood to allow community to adequately disposed their solid waste. They should be in an accessible and safe location. Community preference should be considered in terms of frequency and timing of waste collection when establishing the solid management system. Refer to TSP Solid Waste for recommendations on solid waste management.

5.7.4 Wastewater Reuse for Irrigation

There is a significant opportunity to use wastewater effluent from WWTPs for irrigation of surrounding agricultural and green spaces, particularly for proposed WWTPs in Hejo and Rama. There are numerous benefits for reusing the wastewater:

- The WWTPs provide a reliable supply of water. In a water scarce environment, particularly during the dry winter season, supplies can be supplemented by the consistent flow of effluent from the WWTP.
- The wastewater can act as a fertiliser due to higher nitrogen content. This reduces the cost of importing and spreading fertilisers.
- With less effluent discharging to natural watercourses, background water quality will improve.

Environmental impacts, public health impacts and economic impacts all need to be considered in detail before implementing any wastewater reuse initiatives.

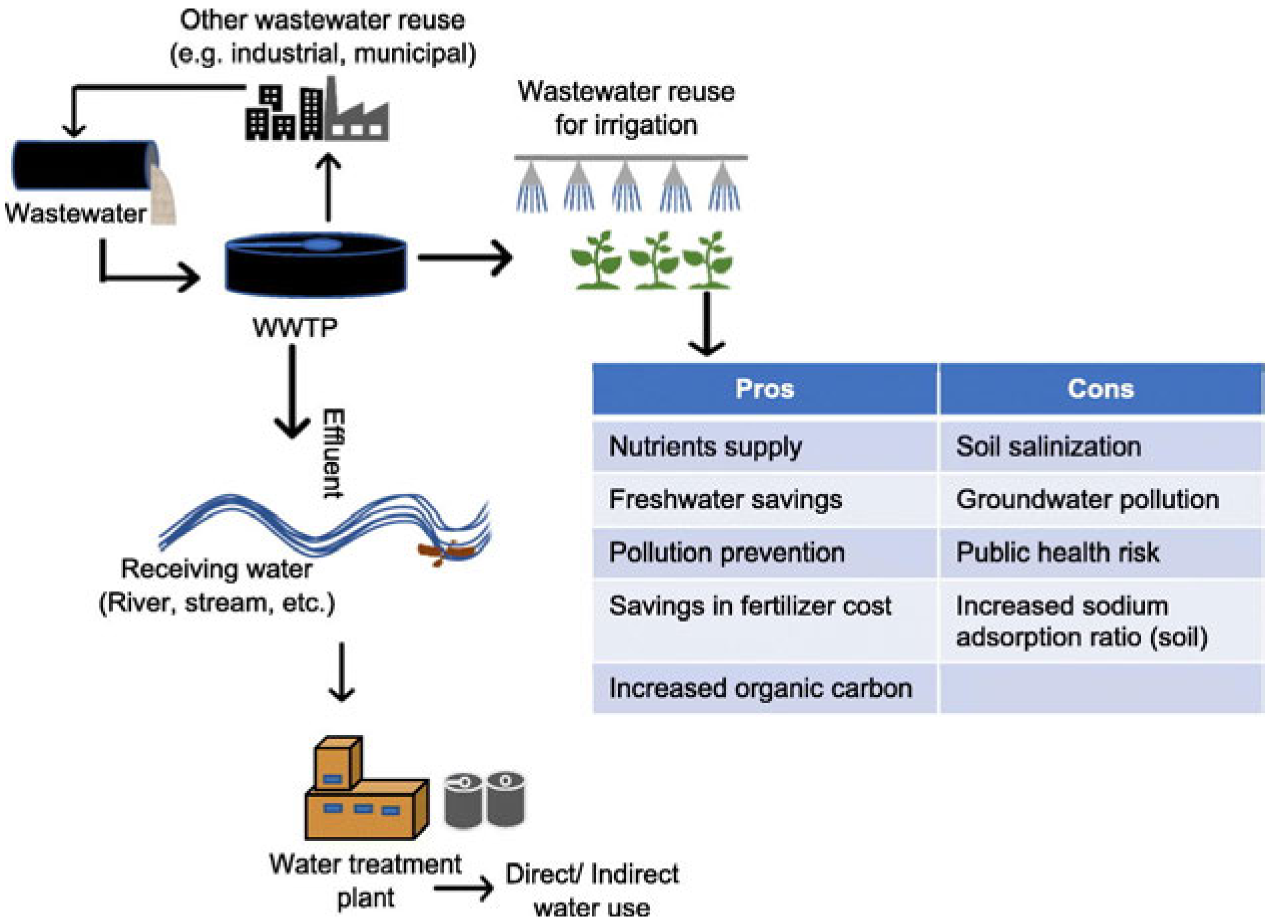


Figure 5-19: Pros and Cons of Wastewater for Irrigation (Ofori, 2021)

5.8 Wastewater Assumptions, Validation and Risks

The preparation of the Wastewater Masterplan involved numerous assumptions particularly in relation to wastewater flows, and to a lesser extent network infrastructure. In light of the limited field data available for validation and the assumptions made during the development of the hydraulic model for the wastewater network, it is essential to acknowledge the potential risks associated with implementing the proposed recommendations without validating these assumptions. The accuracy and reliability of the model results are contingent upon the accuracy of the assumptions made. Relying solely on uncalibrated model results introduces uncertainties and compromises the confidence in the correctness of all recommended improvement works.

Implementing the recommendations without proper validation may lead to unforeseen discrepancies between the model predictions and the actual behaviour of the wastewater system.

There are several risks associated with implementing the recommendations in this Masterplan without proper validation. These include:

- Inaccurate performance predictions
- Suboptimal or ineffective improvements that fail to address issues within the network
- Inefficient resource and investment allocation
- Increased public health and environmental risks
- Public and stakeholder dissatisfaction if the recommended improvement works do not deliver on the expected outcomes

Therefore, it is strongly advised to prioritise efforts towards data collection and validation in to enhance the accuracy and reliability of the hydraulic model, enabling more informed decision-making and reducing the potential risks associated with unvalidated assumptions.

5.9 Wastewater Masterplan Summary

Table 49 shows a summary of the proposed wastewater works and how they contribute to achieving the objectives of the Wastewater Masterplan. Note that these works are based on several assumptions which should be validated before committing to any major capital expenditure.

Table 49: Wastewater Masterplan Summary

		Objectives			
		Protect the environment and public health.	Wastewater services shall be provided for all residents.	All wastewater is treated prior to discharge.	System operated economically and efficiently.
Proposed Works	Minor upgrades to Dechencholing, Taba, Jungshina and Babesa WWTPs to meet proposed treatment standards for flows up to 2032 scenario.	✓		✓	
	Beyond 2032, major upgrades would be required at each WWTP. To ensure the wastewater system operates efficiently and economically, a new 6MLD centralised WWTP is proposed at Hejo to serve the Northern Suburbs. This would result in decommissioning of to Dechencholing, Taba, Jungshina, Hejo and Langjophaka WWTPs.	✓	✓	✓	✓
	A new trunk main (~5.5km) is required to convey wastewater from the northern suburbs to the new WWTP. There are opportunities to reuse sections of existing trunk main where capacity exists. A new Wastewater Pump Station is required on this route to convey wastewater from Dechencholing to Taba. A smaller pump station is also required to convey wastewater from Langjophaka to Hejo.	✓	✓	✓	✓
	The wastewater network in Central Thimphu shall be reconfigured to combine the Lungtenzampa and Babesa catchments. Lungtenzampa WWTP can then be decommissioned. A new pump station will be required at Lungtenzampa.	✓	✓	✓	✓
	Wastewater trunk network should be extended to Kabesa, the Royal Bhutan Army and Depsi to serve developments in these areas.		✓		
	Sections of the existing trunk network are undersized for future design flows and should be upgraded accordingly. Approximately 6km of upgrades are proposed. These works are generally located in the city centre and Olakha.	✓			
	Babesa WWTP should be upgraded to 18MLD in line with population growth in the catchment.	✓	✓	✓	
	A new NBS WWTP is proposed to serve the Southern Extension in Depsi and Rama.	✓	✓	✓	✓
	A coordinated approach to FSM is proposed across all WWTPs whereby thickening and dewatering is undertaken at each WWTP, then transferred to Babesa WWTP for final treatment and processing to enable Waste to Energy usage.	✓			✓
	Treated wastewater from proposed WWTPs at Hejo and Rama should be considered for reuse in irrigation of surrounding park and agricultural areas.	✓			✓
	Separation of wastewater and stormwater.	✓		✓	✓

6. Stormwater Masterplan

6.1 Existing System

The Wang Chhu runs through the heart of Thimphu, forming part of the wider Wang Chhu catchment which includes Paro and Haa valleys. The many tributaries of the Wang Chhu flow from adjacent Himalayan peaks to define the topographical condition of Thimphu Valley. The Wang Chhu is the primary river which flows through Thimphu Thromde. Numerous tributaries join the Wang Chhu, collecting stormwater run-off from developed areas through a network of open and closed drains, which are primarily made of concrete. Key issues identified include:

- Several of these natural watercourses are culverted along parts of their length.
- Utilities are often laid through stormwater drains which reduce the capacity of the drains and increase the risk of damage to the utilities.
- There is no stormwater treatment which results in poor water quality.

6.2 Stormwater Strategies

The stormwater strategies of this Masterplan focus on improving water quality of run-off during rainfall events and proposing natural drainage systems throughout the city to enhance amenity and biodiversity. The Integrated Stormwater Management Plan (ISWMP, 2020) examined the hydraulic performance of the stormwater infrastructure and therefore is not within the scope of this Masterplan.

Creating green infrastructure and sustainable/natural drainage solutions requires an integrated approach between the Water and Landscape teams. Several areas throughout the city were identified for enhancing green-blue infrastructure and creating new open spaces for public use. Incorporating sustainable/natural drainage solutions into these areas is ideal for treating stormwater run-off from the surrounding urban catchments and improving downstream water quality.

The existing stormwater drainage network is dominated by concrete channels which fail to contribute any benefits with regards to water quality or biodiversity. There is a significant opportunity to introduce nature-based solutions in the form of re-naturalised “green streams”, swales and raingardens which will enhance water quality and biodiversity within the city.

Table 50 shows the relationship between the different strategies and the objectives they help to achieve, as outlined in Section 1.3.The following strategies were developed through consultations with stakeholders to meet the objectives of the Masterplan:

- Integrate SuDS features into public streets to reduce run-off rates, provide treatment and attenuation of run-off and enhance biodiversity in public spaces.
- Incorporate SuDS into all new developments to reduce run-off rates, provide treatment and attenuation of run-off and enhance biodiversity within new residential sites.
- Existing culverted streams running through the city should be opened and restored to more natural conditions.
- Divert existing utilities currently in stormwater drains to protect the utilities and reduce blockage risks.
- Solid waste management strategy to reduce dumping in stormwater drains which cause blockages and impact water quality.

Table 50: Stormwater Objectives and Strategies Matrix

		Objectives					
		Improve the water quality of stormwater run-off.	Reduce stormwater run-off rates.	Enhance amenity and biodiversity benefits of stormwater infrastructure.	Improve the water quality of natural watercourses.	Re-naturalise existing culverted streams.	Reduce flood risk from pluvial events.
Strategies	Integrate SuDS features into public streets	✓	✓	✓	✓		✓
	Incorporate SuDS into all new developments	✓	✓	✓	✓		✓
	Daylighting culverted streams along transport corridors			✓	✓	✓	
	Divert existing utilities in stormwater drains				✓		✓
	Solid Waste Management	✓			✓		✓

6.3 SuDS Initiatives

Provision of new SuDS measures is applicable throughout Thimphu Thromde. Rather than individual stormwater projects, SuDS design should form part of all redevelopment work, from upgrades to transport corridors, enhancement of public realm, development new public and private residential and commercial sites, and integrated with the Green Infrastructure and Open Spaces strategy.

As part of this Masterplan, various land topologies for Thimphu were examined and designs developed to incorporate multiple SuDS measures for these spaces. These include:

- City Centre Street (Norzin Lam)
- Urban Park (Changzamtog Park)
- New Residential Development

The designs examined the drainage routes around each area, taking cognisance of various design objectives, including:

- Maximising SuDS features throughout the site.
- Catering for gradients resulting from existing and proposed levels across and around the site, avoiding excessively shallow and/or steep falls in pipes.
- Integrating with the proposals for daylighting the existing culverted streams.
- Integrating with the strategy for service roads, corridors throughout the site and landscape strategy.

This design was developed taking into consideration the ability to overcome topographical and dimensional constraints associated to the proposed scenario and to be able to connect within the existing stormwater network and current streams when this is necessary. Given the emphasis on SuDS, along with the main drainage system. The networks typically comprise:

- The main stormwater drainage network
- Filter trenches and/or swales

- Road drains (i.e., slot or channel drains)
- Rain gardens with network connections
- Permeable pavements

6.3.1 City Centre Street – Norzin Lam

Norzin Lam is the main street in Thimphu City Centre, running 1.4km from Lungtenzampa Bridge to Bhutan Textile Museum. The street is one of the primary thoroughfares in the city and features a blend of commercial properties, shops restaurants and other amenities. As part of the emerging Transport strategy, pedestrianisation or reduced vehicle access is proposed for Norzin Lam as priority project. This will involve a significant redevelopment of the street, improving pedestrian infrastructure and enhancing public realm. For this reason, it was selected in this Masterplan as an example for SuDS enhancement.

A typical plan cross-section for the developed Norzin Lam is shown in Figure 6-1. Along with the ample provision of SuDS features, this proposal consists of two clear routes for run-off coming from both, the private and public realm. This clear outfall route from the private blocks enables development controls to be established, such as flow limitations. These can be easily defined, such as control and monitoring through the Green Roof down pipes with a splash block to prevent erosion on the public footway prior to discharge either on a tree pit system or public pathway.

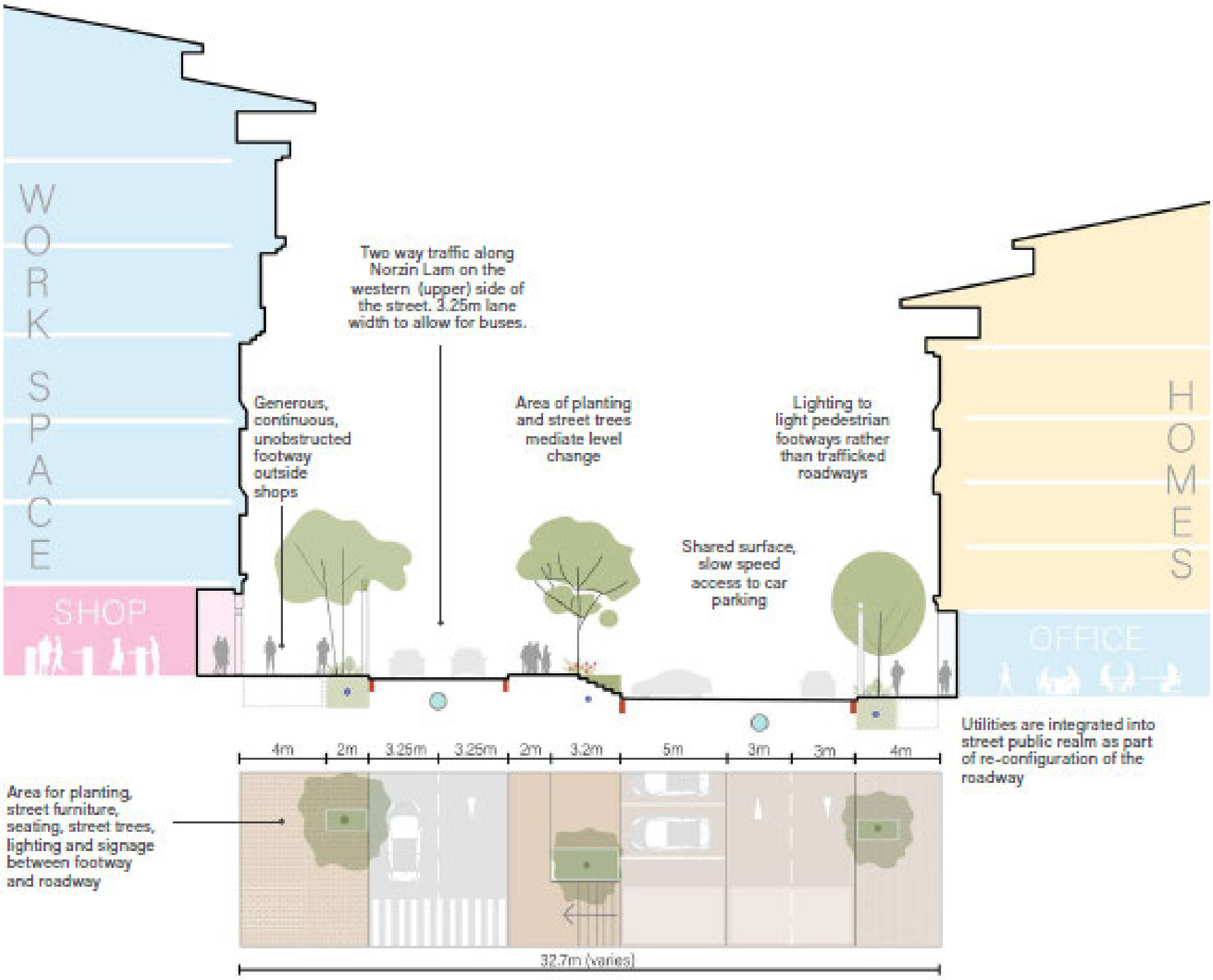


Figure 6-1: Cross-section for Norzin Lam (Northern Section)

The stages involved in development of the roadway SuDS are described further below.

The design guideline in Figure 6-1 is the arrangement for the main public streets, for the other streets such as secondary streets in residential areas or laneways, an alternative arrangement is provided in the TSP. Additional drainage features in the secondary streets consists of porous pavements with water collected in perforated lateral drainage pipes connecting into the main surface water network at the junction with the main public roads.

Run-off from Road

Figure 6-2 shows a potential layout for a SuDS design along a section of Norzin Lam. The proposed design incorporates permeable paving, tree pits, swales, hydrocarbon filters, silt traps and a new stormwater carrier drain. Run-off from the road will pass through a series of these SuDS features which provide water treatment, water storage and/or biodiversity benefits before discharging to the main carrier drain and onward to a nearby urban stream.

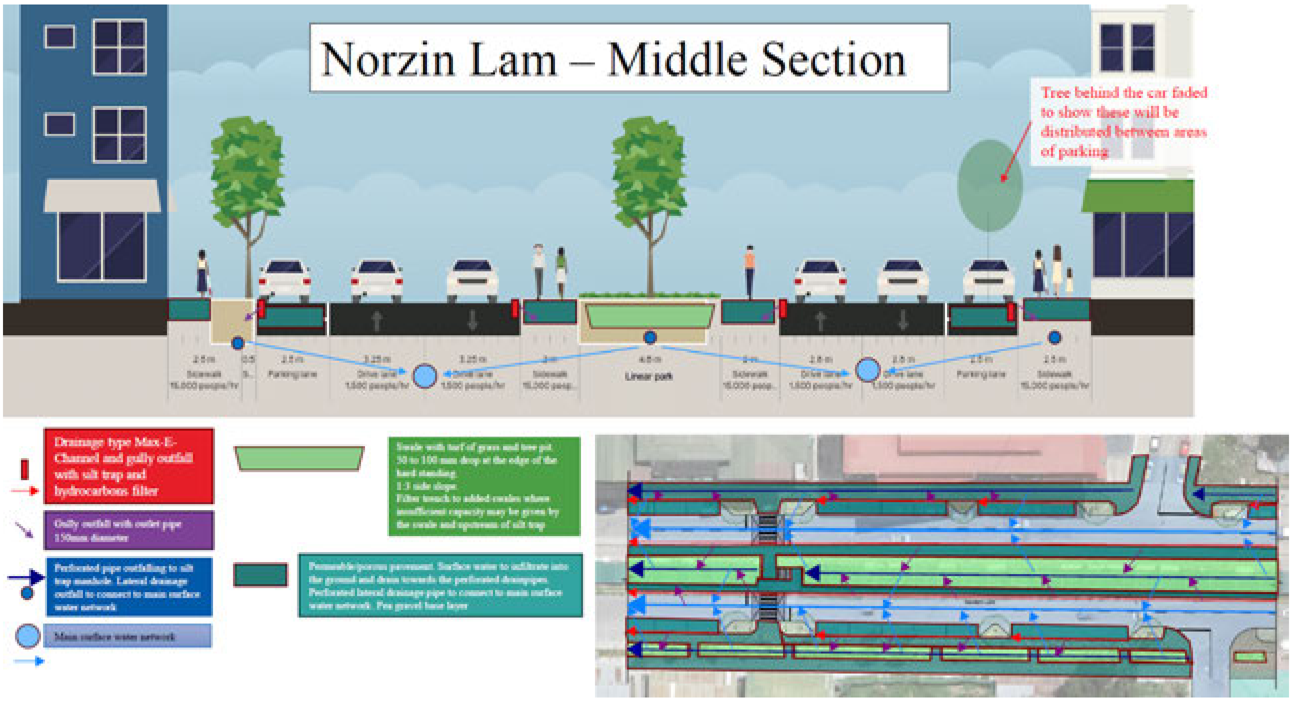


Figure 6-2: Norzin Lam Street Section Plan with SuDS Infrastructure Management Plan

Figure 6-3 shows the flow path and connection details between the different elements.

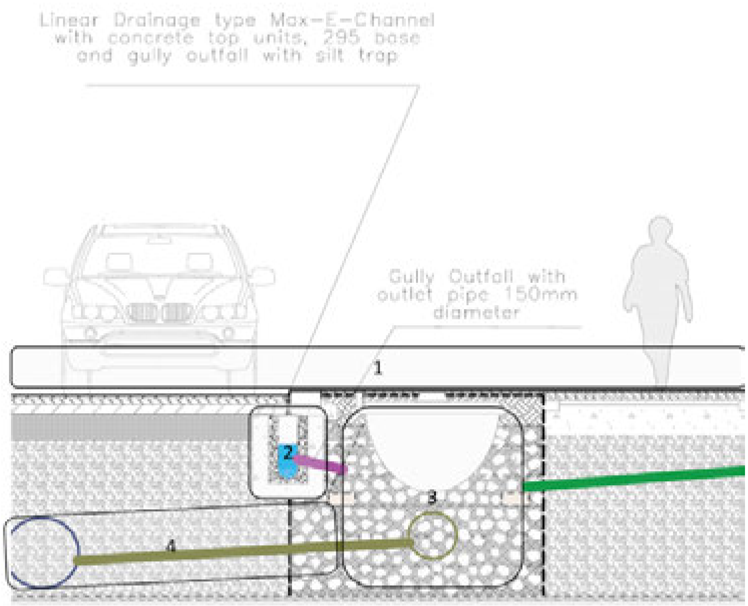


Figure 6-3: Proposed Run-off Route from Main Public Roads

Considerations for handling run-off from public roads include:

- Run-off from impermeable roadway and footpaths will fall to roadside drainage; (1)
- This water will be collected in linear drainage channels, with oversized attenuating channels and petrol interceptors/hydrocarbons filter providing a level of water treatment; (2)
- Water will pass via 150mm outlet to attenuating tree pit (generally continuous trench under public realm surfacing with opening for planting), including perforated pipe out falling to silt trap manhole (3); and
- Final connection will be a lateral drainage outfall to main surface water under the roadway. (4)

Examples of the various SuDS features are depicted in Figure 6-4.

Figure 6-4: Examples of Additional SuDS depicted Clockwise from Top Left: Permeable/Porous Pavement; Perforated Lateral Drain; Swale; and Filter Trench

Considerations for SuDS features include:

- Run-off from permeable/porous pavement (footpaths or parking bays), where surface water will infiltrate into the ground and drain towards a perforated drainpipe.
- Perforated lateral drainage pipe laying down in a pea gravel base layer, will collect water with oversize attenuating channels and petrol interceptors/hydrocarbons filter, which will connect to main surface water network.

- In case of a Linear Park existence/opportunity, SuDS in a swale type will be designed. This swale will consist in a turf of grass and tree pit system, with a 50-100mm drop at the edge of the hardstanding and 1V:3H side slope to allow surface water run-off to connect with.
- Filter trench will be designed where insufficient capacity may be given by the swale and upstream of silt trap.

The design shown for Norzin Lam includes a minimum of two stages of water treatment prior to discharge into the surface water network.

Run-off from Adjacent Buildings
Run-off from adjacent buildings will also need to be considered as part of the redevelopment. For new buildings, developers will be responsible to design a rainfall run-off strategy to tie in the Private Blocks generated surface water run-off volumes within the proposed current plan strategy according to Bhutan and Thimphu local policies and regulations. Current design standards will need to be updated to require stormwater design in line with International Best Practice.

An example design for building run-off is described below and depicted in Figure 6-5.

- Water will be brought from green and hard roof areas (percentage of green roof to be further evaluated) via downpipes, with the opportunity to provide downstream defenders (e.g., splash blocks); (1)
- Roof run-off will gather in a planted bio-retention areas made up of topsoil and pea gravel (still within private development zone); (2)
- Water will be passed via carrier drain to attenuating tree pit and be gathered with run-off from public realm. This stage presents the opportunity for development controls to be placed on private blocks; and (3)
- Final connection will be a lateral drainage outfall to the main surface water network under the roadway (4).

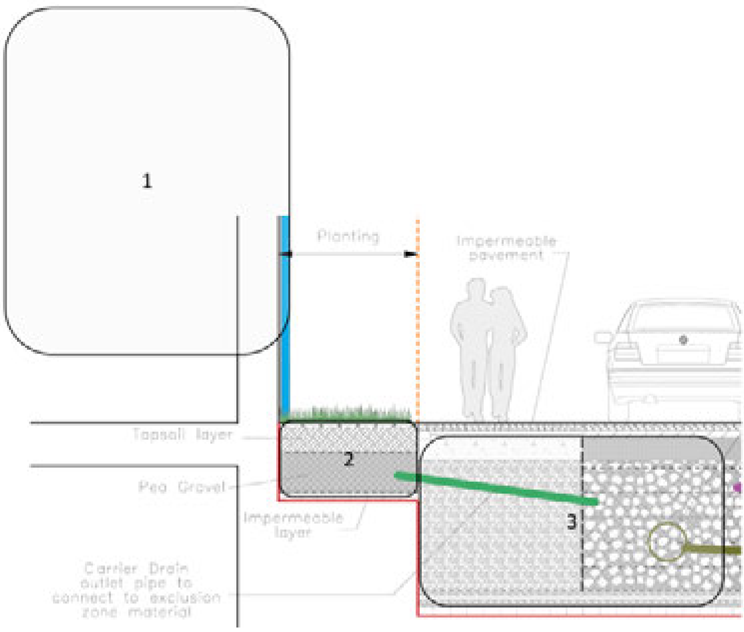


Figure 6-5: Stormwater Drainage Design from Road Adjacent Buildings

This proposal includes a minimum of two stages of water treatment prior to discharge into the surface water network.

6.3.2 Urban Park

Parks are and will be part of a network to provide the opportunity to bring people nature and water together, through accessible public space amenity for everyday use. Parks are at important locations to help to maximise rainwater attenuation through suitable locations for SuDS along drainage corridors.

A concept design for Changzamtog Park was developed as part of the *Green Infrastructure Masterplan* (see Figure 6-6), to show the overall design intent and provide direction for other park designs.

The concept design includes representative general surface water management strategies which should be considered in all parks throughout Thimphu and its peripheral areas. The concept design includes features to deliver high quality and accessible green infrastructure, manage pressures of continued urban growth and achieve sustainable and resilient urban development.

The strategy contemplates the improvement of the surface water quality and turbidity thresholds, by providing different levels of treatments through the different SuDS proposed and the improvement of the temporary storage capacity.

Best-practice park design embeds regenerative and resilient design, with principles of water treatment, storage and reuse as part of an integrated SuDS strategy by opening up potential existing stormwater drains to deliver new SuDS structures (bio swales, filter trenches, stream corridors, wetlands) which can clean, filter and attenuate the existing surface run-off.

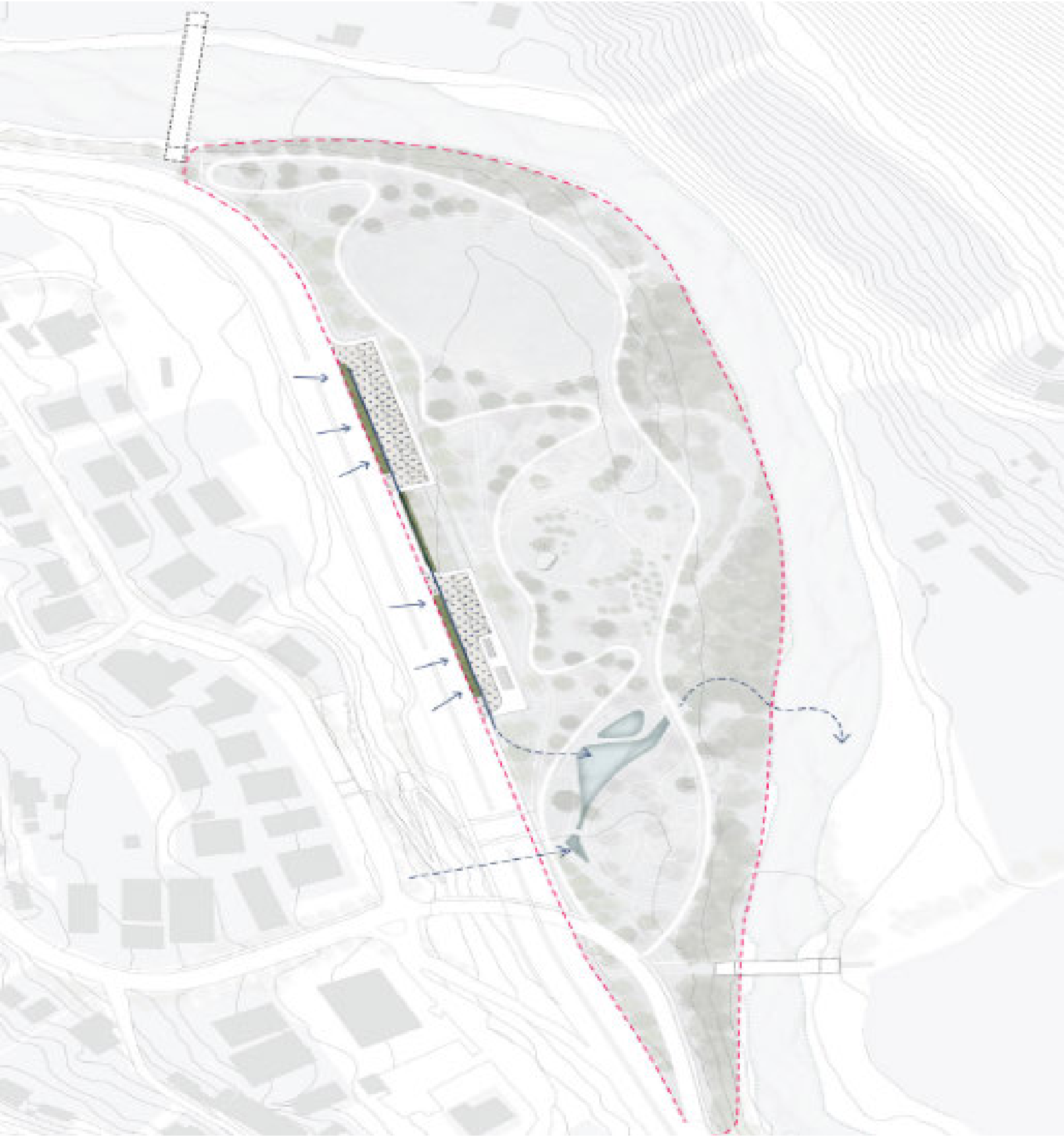


Figure 6-6: Changzamtog Park Concept Design

Stormwater drainage design in parks need to manage internal surface run-off from the park itself and should also provide stormwater management for surrounding streets in the upstream catchment.

Run-off from Main Public Roads and Parking Bays

The proposed route for run-off from the main roadways and parking bays towards the neighbourhood parks is as follows:

- Run-off from impermeable roadway and footpaths will fall to roadside drainage.
- This water will be collected in linear drainage channels, with oversized attenuating channels and petrol interceptors/hydrocarbons filter providing the first level of water treatment.
- Water will pass via 150mm outlet (typical diameter as water is attenuated) to attenuating swale plus tree pit system, including perforated pipe out falling to silt trap manhole providing a secondary level of treatment.
- In case of a higher volume, the run-off not falling to roadside drainages will be directed into a bio-swale with tree pits system acting as a temporary flood barrier attenuating the run-off exceedance and allow infiltration towards the perforated pipe providing a primary level of treatment by infiltration.
- Parking bays and low traffic streets should be designed with permeable/porous pavement, where surface water will infiltrate into the ground and drain towards a perforated drainpipe.
- At the edge of the parking bays, a rain garden or swale should be designed to control the surface run-off exceedance into the SuDS system. This swale will consist in a turf of grass and tree pit system, with a 50-100mm drop at the edge of the permeable/porous pavement and 1V:3H side slope to allow surface water run-off to connect with the swale.
- Perforated lateral drainage pipe laying down in a pea gravel base layer, will collect water with oversize attenuating channels and petrol interceptors/hydrocarbons filter providing a level of water treatment, which will connect to a main filter trench.
- The final filter trench will outfall into a silt trap before this connects to the park swales system.

This design includes a minimum of two stages of water treatment prior to discharge into the park swales system network.

Run-off Generated within the Park

Parks will be part of a network to provide the opportunity to bring people nature and water together, therefore, some key design components will have a direct impact of surface water run-off management. The most important components will be:

- Jogging and walking tracks and associated filter trenches;
- Permeable paving (to be used for park maintenance tasks) and associated rain gardens;
- Bio-swales; and
- Wetlands.

Park surface run-off management strategy designs will be highly influenced by the topography and the final contour levels as these will define the natural flow routes generated within the site and, therefore, the discharging points into the existing streams or surface water networks.

The flow paths to be designed will be intersected either by, the jogging and walking tracks or areas with permeable pavement. These key components have SuDS infrastructures associated to them so the necessary water quality level and turbidity treatment can be guaranteed by infiltration.

Jogging and walking tracks will be associated with a filter trench along these, on either one or both sides of the track. The filter trenches should be offset from the path to form a 300mm to 500mm wide verge between the drain and path edges with a trenching bucket strip off surface vegetation and excavate rectangular trench to the required dimensions, capacity and maximum 6.6% (1:15), or minimum 2% (1:50) gradient to allow sufficient water flow along the drain. Stripped turfs and excavated soil to be landscaped on-site. Figure 6-7 depicts a typical make-up of a filter trench.

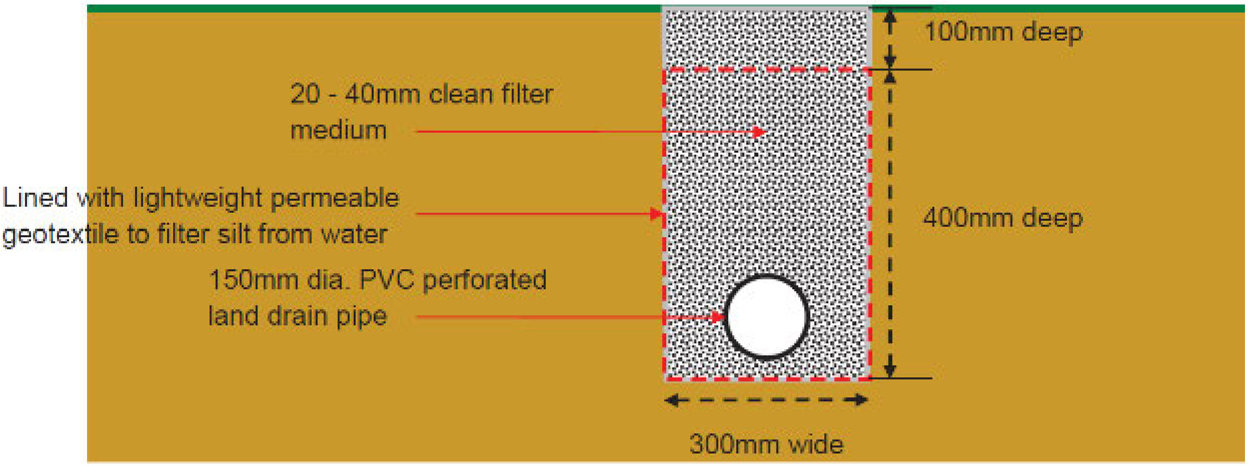


Figure 6-7: Typical Filter Trench Design

The line trench base and sides will be designed with lightweight permeable geotextile, leaving a minimum 300mm overlap at the top of the trench. Laying minimum 50mm depth of filter medium along the trench base. A perforated pipe, with perforations upwards, will be placed along the centre of the trench on the pipe bedding. Backfill pipe and trench with clean filter medium to within 100mm below the edges of the trench – 20mm or 40mm single size aggregate (crushed quarry stone with no fines, clean quarry gravel with no fines) or alternative material (clean as dug gravel with no fines, clean crushed concrete or railway ballast with no fines, rubber shreds).

The line trench would need an overlap geotextile sheets and to backfill the remaining 100mm depth of trench with filter medium to finish stone level with surrounding ground levels if surface water is to be intercepted. If only sub surface water is to be intercepted, then the trench can cover the top of the filter medium with available turfs won from trench excavation works.

Permeable paving will be located in specific areas where park maintenance tasks vehicles need to be placed or access. These parking bays will infiltrate into the ground and drain towards a perforated drainpipe. At the edge of the parking bays, rain gardens should control the surface run-off exceedance into the downstream SuDS components. This rain garden will consist in a turf of grass and local vegetation, with a 50-100mm drop at the edge of the permeable/porous pavement and 1V:3H side slope to allow surface water run-off to connect the permeable pavement to the swale.

Both, filter trenches and rain gardens should have a perforated lateral drainage pipe laying down in a pea gravel base layer, collecting the infiltrated water run-off. The filter trench will outfall into a silt trap before this connect to the park swales or wetland systems.

This design includes a minimum of two stages of water treatment prior to discharge into the park swales system network.

The swales and wetlands will provide a major temporary attenuation impact along with an extra water quality treatment, prior to discharge by the natural terrain slope, to the existing stream.

6.3.3 Major Residential Redevelopment Sites

As described in Section 6.3.1, run-off from development blocks will connect to the main drainage network via carrier drains, giving the opportunity to manage and monitor flows entering the public system from private blocks.

To assess the potential flows, which could be expected from private blocks, an initial modelling exercise should be carried out as the design develops on an example plot taking into consideration its size and the length of the proposed route from the block to the discharge point.

The rationale behind choosing a specific block is to be able to assess a critical block is that if the strategy could be developed to cater for this specific block, then it would provide confidence that the strategy could be applied to the blocks across the site, as well as establishing parameters for invert levels along the drainage routes. This specific block could also be used to test the impact of various development controls as well as any other residential redevelopment.

Along with controlling flows, SuDS measures shall be incorporated into the development to ensure sufficient pollution mitigation is provided for any given land use in accordance with Construction Industry Research and Information Association (CIRIA) C753, which is generally accepted as international best practice for SuDS design.

Run-off from Residential Redevelopment and Private Blocks

Figure 6-8 shows an example drainage design for a typical two by four-block residential development, similar to the Case Study design depicted in the TSP.

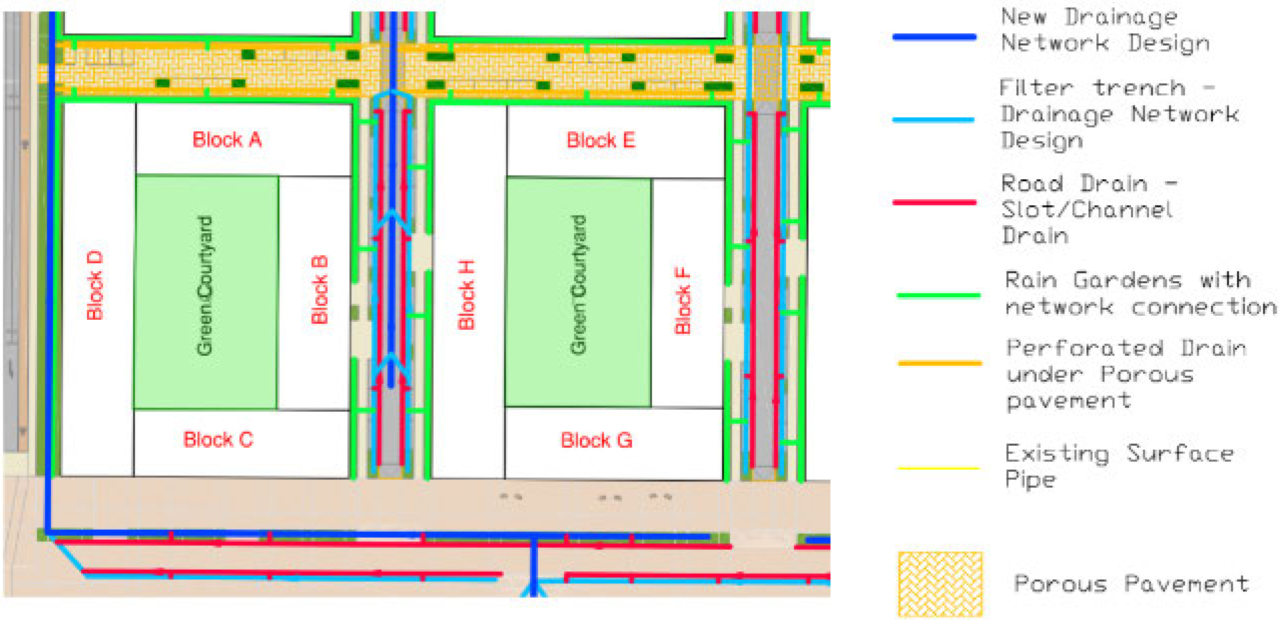


Figure 6-8: Block Section Plan for SuDS Infrastructure Management Plan

The SuDS design for such development involves the following:

- Water will be brought from green and hard roof areas (percentage of green roof still to be decided in local legislation) via downpipes, with the opportunity to provide downstream defenders (e.g., splash blocks).
- Rainwater harvesting can be incorporated for local irrigation.
- Roof run-off will gather in a planted bio-retention area made up of topsoil and pea gravel (still within private development zone).
- Water will be passed via carrier drain to attenuating tree pit (generally continuous trench under public realm surfacing with opening for planting), including perforated pipe out falling to silt trap manhole and be gathered with run-off from public realm. This stage presents the opportunity for development controls to be placed on private blocks.
- Final connection will be a lateral drainage outfall to main surface water network under the roadway.
- Run-off from permeable/porous pavement (footpaths), where surface water will infiltrate into the ground and drain towards a perforated drainpipe.
- Perforated lateral drainage pipe laying down in a pea gravel base layer, will collect water with oversized attenuating channels and petrol interceptors/hydrocarbons filter providing a level of water treatment, which will connect to the main surface water network.
- In case of a Linear Park existence or opportunity, a SuDS in a swale type or temporary storage pond will be designed.

- This swale will consist in a turf of grass and tree pit system, with a 50-100mm drop at the edge of the hardstanding and 1V:3H side slope to allow surface water run-off to connect with the swale.
- Filter trench will be designed where insufficient capacity may be given by the swale and upstream of silt trap.
- For some of the larger blocks it may not be feasible to provide the required level of attenuation (which is established during the design stage based on the generated volume) within the bounds of the block, given potential geometric constraints due to network capacity. This might generate an opportunity to design an attenuation area between blocks where SuDS (swales, park temporary storage ponds, multipurpose temporary flood squares, etc.) could be implemented if the space allows.

6.4 Proposed Interventions for Stream Corridors

As urban areas are developed, with roadways, parking bays and buildings, waterways are sometimes redirected, covered in impervious material and/or buried in pipes, culverts, or a drainage system to create a more buildable surface area. Unfortunately, burying or covering rivers has the unintended consequences of increasing nutrient pollution, degrading habitats and increasing downstream flooding.

Daylighting rivers or streams is the process of removing obstructions (such as concrete or pavement) which are covering a river or drainage way and restoring them to their previous condition. Daylighting removes these artificial impediments and re-establishes rivers within their original channels where possible or, where development is in the way, creates a new channel for the waterway. The resulting restored river or stream provides stormwater benefits as well as numerous aesthetic, economic and environmental co-benefits.

The process of daylighting a river or stream will increase the area available for water to pass through the channel, increasing storage capacity which reduces peak flows and increases flow duration. This helps to reduce downstream flooding. Localised flooding may also be reduced by eliminating choke points where streams were forced into underground channels.

When rivers and streams are unearthed, they transform from liabilities into assets. An attractive stream creates a neighbourhood amenity that provides opportunities for recreation, physical activity, increases property values and can trigger revitalization within the surrounding area.

Open streams, especially small streams, are highly effective in removing pollution. They encourage the transformation of excessive nutrients such as nitrogen and phosphorus, which improves habitats for fish and other wildlife (which leads to more additional recreational opportunities). Humans can also benefit directly from higher drinking water quality abstracted from downstream.

While open rivers and streams provide direct floodwater storage, they also contribute to more effective stormwater management by diverting stormwater from the sewage system. Long-term costs are also less than those needed to repair and maintain culverts and other storm structures, resulting in fiscal benefits for local government.

To facilitate urban growth in Thimphu City Centre, several small streams which run through the city were culverted. These streams are now generally hidden and forgotten by society and are becoming environmental hazards due to dumping of litter and discharge of untreated wastewater.

There are several existing culverted streams running through the City Core, with three of these stream corridors as main target streams for daylighting and re-naturalising as depicted in Figure 6-9.

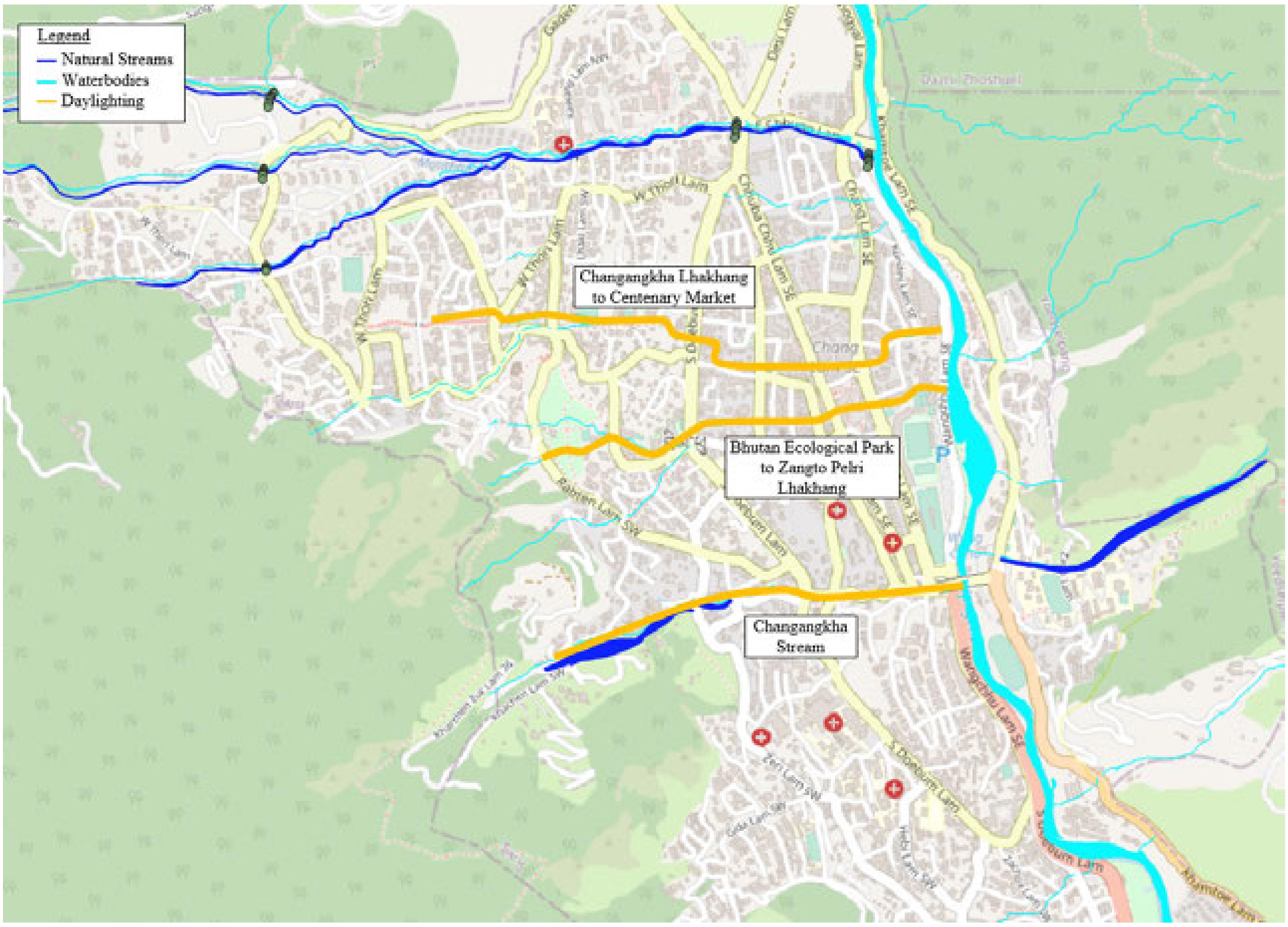


Figure 6-9: Streams for Daylighting

Restoring streams to the surface and creating healthy riparian communities along them creates opportunities for restored wildlife habitat, recreation, groundwater infiltration and greenhouse gas sequestration. Restored streams do not necessarily have to follow their original course, although restoration efforts may be more successful if some semblance of the original topography remains. These will be connected to adjacent water bodies to allow for migration of aquatic organisms and wildlife movement.

There are several technical considerations when undertaking a stream daylighting project. These include the design, performance, water quality objectives, pollutant load and construction logistics. Detailed engineering and hydrology assessments will need to be conducted to determine the appropriate configuration of the daylighted stream given its projected water volume, flow rate and contributing watershed area.

6.5 Stormwater Management for Construction and Operation Activities

The TSP and supporting Masterplans (Water Services, Transport, Open Spaces and Green Infrastructure) aim to enhance the well-being of Thimphu's residents, visitors and its surrounding environment and enable them to thrive in a sustainable manner.

Implementation of the TSP will involve significant construction activities throughout the duration of the plan. Appropriate management of stormwater run-off from construction sites is essential for protecting natural watercourses and aquatic habitats. Construction sites are generally large sources of contaminants, including silt, earthworks sediment, concrete and grout washdown, hydrocarbons, paints and other chemicals.

Table 51 identifies potential sources of contaminants during construction and operation phases along with proposed mitigation measures which should be implemented to prevent negative environmental impacts.

Table 51: Mitigation Measures

Character of Potential Impact	Mitigation Measure
Construction Phase	
Interaction of wash down water from concrete and cementitious material with surface water	All batching and mixing activities will be located in areas away from watercourses and drains. Surface water drainage around the batching plant will be controlled. No hosing into surface water drains of spills of concrete, cement, grout or similar materials. Washout from mixing plant or concrete lorries will be carried out in a designated, contained impermeable area.
Process water used during construction	To be disposed of appropriately.
Surface run-off/rainfall	The existing surface water drainage outfalls will be maintained until the permanent drainage is executed, completed and functioning satisfactorily including its discharge to approved outfalls. Ground profiles and completed hard surfacing will, at all times, be maintained to shed surface water efficiently and directly into the nearest drain and surface water swale where possible.
Discharges to waterbodies	Contractor will ensure to comply with the appropriate legislative requirements: Water Framework Directive 2000/60/EC; European Communities Environmental Objectives (Surface Waters) Regulations 2009 (Statutory Instruments Number 272 of 2009); and European Communities Priority Substances Directive 2008.
De-watering operations and surface run-off discharge	To be controlled and monitored by the contractor. Construction phase mitigation measures were proposed to ensure that significant negative effects on material assets will be avoided, prevented or reduced during the construction of the proposed development.
Groundwater	Groundwater ingress shall be managed during construction to ensure excavations are protected from groundwater flooding.
Generation of effluent and sanitary waste from facilities provided for the work force on-site	Effluent generated on-site from the Contractor's sanitary facilities will be discharged to a holding tank and removed off site by a certified waste removal Contractor(s). Temporary discharge utilising the existing or permitted wastewater network will be in agreement with the Local Authority. All necessary health and safety measures will be undertaken to ensure the safety and welfare of construction personnel, the public and roads users during construction of the wastewater drains.
Water supply	A mains water connection will be required at the construction compounds for staff welfare facilities and other uses associated with the compounds. The water demands during the construction phase on the existing water network are considered to be a slight negative and short-term impact. The contractor will make all necessary arrangements for a temporary water supply.
Impacts on the existing services provided by utility companies and the local authorities, such as electricity, gas, telecommunications and drainage	The Contractor will be obliged to put measures in place to ensure that there are no interruptions to existing services unless this is agreed in advance with the relevant service provider. All works in the vicinity of utilities apparatus will be carried out in ongoing consultation with the relevant utility company or local authority and will be in compliance with any requirements or guidelines they may have. Where new services are proposed, the Contractor will apply to the relevant utility company for a connection permit where appropriate and will adhere to their requirements. Care will be taken to avoid any damage to asbestos cement (AC) watermains when excavating in the vicinity of them. Removal of AC watermains, if required, will be undertaken in accordance with the Safety, Health and Welfare at Work (Exposure to Asbestos) Regulations 2006, as amended and the Safety, Health and Welfare at Work (Construction) Regulations, 2013 by suitably qualified contractors and disposed of in an appropriately licenced waste facility.
Operational Phase	
Road run-off	Maximising design to use of sustainable urban drainage systems to minimise the impact on the surface water system. Excess surface water generated from the proposed works, namely the roads located within the existing sites is to be conveyed through a new sustainable urban drainage system which will provide filtration and storage on site prior to discharge to the existing surface water outfall to the adjacent watercourse. Thus, there will be no impact on the existing surface water drainage network in the vicinity.

Character of Potential Impact	Mitigation Measure
Winter maintenance	Application of salt and grit during icy conditions on the road can adversely affect the ecological balance of the aquatic system and increase the bioavailability of chemical contaminants. Maximising design to use of sustainable urban drainage systems will minimise the impact on the surface water system. Source control is provided by maximising grassed areas and the use of bioretention tree pits, porous pavement/permeable surface, road linear drains and infiltration trenches. These features provide water treatment and infiltration to reduce the amount of water reaching the stormwater network and reduce pollutant loading.
Accidental spillage	Maximising design to use of sustainable urban drainage systems to minimise the impact on the surface water system. Petrol interceptors will be provided to ensure the quality of surface water run-off from the development.
Increase the rate of run-off	Maximising design to use of sustainable urban drainage systems to minimise the impact on the surface water system. Source control is provided by maximising grassed areas and the use of bioretention tree pits, porous pavement/permeable surface, road linear drains and infiltration trenches. These features provide water treatment and infiltration to reduce the amount of water reaching the stormwater network, maximise the infiltration potential of the site and reduce pollutant loading.

6.6 Stormwater Masterplan Summary

The Stormwater Masterplan identifies various measures to enhance water quality of stormwater and natural watercourses in Thimphu.

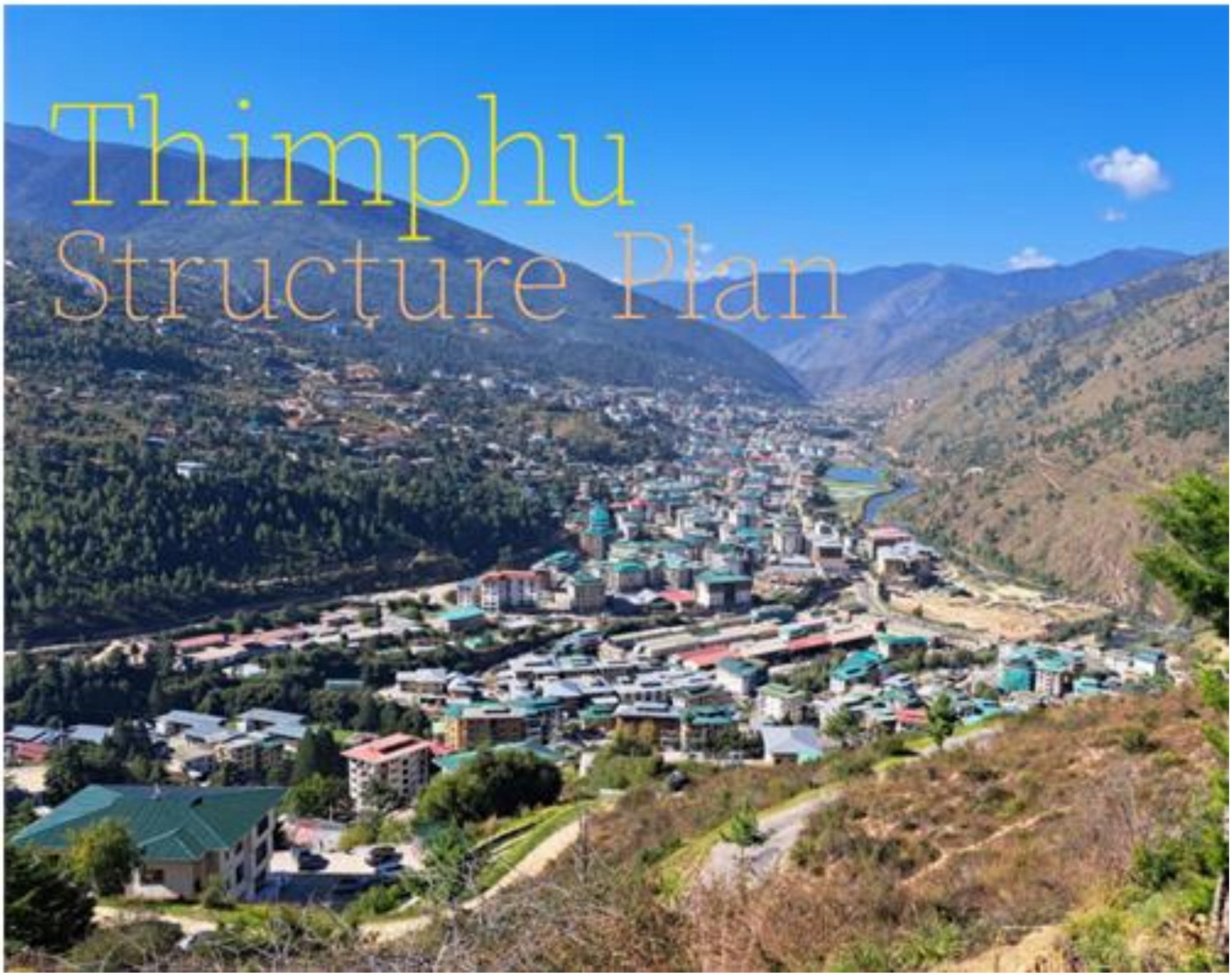
SuDS needs to be implemented as a fundamental design aspect for all developments in Thimphu. Various SuDS design examples are presented for different land typologies – streets, urban buildings, parks and larger residential developments. Each design demonstrates how a series of SuDS features can be interconnected in a “treatment train” to ensure high quality of run-off is discharged to the environment.

Existing urban streams were examined, and proposals developed to daylight and re-naturalise the streams back to their original condition. These proposals were developed in conjunction with the Green Infrastructure and Transport Masterplans to create attractive pedestrian routes into and through the city core, while enhancing amenity, biodiversity and flood risk management.

Climate change is anticipated to increase rainfall intensity and frequency in the region, which would increase runoff rates and thus increase flood risk. It is likely that portions of the existing drainage system will be insufficient to handle the resulting increased flows. Climate change projects should be considered when designing and sizing future drainage systems.

Thimphu Water Services Masterplan

Delivery Plan



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1. Introduction

1.1 Background

Arup are preparing a Water Services Masterplan, in support of the Ministry of Infrastructure and Transport (MoIT) (formerly Ministry of Works and Human Settlement), Thimphu Thromde (TT) and the Royal Commission for Urban Development (RCUD) (the Client Team) in their review of the Thimphu Structure Plan (TSP). The aim of the project is to examine the existing water supply, wastewater and stormwater systems' infrastructure and identify capital improvement projects required to service existing and future development within Thimphu. The Masterplan will run simultaneously with the TSP, providing inputs as required and to inform the TSP. Upon completion, the Masterplan will provide the MoIT and RCUD with a list of recommended concept-level projects at a citywide scale.

1.2 Purpose

This report relates to Phase E of the Thimphu Water Services Masterplan 'Delivery Plan' as shown in Figure 1-1. The report builds on the works undertaken in previous phases, and examines:

- Priority and phasing of interventions
- Capacity of public and private bodies to deliver the works
- Governance structure
- Funding streams

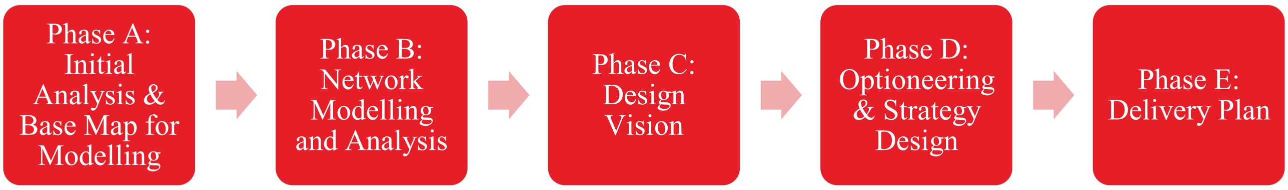


Figure 1-1: Project Phases

This report outlines the proposed Delivery Plan for recommended works as outlined in the Phase D *Water Supply, Wastewater and Stormwater Masterplan*, which was issued in June 2023.

2. Phasing and Prioritisation

The phasing and implementation plan takes the recommended interventions from the *Water Supply, Wastewater and Stormwater Masterplan* strategies and assesses each against different criteria to establish the priority for each intervention. This section describes the Multi-criteria Analysis (MCA) used to prioritise interventions. The estimated timescale for completion of each intervention is also presented.

2.1 Timescale for Implementation

The timescale for implementation of each project is defined as one of four levels as shown in Table 1. The timescale for implementation represents the anticipated amount of time a project will take from inception to completion.

Table 1: Timescale for Implementation

Time Scale	Duration
Quick Win	0-2 years
Short Term	2-5 years
Medium Term	5-10 years
Long Term	10+ years

2.2 Multi-criteria Analysis

The MCA is split into two sections, which are cost and benefit.

Cost

The costs are split into capital cost and operations and maintenance cost with each intervention ranked on both and the value for each ranking tier is shown in Table 2. These are high-level estimates of cost ranges and are subject to detailed design.

Table 2: Cost Ranking for MCA

Rating	Capital Cost ($USD)	Annual Operations + Maintenance Cost ($USD)
Very Low	<500,000	<25,000
Low	500,000 – 1,500,000	25,000 – 50,000
Medium	1,500,000 – 3,000,000	50,000 – 100,000
High	3,000,000 – 5,000,000	100,000 – 200,000
Very High	>5,000,000	>250,000

Benefit

The benefits are also ranked on a five-point scale of very low, low, medium, high and very high. The benefits are across the following three areas:

- Nurture Community – Protect and enhance diverse communities and equitable and healthy neighbourhoods, leading to improvements in the quality of life for city residents.
- Create Opportunity – Short to long-term benefits in economic growth, job creation, livelihoods and worker productivity.
- Cultivate Balance – Create environmental benefits (healthy ecosystems, cleaner air and water), which reduce carbon emissions.

2.3 Priority

The priority for each project determines which implementations should be targeted first to achieve the greatest benefit. This is based on the rating of the three benefits criteria. Each intervention is ranked on a five-point scale as shown in Table 3.

Table 3: Prioritisation Criteria

Rating	Prioritisation
Very Low	Within 20 years
Low	Within 10 years
Medium	Within 5 years
High	Within 2 years
Very High	Immediately

2.4 Phasing and Prioritisation Assessment

The combined project list, MCA and prioritisation is provided in Appendix A.

2.5 Recommended Next Steps

2.5.1 Water Supply

The immediate requirements for the Water Supply System are:

- Reduce Non-revenue Water (NRW).
- Flow and pressure data gathering.

These are required to ensure sustainable, informed decisions are made regarding design of future upgrades to the Water supply system.

The following next steps are recommended:

1. Installation of network flow meters. Indicative locations for 52 flow meters have been identified at the outlet of WTPs, at the outlet of pumps and at the inlet to DMAs.
2. Installation of pressure transducers throughout the network. Indicative locations for 84 pressure transducers (installed directly onto water trunk mains or fire hydrants) have been identified. Pressure transducers should be installed at the maximum and minimum elevations within each DMA.
3. Installation of Pressure Reducing Valves (PRVs). Indicative locations of 30 PRVs have been identified to mitigate very high network pressures.
4. Hydraulic model calibration using gathered flow and pressure data.
5. Implementation of NRW reduction measures as identified in the *Draft Roadmap to NRW Management (25 January 2023).*
6. Extended Period Simulations in the hydraulic model to identify under capacity storage reservoirs and determine location and scale of reservoir upgrades and consolidation.
7. Develop a Water Demand Management policy and standard.
8. Implement monitoring programme for existing water sources.

2.5.2 Wastewater

The immediate requirements for the Wastewater System are:

- Ensure WWTPs are fully operational.
- Network flow monitoring and physical data validation.
- Separation of wastewater and stormwater systems.

These are required to protect the environment, maximise potential of existing infrastructure and ensure a sustainable, informed decisions are made regarding design of future upgrades to the Wastewater system.

To achieve these requirements, the following next steps are recommended:

1. Repair or replace and recommission non-functional WWTP components.
2. Complete manhole surveys and network flow monitoring to verify the depths, dimensions and flows in the wastewater network.
3. Hydraulic model calibration and using manhole surveys and flow monitoring data.
4. Implement the Wastewater Separation Delivery Plan.
5. Develop and implement behavioural change campaigns to avoid illegal dumping of solids in the wastewater network.

2.5.3 Stormwater

The immediate requirements for the Stormwater System are:

- Implementation of Sustainable Urban Drainage Systems (SuDS).
- Separation of wastewater and stormwater systems.

The following next steps are recommended:

1. Develop design standards for SuDS.
2. Implement the Wastewater Separation Delivery Plan.

3. Governance Structure for Implementation

Strong governance is essential for ensuring that the works proposed under this *Water Supply, Wastewater and Stormwater Masterplan* are executed in an appropriate and efficient manner. A coordinated approach to works identified in the entire TSP (including Transport, Water, Utilities, Green Infrastructure, Housing, Healthcare, Education, Employment etc.) is required and led by a single entity.

As part of the TSP Delivery Strategy, the RCUD are proposed to provide overall governance and assurance for all works. MoIT will be responsible for implementation and TT will operate and maintain the infrastructure. The proposed Governance Organisation Chart is shown in Figure 3-1.

There is opportunity to establish a new, apolitical public sector led delivery vehicle. This could take the form of a Project Management Office (PMO) with expanded capacity to deliver projects and would ensure alignment with wider TSP priorities and infrastructure projects. Risk of duplication or overlap of responsibilities would need to be carefully managed.

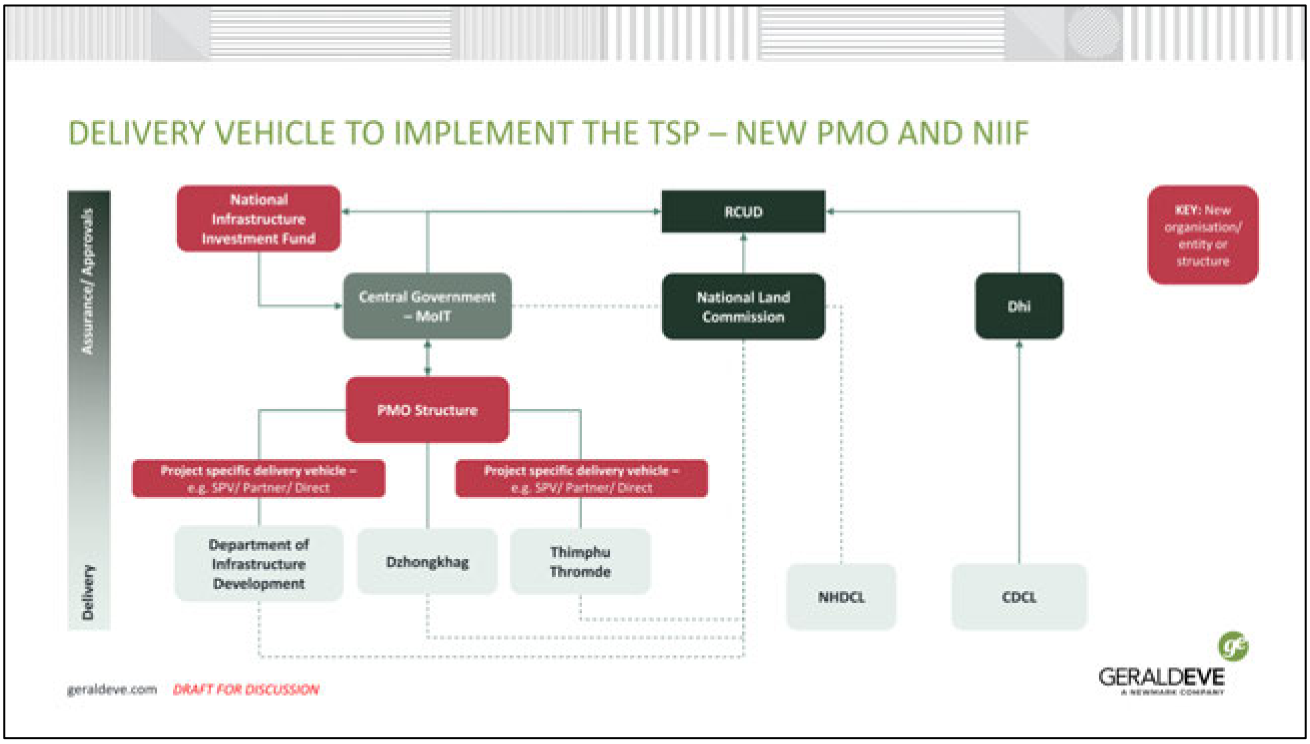


Figure 3-1: Proposed Governance Organisational Chart (Gerald Eve)

4. Organisational Capacity

Analysis of recent spending by Gerald Eve shows limited capacity to spend at a national and local level. MoIT and TT are consistently spending below their allocated annual budgets (average spend 57% and 48%, respectively of annual budgets over the past three years), indicating resource constraints and limited capacity at these organisations. These figures are based on overall institution budgets rather than Water Services specifically.

The following issues relating to organisational capacity were identified during workshops with MoIT and TT in March 2023:

- Local consultants often need to partner with foreign consultants to deliver water projects.
- Generally, local engineers have skills for designing small-scale water services but lack necessary skills for major trunk main infrastructure.
- It is not expected that local contractors have capacity to deliver the programme of works proposed under the *Water Supply, Wastewater and Stormwater Masterplan*.
- There are currently no local contractors with skills to deliver Smart water systems or advanced leak detection.

Foreign experience will be required to supplement local capacity to deliver the proposed programme of works for both design and construction.

5. Funding

Possible funding sources for the delivery and maintenance of water services infrastructure include the following, ranging from public (1) to private (9):

1. Local funding, through taxes, levies and user charges
2. National funding through budget allocation
3. Overseas Development Assistance through grants or loans
4. Financial institutions through grants or loans
5. Infrastructure bonds
6. Land Value Capture policies that allow public authorities to recover increases in land value to fund urban infrastructure and public services
7. Private sector through investors and developers
8. Impact investors
9. Philanthropy

In line with economic proposals developed as part of the TSP, it is generally preferred to fund from public sources, and introduce funding from the private sector to account for any funding gaps which exist. Initially funding is expected to be allocated under the 13th (2024-2029) and 14th (2029-2034) Five Year Plans.

Overseas Development partners are already involved in several Water Services projects in Thimphu and would be expected to continue through the implementation of the TSP and *Water Supply, Wastewater and Stormwater Masterplan*. Existing partners and projects include:

- Asian Development Bank: Water Flagship Programme
- World Bank Group: Draft Roadmap to Non-revenue Water Management
- United Nations Development Programme: Climate Change – Preparation of the National Adaptation Plan

Appendix A

Combined Project List, MCA and Prioritisation

Strategy	Location North / Central / South / City-wide	Infrastructure / Policy / Soft measure / Services	Intervention Name	Description	How long does project implementation take Quick win = 0-2 years Short term = 2-5 years Medium term = 5-10 year Long term = 10+ years	Notes on phasing (e.g. does the project need to come earlier/later than the other projects*in the same strategy?*) *(critical dependencies)*	Capital Costs (Financial) *Capital costs* *VERY LOW = <500k USD* *LOW = 500k - 1.5million USD* *MEDIUM = 1.5 - 3 million USD* *HIGH = 3 - 5 million USD* *VERY HIGH = 5+ million USD*	Operations + Maintenance (Financia) Operations + maintenance costs (ANNUAL) *VERY LOW = <25k USD* *LOW = 25-50k USD* *MED = 50 - 100k USD* *HIGH = 100k - 250k USD* *VERY HIGH = 250k+ USD*	Public health + community Nurture community - Protecting and enhancing diverse communities, equitable + healthy neighborhoods, leading to improvements in quality of life for city residents	Economic benefits Create opportunity - Short to long-term benefits in economic growth, job creation + livelihoods, worker productivity	Environmental / Sustainability Cultivate Balance - Creating environmental benefits (healthy ecosystems, cleaner air + water), reducing carbon emissions	Client priority Client has raised this intervention as a key priority	Priority Prioritisation (when does it need to start) Very high (immediately) High (within 2 years) Medium (within 5 years) Low (within 10 years) Very low (within 20 years)
Water Supply / Wastewater - Network	City-wide	Infrastructure	SCADA and Smart Water Networks	Create Smart water networks by installing monitoring devices throughout the distribution network and at storage reservoirs. SCADA upgrades proposed throughout the system include: online meters and pump controls at WTPs, chlorine residual monitoring at storage reservoirs, and water level monitoring at storage reservoirs.	Short-term		Medium	Medium	High	Medium	High	Low	LOW
Water Supply - WTP upgrades	City-wide	Infrastructure	Flow Meters at All WTPs	Install new inlet and outlet flow meters or replace all malfunctioning flow meters.	Quick-win		Very Low	Very Low	High	High	High	N/A	VERY HIGH
Water Supply - WTP upgrades	City-wide	Infrastructure	Turbidity Meters at All WTPs	Install inlet and outlet turbidity online meters.	Quick-win		Very Low	Very Low	Medium	Medium	Low	N/A	VERY HIGH
Water Supply - WTP upgrades	City-wide	Infrastructure	Chlorine Residual Meters at All WTPs	Install free chlorine residual online meters.	Quick-win		Very Low	Very Low	Very High	Medium	Medium	N/A	VERY HIGH
Water Supply - WTP upgrades	City-wide	Infrastructure	Other Water Quality Online Meters at All WTPs	Install as necessary other water quality parameters online meters depending on the result of raw water quality tests performed above and as applicable.	Short-term		Very Low	Very Low	Medium	Low	Low	N/A	HIGH
Water Supply - WTP upgrades	City-wide	Infrastructure	Filter Pressure Meters at All WTPs	Install filter pressure at each pressure filters of WTPs for monitoring and ensuring filters are not clogged.	Quick-win		Very Low	Very Low	Medium	Low	Low	N/A	HIGH
Water Supply - WTP upgrades	City-wide	Infrastructure	Level Indicators or Transmitters at Tanks for All WTPs	Level Indicators or transmitters at chemical dosing tanks and storage tanks.	Short-term		Very Low	Very Low	High	Medium	Low	N/A	VERY HIGH
Water Supply - WTP upgrades	City-wide	Infrastructure	Automatic Control Program of Pumps in Proportion to Water Quality for All WTPs	Automatic control of dosing pumps in proportion to turbidity and free chlorine residual.	Quick-win		Very Low	Very Low	Medium	Medium	Low	N/A	VERY HIGH
Water Supply - WTP upgrades	City-wide	Infrastructure	Automatic Control of Pumps Based On Tank Levels for All WTPs	Automatic control programs for raw water pumps, distribution pumps, backwash water pumps, dosing pumps and filter feed pumps based on storage tank levels.	Short-term		Very Low	Very Low	Medium	Medium	Low	N/A	VERY HIGH
Water Supply - WTP upgrades	North	Infrastructure	Automatic Control for Distribution Pumps from Jungshina WTP to Run Based On Network Pressure	Automatic control program of distribution pump based on network pressure.	Short-term		Very Low	Very Low	Medium	Medium	Low	N/A	VERY HIGH
Water Supply - WTP upgrades	City-wide	Infrastructure	Automatic Control Programs for Backwashing Operation Regimes for All WTPs	Make an automatic program to control backwashing pump based on the filter pressure, turbidity and backwashing duration and frequency.	Short-term		Very Low	Low	Medium	Low	Low	N/A	MEDIUM
Water Supply - WTP upgrades	City-wide	Infrastructure	Run and Stop Status and Control of Pumps for all WTPs from SCADA	Monitor and control pumps operation from SCADA.	Short-term		Low	Low	Medium	Medium	Low	N/A	LOW
Water Supply - WTP upgrades	South	Infrastructure	Chamgang Old WTP - Intake	Upgrade intake structure with screen.	Quick-win		Very Low	Very Low	High	Medium	Low	Medium	VERY HIGH
Water Supply - WTP upgrades	North	Infrastructure	Jungshina WTP - Repair Leakages	Repair leaks from tanks and pipes.	Quick-win		Very Low	Very Low	Medium	Low	Low	N/A	HIGH
Water Supply - WTP upgrades	Central	Infrastructure	Motihang WTP - Sedimentation tank	Retrofit sedimentation tank with lamella.	Short-term		Very Low	Low	Medium	Medium	Low	N/A	MEDIUM
Water Supply - WTP upgrades	North	Infrastructure	Dechencholing WTP - Upgrade WTP to 2.8MLD	New Water treatment plant with 1.4MLD capacity (total 2.8MLD at Dechencholing).	Short-term		Low	Medium	High	Medium	Medium	High	LOW
Water Supply - WTP upgrades	North	Infrastructure	Taba WTP - Filters	Upgrade BioBall filters to 7.5MLD.	Short-term		Very Low	Very Low	Medium	Medium	Low	N/A	VERY HIGH
Water Supply - WTP upgrades	City-wide	Infrastructure	Sludge Management for All WTPs (Except for Chamgang Old WTP and Jungshina WTP which have Sludge Drying Beds and Sludge Lagoons, Respectively)	Provide an individual sludge treatment facility or provide a centralised sludge treatment facility or sludge drying bed for WTPs serving north, south, and central Thimphu. Provide recovery of supernatant to the inlet of WTP if individual sludge treatment facility is to be pursued.	Short-term		Low	Medium	Medium	Low	Medium	N/A	LOW
Water Supply - WTP upgrades	South & Central	Infrastructure	Chamgang Old WTP and Jungshina WTP - Recovery Line for Supernatant	Install a recovery line for the effluent from the sludge drying bed of Chamgang Old WTP and overflow of sludge lagoon of Jungshina WTP to be recycled back to its respective WTP inlet.	Quick-win		Very Low	Very Low	Low	Low	Medium	N/A	HIGH
Water Supply - WTP Operational Improvements	City-wide	Soft measure	Water Safety Plans at all WTPs	Establish Water Safety Plan based on WHO standard or based on nationally approved WSP guidance for all water treatment plants.	Quick-win		Very Low	Very Low	High	Very low	Very Low	N/A	HIGH
Water Supply - WTP Operational Improvements	City-wide	Soft measure	Raw Water Quality Testing at all WTPs	Perform water quality tests for all parameters required by EU DWR (see parameters list and frequency of testing).	Quick-win		Very Low	Low	High	Low	Very Low	N/A	MEDIUM
Water Supply - WTP Operational Improvements	City-wide	Policy	Sampling Plan and Testing Procedure for all WTPs	Develop a sampling plan and testing procedure for internal and third-party laboratory testing and analysis for all parameters required by Bhutan DWQS as a minimum for all water treatment plants and distribution network. This plan to be updated based on above raw water quality testing.	Quick-win		Very Low	Very Low	Very High	Very low	Very Low	N/A	HIGH
Water Supply - WTP Operational Improvements	City-wide	Soft measure	Jar Testing and Establishing the Dosing Matrix at All WTPs	Conduct jar testing in all water treatment plants. Based on this jar testing, establish dosing matrix for the coagulant and flocculant concentration vs raw water turbidity.	Quick-win		Very Low	Very Low	Very High	Very low	Very Low	N/A	HIGH
Water Supply - WTP Operational Improvements	City-wide	Soft measure	Operation and Maintenance Manuals for All WTPs	Develop Operation and Maintenance Manual for pumps, instruments, and other equipment to ensure proper operation and continuity of services.	Quick-win		Very Low	Very Low	High	Very low	Very Low	N/A	HIGH
Water Supply - WTP Operational Improvements	City-wide	Soft measure	Filter Inspections at All WTPs	Regularly inspect all filters for their condition and amount of media adequacy.	Quick-win		Very Low	Very Low	High	Very low	Low	N/A	HIGH
Water Supply - WTP Operational Improvements	City-wide	Infrastructure	Topping-up of Filters Annually or As Needed	Top-up filters media as necessary or annually.	Quick-win		Very Low	Very Low	High	Very low	Very Low	N/A	HIGH
Water Supply - WTP Operational Improvements	City-wide	Policy	Operations Staff at All WTPs	Consider having plant manager, chemist or chemical technician, and process engineer to provide relevant technical skills required to operate the plant efficiently. These personnel may be responsible for multiple WTPs.	Short-term		Very Low	Medium	Medium	High	Very Low	Medium	LOW
Water Supply - WTP Operational Improvements	South	Soft measure	Chamgang Old WTP - Monitor Turbidity	Monitor turbidity to check BioBall Filter (BBF) performance especially at higher flows.	Quick-win		Very Low	Very Low	Medium	Very low	Low	N/A	HIGH
Water Supply - WTP Operational Improvements	North	Soft measure	Jungshina WTP - Pumps	Check pumps as pumps have already reached its design life and repair or replace as necessary.	Quick-win		Very Low	Very Low	Medium	Low	Low	N/A	HIGH
Water Supply - WTP Operational Improvements	Central	Soft measure	Motihang WTP - Monitor Free Chlorine Residual	Monitor free chlorine residual at treated water storage tank outlet to ensure water quality meets standards.	Quick-win		Very Low	Low	High	Low	Low	N/A	MEDIUM
Water Supply - WTP Operational Improvements	North	Soft measure	Taba WTP - Intake Structure	Investigate the root cause of intake structures frequent disconnection or damage and rectify as this is necessary to ensure continuity of services.	Short-term		Very Low	Low	High	Medium	Low	N/A	HIGH
Water Supply - WTP Operational Improvements	North	Soft measure	Taba WTP - Monitor Turbidity	Continue monitoring the turbidity at raw water and the quality of water after the lamella clarifier to ensure the flocculation tank and lamella clarifier continue to meet the required treatment performance.	Quick-win		Very Low	Very Low	Medium	Low	Low	N/A	HIGH
Water Supply - WTP	Central	Soft measure	Motihang WTP - Structural Integrity	Inspect structures and renew as needed as plant has already reached its design life and has been running beyond the assessed capacity.	Quick-win		Very Low	Very Low	Medium	Medium	Low	N/A	VERY HIGH
Water Supply - WTP	Central	Soft measure	Motihang WTP - Flocculation Tank	Check flocculation tanks size if retention time is met at 40min for 10MLD current flow. If this retention time is not met, reduce production flow during high turbidity.	Quick-win		Very Low	Very Low	Medium	Low	Low	N/A	HIGH
Water Supply - WTP	North	Soft measure	Dechencholing WTP - Flow meters	Investigate the root cause of frequent blockage or malfunctioning of flow meters to inform future upgrades or modifications.	Quick-win		Very Low	Very Low	Medium	Very low	Low	N/A	HIGH
Water Supply - WTP	Central	Soft measure	Babena WTP - Design Check	Check for flocculation tank, coagulant/flocculant dosing tanks and pumps and chlorination. Install the systems as necessary. Confirm filter size as it is significantly oversized. Confirm sedimentation tank size as it is slightly undersized.	Quick-win		Very Low	Very Low	Medium	Low	Low	N/A	HIGH
Water Supply - Network	City-wide	Infrastructure	Increase Water Storage	Increase storage from 10.5ML to 55MLD. Increased water storage could result from the expansion of existing storage reservoirs or by additional storage by new storage reservoirs close to existing WTPs, which are also at higher elevations.	Medium-term		Very High	Low	High	High	Medium	Medium	LOW
Water Supply - Network	City-wide	Infrastructure	Reduce Non Revenue Water	Reducing leakage, illegal connections and metering inaccuracies from >50% NRW to <15%. Process involves collecting data from flow and pressure monitoring to help to identify leaks in the system, repairs, renewals and pressure management	Medium-term		High	Very Low	Very High	Very High	Very High	Very High	HIGH
Water Supply - Network	City-wide	Infrastructure	Upgrade Existing Network to Cater for Firefighting	Upgrades to the water supply infrastructure, including hydrant installation, storage reservoir or supply improvements, and adequate water main pipe capacities, allow the network to deliver necessary flows and pressures throughout the city for firefighting.	Medium-term		Medium	Very Low	Very High	Medium	Medium	Very High	HIGH
Water Supply - Network	City-wide	Infrastructure	Protect Watermains	Divert and protect water supply trunk lines which could be affected by natural hazards such as flooding or landslides. Up to 70km of existing trunk mains in hazard zones.	Medium-term		High	Low	High	Medium	Medium	Medium	LOW
Water Supply - Network	City-wide	Infrastructure	Pressure Reduction	At locations within the water supply network with high pressures (~50 locations initially identified), pressure reducing valves (PRVs) can be installed to limit the pressure levels and to reduce leakage losses in the network.	Quick-win		Low	Very Low	High	High	Very High	Very High	VERY HIGH
Water Supply - Network	North	Infrastructure	Pump Station to Serve Community Supply DMA	Booster pump station to serve Community Supply DMA from Dechencholing Tank 1.	Short-term	Reservoir upgrades, NRW reduction and Dling WTP upgrade	Low	Low	High	High	Low	High	MEDIUM
Water Supply - Network	Central	Infrastructure	Pump Station to Serve Changiji 2 DMA	Booster pump station to serve Changiji 2 DMA from Changiji Tanks.	Medium-term	Reservoir upgrades and NRW reduction	Low	Low	High	High	Low	High	MEDIUM
Water Supply - Network	South	Infrastructure	Pump Station to Serve Lubding DMA	Booster pump station to serve Lubding DMA from Lungtenphu Tanks.	Medium-term	Reservoir upgrades and NRW reduction	Low	Low	High	High	Low	High	MEDIUM
Water Supply - Network	Central	Infrastructure	Pump Station to Serve YHS 2 DMA	Booster pump station to serve new DMA - YHS2.	Medium-term	Reservoir upgrades and NRW reduction	Low	Low	High	High	Low	High	MEDIUM
Water Supply - Network	City-wide	Infrastructure	Water Supply Flow and Pressure Monitoring	84 pressure transducers located in the highest and lowest points of each DMA. Those located in the lowest points are to monitor the pressure reducing valves set pressure and those in the highest points are to monitor that the minimum supply pressure is being provided to the network. 52 flow meters located: - at the inlet of DMAs to monitor usage and leakages, - at the inlet of hospital to monitor usage, at the outlet of pumps to control pump operation and at the outlet of WTPs to measure production capacity.	Quick-win	Prior to all other Water Supply works	Low	Very Low	High	High	Low	High	HIGH
Water Supply - Network	North	Infrastructure	Pipe Extension to Connect Taba WTP and Jungshina WTP	Extend existing spare 150mm diameter watermain 600m to Jungshina to provide an additional 3 MLD to Jungshina WTP during periods of low supply	Short-term		Low	Very Low	High	Medium	Medium	Medium	HIGH
Water Supply - Network	South	Infrastructure	Watermain Extension to Southern Extension	Extension to supply Rama (1.63km of pipes), Debsi (1.02km of pipes), Serbithang (360m of pipes), Gangchey Nyezergang (530m of pipes), Simtoka Upper 1 (700m of pipes) and Simtoka E4 (600m of pipes) DMAs and extension from Chamgang New to Chamgang Old to support water availability (1.93km of pipes).	Long-term	Reservoir upgrades and NRW reduction. Access infrastructure to Rama	Medium	Low	High	Medium	Medium	N/A	LOW
Water Supply - Network	North	Infrastructure	Watermain Extensions in Northern suburbs	Extension to supply Pamtsho Tanks (1.83km of pipes) as well as Pamtsho 1 (270m of pipes), Pamtsho 2 (2.07km of pipes), Community Supply (1.29km of pipes) and Dangrina Proposed (1.15km of pipes) DMAs.	Short-term	Reservoir upgrades, NRW reduction and Dling WTP upgrade	Medium	Low	High	Medium	Low	High	LOW

							Capital Costs (Financial)	Operations + Maintenance (Financia)	Public health + community	Economic benefits	Environmental / Sustainability	Client priority	Priority
Strategy	**Location** **North / Central / South / City-wide**	**Infrastructure / Policy / Soft measure / Services**	**Intervention Name**	**Description**	**How long does project implementation take** Quick win = 0-2 years Short term = 2-5 years Medium term = 5-10 year Long term = 10+ years	**Notes on phasing** (e.g. does the project need to come earlier/later than the other projects*in the same strategy?) (critical dependencies)*	***Capital costs*** *VERY LOW = <500k USD* *LOW = 500k - 1.5million USD* *MEDIUM = 1.5 - 3 million USD* *HIGH = 3 - 5 million USD* *VERY HIGH = 5+ million USD*	**Operations + maintenance costs (ANNUAL)** *VERY LOW = <25k USD* *LOW = 25-50k USD* *MED = 50 - 100k USD* *HIGH = 100k - 250k USD* *VERY HIGH = 250k+ USD*	**Nurture community -** Protecting and enhancing diverse communities, equitable + healthy neighborhoods, leading to improvements in quality of life for city residents	**Create opportunity -** Short to long-term benefits in economic growth, job creation + livelihoods, worker productivity	**Cultivate Balance -** Creating environmental benefits (healthy ecosystems, cleaner air + water), reducing carbon emissions	Client has raised this intervention as a key priority	**Prioritisation (when does it need to start)** Very high (immediately) High (within 2 years) Medium (within 5 years) Low (within 10 years) Very low (within 20 years)
Water Supply - Network	Central	Infrastructure	Watermain Extensions to New Central DMAs	Extension to supply Workshop (220m of pipes), Lubding (250m of pipes), Changiji 2 (1.58km of pipes) and Changzamtog (1.34km of pipes), Bangdu Areas (190m of pipes) and YHS 2 (550m of pipes) DMAs.	Short-term	Reservoir upgrades, NRW reduction	Medium	Low	High	Medium	Low	High	LOW
Water Supply - Network	City-wide	Infrastructure	Watermain Reconfiguration for Water Source Availability	Network reconfiguration to balance the demand from seven DMAs with the lean season availability of water from their respective WTPs. These include Pamtsho 1, Babesa Right, Above Old Highway, Babesa Left, Bangdu Residents and Bangdu Area Left and Changzamtog.	Medium-term	NRW Reduction	Low	Very Low	High	Medium	Medium	N/A	HIGH
Water Supply - Network	North and Central	Infrastructure	Watermain Upgrades for Increased Supply from Taba WTP	Rezoning of Chamgang Old WTP demand to Taba WTP by reinforcing sections of the mains from the Taba WTP to the YHS Tanks.	Long-term		Low	Low	Medium	Medium	Low	N/A	LOW
Water Supply - Network	City-wide	Infrastructure	Begana WTP and New Trunk Main to Rama	New abstraction from Wang Chhu at Begana, new trunk main from Begana to Rama. All residents served by Begana and Taba WTPs, both fed from Wang Chhu, replacing all other WTPs to provide long term resiliency if existing sources cannot provide reliable supply. The main is composed of twin and triple parallel pipes.	Long-term	Long term monitoring of sources	Very High	Medium	High	High	Medium	N/A	VERY LOW
Water Supply	City-wide	Soft measure	Water Demand Management	Water Demand Management is a strategy for managing water resources, which focuses on reducing water demand by encouraging efficient usage, which is achieved by education and offering targeted incentives that promote fair and sustainable water usage.	Medium-term		Very Low	Very Low	High	High	Very High	Medium	VERY HIGH
Wastewater / Stormwater - Network	City-wide	Infrastructure	Disconnect Stormwater from Wastewater	Disconnect stormwater drains from the wastewater network to avoid the treatment of stormwater at the WWTPs.	Short-term		Medium	Very Low	High	High	High	High	HIGH
Wastewater / Stormwater - Network	City-wide	Infrastructure	Disconnect Wastewater from Stormwater	Disconnect wastewater drains from the stormwater network to avoid polluting the environment and to improve public and ecosystem health.	Short-term	Disconnect SW from WW first	Medium	Very Low	Very High	High	Very High	High	HIGH
Wastewater - WWTP Upgrades	City-wide	Infrastructure	Ammonia Removal for All WWTPs	Waste Assimilative Capacity assessment of Wang Chhu to determine maximum ammonia concentration for 'Good Status'. Upgrades to existing WWTPs to reduce ammonia to acceptable levels.	Short-term		Low	Medium	Medium	Low	High	N/A	LOW
Wastewater - WWTP Upgrades	City-wide	Infrastructure	Phosphate (MRP) Removal for All WWTPs	Waste Assimilative Capacity assessment of Wang Chhu to determine maximum MRP concentration for 'Good Status'. Upgrades to existing WWTPs to reduce MRP to acceptable levels.	Short-term		Low	Medium	Medium	Low	High	N/A	LOW
Wastewater - WWTP Upgrades	City-wide	Infrastructure	Odour Control Units (OCU) for All Existing WWTPs	Investigate odour issues at each WWTP and provide a good ventilation and OCU (except Babesa which already has OCU). Consider adding a trash bin with the lid for all WWTPs and have a proper disposal method of the screenings.	Quick-win		Low	Low	High	Low	Medium	N/A	MEDIUM
Wastewater - WWTP Upgrades	City-wide	Infrastructure	SCADA and Instruments for All WWTPs	Install influent, effluent and Return Activated Sludge (RAS) and Waste Activated Sludge (WAS) flowmeters which are not available on site. Install online pH and DO meter as well as turbidity/TSS analyser, if necessary. All the instruments should be connected to the SCADA control. (Babesa excluded as already provided)	Short-term		Low	Low	Medium	Medium	Medium	N/A	MEDIUM
Wastewater - WWTP Upgrades	North	Soft measure	Safety Plan for Recommissioning of Dechencholing WWTP	Possible produced toxic gases (i.e. hydrogen sulphide) in the shutdown aeration tank hence it requires safety plan before recommissioning the plant.	Quick-win		Very Low	Very Low	Medium	Very Low	High	N/A	VERY HIGH
Wastewater - WWTP Upgrades	North	Infrastructure	Dechencholing WWTP MBBR Tanks	Check the effluent BOD while operating conditions of DO and pH are maintained. If it is not meeting the standard, provide additional media or increase air flow or add another unit of MBBR.	Short-term		Very Low	Low	Medium	Low	Medium	N/A	MEDIUM
Wastewater - WWTP Upgrades	North	Infrastructure	Diffusers Replacement at Dechencholing WWTP	Possible clogging of diffusers of Dechencholing WWTP MBBR and reached its design life.	Quick-win		Very Low	Very Low	High	Low	High	N/A	VERY HIGH
Wastewater - WWTP Upgrades	North	Infrastructure	Dechencholing WWTP MBBR Media	Wash the media and replenish up to its design volume or replace the worn-out media.	Quick-win		Very Low	Very Low	High	Low	High	N/A	VERY HIGH
Wastewater - WWTP Upgrades	North	Soft measure	Dechencholing WWTP Tubedek Settler	If the effluent has high TSS, change the configuration of settler like the slope to increase the settling area or provide additional unit.	Quick-win		Very Low	Very Low	Medium	Low	Medium	N/A	VERY HIGH
Wastewater - WWTP Upgrades	North	Infrastructure	Dechencholing WWTP Filter Media	Check the size of the filters, if it has enough capacity to cater the 2032 flow, replace the missing media, if not, replace the filters.	Quick-win		Very Low	Very Low	High	Low	Medium	N/A	VERY HIGH
Wastewater - WWTP Upgrades	North	Infrastructure	Sludge Holding Tank in Dechencholing WWTP	Check if there is one sludge holding tank on site and if its capacity is sufficient to handle the sludge while the plate and frame filter press is running. If there's none, construct a sludge holding tank	Short-term		Very Low	Low	Medium	Low	High	N/A	HIGH
Wastewater - WWTP Upgrades	North & Central	Infrastructure	Overloaded Screens in Taba and Lungtenzampa WWTPs	If there is a lot of solid being carried out after the screens, provide additional unit of screens	Quick-win		Very Low	Low	Low	Low	High	N/A	MEDIUM
Wastewater - WWTP Upgrades	North	Infrastructure	Taba WWTP Pump Repair/Replacement	Conduct full maintenance of troubleshooting. If it cannot be recovered and has insufficient flow to cater the 2032 flow, replace the damaged pumps	Quick-win		Very Low	Low	Medium	Low	High	N/A	HIGH
Wastewater - WWTP Upgrades	North	Infrastructure	Taba WWTP Eco-line	Check the effluent BOD while operating conditions of DO and pH are maintained. If it is not meeting the standard, consider add another train of eco-line.	Short-term		Very Low	Low	Medium	Low	Medium	N/A	MEDIUM
Wastewater - WWTP Upgrades	North	Infrastructure	Taba WWTP Disinfection Well	If the effluent has faecal coliform, increase the chlorine dosage or add another tank with sufficient capacity to have enough contact time.	Quick-win		Very Low	Very Low	Medium	Low	High	N/A	VERY HIGH
Wastewater - WWTP Upgrades	North	Infrastructure	Sludge Treatment in Taba WWTP	Check the dewatering unit of Jungshina if there's an excess capacity. If yes, treat it in Jungshina, if no, provide additional unit.	Quick-win		Very Low	Low	Medium	Low	High	N/A	HIGH
Wastewater - WWTP Upgrades	North	Infrastructure	Jungshina WWTP SBR	Check the effluent BOD while operating conditions of DO and pH are maintained. If it is not meeting the standard, adjust the operation by modifying inter-cycle phase duration or replace the activated sludge into granular sludge or provide additional unit of SBR.	Short-term		Very Low	Low	Medium	Low	Medium	N/A	MEDIUM
Wastewater - WWTP Upgrades	North	Infrastructure	Jungshina WWTP Auxiliaries	Check the auxiliaries if it is sufficient to increase the flow, if not, provide additional unit.	Short-term		Very Low	Low	Medium	Low	Medium	N/A	MEDIUM
Wastewater - WWTP Upgrades	North & Central	Infrastructure	Dechencholing, Langjophakha & Lungtenzampa WWTP Disinfection Well	Possible short circuiting happens in a disinfection well/treated water tank. If the effluent has faecal coliform, provide additional baffle or mixer.	Quick-win		Very Low	Very Low	Medium	Low	Medium	N/A	VERY HIGH
Wastewater - WWTP Upgrades	North	Infrastructure	Langjophakha WWTP Minor Upgrades	Check the capacity of all other components e.g. auxiliaries, filters, that were not hydraulically assessed if it sufficient to cater 2032 flow. If not, provide additional unit of these equipment.	Short-term		Very Low	Very Low	Medium	Low	Medium	N/A	VERY HIGH
Wastewater - WWTP Upgrades	Central	Infrastructure	Sludge Treatment in Langjophakha and Lungtenzampa WWTP	Provide a dewatering unit.	Quick-win		Very Low	Low	Medium	Low	Medium	N/A	MEDIUM
Wastewater - WWTP Upgrades	Central	Infrastructure	Lungtenzampa WWTP Pumps	Pumps leaking. Conduct full maintenance of troubleshooting. If it cannot be recovered and has insufficient flow to cater the 2032 flow, replace the damaged pumps.	Quick-win		Very Low	Low	Medium	Low	High	N/A	HIGH
Wastewater - WWTP Upgrades	Central	Infrastructure	Lungtenzampa WWTP Diffusers	Possible clogging of diffusers of Lungtenzampa WWTP Aeration Tanks and Wastewater Storage Tanks. Investigate and replace diffusers if required.	Quick-win		Very Low	Very Low	Medium	Low	High	N/A	VERY HIGH
Wastewater - WWTP Upgrades	Central	Infrastructure	Lungtenzampa WWTP Sedimentation Tank	Sedimentation tank is not reaching its design capacity. If the effluent has high TSS, provide a lamella in the tank or create additional unit.	Quick-win		Very Low	Very Low	Medium	Low	Medium	N/A	VERY HIGH
Wastewater - WWTP Upgrades	South	Infrastructure	Coarse Screen in Babesa WWTP	Conduct full maintenance of troubleshooting and validate actual flow measures coming from the new sewer line. If the coarse screen is insufficient and there is a lot of solid being carried out after the screen, replace or add unit.	Quick-win		Very Low	Low	Medium	Low	Medium	N/A	MEDIUM
Wastewater - WWTP Upgrades	South	Infrastructure	Wastewater Pumps in Babesa WWTP	Potential insufficient capacity of existing pumps based on the actual flow from the new sewer line, provide additional unit or replace with higher capacity. If it is validated that this is sufficient, no necessary actions needed.	Quick-win		Very Low	Low	Medium	Low	Medium	N/A	MEDIUM
Wastewater - WWTP Upgrades	South	Infrastructure	Coarse, Medium and Fine Screens in Babesa WWTP	Validate the flow from the old sewer line and if it is higher than the capacity of these screens, provide additional unit. If it is lower, no action needed.	Quick-win		Very Low	Low	Medium	Low	Medium	N/A	MEDIUM
Wastewater - WWTP Upgrades	South	Infrastructure	Babesa WWTP SBR and Blower	Possible Insufficient Capacity. Check the effluent BOD while operating conditions of DO and pH are maintained. If it is not meeting the standard, adjust the operation by modifying inter-cycle phase duration or replace the activated sludge into granular sludge or provide additional unit of SBR. If the DO is not reaching its required value, provide additional unit.	Short-term		Low	Low	High	Low	High	N/A	MEDIUM
Wastewater - WWTP Upgrades	South	Infrastructure	Babesa WWTP Disinfection Well	If the effluent has faecal coliform, increase the chlorine dosage or provide additional baffle or mixer.	Quick-win		Very Low	Very Low	Medium	Low	Medium	N/A	VERY HIGH
Wastewater - WWTP Upgrades	South	Infrastructure	Babesa WWTP Sludge Holding Tank	Identify the flow of the waste activated sludge, if it insufficient to cater WAS with enough time, provide additional sludge holding tank.	Quick-win		Very Low	Low	Medium	Low	Medium	N/A	MEDIUM
Wastewater - WWTP Upgrades	South	Infrastructure	Babesa WWTP Gravity Sludge Thickener and Centrifuge	Provide additional polymer dosing or provide additional unit of thickener and dewatering unit to manage insufficient capacity.	Quick-win		Very Low	Low	Medium	Low	Medium	N/A	MEDIUM
Wastewater - WWTP Upgrades	South	Infrastructure	Additional 6 MLD Babesa WWTP	Provide additional units of tanks, equipment and auxiliaries or a modular WWTP with a capacity of 6 MLD.	Medium-term		Medium	Medium	High	Medium	High	Medium	LOW
Wastewater - WWTP Upgrades	City-wide	Infrastructure	Sludge Management	Provide sludge treatment facility for the whole city before disposing or use it as any product that can be produced from the sludge.	Medium-term		Low	Medium	Medium	Low	High	N/A	LOW
Wastewater - WWTP Operational Improvements	City-wide	Policy	Sampling Plan for All WWTPs	Investigate the performance of wastewater via developing sampling plan and testing procedure for internal and third-party laboratory testing and analysis for all required parameters for influent and effluent.	Quick win		Very Low	Low	High	Medium	Medium	N/A	HIGH
Wastewater - WWTP Operational Improvements	City-wide	Soft measure	Skilled Personnel for All WWTPs	Provide Plant Manager, Process and/or Electro-mechanical Engineers to ensure the continuous operation and efficiently running of the plant as well as with the assurance that the effluent is conforming to the standard. These personnel may be responsible for multiple WTPs.	Short-term		Very Low	Medium	Medium	Medium	Medium	N/A	MEDIUM
Wastewater - WWTP Operational Improvements	City-wide	Soft measure	Operation and Maintenance Manuals for All WWTPs	Develop Operation and Maintenance Manual for pumps, instruments, and other equipment to ensure proper operation and continuity of services.	Quick-win		Very Low	Very Low	Medium	Low	Low	N/A	HIGH
Wastewater - WWTP	North & Central	Infrastructure	All Non-functional WWTPs (Dechencholing, Lungtenzampa)	Assess all equipment, auxiliaries, pipelines and cables that are not functioning as per specification.	Quick win		Very Low	Very Low	High	Medium	Very High	N/A	VERY HIGH

							Capital Costs (Financial)	Operations + Maintenance (Financia)	Public health + community	Economic benefits	Environmental / Sustainability	Client priority	Priority
Strategy	Location North / Central / South / City-wide	Infrastructure / Policy / Soft measure / Services	Intervention Name	Description	How long does project implementation take Quick win = 0-2 years Short term = 2-5 years Medium term = 5-10 year Long term = 10+ years	Notes on phasing (e.g. does the project need to come earlier/later than the other projects*in the same strategy*?) *(critical dependencies)*	***Capital costs*** *VERY LOW = <500k USD* *LOW = 500k - 1.5million USD* *MEDIUM = 1.5 - 3 million USD* *HIGH = 3 - 5 million USD* *VERY HIGH = 5+ million USD*	**Operations + maintenance costs (ANNUAL)** *VERY LOW = <25k USD* *LOW = 25-50k USD* *MED = 50 - 100k USD* *HIGH = 100k - 250k USD* *VERY HIGH = 250k+ USD*	**Nurture community -** Protecting and enhancing diverse communities, equitable + healthy neighborhoods, leading to improvements in quality of life for city residents	**Create opportunity -** Short to long-term benefits in economic growth, job creation + livelihoods, worker productivity	**Cultivate Balance -** Creating environmental benefits (healthy ecosystems, cleaner air + water), reducing carbon emissions	Client has raised this intervention as a key priority	**Prioritisation (when does it need to start)** Very high (immediately) High (within 2 years) Medium (within 5 years) Low (within 10 years) Very low (within 20 years)
Wastewater - WWTP	North	Infrastructure	New WWTP in Hejo	Create a consolidated wastewater treatment plant in northern part of the Thimphu with a capacity of 6 MLD, replacing Dechencholing, Taba, Jungshina, Langjophaka WWTPs	Long-term	Not proposed until existing WWTPs reach capacity without requiring significant upgrades	High	High	Medium	Medium	High	High	VERY LOW
Wastewater - WWTP	South	Infrastructure	New WWTP in Rama	New 1MLD NBS Wastewater Treatment faccility in Rama to serve Southern Extension 1 MLD	Long-term	Servicing infrastructure for Rama	Low	Medium	Medium	Medium	High	N/A	LOW
Wastewater - Network	City-wide	Infrastructure	Wastewater Network Flow Monitoring	Create Smart wastewater networks by installing reliable flow monitoring devices across the wastewater network. Flow rates to be recorded to identify high inflow areas and to target improvement projects. Associated Information Technology (IT) systems and trained operators to be included.	Quick-win		Low	Low	Medium	Medium	High	High	MEDIUM
Wastewater - Network	Central	Infrastructure	Upsizing of Wastewater Pipes in Central Area	3.9km existing wastewater mains from Bhutan Craft Market to Changzamtog Park to be upsized between 350mm and 600mm diameter to reduce risk of surcharging.	Short-term	Wastewater network flow monitoring	Medium	Low	High	Medium	High	High	MEDIUM
Wastewater - Network	South	Infrastructure	Upsizing of Wastewater Pipes in Olakha Area	1.8km existing wastewater mains from Helipad to Babesa WSP to be upsized to 600mm diameter to reduce risk of surcharging.	Short-term	Wastewater network flow monitoring	Medium	Low	High	Medium	High	Medium	LOW
Wastewater - Network	North	Infrastructure	Wastewater Network Extension to Kabesa	Construction of 1.5km 160mm gravity pipe from Kabesa to Existing Dechencholing Network.	Long-term	Construction of Northern WWTP, Upisizing of Sewer Pipes	Low	Low	High	Medium	High	Medium	MEDIUM
Wastewater - Network	South	Infrastructure	Wastewater Network Extension in Babesa WWTP Catchment	Construction of 500m 250mm gravity pipe from Royal Bhutan Army to Existing Babesa Network. Construction of 1500m 100mm force main from Depsi to Existing Babesa Network.	Long-term	Upgraded Babesa WWTP, Upsizing of sewer pipes	Low	Low	High	Medium	High	Medium	MEDIUM
Wastewater - Network	South	Infrastructure	Wastewater Pump Station at Dechencholing	New WWPS to provide pressure from Dechencholing to northern sewer trunk mains.	Long-term	Upgraded Babesa WWTP, Upsizing of sewer pipes	Low	Low	Medium	Medium	High	Medium	MEDIUM
Wastewater - Network	South	Infrastructure	Wastewater Pump Stations at Lungtenzampa and at Langjophakha	New WWPSs to provide pressure for crossing Wang Chhu from Lungtenzampa and at Langjophakha.	Long-term	Upgraded Babesa WWTP, Upsizing of sewer pipes	Low	Medium	Medium	Medium	High	Medium	LOW
Wastewater - Network	South	Infrastructure	Wastewater Pump Station at Depsi	New WWPS to provide pressure from Depsi to existing Babesa Trunks for treatment at Babesa WWTP.	Long-term	Upgraded Babesa WWTP, Upsizing of sewer pipes	Very Low	Medium	Medium	Medium	High	Medium	MEDIUM
Wastewater - Network	North	Infrastructure	Northern Trunk Main - Rising Main Dechencholing to Taba	1,700m of 200mm diameter rising main to connect Dechencholing and Kabesa catchments to Taba.	Long-term	Construction of Northern WWTP, upgrade of sewer pipes	Low	Low	Medium	Medium	High	Medium	MEDIUM
Wastewater - Network	Central	Infrastructure	Northern Trunk Main - Gravity Mains from Jungshina to Northern WWTP	1,300m of 600mm diameter gravity main to connect Jungshina and northern catchments to the new WWTP.	Long-term	Construction of Northern WWTP, upgrade of sewer pipes	Medium	Medium	Medium	Medium	High	Medium	LOW
Wastewater - Network	Central	Infrastructure	Northern Trunk Main - Rising Mains from Langjophakha to Northern WWTP	450m of 100mm dia Rising main to connect Langjophaka to the new WWTP.	Long-term	Construction of Northern WWTP, upgrade of sewer pipes	Medium	Medium	Medium	Medium	High	Medium	LOW
Wastewater - Network	South	Infrastructure	Wastewater Network Reconfiguration - Lungtenzampa to Babesa	220m 200mm dia rising main to connect Lungtenzampa to existing Babesa Sewer Trunks to be treated at Babesa WWTP.	Long-term	Upgraded Babesa WWTP, Upsizing of sewer pipes	Low	Low	Medium	Medium	High	Medium	MEDIUM
Wastewater - Network	Central	Infrastructure	Upsizing of Wastewater Pipes in Central Area (2nd Phase)	60m of 300mm gravity pipe to reduce risk of surcharging at Dechencholing Influent.	Long-term	Construction of Northern WWTP, upgrade of sewer pipes	Low	Low	High	Medium	High	High	MEDIUM
Wastewater - Network	South	Infrastructure	Upsizing of Wastewater Pipes in Olakha Area (2nd Phase)	500m of 300mm gravity pipe to reduce risk of surcharging at Mapho Lam.	Long-term	Upgraded Babesa WWTP, Upsizing of sewer pipes	Low	Low	High	Medium	High	Medium	MEDIUM
Stormwater	City-wide	Infrastructure	Daylighting Culverted Watercourses	Daylight existing culverted streams through urban areas, enhancing amenity and biodiversity benefits and assisting with flood management. 4 streams through city centre.	Short-term		High	Low	High	High	High	Medium	LOW
Stormwater	City-wide	Policy	Sustainable Urban Drainage Systems (SuDS) Policy	Prepare a policy stating the requirements for SuDS on new/re-development projects	Quick-win		Very Low	Very Low	High	High	Very High	Medium	VERY HIGH
Stormwater	City-wide	Infrastructure	Sustainable Urban Drainage Systems (SuDS) Implementation	Incorporate SuDS in all new/re-development to reduce runoff flow rates, improve water quality, amenity and biodiversity. SuDS may include rainwater harvesting, infiltration systems, filter strips, filter drains, swales, bioretention systems, pervious pavement, detention basins, ponds or wetlands.	Medium-term	SuDS policy required first	Medium	Medium	High	High	High	High	LOW
Water Supply	City-wide	Infrastructure	Source Monitoring	Monitoring of stream flows to verify baseflows, seasonal variation and climate change trends	Short-term		Very Low	Low	High	High	High	Medium	VERY HIGH

Appendix A

Climate Change Assessment Risk Matrix

Summary of the risk matrix analysis:

				Overall Rating	Total Score (Avg)	Climate Change Indicators								
Service	Opportunity	Climate Change Resilience Assessment	Additional Detail	H/M/L	1 to 3	Precip: Seasonality	Precip: Increase	Precip: Decrease	Temp: Seasonality	Temp: Increase	Temp: Decrease	Rainfall runoff: Seasonality	Rainfall Runoff: Increase	Rainfall Runoff : Decrease
Water Supply	Network Re-configuration	N	Reduction of intermittent supply		0									
	Demand Reduction	Y	Efficient design, water reuse, education	Medium	2	3	1	3	2	3	1	1	1	3
	Water Loss Reduction	N	Leakage repair		0									
	Water Supply Expansion	Y	Expansion of centralised network to all households	Low	1	1	1	2	2	1	2	1	1	1
	New Abstraction Exploitation	Y	Features both surface water and groundwater abstractions	High	3	3	3	3	2	3	2	3	3	3
	Upsize Storage Tanks	Y		Low	1	1	2	1	1	1	1	2	2	1
	Rationalise WTPs	Y	Addressing WTPs at capacity	Low	1	3	3	1						
	Source Monitoring	Y	Yield and quality outputs	Low	1	2	2	3						
	Scaled Metering	N	support leakage detection and system operations		0									
	Public Awareness Campaign	Y	Water efficiency and behaviour influence	High	3	3	3	3	3	3	3	3	3	3

				Overall Rating	Total Score (Avg)	Climate Change Indicators								
Service	Opportunity	Climate Change Resilience Assessment	Additional Detail	H/M/L	1 to 3	Precip: Seasonality	Precip: Increase	Precip: Decrease	Temp: Seasonality	Temp: Increase	Temp: Decrease	Rainfall runoff: Seasonality	Rainfall Runoff: Increase	Rainfall Runoff : Decrease
Wastewater	Expand Sewer Network	N	Reduction of septic tanks		0									
	Safe Disposal of Septic Tank Waste	Y		Medium	2	1	3	1	3	2	3	2	3	1
	Monitoring of Blockages	Y		Medium	2	3	3	1	1	1	1	3	3	1
	Implement Greywater Reuse	Y	Water reuse in new developments	Low	1	3	1	3	1	1	2	1		
	Rationalise WWTPs	N	Diagnostic of efficiency improvement in the WWTP		0									
	New / Upgrades WWTP	Y	Ensuring cost efficiency and system efficiency and delivery	Medium	2	3	3	1	1	3	1	2	3	1
	Solid Effluent Disposal and Management	Y		Medium	2	3	2	1	3	3	3		3	
	Sanitation Public Awareness Campaign	Y		Medium	2	2	2	2	3	3	1	3	2	1
	Flow Monitoring of Stormwater Inflows	Y		Medium	2	3	3	3	1	1	1	3	3	3

				Overall Rating	Total Score (Avg)	Climate Change Indicators								
Service	Opportunity	Climate Change Resilience Assessment	Additional Detail	H/M/L	1 to 3	Precip: Seasonality	Precip: Increase	Precip: Decrease	Temp: Seasonality	Temp: Increase	Temp: Decrease	Rainfall runoff: Seasonality	Rainfall Runoff: Increase	Rainfall Runoff : Decrease
Stormwater	Coordinated Inclusion of SuDS and NBS	Y	Coordination with Green infrastructure and open space teams	Medium	2	3	2	2	1	1	1	3	2	1
	Daylighting Existing Culverted Streams	Y	For urban areas	Low	1	1	1	1	2	2	1	2	1	1
	Stormwater Reuse	Y	For irrigation, biodiversity and amenity benefit	Medium	2	2	2	2	1	2	1	2	2	2
	Reconnect Greywater to Wastewater Network	Y		Low	1	1	1	1	3	3	1	1	1	1
	First Flush Capture and Treatment	Y	Avoiding increased contamination of water sources	Low	1	1	1	2	1	1	1	1	1	3
	Community Awareness of Stormwater Management	Y		Medium	2	3	3	1	1	1	1	3	3	1
	Diverted Utilities	N	Away from stream corridors		0									
	Monitoring Water Quality Improvements	N	Through SCADA		0									

Appendix B

Water Supply Maps

Figure 4-3: Identified Network Pressure Deficiencies, Velocity Deficiencies and Proposed Pumps and Valves

Figure 4-2: DMAs with Reallocated WTP Supply Source

Figure 4-4: Upgrades to the Existing Network

Figure 4-7: Water Mains Relative to Landslide Hazard Zones

Figure 4-10: Utility Corridor with Flow Breakdown and DMAs with Insufficient Head from Begana-Rama Trunk Main

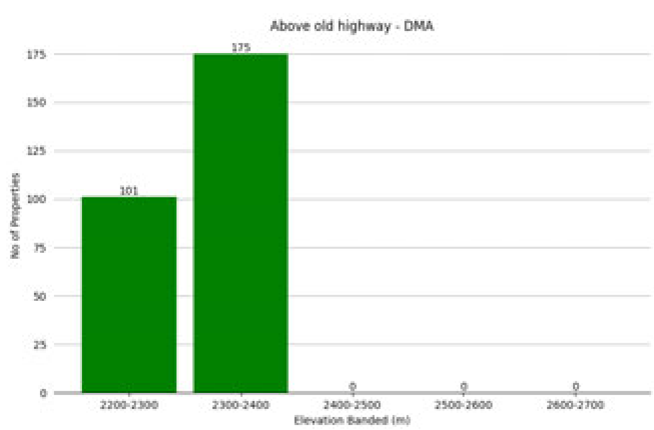
Figure 4-9: Potential Mains Reinforcement for Rezoning Chamgang Old WTP Demand to Taba WTP

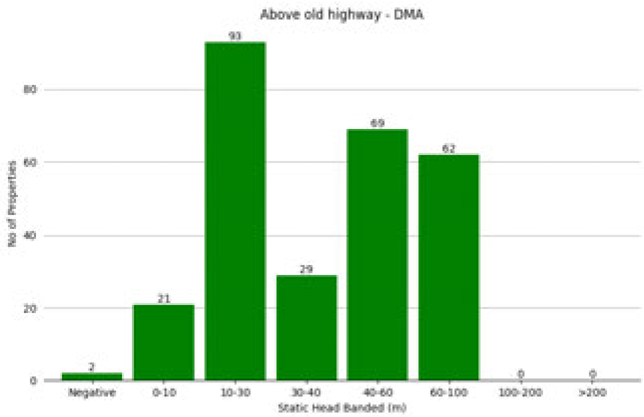
Appendix C

Data Sheets – DMAs and Storage Reservoirs

Data Sheet

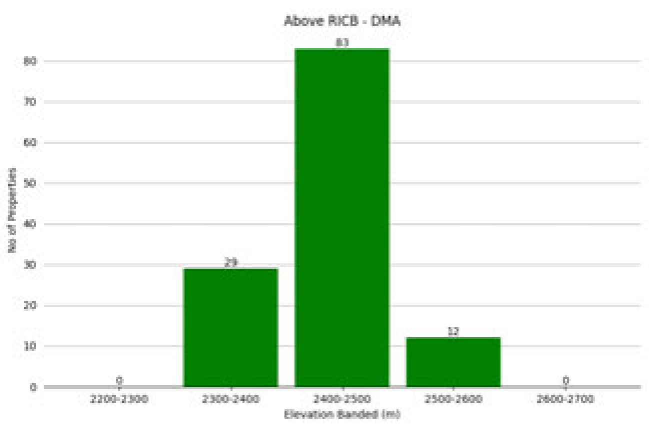
Demand Management Area – ***Above old highway***

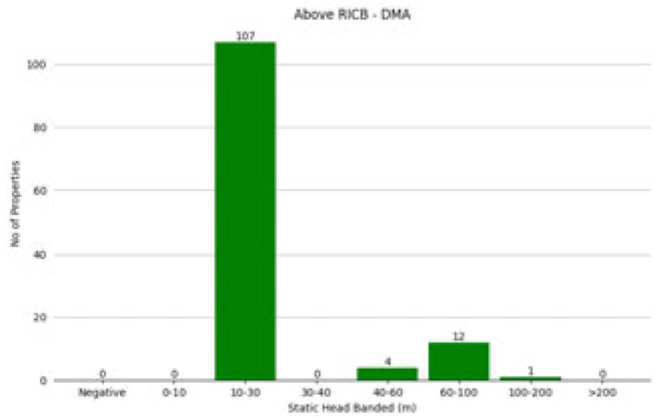
Value	Result
DMA Name	***Above old highway***
Storage Reservoir Name	***Gabjakha Tank***
Storage Reservoir Volume (m^3)	***360***
Total Storage Reservoir Volume per DMA (m^3)	***360.0***
Top Water Level (m)	***2399.5***
Supplying WTP	***Chamgang old WTP and Ngabirongchu WTP***
Common Supply Pipe Diameter (mm)	***150***
Number of Properties	***276***
Current Population	***3443***
2032 Population	***2968***
2047 Population	***3937***
Current Zone Descriptor of Use	***Medium***
2047 Zone Descriptor of Use	***Medium***
Supply Times	***6am-9am and 6pm-9pm***
Property Level - Lowest Elevation (m)	***2260***
Property Level - Highest Elevation (m)	***2390***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.845***
2032 Water Demand (MLD)	***0.555***
2047 Water Demand (MLD)	***0.429***
Required Storage Capacity for 24hours (m^3)	***845***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***485***

Data Sheet

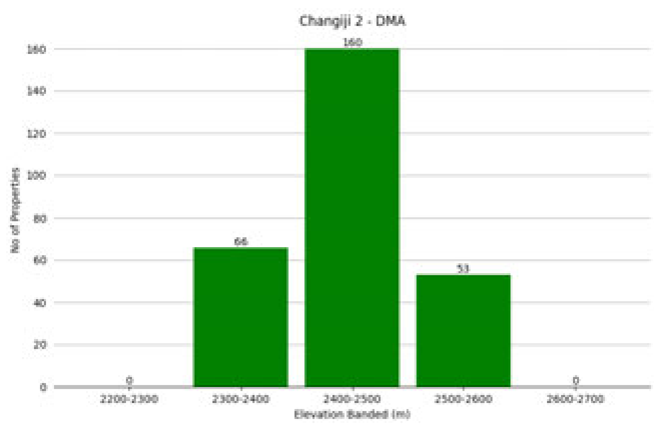
Demand Management Area – ***Above RICB***

Value	Result
DMA Name	***Above RICB***
Storage Reservoir Name	***Kuengacholing Tank 1, Kuengacholing Tank 2***
Storage Reservoir Volume (m^3)	***320, 320***
Total Storage Reservoir Volume per DMA (m^3)	***640.0***
Top Water Level (m)	***2592.5, 2593.5***
Supplying WTP	***Motihang WTP***
Common Supply Pipe Diameter (mm)	***100***
Number of Properties	***124***
Current Population	***845***
2032 Population	***1504***
2047 Population	***2339***
Current Zone Descriptor of Use	***Low***
2047 Zone Descriptor of Use	***Low***
Supply Times	***Unknown***
Property Level - Lowest Elevation (m)	***2390***
Property Level - Highest Elevation (m)	***2540***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.207***
2032 Water Demand (MLD)	***0.281***
2047 Water Demand (MLD)	***0.255***
Required Storage Capacity for 24hours (m^3)	***207***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***-433***

Data Sheet

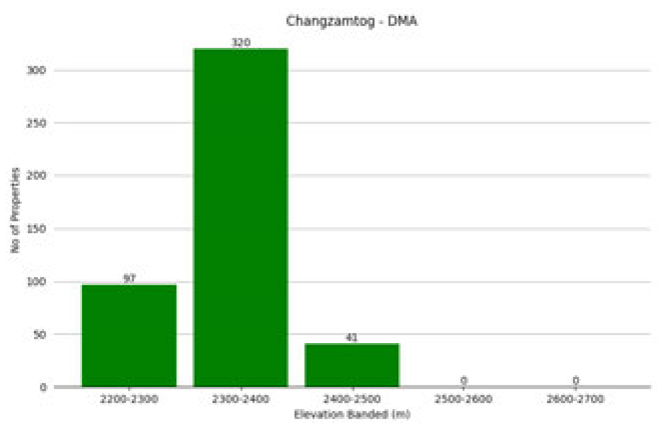
Demand Management Area – ***Changiji 2***

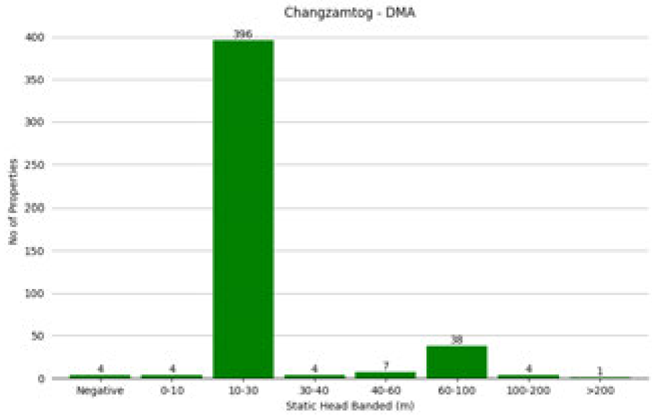
Value	Result
DMA Name	***Changiji 2***
Storage Reservoir Name	***None***
Storage Reservoir Volume (m^3)	***nan***
Total Storage Reservoir Volume per DMA (m^3)	***0.0***
Top Water Level (m)	***nan***
Supplying WTP	***Community supply. Proposed Taba WTP***
Common Supply Pipe Diameter (mm)	***nan***
Number of Properties	***367***
Current Population	***4748***
2032 Population	***3165***
2047 Population	***3539***
Current Zone Descriptor of Use	***Low***
2047 Zone Descriptor of Use	***Medium***
Supply Times	***Not currently supplied by system***
Property Level - Lowest Elevation (m)	***2360***
Property Level - Highest Elevation (m)	***2590***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.945***
2032 Water Demand (MLD)	***0.591***
2047 Water Demand (MLD)	***0.454***
Required Storage Capacity for 24hours (m^3)	***945***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***945***

Data Sheet

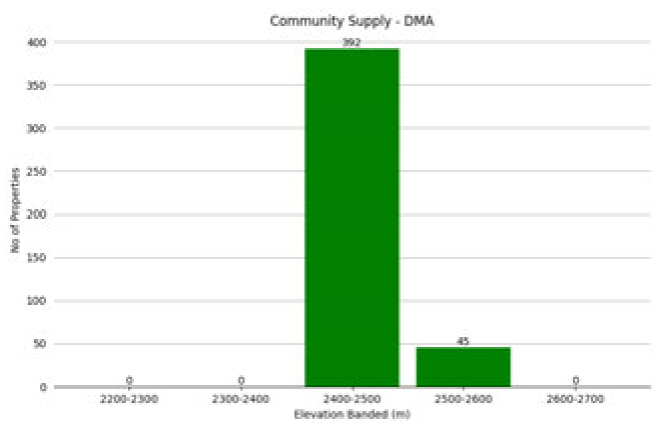
Demand Management Area – ***Changzamtog***

Value	Result
DMA Name	***Changzamtog***
Storage Reservoir Name	***Kuenselohodrang Tank 1, Kuenselphodreang Tank 2***
Storage Reservoir Volume (m^3)	***230, 100***
Total Storage Reservoir Volume per DMA (m^3)	***330.0***
Top Water Level (m)	***2490.5, 2488.5***
Supplying WTP	***Changbangdu WTP (boreholes)***
Common Supply Pipe Diameter (mm)	***100***
Number of Properties	***457***
Current Population	***7749***
2032 Population	***7508***
2047 Population	***9456***
Current Zone Descriptor of Use	***High***
2047 Zone Descriptor of Use	***High***
Supply Times	***Unknown***
Property Level - Lowest Elevation (m)	***2290***
Property Level - Highest Elevation (m)	***2490***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***1.883***
2032 Water Demand (MLD)	***1.403***
2047 Water Demand (MLD)	***1.213***
Required Storage Capacity for 24hours (m^3)	***1883***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***1553***

Data Sheet

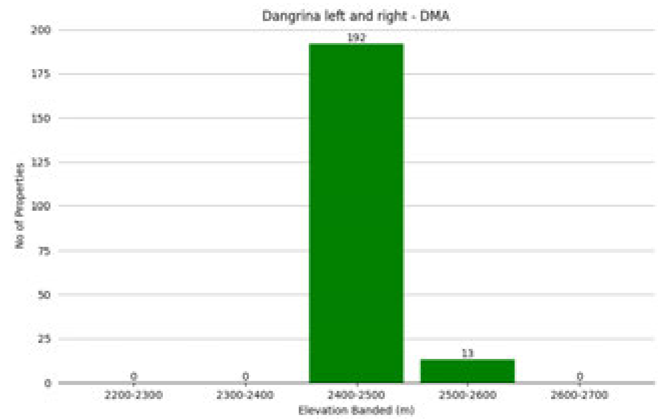
Demand Management Area – ***Community Supply***

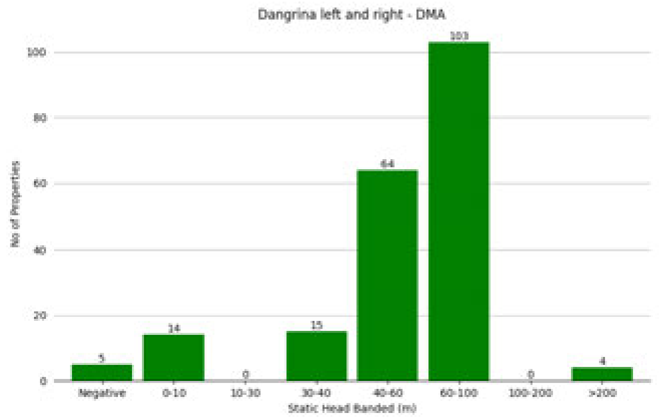
Value	Result
DMA Name	***Community Supply***
Storage Reservoir Name	***None***
Storage Reservoir Volume (m^3)	***nan***
Total Storage Reservoir Volume per DMA (m^3)	***nan***
Top Water Level (m)	***nan***
Supplying WTP	***Community Supply. Proposed Taba WTP***
Common Supply Pipe Diameter (mm)	***nan***
Number of Properties	***437***
Current Population	***2321***
2032 Population	***2294***
2047 Population	***2388***
Current Zone Descriptor of Use	***nan***
2047 Zone Descriptor of Use	***nan***
Supply Times	***Not currently supplied by system***
Property Level - Lowest Elevation (m)	***2410***
Property Level - Highest Elevation (m)	***2570***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.566***
2032 Water Demand (MLD)	***0.429***
2047 Water Demand (MLD)	***0.306***
Required Storage Capacity for 24hours (m^3)	***566***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***566***

Data Sheet

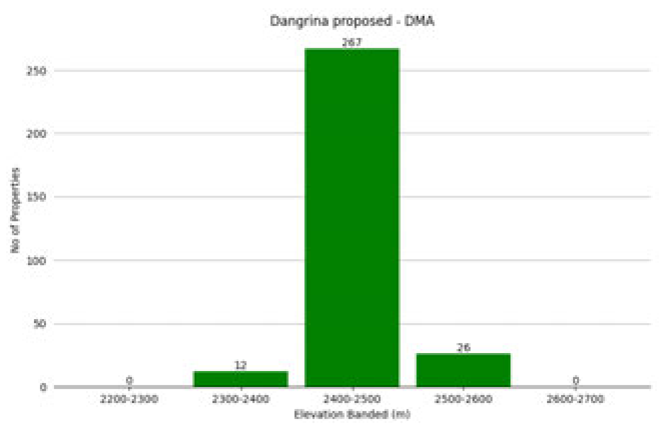
Demand Management Area – ***Dangrina left and right***

Value	Result
DMA Name	***Dangrina left and right***
Storage Reservoir Name	***Dechencholing Tank 1, Dechencholing Tank 2***
Storage Reservoir Volume (m^3)	***230, 230***
Total Storage Reservoir Volume per DMA (m^3)	***460.0***
Top Water Level (m)	***2522.5, 2484.5***
Supplying WTP	***Dechencholing WTP***
Common Supply Pipe Diameter (mm)	***150***
Number of Properties	***205***
Current Population	***3967***
2032 Population	***4434***
2047 Population	***5921***
Current Zone Descriptor of Use	***Low***
2047 Zone Descriptor of Use	***Medium***
Supply Times	***24hour***
Property Level - Lowest Elevation (m)	***2430***
Property Level - Highest Elevation (m)	***2520***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.684***
2032 Water Demand (MLD)	***0.828***
2047 Water Demand (MLD)	***0.759***
Required Storage Capacity for 24hours (m^3)	***684***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***224***

Data Sheet

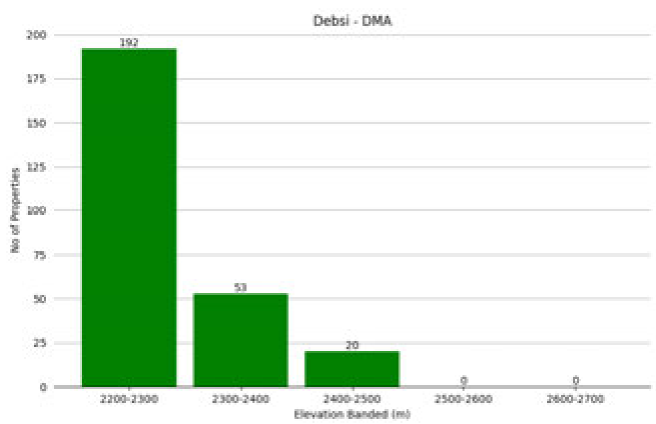
Demand Management Area – ***Dangrina proposed***

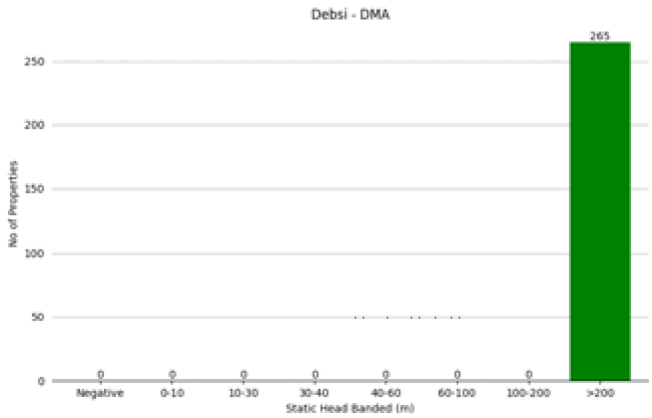
Value	Result
DMA Name	***Dangrina proposed***
Storage Reservoir Name	***None***
Storage Reservoir Volume (m^3)	***nan***
Total Storage Reservoir Volume per DMA (m^3)	***nan***
Top Water Level (m)	***nan***
Supplying WTP	***Community supply. Proposed Dechencholing WTP***
Common Supply Pipe Diameter (mm)	***nan***
Number of Properties	***305***
Current Population	***3698***
2032 Population	***4301***
2047 Population	***6432***
Current Zone Descriptor of Use	***Very Low***
2047 Zone Descriptor of Use	***Medium***
Supply Times	***Not currently supplied by system***
Property Level - Lowest Elevation (m)	***2400***
Property Level - Highest Elevation (m)	***2520***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.908***
2032 Water Demand (MLD)	***0.804***
2047 Water Demand (MLD)	***0.825***
Required Storage Capacity for 24hours (m^3)	***908***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***908***

Data Sheet

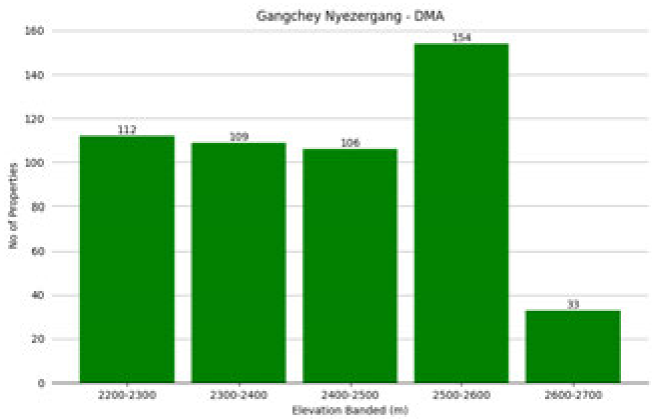
Demand Management Area – ***Debsi***

Value	Result
DMA Name	***Debsi***
Storage Reservoir Name	***Debsi Tank***
Storage Reservoir Volume (m^3)	***0***
Total Storage Reservoir Volume per DMA (m^3)	***0.0***
Top Water Level (m)	***0***
Supplying WTP	***Ngabirongchu WTP***
Common Supply Pipe Diameter (mm)	***250***
Number of Properties	***264***
Current Population	***1541***
2032 Population	***1335***
2047 Population	***4764***
Current Zone Descriptor of Use	***Very Low***
2047 Zone Descriptor of Use	***Medium***
Supply Times	***Unknown***
Property Level - Lowest Elevation (m)	***2250***
Property Level - Highest Elevation (m)	***2480***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.378***
2032 Water Demand (MLD)	***0.249***
2047 Water Demand (MLD)	***0.611***
Required Storage Capacity for 24hours (m^3)	***378***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***378***

Data Sheet

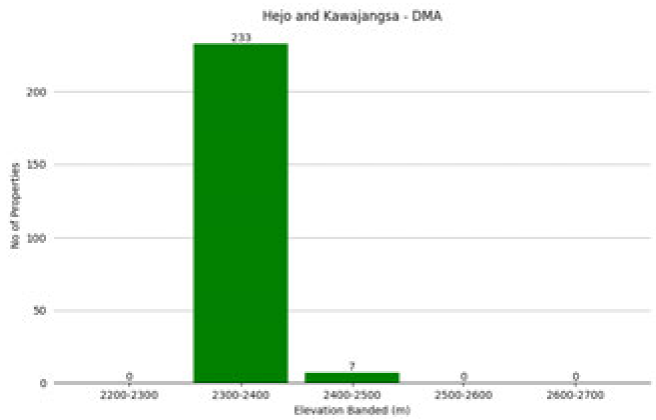
Demand Management Area – ***Gangchey Nyezergang***

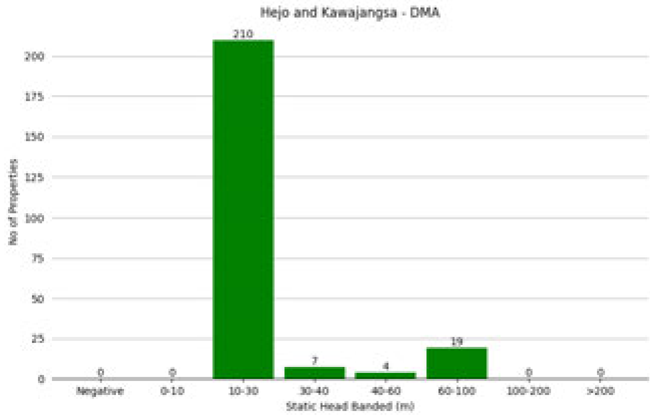
Value	Result
DMA Name	***Gangchey Nyezergang***
Storage Reservoir Name	***None***
Storage Reservoir Volume (m^3)	***nan***
Total Storage Reservoir Volume per DMA (m^3)	***nan***
Top Water Level (m)	***nan***
Supplying WTP	***Community supply. Proposed Ngabirongchu WTP***
Common Supply Pipe Diameter (mm)	***250***
Number of Properties	***514***
Current Population	***2005***
2032 Population	***2197***
2047 Population	***2738***
Current Zone Descriptor of Use	***Low***
2047 Zone Descriptor of Use	***Low***
Supply Times	***Not currently supplied by system***
Property Level - Lowest Elevation (m)	***2250***
Property Level - Highest Elevation (m)	***2640***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.491***
2032 Water Demand (MLD)	***0.411***
2047 Water Demand (MLD)	***0.351***
Required Storage Capacity for 24hours (m^3)	***491***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***491***

Data Sheet

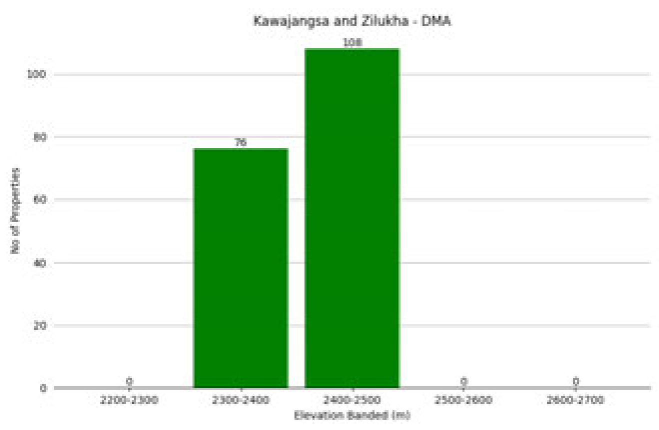
Demand Management Area – ***Hejo and Kawajangsa***

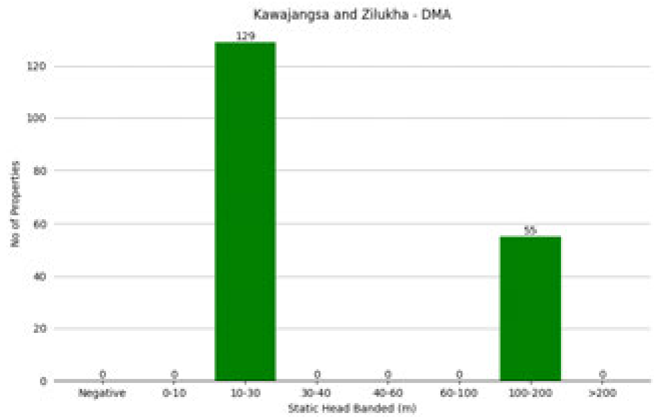
Value	Result
DMA Name	***Hejo and Kawajangsa***
Storage Reservoir Name	***Dzong Tank, Zilukha Tank***
Storage Reservoir Volume (m^3)	***250***
Total Storage Reservoir Volume per DMA (m^3)	***480.0***
Top Water Level (m)	***2402.5***
Supplying WTP	***Jungshina WTP. Taba WTP. Babena WTP.***
Common Supply Pipe Diameter (mm)	***150; 110***
Number of Properties	***240***
Current Population	***1852***
2032 Population	***2517***
2047 Population	***3258***
Current Zone Descriptor of Use	***Low***
2047 Zone Descriptor of Use	***Medium***
Supply Times	***8am-11am and 3pm-6pm***
Property Level - Lowest Elevation (m)	***2320***
Property Level - Highest Elevation (m)	***2420***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.455***
2032 Water Demand (MLD)	***0.47***
2047 Water Demand (MLD)	***0.418***
Required Storage Capacity for 24hours (m^3)	***455***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***-25***

Data Sheet

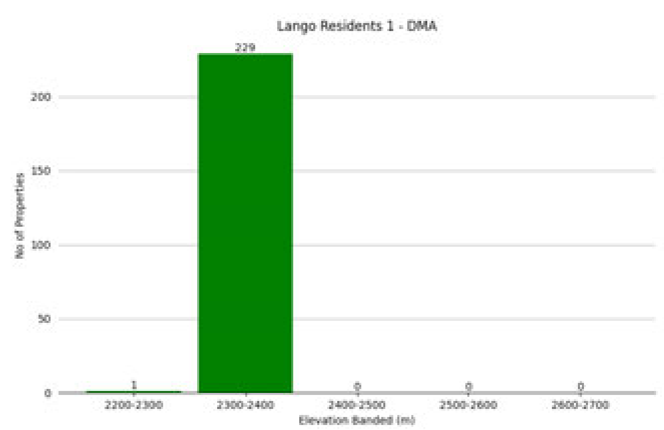
Demand Management Area – ***Kawajangsa and Zilukha***

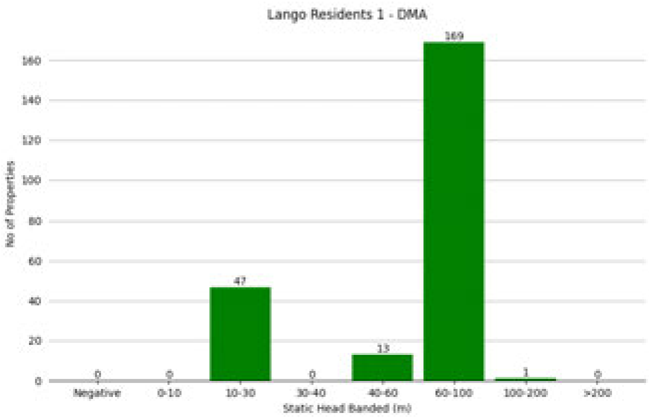
Value	Result
DMA Name	***Kawajangsa and Zilukha***
Storage Reservoir Name	***Dzong Tank, Kuengacholing Tank 1, Kuengacholing Tank 2, Zilukha Sintex Tank 1, Zilukha Sintex Tank 2, Zilukha Tank***
Storage Reservoir Volume (m^3)	***250, 320, 320, 6, 6, 230***
Total Storage Reservoir Volume per DMA (m^3)	***1132.0***
Top Water Level (m)	***2402.5, 2592.5, 2593.5, 2459.5, 2443.5, 2445.5***
Supplying WTP	***Motihang WTP***
Common Supply Pipe Diameter (mm)	***150; 80***
Number of Properties	***183***
Current Population	***2670***
2032 Population	***1928***
2047 Population	***2059***
Current Zone Descriptor of Use	***Low***
2047 Zone Descriptor of Use	***Low***
Supply Times	***8am-11am and 3pm-6pm***
Property Level - Lowest Elevation (m)	***2360***
Property Level - Highest Elevation (m)	***2450***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.471***
2032 Water Demand (MLD)	***0.36***
2047 Water Demand (MLD)	***0.264***
Required Storage Capacity for 24hours (m^3)	***471***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***-661***

Data Sheet

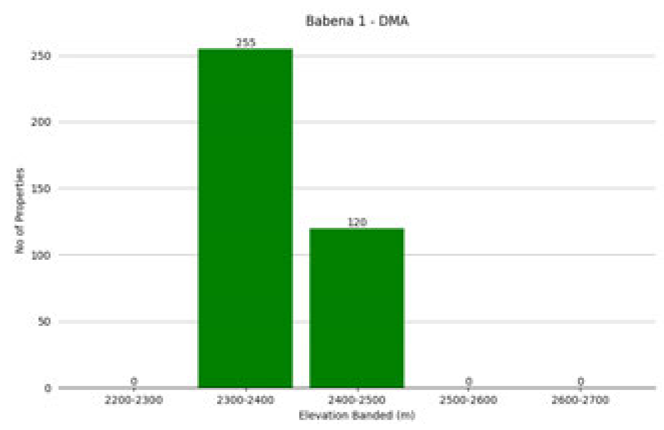
Demand Management Area – ***Lango Residents 1***

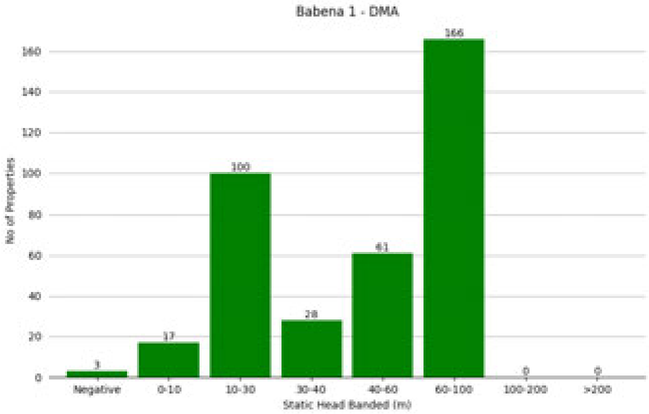
Value	Result
DMA Name	***Lango Residents 1***
Storage Reservoir Name	***Langjophakha Tank 2, Langjophakha tank 3***
Storage Reservoir Volume (m^3)	***320, 230***
Total Storage Reservoir Volume per DMA (m^3)	***550.0***
Top Water Level (m)	***2404.5***
Supplying WTP	***Taba WTP and Jungshina WTP***
Common Supply Pipe Diameter (mm)	***150***
Number of Properties	***230***
Current Population	***2408***
2032 Population	***1250***
2047 Population	***1624***
Current Zone Descriptor of Use	***Medium***
2047 Zone Descriptor of Use	***Medium***
Supply Times	***24hour***
Property Level - Lowest Elevation (m)	***2310***
Property Level - Highest Elevation (m)	***2390***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.591***
2032 Water Demand (MLD)	***0.234***
2047 Water Demand (MLD)	***0.208***
Required Storage Capacity for 24hours (m^3)	***591***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***41***

Data Sheet

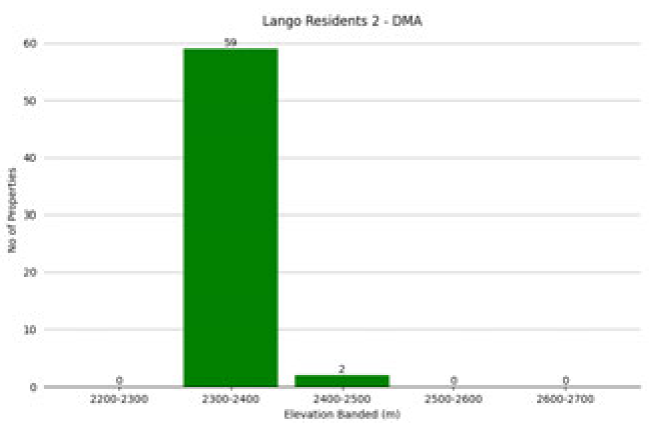
Demand Management Area – ***Babena 1***

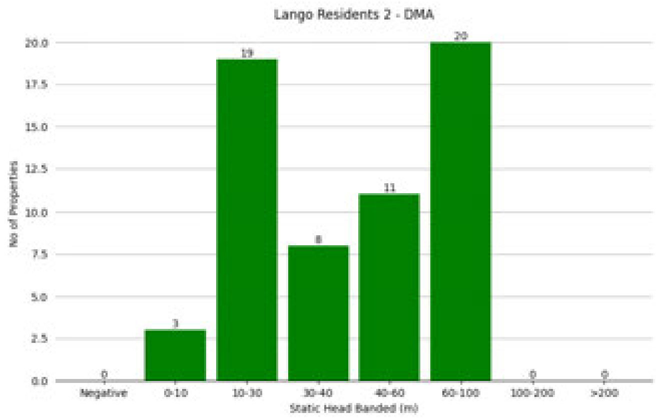
Value	Result
DMA Name	***Babena 1***
Storage Reservoir Name	***Samtenling Tank 1, Samtenling Tank 2***
Storage Reservoir Volume (m^3)	***230, 230***
Total Storage Reservoir Volume per DMA (m^3)	***460.0***
Top Water Level (m)	***2467.5, 2467.5***
Supplying WTP	***Babena WTP***
Common Supply Pipe Diameter (mm)	***160***
Number of Properties	***375***
Current Population	***4098***
2032 Population	***4963***
2047 Population	***6584***
Current Zone Descriptor of Use	***Medium***
2047 Zone Descriptor of Use	***High***
Supply Times	***Unknown***
Property Level - Lowest Elevation (m)	***2350***
Property Level - Highest Elevation (m)	***2460***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***1.0***
2032 Water Demand (MLD)	***0.927***
2047 Water Demand (MLD)	***0.844***
Required Storage Capacity for 24hours (m^3)	***1000***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***540***

Data Sheet

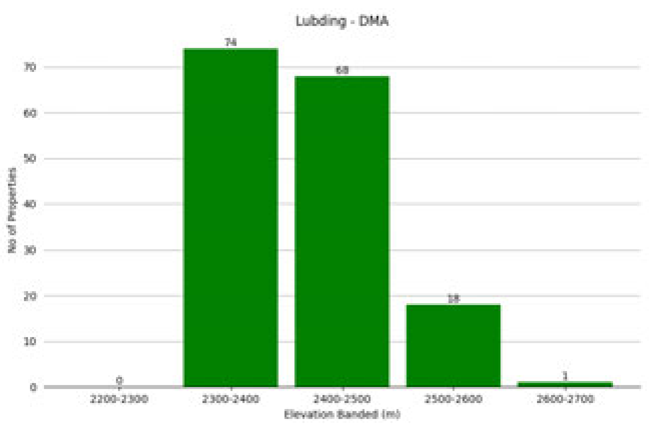
Demand Management Area – ***Lango Residents 2***

Value	Result
DMA Name	***Lango Residents 2***
Storage Reservoir Name	***Langjophakha Tank 2, Langjophakha Tank 3***
Storage Reservoir Volume (m^3)	***320, 230***
Total Storage Reservoir Volume per DMA (m^3)	***550.0***
Top Water Level (m)	***2404.5***
Supplying WTP	***Taba WTP and Jungshina WTP***
Common Supply Pipe Diameter (mm)	***150; 100***
Number of Properties	***61***
Current Population	***273***
2032 Population	***1316***
2047 Population	***1723***
Current Zone Descriptor of Use	***Medium***
2047 Zone Descriptor of Use	***Medium***
Supply Times	***24hour***
Property Level - Lowest Elevation (m)	***2320***
Property Level - Highest Elevation (m)	***2410***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.067***
2032 Water Demand (MLD)	***0.246***
2047 Water Demand (MLD)	***0.221***
Required Storage Capacity for 24hours (m^3)	***67***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***-483***

Data Sheet

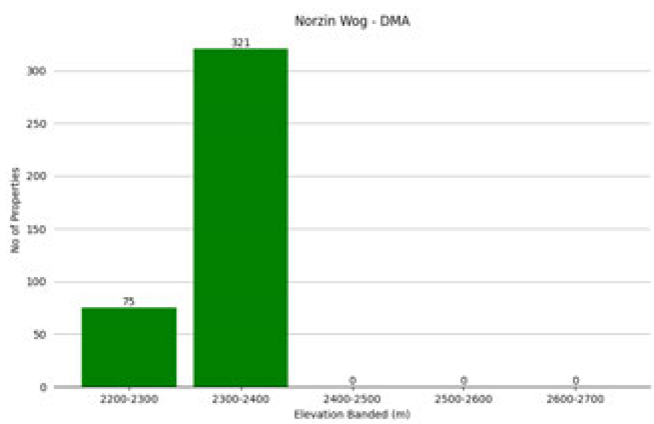
Demand Management Area – ***Lubding***

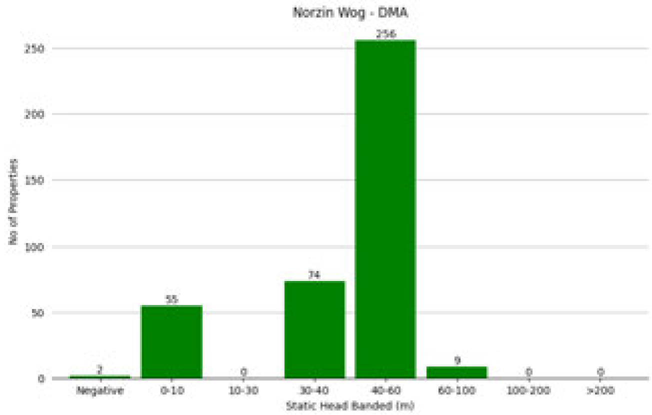
Value	Result
DMA Name	***Lubding***
Storage Reservoir Name	***Lubding Tank 1***
Storage Reservoir Volume (m^3)	***100***
Total Storage Reservoir Volume per DMA (m^3)	***100.0***
Top Water Level (m)	***2646.5***
Supplying WTP	***Community supply. Proposed Chamgang Old WTP***
Common Supply Pipe Diameter (mm)	***nan***
Number of Properties	***161***
Current Population	***1116***
2032 Population	***2435***
2047 Population	***2849***
Current Zone Descriptor of Use	***Very Low***
2047 Zone Descriptor of Use	***Very Low***
Supply Times	***Not currently supplied by system***
Property Level - Lowest Elevation (m)	***2320***
Property Level - Highest Elevation (m)	***2620***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.274***
2032 Water Demand (MLD)	***0.455***
2047 Water Demand (MLD)	***0.365***
Required Storage Capacity for 24hours (m^3)	***274***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***174***

Data Sheet

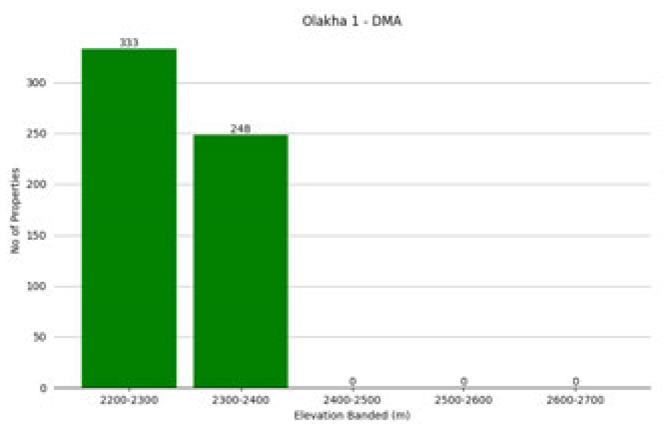
Demand Management Area – ***Norzin Wog***

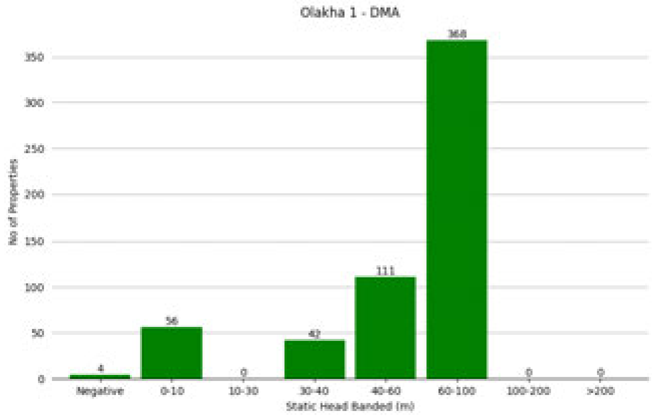
Value	Result
DMA Name	***Norzin Wog***
Storage Reservoir Name	***BCCI Tank***
Storage Reservoir Volume (m^3)	***230***
Total Storage Reservoir Volume per DMA (m^3)	***230.0***
Top Water Level (m)	***2361.5***
Supplying WTP	***Jungshina WTP***
Common Supply Pipe Diameter (mm)	***250***
Number of Properties	***395***
Current Population	***4015***
2032 Population	***7623***
2047 Population	***10589***
Current Zone Descriptor of Use	***High***
2047 Zone Descriptor of Use	***High***
Supply Times	***6am-9am and 6pm-9pm***
Property Level - Lowest Elevation (m)	***2300***
Property Level - Highest Elevation (m)	***2350***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.805***
2032 Water Demand (MLD)	***1.425***
2047 Water Demand (MLD)	***1.358***
Required Storage Capacity for 24hours (m^3)	***805***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***575***

Data Sheet

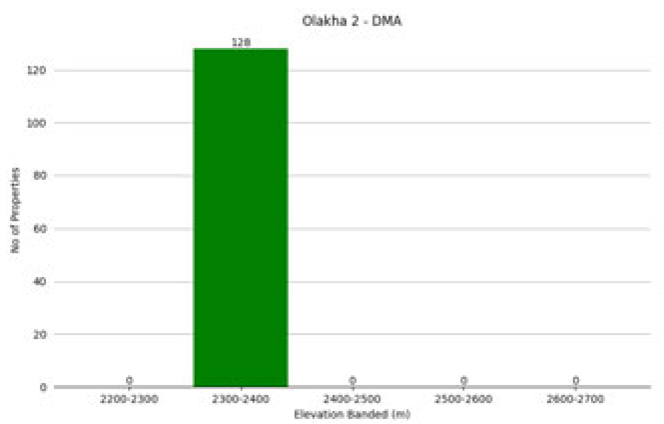
Demand Management Area – ***Olakha 1***

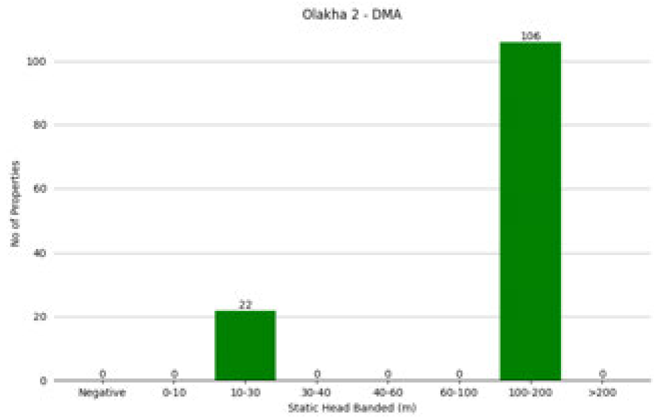
Value	Result
DMA Name	***Olakha 1***
Storage Reservoir Name	***Lungtenphu Tank 1, Lungtenphu Tank 2***
Storage Reservoir Volume (m^3)	***450, 360***
Total Storage Reservoir Volume per DMA (m^3)	***810.0***
Top Water Level (m)	***2365.5, 2365.5***
Supplying WTP	***Chamgang old WTP***
Common Supply Pipe Diameter (mm)	***200***
Number of Properties	***580***
Current Population	***10548***
2032 Population	***10919***
2047 Population	***12453***
Current Zone Descriptor of Use	***High***
2047 Zone Descriptor of Use	***High***
Supply Times	***6am-9am and 6pm-9pm***
Property Level - Lowest Elevation (m)	***2270***
Property Level - Highest Elevation (m)	***2370***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***2.349***
2032 Water Demand (MLD)	***2.04***
2047 Water Demand (MLD)	***1.597***
Required Storage Capacity for 24hours (m^3)	***2349***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***1539***

Data Sheet

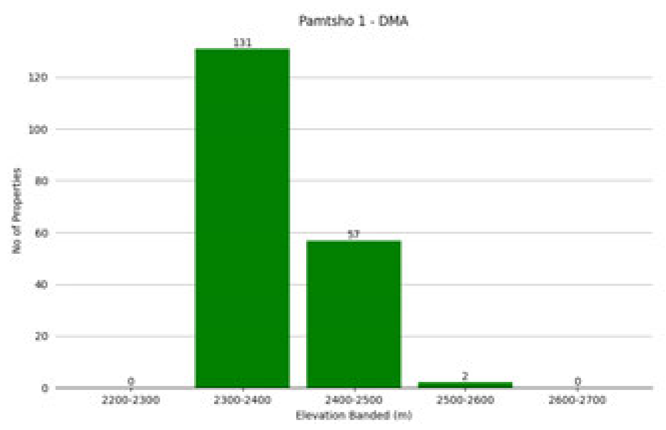
Demand Management Area – ***Olakha 2***

Value	Result
DMA Name	***Olakha 2***
Storage Reservoir Name	***Balancing Tank***
Storage Reservoir Volume (m^3)	***0***
Total Storage Reservoir Volume per DMA (m^3)	***0.0***
Top Water Level (m)	***2568.5***
Supplying WTP	***Chamgang old WTP***
Common Supply Pipe Diameter (mm)	***250***
Number of Properties	***128***
Current Population	***965***
2032 Population	***516***
2047 Population	***602***
Current Zone Descriptor of Use	***Medium***
2047 Zone Descriptor of Use	***Medium***
Supply Times	***6am-9am and 6pm-9pm***
Property Level - Lowest Elevation (m)	***2310***
Property Level - Highest Elevation (m)	***2390***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.236***
2032 Water Demand (MLD)	***0.096***
2047 Water Demand (MLD)	***0.077***
Required Storage Capacity for 24hours (m^3)	***236***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***236***

Data Sheet

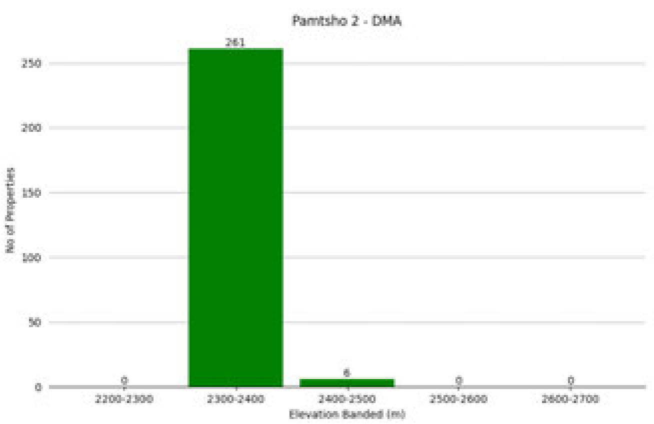
Demand Management Area – ***Pamtsho 1***

Value	Result
DMA Name	***Pamtsho 1***
Storage Reservoir Name	***None***
Storage Reservoir Volume (m^3)	***nan***
Total Storage Reservoir Volume per DMA (m^3)	***nan***
Top Water Level (m)	***nan***
Supplying WTP	***Community supply. Proposed Dechencholing WTP***
Common Supply Pipe Diameter (mm)	***150***
Number of Properties	***190***
Current Population	***1562***
2032 Population	***3007***
2047 Population	***4450***
Current Zone Descriptor of Use	***Low***
2047 Zone Descriptor of Use	***Medium***
Supply Times	***Not currently supplied by system***
Property Level - Lowest Elevation (m)	***2340***
Property Level - Highest Elevation (m)	***2560***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.383***
2032 Water Demand (MLD)	***0.562***
2047 Water Demand (MLD)	***0.571***
Required Storage Capacity for 24hours (m^3)	***383***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***383***

Data Sheet

Demand Management Area – ***Pamtsho 2***

Value	Result
DMA Name	***Pamtsho 2***
Storage Reservoir Name	***None***
Storage Reservoir Volume (m^3)	***nan***
Total Storage Reservoir Volume per DMA (m^3)	***nan***
Top Water Level (m)	***nan***
Supplying WTP	***Community supply. Proposed Dechencholing WTP***
Common Supply Pipe Diameter (mm)	***150***
Number of Properties	***266***
Current Population	***3494***
2032 Population	***2811***
2047 Population	***3931***
Current Zone Descriptor of Use	***Low***
2047 Zone Descriptor of Use	***High***
Supply Times	***Not currently supplied by system***
Property Level - Lowest Elevation (m)	***2330***
Property Level - Highest Elevation (m)	***2470***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.762***
2032 Water Demand (MLD)	***0.525***
2047 Water Demand (MLD)	***0.504***
Required Storage Capacity for 24hours (m^3)	***762***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***762***

Data Sheet

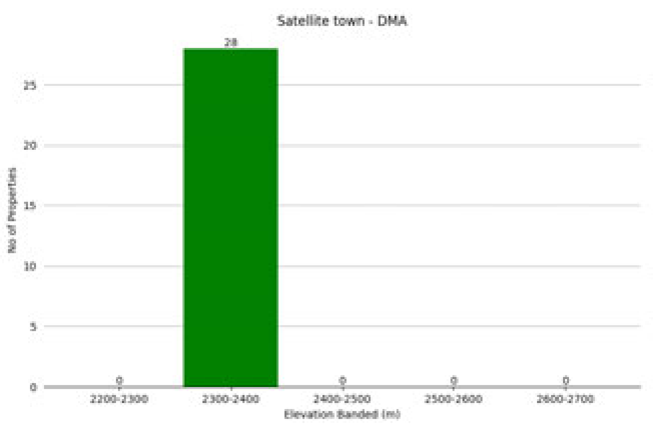
Demand Management Area – ***Rama***

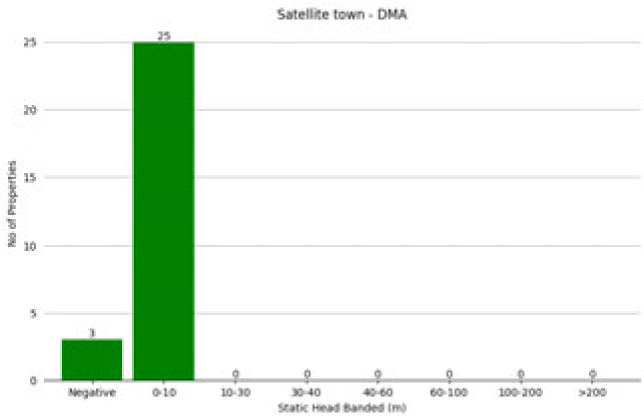
Value	Result
DMA Name	***Rama***
Storage Reservoir Name	***None***
Storage Reservoir Volume (m^3)	***nan***
Total Storage Reservoir Volume per DMA (m^3)	***nan***
Top Water Level (m)	***nan***
Supplying WTP	***Community supply. Proposed Ngabirongchu WTP***
Common Supply Pipe Diameter (mm)	***nan***
Number of Properties	***0***
Current Population	***0***
2032 Population	***0***
2047 Population	***4349***
Current Zone Descriptor of Use	***Very Low***
2047 Zone Descriptor of Use	***Medium***
Supply Times	***Not currently supplied by system***
Property Level - Lowest Elevation (m)	***2250***
Property Level - Highest Elevation (m)	***2400***
Property Level – Bell Curve by Elevation	
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.0***
2032 Water Demand (MLD)	***0.0***
2047 Water Demand (MLD)	***0.558***

Value	Result
Required Storage Capacity for 24hours (m^3)	***0***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***0***

Data Sheet

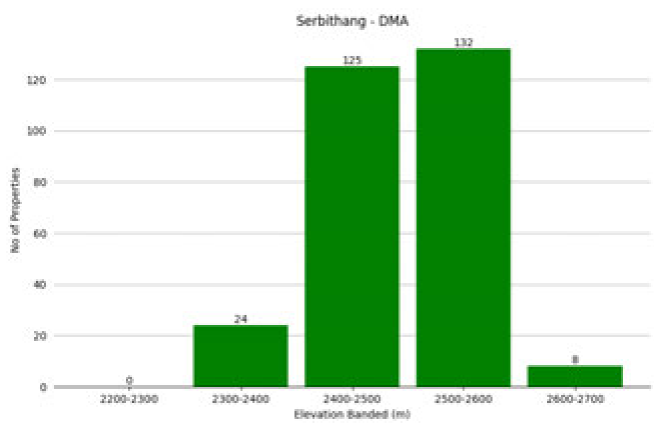
Demand Management Area – ***Satellite town***

Value	Result
DMA Name	***Satellite town***
Storage Reservoir Name	***Dechenling Satellite Town***
Storage Reservoir Volume (m^3)	***50***
Total Storage Reservoir Volume per DMA (m^3)	***50.0***
Top Water Level (m)	***2398.5***
Supplying WTP	***Dechencholing WTP***
Common Supply Pipe Diameter (mm)	***80***
Number of Properties	***28***
Current Population	***218***
2032 Population	***213***
2047 Population	***318***
Current Zone Descriptor of Use	***Very Low***
2047 Zone Descriptor of Use	***Very Low***
Supply Times	***24hour***
Property Level - Lowest Elevation (m)	***2380***
Property Level - Highest Elevation (m)	***2390***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.053***
2032 Water Demand (MLD)	***0.04***
2047 Water Demand (MLD)	***0.041***
Required Storage Capacity for 24hours (m^3)	***53***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***3***

Data Sheet

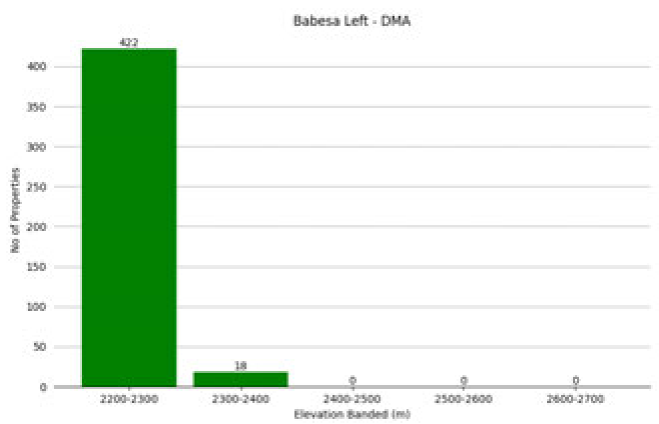
Demand Management Area – ***Serbithang***

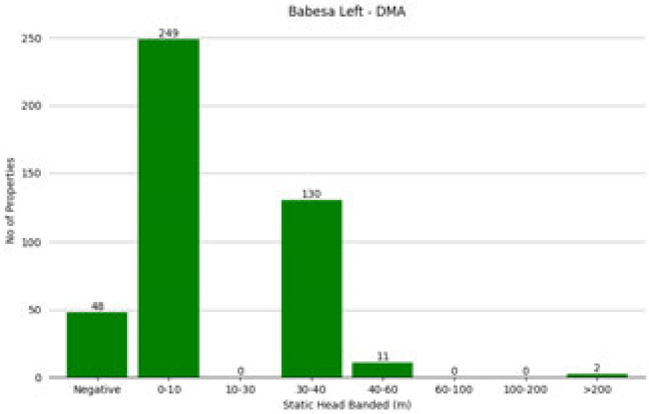
Value	Result
DMA Name	***Serbithang***
Storage Reservoir Name	***None***
Storage Reservoir Volume (m^3)	***nan***
Total Storage Reservoir Volume per DMA (m^3)	***nan***
Top Water Level (m)	***nan***
Supplying WTP	***Community supply. Proposed Ngabirongchu WTP***
Common Supply Pipe Diameter (mm)	***150***
Number of Properties	***289***
Current Population	***835***
2032 Population	***692***
2047 Population	***789***
Current Zone Descriptor of Use	***Very Low***
2047 Zone Descriptor of Use	***Very Low***
Supply Times	***Not currently supplied by system***
Property Level - Lowest Elevation (m)	***2350***
Property Level - Highest Elevation (m)	***2630***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.205***
2032 Water Demand (MLD)	***0.129***
2047 Water Demand (MLD)	***0.101***
Required Storage Capacity for 24hours (m^3)	***205***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***205***

Data Sheet

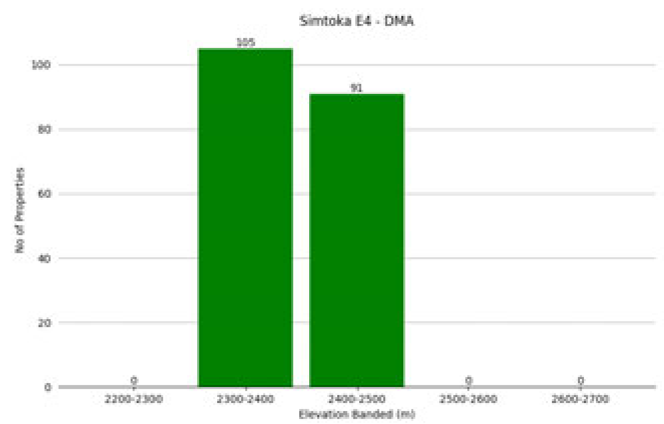
Demand Management Area – ***Babesa Left***

Value	Result
DMA Name	***Babesa Left***
Storage Reservoir Name	***Simtokha Tank Dantak***
Storage Reservoir Volume (m^3)	***735***
Total Storage Reservoir Volume per DMA (m^3)	***735.0***
Top Water Level (m)	***2308.5***
Supplying WTP	***Chamgang old WTP***
Common Supply Pipe Diameter (mm)	***200***
Number of Properties	***440***
Current Population	***5726***
2032 Population	***5946***
2047 Population	***7553***
Current Zone Descriptor of Use	***High***
2047 Zone Descriptor of Use	***High***
Supply Times	***6am-9am and 6pm-9pm***
Property Level - Lowest Elevation (m)	***2260***
Property Level - Highest Elevation (m)	***2310***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***1.399***
2032 Water Demand (MLD)	***1.111***
2047 Water Demand (MLD)	***0.969***
Required Storage Capacity for 24hours (m^3)	***1399***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***664***

Data Sheet

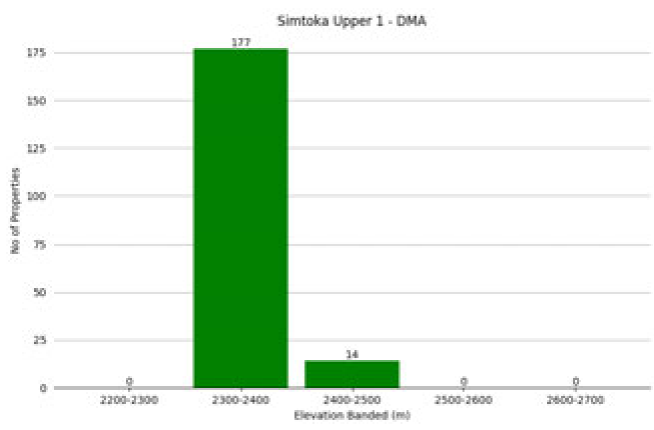
Demand Management Area – ***Simtoka E4***

Value	Result
DMA Name	***Simtoka E4***
Storage Reservoir Name	***Simtokha E4 New Tank 1***
Storage Reservoir Volume (m^3)	***200***
Total Storage Reservoir Volume per DMA (m^3)	***200.0***
Top Water Level (m)	***2522.5***
Supplying WTP	***Chamgang New WTP***
Common Supply Pipe Diameter (mm)	***nan***
Number of Properties	***196***
Current Population	***870***
2032 Population	***1619***
2047 Population	***1887***
Current Zone Descriptor of Use	***Very Low***
2047 Zone Descriptor of Use	***Very Low***
Supply Times	***Not currently supplied by system***
Property Level - Lowest Elevation (m)	***2310***
Property Level - Highest Elevation (m)	***2500***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.214***
2032 Water Demand (MLD)	***0.303***
2047 Water Demand (MLD)	***0.242***
Required Storage Capacity for 24hours (m^3)	***214***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***14***

Data Sheet

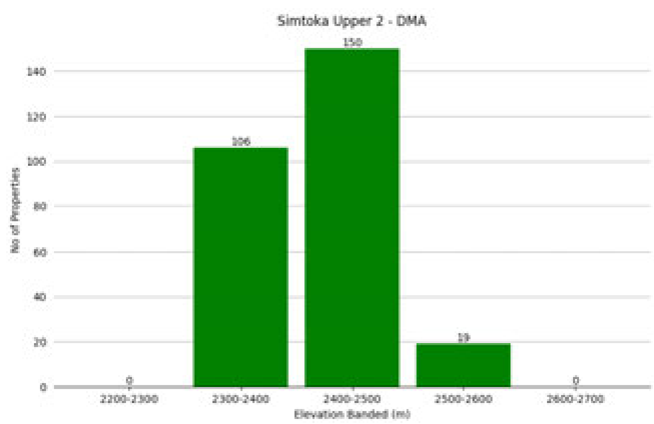
Demand Management Area – ***Simtoka Upper 1***

Value	Result
DMA Name	***Simtoka Upper 1***
Storage Reservoir Name	***None***
Storage Reservoir Volume (m^3)	***nan***
Total Storage Reservoir Volume per DMA (m^3)	***nan***
Top Water Level (m)	***nan***
Supplying WTP	***Chamgang New WTP***
Common Supply Pipe Diameter (mm)	***150***
Number of Properties	***191***
Current Population	***968***
2032 Population	***800***
2047 Population	***933***
Current Zone Descriptor of Use	***Low***
2047 Zone Descriptor of Use	***Low***
Supply Times	***Not currently supplied by system***
Property Level - Lowest Elevation (m)	***2310***
Property Level - Highest Elevation (m)	***2470***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.237***
2032 Water Demand (MLD)	***0.15***
2047 Water Demand (MLD)	***0.12***
Required Storage Capacity for 24hours (m^3)	***237***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***237***

Data Sheet

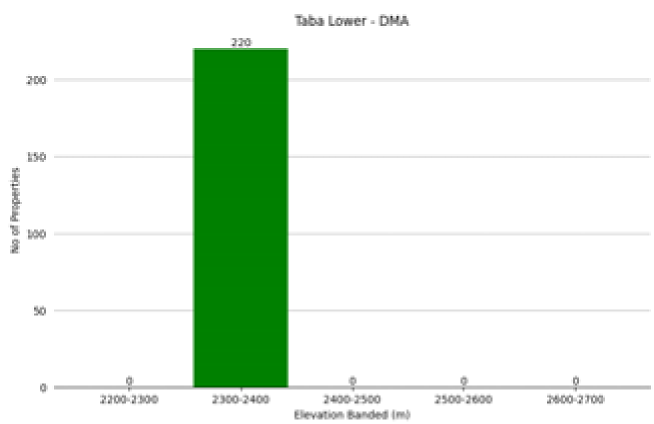
Demand Management Area – ***Simtoka Upper 2***

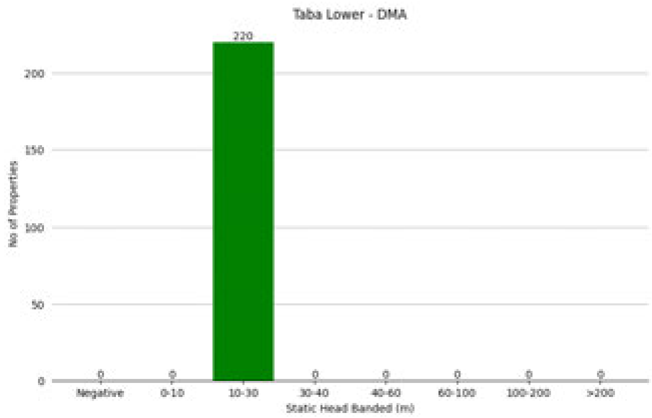
Value	Result
DMA Name	***Simtoka Upper 2***
Storage Reservoir Name	***None***
Storage Reservoir Volume (m^3)	***nan***
Total Storage Reservoir Volume per DMA (m^3)	***nan***
Top Water Level (m)	***nan***
Supplying WTP	***Chamgang New WTP***
Common Supply Pipe Diameter (mm)	***150***
Number of Properties	***274***
Current Population	***1814***
2032 Population	***1383***
2047 Population	***1559***
Current Zone Descriptor of Use	***Very Low***
2047 Zone Descriptor of Use	***Very Low***
Supply Times	***Not currently supplied by system***
Property Level - Lowest Elevation (m)	***2310***
Property Level - Highest Elevation (m)	***2540***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.363***
2032 Water Demand (MLD)	***0.258***
2047 Water Demand (MLD)	***0.2***
Required Storage Capacity for 24hours (m^3)	***363***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***363***

Data Sheet

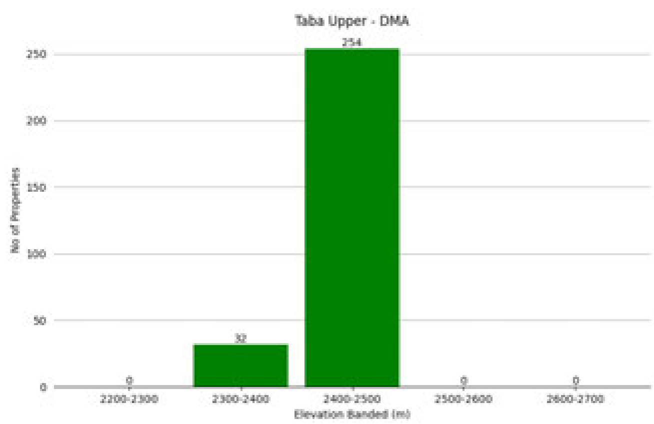
Demand Management Area – ***Taba Lower***

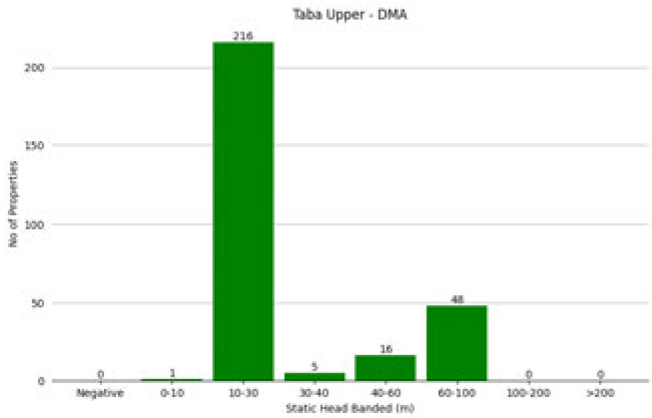
Value	Result
DMA Name	***Taba Lower***
Storage Reservoir Name	***Taba Tank***
Storage Reservoir Volume (m^3)	***230***
Total Storage Reservoir Volume per DMA (m^3)	***230.0***
Top Water Level (m)	***2531.5***
Supplying WTP	***Taba WTP***
Common Supply Pipe Diameter (mm)	***200***
Number of Properties	***219***
Current Population	***3842***
2032 Population	***3176***
2047 Population	***4064***
Current Zone Descriptor of Use	***Very High***
2047 Zone Descriptor of Use	***High***
Supply Times	***6am-9am and 6pm-9pm***
Property Level - Lowest Elevation (m)	***2360***
Property Level - Highest Elevation (m)	***2400***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.873***
2032 Water Demand (MLD)	***0.593***
2047 Water Demand (MLD)	***0.521***
Required Storage Capacity for 24hours (m^3)	***873***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***643***

Data Sheet

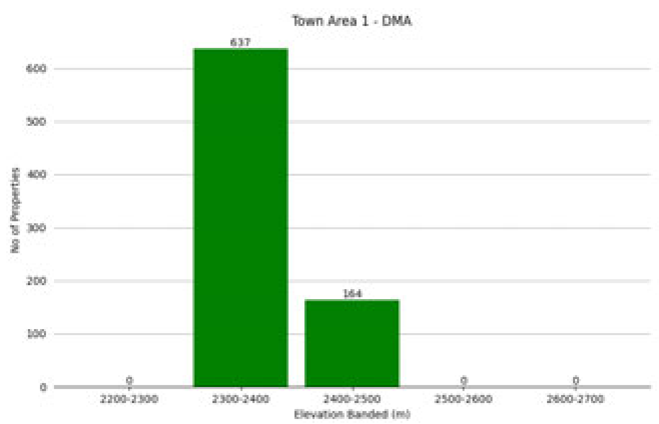
Demand Management Area – ***Taba Upper***

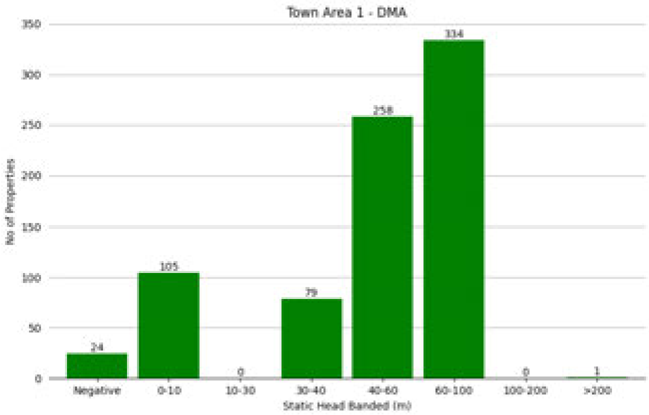
Value	Result
DMA Name	***Taba Upper***
Storage Reservoir Name	***Taba Tank***
Storage Reservoir Volume (m^3)	***230***
Total Storage Reservoir Volume per DMA (m^3)	***230.0***
Top Water Level (m)	***2531.5***
Supplying WTP	***Taba WTP***
Common Supply Pipe Diameter (mm)	***150***
Number of Properties	***286***
Current Population	***2995***
2032 Population	***3655***
2047 Population	***4684***
Current Zone Descriptor of Use	***Medium***
2047 Zone Descriptor of Use	***Medium***
Supply Times	***6am-9am and 6pm-9pm***
Property Level - Lowest Elevation (m)	***2390***
Property Level - Highest Elevation (m)	***2500***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.658***
2032 Water Demand (MLD)	***0.683***
2047 Water Demand (MLD)	***0.601***
Required Storage Capacity for 24hours (m^3)	***658***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***428***

Data Sheet

Demand Management Area – ***Town Area 1***

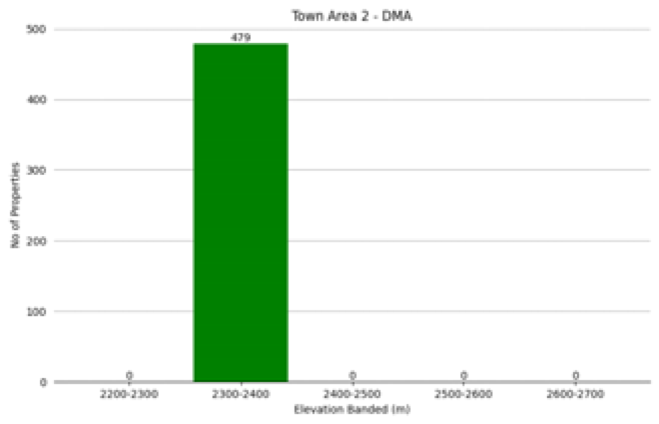
Value	Result
DMA Name	***Town Area 1***
Storage Reservoir Name	***Motithang Three Tanks 1, Motithang Three Tanks 3, Motithang Three Tanks 2***
Storage Reservoir Volume (m^3)	***320, 320, 320***
Total Storage Reservoir Volume per DMA (m^3)	***960.0***
Top Water Level (m)	***2440.5, 2439.5, 2440.5***
Supplying WTP	***Motihang WTP. Taba WTP. Jungshina WTP.***
Common Supply Pipe Diameter (mm)	***150***
Number of Properties	***797***
Current Population	***8555***
2032 Population	***8342***
2047 Population	***11230***
Current Zone Descriptor of Use	***Medium***
2047 Zone Descriptor of Use	***High***
Supply Times	***6am-9am and 6pm-9pm***
Property Level - Lowest Elevation (m)	***2350***
Property Level - Highest Elevation (m)	***2440***
Property Level – Bell Curve by Elevation	

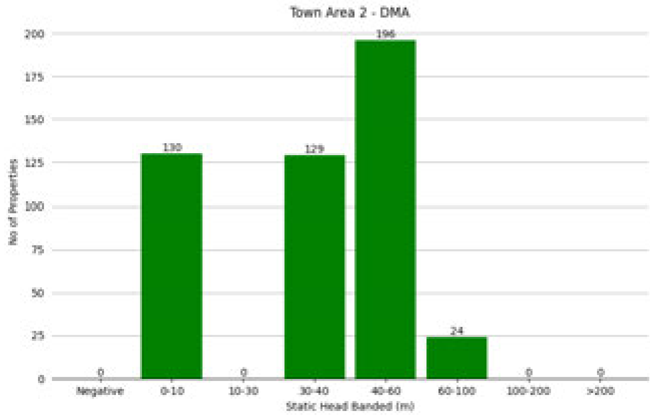
<table>
<tr><th>Value</th><th>Result</th></tr>
<tr><td>Property Level – Bell Curve by Pressure</td><td>


</td></tr>
<tr><td>Current Water Demand (MLD)</td><td>1.661</td></tr>
<tr><td>2032 Water Demand (MLD)</td><td>1.559</td></tr>
<tr><td>2047 Water Demand (MLD)</td><td>1.44</td></tr>
<tr><td>Required Storage Capacity for 24hours (m^3)</td><td>1661</td></tr>
<tr><td>Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity</td><td>701</td></tr>
</table>

Data Sheet

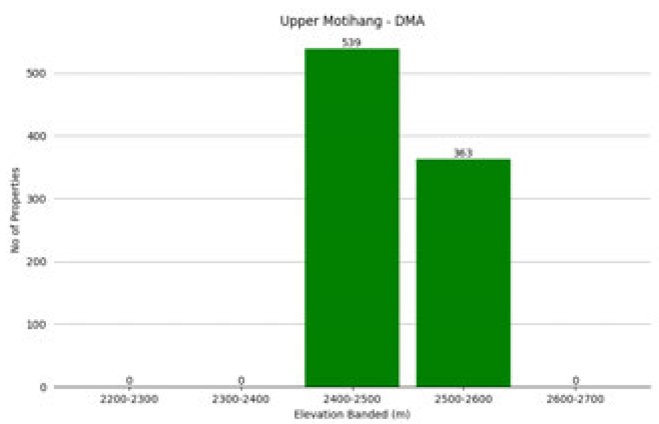
Demand Management Area – ***Town Area 2***

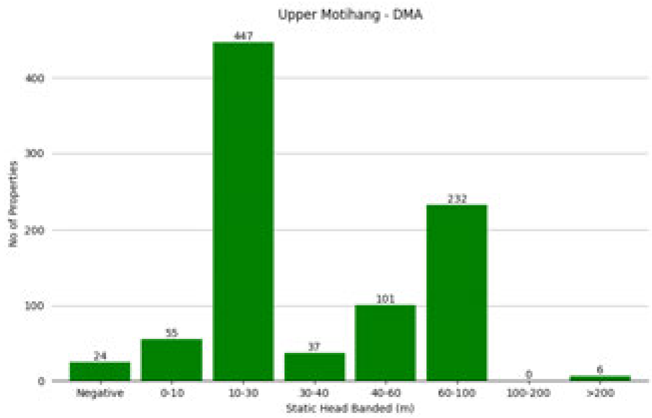
Value	Result
DMA Name	***Town Area 2***
Storage Reservoir Name	***Swimming Pool Tank 1, Swimming Pool Tank 2***
Storage Reservoir Volume (m^3)	***230, 230***
Total Storage Reservoir Volume per DMA (m^3)	***460.0***
Top Water Level (m)	***2375.5, 2375.5***
Supplying WTP	***Motihang WTP. Taba WTP. Jungshina WTP.***
Common Supply Pipe Diameter (mm)	***150***
Number of Properties	***478***
Current Population	***4411***
2032 Population	***5766***
2047 Population	***8130***
Current Zone Descriptor of Use	***Very High***
2047 Zone Descriptor of Use	***Very High***
Supply Times	***6am-9am and 6pm-9pm***
Property Level - Lowest Elevation (m)	***2310***
Property Level - Highest Elevation (m)	***2360***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***1.005***
2032 Water Demand (MLD)	***1.077***
2047 Water Demand (MLD)	***1.043***
Required Storage Capacity for 24hours (m^3)	***1005***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***545***

Data Sheet

Demand Management Area – ***Upper Motihang***

Value	Result
DMA Name	***Upper Motihang***
Storage Reservoir Name	***Kuengacholing Tank 1, Kuengacholing Tank 2***
Storage Reservoir Volume (m^3)	***320, 320***
Total Storage Reservoir Volume per DMA (m^3)	***640.0***
Top Water Level (m)	***2592.5, 2593.5***
Supplying WTP	***Motihang WTP***
Common Supply Pipe Diameter (mm)	***150***
Number of Properties	***897***
Current Population	***10825***
2032 Population	***9384***
2047 Population	***10561***
Current Zone Descriptor of Use	***Medium***
2047 Zone Descriptor of Use	***Medium***
Supply Times	***Unknown***
Property Level - Lowest Elevation (m)	***2410***
Property Level - Highest Elevation (m)	***2590***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***2.23***
2032 Water Demand (MLD)	***1.753***
2047 Water Demand (MLD)	***1.354***
Required Storage Capacity for 24hours (m^3)	***2230***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***1590***

Data Sheet

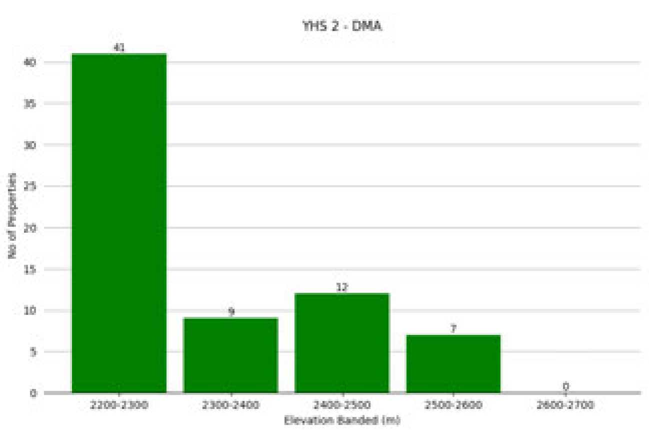
Demand Management Area – ***Workshop***

Value	Result
DMA Name	***Workshop***
Storage Reservoir Name	***Workshop Tank 1, Workshop Tank 2, Workshop Tank 3, Workshop Tank 4***
Storage Reservoir Volume (m^3)	***2, 2, 2, 2***
Total Storage Reservoir Volume per DMA (m^3)	***8.0***
Top Water Level (m)	***2307.5, 2309.5, 2296.5, 2295.5***
Supplying WTP	***Private supply. Proposed Chamgang Old.***
Common Supply Pipe Diameter (mm)	***75***
Number of Properties	***130***
Current Population	***1492***
2032 Population	***1501***
2047 Population	***1750***
Current Zone Descriptor of Use	***Medium***
2047 Zone Descriptor of Use	***High***
Supply Times	***Unknown***
Property Level - Lowest Elevation (m)	***2270***
Property Level - Highest Elevation (m)	***2300***
Property Level – Bell Curve by Elevation	
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.336***
2032 Water Demand (MLD)	***0.28***
2047 Water Demand (MLD)	***0.224***

Value	Result
Required Storage Capacity for 24hours (m^3)	***336***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***328***

Data Sheet

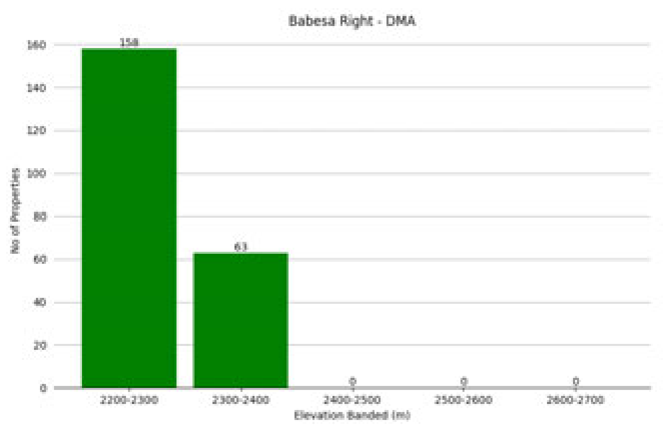
Demand Management Area – ***YHS 2***

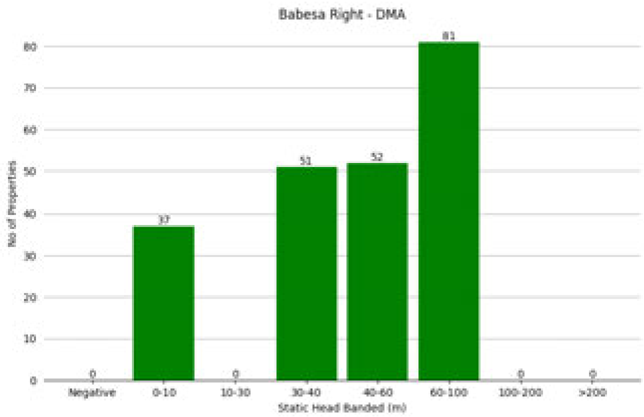
Value	Result
DMA Name	***YHS 2***
Storage Reservoir Name	***None***
Storage Reservoir Volume (m^3)	***nan***
Total Storage Reservoir Volume per DMA (m^3)	***nan***
Top Water Level (m)	***nan***
Supplying WTP	***Community supply. Proposed Taba WTP***
Common Supply Pipe Diameter (mm)	***200***
Number of Properties	***68***
Current Population	***981***
2032 Population	***1030***
2047 Population	***1427***
Current Zone Descriptor of Use	***Low***
2047 Zone Descriptor of Use	***Very Low***
Supply Times	***Not currently supplied by system***
Property Level - Lowest Elevation (m)	***2280***
Property Level - Highest Elevation (m)	***2520***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.213***
2032 Water Demand (MLD)	***0.192***
2047 Water Demand (MLD)	***0.183***
Required Storage Capacity for 24hours (m^3)	***213***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***213***

Data Sheet

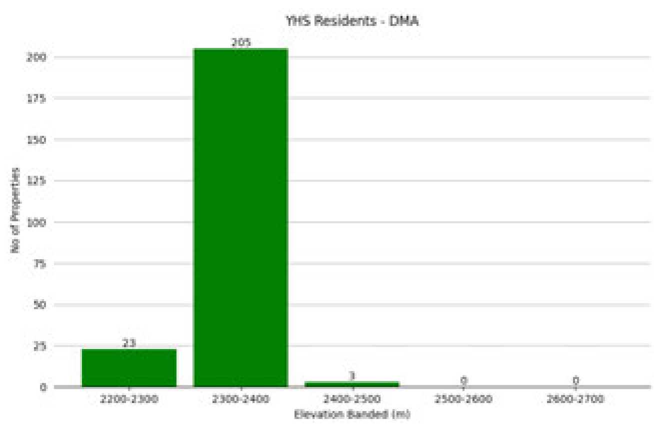
Demand Management Area – ***Babesa Right***

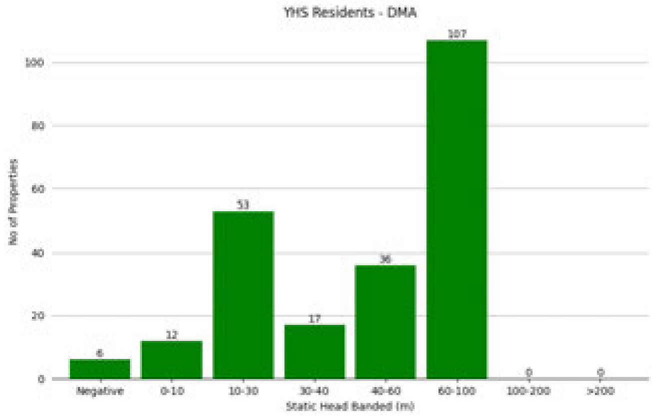
Value	Result
DMA Name	***Babesa Right***
Storage Reservoir Name	***Babesa Tank 1***
Storage Reservoir Volume (m^3)	***360***
Total Storage Reservoir Volume per DMA (m^3)	***360.0***
Top Water Level (m)	***2335.5***
Supplying WTP	***Chamgang old WTP and Ngabirongchu WTP***
Common Supply Pipe Diameter (mm)	***150***
Number of Properties	***219***
Current Population	***4612***
2032 Population	***3455***
2047 Population	***4243***
Current Zone Descriptor of Use	***Medium***
2047 Zone Descriptor of Use	***High***
Supply Times	***6am-9am and 6pm-9pm***
Property Level - Lowest Elevation (m)	***2260***
Property Level - Highest Elevation (m)	***2330***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.904***
2032 Water Demand (MLD)	***0.646***
2047 Water Demand (MLD)	***0.544***
Required Storage Capacity for 24hours (m^3)	***904***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***544***

Data Sheet

Demand Management Area – ***YHS Residents***

Value	Result
DMA Name	***YHS Residents***
Storage Reservoir Name	***YHS Tank 1, YHS Tank 2***
Storage Reservoir Volume (m^3)	***320, 230***
Total Storage Reservoir Volume per DMA (m^3)	***550.0***
Top Water Level (m)	***2406.5, 2406.5***
Supplying WTP	***Taba WTP***
Common Supply Pipe Diameter (mm)	***80***
Number of Properties	***229***
Current Population	***3854***
2032 Population	***3577***
2047 Population	***4264***
Current Zone Descriptor of Use	***Low***
2047 Zone Descriptor of Use	***Medium***
Supply Times	***24hour***
Property Level - Lowest Elevation (m)	***2290***
Property Level - Highest Elevation (m)	***2410***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.532***
2032 Water Demand (MLD)	***0.668***
2047 Water Demand (MLD)	***0.547***
Required Storage Capacity for 24hours (m^3)	***532***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***-18***

Data Sheet

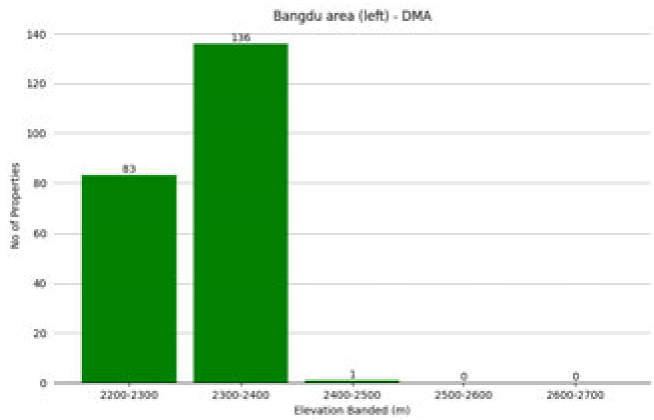
Demand Management Area – ***Zilukha***

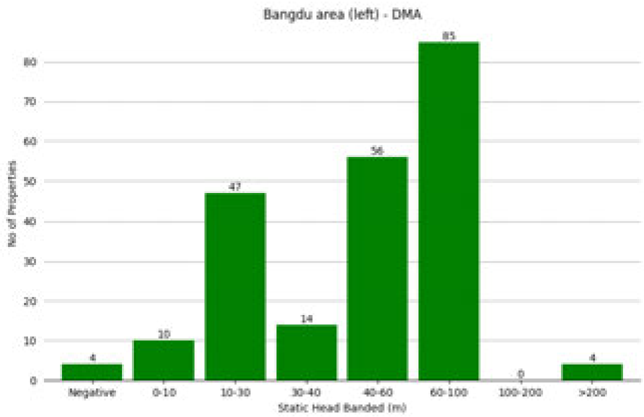
Value	Result
DMA Name	***Zilukha***
Storage Reservoir Name	***Dzong Tank***
Storage Reservoir Volume (m^3)	***250***
Total Storage Reservoir Volume per DMA (m^3)	***250.0***
Top Water Level (m)	***2402.5***
Supplying WTP	***Motihang WTP. Jungshina WTP.***
Common Supply Pipe Diameter (mm)	***100***
Number of Properties	***0***
Current Population	***232***
2032 Population	***194***
2047 Population	***202***
Current Zone Descriptor of Use	***Very Low***
2047 Zone Descriptor of Use	***Very Low***
Supply Times	***8am-11am and 3pm-6pm***
Property Level - Lowest Elevation (m)	***2370***
Property Level - Highest Elevation (m)	***2480***
Property Level – Bell Curve by Elevation	
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.025***
2032 Water Demand (MLD)	***0.036***
2047 Water Demand (MLD)	***0.026***

Value	Result
Required Storage Capacity for 24hours (m^3)	***25***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***-225***

Data Sheet

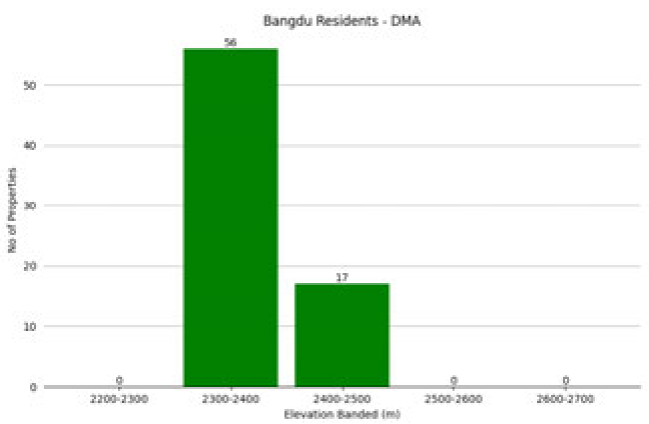
Demand Management Area – ***Bangdu area (left)***

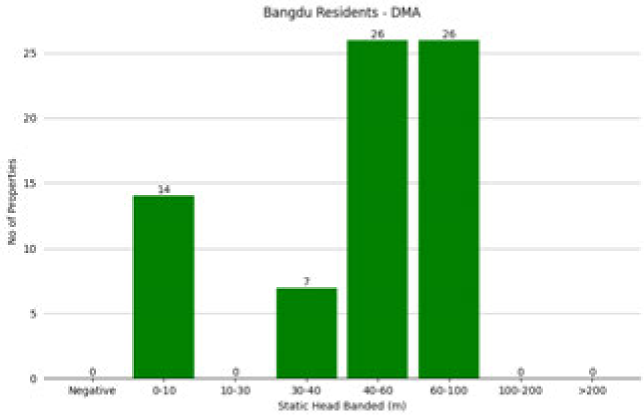
Value	Result
DMA Name	***Bangdu area (left)***
Storage Reservoir Name	***Changbangdu Tank 2, Changbangdu Tank 1***
Storage Reservoir Volume (m^3)	***270, 270***
Total Storage Reservoir Volume per DMA (m^3)	***270.0***
Top Water Level (m)	***2391.5, 2435.5***
Supplying WTP	***Chamgang old WTP***
Common Supply Pipe Diameter (mm)	***210***
Number of Properties	***220***
Current Population	***2871***
2032 Population	***1868***
2047 Population	***2345***
Current Zone Descriptor of Use	***Medium***
2047 Zone Descriptor of Use	***High***
Supply Times	***24hour***
Property Level - Lowest Elevation (m)	***2280***
Property Level - Highest Elevation (m)	***2410***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.705***
2032 Water Demand (MLD)	***0.349***
2047 Water Demand (MLD)	***0.301***
Required Storage Capacity for 24hours (m^3)	***705***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***435***

Data Sheet

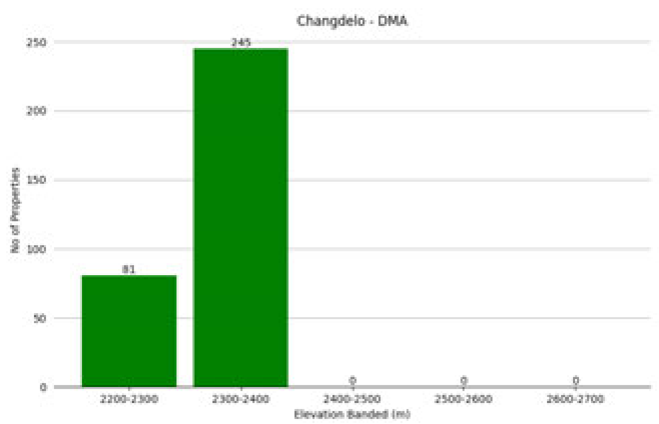
Demand Management Area – ***Bangdu Residents***

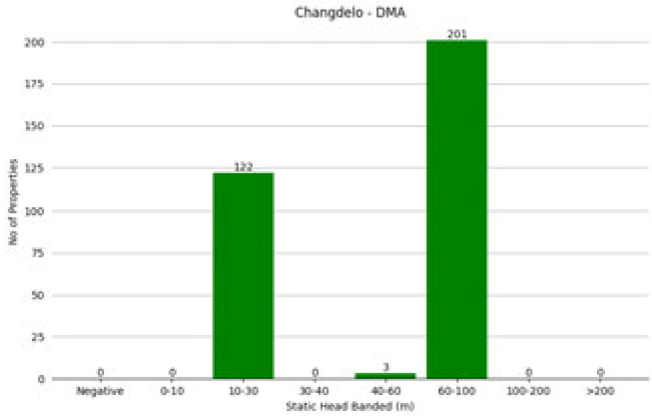
Value	Result
DMA Name	***Bangdu Residents***
Storage Reservoir Name	***Changbangdu Tank 1***
Storage Reservoir Volume (m^3)	***270***
Total Storage Reservoir Volume per DMA (m^3)	***270.0***
Top Water Level (m)	***2435.5***
Supplying WTP	***Chamgang old WTP***
Common Supply Pipe Diameter (mm)	***200***
Number of Properties	***72***
Current Population	***830***
2032 Population	***1003***
2047 Population	***1192***
Current Zone Descriptor of Use	***Low***
2047 Zone Descriptor of Use	***Low***
Supply Times	***24hour***
Property Level - Lowest Elevation (m)	***2360***
Property Level - Highest Elevation (m)	***2430***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***0.147***
2032 Water Demand (MLD)	***0.187***
2047 Water Demand (MLD)	***0.153***
Required Storage Capacity for 24hours (m^3)	***147***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***-123***

Data Sheet

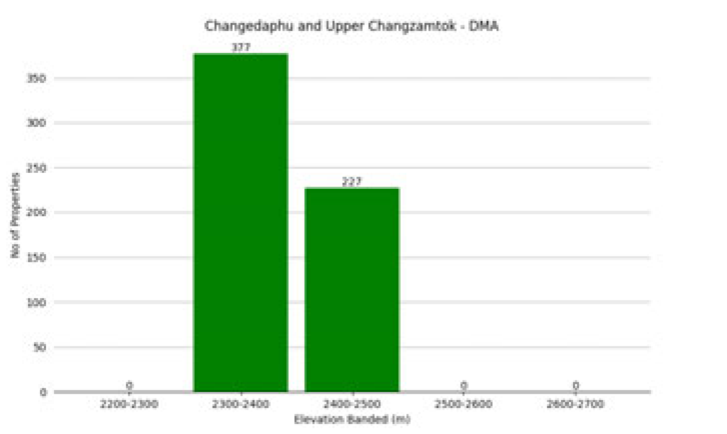
Demand Management Area – ***Changdelo***

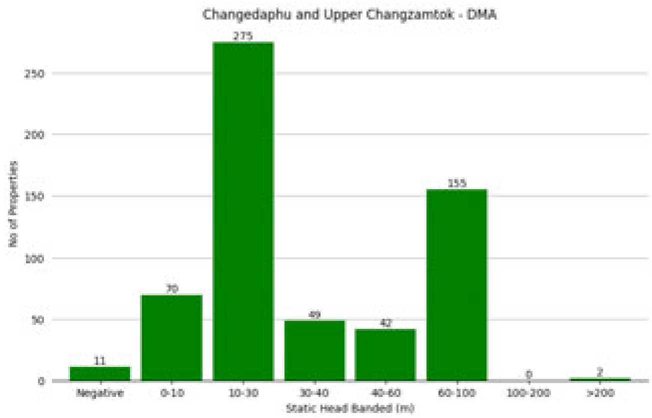
Value	Result
DMA Name	***Changdelo***
Storage Reservoir Name	***YHS Tank 1, YHS Tank 2***
Storage Reservoir Volume (m^3)	***320, 230***
Total Storage Reservoir Volume per DMA (m^3)	***550.0***
Top Water Level (m)	***2406.5, 2406.5***
Supplying WTP	***Taba WTP***
Common Supply Pipe Diameter (mm)	***80; 80***
Number of Properties	***324***
Current Population	***5003***
2032 Population	***6148***
2047 Population	***7517***
Current Zone Descriptor of Use	***Medium***
2047 Zone Descriptor of Use	***Very High***
Supply Times	***Unknown***
Property Level - Lowest Elevation (m)	***2290***
Property Level - Highest Elevation (m)	***2350***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***1.003***
2032 Water Demand (MLD)	***1.149***
2047 Water Demand (MLD)	***0.964***
Required Storage Capacity for 24hours (m^3)	***1003***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***453***

Data Sheet

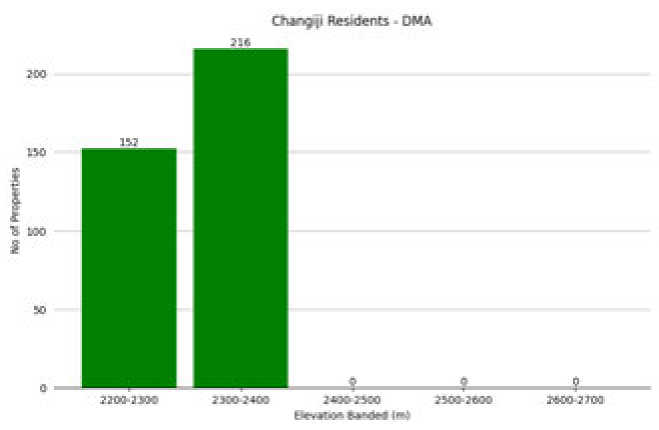
Demand Management Area – ***Changedaphu and Upper Changzamtok***

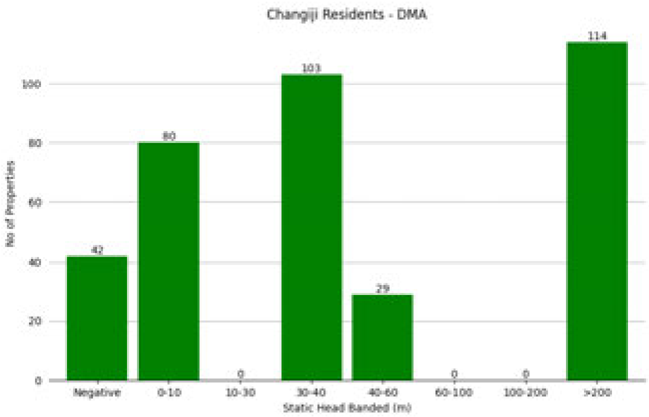
Value	Result
DMA Name	***Changedaphu and Upper Changzamtok***
Storage Reservoir Name	***Changedaphu Tank 1, Changedaphu Tank 2***
Storage Reservoir Volume (m^3)	***230, 100***
Total Storage Reservoir Volume per DMA (m^3)	***330.0***
Top Water Level (m)	***2482.5, 2481.5***
Supplying WTP	***Motihang WTP for all but hospital which is Taba WTP***
Common Supply Pipe Diameter (mm)	***100; 80***
Number of Properties	***601***
Current Population	***9263***
2032 Population	***10860***
2047 Population	***13003***
Current Zone Descriptor of Use	***Very High***
2047 Zone Descriptor of Use	***High***
Supply Times	***6am-9am and 6pm-9pm***
Property Level - Lowest Elevation (m)	***2310***
Property Level - Highest Elevation (m)	***2480***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***2.047***
2032 Water Demand (MLD)	***2.029***
2047 Water Demand (MLD)	***1.667***
Required Storage Capacity for 24hours (m^3)	***2047***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***1717***

Data Sheet

Demand Management Area – ***Changiji Residents***

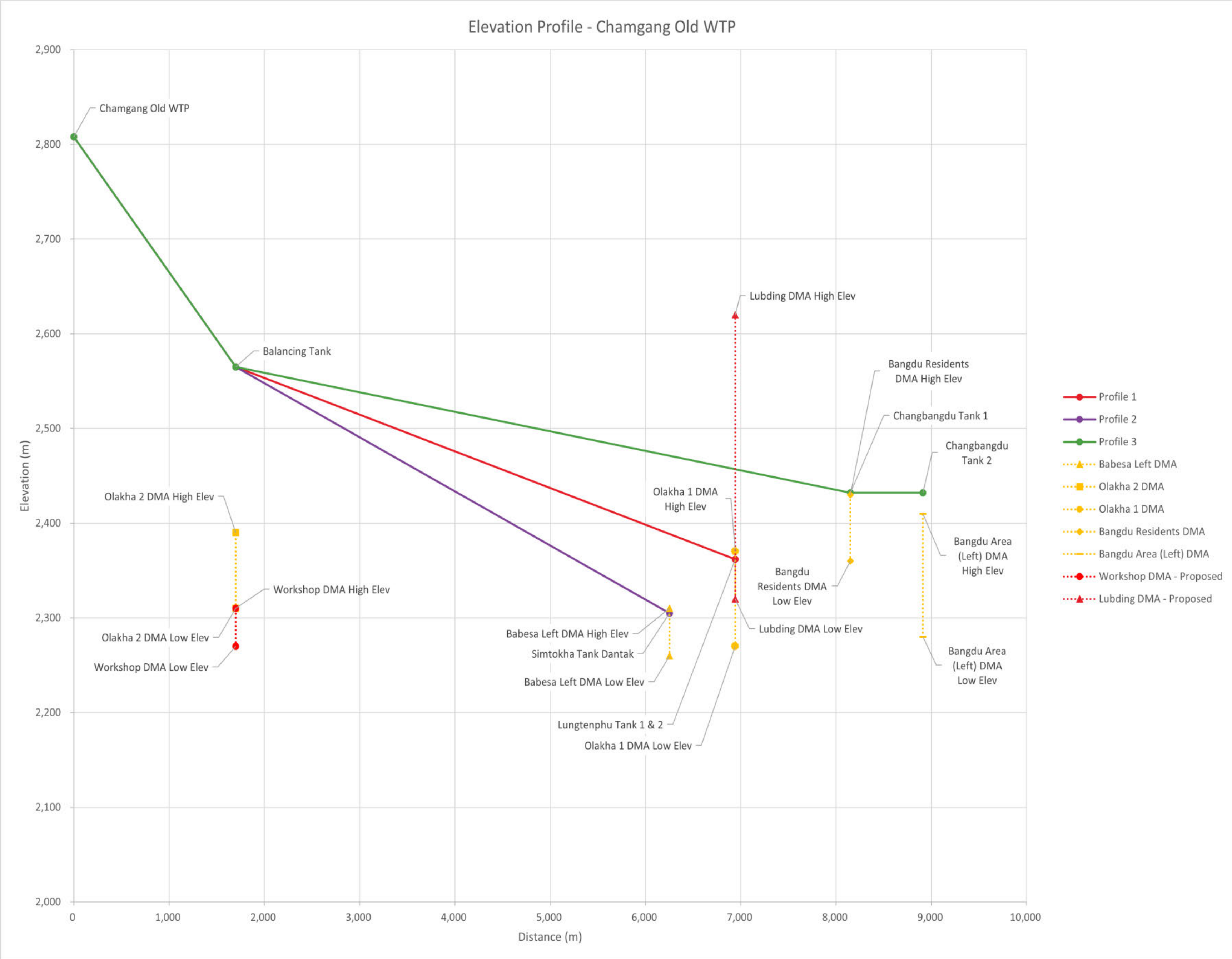
Value	Result
DMA Name	***Changiji Residents***
Storage Reservoir Name	***Changiji Tank 2, Changiji Tank 1, Changiji Tank 3***
Storage Reservoir Volume (m^3)	***230, 230, 230***
Total Storage Reservoir Volume per DMA (m^3)	***690.0***
Top Water Level (m)	***2330.5, 2330.5, 2330.5***
Supplying WTP	***Taba WTP***
Common Supply Pipe Diameter (mm)	***150***
Number of Properties	***278***
Current Population	***6755***
2032 Population	***5892***
2047 Population	***6938***
Current Zone Descriptor of Use	***Medium***
2047 Zone Descriptor of Use	***Medium***
Supply Times	***24hour***
Property Level - Lowest Elevation (m)	***2280***
Property Level - Highest Elevation (m)	***2390***
Property Level – Bell Curve by Elevation	

Value	Result
Property Level – Bell Curve by Pressure	
Current Water Demand (MLD)	***1.439***
2032 Water Demand (MLD)	***1.101***
2047 Water Demand (MLD)	***0.89***
Required Storage Capacity for 24hours (m^3)	***1439***
Deficient Storage Capacity for 24hours (m^3) – if a negative value, then there is excess storage capacity	***749***

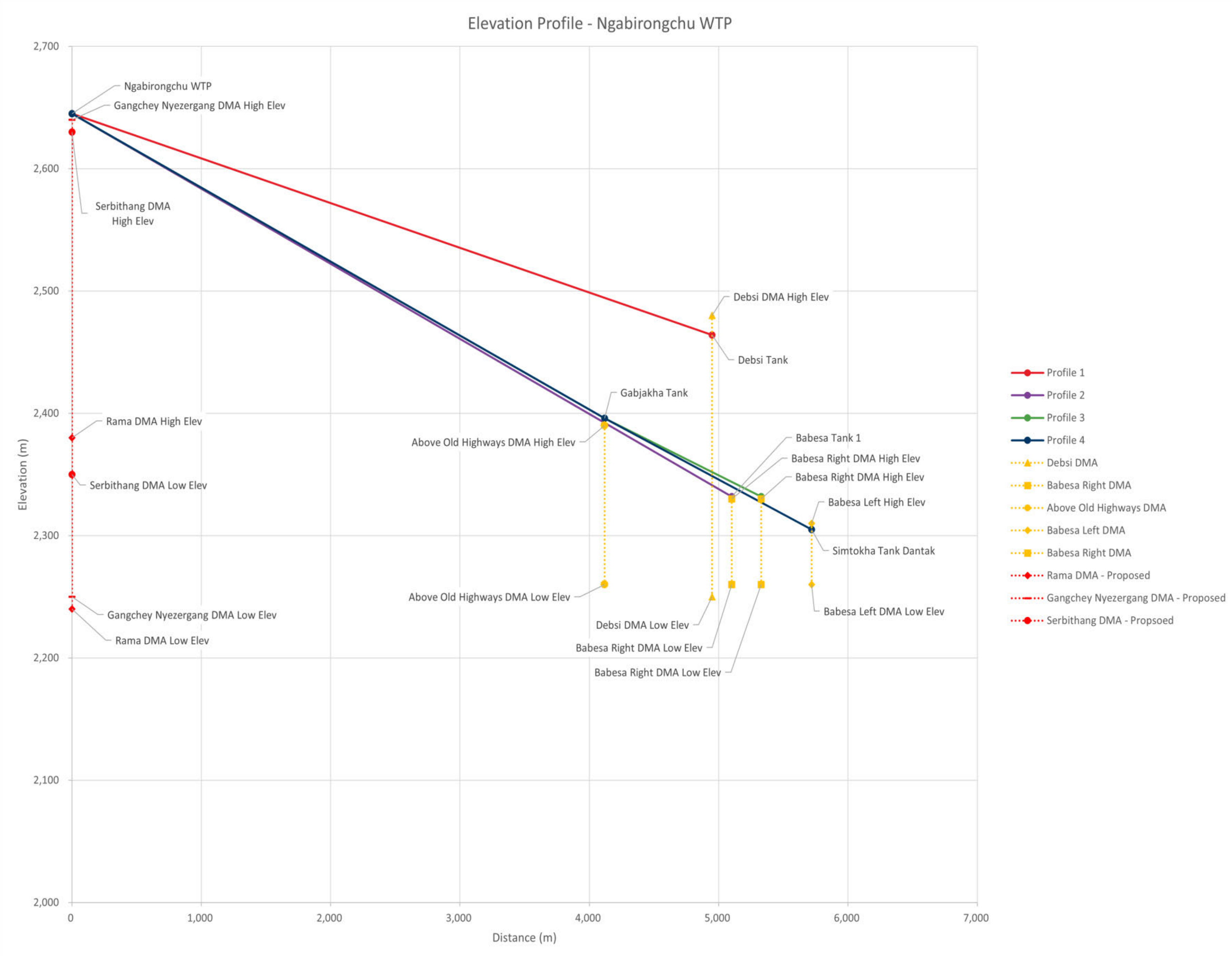
Data Sheet

Storage Reservoir – Babesa Tank 1

Value	Result
Storage Reservoir Name	Babesa Tank 1
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	None
Downstream DMA(s)	Babesa right
WTP Supplying Storage Reservoir	Chamgang Old WTP; Ngabirongchu WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	90
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	150
Operations	6am-9am and 6pm-9pm
Top Water Elevation (m)	2335.5
Bottom Water Elevation (m)	2332
Storage Reservoir Volume (m^3)	360
Storage Reservoir Material	RCC_circular



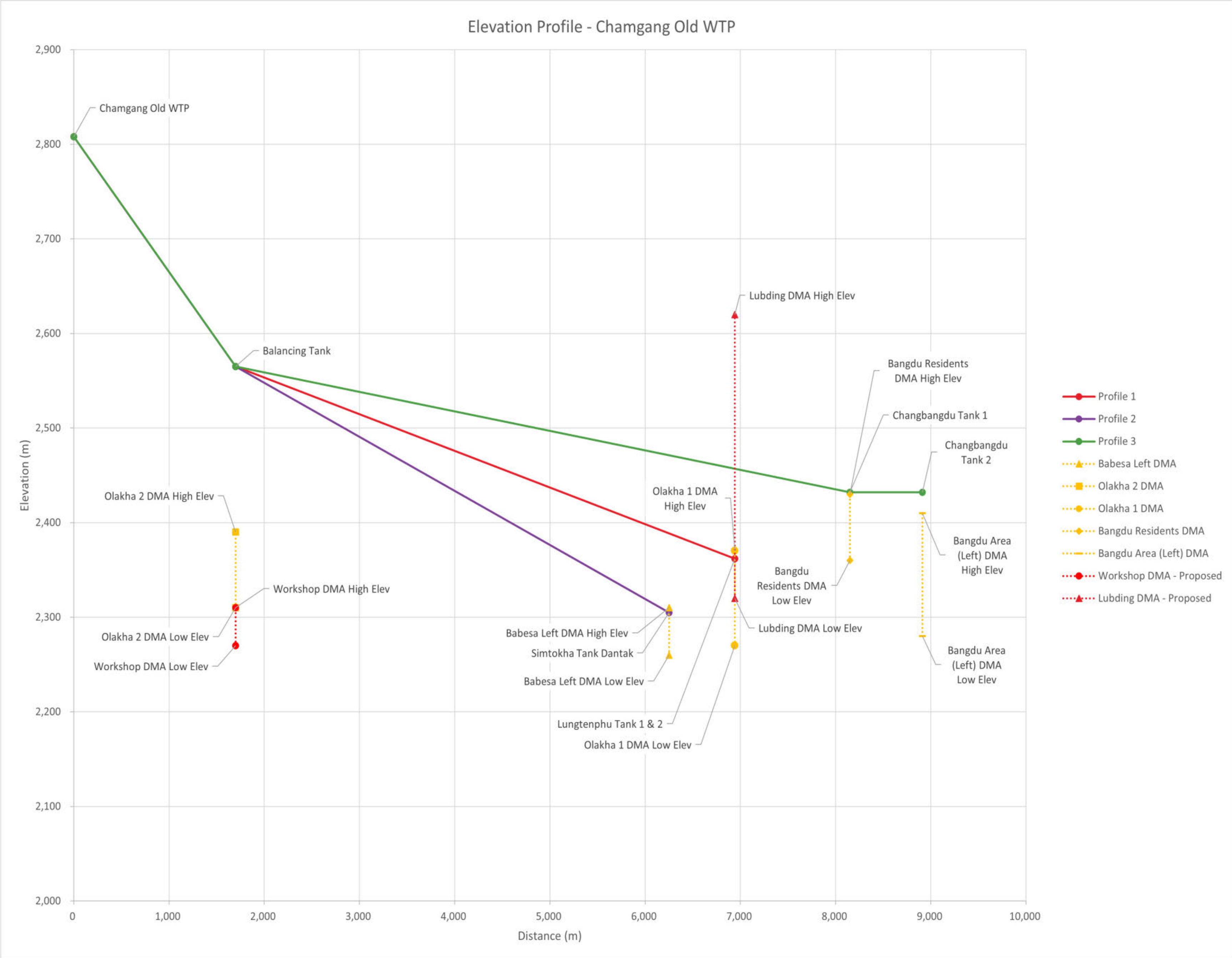
Elevation Profile - Chamgang Old WTP
Elevation (m)
Distance (m)
2,900
2,800
2,700
2,600
2,500
2,400
2,300
2,200
2,100
2,000
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
Chamgang Old WTP
Balancing Tank
Olakha 2 DMA High Elev
Workshop DMA High Elev
Olakha 2 DMA Low Elev
Workshop DMA Low Elev
Lubding DMA High Elev
Bangdu Residents DMA High Elev
Changbangdu Tank 1
Changbangdu Tank 2
Olakha 1 DMA High Elev
Bangdu Area (Left) DMA High Elev
Bangdu Residents DMA Low Elev
Lubding DMA Low Elev
Babesa Left DMA High Elev
Simtokha Tank Dantak
Babesa Left DMA Low Elev
Bangdu Area (Left) DMA Low Elev
Lungtenphu Tank 1 & 2
Olakha 1 DMA Low Elev
Profile 1
Profile 2
Profile 3
Babesa Left DMA
Olakha 2 DMA
Olakha 1 DMA
Bangdu Residents DMA
Bangdu Area (Left) DMA
Workshop DMA - Proposed
Lubding DMA - Proposed


Elevation Profile - Ngabirongchu WTP
Elevation (m)
Distance (m)
2,700
2,600
2,500
2,400
2,300
2,200
2,100
2,000
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Ngabirongchu WTP
Gangchey Nyezergang DMA High Elev
Serbithang DMA High Elev
Rama DMA High Elev
Serbithang DMA Low Elev
Gangchey Nyezergang DMA Low Elev
Rama DMA Low Elev
Debsi DMA High Elev
Debsi Tank
Gabjakha Tank
Above Old Highways DMA High Elev
Above Old Highways DMA Low Elev
Babesa Tank 1
Babesa Right DMA High Elev
Babesa Right DMA High Elev
Babesa Left High Elev
Simtokha Tank Dantak
Babesa Left DMA Low Elev
Debsi DMA Low Elev
Babesa Right DMA Low Elev
Babesa Right DMA Low Elev
Profile 1
Profile 2
Profile 3
Profile 4
Debsi DMA
Babesa Right DMA
Above Old Highways DMA
Babesa Left DMA
Babesa Right DMA
Rama DMA - Proposed
Gangchey Nyezergang DMA - Proposed
Serbithang DMA - Propsoed

Data Sheet

Storage Reservoir – Balancing Tank

Value	Result
Storage Reservoir Name	Balancing Tank
Downstream Storage Reservoir(s)	Luntenphu Tank 1; Luntenphu Tank 2; Gabjakha tank; Babesa Tank 1; Simtokha Tank-Dantak; Changbangdu Tank 1; Changbangdu Tank 2
Adjacent Reservoir(s)	None
Downstream DMA(s)	Olakha 2; Lungtenphu Tank 1 and 2 which serves Olakha 1; Gabjakha Tank which serves Above Old Highway; Gabjakha tank which serves Simtokha Tank - Danak Tank which serves Babesa Left; Gabjakha Tank which serves Babesa Tank 1 which serves Babesa Right; Changbangdu Tank 1 which serves Bangdu Residents; Changbangdu Tank 1 which serves Changbangdu Tank 2 which serves Bangdu Area (Left)
WTP Supplying Storage Reservoir	Chamgang Old WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	250
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	350
Operations	Not provided
Top Water Elevation (m)	2568.5
Bottom Water Elevation (m)	2565
Storage Reservoir Volume (m^3)	0
Storage Reservoir Material	nan

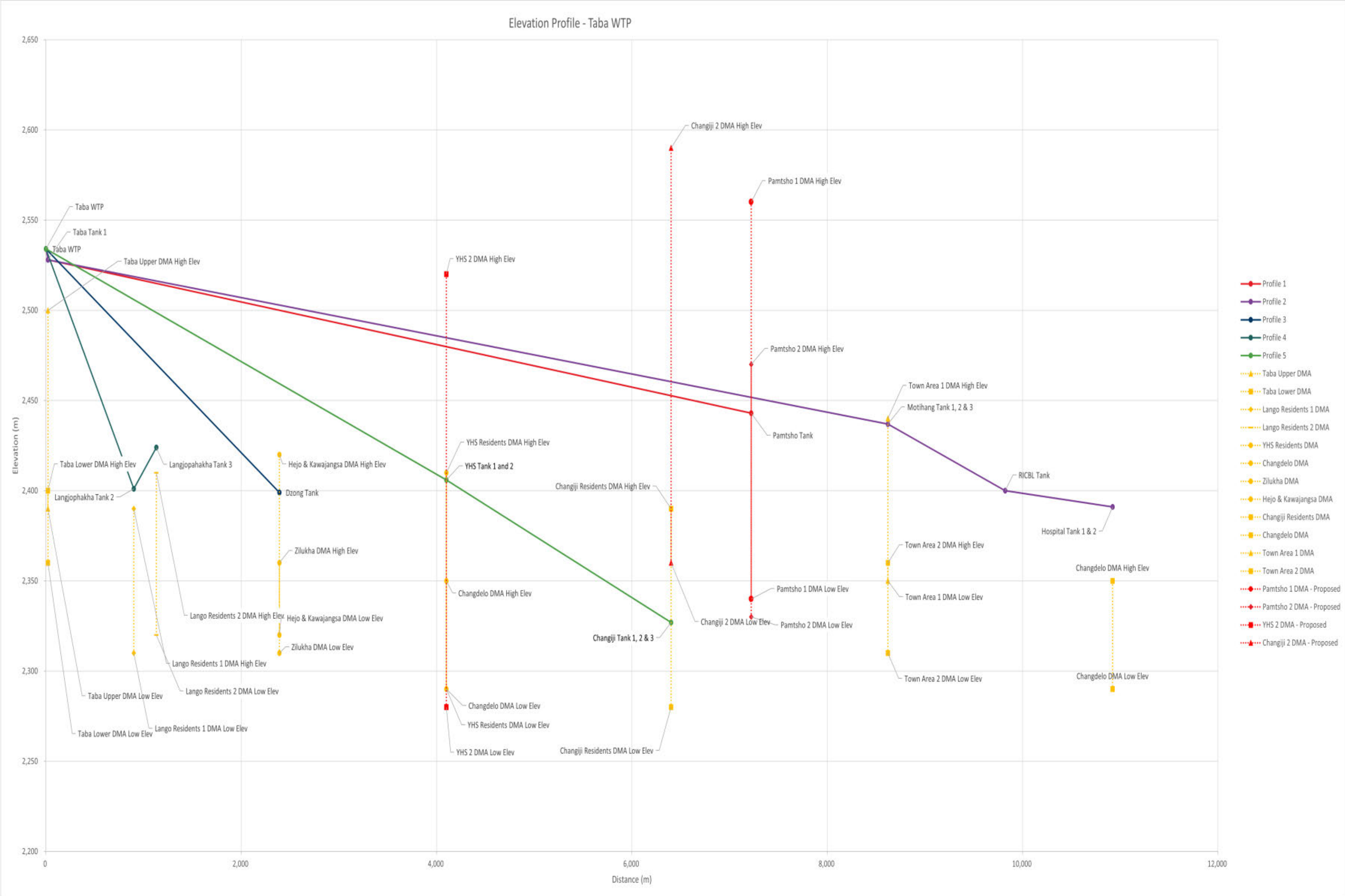


Elevation Profile - Chamgang Old WTP
Elevation (m)
2,900
2,800
2,700
2,600
2,500
2,400
2,300
2,200
2,100
2,000
Distance (m)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
Chamgang Old WTP
Balancing Tank
Olakha 2 DMA High Elev
Workshop DMA High Elev
Olakha 2 DMA Low Elev
Workshop DMA Low Elev
Babesa Left DMA High Elev
Simtokha Tank Dantak
Babesa Left DMA Low Elev
Lungtenphu Tank 1 & 2
Olakha 1 DMA Low Elev
Olakha 1 DMA High Elev
Lubding DMA High Elev
Lubding DMA Low Elev
Bangdu Residents DMA Low Elev
Bangdu Residents DMA High Elev
Changbangdu Tank 1
Changbangdu Tank 2
Bangdu Area (Left) DMA High Elev
Bangdu Area (Left) DMA Low Elev
Profile 1
Profile 2
Profile 3
Babesa Left DMA
Olakha 2 DMA
Olakha 1 DMA
Bangdu Residents DMA
Bangdu Area (Left) DMA
Workshop DMA - Proposed
Lubding DMA - Proposed

Data Sheet

Storage Reservoir – Changiji Tank 3

Value	Result
Storage Reservoir Name	Changiji Tank 3
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	Changiji Tank 1 and 2
Downstream DMA(s)	Changiji Residents
WTP Supplying Storage Reservoir	Taba WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	150
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	100
Operations	24hour
Top Water Elevation (m)	2330.5
Bottom Water Elevation (m)	2327
Storage Reservoir Volume (m^3)	230
Storage Reservoir Material	RCC_circular

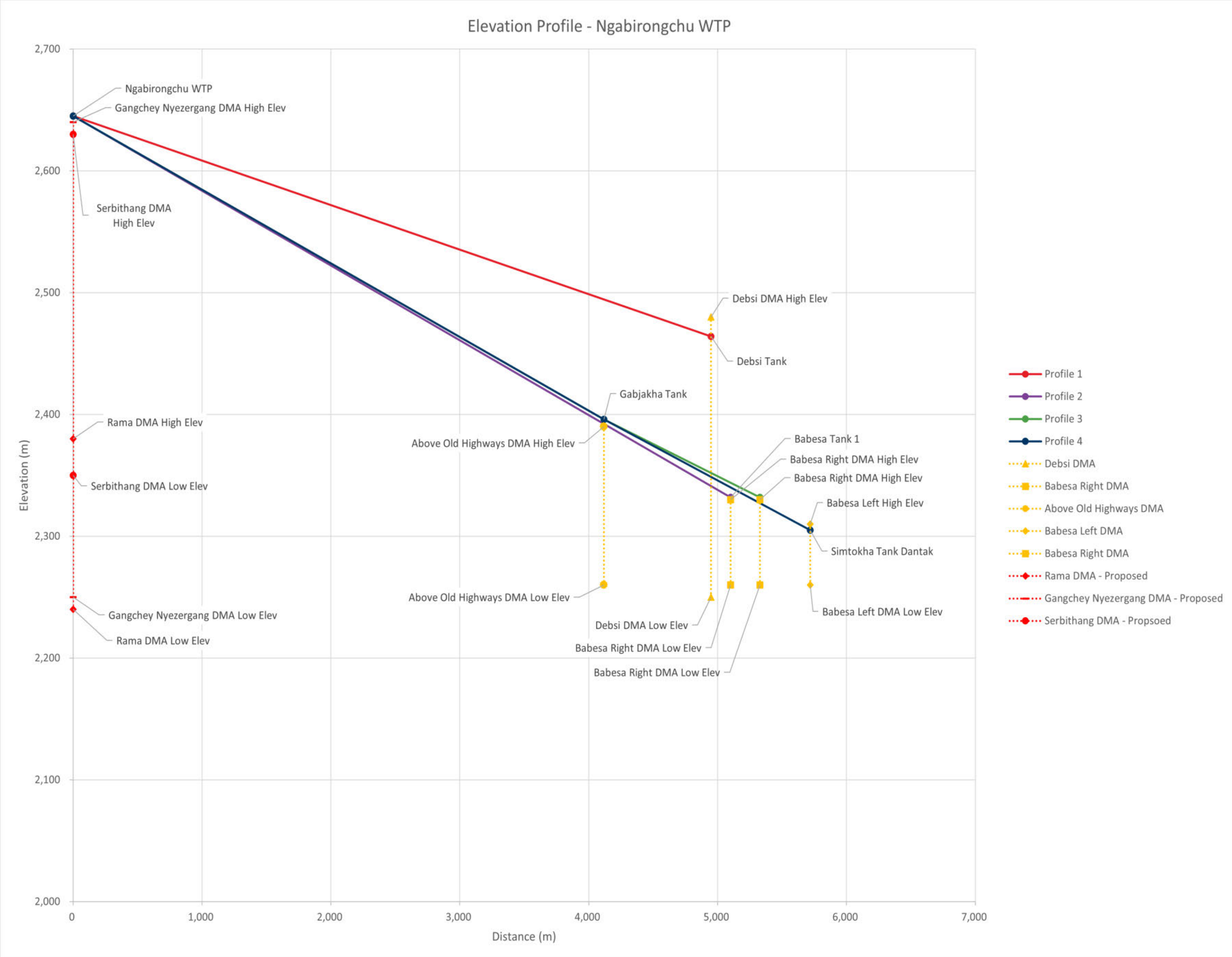


Elevation Profile - Taba WTP
Elevation (m)
Distance (m)
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
0
2,000
4,000
6,000
8,000
10,000
12,000
Taba WTP
Taba Tank 1
Taba WTP
Taba Upper DMA High Elev
Taba Lower DMA High Elev
Langjophakha Tank 2
Langjopahakha Tank 3
Lango Residents 2 DMA High Elev
Lango Residents 1 DMA High Elev
Lango Residents 2 DMA Low Elev
Taba Upper DMA Low Elev
Taba Lower DMA Low Elev
Lango Residents 1 DMA Low Elev
Hejo & Kawajangsa DMA High Elev
Dzong Tank
Zilukha DMA High Elev
Hejo & Kawajangsa DMA Low Elev
Zilukha DMA Low Elev
YHS 2 DMA High Elev
YHS Residents DMA High Elev
YHS Tank 1 and 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
YHS Residents DMA Low Elev
YHS 2 DMA Low Elev
Changiji 2 DMA High Elev
Changiji Residents DMA High Elev
Changiji Tank 1, 2 & 3
Changiji 2 DMA Low Elev
Changiji Residents DMA Low Elev
Pamtsho 1 DMA High Elev
Pamtsho 2 DMA High Elev
Pamtsho Tank
Pamtsho 1 DMA Low Elev
Pamtsho 2 DMA Low Elev
Town Area 1 DMA High Elev
Motihang Tank 1, 2 & 3
Town Area 2 DMA High Elev
Town Area 1 DMA Low Elev
Town Area 2 DMA Low Elev
RICBL Tank
Hospital Tank 1 & 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
Profile 1
Profile 2
Profile 3
Profile 4
Profile 5
Taba Upper DMA
Taba Lower DMA
Lango Residents 1 DMA
Lango Residents 2 DMA
YHS Residents DMA
Changdelo DMA
Zilukha DMA
Hejo & Kawajangsa DMA
Changiji Residents DMA
Changdelo DMA
Town Area 1 DMA
Town Area 2 DMA
Pamtsho 1 DMA - Proposed
Pamtsho 2 DMA - Proposed
YHS 2 DMA - Proposed
Changiji 2 DMA - Proposed

Data Sheet

Storage Reservoir – Debsi Tank

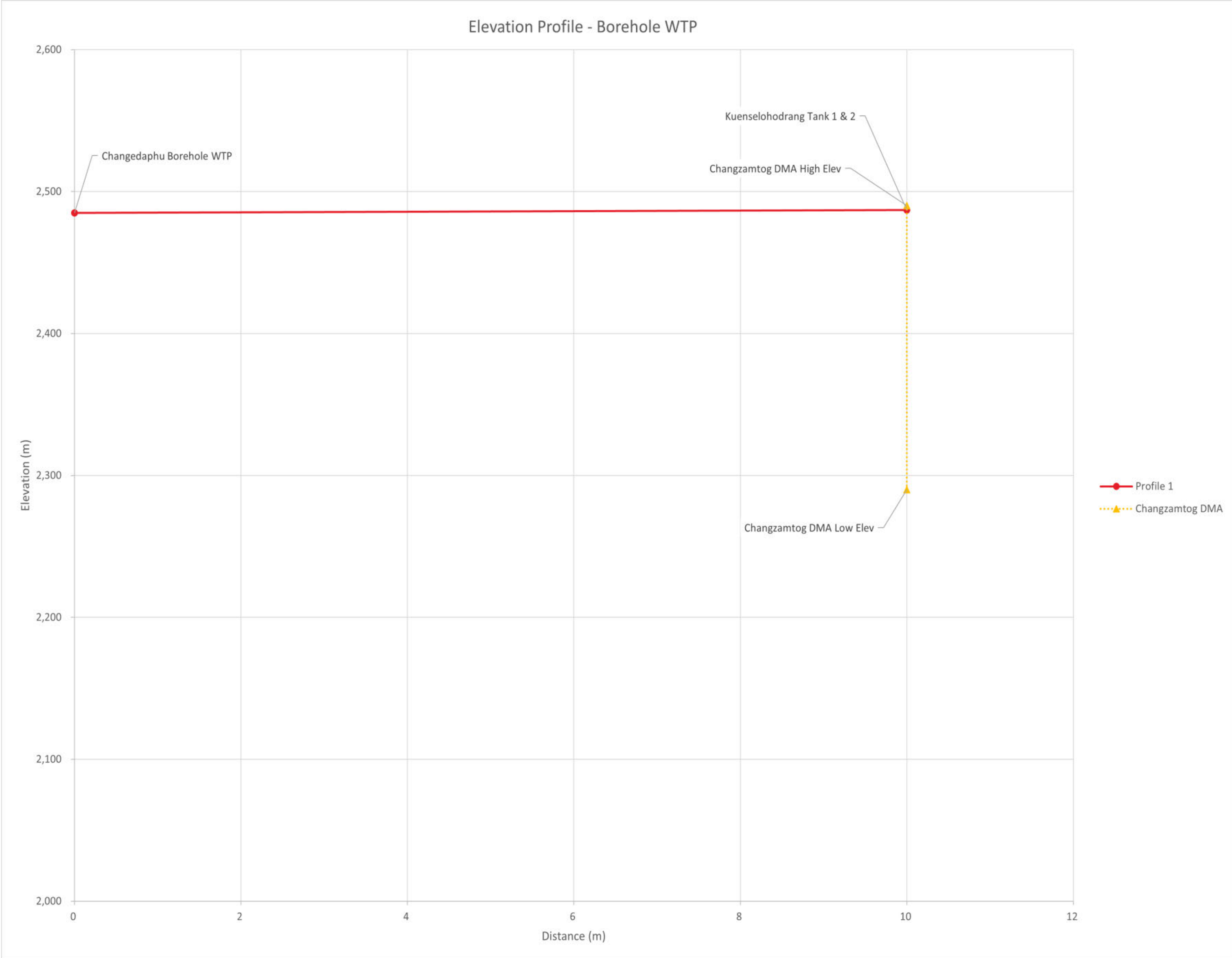
Value	Result
Storage Reservoir Name	Debsi Tank
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	None
Downstream DMA(s)	Debsi
WTP Supplying Storage Reservoir	Ngabirongchu WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	250
Number of Outlet Pipes	0
Diameter of Outlet Pipes (mm)	nan
Operations	Not provided
Top Water Elevation (m)	0
Bottom Water Elevation (m)	-3.5
Storage Reservoir Volume (m^3)	0
Storage Reservoir Material	nan


Elevation Profile - Ngabirongchu WTP
Elevation (m)
2,700
2,600
2,500
2,400
2,300
2,200
2,100
2,000
Distance (m)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Ngabirongchu WTP
Gangchey Nyezergang DMA High Elev
Serbithang DMA High Elev
Rama DMA High Elev
Serbithang DMA Low Elev
Gangchey Nyezergang DMA Low Elev
Rama DMA Low Elev
Debsi DMA High Elev
Debsi Tank
Gabjakha Tank
Above Old Highways DMA High Elev
Above Old Highways DMA Low Elev
Debsi DMA Low Elev
Babesa Right DMA Low Elev
Babesa Right DMA Low Elev
Babesa Tank 1
Babesa Right DMA High Elev
Babesa Right DMA High Elev
Babesa Left High Elev
Simtokha Tank Dantak
Babesa Left DMA Low Elev
Profile 1
Profile 2
Profile 3
Profile 4
Debsi DMA
Babesa Right DMA
Above Old Highways DMA
Babesa Left DMA
Babesa Right DMA
Rama DMA - Proposed
Gangchey Nyezergang DMA - Proposed
Serbithang DMA - Propsoed

Data Sheet

Storage Reservoir – Dechencholing Tank 1

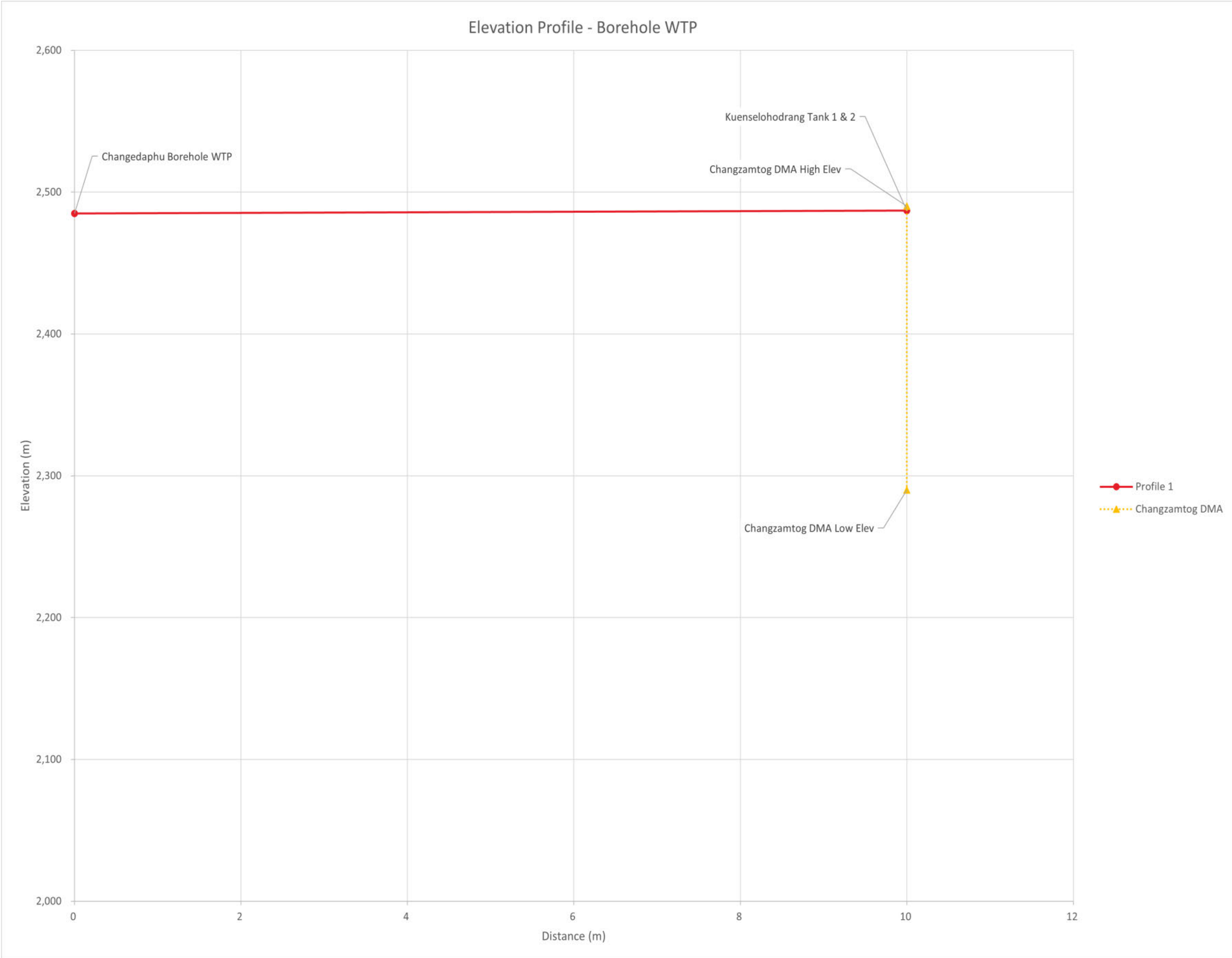
Value	Result
Storage Reservoir Name	Dechencholing Tank 1
Downstream Storage Reservoir(s)	Dechencholing Tank 2; Dechencholing satellite town
Adjacent Reservoir(s)	Dechencholing Tank 2
Downstream DMA(s)	Dangrina Left and Right; Dechencholing Tank 2 which supplies Dangrina Left and Right; Satellite Town Tank which supplies Satellite Town
WTP Supplying Storage Reservoir	Dechencholing WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	150
Number of Outlet Pipes	3
Diameter of Outlet Pipes (mm)	150; 150; 80
Operations	24hour
Top Water Elevation (m)	2522.5
Bottom Water Elevation (m)	2519
Storage Reservoir Volume (m^3)	230
Storage Reservoir Material	RCC_circular


Elevation Profile - Borehole WTP
Changedaphu Borehole WTP
Kuenselohodrang Tank 1 & 2
Changzamtog DMA High Elev
Changzamtog DMA Low Elev
Profile 1
Changzamtog DMA
Elevation (m)
2,600
2,500
2,400
2,300
2,200
2,100
2,000
0
2
4
6
8
10
12
Distance (m)

Data Sheet

Storage Reservoir – Dechencholing Tank 2

Value	Result
Storage Reservoir Name	Dechencholing Tank 2
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	Dechencholing Tank 1
Downstream DMA(s)	Dangrina Left and Right
WTP Supplying Storage Reservoir	Dechencholing WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	150
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	100
Operations	24hour
Top Water Elevation (m)	2484.5
Bottom Water Elevation (m)	2481
Storage Reservoir Volume (m^3)	230
Storage Reservoir Material	RCC_circular

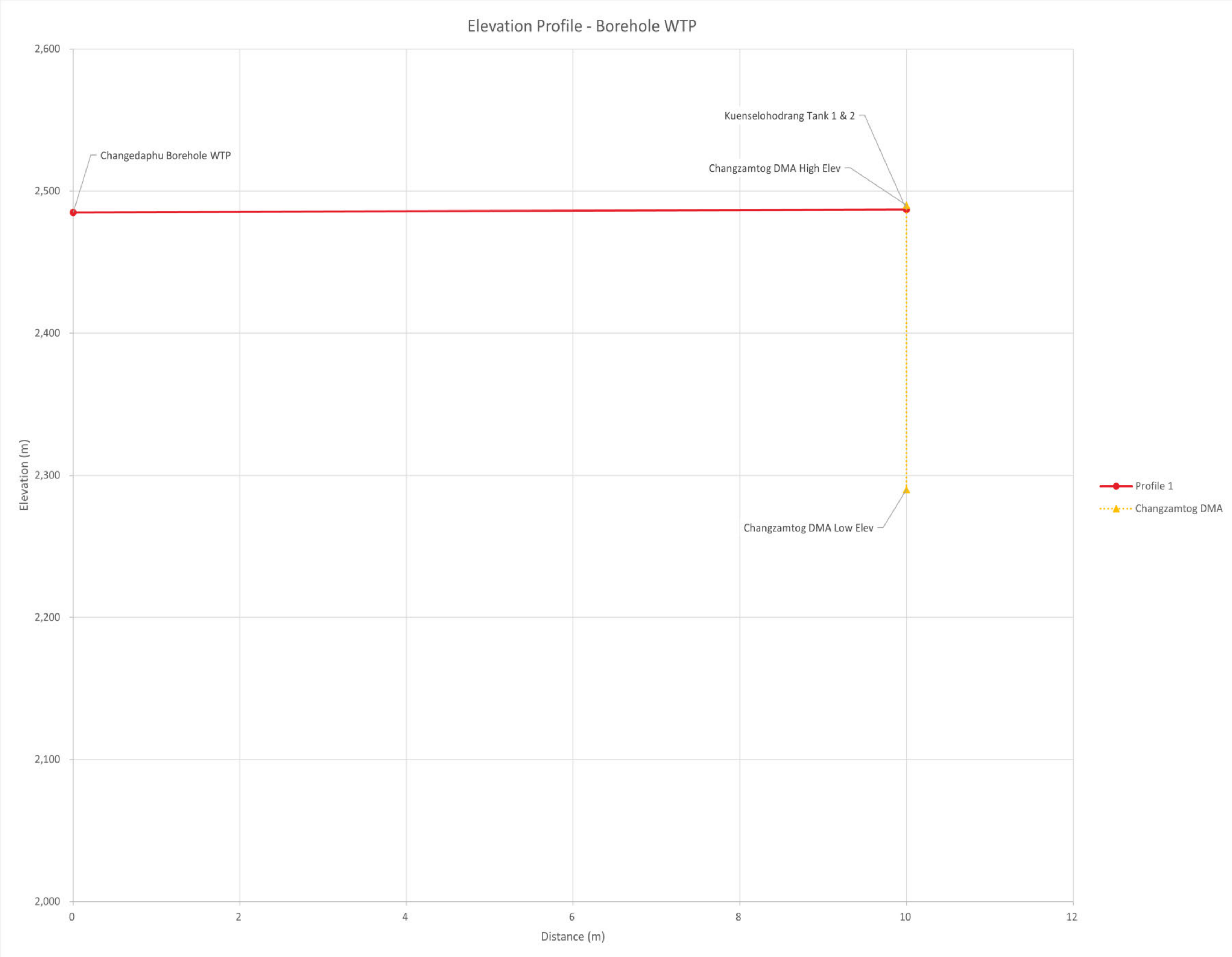


Elevation Profile - Borehole WTP
Changedaphu Borehole WTP
Kuenselohodrang Tank 1 & 2
Changzamtog DMA High Elev
Changzamtog DMA Low Elev
Profile 1
Changzamtog DMA
Elevation (m)
2,600
2,500
2,400
2,300
2,200
2,100
2,000
0
2
4
6
8
10
12
Distance (m)

Data Sheet

Storage Reservoir – Dechenling Satellite Town

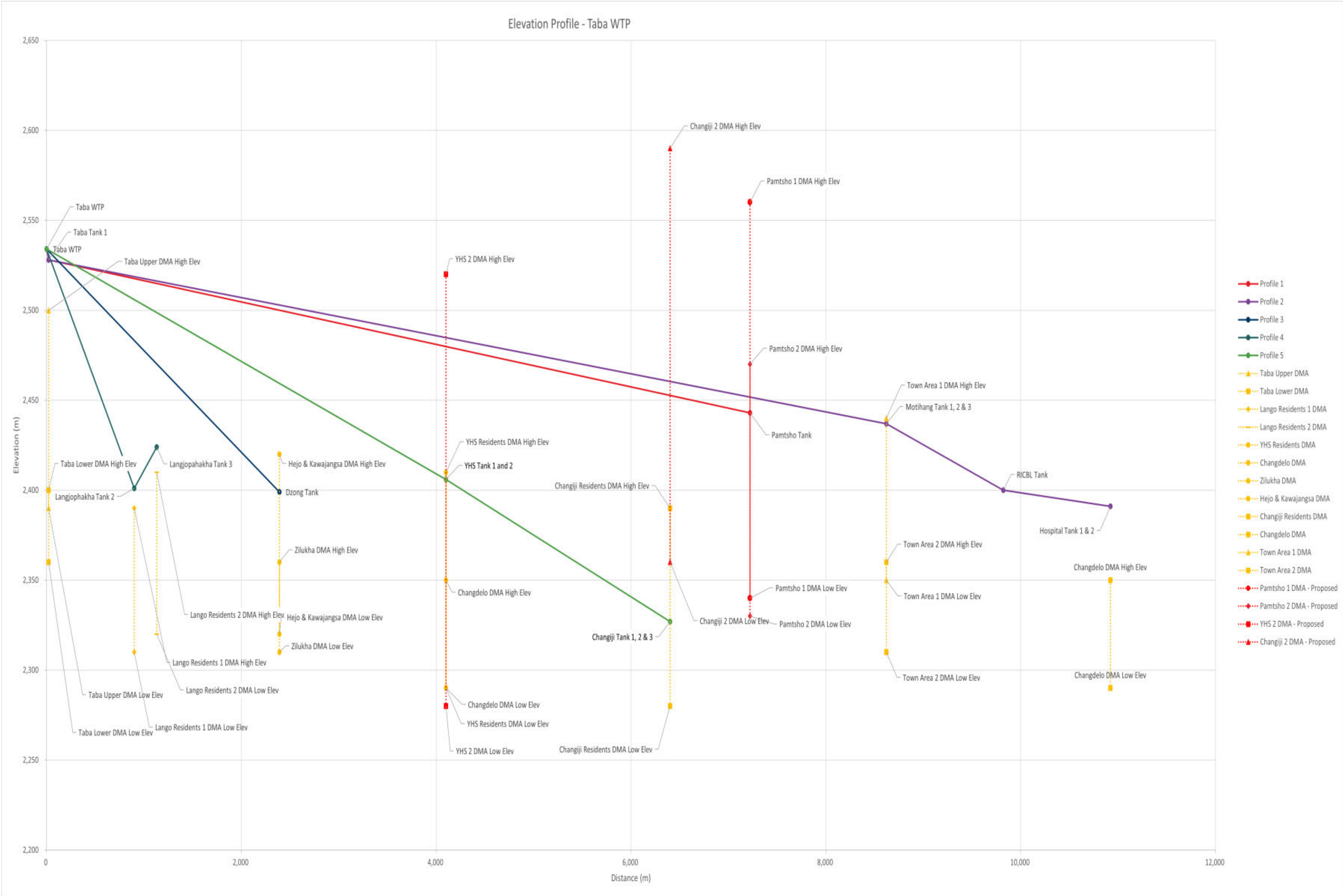
Value	Result
Storage Reservoir Name	Dechenling Satellite Town
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	None
Downstream DMA(s)	Satellite Town
WTP Supplying Storage Reservoir	Dechencholing WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	80
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	80
Operations	24hour
Top Water Elevation (m)	2398.5
Bottom Water Elevation (m)	2395
Storage Reservoir Volume (m^3)	50
Storage Reservoir Material	Syntax_circular_3x2000litre


Elevation Profile - Borehole WTP
Elevation (m)
2,600
2,500
2,400
2,300
2,200
2,100
2,000
0
2
4
6
8
10
12
Distance (m)
Changedaphu Borehole WTP
Kuenselohodrang Tank 1 & 2
Changzamtog DMA High Elev
Changzamtog DMA Low Elev
Profile 1
Changzamtog DMA

Data Sheet

Storage Reservoir – Dzong Tank

Value	Result
Storage Reservoir Name	Dzong Tank
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	None
Downstream DMA(s)	Hejo and Kawajangsa; Zilukha
WTP Supplying Storage Reservoir	Taba WTP
Number of Inlet Pipes	3
Diameter of Inlet Pipes (mm)	150; 150; 75
Number of Outlet Pipes	2
Diameter of Outlet Pipes (mm)	100; 100
Operations	8am-11am and 3pm-6pm
Top Water Elevation (m)	2402.5
Bottom Water Elevation (m)	2399
Storage Reservoir Volume (m^3)	250
Storage Reservoir Material	RRM_rectangular

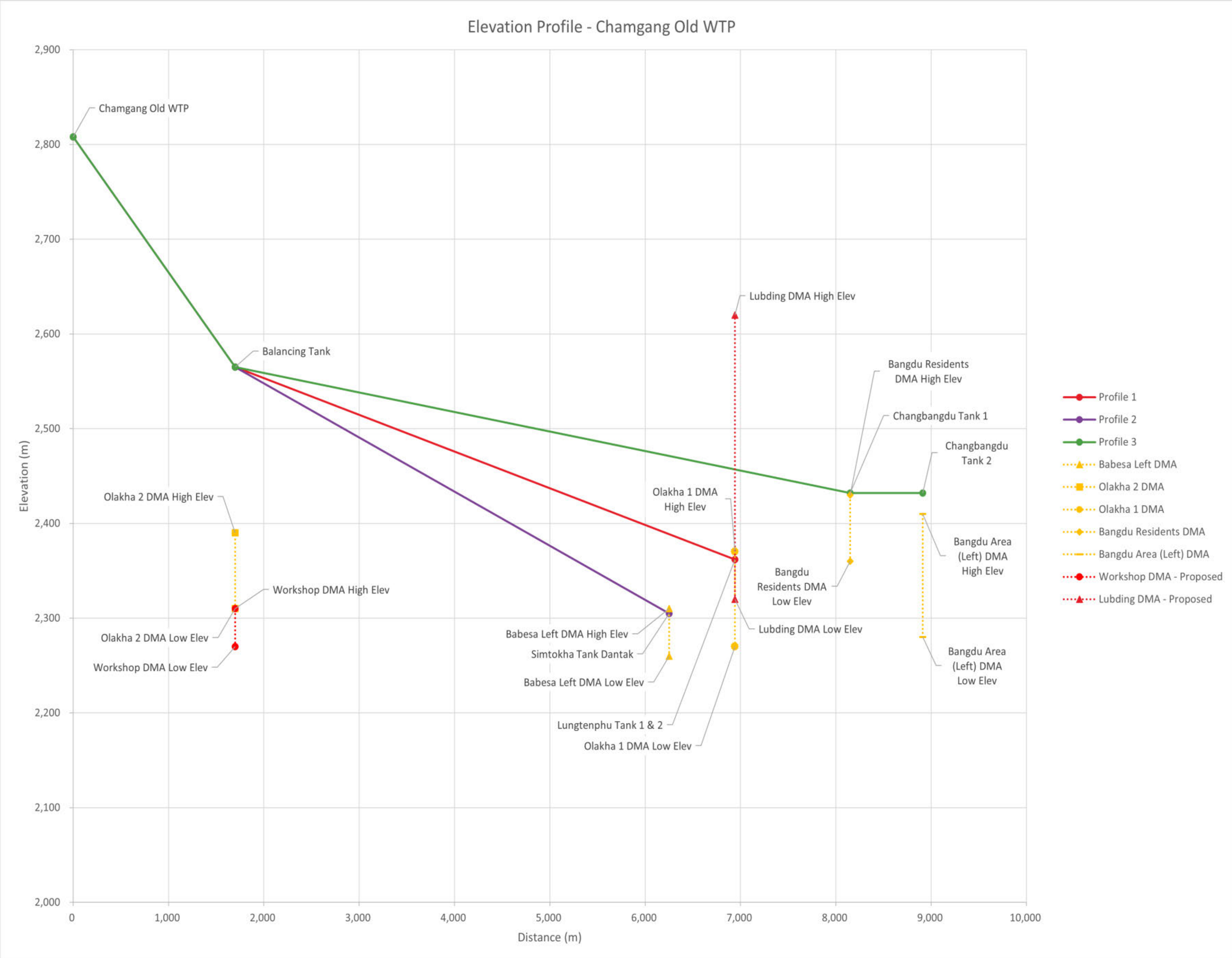


Elevation Profile - Taba WTP
Elevation (m)
Distance (m)
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
0
2,000
4,000
6,000
8,000
10,000
12,000
Taba WTP
Taba Tank 1
Taba WTP
Taba Upper DMA High Elev
Taba Lower DMA High Elev
Langjophakha Tank 2
Langjopahakha Tank 3
Lango Residents 2 DMA High Elev
Lango Residents 1 DMA High Elev
Lango Residents 2 DMA Low Elev
Taba Upper DMA Low Elev
Lango Residents 1 DMA Low Elev
Taba Lower DMA Low Elev
Hejo & Kawajangsa DMA High Elev
Dzong Tank
Zilukha DMA High Elev
Hejo & Kawajangsa DMA Low Elev
Zilukha DMA Low Elev
YHS 2 DMA High Elev
YHS Residents DMA High Elev
YHS Tank 1 and 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
YHS Residents DMA Low Elev
YHS 2 DMA Low Elev
Changiji 2 DMA High Elev
Changiji Residents DMA High Elev
Changiji Tank 1, 2 & 3
Changiji 2 DMA Low Elev
Changiji Residents DMA Low Elev
Pamtsho 1 DMA High Elev
Pamtsho 2 DMA High Elev
Pamtsho Tank
Pamtsho 1 DMA Low Elev
Pamtsho 2 DMA Low Elev
Town Area 1 DMA High Elev
Motihang Tank 1, 2 & 3
Town Area 2 DMA High Elev
Town Area 1 DMA Low Elev
Town Area 2 DMA Low Elev
RICBL Tank
Hospital Tank 1 & 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
Profile 1
Profile 2
Profile 3
Profile 4
Profile 5
Taba Upper DMA
Taba Lower DMA
Lango Residents 1 DMA
Lango Residents 2 DMA
YHS Residents DMA
Changdelo DMA
Zilukha DMA
Hejo & Kawajangsa DMA
Changiji Residents DMA
Changdelo DMA
Town Area 1 DMA
Town Area 2 DMA
Pamtsho 1 DMA - Proposed
Pamtsho 2 DMA - Proposed
YHS 2 DMA - Proposed
Changiji 2 DMA - Proposed

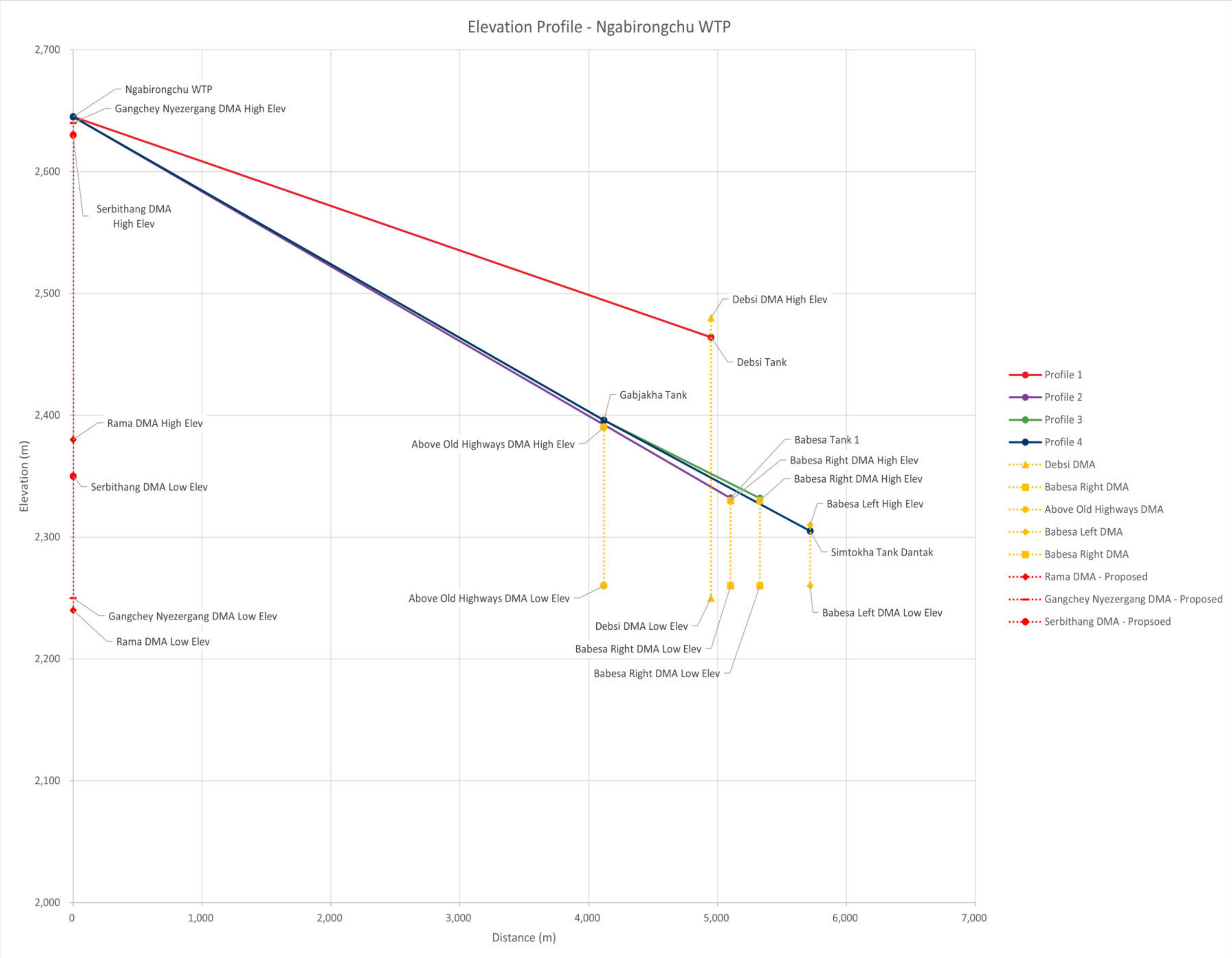
Data Sheet

Storage Reservoir – Gabjakha Tank

Value	Result
Storage Reservoir Name	Gabjakha Tank
Downstream Storage Reservoir(s)	Babesa 1; Simtokha Tank - Dantak
Adjacent Reservoir(s)	None
Downstream DMA(s)	Above Old Highway; Simtokha Tank - Dantak which supplies Babesa Left; Babesa Tank 1 which supplies Babesa Right
WTP Supplying Storage Reservoir	Chamgang Old WTP; Ngabirongchu WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	150
Number of Outlet Pipes	3
Diameter of Outlet Pipes (mm)	250; 150; 100
Operations	6am-9am and 6pm-9pm
Top Water Elevation (m)	2399.5
Bottom Water Elevation (m)	2396
Storage Reservoir Volume (m^3)	360
Storage Reservoir Material	RCC_circular



Elevation Profile - Chamgang Old WTP
Elevation (m)
Distance (m)
2,900
2,800
2,700
2,600
2,500
2,400
2,300
2,200
2,100
2,000
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
Chamgang Old WTP
Balancing Tank
Olakha 2 DMA High Elev
Workshop DMA High Elev
Olakha 2 DMA Low Elev
Workshop DMA Low Elev
Babesa Left DMA High Elev
Simtokha Tank Dantak
Babesa Left DMA Low Elev
Lungtenphu Tank 1 & 2
Olakha 1 DMA Low Elev
Olakha 1 DMA High Elev
Lubding DMA High Elev
Lubding DMA Low Elev
Bangdu Residents DMA Low Elev
Bangdu Residents DMA High Elev
Changbangdu Tank 1
Changbangdu Tank 2
Bangdu Area (Left) DMA High Elev
Bangdu Area (Left) DMA Low Elev
Profile 1
Profile 2
Profile 3
Babesa Left DMA
Olakha 2 DMA
Olakha 1 DMA
Bangdu Residents DMA
Bangdu Area (Left) DMA
Workshop DMA - Proposed
Lubding DMA - Proposed

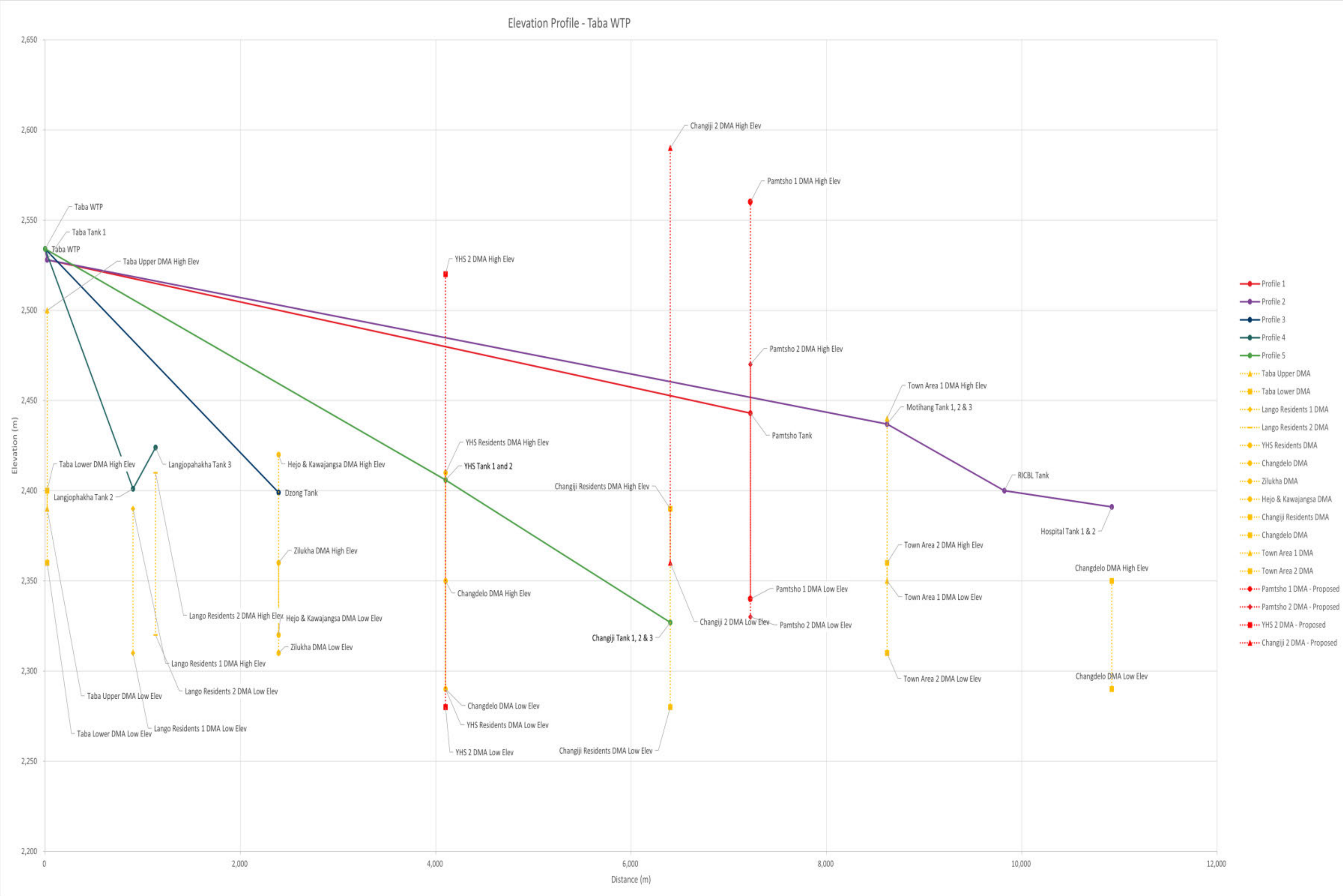


Elevation Profile - Ngabirongchu WTP
Elevation (m)
Distance (m)
2,700
2,600
2,500
2,400
2,300
2,200
2,100
2,000
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Ngabirongchu WTP
Gangchey Nyezergang DMA High Elev
Serbithang DMA High Elev
Rama DMA High Elev
Serbithang DMA Low Elev
Gangchey Nyezergang DMA Low Elev
Rama DMA Low Elev
Debsi DMA High Elev
Debsi Tank
Gabjakha Tank
Above Old Highways DMA High Elev
Above Old Highways DMA Low Elev
Babesa Tank 1
Babesa Right DMA High Elev
Babesa Right DMA High Elev
Babesa Left High Elev
Simtokha Tank Dantak
Babesa Left DMA Low Elev
Debsi DMA Low Elev
Babesa Right DMA Low Elev
Babesa Right DMA Low Elev
Profile 1
Profile 2
Profile 3
Profile 4
Debsi DMA
Babesa Right DMA
Above Old Highways DMA
Babesa Left DMA
Babesa Right DMA
Rama DMA - Proposed
Gangchey Nyezergang DMA - Proposed
Serbithang DMA - Propsoed

Data Sheet

Storage Reservoir – Hosiptal Tank 2

Value	Result
Storage Reservoir Name	Hosiptal Tank 2
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	Hospital Tank 1
Downstream DMA(s)	Hospital and Changdelo
WTP Supplying Storage Reservoir	Taba WTP
Number of Inlet Pipes	2
Diameter of Inlet Pipes (mm)	150; 80
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	80
Operations	6am-9am and 6pm-9pm
Top Water Elevation (m)	2394.5
Bottom Water Elevation (m)	2391
Storage Reservoir Volume (m^3)	250
Storage Reservoir Material	RRM_rectangular

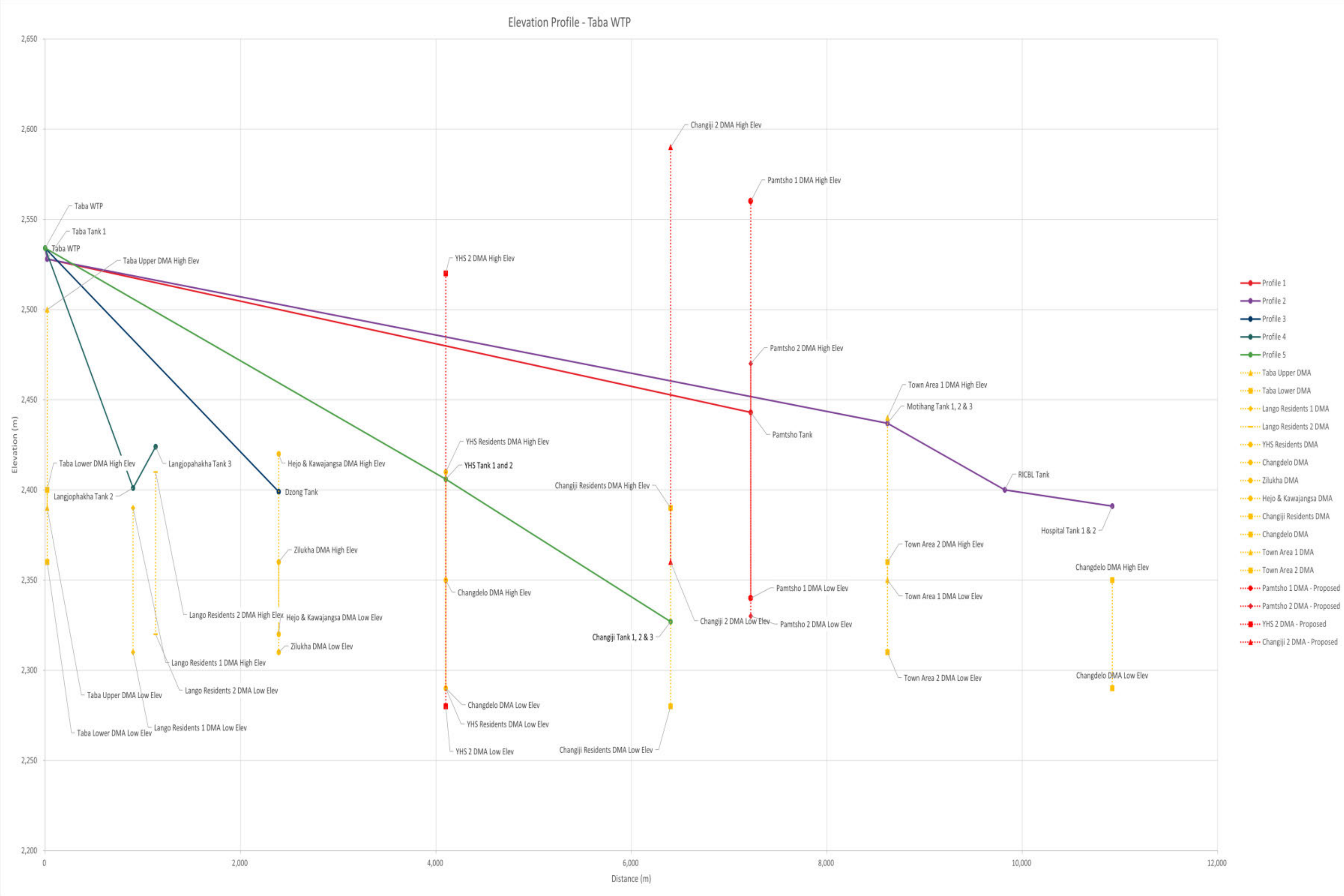


Elevation Profile - Taba WTP
Elevation (m)
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
Distance (m)
0
2,000
4,000
6,000
8,000
10,000
12,000
Taba WTP
Taba Tank 1
Taba WTP
Taba Upper DMA High Elev
Taba Lower DMA High Elev
Langjophakha Tank 2
Langjopahakha Tank 3
Hejo & Kawajangsa DMA High Elev
Dzong Tank
Zilukha DMA High Elev
Lango Residents 2 DMA High Elev
Hejo & Kawajangsa DMA Low Elev
Zilukha DMA Low Elev
Lango Residents 1 DMA High Elev
Lango Residents 2 DMA Low Elev
Taba Upper DMA Low Elev
Lango Residents 1 DMA Low Elev
Taba Lower DMA Low Elev
YHS 2 DMA High Elev
YHS Residents DMA High Elev
YHS Tank 1 and 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
YHS Residents DMA Low Elev
YHS 2 DMA Low Elev
Changiji 2 DMA High Elev
Changiji Residents DMA High Elev
Changiji Tank 1, 2 & 3
Changiji 2 DMA Low Elev
Changiji Residents DMA Low Elev
Pamtsho 1 DMA High Elev
Pamtsho 2 DMA High Elev
Pamtsho Tank
Pamtsho 1 DMA Low Elev
Pamtsho 2 DMA Low Elev
Town Area 1 DMA High Elev
Motihang Tank 1, 2 & 3
Town Area 2 DMA High Elev
Town Area 1 DMA Low Elev
Town Area 2 DMA Low Elev
RICBL Tank
Hospital Tank 1 & 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
Profile 1
Profile 2
Profile 3
Profile 4
Profile 5
Taba Upper DMA
Taba Lower DMA
Lango Residents 1 DMA
Lango Residents 2 DMA
YHS Residents DMA
Changdelo DMA
Zilukha DMA
Hejo & Kawajangsa DMA
Changiji Residents DMA
Changdelo DMA
Town Area 1 DMA
Town Area 2 DMA
Pamtsho 1 DMA - Proposed
Pamtsho 2 DMA - Proposed
YHS 2 DMA - Proposed
Changiji 2 DMA - Proposed

Data Sheet

Storage Reservoir – Hospital Tank 1

Value	Result
Storage Reservoir Name	Hospital Tank 1
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	Hospital Tank 2
Downstream DMA(s)	Hospital and Changdelo
WTP Supplying Storage Reservoir	Taba WTP
Number of Inlet Pipes	2
Diameter of Inlet Pipes (mm)	150; 80
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	80
Operations	6am-9am and 6pm-9pm
Top Water Elevation (m)	2394.5
Bottom Water Elevation (m)	2391
Storage Reservoir Volume (m^3)	320
Storage Reservoir Material	RCC_circular

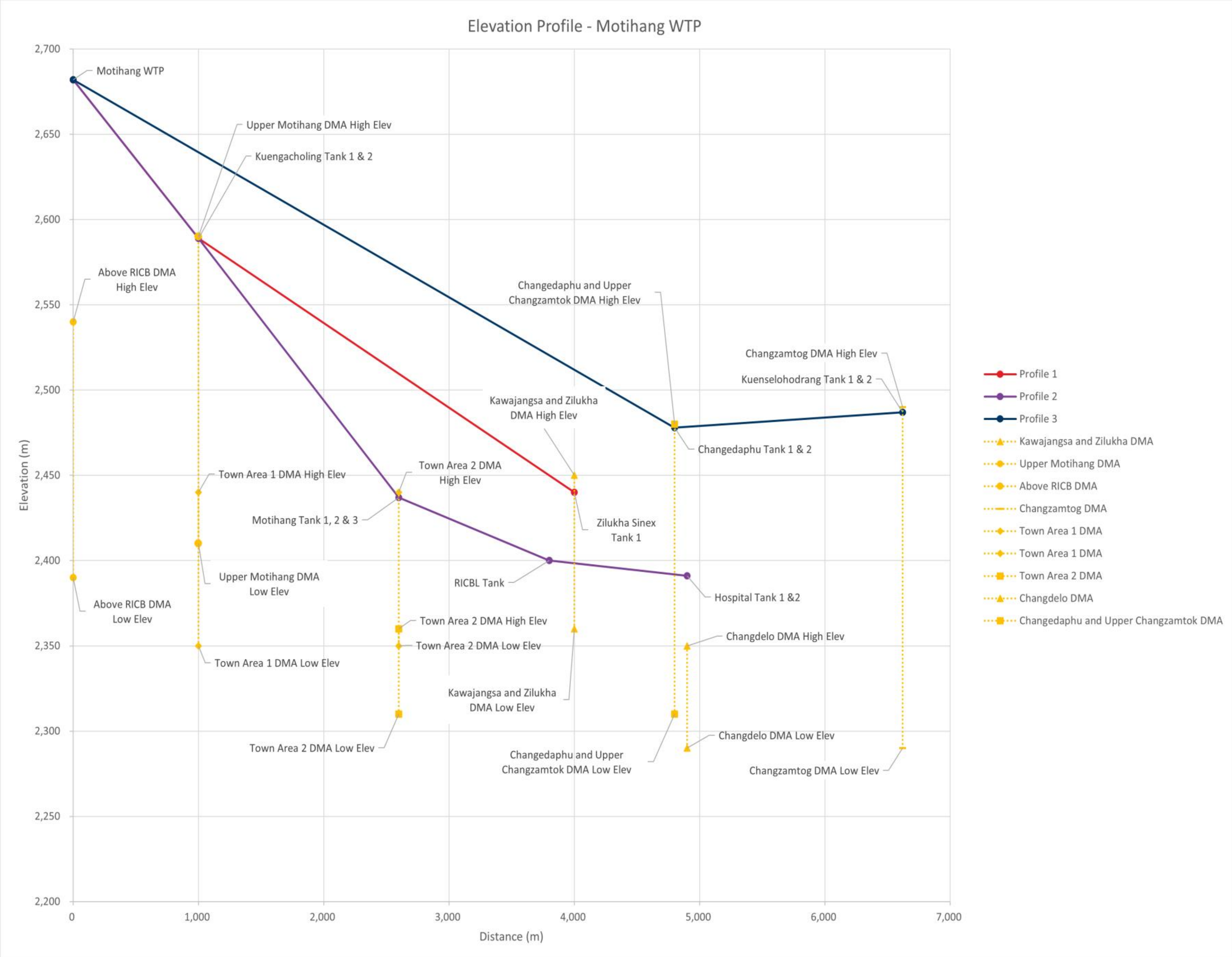


Elevation Profile - Taba WTP
Elevation (m)
Distance (m)
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
0
2,000
4,000
6,000
8,000
10,000
12,000
Taba WTP
Taba Tank 1
Taba WTP
Taba Upper DMA High Elev
Taba Lower DMA High Elev
Langjopahakha Tank 3
Langjophakha Tank 2
Hejo & Kawajangsa DMA High Elev
Dzong Tank
Zilukha DMA High Elev
Lango Residents 2 DMA High Elev
Hejo & Kawajangsa DMA Low Elev
Zilukha DMA Low Elev
Lango Residents 1 DMA High Elev
Lango Residents 2 DMA Low Elev
Taba Upper DMA Low Elev
Lango Residents 1 DMA Low Elev
Taba Lower DMA Low Elev
YHS 2 DMA High Elev
YHS Residents DMA High Elev
YHS Tank 1 and 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
YHS Residents DMA Low Elev
YHS 2 DMA Low Elev
Changiji 2 DMA High Elev
Changiji Residents DMA High Elev
Changiji Tank 1, 2 & 3
Changiji 2 DMA Low Elev
Changiji Residents DMA Low Elev
Pamtsho 1 DMA High Elev
Pamtsho 2 DMA High Elev
Pamtsho Tank
Pamtsho 1 DMA Low Elev
Pamtsho 2 DMA Low Elev
Town Area 1 DMA High Elev
Motihang Tank 1, 2 & 3
Town Area 2 DMA High Elev
Town Area 1 DMA Low Elev
Town Area 2 DMA Low Elev
RICBL Tank
Hospital Tank 1 & 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
Profile 1
Profile 2
Profile 3
Profile 4
Profile 5
Taba Upper DMA
Taba Lower DMA
Lango Residents 1 DMA
Lango Residents 2 DMA
YHS Residents DMA
Changdelo DMA
Zilukha DMA
Hejo & Kawajangsa DMA
Changiji Residents DMA
Changdelo DMA
Town Area 1 DMA
Town Area 2 DMA
Pamtsho 1 DMA - Proposed
Pamtsho 2 DMA - Proposed
YHS 2 DMA - Proposed
Changiji 2 DMA - Proposed

Data Sheet

Storage Reservoir – Kuengacholing Tank 1

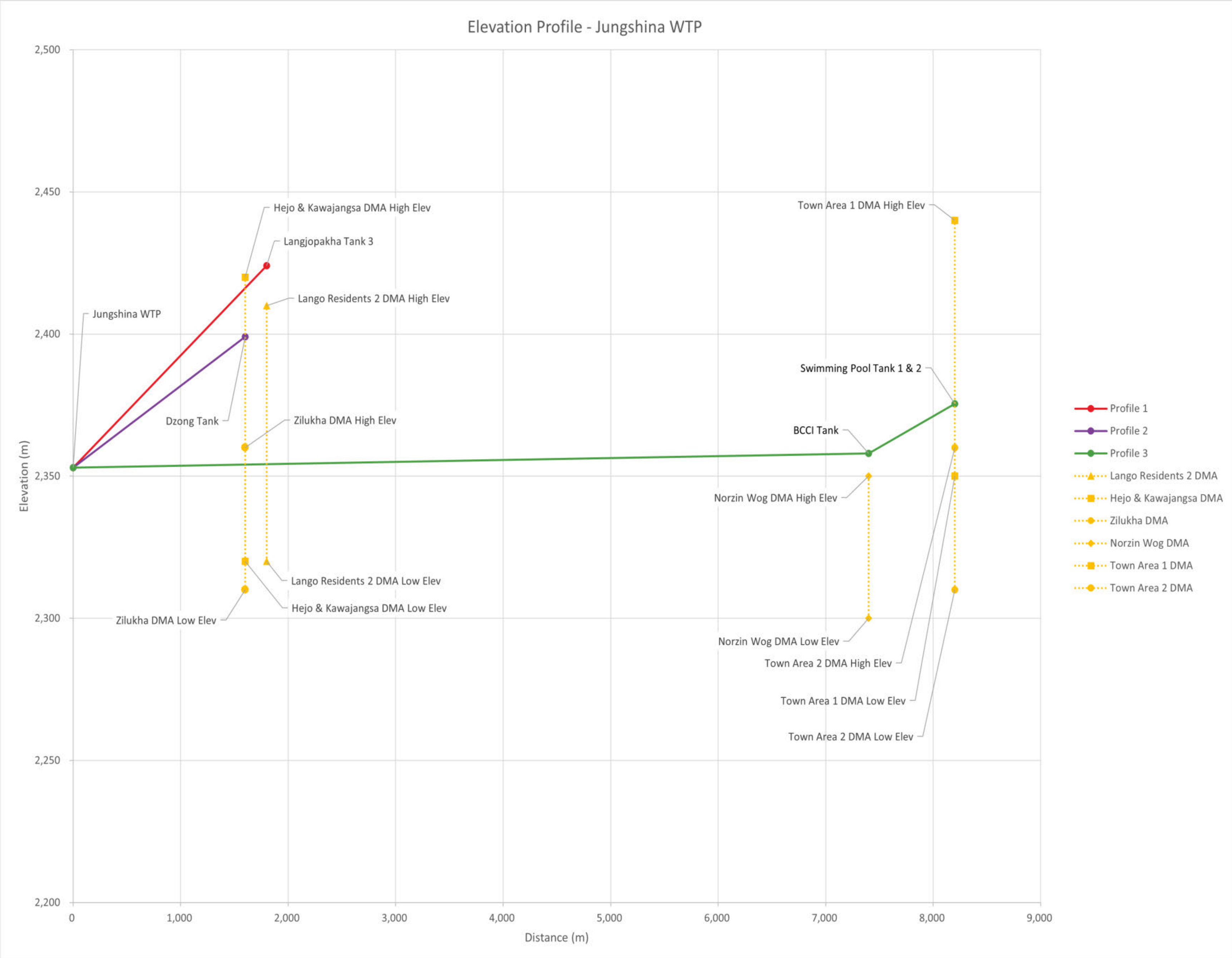
Value	Result
Storage Reservoir Name	Kuengacholing Tank 1
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	Kuengacholing Tank 2
Downstream DMA(s)	Upper Motihang; Zilukha Sintex Tank 1 which supplies Kawajangsa and Zilukha; Town Area 1; Town Area 2; Motihang Three Tanks which supplies RICBL Tanks and Hospital Tanks which supply Changdelo
WTP Supplying Storage Reservoir	Motihang WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	150
Number of Outlet Pipes	4
Diameter of Outlet Pipes (mm)	150; 100; 80; 80
Operations	8am-11am and 3pm-6pm
Top Water Elevation (m)	2592.5
Bottom Water Elevation (m)	2589
Storage Reservoir Volume (m^3)	320
Storage Reservoir Material	RCC_circular


Elevation Profile - Motihang WTP
Elevation (m)
Distance (m)
2,700
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Motihang WTP
Upper Motihang DMA High Elev
Kuengacholing Tank 1 & 2
Above RICB DMA High Elev
Above RICB DMA Low Elev
Town Area 1 DMA High Elev
Upper Motihang DMA Low Elev
Town Area 1 DMA Low Elev
Motihang Tank 1, 2 & 3
Town Area 2 DMA High Elev
Town Area 2 DMA High Elev
Town Area 2 DMA Low Elev
Town Area 2 DMA Low Elev
RICBL Tank
Kawajangsa and Zilukha DMA High Elev
Zilukha Sinex Tank 1
Kawajangsa and Zilukha DMA Low Elev
Changedaphu and Upper Changzamtok DMA High Elev
Changedaphu Tank 1 & 2
Changedaphu and Upper Changzamtok DMA Low Elev
Hospital Tank 1 &2
Changdelo DMA High Elev
Changdelo DMA Low Elev
Changzamtog DMA High Elev
Kuenselohodrang Tank 1 & 2
Changzamtog DMA Low Elev
Profile 1
Profile 2
Profile 3
Kawajangsa and Zilukha DMA
Upper Motihang DMA
Above RICB DMA
Changzamtog DMA
Town Area 1 DMA
Town Area 1 DMA
Town Area 2 DMA
Changdelo DMA
Changedaphu and Upper Changzamtok DMA

Data Sheet

Storage Reservoir – BCCI Tank

Value	Result
Storage Reservoir Name	BCCI Tank
Downstream Storage Reservoir(s)	Swimming pool tank 1; Swimming pool tank 2
Adjacent Reservoir(s)	None
Downstream DMA(s)	Norzin Wog; Swimming pool tank to Town Area 1; Swimming pool tank to Town Area 2; Swimming pool tank to hospital tank which services the hospital and Changdelo
WTP Supplying Storage Reservoir	Jungshina WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	100
Number of Outlet Pipes	2
Diameter of Outlet Pipes (mm)	100; 100
Operations	6am-9am and 6pm-9pm
Top Water Elevation (m)	2361.5
Bottom Water Elevation (m)	2358
Storage Reservoir Volume (m^3)	230
Storage Reservoir Material	RCC_circular

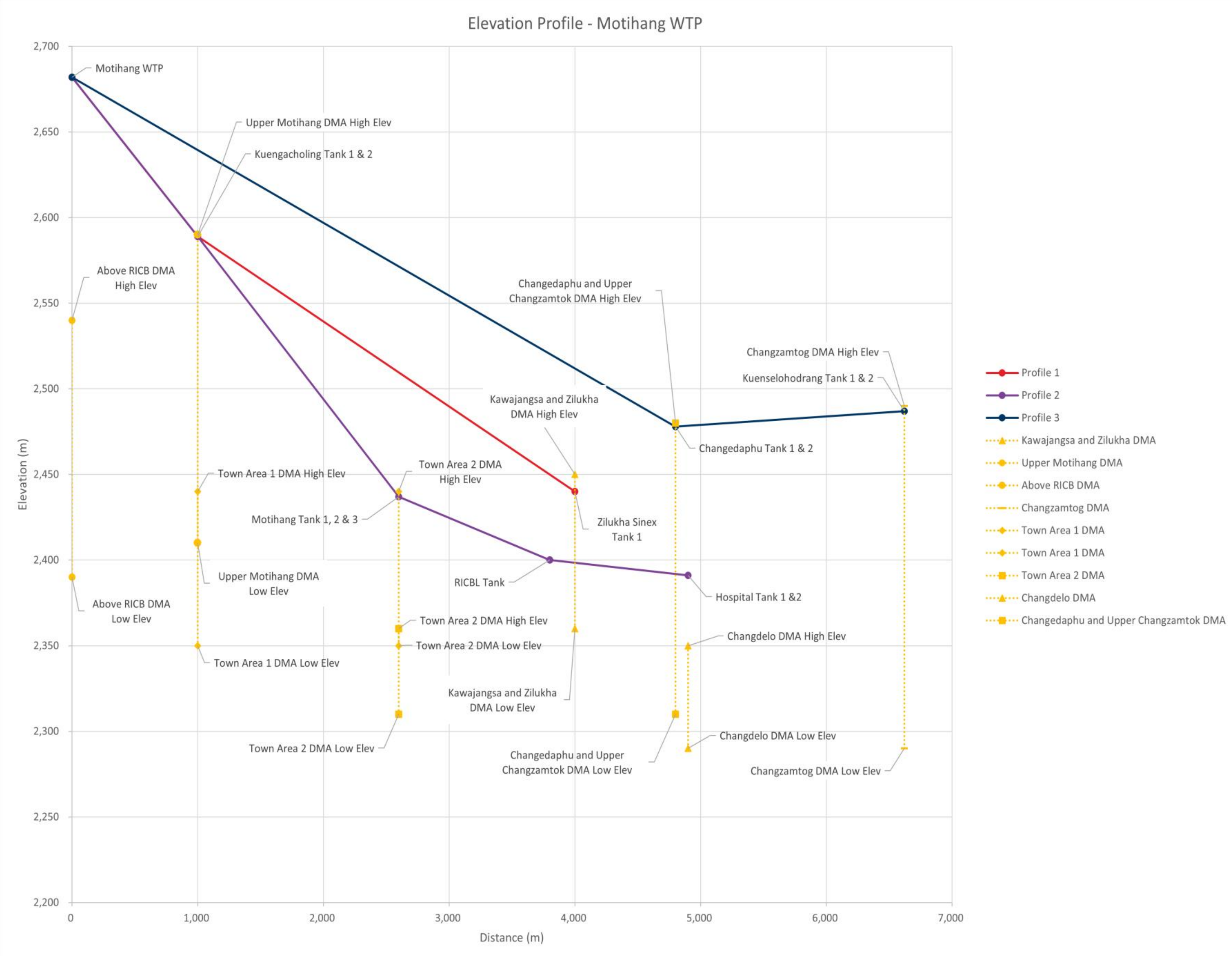


Elevation Profile - Jungshina WTP
Elevation (m)
Distance (m)
2,500
2,450
2,400
2,350
2,300
2,250
2,200
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
Jungshina WTP
Hejo & Kawajangsa DMA High Elev
Langjopakha Tank 3
Lango Residents 2 DMA High Elev
Dzong Tank
Zilukha DMA High Elev
Lango Residents 2 DMA Low Elev
Hejo & Kawajangsa DMA Low Elev
Zilukha DMA Low Elev
Town Area 1 DMA High Elev
Swimming Pool Tank 1 & 2
BCCI Tank
Norzin Wog DMA High Elev
Norzin Wog DMA Low Elev
Town Area 2 DMA High Elev
Town Area 1 DMA Low Elev
Town Area 2 DMA Low Elev
Profile 1
Profile 2
Profile 3
Lango Residents 2 DMA
Hejo & Kawajangsa DMA
Zilukha DMA
Norzin Wog DMA
Town Area 1 DMA
Town Area 2 DMA

Data Sheet

Storage Reservoir – Kuengacholing Tank 2

Value	Result
Storage Reservoir Name	Kuengacholing Tank 2
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	Kuengacholing Tank 1
Downstream DMA(s)	Upper Motihang; Zilukha Sintex Tank 1 which supplies Kawajangsa and Zilukha; Town Area 1; Town Area 2; Motihang Three Tanks which supplies RICBL Tanks and Hospital Tanks which supply Changdelo
WTP Supplying Storage Reservoir	Motihang WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	150
Number of Outlet Pipes	4
Diameter of Outlet Pipes (mm)	150; 100; 80; 80
Operations	8am-11am and 3pm-6pm
Top Water Elevation (m)	2593.5
Bottom Water Elevation (m)	2590
Storage Reservoir Volume (m^3)	320
Storage Reservoir Material	RCC_circular

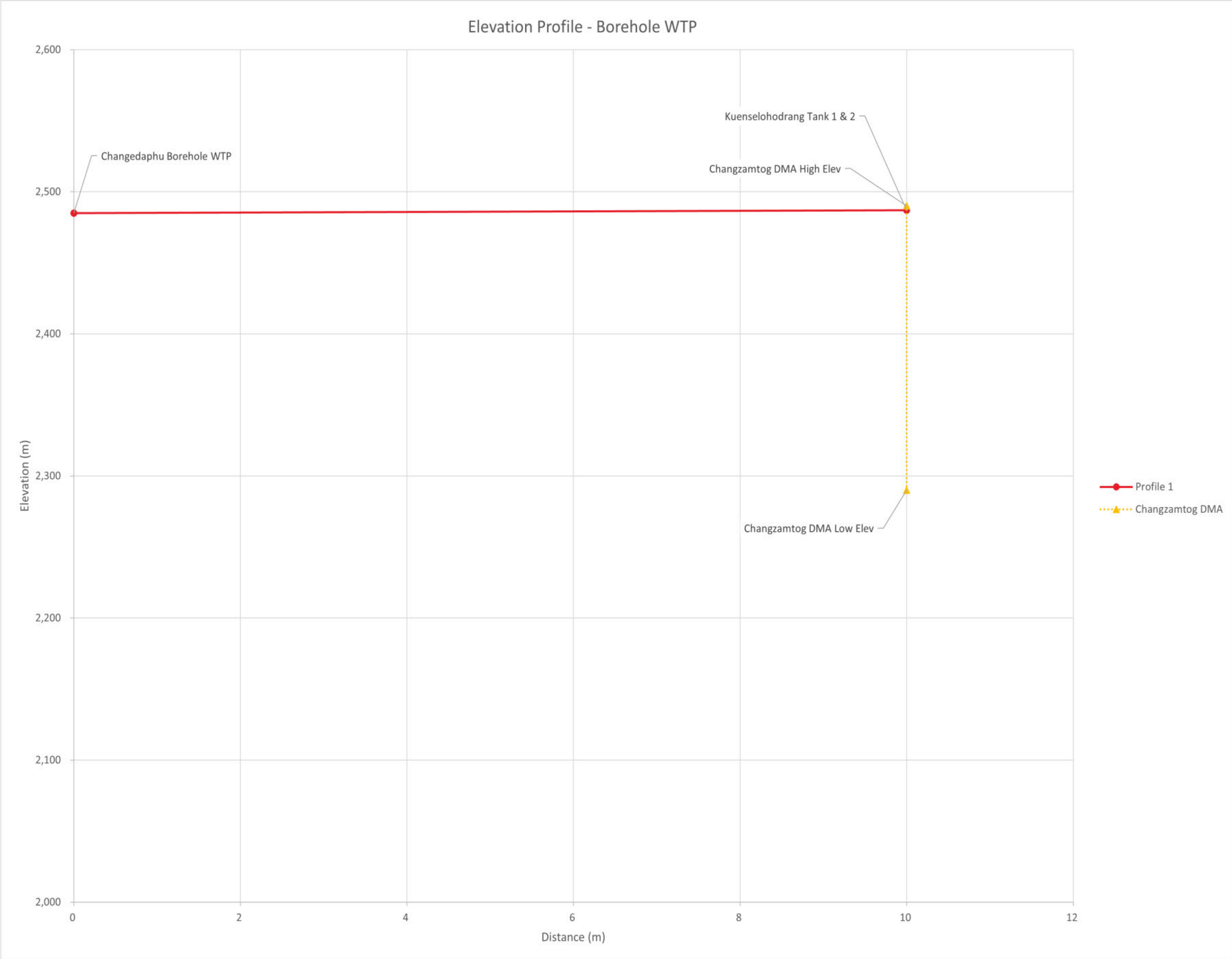


Elevation Profile - Motihang WTP
Elevation (m)
Distance (m)
2,700
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Motihang WTP
Upper Motihang DMA High Elev
Kuengacholing Tank 1 & 2
Above RICB DMA High Elev
Above RICB DMA Low Elev
Town Area 1 DMA High Elev
Upper Motihang DMA Low Elev
Town Area 1 DMA Low Elev
Motihang Tank 1, 2 & 3
Town Area 2 DMA High Elev
Town Area 2 DMA High Elev
Town Area 2 DMA Low Elev
Town Area 2 DMA Low Elev
Kawajangsa and Zilukha DMA High Elev
Zilukha Sinex Tank 1
RICBL Tank
Kawajangsa and Zilukha DMA Low Elev
Changedaphu and Upper Changzamtok DMA High Elev
Changedaphu Tank 1 & 2
Hospital Tank 1 &2
Changdelo DMA High Elev
Changedaphu and Upper Changzamtok DMA Low Elev
Changdelo DMA Low Elev
Changzamtog DMA High Elev
Kuenselohodrang Tank 1 & 2
Changzamtog DMA Low Elev
Profile 1
Profile 2
Profile 3
Kawajangsa and Zilukha DMA
Upper Motihang DMA
Above RICB DMA
Changzamtog DMA
Town Area 1 DMA
Town Area 1 DMA
Town Area 2 DMA
Changdelo DMA
Changedaphu and Upper Changzamtok DMA

Data Sheet

Storage Reservoir – Kuenselohodrang Tank 1

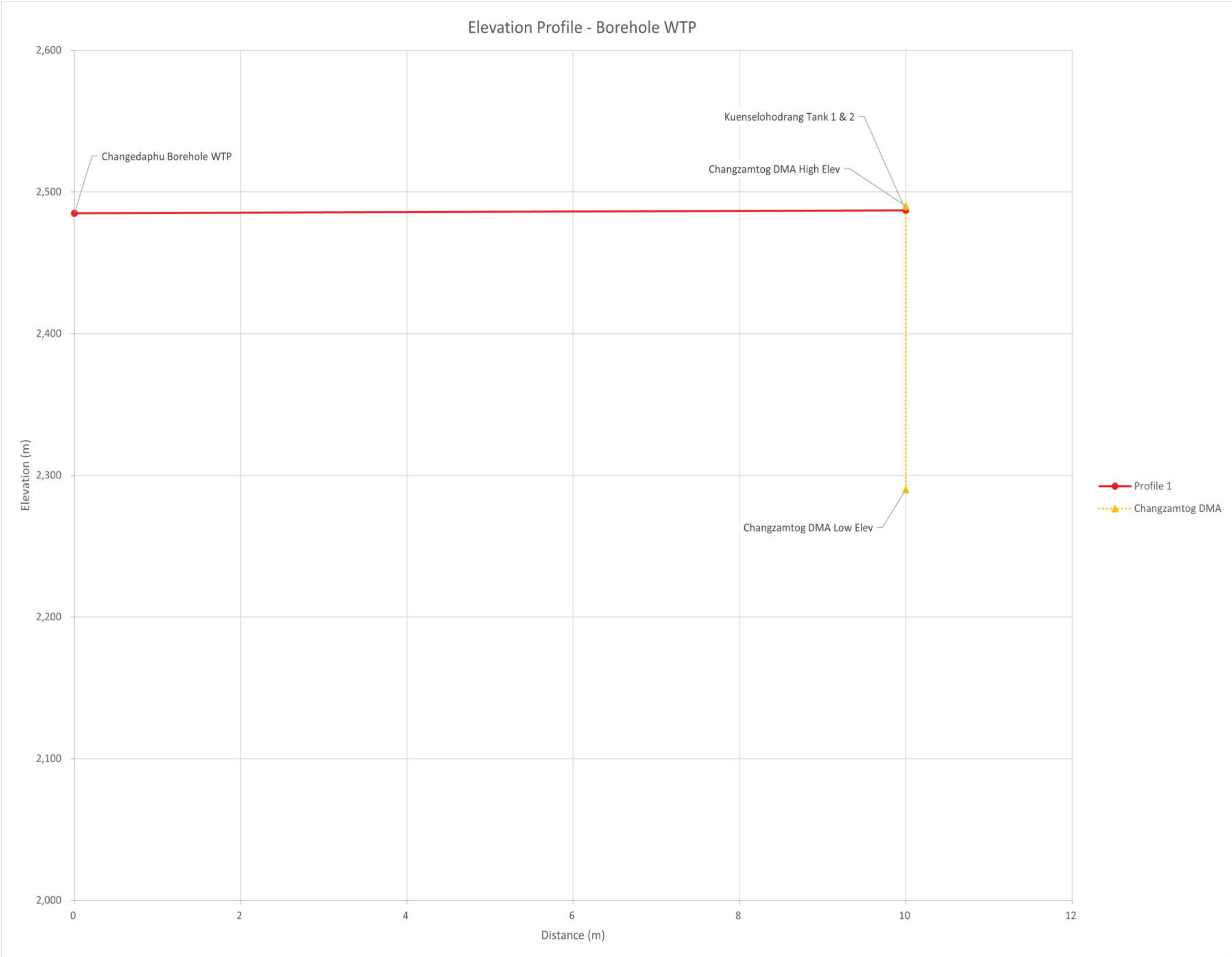
Value	Result
Storage Reservoir Name	Kuenselohodrang Tank 1
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	Kuenselphodreang Tank 2
Downstream DMA(s)	Changzamtog
WTP Supplying Storage Reservoir	Boreholes
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	100
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	80
Operations	Not provided
Top Water Elevation (m)	2490.5
Bottom Water Elevation (m)	2487
Storage Reservoir Volume (m^3)	230
Storage Reservoir Material	RCC_circular


Elevation Profile - Borehole WTP
Elevation (m)
2,600
2,500
2,400
2,300
2,200
2,100
2,000
0
2
4
6
8
10
12
Distance (m)
Changedaphu Borehole WTP
Kuenselohodrang Tank 1 & 2
Changzamtog DMA High Elev
Changzamtog DMA Low Elev
Profile 1
Changzamtog DMA

Data Sheet

Storage Reservoir – Kuenselphodreang Tank 2

Value	Result
Storage Reservoir Name	Kuenselphodreang Tank 2
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	Kuenselohodrang Tank 1
Downstream DMA(s)	Changzamtog
WTP Supplying Storage Reservoir	Boreholes
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	100
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	80
Operations	Not provided
Top Water Elevation (m)	2488.5
Bottom Water Elevation (m)	2485
Storage Reservoir Volume (m^3)	100
Storage Reservoir Material	RCC_circular

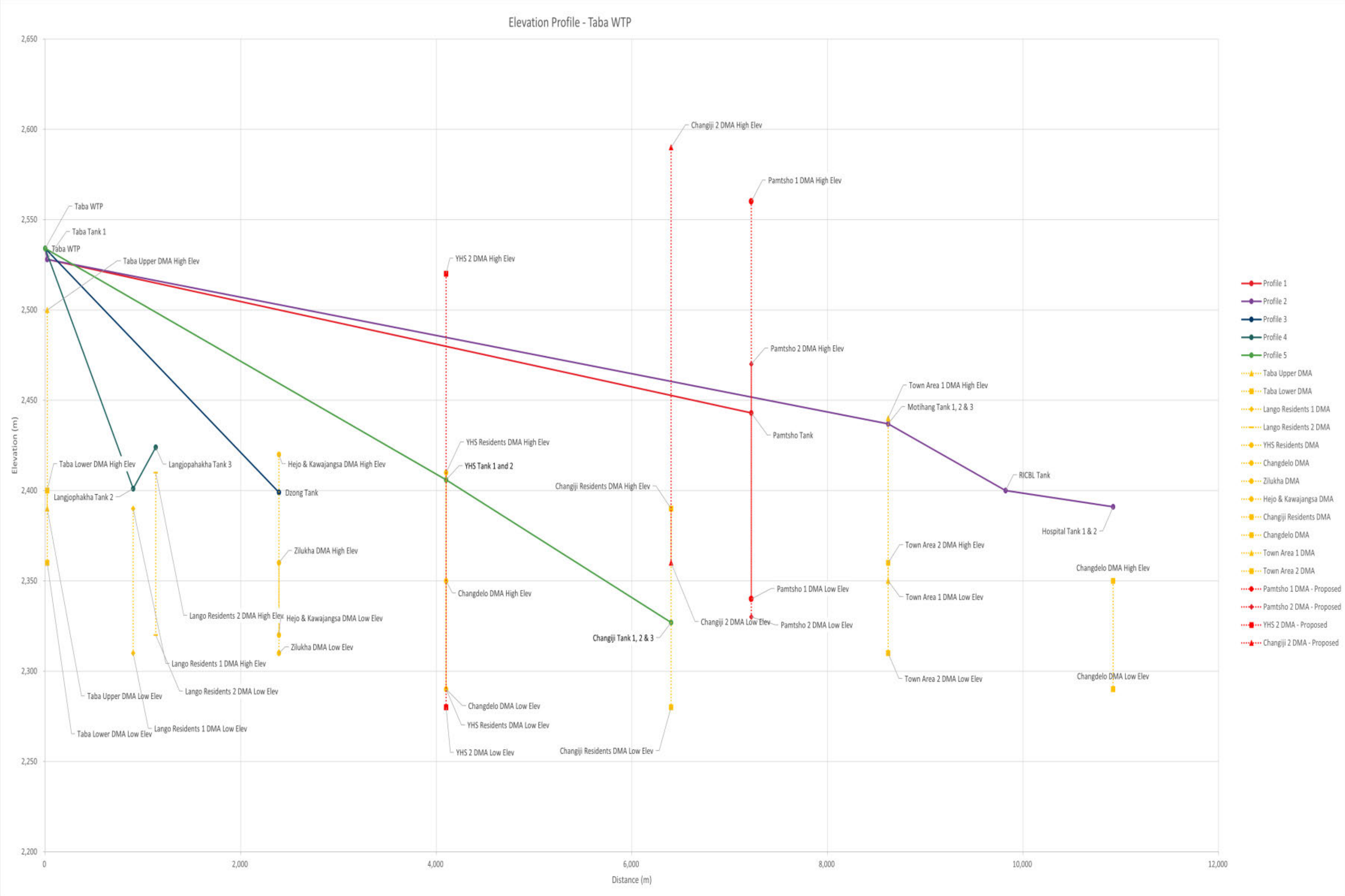


Elevation Profile - Borehole WTP
2,600
2,500
2,400
2,300
2,200
2,100
2,000
Elevation (m)
0
2
4
6
8
10
12
Distance (m)
Changedaphu Borehole WTP
Kuenselohodrang Tank 1 & 2
Changzamtog DMA High Elev
Changzamtog DMA Low Elev
Profile 1
Changzamtog DMA

Data Sheet

Storage Reservoir – Langjophakha Tank 2

Value	Result
Storage Reservoir Name	Langjophakha Tank 2
Downstream Storage Reservoir(s)	YHS 2 Tank; Changiji Tank 1; Changiji Tank 2; Changiji Tank 3
Adjacent Reservoir(s)	Langjophakha Tank 3
Downstream DMA(s)	Lango Residents 1; Langjophaka Tank 3 which supplies Lango Residents 2
WTP Supplying Storage Reservoir	Taba WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	150
Number of Outlet Pipes	2
Diameter of Outlet Pipes (mm)	150; 100
Operations	24hour
Top Water Elevation (m)	2404.5
Bottom Water Elevation (m)	2401
Storage Reservoir Volume (m^3)	320
Storage Reservoir Material	RCC_circular

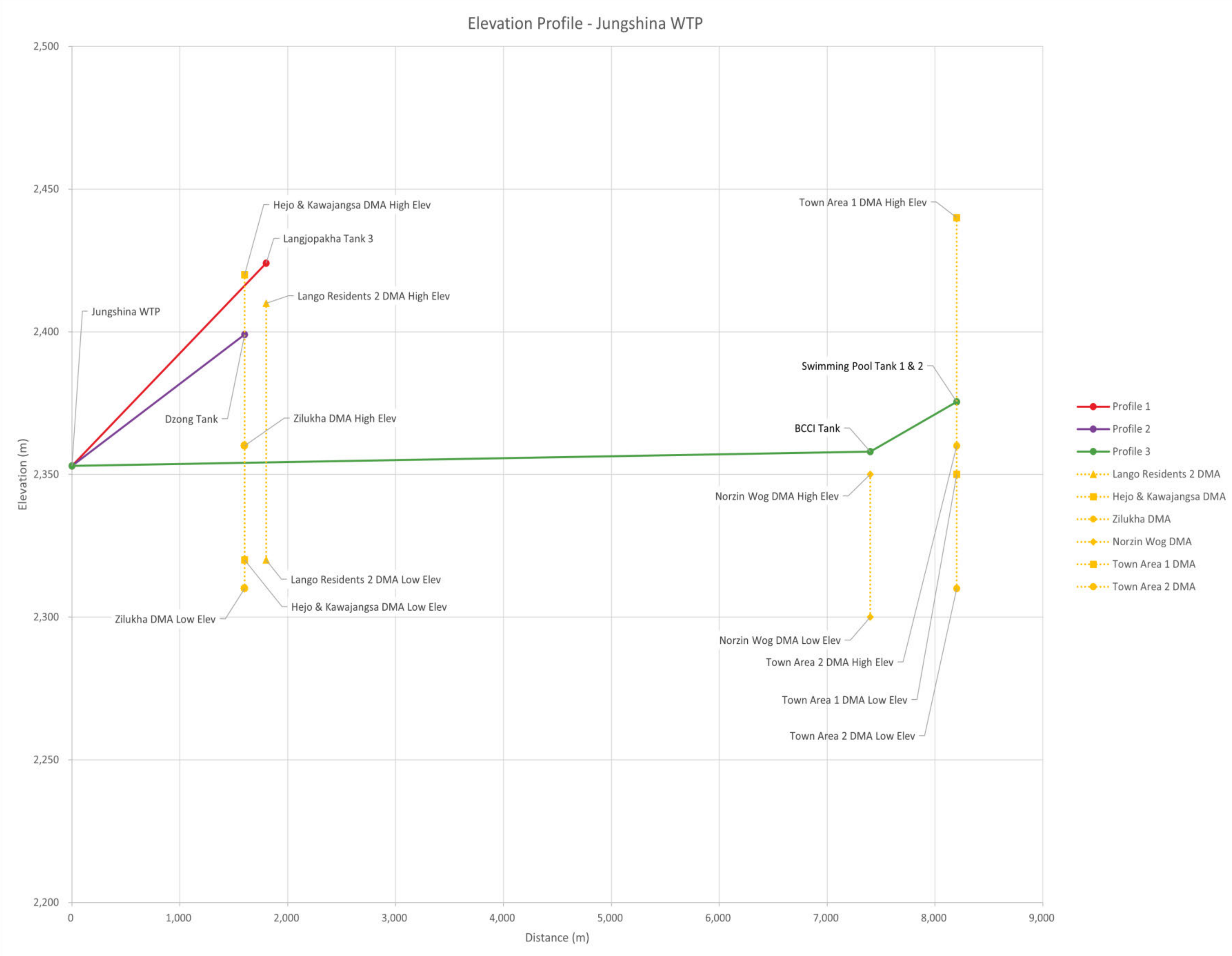


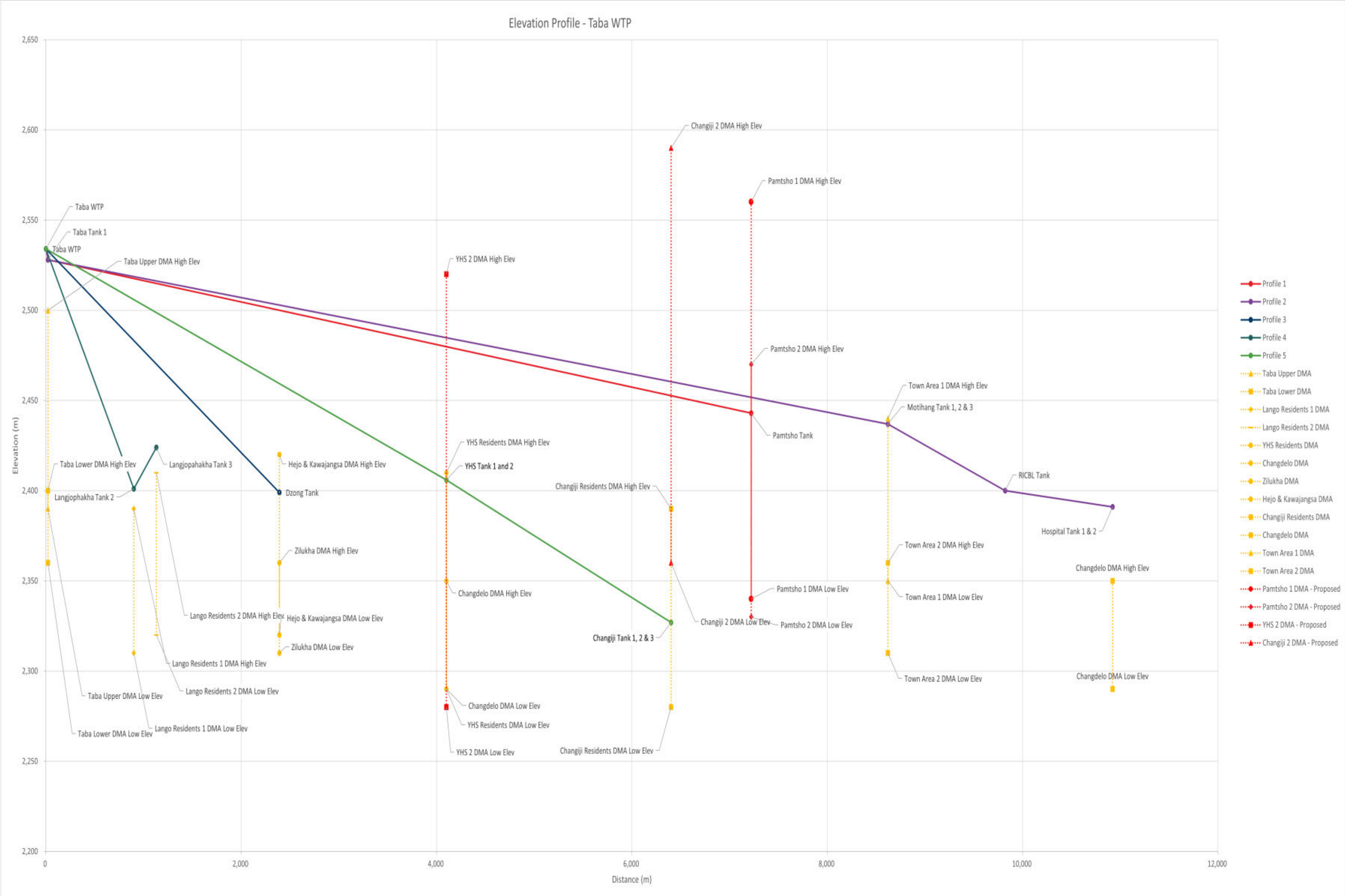
Elevation Profile - Taba WTP
Elevation (m)
Distance (m)
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
0
2,000
4,000
6,000
8,000
10,000
12,000
Taba WTP
Taba Tank 1
Taba WTP
Taba Upper DMA High Elev
Taba Lower DMA High Elev
Langjopahakha Tank 2
Langjopahakha Tank 3
Lango Residents 2 DMA High Elev
Lango Residents 1 DMA High Elev
Lango Residents 2 DMA Low Elev
Taba Upper DMA Low Elev
Taba Lower DMA Low Elev
Lango Residents 1 DMA Low Elev
Hejo & Kawajangsa DMA High Elev
Dzong Tank
Zilukha DMA High Elev
Hejo & Kawajangsa DMA Low Elev
Zilukha DMA Low Elev
YHS 2 DMA High Elev
YHS Residents DMA High Elev
YHS Tank 1 and 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
YHS Residents DMA Low Elev
YHS 2 DMA Low Elev
Changiji 2 DMA High Elev
Changiji Residents DMA High Elev
Changiji Tank 1, 2 & 3
Changiji 2 DMA Low Elev
Changiji Residents DMA Low Elev
Pamtsho 1 DMA High Elev
Pamtsho 2 DMA High Elev
Pamtsho Tank
Pamtsho 1 DMA Low Elev
Pamtsho 2 DMA Low Elev
Town Area 1 DMA High Elev
Motihang Tank 1, 2 & 3
Town Area 2 DMA High Elev
Town Area 1 DMA Low Elev
Town Area 2 DMA Low Elev
RICBL Tank
Hospital Tank 1 & 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
Profile 1
Profile 2
Profile 3
Profile 4
Profile 5
Taba Upper DMA
Taba Lower DMA
Lango Residents 1 DMA
Lango Residents 2 DMA
YHS Residents DMA
Changdelo DMA
Zilukha DMA
Hejo & Kawajangsa DMA
Changiji Residents DMA
Changdelo DMA
Town Area 1 DMA
Town Area 2 DMA
Pamtsho 1 DMA - Proposed
Pamtsho 2 DMA - Proposed
YHS 2 DMA - Proposed
Changiji 2 DMA - Proposed

Data Sheet

Storage Reservoir – Langjophakha Tank 3

Value	Result
Storage Reservoir Name	Langjophakha Tank 3
Downstream Storage Reservoir(s)	YHS 2 Tank; Changiji Tank 1; Changiji Tank 2; Changiji Tank 3
Adjacent Reservoir(s)	Langjophakha Tank 2
Downstream DMA(s)	Lango Residents 2
WTP Supplying Storage Reservoir	Jungshina WTP; Taba WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	100
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	63
Operations	24hour
Top Water Elevation (m)	2427.5
Bottom Water Elevation (m)	2424
Storage Reservoir Volume (m^3)	230
Storage Reservoir Material	RCC_circular


Elevation Profile - Jungshina WTP
Elevation (m)
2,500
2,450
2,400
2,350
2,300
2,250
2,200
Distance (m)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
Jungshina WTP
Hejo & Kawajangsa DMA High Elev
Langjopakha Tank 3
Lango Residents 2 DMA High Elev
Dzong Tank
Zilukha DMA High Elev
Lango Residents 2 DMA Low Elev
Hejo & Kawajangsa DMA Low Elev
Zilukha DMA Low Elev
Town Area 1 DMA High Elev
Swimming Pool Tank 1 & 2
BCCI Tank
Norzin Wog DMA High Elev
Norzin Wog DMA Low Elev
Town Area 2 DMA High Elev
Town Area 1 DMA Low Elev
Town Area 2 DMA Low Elev
Profile 1
Profile 2
Profile 3
Lango Residents 2 DMA
Hejo & Kawajangsa DMA
Zilukha DMA
Norzin Wog DMA
Town Area 1 DMA
Town Area 2 DMA


Elevation Profile - Taba WTP
Elevation (m)
Distance (m)
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
0
2,000
4,000
6,000
8,000
10,000
12,000
Taba WTP
Taba Tank 1
Taba WTP
Taba Upper DMA High Elev
Taba Lower DMA High Elev
Langjophakha Tank 2
Langjopahakha Tank 3
Hejo & Kawajangsa DMA High Elev
Dzong Tank
Zilukha DMA High Elev
Lango Residents 2 DMA High Elev
Hejo & Kawajangsa DMA Low Elev
Zilukha DMA Low Elev
Lango Residents 1 DMA High Elev
Lango Residents 2 DMA Low Elev
Taba Upper DMA Low Elev
Lango Residents 1 DMA Low Elev
Taba Lower DMA Low Elev
YHS 2 DMA High Elev
YHS Residents DMA High Elev
YHS Tank 1 and 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
YHS Residents DMA Low Elev
YHS 2 DMA Low Elev
Changiji 2 DMA High Elev
Changiji Residents DMA High Elev
Changiji Tank 1, 2 & 3
Changiji 2 DMA Low Elev
Changiji Residents DMA Low Elev
Pamtsho 1 DMA High Elev
Pamtsho 2 DMA High Elev
Pamtsho Tank
Pamtsho 1 DMA Low Elev
Pamtsho 2 DMA Low Elev
Town Area 1 DMA High Elev
Motihang Tank 1, 2 & 3
Town Area 2 DMA High Elev
Town Area 1 DMA Low Elev
Town Area 2 DMA Low Elev
RICBL Tank
Hospital Tank 1 & 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
Profile 1
Profile 2
Profile 3
Profile 4
Profile 5
Taba Upper DMA
Taba Lower DMA
Lango Residents 1 DMA
Lango Residents 2 DMA
YHS Residents DMA
Changdelo DMA
Zilukha DMA
Hejo & Kawajangsa DMA
Changiji Residents DMA
Changdelo DMA
Town Area 1 DMA
Town Area 2 DMA
Pamtsho 1 DMA - Proposed
Pamtsho 2 DMA - Proposed
YHS 2 DMA - Proposed
Changiji 2 DMA - Proposed

Data Sheet

Storage Reservoir – Lubding Tank 1

Value	Result
Storage Reservoir Name	Lubding Tank 1
Downstream Storage Reservoir(s)	Lubding Tank 2
Adjacent Reservoir(s)	Lubding Tank 2
Downstream DMA(s)	Lubding
WTP Supplying Storage Reservoir	Community Supply
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	100
Number of Outlet Pipes	2
Diameter of Outlet Pipes (mm)	100; 80
Operations	Not provided
Top Water Elevation (m)	2646.5
Bottom Water Elevation (m)	2643
Storage Reservoir Volume (m^3)	100
Storage Reservoir Material	RCC_circular

Data Sheet

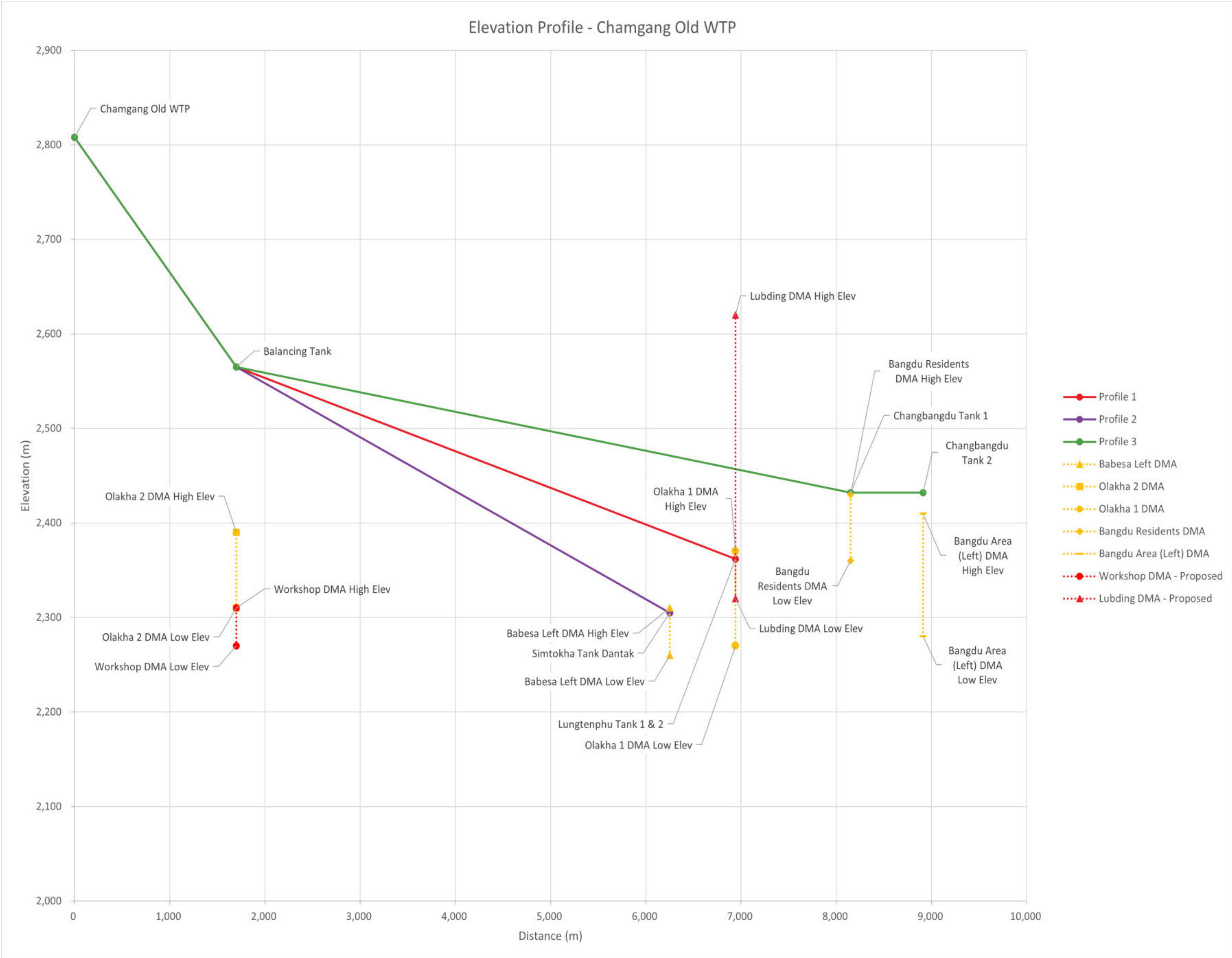
Storage Reservoir – Lubding Tank 2

Value	Result
Storage Reservoir Name	Lubding Tank 2
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	Lubding Tank 1
Downstream DMA(s)	Lubding
WTP Supplying Storage Reservoir	Community Supply
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	80
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	100
Operations	Not provided
Top Water Elevation (m)	2520.5
Bottom Water Elevation (m)	2517
Storage Reservoir Volume (m^3)	50
Storage Reservoir Material	RRM_rectangular

Data Sheet

Storage Reservoir – Lungtenphu Tank 1

Value	Result
Storage Reservoir Name	Lungtenphu Tank 1
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	Lungtenphu Tank 2
Downstream DMA(s)	Olakha 1
WTP Supplying Storage Reservoir	Chamgang Old WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	200
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	200
Operations	6am-9am and 6pm-10pm
Top Water Elevation (m)	2365.5
Bottom Water Elevation (m)	2362
Storage Reservoir Volume (m^3)	450
Storage Reservoir Material	RCC_circular

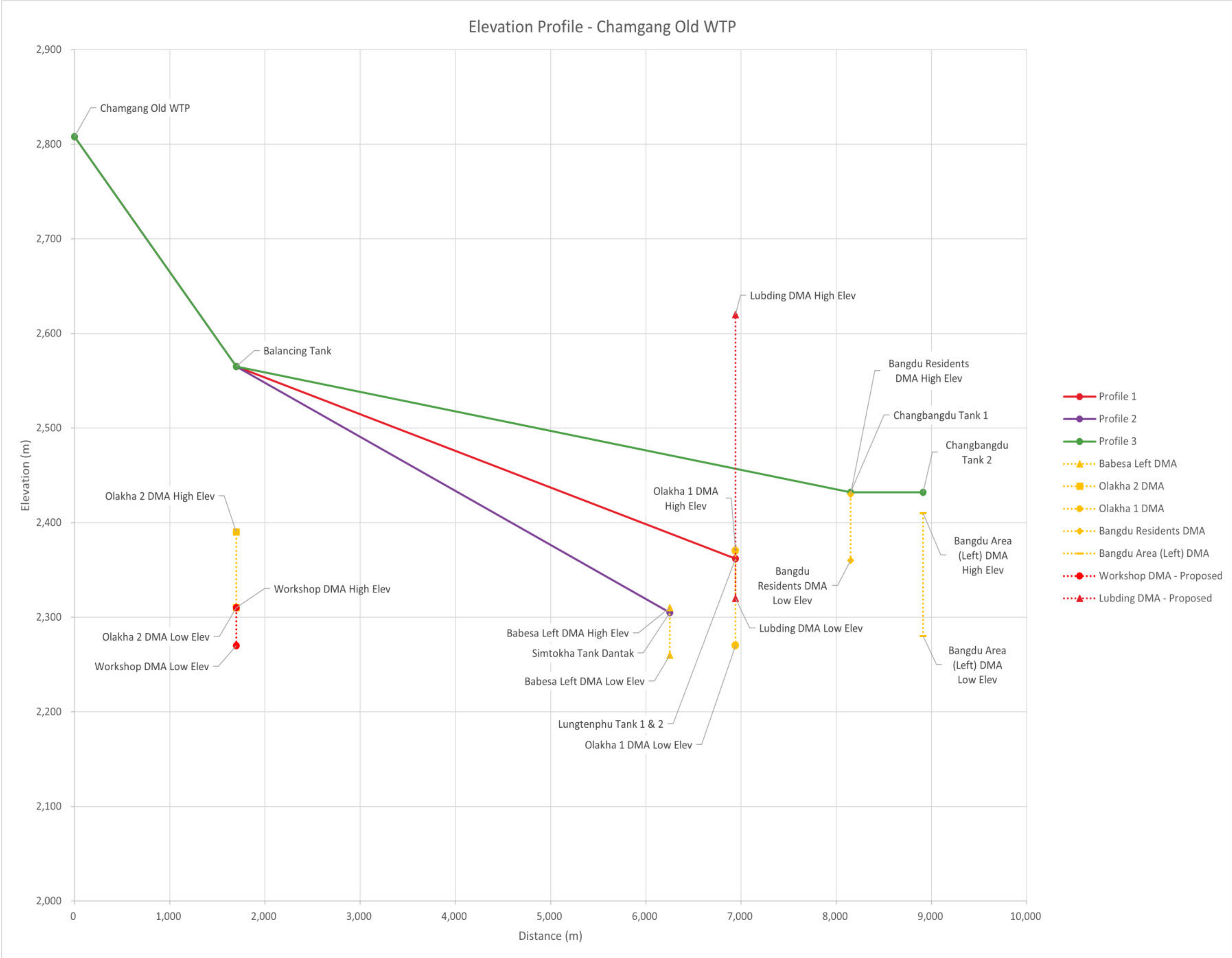


Elevation Profile - Chamgang Old WTP
Elevation (m)
Distance (m)
Chamgang Old WTP
Balancing Tank
Olakha 2 DMA High Elev
Workshop DMA High Elev
Olakha 2 DMA Low Elev
Workshop DMA Low Elev
Babesa Left DMA High Elev
Simtokha Tank Dantak
Babesa Left DMA Low Elev
Lungtenphu Tank 1 & 2
Olakha 1 DMA Low Elev
Olakha 1 DMA High Elev
Lubding DMA High Elev
Lubding DMA Low Elev
Bangdu Residents DMA High Elev
Changbangdu Tank 1
Changbangdu Tank 2
Bangdu Residents DMA Low Elev
Bangdu Area (Left) DMA High Elev
Bangdu Area (Left) DMA Low Elev
Profile 1
Profile 2
Profile 3
Babesa Left DMA
Olakha 2 DMA
Olakha 1 DMA
Bangdu Residents DMA
Bangdu Area (Left) DMA
Workshop DMA - Proposed
Lubding DMA - Proposed

Data Sheet

Storage Reservoir – Lungtenphu Tank 2

Value	Result
Storage Reservoir Name	Lungtenphu Tank 2
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	Lungtenphu Tank 1
Downstream DMA(s)	Olakha 1
WTP Supplying Storage Reservoir	Chamgang Old WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	200
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	200
Operations	6am-9am and 6pm-10pm
Top Water Elevation (m)	2365.5
Bottom Water Elevation (m)	2362
Storage Reservoir Volume (m^3)	360
Storage Reservoir Material	RCC_circular

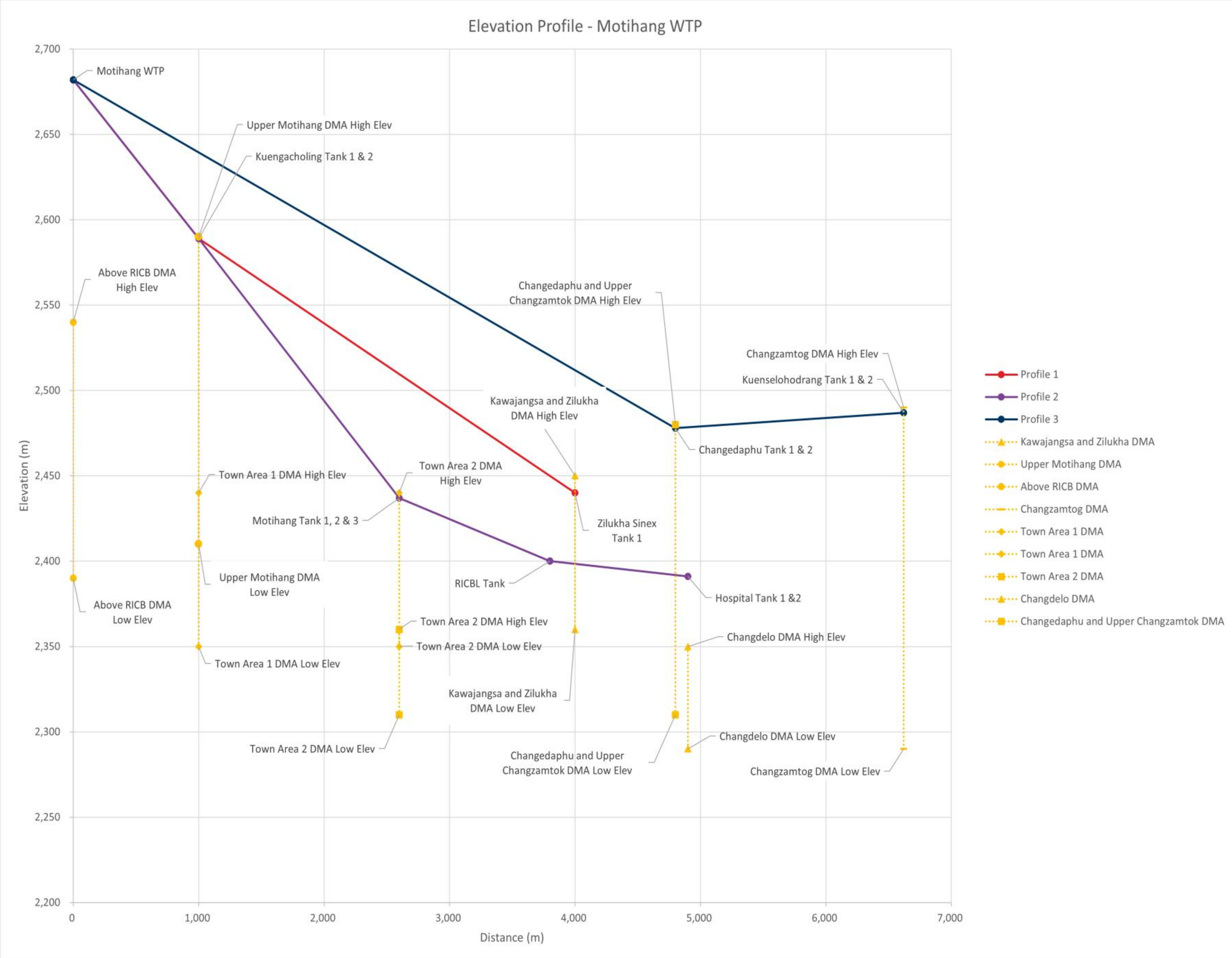


Elevation Profile - Chamgang Old WTP
Elevation (m)
Distance (m)
2,900
2,800
2,700
2,600
2,500
2,400
2,300
2,200
2,100
2,000
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
Chamgang Old WTP
Balancing Tank
Olakha 2 DMA High Elev
Workshop DMA High Elev
Olakha 2 DMA Low Elev
Workshop DMA Low Elev
Babesa Left DMA High Elev
Simtokha Tank Dantak
Babesa Left DMA Low Elev
Lungtenphu Tank 1 & 2
Olakha 1 DMA Low Elev
Olakha 1 DMA High Elev
Lubding DMA High Elev
Lubding DMA Low Elev
Bangdu Residents DMA Low Elev
Bangdu Residents DMA High Elev
Changbangdu Tank 1
Changbangdu Tank 2
Bangdu Area (Left) DMA High Elev
Bangdu Area (Left) DMA Low Elev
Profile 1
Profile 2
Profile 3
Babesa Left DMA
Olakha 2 DMA
Olakha 1 DMA
Bangdu Residents DMA
Bangdu Area (Left) DMA
Workshop DMA - Proposed
Lubding DMA - Proposed

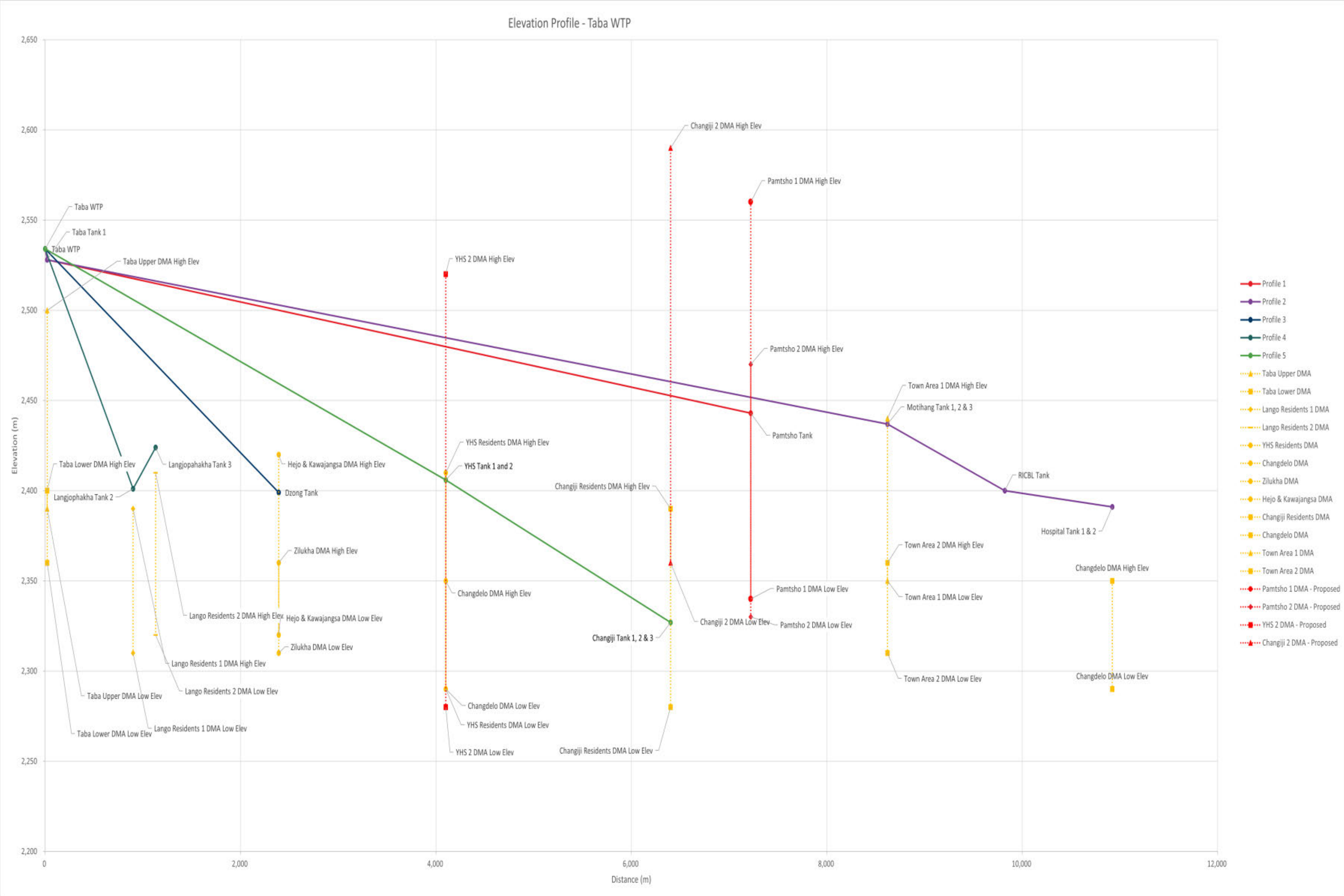
Data Sheet

Storage Reservoir – Motithang Three Tanks 1

Value	Result
Storage Reservoir Name	Motithang Three Tanks 1
Downstream Storage Reservoir(s)	To RICB Tank
Adjacent Reservoir(s)	Motithang Three Tanks 2 and 3
Downstream DMA(s)	Town Area 1; Town Area 2; RICBL Tanks and Hospital Tanks which supply hospital and Changdelo
WTP Supplying Storage Reservoir	Motihang WTP; Taba WTP
Number of Inlet Pipes	2
Diameter of Inlet Pipes (mm)	200; 150
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	200
Operations	6am-9am and 6pm-9pm
Top Water Elevation (m)	2440.5
Bottom Water Elevation (m)	2437
Storage Reservoir Volume (m^3)	320
Storage Reservoir Material	RCC_circular



Elevation Profile - Motihang WTP
Motihang WTP
Upper Motihang DMA High Elev
Kuengacholing Tank 1 & 2
Above RICB DMA High Elev
Changedaphu and Upper Changzamtok DMA High Elev
Changzamtog DMA High Elev
Kuenselohodrang Tank 1 & 2
Kawajangsa and Zilukha DMA High Elev
Changedaphu Tank 1 & 2
Town Area 1 DMA High Elev
Town Area 2 DMA High Elev
Motihang Tank 1, 2 & 3
Zilukha Sinex Tank 1
Upper Motihang DMA Low Elev
RICBL Tank
Hospital Tank 1 &2
Above RICB DMA Low Elev
Town Area 2 DMA High Elev
Town Area 2 DMA Low Elev
Changdelo DMA High Elev
Town Area 1 DMA Low Elev
Kawajangsa and Zilukha DMA Low Elev
Town Area 2 DMA Low Elev
Changedaphu and Upper Changzamtok DMA Low Elev
Changdelo DMA Low Elev
Changzamtog DMA Low Elev
Elevation (m)
2,700
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance (m)
Profile 1
Profile 2
Profile 3
Kawajangsa and Zilukha DMA
Upper Motihang DMA
Above RICB DMA
Changzamtog DMA
Town Area 1 DMA
Town Area 1 DMA
Town Area 2 DMA
Changdelo DMA
Changedaphu and Upper Changzamtok DMA

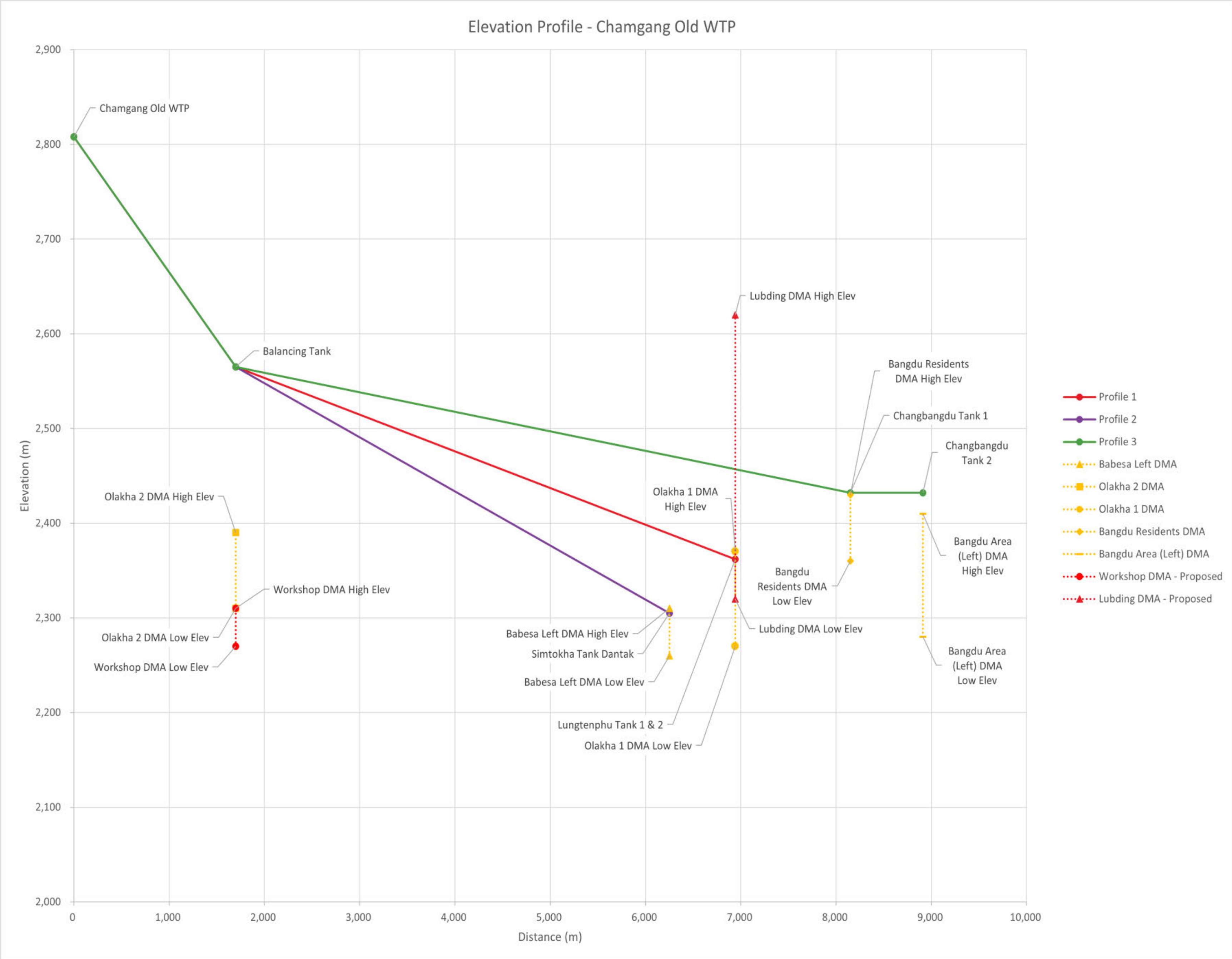


Elevation Profile - Taba WTP
Elevation (m)
Distance (m)
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
0
2,000
4,000
6,000
8,000
10,000
12,000
Taba WTP
Taba Tank 1
Taba WTP
Taba Upper DMA High Elev
Taba Lower DMA High Elev
Langjophakha Tank 2
Langjopahakha Tank 3
Hejo & Kawajangsa DMA High Elev
Dzong Tank
Zilukha DMA High Elev
Lango Residents 2 DMA High Elev
Hejo & Kawajangsa DMA Low Elev
Zilukha DMA Low Elev
Lango Residents 1 DMA High Elev
Lango Residents 2 DMA Low Elev
Taba Upper DMA Low Elev
Lango Residents 1 DMA Low Elev
Taba Lower DMA Low Elev
YHS 2 DMA High Elev
YHS Residents DMA High Elev
YHS Tank 1 and 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
YHS Residents DMA Low Elev
YHS 2 DMA Low Elev
Changjiji 2 DMA High Elev
Changjiji Residents DMA High Elev
Changjiji Tank 1, 2 & 3
Changjiji 2 DMA Low Elev
Changjiji Residents DMA Low Elev
Pamtsho 1 DMA High Elev
Pamtsho 2 DMA High Elev
Pamtsho Tank
Pamtsho 1 DMA Low Elev
Pamtsho 2 DMA Low Elev
Town Area 1 DMA High Elev
Motihang Tank 1, 2 & 3
Town Area 2 DMA High Elev
Town Area 1 DMA Low Elev
Town Area 2 DMA Low Elev
RICBL Tank
Hospital Tank 1 & 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
Profile 1
Profile 2
Profile 3
Profile 4
Profile 5
Taba Upper DMA
Taba Lower DMA
Lango Residents 1 DMA
Lango Residents 2 DMA
YHS Residents DMA
Changdelo DMA
Zilukha DMA
Hejo & Kawajangsa DMA
Changjiji Residents DMA
Changdelo DMA
Town Area 1 DMA
Town Area 2 DMA
Pamtsho 1 DMA - Proposed
Pamtsho 2 DMA - Proposed
YHS 2 DMA - Proposed
Changjiji 2 DMA - Proposed

Data Sheet

Storage Reservoir – Changbangdu Tank 2

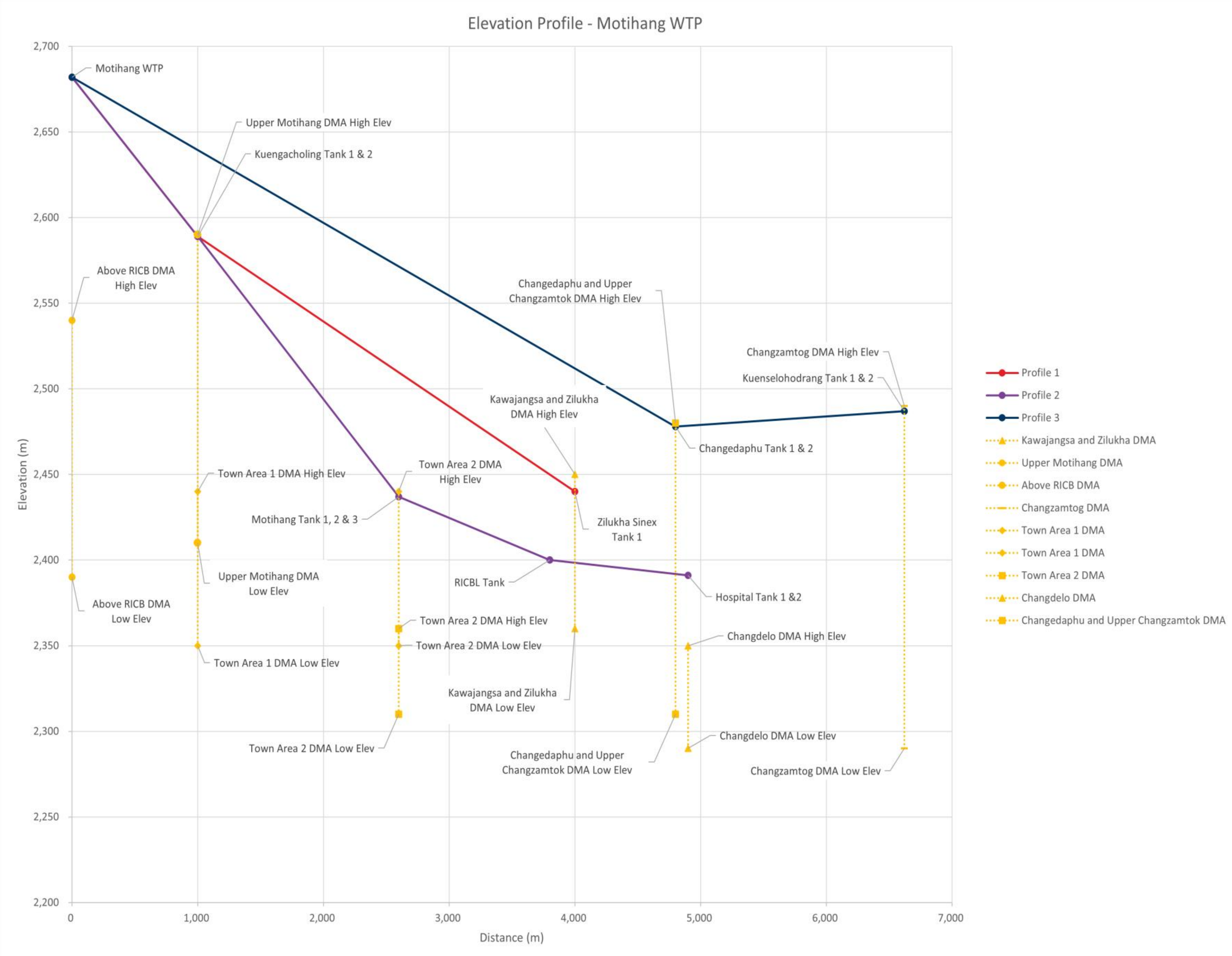
Value	Result
Storage Reservoir Name	Changbangdu Tank 2
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	Changbangdu Tank 1 and 3
Downstream DMA(s)	Bangdu Area (Left)
WTP Supplying Storage Reservoir	Chamgang Old WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	100
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	100
Operations	24hour
Top Water Elevation (m)	2391.5
Bottom Water Elevation (m)	2388
Storage Reservoir Volume (m^3)	270
Storage Reservoir Material	RCC_circular


Elevation Profile - Chamgang Old WTP
Elevation (m)
2,900
2,800
2,700
2,600
2,500
2,400
2,300
2,200
2,100
2,000
Distance (m)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
Chamgang Old WTP
Balancing Tank
Olakha 2 DMA High Elev
Workshop DMA High Elev
Olakha 2 DMA Low Elev
Workshop DMA Low Elev
Babesa Left DMA High Elev
Simtokha Tank Dantak
Babesa Left DMA Low Elev
Lungtenphu Tank 1 & 2
Olakha 1 DMA Low Elev
Olakha 1 DMA High Elev
Lubding DMA High Elev
Lubding DMA Low Elev
Bangdu Residents DMA Low Elev
Bangdu Residents DMA High Elev
Changbangdu Tank 1
Changbangdu Tank 2
Bangdu Area (Left) DMA High Elev
Bangdu Area (Left) DMA Low Elev
Profile 1
Profile 2
Profile 3
Babesa Left DMA
Olakha 2 DMA
Olakha 1 DMA
Bangdu Residents DMA
Bangdu Area (Left) DMA
Workshop DMA - Proposed
Lubding DMA - Proposed

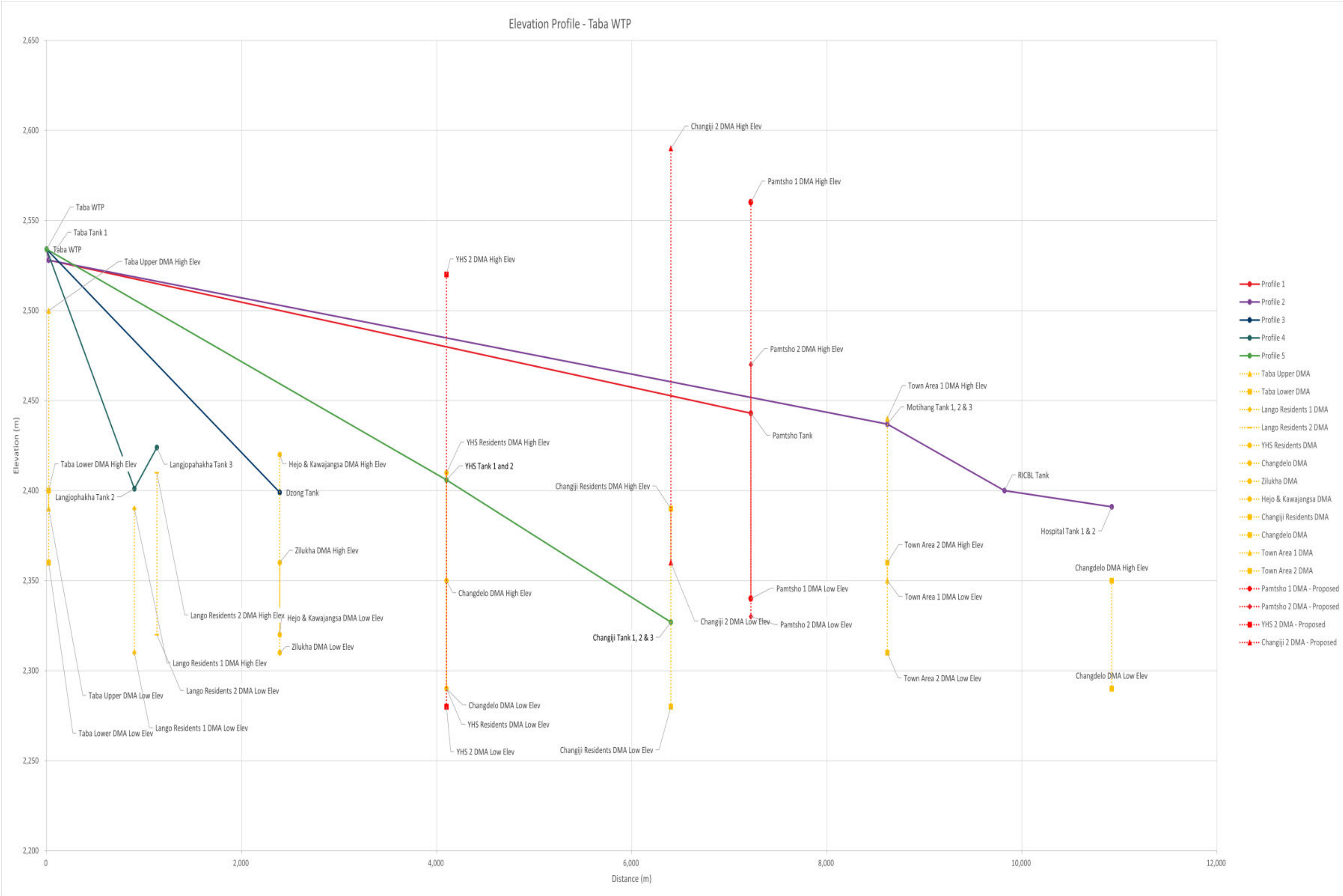
Data Sheet

Storage Reservoir – Motithang Three Tanks 3

Value	Result
Storage Reservoir Name	Motithang Three Tanks 3
Downstream Storage Reservoir(s)	To RICB Tank
Adjacent Reservoir(s)	Motithang Three Tanks 1 and 2
Downstream DMA(s)	Town Area 1; Town Area 2; RICBL Tanks and Hospital Tanks which supply hospital and Changdelo
WTP Supplying Storage Reservoir	Motihang WTP; Taba WTP
Number of Inlet Pipes	2
Diameter of Inlet Pipes (mm)	150; 150
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	200
Operations	6am-9am and 6pm-9pm
Top Water Elevation (m)	2439.5
Bottom Water Elevation (m)	2436
Storage Reservoir Volume (m^3)	320
Storage Reservoir Material	RCC_circular



Elevation Profile - Motihang WTP
Elevation (m)
2,700
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
Distance (m)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Motihang WTP
Upper Motihang DMA High Elev
Kuengacholing Tank 1 & 2
Above RICB DMA High Elev
Above RICB DMA Low Elev
Town Area 1 DMA High Elev
Upper Motihang DMA Low Elev
Town Area 1 DMA Low Elev
Motihang Tank 1, 2 & 3
Town Area 2 DMA High Elev
Town Area 2 DMA High Elev
Town Area 2 DMA Low Elev
Town Area 2 DMA Low Elev
RICBL Tank
Kawajangsa and Zilukha DMA High Elev
Zilukha Sinex Tank 1
Kawajangsa and Zilukha DMA Low Elev
Changedaphu and Upper Changzamtok DMA High Elev
Changedaphu Tank 1 & 2
Changedaphu and Upper Changzamtok DMA Low Elev
Hospital Tank 1 &2
Changdelo DMA High Elev
Changdelo DMA Low Elev
Changzamtog DMA High Elev
Kuenselohodrang Tank 1 & 2
Changzamtog DMA Low Elev
Profile 1
Profile 2
Profile 3
Kawajangsa and Zilukha DMA
Upper Motihang DMA
Above RICB DMA
Changzamtog DMA
Town Area 1 DMA
Town Area 1 DMA
Town Area 2 DMA
Changdelo DMA
Changedaphu and Upper Changzamtok DMA

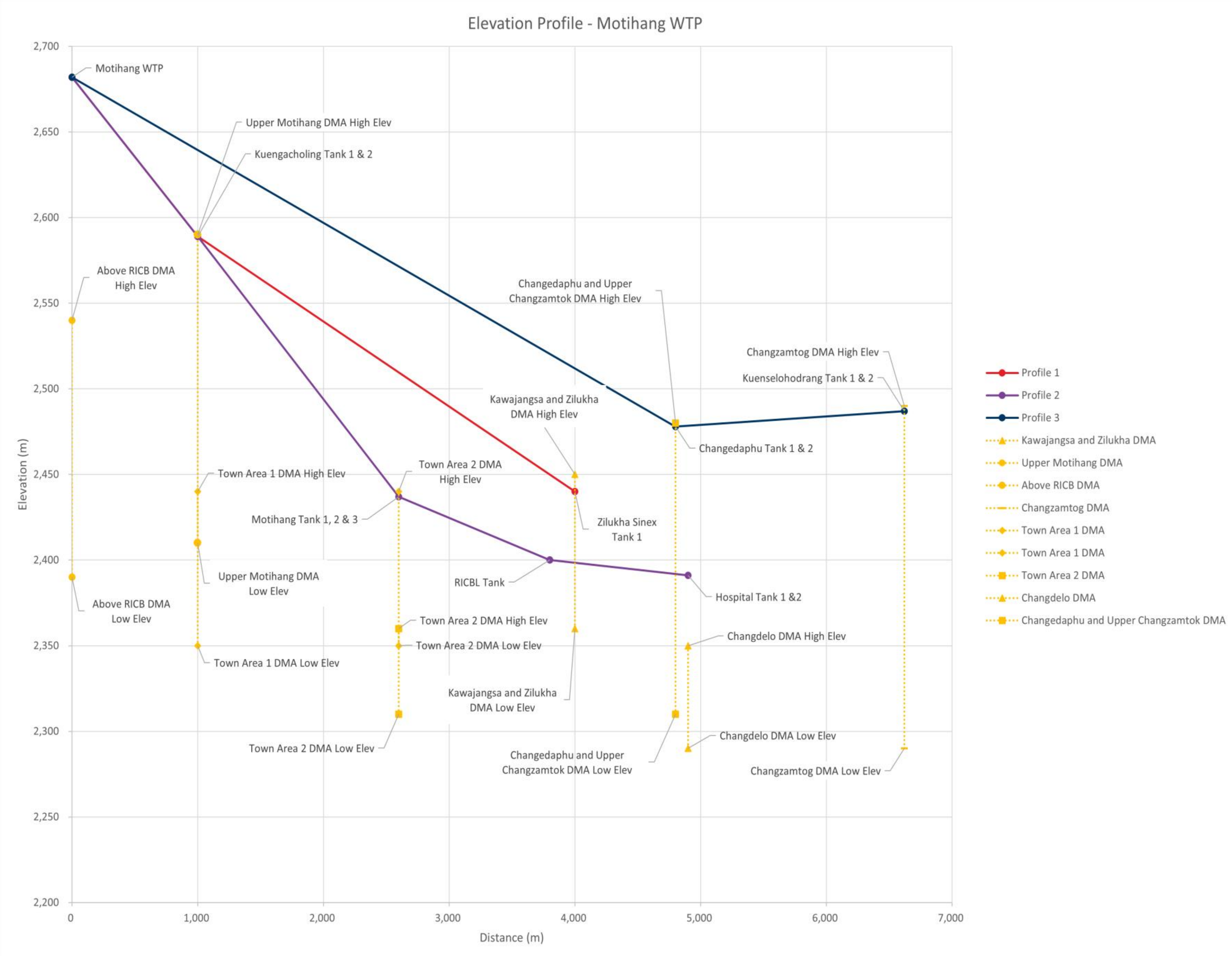


Elevation Profile - Taba WTP
Elevation (m)
Distance (m)
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
0
2,000
4,000
6,000
8,000
10,000
12,000
Taba WTP
Taba Tank 1
Taba WTP
Taba Upper DMA High Elev
Taba Lower DMA High Elev
Langjophakha Tank 2
Langjopahakha Tank 3
Dzong Tank
Hejo & Kawajangsa DMA High Elev
Zilukha DMA High Elev
Lango Residents 2 DMA High Elev
Hejo & Kawajangsa DMA Low Elev
Zilukha DMA Low Elev
Lango Residents 1 DMA High Elev
Lango Residents 2 DMA Low Elev
Taba Upper DMA Low Elev
Lango Residents 1 DMA Low Elev
Taba Lower DMA Low Elev
YHS 2 DMA High Elev
YHS Residents DMA High Elev
YHS Tank 1 and 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
YHS Residents DMA Low Elev
YHS 2 DMA Low Elev
Changiji 2 DMA High Elev
Changiji Residents DMA High Elev
Changiji Tank 1, 2 & 3
Changiji 2 DMA Low Elev
Changiji Residents DMA Low Elev
Pamtsho 1 DMA High Elev
Pamtsho 2 DMA High Elev
Pamtsho Tank
Pamtsho 1 DMA Low Elev
Pamtsho 2 DMA Low Elev
Town Area 1 DMA High Elev
Motihang Tank 1, 2 & 3
Town Area 2 DMA High Elev
Town Area 1 DMA Low Elev
Town Area 2 DMA Low Elev
RICBL Tank
Hospital Tank 1 & 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
Profile 1
Profile 2
Profile 3
Profile 4
Profile 5
Taba Upper DMA
Taba Lower DMA
Lango Residents 1 DMA
Lango Residents 2 DMA
YHS Residents DMA
Changdelo DMA
Zilukha DMA
Hejo & Kawajangsa DMA
Changiji Residents DMA
Changdelo DMA
Town Area 1 DMA
Town Area 2 DMA
Pamtsho 1 DMA - Proposed
Pamtsho 2 DMA - Proposed
YHS 2 DMA - Proposed
Changiji 2 DMA - Proposed

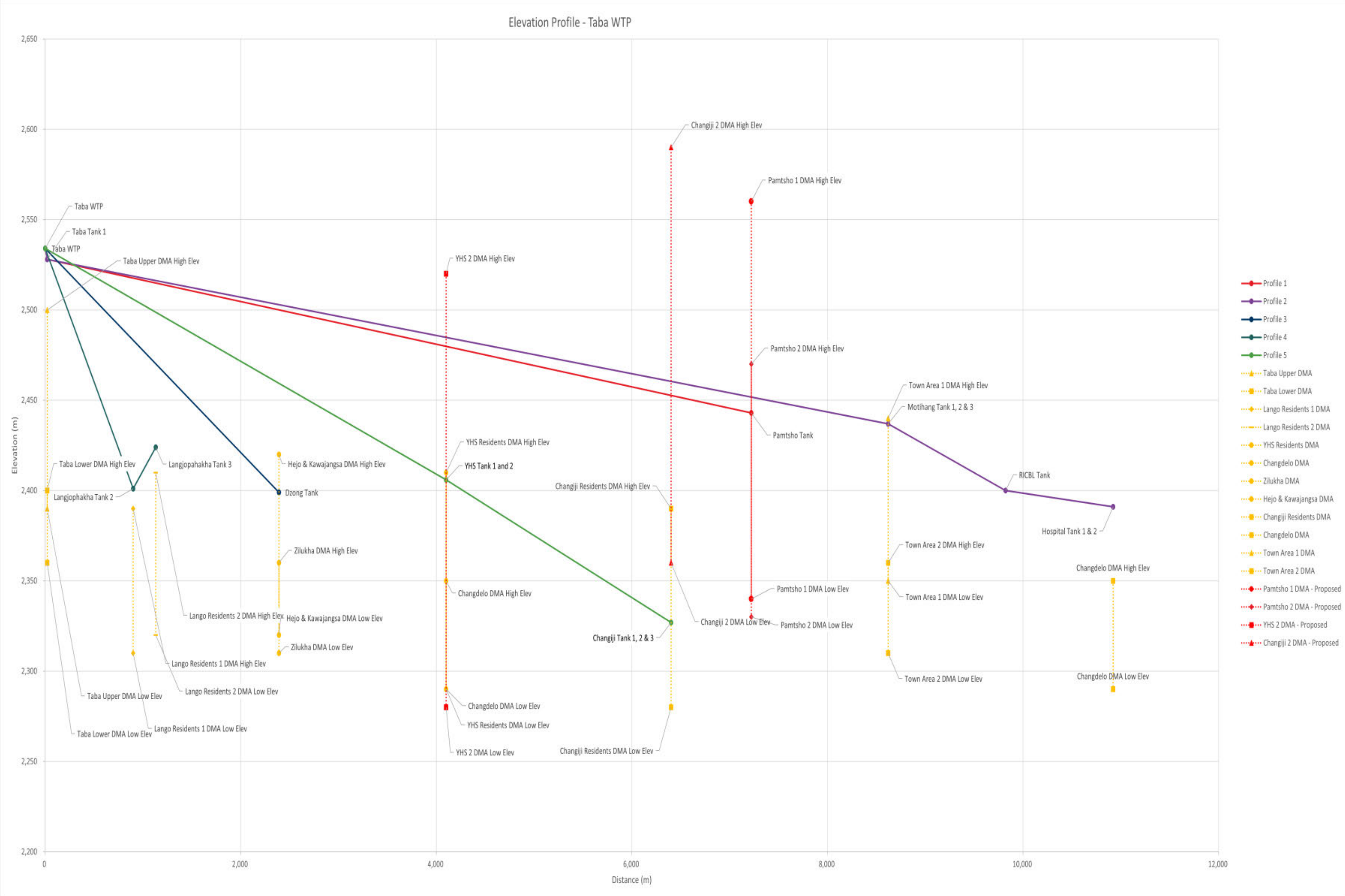
Data Sheet

Storage Reservoir – Motithang Three Tanks 2

Value	Result
Storage Reservoir Name	Motithang Three Tanks 2
Downstream Storage Reservoir(s)	To RICB Tank
Adjacent Reservoir(s)	Motithang Three Tanks 1 and 3
Downstream DMA(s)	Town Area 1; Town Area 2; RICBL Tanks and Hospital Tanks which supply hospital and Changdelo
WTP Supplying Storage Reservoir	Motihang WTP; Taba WTP
Number of Inlet Pipes	2
Diameter of Inlet Pipes (mm)	150; 150
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	200
Operations	6am-9am and 6pm-9pm
Top Water Elevation (m)	2440.5
Bottom Water Elevation (m)	2437
Storage Reservoir Volume (m^3)	320
Storage Reservoir Material	RCC_circular



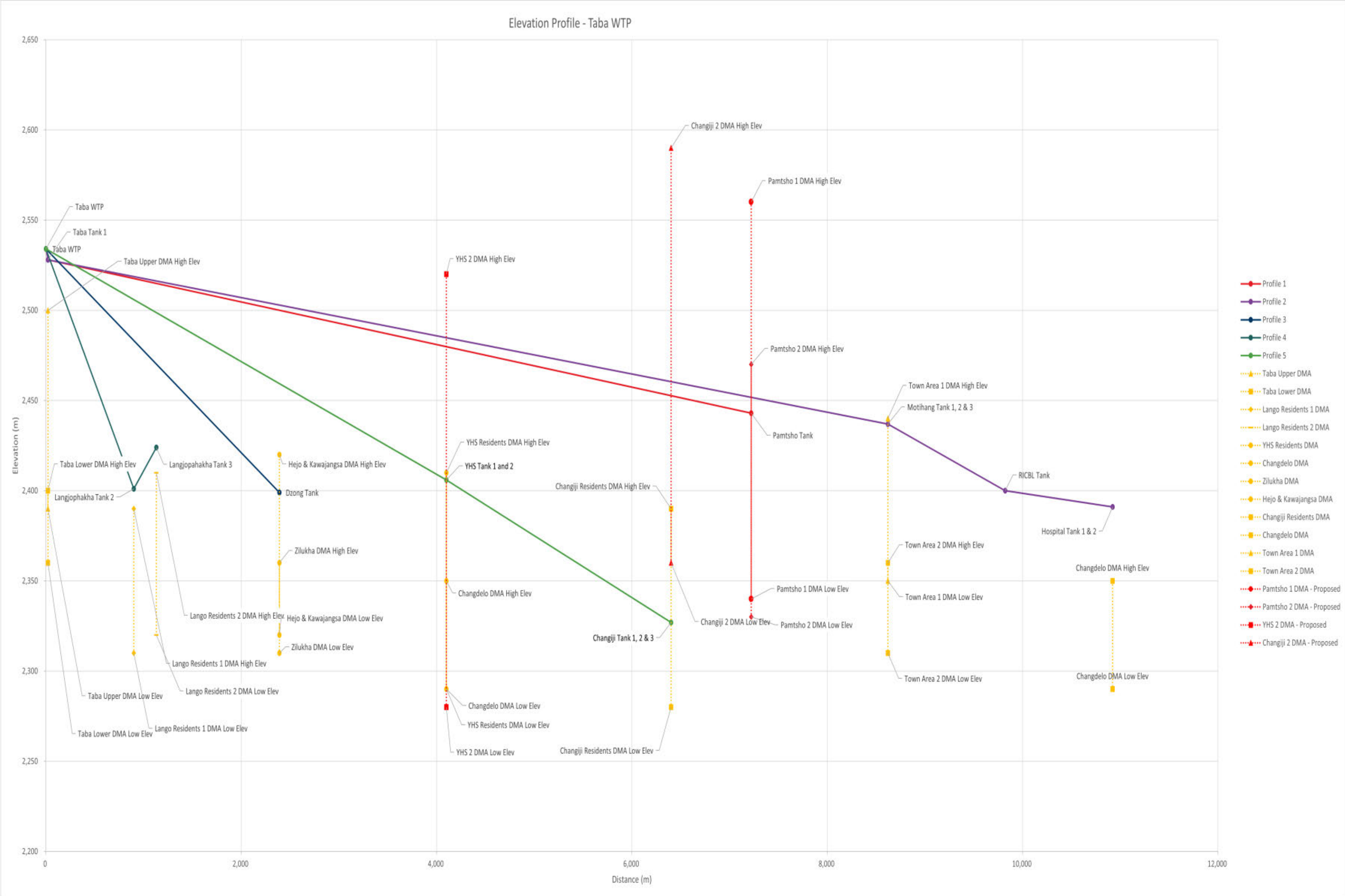
Elevation Profile - Motihang WTP
Elevation (m)
Distance (m)
2,700
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Motihang WTP
Upper Motihang DMA High Elev
Kuengacholing Tank 1 & 2
Above RICB DMA High Elev
Above RICB DMA Low Elev
Town Area 1 DMA High Elev
Upper Motihang DMA Low Elev
Town Area 1 DMA Low Elev
Motihang Tank 1, 2 & 3
Town Area 2 DMA High Elev
Town Area 2 DMA High Elev
Town Area 2 DMA Low Elev
Town Area 2 DMA Low Elev
RICBL Tank
Kawajangsa and Zilukha DMA High Elev
Zilukha Sinex Tank 1
Kawajangsa and Zilukha DMA Low Elev
Changedaphu and Upper Changzamtok DMA High Elev
Changedaphu Tank 1 & 2
Changedaphu and Upper Changzamtok DMA Low Elev
Hospital Tank 1 &2
Changdelo DMA High Elev
Changdelo DMA Low Elev
Changzamtog DMA High Elev
Kuenselohodrang Tank 1 & 2
Changzamtog DMA Low Elev
Profile 1
Profile 2
Profile 3
Kawajangsa and Zilukha DMA
Upper Motihang DMA
Above RICB DMA
Changzamtog DMA
Town Area 1 DMA
Town Area 1 DMA
Town Area 2 DMA
Changdelo DMA
Changedaphu and Upper Changzamtok DMA


Elevation Profile - Taba WTP
Elevation (m)
Distance (m)
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
0
2,000
4,000
6,000
8,000
10,000
12,000
Taba WTP
Taba Tank 1
Taba WTP
Taba Upper DMA High Elev
Taba Lower DMA High Elev
Langjophakha Tank 2
Langjopahakha Tank 3
Hejo & Kawajangsa DMA High Elev
Dzong Tank
Zilukha DMA High Elev
Lango Residents 2 DMA High Elev
Hejo & Kawajangsa DMA Low Elev
Zilukha DMA Low Elev
Lango Residents 1 DMA High Elev
Lango Residents 2 DMA Low Elev
Taba Upper DMA Low Elev
Lango Residents 1 DMA Low Elev
Taba Lower DMA Low Elev
YHS 2 DMA High Elev
YHS Residents DMA High Elev
YHS Tank 1 and 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
YHS Residents DMA Low Elev
YHS 2 DMA Low Elev
Changjiji 2 DMA High Elev
Changjiji Residents DMA High Elev
Changjiji Tank 1, 2 & 3
Changjiji 2 DMA Low Elev
Changjiji Residents DMA Low Elev
Pamtsho 1 DMA High Elev
Pamtsho 2 DMA High Elev
Pamtsho Tank
Pamtsho 1 DMA Low Elev
Pamtsho 2 DMA Low Elev
Town Area 1 DMA High Elev
Motihang Tank 1, 2 & 3
Town Area 2 DMA High Elev
Town Area 1 DMA Low Elev
Town Area 2 DMA Low Elev
RICBL Tank
Hospital Tank 1 & 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
Profile 1
Profile 2
Profile 3
Profile 4
Profile 5
Taba Upper DMA
Taba Lower DMA
Lango Residents 1 DMA
Lango Residents 2 DMA
YHS Residents DMA
Changdelo DMA
Zilukha DMA
Hejo & Kawajangsa DMA
Changjiji Residents DMA
Changdelo DMA
Town Area 1 DMA
Town Area 2 DMA
Pamtsho 1 DMA - Proposed
Pamtsho 2 DMA - Proposed
YHS 2 DMA - Proposed
Changjiji 2 DMA - Proposed

Data Sheet

Storage Reservoir – RICBL Tank

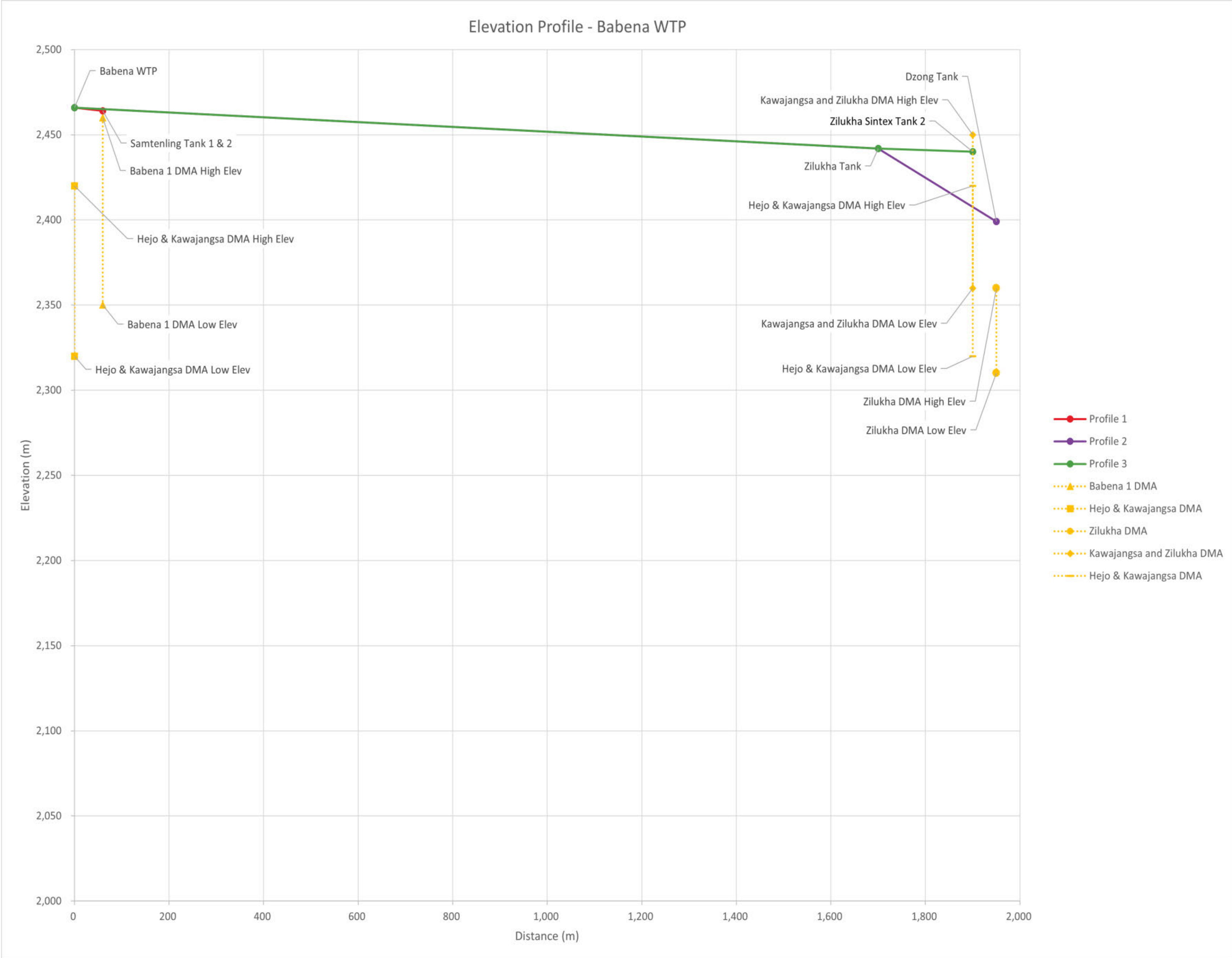
Value	Result
Storage Reservoir Name	RICBL Tank
Downstream Storage Reservoir(s)	Hospital Tank
Adjacent Reservoir(s)	None
Downstream DMA(s)	no demand - supplies Hospital Tank which supply Changdelo
WTP Supplying Storage Reservoir	Taba WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	200
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	150
Operations	6am-9am and 6pm-9pm
Top Water Elevation (m)	2403.5
Bottom Water Elevation (m)	2400
Storage Reservoir Volume (m^3)	320
Storage Reservoir Material	RCC_circular


Elevation Profile - Taba WTP
Elevation (m)
Distance (m)
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
0
2,000
4,000
6,000
8,000
10,000
12,000
Taba WTP
Taba Tank 1
Taba WTP
Taba Upper DMA High Elev
Taba Lower DMA High Elev
Langjophakha Tank 2
Langjopahakha Tank 3
Lango Residents 2 DMA High Elev
Lango Residents 1 DMA High Elev
Lango Residents 2 DMA Low Elev
Taba Upper DMA Low Elev
Lango Residents 1 DMA Low Elev
Taba Lower DMA Low Elev
Hejo & Kawajangsa DMA High Elev
Dzong Tank
Zilukha DMA High Elev
Hejo & Kawajangsa DMA Low Elev
Zilukha DMA Low Elev
YHS 2 DMA High Elev
YHS Residents DMA High Elev
YHS Tank 1 and 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
YHS Residents DMA Low Elev
YHS 2 DMA Low Elev
Changiji 2 DMA High Elev
Changiji Residents DMA High Elev
Changiji Tank 1, 2 & 3
Changiji 2 DMA Low Elev
Changiji Residents DMA Low Elev
Pamtsho 1 DMA High Elev
Pamtsho 2 DMA High Elev
Pamtsho Tank
Pamtsho 1 DMA Low Elev
Pamtsho 2 DMA Low Elev
Town Area 1 DMA High Elev
Motihang Tank 1, 2 & 3
Town Area 2 DMA High Elev
Town Area 1 DMA Low Elev
Town Area 2 DMA Low Elev
RICBL Tank
Hospital Tank 1 & 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
Profile 1
Profile 2
Profile 3
Profile 4
Profile 5
Taba Upper DMA
Taba Lower DMA
Lango Residents 1 DMA
Lango Residents 2 DMA
YHS Residents DMA
Changdelo DMA
Zilukha DMA
Hejo & Kawajangsa DMA
Changiji Residents DMA
Changdelo DMA
Town Area 1 DMA
Town Area 2 DMA
Pamtsho 1 DMA - Proposed
Pamtsho 2 DMA - Proposed
YHS 2 DMA - Proposed
Changiji 2 DMA - Proposed

Data Sheet

Storage Reservoir – Samtenling Tank 1

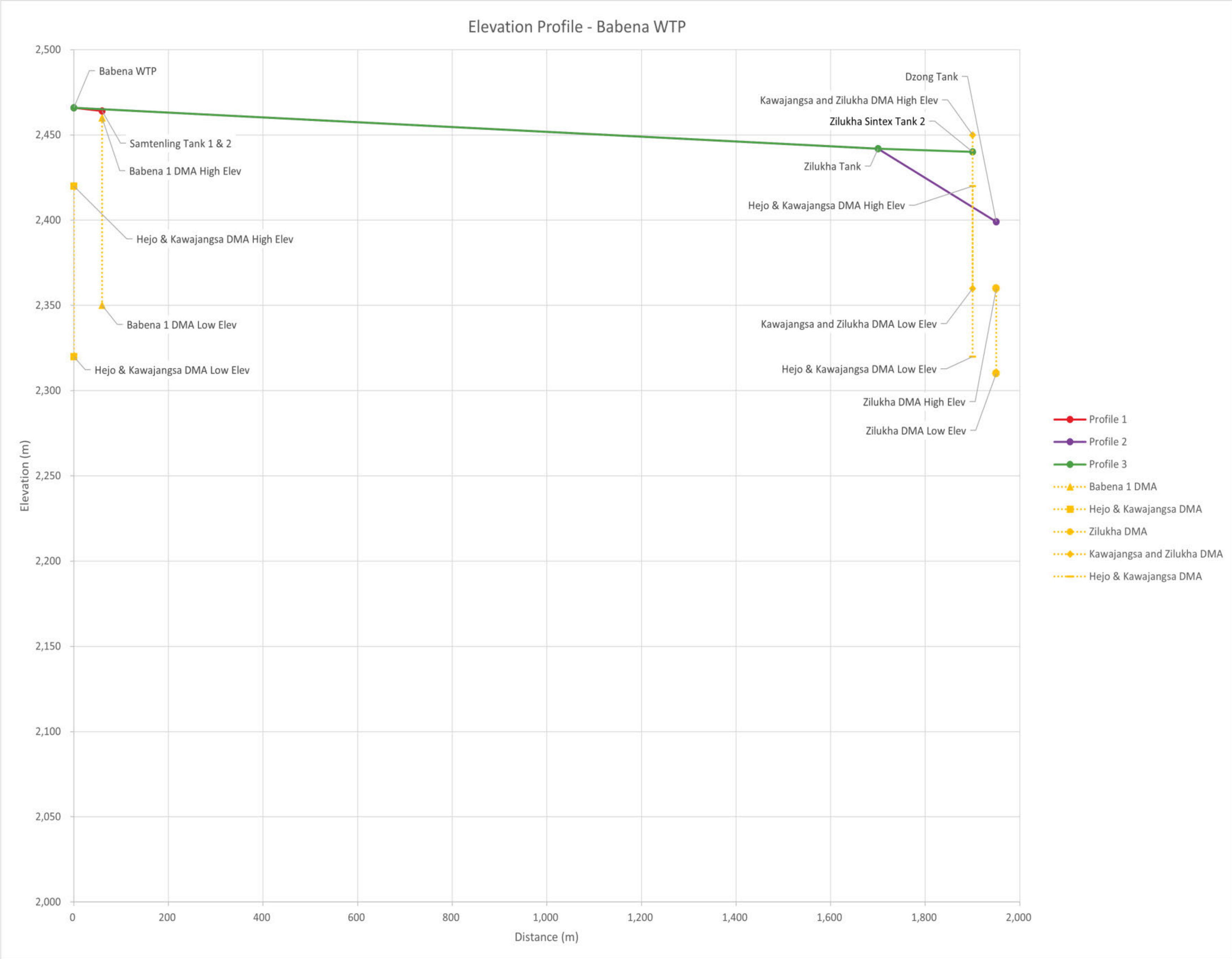
Value	Result
Storage Reservoir Name	Samtenling Tank 1
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	Samtenling Tank 2
Downstream DMA(s)	Babena 1
WTP Supplying Storage Reservoir	Babena WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	150
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	150
Operations	Not provided
Top Water Elevation (m)	2467.5
Bottom Water Elevation (m)	2464
Storage Reservoir Volume (m^3)	230
Storage Reservoir Material	RCC_circular


Elevation Profile - Babena WTP
Elevation (m)
Distance (m)
2,500
2,450
2,400
2,350
2,300
2,250
2,200
2,150
2,100
2,050
2,000
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
Babena WTP
Samtenling Tank 1 & 2
Babena 1 DMA High Elev
Hejo & Kawajangsa DMA High Elev
Babena 1 DMA Low Elev
Hejo & Kawajangsa DMA Low Elev
Dzong Tank
Kawajangsa and Zilukha DMA High Elev
Zilukha Sintex Tank 2
Zilukha Tank
Hejo & Kawajangsa DMA High Elev
Kawajangsa and Zilukha DMA Low Elev
Hejo & Kawajangsa DMA Low Elev
Zilukha DMA High Elev
Zilukha DMA Low Elev
Profile 1
Profile 2
Profile 3
Babena 1 DMA
Hejo & Kawajangsa DMA
Zilukha DMA
Kawajangsa and Zilukha DMA
Hejo & Kawajangsa DMA

Data Sheet

Storage Reservoir – Samtenling Tank 2

Value	Result
Storage Reservoir Name	Samtenling Tank 2
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	Samtenling Tank 1
Downstream DMA(s)	Babena 1
WTP Supplying Storage Reservoir	Babena WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	150
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	150
Operations	Not provided
Top Water Elevation (m)	2467.5
Bottom Water Elevation (m)	2464
Storage Reservoir Volume (m^3)	230
Storage Reservoir Material	RCC_circular

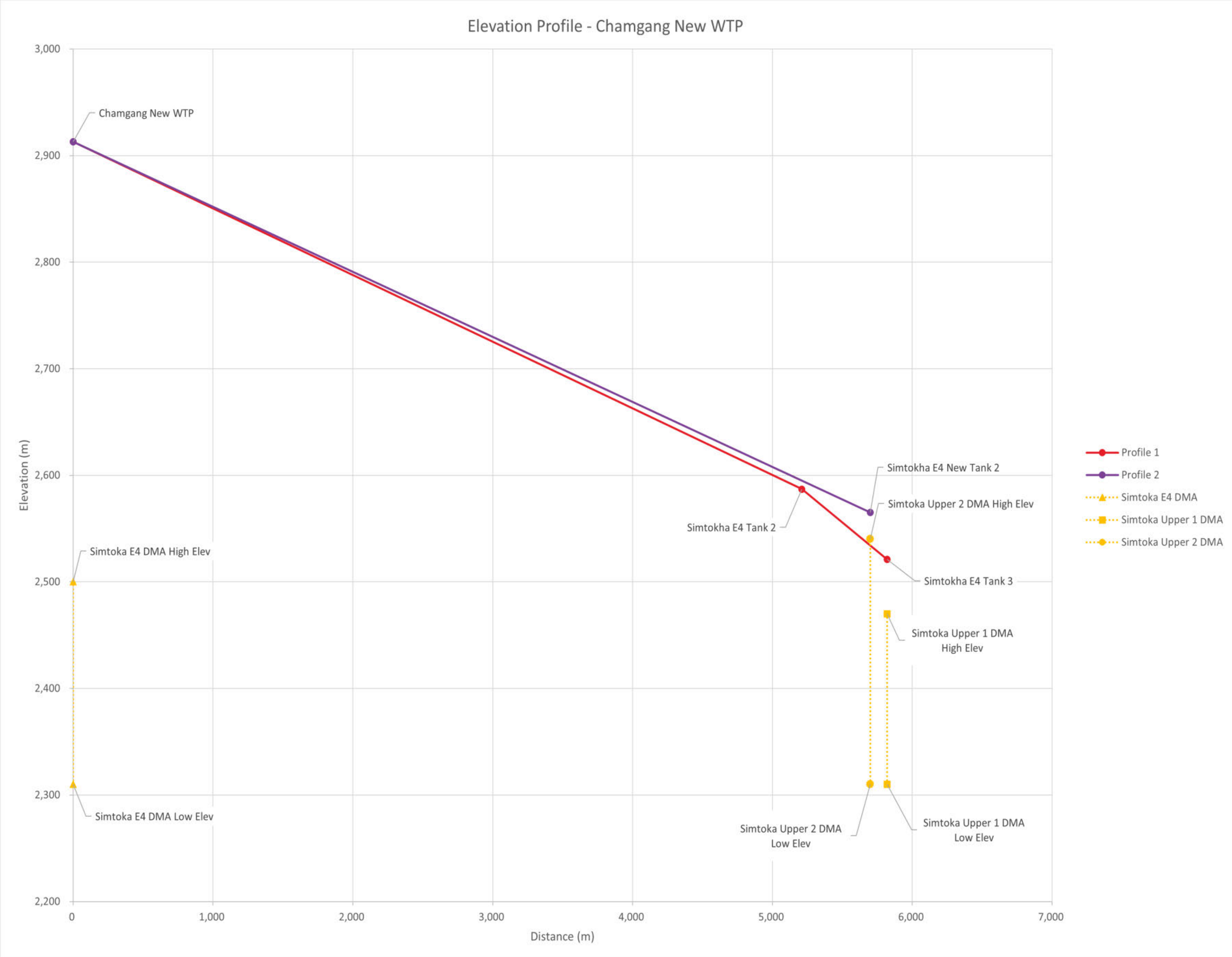


Elevation Profile - Babena WTP
Babena WTP
Samtenling Tank 1 & 2
Babena 1 DMA High Elev
Hejo & Kawajangsa DMA High Elev
Babena 1 DMA Low Elev
Hejo & Kawajangsa DMA Low Elev
Dzong Tank
Kawajangsa and Zilukha DMA High Elev
Zilukha Sintex Tank 2
Zilukha Tank
Hejo & Kawajangsa DMA High Elev
Kawajangsa and Zilukha DMA Low Elev
Hejo & Kawajangsa DMA Low Elev
Zilukha DMA High Elev
Zilukha DMA Low Elev
Elevation (m)
2,500
2,450
2,400
2,350
2,300
2,250
2,200
2,150
2,100
2,050
2,000
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
Distance (m)
Profile 1
Profile 2
Profile 3
Babena 1 DMA
Hejo & Kawajangsa DMA
Zilukha DMA
Kawajangsa and Zilukha DMA
Hejo & Kawajangsa DMA

Data Sheet

Storage Reservoir – Simtokha E4 New Tank 2

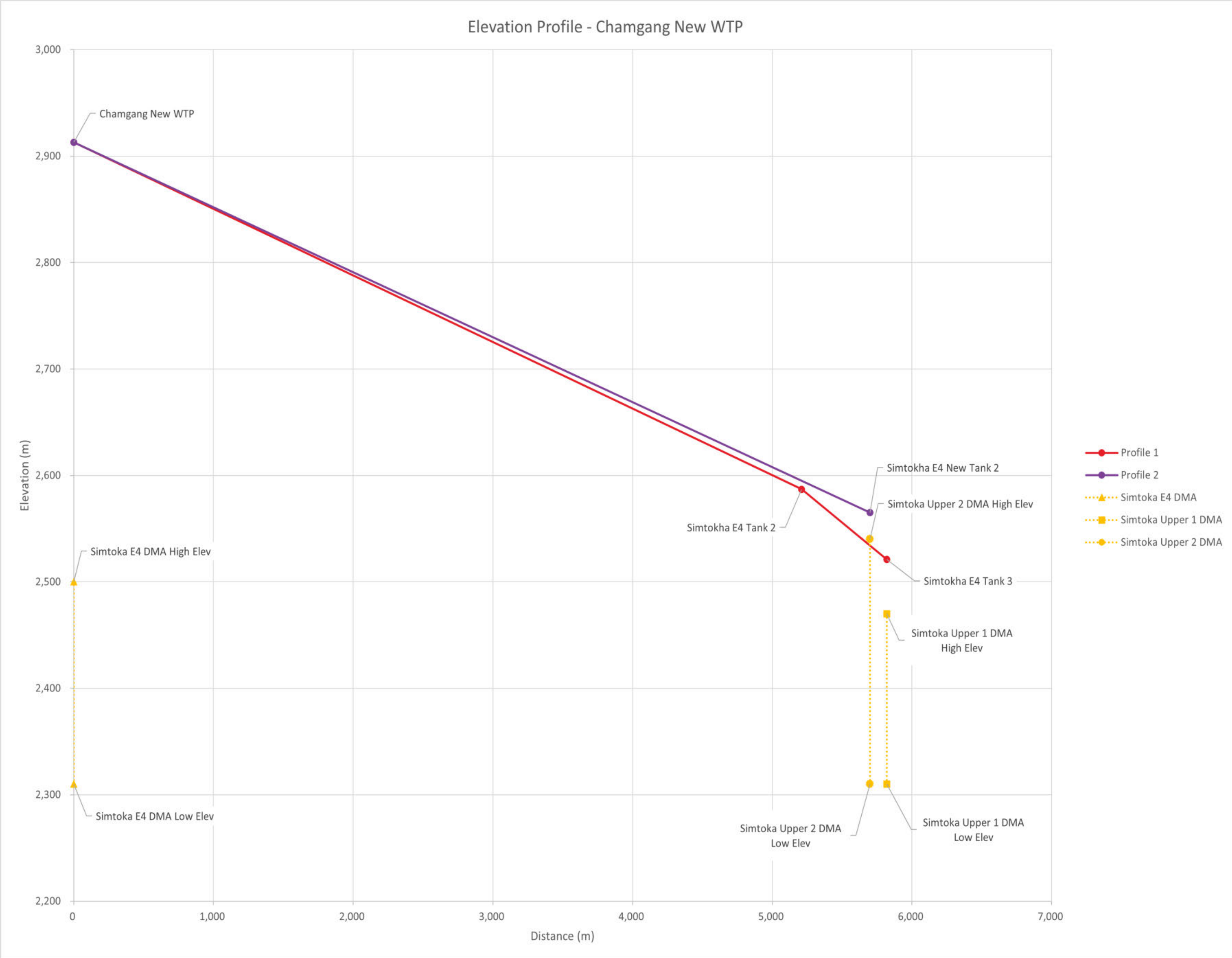
Value	Result
Storage Reservoir Name	Simtokha E4 New Tank 2
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	None
Downstream DMA(s)	Simtoka Upper 2
WTP Supplying Storage Reservoir	Chamgang New WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	150
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	80
Operations	Not provided
Top Water Elevation (m)	2522.5
Bottom Water Elevation (m)	2519
Storage Reservoir Volume (m^3)	200
Storage Reservoir Material	Zincalume


Elevation Profile - Chamgang New WTP
Elevation (m)
3,000
2,900
2,800
2,700
2,600
2,500
2,400
2,300
2,200
Distance (m)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Chamgang New WTP
Simtokha E4 New Tank 2
Simtoka Upper 2 DMA High Elev
Simtokha E4 Tank 2
Simtokha E4 Tank 3
Simtoka E4 DMA High Elev
Simtoka E4 DMA Low Elev
Simtoka Upper 1 DMA High Elev
Simtoka Upper 2 DMA Low Elev
Simtoka Upper 1 DMA Low Elev
Profile 1
Profile 2
Simtoka E4 DMA
Simtoka Upper 1 DMA
Simtoka Upper 2 DMA

Data Sheet

Storage Reservoir – Simtokha E4 Tank 3

Value	Result
Storage Reservoir Name	Simtokha E4 Tank 3
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	None
Downstream DMA(s)	Simtoka Upper 1
WTP Supplying Storage Reservoir	Chamgang New WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	100
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	100
Operations	Not provided
Top Water Elevation (m)	2524.5
Bottom Water Elevation (m)	2521
Storage Reservoir Volume (m^3)	50
Storage Reservoir Material	RRM_rectangular

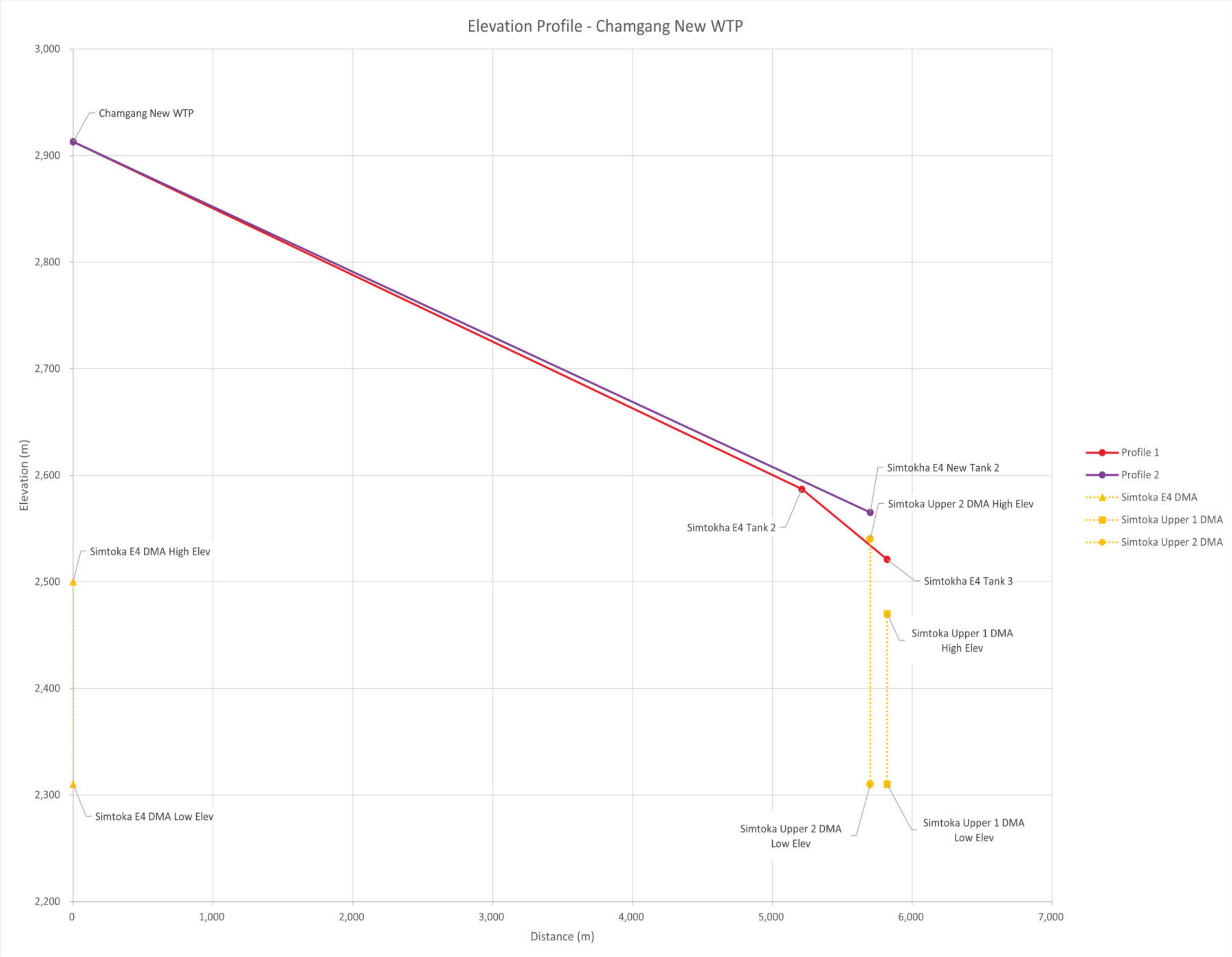


Elevation Profile - Chamgang New WTP
Elevation (m)
3,000
2,900
2,800
2,700
2,600
2,500
2,400
2,300
2,200
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance (m)
Chamgang New WTP
Simtokha E4 New Tank 2
Simtoka Upper 2 DMA High Elev
Simtokha E4 Tank 2
Simtokha E4 Tank 3
Simtoka E4 DMA High Elev
Simtoka Upper 1 DMA High Elev
Simtoka E4 DMA Low Elev
Simtoka Upper 2 DMA Low Elev
Simtoka Upper 1 DMA Low Elev
Profile 1
Profile 2
Simtoka E4 DMA
Simtoka Upper 1 DMA
Simtoka Upper 2 DMA

Data Sheet

Storage Reservoir – Simtokha E4 Tank 2

Value	Result
Storage Reservoir Name	Simtokha E4 Tank 2
Downstream Storage Reservoir(s)	Simtokha E4 Tank 3
Adjacent Reservoir(s)	None
Downstream DMA(s)	Simtoka Upper 1
WTP Supplying Storage Reservoir	Chamgang New WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	100
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	100
Operations	Not provided
Top Water Elevation (m)	2590.5
Bottom Water Elevation (m)	2587
Storage Reservoir Volume (m^3)	50
Storage Reservoir Material	RRM_rectangular



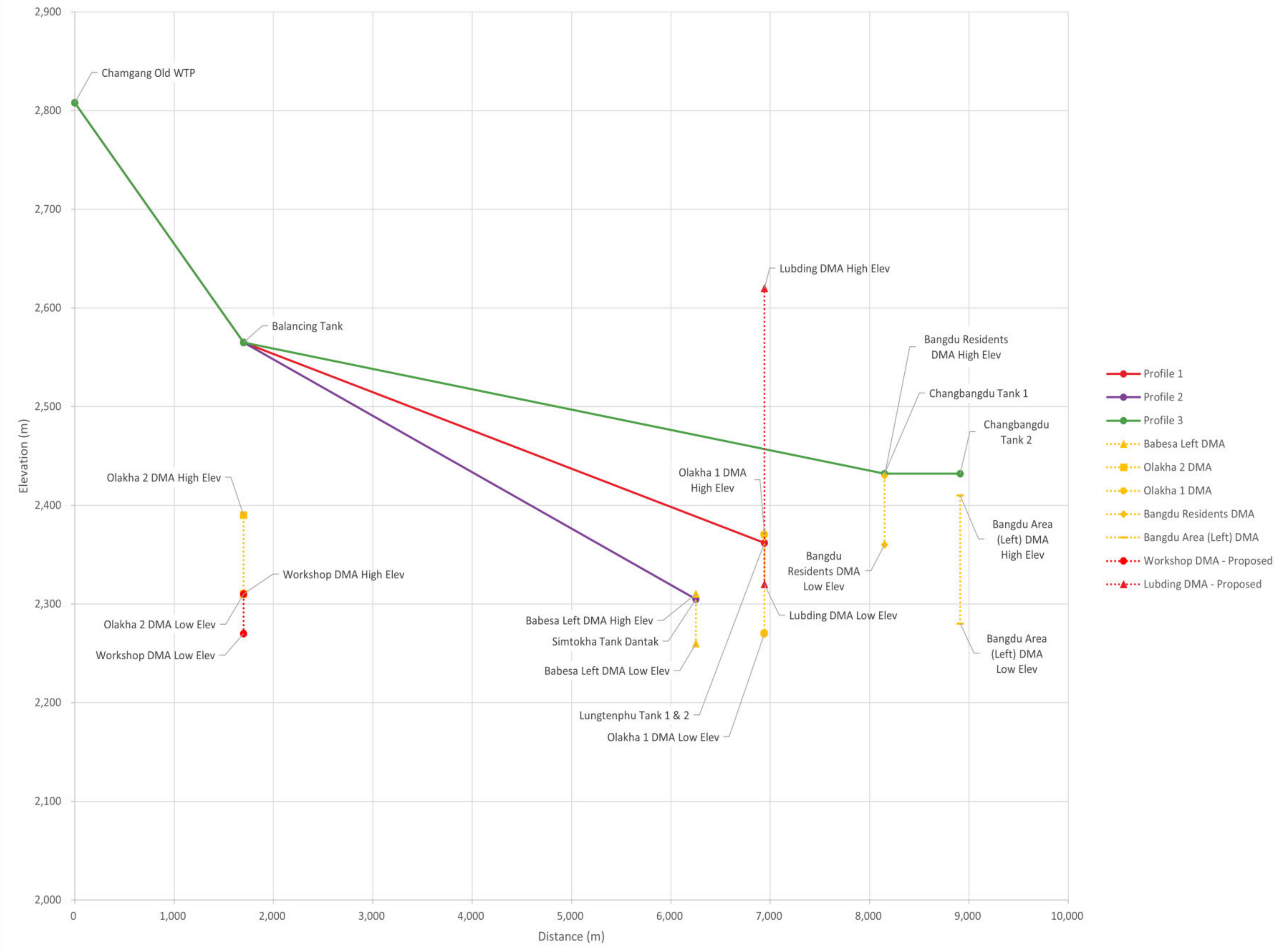
Elevation Profile - Chamgang New WTP
3,000
2,900
2,800
2,700
2,600
2,500
2,400
2,300
2,200
Elevation (m)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance (m)
Chamgang New WTP
Simtokha E4 Tank 2
Simtokha E4 New Tank 2
Simtoka Upper 2 DMA High Elev
Simtokha E4 Tank 3
Simtoka Upper 1 DMA High Elev
Simtoka Upper 2 DMA Low Elev
Simtoka Upper 1 DMA Low Elev
Simtoka E4 DMA High Elev
Simtoka E4 DMA Low Elev
Profile 1
Profile 2
Simtoka E4 DMA
Simtoka Upper 1 DMA
Simtoka Upper 2 DMA

Data Sheet

Storage Reservoir – Simtokha Tank Dantak

Value	Result
Storage Reservoir Name	Simtokha Tank Dantak
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	None
Downstream DMA(s)	Babesa Left
WTP Supplying Storage Reservoir	Chamgang Old WTP
Number of Inlet Pipes	2
Diameter of Inlet Pipes (mm)	250
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	200
Operations	6am-9am and 6pm-9pm
Top Water Elevation (m)	2308.5
Bottom Water Elevation (m)	2305
Storage Reservoir Volume (m^3)	735
Storage Reservoir Material	RCC

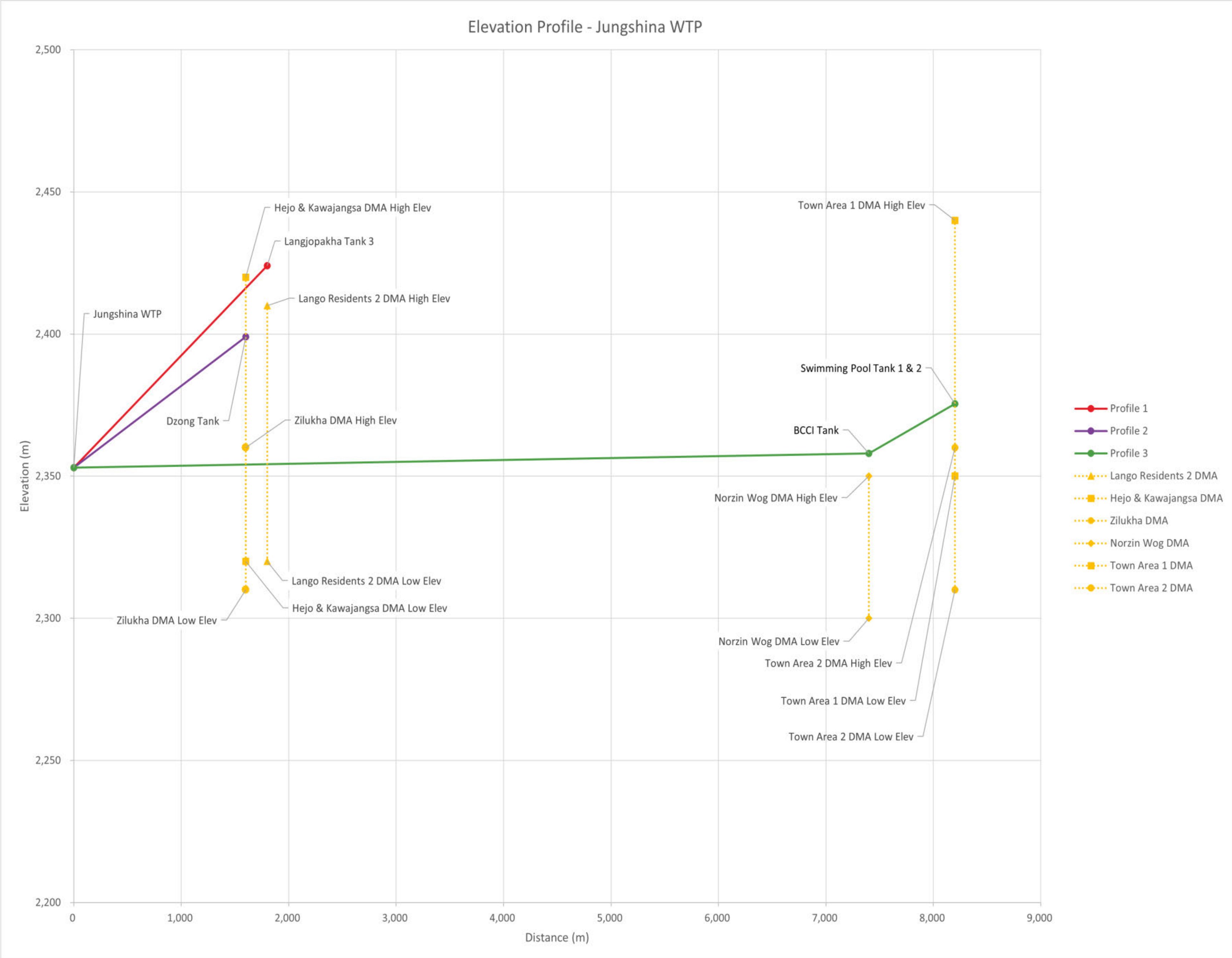
Elevation Profile - Chamgang Old WTP



Data Sheet

Storage Reservoir – Swimming Pool Tank 1

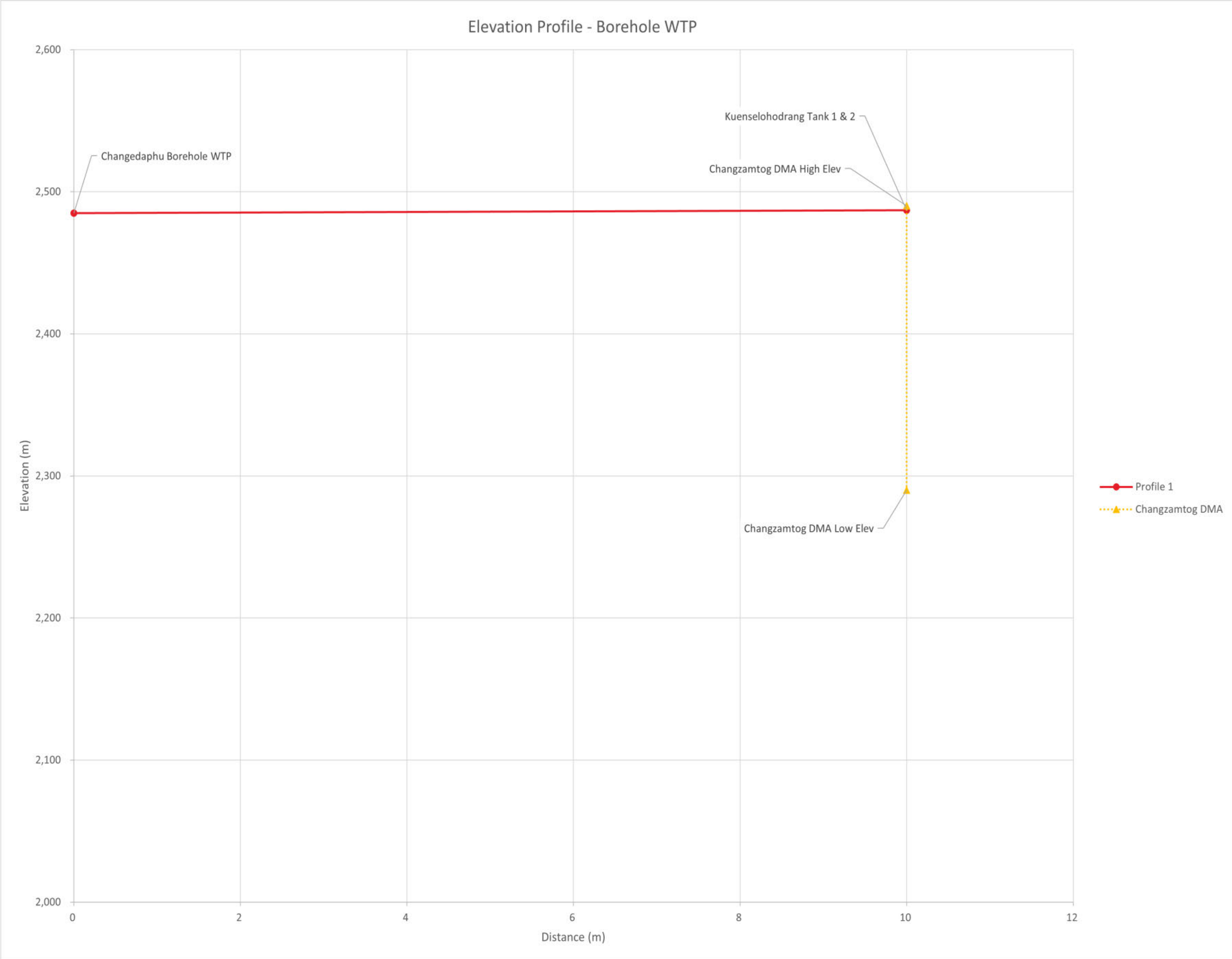
Value	Result
Storage Reservoir Name	Swimming Pool Tank 1
Downstream Storage Reservoir(s)	Hospital Tank
Adjacent Reservoir(s)	Swimming Pool Tank 2
Downstream DMA(s)	Town Area 1; Town Area 2; Hospital Tanks which supply hospital and Changdelo
WTP Supplying Storage Reservoir	Jungshina WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	100
Number of Outlet Pipes	2
Diameter of Outlet Pipes (mm)	100; 80
Operations	6am-9am and 6pm-9pm
Top Water Elevation (m)	2375.5
Bottom Water Elevation (m)	2372
Storage Reservoir Volume (m^3)	230
Storage Reservoir Material	RCC_circular


Elevation Profile - Jungshina WTP
Elevation (m)
2,500
2,450
2,400
2,350
2,300
2,250
2,200
Distance (m)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
Jungshina WTP
Hejo & Kawajangsa DMA High Elev
Langjopakha Tank 3
Lango Residents 2 DMA High Elev
Dzong Tank
Zilukha DMA High Elev
Lango Residents 2 DMA Low Elev
Hejo & Kawajangsa DMA Low Elev
Zilukha DMA Low Elev
Town Area 1 DMA High Elev
Swimming Pool Tank 1 & 2
BCCI Tank
Norzin Wog DMA High Elev
Norzin Wog DMA Low Elev
Town Area 2 DMA High Elev
Town Area 1 DMA Low Elev
Town Area 2 DMA Low Elev
Profile 1
Profile 2
Profile 3
Lango Residents 2 DMA
Hejo & Kawajangsa DMA
Zilukha DMA
Norzin Wog DMA
Town Area 1 DMA
Town Area 2 DMA

Data Sheet

Storage Reservoir – Changbangdu Tank 3

Value	Result
Storage Reservoir Name	Changbangdu Tank 3
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	Changbangdu Tank 1 and 2
Downstream DMA(s)	None - Supplies Boreholes WTP
WTP Supplying Storage Reservoir	Boreholes
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	150
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	150
Operations	Not provided
Top Water Elevation (m)	2400.5
Bottom Water Elevation (m)	2397
Storage Reservoir Volume (m^3)	supplies Boreholes WTP
Storage Reservoir Material	RCC_circular

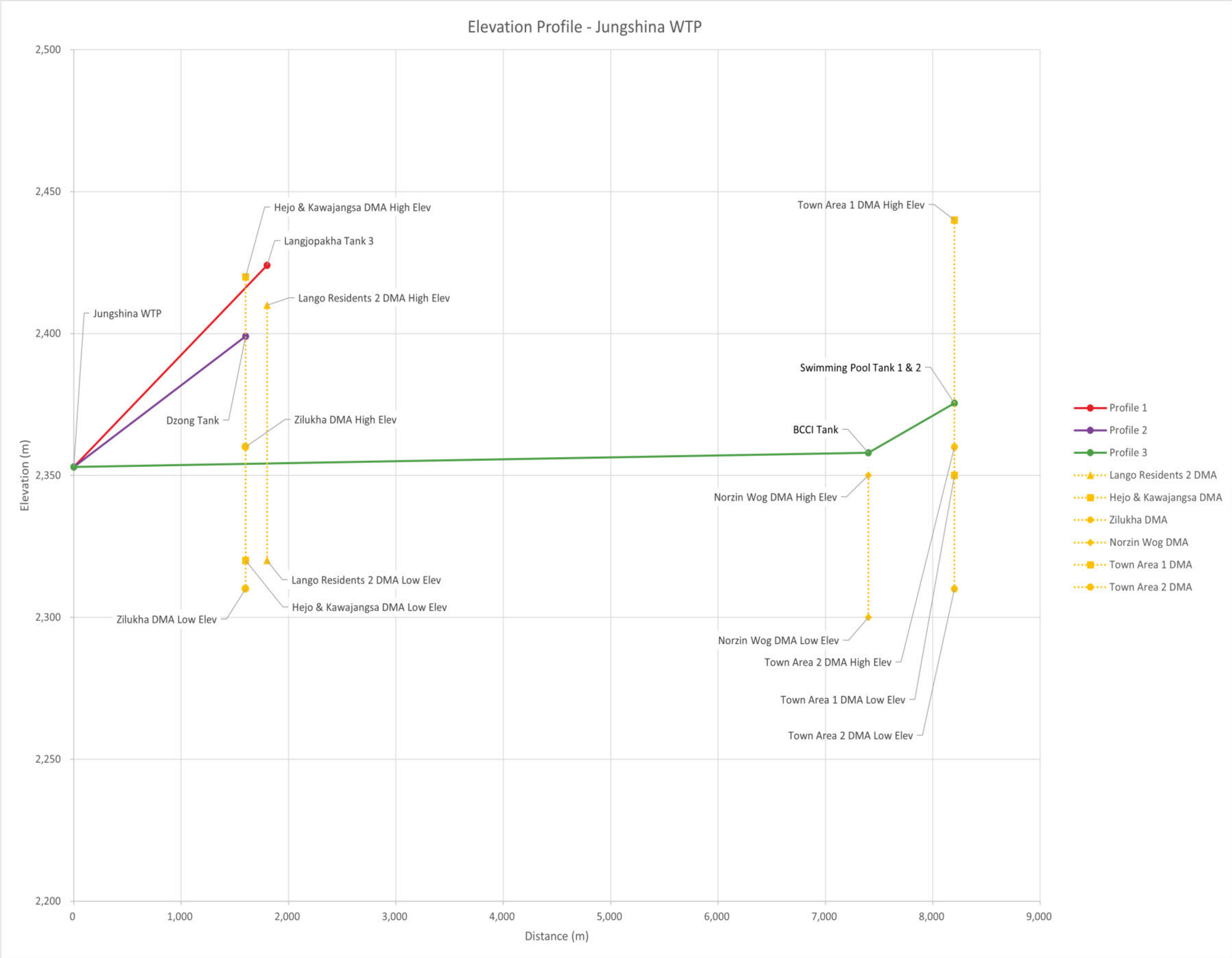


Elevation Profile - Borehole WTP
Elevation (m)
2,600
2,500
2,400
2,300
2,200
2,100
2,000
Distance (m)
0
2
4
6
8
10
12
Changedaphu Borehole WTP
Kuenselohodrang Tank 1 & 2
Changzamtog DMA High Elev
Changzamtog DMA Low Elev
Profile 1
Changzamtog DMA

Data Sheet

Storage Reservoir – Swimming Pool Tank 2

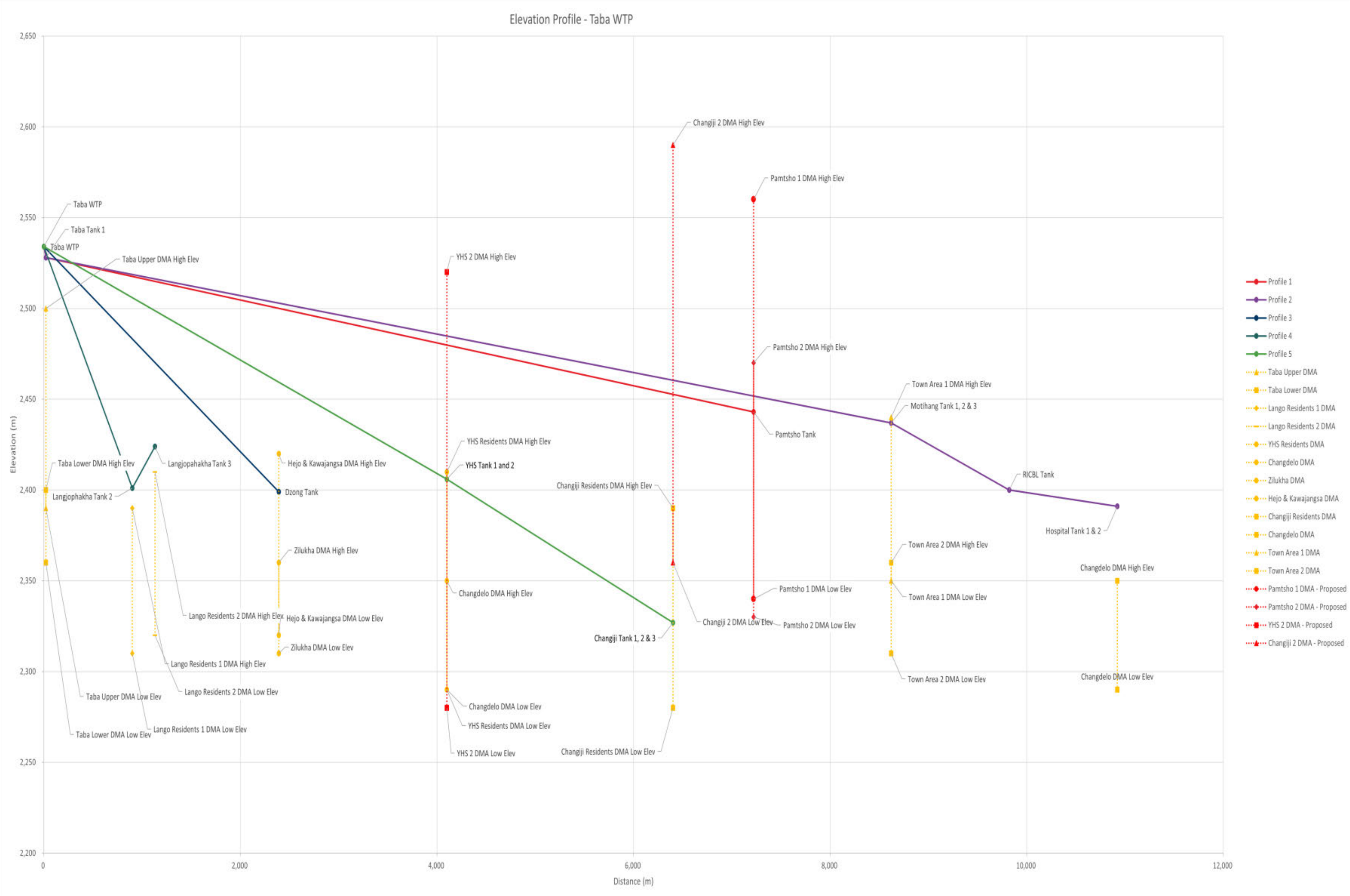
Value	Result
Storage Reservoir Name	Swimming Pool Tank 2
Downstream Storage Reservoir(s)	Hospital Tank
Adjacent Reservoir(s)	Swimming Pool Tank 1
Downstream DMA(s)	Town Area 1; Town Area 2; Hospital Tanks which supply hospital and Changdelo
WTP Supplying Storage Reservoir	Jungshina WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	100
Number of Outlet Pipes	2
Diameter of Outlet Pipes (mm)	100; 80
Operations	6am-9am and 6pm-9pm
Top Water Elevation (m)	2375.5
Bottom Water Elevation (m)	2372
Storage Reservoir Volume (m^3)	230
Storage Reservoir Material	RCC_circular


Elevation Profile - Jungshina WTP
Elevation (m)
2,500
2,450
2,400
2,350
2,300
2,250
2,200
Distance (m)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
Jungshina WTP
Hejo & Kawajangsa DMA High Elev
Langjopakha Tank 3
Lango Residents 2 DMA High Elev
Dzong Tank
Zilukha DMA High Elev
Lango Residents 2 DMA Low Elev
Hejo & Kawajangsa DMA Low Elev
Zilukha DMA Low Elev
Town Area 1 DMA High Elev
Swimming Pool Tank 1 & 2
BCCI Tank
Norzin Wog DMA High Elev
Norzin Wog DMA Low Elev
Town Area 2 DMA High Elev
Town Area 1 DMA Low Elev
Town Area 2 DMA Low Elev
Profile 1
Profile 2
Profile 3
Lango Residents 2 DMA
Hejo & Kawajangsa DMA
Zilukha DMA
Norzin Wog DMA
Town Area 1 DMA
Town Area 2 DMA

Data Sheet

Storage Reservoir – Taba Tank

Value	Result
Storage Reservoir Name	Taba Tank
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	None
Downstream DMA(s)	Taba Upper; Taba Lower
WTP Supplying Storage Reservoir	Taba WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	400
Number of Outlet Pipes	3
Diameter of Outlet Pipes (mm)	200; 200; 150
Operations	6am-9am and 6pm-9pm
Top Water Elevation (m)	2531.5
Bottom Water Elevation (m)	2528
Storage Reservoir Volume (m^3)	230
Storage Reservoir Material	RCC_circular



Elevation Profile - Taba WTP
Elevation (m)
Distance (m)
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
0
2,000
4,000
6,000
8,000
10,000
12,000
Taba WTP
Taba Tank 1
Taba WTP
Taba Upper DMA High Elev
Taba Lower DMA High Elev
Langjophakha Tank 2
Langjopahakha Tank 3
Lango Residents 2 DMA High Elev
Lango Residents 1 DMA High Elev
Lango Residents 2 DMA Low Elev
Taba Upper DMA Low Elev
Taba Lower DMA Low Elev
Lango Residents 1 DMA Low Elev
Hejo & Kawajangsa DMA High Elev
Dzong Tank
Zilukha DMA High Elev
Hejo & Kawajangsa DMA Low Elev
Zilukha DMA Low Elev
YHS 2 DMA High Elev
YHS Residents DMA High Elev
YHS Tank 1 and 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
YHS Residents DMA Low Elev
YHS 2 DMA Low Elev
Changiji 2 DMA High Elev
Changiji Residents DMA High Elev
Changiji Tank 1, 2 & 3
Changiji 2 DMA Low Elev
Changiji Residents DMA Low Elev
Pamtsho 1 DMA High Elev
Pamtsho 2 DMA High Elev
Pamtsho Tank
Pamtsho 1 DMA Low Elev
Pamtsho 2 DMA Low Elev
Town Area 1 DMA High Elev
Motihang Tank 1, 2 & 3
Town Area 2 DMA High Elev
Town Area 1 DMA Low Elev
Town Area 2 DMA Low Elev
RICBL Tank
Hospital Tank 1 & 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
Profile 1
Profile 2
Profile 3
Profile 4
Profile 5
Taba Upper DMA
Taba Lower DMA
Lango Residents 1 DMA
Lango Residents 2 DMA
YHS Residents DMA
Changdelo DMA
Zilukha DMA
Hejo & Kawajangsa DMA
Changiji Residents DMA
Changdelo DMA
Town Area 1 DMA
Town Area 2 DMA
Pamtsho 1 DMA - Proposed
Pamtsho 2 DMA - Proposed
YHS 2 DMA - Proposed
Changiji 2 DMA - Proposed

Data Sheet

Storage Reservoir – Workshop Tank 1

Value	Result
Storage Reservoir Name	Workshop Tank 1
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	Workshop Tank 2, 3 and 4
Downstream DMA(s)	Workshop
WTP Supplying Storage Reservoir	Private Supply
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	75
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	75
Operations	Not provided
Top Water Elevation (m)	2307.5
Bottom Water Elevation (m)	2304
Storage Reservoir Volume (m^3)	2
Storage Reservoir Material	Syntax

Data Sheet

Storage Reservoir – Workshop Tank 2

Value	Result
Storage Reservoir Name	Workshop Tank 2
Downstream Storage Reservoir(s)	Workshop Tank 1
Adjacent Reservoir(s)	Workshop Tank 1, 3 and 4
Downstream DMA(s)	Workshop
WTP Supplying Storage Reservoir	Private Supply
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	75
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	75
Operations	Not provided
Top Water Elevation (m)	2309.5
Bottom Water Elevation (m)	2306
Storage Reservoir Volume (m^3)	2
Storage Reservoir Material	Syntax

Data Sheet

Storage Reservoir – Workshop Tank 3

Value	Result
Storage Reservoir Name	Workshop Tank 3
Downstream Storage Reservoir(s)	Workshop Tank 4
Adjacent Reservoir(s)	Workshop Tank 1, 2 and 4
Downstream DMA(s)	Workshop
WTP Supplying Storage Reservoir	Private Supply
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	75
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	75
Operations	Not provided
Top Water Elevation (m)	2296.5
Bottom Water Elevation (m)	2293
Storage Reservoir Volume (m^3)	2
Storage Reservoir Material	Syntax

Data Sheet

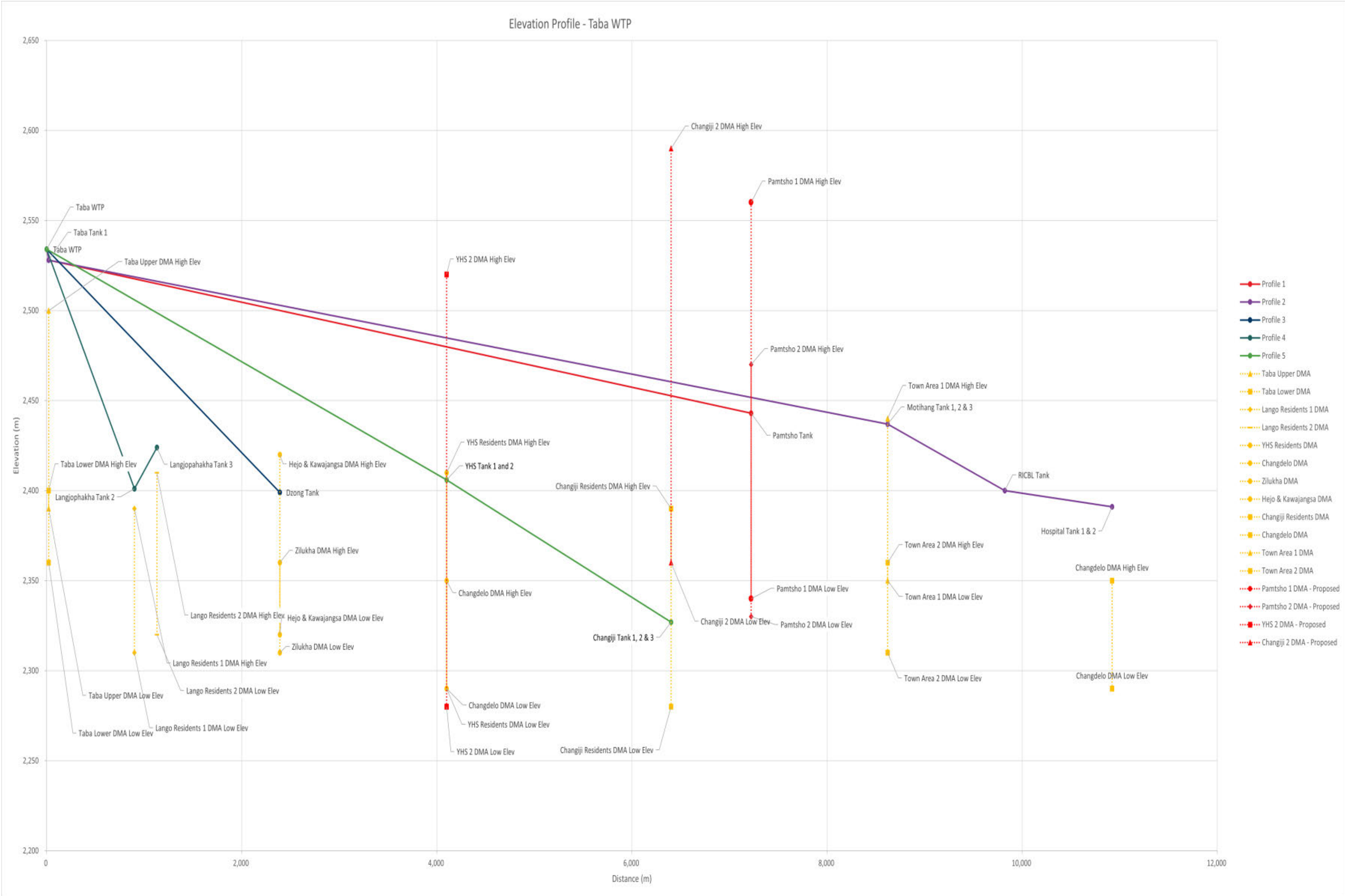
Storage Reservoir – Workshop Tank 4

Value	Result
Storage Reservoir Name	Workshop Tank 4
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	Workshop Tank 1, 2 and 3
Downstream DMA(s)	Workshop
WTP Supplying Storage Reservoir	Private Supply
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	75
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	75
Operations	Not provided
Top Water Elevation (m)	2295.5
Bottom Water Elevation (m)	2292
Storage Reservoir Volume (m^3)	2
Storage Reservoir Material	Syntax

Data Sheet

Storage Reservoir – YHS Tank 1

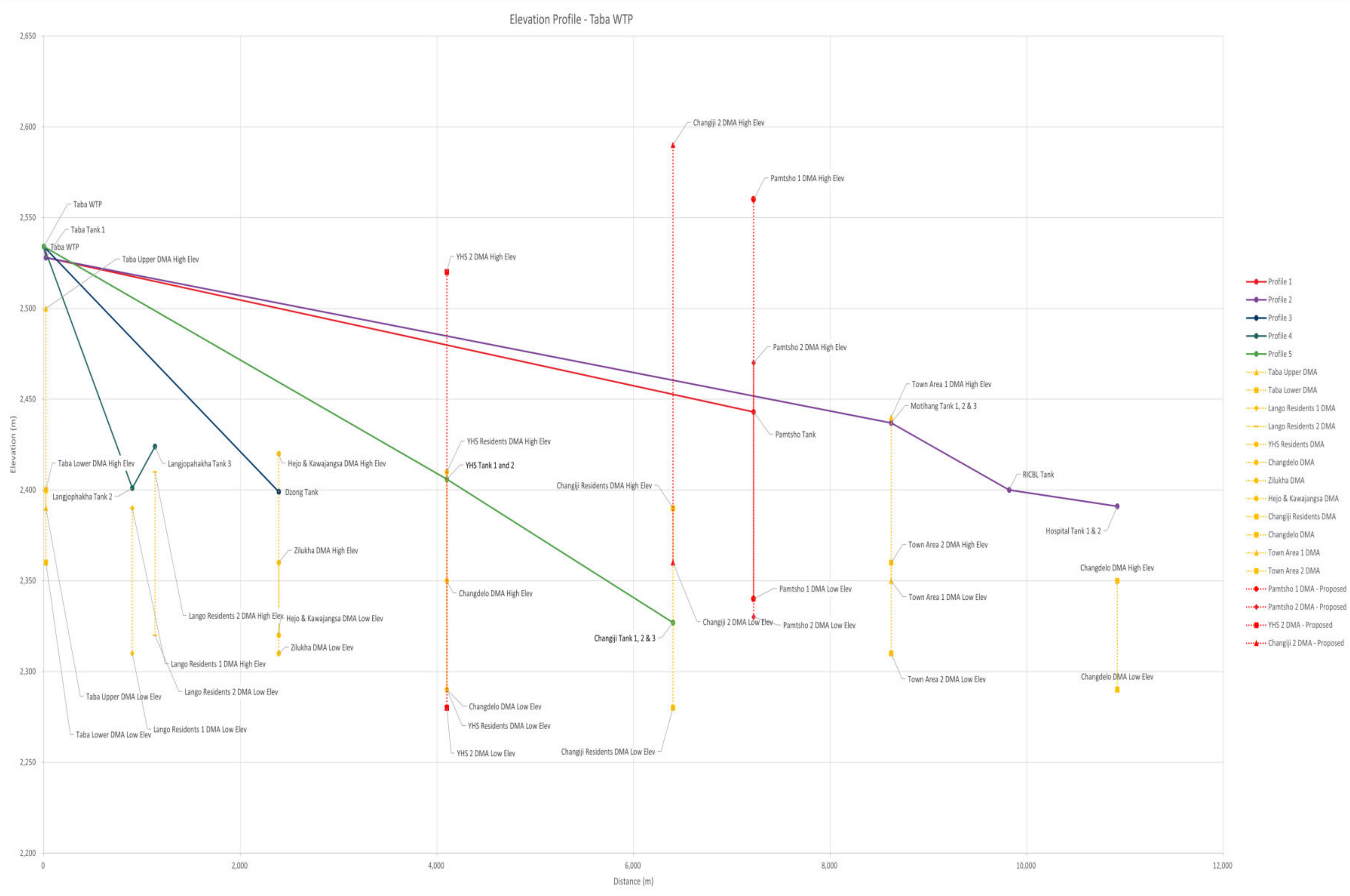
Value	Result
Storage Reservoir Name	YHS Tank 1
Downstream Storage Reservoir(s)	Changjiji tank 1; Changjiji tank 2; Changjiji tank 3
Adjacent Reservoir(s)	YHS Tank 2
Downstream DMA(s)	YHS Residents; Changdelo; Changjiji Tank 1, 2 and 3 which serves Changiji Residents
WTP Supplying Storage Reservoir	Taba WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	200
Number of Outlet Pipes	3
Diameter of Outlet Pipes (mm)	150; 100; 80
Operations	24hour
Top Water Elevation (m)	2406.5
Bottom Water Elevation (m)	2403
Storage Reservoir Volume (m^3)	320
Storage Reservoir Material	RCC_circular


Elevation Profile - Taba WTP
Elevation (m)
Distance (m)
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
0
2,000
4,000
6,000
8,000
10,000
12,000
Taba WTP
Taba Tank 1
Taba WTP
Taba Upper DMA High Elev
Taba Lower DMA High Elev
Langjophakha Tank 2
Langjopahakha Tank 3
Taba Upper DMA Low Elev
Taba Lower DMA Low Elev
Lango Residents 2 DMA High Elev
Lango Residents 1 DMA High Elev
Lango Residents 2 DMA Low Elev
Lango Residents 1 DMA Low Elev
Hejo & Kawajangsa DMA High Elev
Dzong Tank
Zilukha DMA High Elev
Hejo & Kawajangsa DMA Low Elev
Zilukha DMA Low Elev
YHS 2 DMA High Elev
YHS Residents DMA High Elev
YHS Tank 1 and 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
YHS Residents DMA Low Elev
YHS 2 DMA Low Elev
Changiji 2 DMA High Elev
Changiji Residents DMA High Elev
Changiji Tank 1, 2 & 3
Changiji 2 DMA Low Elev
Changiji Residents DMA Low Elev
Pamtsho 1 DMA High Elev
Pamtsho 2 DMA High Elev
Pamtsho Tank
Pamtsho 1 DMA Low Elev
Pamtsho 2 DMA Low Elev
Town Area 1 DMA High Elev
Motihang Tank 1, 2 & 3
Town Area 2 DMA High Elev
Town Area 1 DMA Low Elev
Town Area 2 DMA Low Elev
RICBL Tank
Hospital Tank 1 & 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
Profile 1
Profile 2
Profile 3
Profile 4
Profile 5
Taba Upper DMA
Taba Lower DMA
Lango Residents 1 DMA
Lango Residents 2 DMA
YHS Residents DMA
Changdelo DMA
Zilukha DMA
Hejo & Kawajangsa DMA
Changiji Residents DMA
Changdelo DMA
Town Area 1 DMA
Town Area 2 DMA
Pamtsho 1 DMA - Proposed
Pamtsho 2 DMA - Proposed
YHS 2 DMA - Proposed
Changiji 2 DMA - Proposed

Data Sheet

Storage Reservoir – YHS Tank 2

Value	Result
Storage Reservoir Name	YHS Tank 2
Downstream Storage Reservoir(s)	Changjiji tank 1; Changjiji tank 2; Changjiji tank 3
Adjacent Reservoir(s)	YHS Tank 1
Downstream DMA(s)	YHS Residents; Changdelo; Changjiji Tank 1, 2 and 3 which serves Changiji Residents
WTP Supplying Storage Reservoir	Taba WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	200
Number of Outlet Pipes	3
Diameter of Outlet Pipes (mm)	150; 100; 80
Operations	24hour
Top Water Elevation (m)	2406.5
Bottom Water Elevation (m)	2403
Storage Reservoir Volume (m^3)	230
Storage Reservoir Material	Zincalume

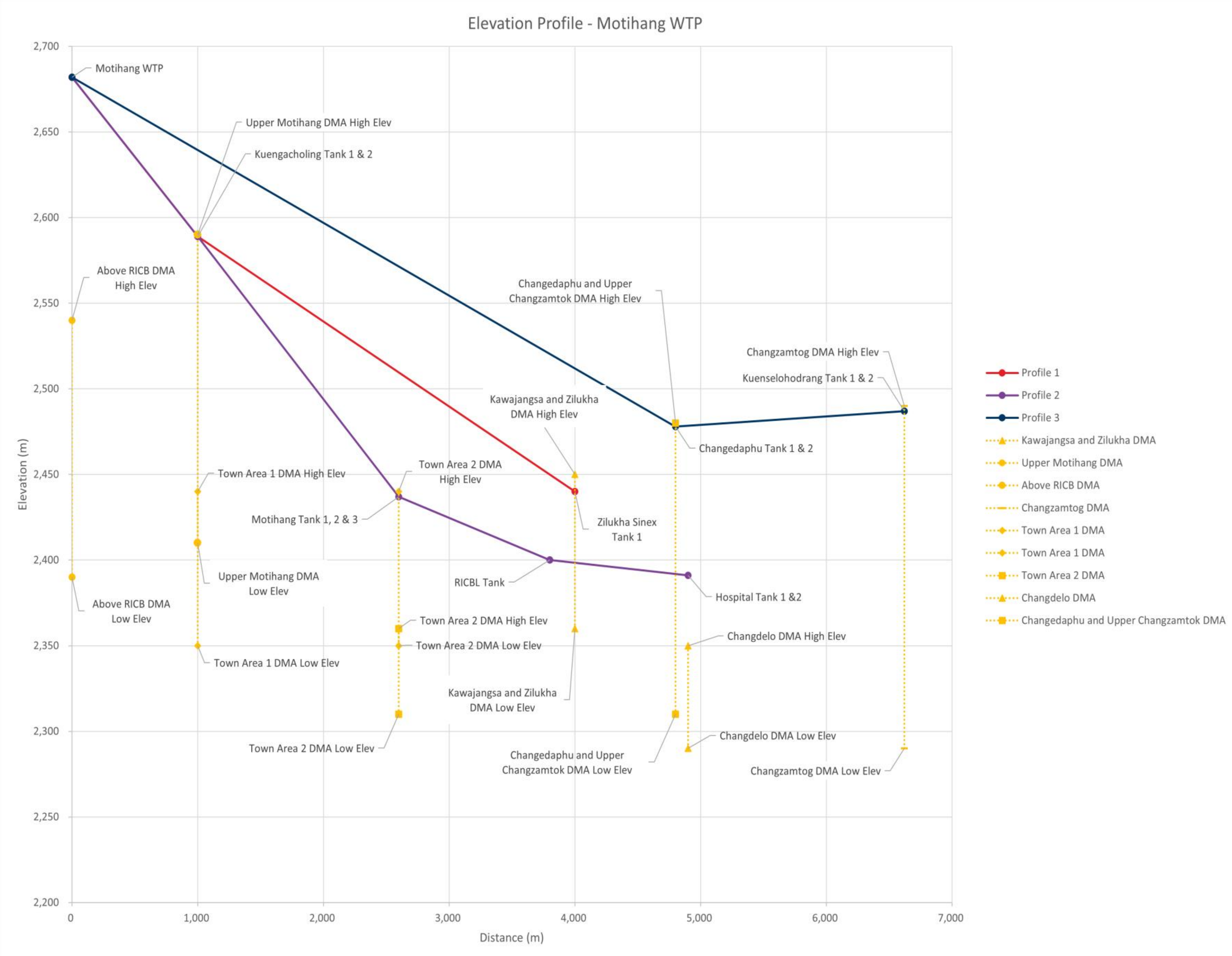


Elevation Profile - Taba WTP
Elevation (m)
Distance (m)
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
0
2,000
4,000
6,000
8,000
10,000
12,000
Taba WTP
Taba Tank 1
Taba WTP
Taba Upper DMA High Elev
Taba Lower DMA High Elev
Langjophakha Tank 2
Langjopahakha Tank 3
Lango Residents 2 DMA High Elev
Lango Residents 1 DMA High Elev
Lango Residents 2 DMA Low Elev
Taba Upper DMA Low Elev
Lango Residents 1 DMA Low Elev
Taba Lower DMA Low Elev
Hejo & Kawajangsa DMA High Elev
Dzong Tank
Zilukha DMA High Elev
Hejo & Kawajangsa DMA Low Elev
Zilukha DMA Low Elev
YHS 2 DMA High Elev
YHS Residents DMA High Elev
YHS Tank 1 and 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
YHS Residents DMA Low Elev
YHS 2 DMA Low Elev
Changjiji 2 DMA High Elev
Changjiji Residents DMA High Elev
Changjiji Tank 1, 2 & 3
Changjiji 2 DMA Low Elev
Changjiji Residents DMA Low Elev
Pamtsho 1 DMA High Elev
Pamtsho 2 DMA High Elev
Pamtsho Tank
Pamtsho 1 DMA Low Elev
Pamtsho 2 DMA Low Elev
Town Area 1 DMA High Elev
Motihang Tank 1, 2 & 3
Town Area 2 DMA High Elev
Town Area 1 DMA Low Elev
Town Area 2 DMA Low Elev
RICBL Tank
Hospital Tank 1 & 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
Profile 1
Profile 2
Profile 3
Profile 4
Profile 5
Taba Upper DMA
Taba Lower DMA
Lango Residents 1 DMA
Lango Residents 2 DMA
YHS Residents DMA
Changdelo DMA
Zilukha DMA
Hejo & Kawajangsa DMA
Changjiji Residents DMA
Changdelo DMA
Town Area 1 DMA
Town Area 2 DMA
Pamtsho 1 DMA - Proposed
Pamtsho 2 DMA - Proposed
YHS 2 DMA - Proposed
Changjiji 2 DMA - Proposed

Data Sheet

Storage Reservoir – Zilukha Sintex Tank 1

Value	Result
Storage Reservoir Name	Zilukha Sintex Tank 1
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	Zilukha Sintex Tank 2
Downstream DMA(s)	Kawajangsa and Zilukha
WTP Supplying Storage Reservoir	Motihang WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	80
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	100
Operations	Not provided
Top Water Elevation (m)	2459.5
Bottom Water Elevation (m)	2456
Storage Reservoir Volume (m^3)	6
Storage Reservoir Material	nan

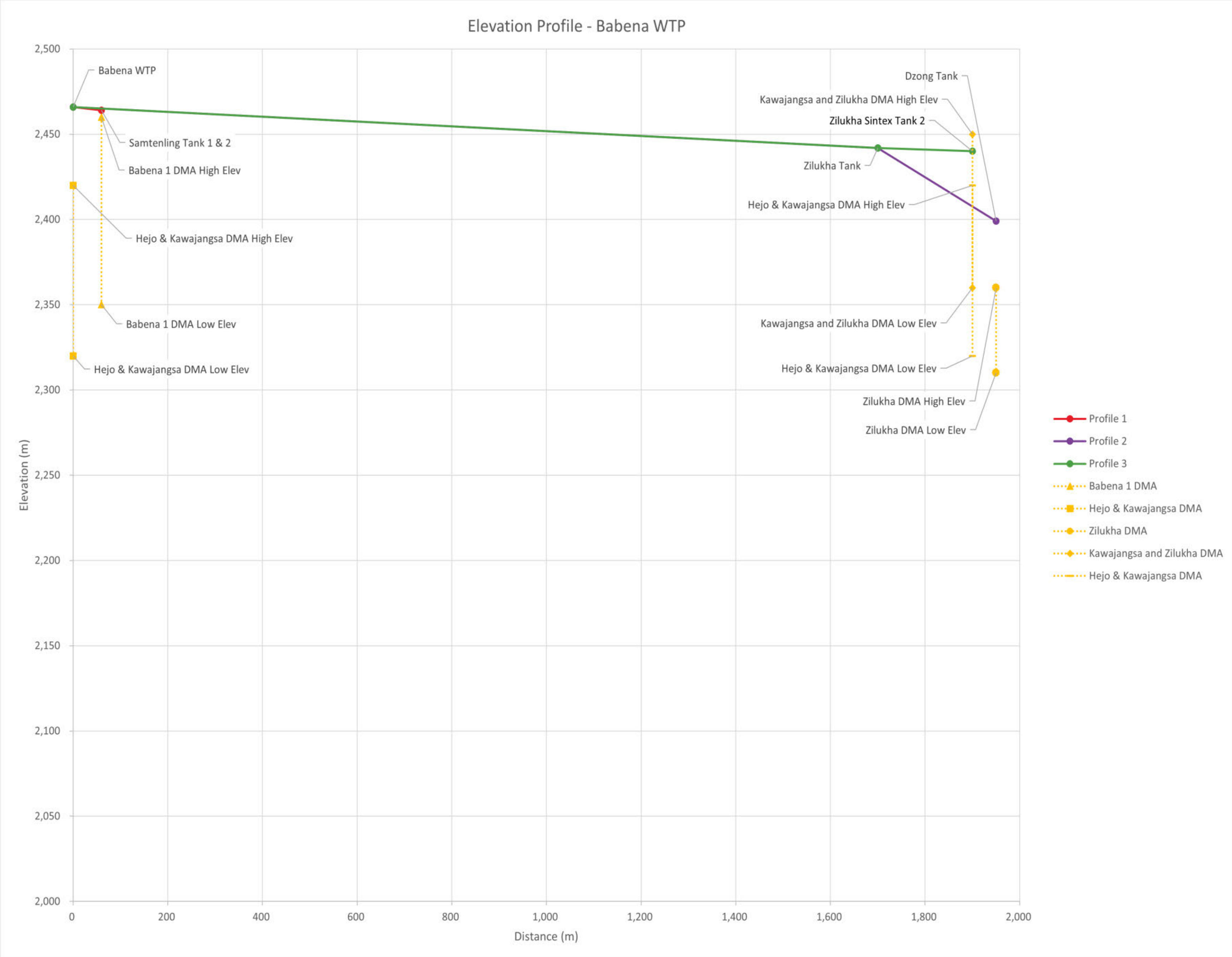


Elevation Profile - Motihang WTP
Elevation (m)
Distance (m)
2,700
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Motihang WTP
Upper Motihang DMA High Elev
Kuengacholing Tank 1 & 2
Above RICB DMA High Elev
Above RICB DMA Low Elev
Town Area 1 DMA High Elev
Upper Motihang DMA Low Elev
Town Area 1 DMA Low Elev
Motihang Tank 1, 2 & 3
Town Area 2 DMA High Elev
Town Area 2 DMA High Elev
Town Area 2 DMA Low Elev
Town Area 2 DMA Low Elev
Kawajangsa and Zilukha DMA High Elev
Zilukha Sinex Tank 1
RICBL Tank
Kawajangsa and Zilukha DMA Low Elev
Changedaphu and Upper Changzamtok DMA High Elev
Changedaphu Tank 1 & 2
Hospital Tank 1 &2
Changdelo DMA High Elev
Changedaphu and Upper Changzamtok DMA Low Elev
Changdelo DMA Low Elev
Changzamtog DMA High Elev
Kuenselohodrang Tank 1 & 2
Changzamtog DMA Low Elev
Profile 1
Profile 2
Profile 3
Kawajangsa and Zilukha DMA
Upper Motihang DMA
Above RICB DMA
Changzamtog DMA
Town Area 1 DMA
Town Area 1 DMA
Town Area 2 DMA
Changdelo DMA
Changedaphu and Upper Changzamtok DMA

Data Sheet

Storage Reservoir – Zilukha Sintex Tank 2

Value	Result
Storage Reservoir Name	Zilukha Sintex Tank 2
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	Zilukha Sintex Tank 1
Downstream DMA(s)	Kawajangsa and Zilukha
WTP Supplying Storage Reservoir	Babena WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	150
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	80
Operations	Not provided
Top Water Elevation (m)	2443.5
Bottom Water Elevation (m)	2440
Storage Reservoir Volume (m^3)	6
Storage Reservoir Material	nan

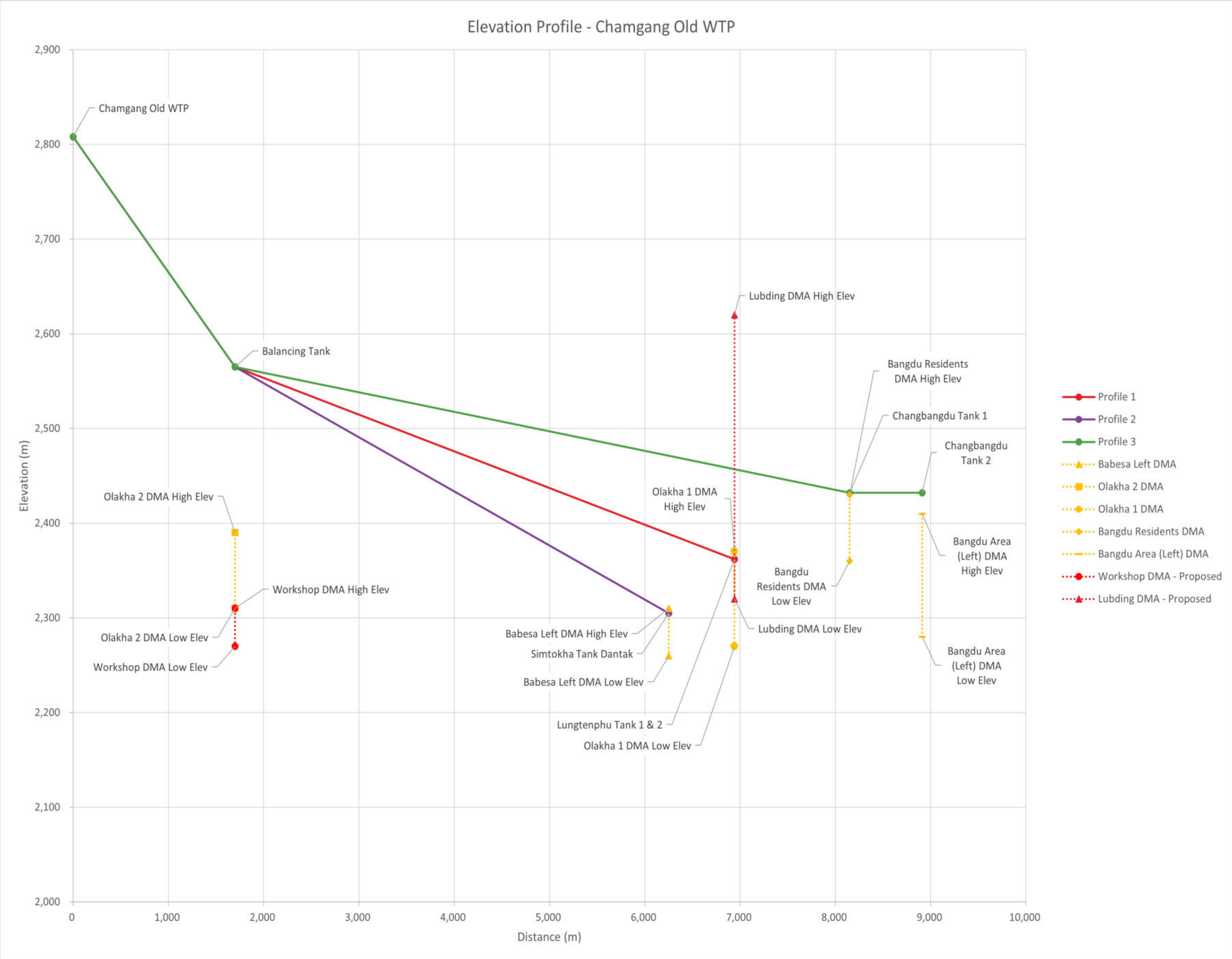


Elevation Profile - Babena WTP
Elevation (m)
Distance (m)
2,500
2,450
2,400
2,350
2,300
2,250
2,200
2,150
2,100
2,050
2,000
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
Babena WTP
Samtenling Tank 1 & 2
Babena 1 DMA High Elev
Hejo & Kawajangsa DMA High Elev
Babena 1 DMA Low Elev
Hejo & Kawajangsa DMA Low Elev
Dzong Tank
Kawajangsa and Zilukha DMA High Elev
Zilukha Sintex Tank 2
Zilukha Tank
Hejo & Kawajangsa DMA High Elev
Kawajangsa and Zilukha DMA Low Elev
Hejo & Kawajangsa DMA Low Elev
Zilukha DMA High Elev
Zilukha DMA Low Elev
Profile 1
Profile 2
Profile 3
Babena 1 DMA
Hejo & Kawajangsa DMA
Zilukha DMA
Kawajangsa and Zilukha DMA
Hejo & Kawajangsa DMA

Data Sheet

Storage Reservoir – Changbangdu Tank 1

Value	Result
Storage Reservoir Name	Changbangdu Tank 1
Downstream Storage Reservoir(s)	Changbangdu Tank 2
Adjacent Reservoir(s)	Changbangdu Tank 2 and 3
Downstream DMA(s)	Bangdu Residents; Changbangdu Tank 2 which services Bangdu Area (Left)
WTP Supplying Storage Reservoir	Chamgang Old WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	200
Number of Outlet Pipes	2
Diameter of Outlet Pipes (mm)	100; 100
Operations	24hour
Top Water Elevation (m)	2435.5
Bottom Water Elevation (m)	2432
Storage Reservoir Volume (m^3)	270
Storage Reservoir Material	RCC_circular

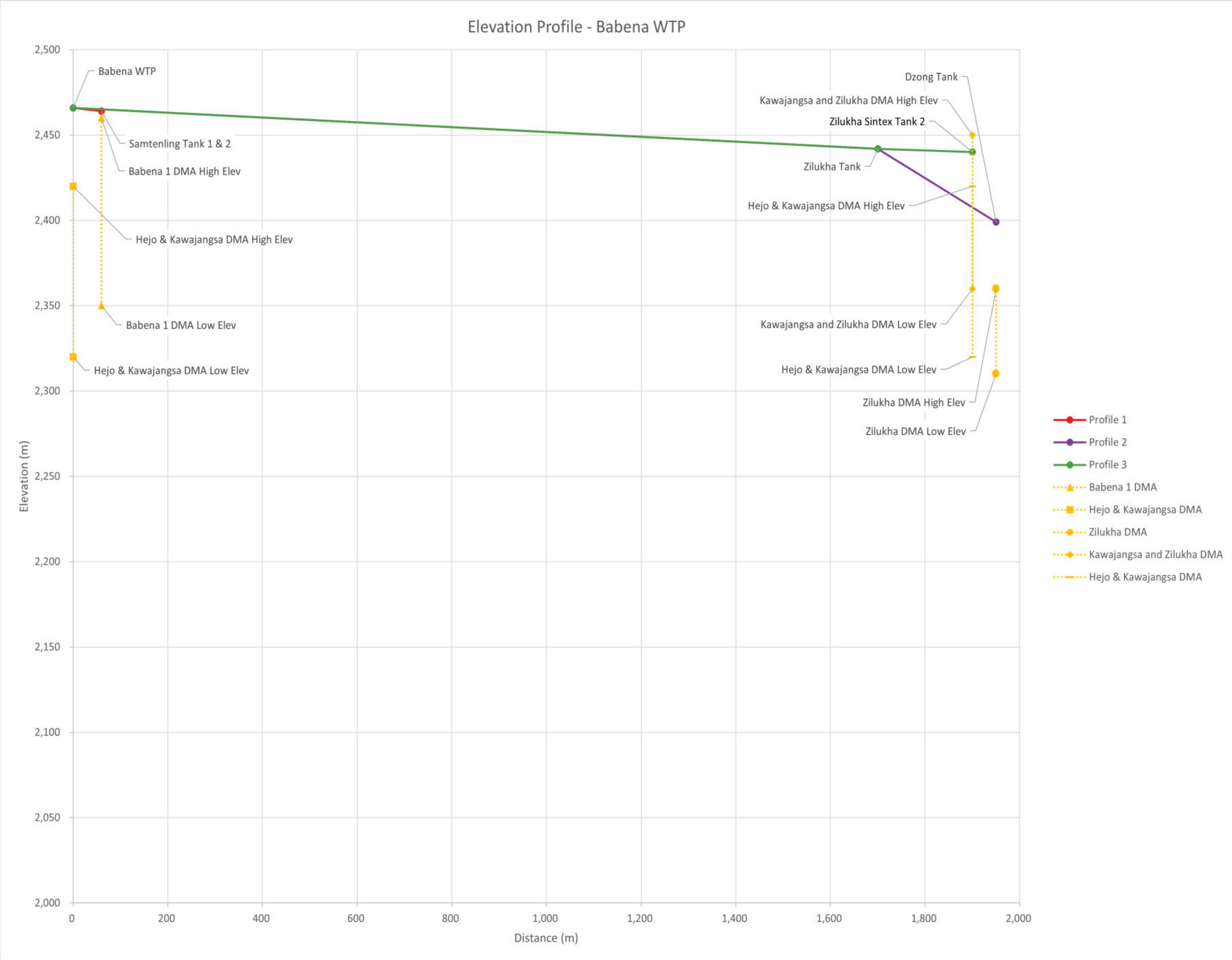


Elevation Profile - Chamgang Old WTP
Elevation (m)
2,900
2,800
2,700
2,600
2,500
2,400
2,300
2,200
2,100
2,000
Distance (m)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
Chamgang Old WTP
Balancing Tank
Olakha 2 DMA High Elev
Workshop DMA High Elev
Olakha 2 DMA Low Elev
Workshop DMA Low Elev
Lubding DMA High Elev
Olakha 1 DMA High Elev
Babesa Left DMA High Elev
Simtokha Tank Dantak
Babesa Left DMA Low Elev
Lungtenphu Tank 1 & 2
Olakha 1 DMA Low Elev
Lubding DMA Low Elev
Bangdu Residents DMA Low Elev
Bangdu Residents DMA High Elev
Changbangdu Tank 1
Changbangdu Tank 2
Bangdu Area (Left) DMA High Elev
Bangdu Area (Left) DMA Low Elev
Profile 1
Profile 2
Profile 3
Babesa Left DMA
Olakha 2 DMA
Olakha 1 DMA
Bangdu Residents DMA
Bangdu Area (Left) DMA
Workshop DMA - Proposed
Lubding DMA - Proposed

Data Sheet

Storage Reservoir – Zilukha Tank

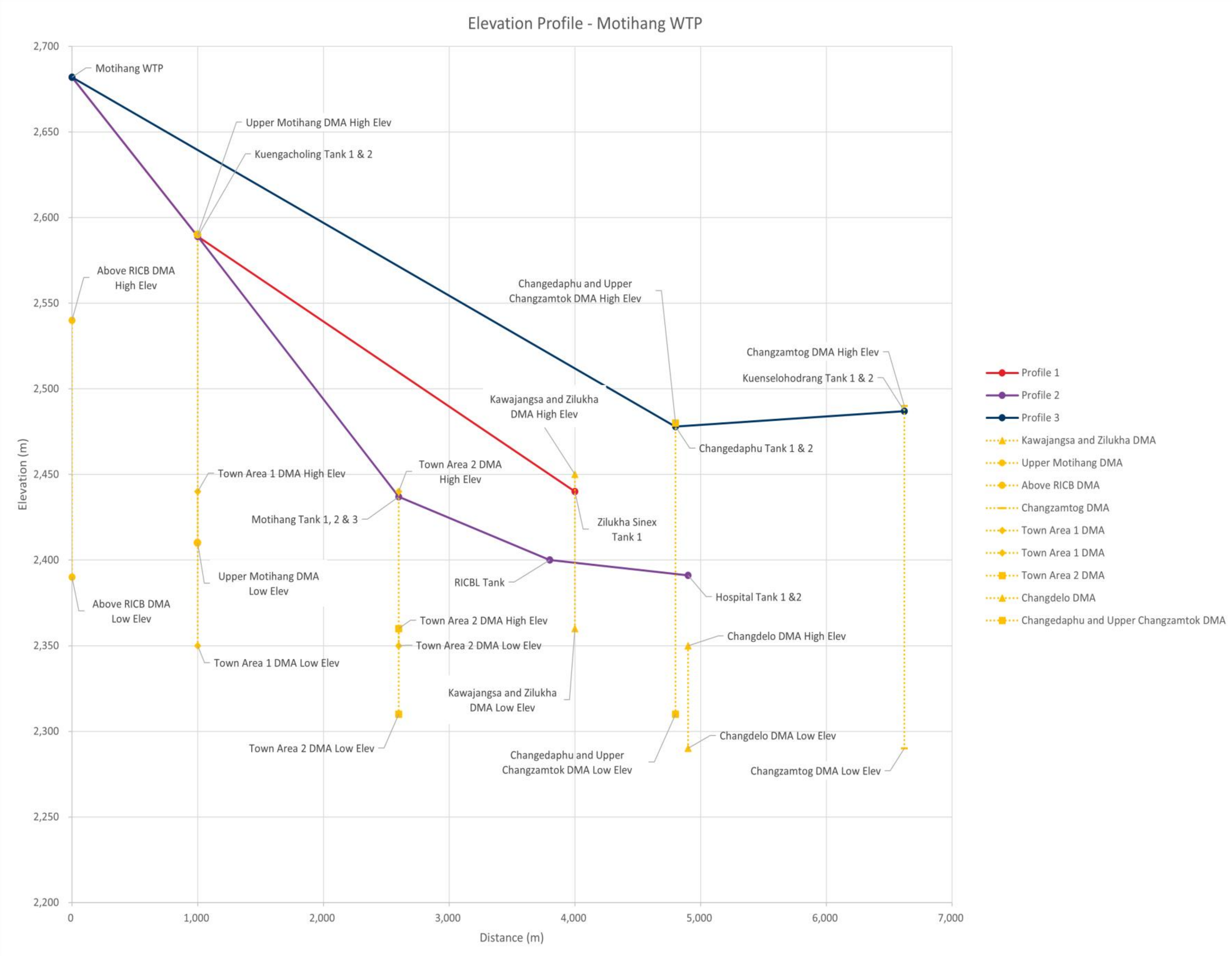
Value	Result
Storage Reservoir Name	Zilukha Tank
Downstream Storage Reservoir(s)	Zilukha_Sintex_tank 2; Dzong Tank
Adjacent Reservoir(s)	None
Downstream DMA(s)	Zilukha Sintex Tank 2 which supplies Kawajangsa and Zilukha; Dzong Tank which supplies Zilukha and Hejo and Kawajangsa
WTP Supplying Storage Reservoir	Babena WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	110
Number of Outlet Pipes	2
Diameter of Outlet Pipes (mm)	150; 75
Operations	Not provided
Top Water Elevation (m)	2445.5
Bottom Water Elevation (m)	2442
Storage Reservoir Volume (m^3)	230
Storage Reservoir Material	RCC_circular


Elevation Profile - Babena WTP
Elevation (m)
Distance (m)
2,500
2,450
2,400
2,350
2,300
2,250
2,200
2,150
2,100
2,050
2,000
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
Babena WTP
Samtenling Tank 1 & 2
Babena 1 DMA High Elev
Hejo & Kawajangsa DMA High Elev
Babena 1 DMA Low Elev
Hejo & Kawajangsa DMA Low Elev
Dzong Tank
Kawajangsa and Zilukha DMA High Elev
Zilukha Sintex Tank 2
Zilukha Tank
Hejo & Kawajangsa DMA High Elev
Kawajangsa and Zilukha DMA Low Elev
Hejo & Kawajangsa DMA Low Elev
Zilukha DMA High Elev
Zilukha DMA Low Elev
Profile 1
Profile 2
Profile 3
Babena 1 DMA
Hejo & Kawajangsa DMA
Zilukha DMA
Kawajangsa and Zilukha DMA
Hejo & Kawajangsa DMA

Data Sheet

Storage Reservoir – Changedaphu Tank 1

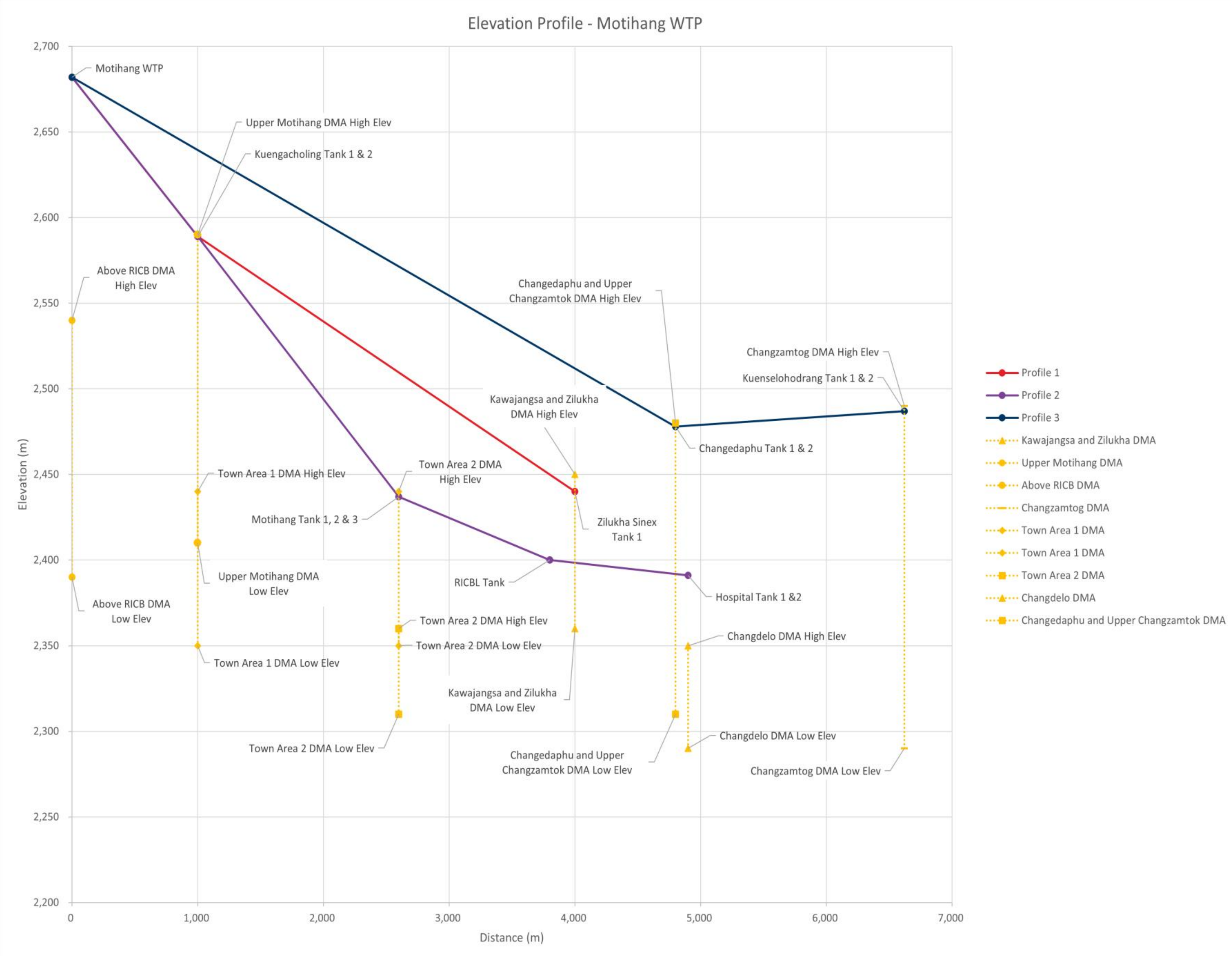
Value	Result
Storage Reservoir Name	Changedaphu Tank 1
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	Changedaphu Tank 2
Downstream DMA(s)	Changedaphu and Upper Changzamtok; Chamgzamtog
WTP Supplying Storage Reservoir	Motihang WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	100
Number of Outlet Pipes	1
Diameter of Outlet Pipes (mm)	100
Operations	6am-9am and 6pm-9pm
Top Water Elevation (m)	2482.5
Bottom Water Elevation (m)	2479
Storage Reservoir Volume (m^3)	230
Storage Reservoir Material	RCC_circular


Elevation Profile - Motihang WTP
Elevation (m)
Distance (m)
2,700
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Motihang WTP
Upper Motihang DMA High Elev
Kuengacholing Tank 1 & 2
Above RICB DMA High Elev
Above RICB DMA Low Elev
Town Area 1 DMA High Elev
Upper Motihang DMA Low Elev
Town Area 1 DMA Low Elev
Town Area 2 DMA High Elev
Motihang Tank 1, 2 & 3
Town Area 2 DMA High Elev
Town Area 2 DMA Low Elev
Town Area 2 DMA Low Elev
Kawajangsa and Zilukha DMA High Elev
Zilukha Sinex Tank 1
RICBL Tank
Kawajangsa and Zilukha DMA Low Elev
Changedaphu and Upper Changzamtok DMA High Elev
Changedaphu Tank 1 & 2
Hospital Tank 1 &2
Changdelo DMA High Elev
Changedaphu and Upper Changzamtok DMA Low Elev
Changdelo DMA Low Elev
Changzamtog DMA High Elev
Kuenselohodrang Tank 1 & 2
Changzamtog DMA Low Elev
Profile 1
Profile 2
Profile 3
Kawajangsa and Zilukha DMA
Upper Motihang DMA
Above RICB DMA
Changzamtog DMA
Town Area 1 DMA
Town Area 1 DMA
Town Area 2 DMA
Changdelo DMA
Changedaphu and Upper Changzamtok DMA

Data Sheet

Storage Reservoir – Changedaphu Tank 2

Value	Result
Storage Reservoir Name	Changedaphu Tank 2
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	Changedaphu Tank 1
Downstream DMA(s)	Changedaphu and Upper Changzamtok; Chamgzamtog
WTP Supplying Storage Reservoir	Motihang WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	100
Number of Outlet Pipes	2
Diameter of Outlet Pipes (mm)	150; 100
Operations	6am-9am and 6pm-9pm
Top Water Elevation (m)	2481.5
Bottom Water Elevation (m)	2478
Storage Reservoir Volume (m^3)	100
Storage Reservoir Material	RCC_circular

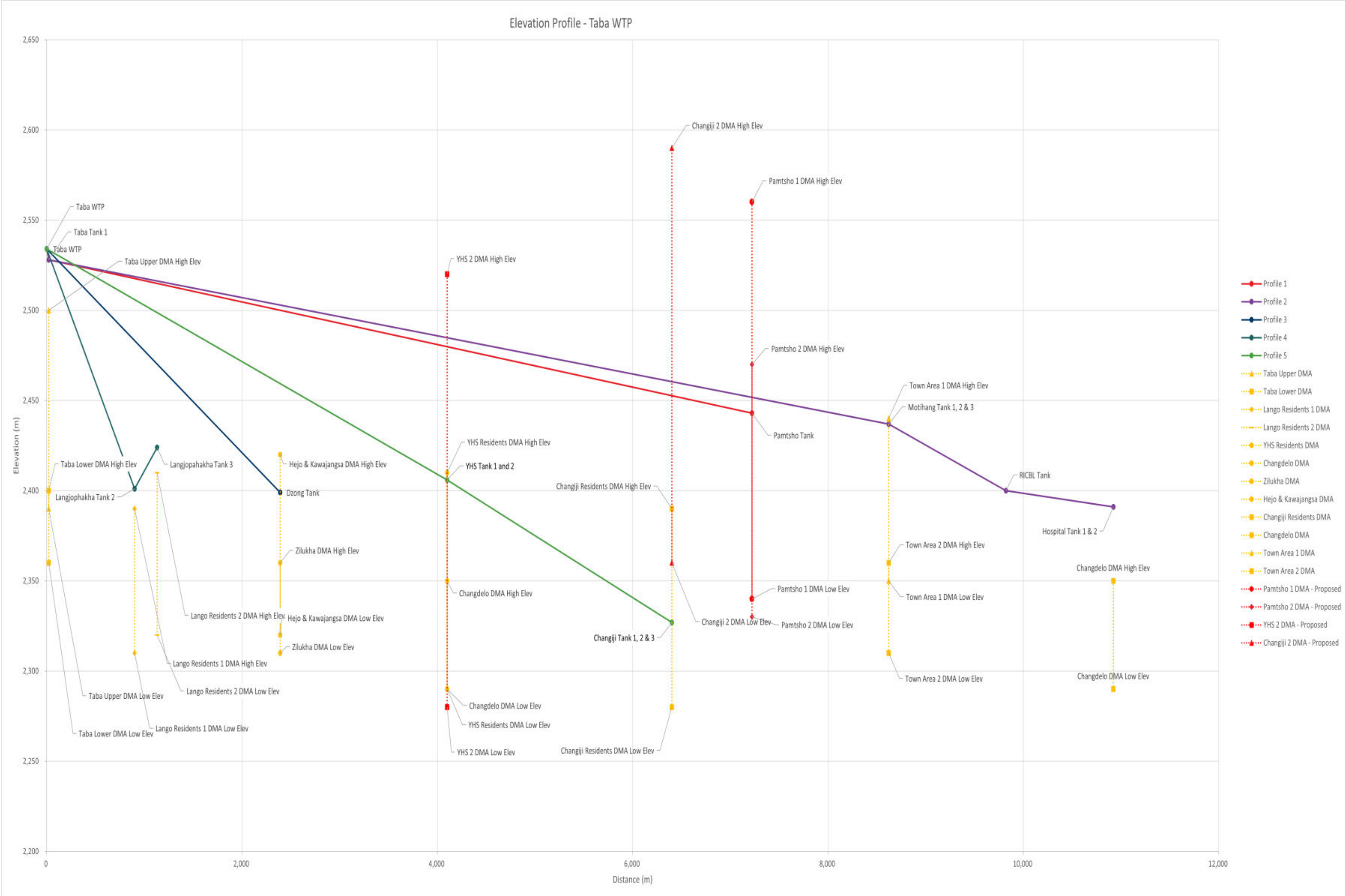


Elevation Profile - Motihang WTP
Elevation (m)
Distance (m)
2,700
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Motihang WTP
Upper Motihang DMA High Elev
Kuengacholing Tank 1 & 2
Above RICB DMA High Elev
Above RICB DMA Low Elev
Town Area 1 DMA High Elev
Upper Motihang DMA Low Elev
Town Area 1 DMA Low Elev
Motihang Tank 1, 2 & 3
Town Area 2 DMA High Elev
Town Area 2 DMA High Elev
Town Area 2 DMA Low Elev
Town Area 2 DMA Low Elev
RICBL Tank
Kawajangsa and Zilukha DMA High Elev
Zilukha Sinex Tank 1
Kawajangsa and Zilukha DMA Low Elev
Changedaphu and Upper Changzamtok DMA High Elev
Changedaphu Tank 1 & 2
Changedaphu and Upper Changzamtok DMA Low Elev
Hospital Tank 1 &2
Changdelo DMA High Elev
Changdelo DMA Low Elev
Changzamtog DMA High Elev
Kuenselohodrang Tank 1 & 2
Changzamtog DMA Low Elev
Profile 1
Profile 2
Profile 3
Kawajangsa and Zilukha DMA
Upper Motihang DMA
Above RICB DMA
Changzamtog DMA
Town Area 1 DMA
Town Area 1 DMA
Town Area 2 DMA
Changdelo DMA
Changedaphu and Upper Changzamtok DMA

Data Sheet

Storage Reservoir – Changiji Tank 2

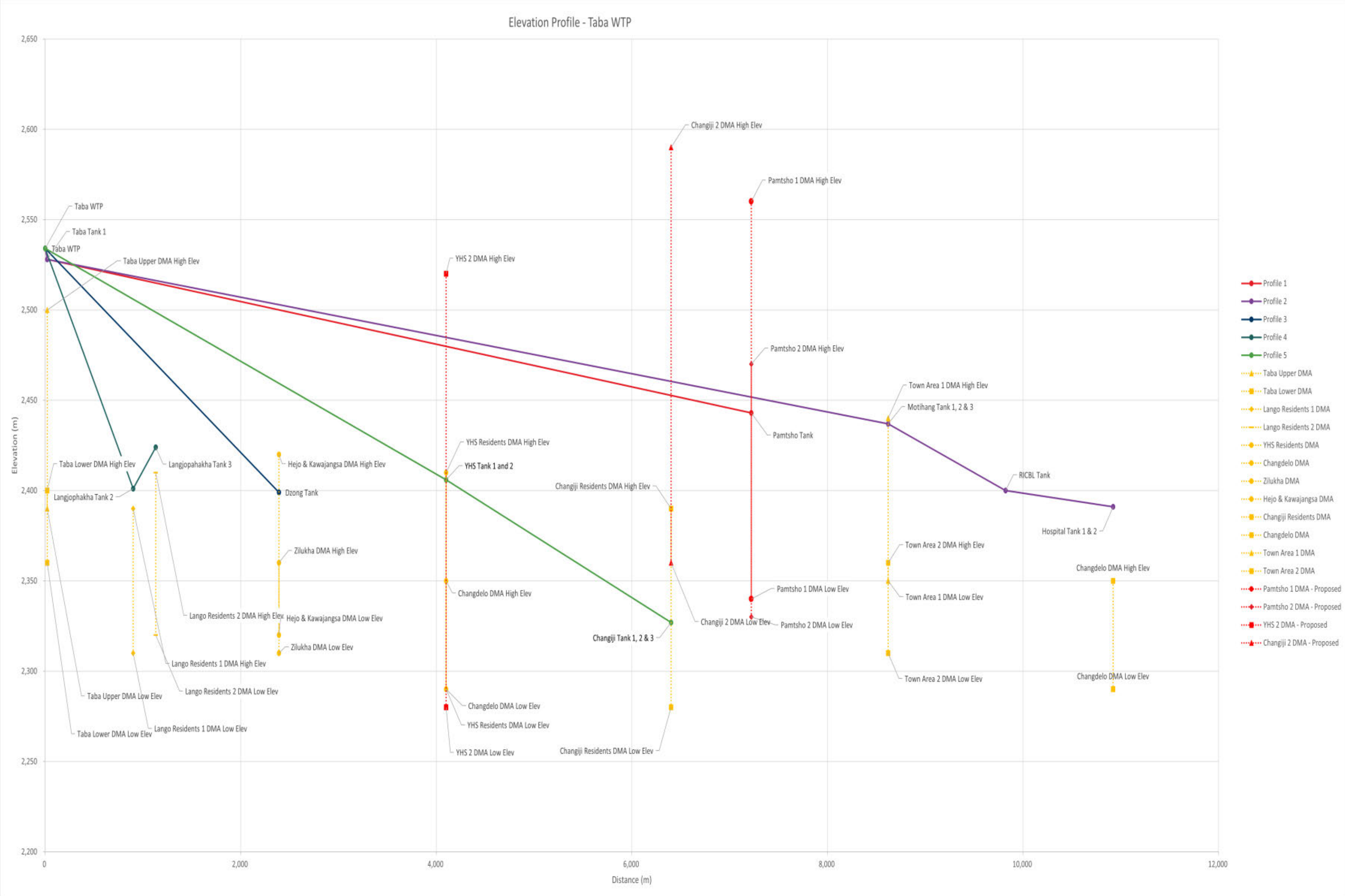
Value	Result
Storage Reservoir Name	Changiji Tank 2
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	Changiji Tank 1 and 3
Downstream DMA(s)	Changiji Residents
WTP Supplying Storage Reservoir	Taba WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	150
Number of Outlet Pipes	2
Diameter of Outlet Pipes (mm)	150; 100
Operations	24hour
Top Water Elevation (m)	2330.5
Bottom Water Elevation (m)	2327
Storage Reservoir Volume (m^3)	230
Storage Reservoir Material	RCC_circular


Elevation Profile - Taba WTP
Elevation (m)
Distance (m)
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
0
2,000
4,000
6,000
8,000
10,000
12,000
Taba WTP
Taba Tank 1
Taba WTP
Taba Upper DMA High Elev
Taba Lower DMA High Elev
Langjophakha Tank 2
Langjopahakha Tank 3
Dzong Tank
Hejo & Kawajangsa DMA High Elev
Zilukha DMA High Elev
Lango Residents 2 DMA High Elev
Hejo & Kawajangsa DMA Low Elev
Zilukha DMA Low Elev
Lango Residents 1 DMA High Elev
Lango Residents 2 DMA Low Elev
Taba Upper DMA Low Elev
Lango Residents 1 DMA Low Elev
Taba Lower DMA Low Elev
YHS 2 DMA High Elev
YHS Residents DMA High Elev
YHS Tank 1 and 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
YHS Residents DMA Low Elev
YHS 2 DMA Low Elev
Changiji 2 DMA High Elev
Changiji Residents DMA High Elev
Changiji Tank 1, 2 & 3
Changiji 2 DMA Low Elev
Changiji Residents DMA Low Elev
Pamtsho 1 DMA High Elev
Pamtsho 2 DMA High Elev
Pamtsho Tank
Pamtsho 1 DMA Low Elev
Pamtsho 2 DMA Low Elev
Town Area 1 DMA High Elev
Motihang Tank 1, 2 & 3
Town Area 2 DMA High Elev
Town Area 1 DMA Low Elev
Town Area 2 DMA Low Elev
RICBL Tank
Hospital Tank 1 & 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
Profile 1
Profile 2
Profile 3
Profile 4
Profile 5
Taba Upper DMA
Taba Lower DMA
Lango Residents 1 DMA
Lango Residents 2 DMA
YHS Residents DMA
Changdelo DMA
Zilukha DMA
Hejo & Kawajangsa DMA
Changiji Residents DMA
Changdelo DMA
Town Area 1 DMA
Town Area 2 DMA
Pamtsho 1 DMA - Proposed
Pamtsho 2 DMA - Proposed
YHS 2 DMA - Proposed
Changiji 2 DMA - Proposed

Data Sheet

Storage Reservoir – Changiji Tank 1

Value	Result
Storage Reservoir Name	Changiji Tank 1
Downstream Storage Reservoir(s)	None
Adjacent Reservoir(s)	Changiji Tank 2 and 3
Downstream DMA(s)	Changiji Residents
WTP Supplying Storage Reservoir	Taba WTP
Number of Inlet Pipes	1
Diameter of Inlet Pipes (mm)	150
Number of Outlet Pipes	2
Diameter of Outlet Pipes (mm)	150; 100
Operations	24hour
Top Water Elevation (m)	2330.5
Bottom Water Elevation (m)	2327
Storage Reservoir Volume (m^3)	230
Storage Reservoir Material	RCC_circular


Elevation Profile - Taba WTP
Elevation (m)
Distance (m)
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
0
2,000
4,000
6,000
8,000
10,000
12,000
Taba WTP
Taba Tank 1
Taba WTP
Taba Upper DMA High Elev
Taba Lower DMA High Elev
Langjophakha Tank 2
Langjopahakha Tank 3
Lango Residents 2 DMA High Elev
Lango Residents 1 DMA High Elev
Lango Residents 2 DMA Low Elev
Taba Upper DMA Low Elev
Lango Residents 1 DMA Low Elev
Taba Lower DMA Low Elev
Hejo & Kawajangsa DMA High Elev
Dzong Tank
Zilukha DMA High Elev
Hejo & Kawajangsa DMA Low Elev
Zilukha DMA Low Elev
YHS 2 DMA High Elev
YHS Residents DMA High Elev
YHS Tank 1 and 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
YHS Residents DMA Low Elev
YHS 2 DMA Low Elev
Changjiji 2 DMA High Elev
Changjiji Residents DMA High Elev
Changjiji Tank 1, 2 & 3
Changjiji 2 DMA Low Elev
Changjiji Residents DMA Low Elev
Pamtsho 1 DMA High Elev
Pamtsho 2 DMA High Elev
Pamtsho Tank
Pamtsho 1 DMA Low Elev
Pamtsho 2 DMA Low Elev
Town Area 1 DMA High Elev
Motihang Tank 1, 2 & 3
Town Area 2 DMA High Elev
Town Area 1 DMA Low Elev
Town Area 2 DMA Low Elev
RICBL Tank
Hospital Tank 1 & 2
Changdelo DMA High Elev
Changdelo DMA Low Elev
Profile 1
Profile 2
Profile 3
Profile 4
Profile 5
Taba Upper DMA
Taba Lower DMA
Lango Residents 1 DMA
Lango Residents 2 DMA
YHS Residents DMA
Changdelo DMA
Zilukha DMA
Hejo & Kawajangsa DMA
Changjiji Residents DMA
Changdelo DMA
Town Area 1 DMA
Town Area 2 DMA
Pamtsho 1 DMA - Proposed
Pamtsho 2 DMA - Proposed
YHS 2 DMA - Proposed
Changjiji 2 DMA - Proposed

Appendix D

Water Supply Hydraulic Modelling Results

ARUP

Job Title	Thimphu Water Services Masterplan
Job Number	289551
Made By	LZ
Checked By	IF
Date	26/05/2023
Description of spreadsheet	Hydraulic modelling outputs
Sheet Number prefix	Sheet number prefix
Member/Location	Member/Location
Drawing Reference	Drawing reference
Filename	Filename

Contents of Spreadsheet

Sheet	Description
Cover	
Notes	
Calc(P)	
Calc(L)	
Calc(side)	
Sheet6	
Sheet7	

Authorisation of latest version

Type and method of check		
Signatures & dates:	Made by	
	Checked	

Revisions

Current Revision

Rev.	Date	Made by	Checked	Description

ARUP

Job No. 289551 | Sheet No. Sheet number | Rev.

Member/Location Member/Location

Drg. Ref. Drawing reference

Made by LZ | Date 26/05/2023 | Chd. IF

Job Title Thimphu Water Services Masterplan

Calculation

Exsiting Model: Node pressure

ID	Label	X (m)	Y (m)	Elevation (m)	Demand (L/s)	Pressure (m H2O)
63	J-11	764,118.88	3,037,859.93	2,306.25	0	257.65
67	J-13	764,994.75	3,037,477.71	2,379.98	0	184.89
70	Olakha 2_PC2	764,091.47	3,038,212.79	2,393.29	2.73	171.21
72	J-15	764,722.36	3,036,334.19	2,757.00	0	108.53
78	Debsi_PC1	760,439.75	3,037,252.66	2,475.54	0	183.49
115	J-27	763,086.87	3,039,176.30	2,367.53	0	191.41
128	J-31	761,548.90	3,039,496.87	2,390.52	0	169.88
131	J-32	761,528.39	3,039,306.87	2,430.19	0	130.13
134	Olokha 1	763,053.53	3,039,189.09	2,358.75	13.59	5.21
136	Olakha1a	763,062.80	3,039,176.63	2,359.47	13.59	4.5
138	J-35	763,265.85	3,038,050.91	2,304.86	0	257.94
143	J-37	761,385.95	3,036,513.60	2,288.11	0	370.54
146	J-38	763,209.68	3,033,510.97	2,640.00	0	19.36
151	J-39	760,566.79	3,048,382.11	2,500.38	0	20.05
155	J-41	760,444.69	3,048,527.23	2,523.06	0	53.99
159	J-43	760,458.67	3,048,463.66	2,515.64	0	5.24
165	J-44	758,318.59	3,041,995.88	2,590.85	0	251.57
171	J-45	760,218.30	3,040,087.93	2,479.05	0	271.33
179	J-46	759,066.26	3,044,620.53	2,465.35	0	6.61
188	J-48	759,642.77	3,041,906.29	2,437.68	0	370.82
200	J-50	760,321.97	3,044,993.07	2,361.50	0	178.21
204	J-51	761,309.09	3,043,589.71	2,423.13	0	29.3
206	J-52	761,148.08	3,043,618.75	2,399.27	0	48.43
214	Upper Taba	760,952.29	3,045,755.26	2,404.68	7.61	122.64
218	J-54	761,780.43	3,041,091.48	2,402.77	0	40.36
224	J-55	762,557.00	3,039,586.51	2,327.92	0	1.39
226	J-56	761,786.39	3,041,087.77	2,402.80	0	2.19
227	Changdelo_PC1	760,679.73	3,040,887.03	2,351.08	0	53.8
232	J-58	762,528.51	3,039,581.26	2,323.98	0	4.84
233	J-59	760,087.09	3,041,513.77	2,371.39	0	5.26
244	Changjiji Demand_PC	762,151.61	3,039,520.56	2,279.98	0.01	48.92
246	Bhutan Hospital	762,631.99	3,039,641.73	2,362.94	0	41.97
249	J-63	759,655.78	3,041,927.41	2,436.39	0	84.08
254	J-64	760,076.99	3,041,131.75	2,396.54	0	15.19
257	J-65	760,523.56	3,040,395.63	2,391.35	0	9.38
269	J-66	760,331.89	3,042,137.06	2,359.01	0	21.76
275	J-67	762,568.91	3,039,091.00	2,291.44	0	72.39
277	J-68	762,337.84	3,039,309.18	2,289.19	0	74.63
279	J-69	762,913.17	3,038,694.17	2,279.63	0	84.17
281	J-70	763,384.81	3,038,634.82	2,343.90	0	20.04
283	J-71	762,706.39	3,039,285.77	2,316.26	0	47.62
286	Dangrina_PC1	760,802.11	3,047,749.34	2,425.87	9.78	42.53
288	Dangrina proposed	760,513.32	3,048,483.79	2,514.90	0	6.09
290	Satellite Town_PC1	761,562.99	3,047,981.72	2,380.91	0.61	11.54
292	Lower Taba_PC1	760,912.88	3,045,807.98	2,402.46	10.1	126.68
294	Lango Residents 1	761,024.89	3,043,672.81	2,384.74	6.84	16.25
298	Langho Res1_PC1	760,484.04	3,043,685.87	2,314.94	0	111.44
300	YHS Residents	761,605.40	3,041,158.13	2,387.08	6.16	16.02
302	Changjiji Residents De	761,992.32	3,039,937.83	2,310.59	16.65	13.08
304	Above Old Highway D	762,388.78	3,036,764.87	2,385.80	9.78	4.96
307	J-82	763,000.28	3,037,793.73	2,308.10	0	89.53
311	Bebesa Left Demand	763,192.43	3,038,106.06	2,294.68	16.19	11.37
313	Bebesa Left_PC1	761,850.25	3,037,311.43	2,264.80	8.1	41.33
315	J-85	763,819.94	3,036,963.52	2,587.49	0	273.79
318	Simtokha E4 Demand	763,896.40	3,037,056.79	2,559.08	2.47	302.11
320	Simtoka Upper 1_PC1	763,331.45	3,037,349.05	2,458.12	1.37	62.53
322	Simtokha Upper 1_PC	762,708.09	3,037,403.33	2,308.64	1.37	211.54
325	Lango Res1_PC2	761,047.61	3,043,598.41	2,386.85	0.01	14.37
331	Bangdu Residents_P(	761,578.82	3,039,158.04	2,428.10	1.7	3.92
334	J-92	761,340.61	3,039,430.74	2,488.86	0	-0.31
349	Changzamtog Deman	761,399.49	3,039,558.15	2,427.70	10.9	54.46
351	Hejo& Kawajangsa_P	760,407.82	3,043,922.64	2,316.24	2.63	82.58
357	J-97	761,054.17	3,044,126.19	2,377.18	0	85.51
361	J-98	760,396.89	3,044,941.82	2,356.19	0	3.79
374	J-100	760,450.15	3,044,936.23	2,353.70	0	47.2
380	J-101	760,379.99	3,044,955.61	2,356.68	0	3.17
383	J-102	760,386.72	3,044,930.46	2,357.32	0	46.65
399	J-104	760,553.00	3,040,398.73	2,387.11	0	5.98
404	J-105	760,054.26	3,041,482.39	2,370.63	0	3.26
415	J-108	758,382.11	3,042,032.19	2,583.62	0	-4.8
422	Taba / Dotena	761,474.11	3,045,679.81	2,533.35	0	6.7
424	J-112	760,297.08	3,045,020.63	2,360.81	0	166.01
429	Pamtsho_PC1	760,303.92	3,046,710.20	2,564.66	0	-119.42
434	J-117	759,745.29	3,043,709.89	2,451.02	0	-1.33
439	J-119	759,776.42	3,043,705.43	2,436.35	0	13.27
442	Hejo & Kawajangsa_F	760,046.89	3,044,313.59	2,417.12	2.63	32.27
445	Kawajangsa and Ziluk	759,590.95	3,043,424.69	2,451.37	5.45	-9.29
447	J-122	759,741.74	3,042,529.17	2,446.23	0	93.98
449	Town Area 1 Demand	759,934.58	3,042,599.10	2,393.55	6.41	140.02
452	Norzin Wog_PC1	760,434.23	3,042,234.65	2,351.90	9.32	4.9
454	J-125	761,264.69	3,040,163.06	2,305.76	0	22.76
457	Changzamtog Deman	761,272.04	3,040,131.04	2,305.95	10.9	21.72
460	Changedaphu & UCha	760,897.74	3,039,985.82	2,382.90	11	92.87
463	Changbangdu - BHs	761,353.45	3,039,416.84	2,488.98	0	-0.23
467	Jungshina	760,376.27	3,044,970.08	2,357.77	0	2.21
468	Ziluka _PC1	760,603.51	3,043,112.32	2,314.12	0.29	86.67
470	J-136	759,674.27	3,042,093.32	2,430.89	0	89.7
473	Town Area 1_PC1	760,375.62	3,042,631.67	2,347.52	6.41	162.55
475	Town Area 2a	760,492.18	3,041,462.19	2,335.14	3.88	36.58
477	Town Area 2_PC2	760,924.41	3,041,040.67	2,313.18	3.88	38.9
479	J-140	759,676.62	3,041,912.72	2,432.94	0	5.9
480	Town Area 2c	760,287.79	3,041,682.73	2,356.47	3.88	78.67
482	Upper Mothiang Dema	758,872.79	3,041,988.83	2,522.41	25.81	-21.1
484	J-143	759,923.06	3,040,755.22	2,453.51	0	316.66
487	Above RICB Demand	759,943.07	3,040,768.73	2,452.84	1.39	317.31
489	Above RICB Tank a	760,062.17	3,041,105.88	2,399.98	1	2.01
491	J-146	760,243.18	3,040,089.64	2,477.61	0	3.25
492	Changedaphu & UCha	761,620.86	3,040,032.25	2,287.55	11	186.01
494	J-148	760,556.76	3,040,397.66	2,387.04	0	5.75
497	Changdelo_PC2	761,335.27	3,040,377.10	2,290.78	5.805	93.5
499	Changdelo Demand 2	760,659.45	3,040,786.44	2,353.19	5.805	28.58
501	J-151	761,619.09	3,040,392.20	2,314.22	0	90.59
510	Bangdu Area left_PC1	762,090.51	3,038,962.40	2,405.02	8.16	-16.87
516	Bebesa Right_PC1	761,598.56	3,036,529.10	2,329.80	5.23	3.56
518	J-157	761,375.13	3,036,330.99	2,305.19	0	353.5
521	Gangchey Nyezergan	760,866.82	3,036,196.70	2,252.43	0	406.15
532	J-160	760,847.04	3,039,952.85	2,410.33	0	67.09
548	J-162	763,275.08	3,033,563.22	2,644.00	0	15.02
575	Bebena 1_PC1	760,350.72	3,044,483.92	2,345.83	0.01	120.23
578	Bebena 1a Demand	759,260.84	3,044,773.37	2,441.47	11.57	24.08
601	J-168	757,564.56	3,042,096.37	2,675.00	0	193.83
605	J-169	757,550.83	3,042,074.31	2,682.00	0	187.61
624	J-172	767,183.67	3,033,559.92	2,915.00	0	-3.68
632	J-173	767,809.18	3,035,688.01	2,792.00	0	13.05
651	Simtoka Upper 2b_PC	763,016.48	3,036,669.73	2,537.68	4.2	19.37
750	J-176	761,147.43	3,043,624.77	2,399.49	0	1.77
755	J-177	760,395.40	3,044,933.85	2,356.20	0	47.76
766	J-178	760,123.92	3,048,687.37	2,573.00	0	6.84
782	Luding Demand 1	763,846.55	3,039,059.53	2,634.50	0	10.48
785	Lubding Demand 2	763,921.25	3,038,737.26	2,513.27	0	5.72
797	J-182	761,599.65	3,040,713.58	2,396.84	0	-7.06
804	J-185	761,061.79	3,036,909.98	2,290.16	0	368.5
807	Rama _PC2	759,847.66	3,035,658.15	2,244.00	0	414.56
809	Town Area 1.1	760,491.21	3,041,163.14	2,357.57	6.41	64.95
811	J-188	762,165.23	3,035,991.09	2,498.29	0	17.01
815	J-189	761,100.29	3,040,938.84	2,299.88	0	104.9
818	Changdelo 1a	761,184.30	3,040,535.49	2,305.04	0	99.75
822	J-191	764,380.46	3,037,901.85	2,346.00	0	218.56
825	Olakha 2_PC1	764,178.80	3,037,879.71	2,307.88	0	256.61
827	J-193	759,800.25	3,035,899.49	2,274.00	0	384.63
830	Rama_PC1	759,218.61	3,036,266.35	2,381.00	0	277.84
832	J-195	760,642.46	3,037,372.92	2,463.08	0	195.93
835	Debsi_PC2	760,435.22	3,036,250.18	2,249.97	0	408.61
837	Bebesa Right_PC2	761,367.77	3,036,913.39	2,263.39	5.23	69.91

Existing Model: Pipeline hydraulics

ID	Label	Length (Scaled) (m)	Diameter (mm)	Flow (L/s)	Velocity (m/s)	Headloss Gradient (m/km)
68	P-11(1)	2,096.00	350.00	46.13	0.48	0.839
321	P-110	411.00	100.00	1.37	0.17	0.557
323	P-111	702.00	100.00	1.37	0.17	0.557
639	P-6(1)	1,210.00	150.00	10.00	0.57	3.067
845	P-105(1)	149.00	100.00	9.78	1.25	21.208
517	P-176	95.00	100.00	5.23	0.67	6.653
838	P-218	652.00	100.00	5.23	0.67	6.654
116	P-12(1)	1,871.00	200.00	20.00	0.64	2.726
139	P-26(1)	895.00	250.00	23.40	0.48	1.23
69	P-11(2)	1,090.00	350.00	43.40	0.45	0.75
823	P-13(1)	852.00	150.00	2.73	0.15	0.277
316	P-4(2)(1)	1,112.00	200.00	22.97	0.73	3.523
657	P-14(1)	1,664.00	150.00	20.00	1.13	11.07
652	P-193	199.00	80.00	4.20	0.84	13.143
287	P-96	684.00	100.00	9.78	1.25	21.208
576	P-46(1)	1,807.00	160.00	0.01	0	0
675	P-12(2)(1)	9.00	200.00	10.00	0.32	0.748
678	P-24(1)	17.00	200.00	10.00	0.32	0.75
135	P-30	20.00	200.00	13.59	0.43	1.336
137	P-31	13.00	200.00	13.59	0.43	1.334
332	P-115	211.00	100.00	1.70	0.22	0.83
660	P-114(1)	757.00	100.00	10.00	1.27	22.1
132	P-28	216.00	200.00	10.00	0.32	0.755
663	P-27(1)	3.00	250.00	10.00	0.2	0.227
938	P-243	406.00	100.00	0.00	0	0
666	P-29(1)	3	250	10	0.2	0.291
863	P-92(1)(1)	139	160	0.002	0	0
282	P-95	664	200	0	0	0
648	P-32(1)(1)	454	250	3.4	0.07	0.034
868	P-26(2)(1)	669	250	20.001	0.41	0.919
805	P-15(2)(1)	614	150	0.003	0	0
519	P-33(1)	3,664	250	0.004	0	0
558	P-184	84	250	50.073	1.02	5.032
637	P-192	87	250	-50.077	1.02	5.031
289	P-97	94	150	0.001	0	0
770	P-202	36	150	10	0.57	3.07
775	P-35(1)	1,137	80	0.5	0.1	0.255
778	P-18(1)	966	150	10	0.57	3.066
291	P-98	81	150	0.61	0.03	0.017
873	P-226	188	90	0	0	0
772	P-16(2)(1)	28	150	16.2	0.92	7.492
161	P-17(2)	136	150	10	0.57	3.066
177	P-43	3,877	100	10.392	1.32	23.73
723	P-39(1)	19	100	11.85	1.51	30.266
726	P-38(1)	14	100	11.85	1.51	30.249
686	P-42(1)	9	100	10	1.27	22.094
720	P-41(1)	15	100	10	1.27	22.089
821	P-214	23	100	4.885	0.62	5.864
533	P-117(1)	807	100	4.116	0.52	4.27
579	P-45(1)	240	160	11.57	0.58	2.934
435	P-47(1)	1,700	110	9.69	1.02	13.105
739	P-44(1)	7	150	3.53	0.2	0.457
742	P-20(2)(1)	11	150	3.53	0.2	0.46
736	P-144(1)	207	75	5	1.13	24.858
710	P-49(1)	8	150	10	0.57	3.079
713	P-50(1)	9	150	10	0.57	3.054
716	P-51(1)	13	150	10	0.57	3.064
537	P-181	23	100	5.196	0.66	6.573
905	P-81(1)	407	150	30	1.7	23.458
352	P-124	1,081	100	2.63	0.33	1.863
375	P-52(1)(1)(	1,565	150	0	0	0
529	P-151(1)	16	100	1.097	0.14	0.37
219	P-62	3,403	200	20	0.64	2.726
895	P-57(1)	125	150	31.248	1.77	25.296
213	P-60	238	100	21.248	2.71	89.244
745	P-59(1)	3	100	10	1.27	22.119
295	P-100	150	150	6.84	0.39	1.518
328	P-113	105	80	0.01	0	0
299	P-102	969	63	0	0	0
425	P-77(1)	1,505	200	16.41	0.52	1.89
764	P-53(1)	4	200	-10	0.32	0.75
885	P-99(1)	768	200	10.1	0.32	0.769
890	P-61(1)	332	150	7.61	0.43	1.849
695	P-63(1)	4	150	10	0.57	3.058
698	P-64(1)	10	150	10	0.57	3.063
248	P-76	6	150	6.162	0.35	1.244
924	P-239	50	80	0	0	0
798	P-65(1)	444	150	36.826	2.08	34.29
241	P-71	6	100	15.293	1.95	48.549
242	P-72	8	100	13.352	1.7	37.758
243	P-73	20	100	8.181	1.04	15.241
301	P-103	207	100	6.16	0.78	9.009
502	P-75(1)	828	100	0.001	0	0
926	P-66(1)(1)	732	150	0.002	0	0
245	P-74	692	150	0.01	0	0
238	P-68	16	100	-6.773	0.86	10.742
239	P-69	22	100	-5.716	0.73	7.844
240	P-70	30	100	-4.778	0.61	5.629
303	P-104	651	150	16.65	0.94	7.883
455	P-67(1)	2,043	100	0.616	0.08	0.127
264	P-86	27	100	22.519	2.87	99.378
265	P-87	40	100	18.216	2.32	67.101
396	P-135	29	80	2.092	0.42	3.613
397	P-136	19	80	2.603	0.52	5.416
476	P-159	577	100	3.88	0.49	3.828
707	P-78(1)	5	200	10	0.32	0.735
258	P-82	995	150	20	1.13	11.07
701	P-85(1)	13	100	10	1.27	22.092
490	P-164	9	100	1	0.13	0.305
689	P-83(1)	7	100	10	1.27	22.116
692	P-84(1)	12	100	10	1.27	22.107
495	P-166	23	100	6.061	0.77	8.741
496	P-167	27	100	5.549	0.71	7.424
273	P-91	801	250	51.018	1.04	5.209
704	P-90(1)	8	100	10	1.27	22.104
453	P-154	164	100	9.32	1.19	19.398
912	P-160(1)	359	100	3.88	0.49	3.828
278	P-93	318	110	0.001	0	0
280	P-94	529	110	0.001	0	0
285	P-92(2)	239	160	0.001	0	0
312	P-107	505	200	16.19	0.52	1.843
840	P-108(1)	986	200	8.1	0.26	0.511
642	P-106(1)	8	150	10	0.57	3.075
858	P-32(2)(1)	651	250	-6.6	0.13	0.118
319	P-109	121	150	2.47	0.14	0.23
654	P-4(2)(2)(1	605	150	20.5	1.16	11.589
340	P-118	19	100	-6.884	0.88	11.066
350	P-123	182	100	10.9	1.39	25.925
359	P-56(2)	666	200	51.248	1.63	15.574
360	P-126	2,393	150	31.619	1.79	25.855
363	P-52(2)	35	150	0	0	0
373	P-127	18	100	0	0	0
378	P-129	14	100	0	0	0
370	P-52(1)(2)	15	100	0	0	0
377	P-128	39	100	0	0	0
379	P-130	40	100	0	0	0
376	P-52(1)(1)(	39	100	0	0	0
387	P-89(2)(1)(	12	250	22.654	0.46	1.149
391	P-131	15	250	22.652	0.46	1.153
393	P-133	13	250	22.654	0.46	1.152
385	P-89(2)(2)	3,214	250	61.018	1.24	7.256
388	P-89(2)(1)(	14	250	22.654	0.46	1.158
392	P-132	16	250	22.652	0.46	1.159
394	P-134	14	250	22.654	0.46	1.156

839	J-198	762,294.91	3,037,371.34	2,280.85	0	25.59
842	Bebesa Left_PC2	762,320.58	3,037,187.46	2,311.27	0	-4.76
844	J-200	762,361.42	3,036,884.43	2,377.91	0	16.89
847	Above Old Highway D	761,726.57	3,037,092.61	2,264.04	0	130.54
850	Serbithang_PC1	761,670.37	3,036,462.73	2,345.02	0	13.3
852	J-204	762,779.65	3,034,747.27	2,519.65	0	70.82
855	Serbithang_PC2	763,021.62	3,035,017.70	2,634.70	0	-44
857	J-206	762,632.60	3,037,430.70	2,305.97	0	91.74
860	Simtokha Upper 2b_P	762,637.10	3,037,436.71	2,305.16	0	92.54
862	J-208	763,002.65	3,039,314.24	2,344.38	0	19.55
865	J-209	763,050.22	3,039,335.70	2,367.75	0	-3.77
867	J-210	762,978.88	3,038,534.41	2,280.10	0	282.04
870	Olakha 1_PC1	762,916.19	3,038,370.99	2,274.50	0	287.63
872	Satellite Town_PC2	761,574.68	3,048,215.92	2,393.49	0	-1.01
874	Pamtsho_PC2	760,513.38	3,045,930.64	2,338.45	0	106.34
876	J-214	760,382.60	3,046,047.78	2,359.60	0	85.23
879	Pamtsho 2_PC1	760,595.12	3,045,476.93	2,331.83	0	112.95
882	Pamtsho_PC2	759,907.65	3,045,359.03	2,473.73	0	-28.67
884	J-218	760,929.45	3,045,813.00	2,403.78	0	125.38
887	Lower Taba_PC2	760,672.26	3,046,292.66	2,360.23	0	168.84
889	J-220	761,567.35	3,045,903.46	2,498.77	0	30.55
892	Upper Taba_PC	761,151.31	3,046,515.51	2,391.94	0	137.17
894	J-222	761,188.38	3,043,585.34	2,406.91	0	42.34
897	Lang 2_PC1	761,192.29	3,043,601.97	2,407.48	0	41.77
899	J-224	759,867.39	3,043,014.07	2,416.91	0	123.27
902	Kawajangsa and Ziluk	760,038.10	3,043,112.02	2,357.72	0	182.34
904	J-226	759,835.02	3,041,718.68	2,410.42	0	19
907	Upper Motihang_PC	759,819.36	3,041,716.77	2,412.82	0	16.61
909	Upper Motihang_PC2	758,333.90	3,041,893.22	2,594.83	0	-15.99
911	J-229	760,282.72	3,041,787.46	2,364.11	0	-5.47
914	Town Area 2_PC1	760,304.24	3,041,798.22	2,363.23	0	-4.6
916	Norzin Wog_PC2	761,111.67	3,041,238.63	2,298.01	0	73.63
918	J-232	762,581.84	3,039,665.86	2,361.98	0	42.93
921	Changjiji Res_PC2	762,630.16	3,039,730.41	2,394.36	0	10.62
923	YHS Res_PC1	761,805.84	3,041,140.16	2,408.97	0	-3.96
925	J-235	761,175.06	3,040,950.54	2,301.85	0	102.93
928	YHS Res_PC2	761,201.33	3,040,866.96	2,293.33	0	111.44
930	J-237	761,164.94	3,040,228.87	2,315.68	0	15.71
933	Changdelo_PC	761,197.65	3,040,162.27	2,311.94	0	19.43
935	Changedaphu & UCha	761,285.73	3,039,394.71	2,493.83	1.69	-7.01
937	Bangdu Residents_P(	761,743.06	3,039,281.11	2,358.47	0	201.87
939	J-241	761,556.09	3,036,390.81	2,354.33	0	4.01
942	J-242	761,558.29	3,036,399.08	2,371.99	0	-13.61

401	P-138	19	80	2.499	0.5	5.022
402	P-139	25	80	2.196	0.44	3.956
410	P-137(1)	30	80	4.695	0.93	16.156
411	P-137(2)	1,490	80	4.695	0.93	16.155
416	P-141	2,790	80	-7.995	1.59	43.297
417	P-142	57	80	-19.675	3.91	229.484
418	P-143	54	80	-19.444	3.87	224.533
483	P-162	606	100	25.81	3.29	127.945
910	P-235	235	100	0.001	0	0
201	P-54	1,516	200	0	0	0
358	P-56(1)	2,036	200	82.867	2.64	37.924
430	P-146	869	150	0	0	0
877	P-227(1)	475	100	0.001	0	0
883	P-229	763	63	0	0	0
471	P-77(2)(1)	3,380	200	16.41	0.52	1.89
760	P-145(1)	1,179	150	0	0	0
440	P-148(1)	31	150	6.16	0.35	1.25
733	P-47(2)(1)	25	150	3.53	0.2	0.447
443	P-149	755	150	2.63	0.15	0.259
729	P-148(2)(1	255	150	3.53	0.2	0.446
446	P-150	142	150	5.45	0.31	0.996
450	P-152	228	80	6.41	1.28	28.757
451	P-153	1,891	80	-5.313	1.06	20.314
458	P-155	33	100	10.9	1.39	25.925
931	P-67(2)(1)	122	100	-10.284	1.31	23.275
341	P-119	22	100	-6.884	0.88	11.07
381	P-89(1)	15	250	67.96	1.38	8.862
469	P-157	1,151	100	-0.29	0.04	0.031
472	P-77(2)(2)	173	200	10	0.32	0.755
474	P-158	1,069	100	6.41	0.82	9.698
917	P-237	1,398	100	0.001	0	0
481	P-161	928	100	3.88	0.49	3.827
538	P-182	24	100	-5.094	0.65	6.335
810	P-211	1,670	100	6.41	0.82	9.698
486	P-40(2)	968	100	9.609	1.22	20.526
488	P-163	24	100	1.39	0.18	0.567
493	P-165	1,894	150	11	0.62	3.659
536	P-180	15	100	-6.115	0.78	8.892
498	P-168	1,033	100	5.805	0.74	8.071
500	P-169	458	80	5.805	1.15	23.933
919	P-75(2)(1)	1,258	100	0.001	0	0
511	P-173	124	100	8.16	1.04	15.165
520	P-33(2)	187	200	0.003	0	0
522	P-177	526	100	0.001	0	0
900	P-151(2)(1	845	150	1.097	0.06	0.051
534	P-117(2)	993	100	-6.884	0.88	11.067
535	P-179	60	100	11	1.4	26.367
627	P-190	61	200	42.971	1.37	11.237
853	P-10(2)(1)(	1,370	150	50.073	2.83	60.578
769	P-201	19	150	16.2	0.92	7.494
762	P-200	21	400	92.867	0.74	1.604
754	P-198	13	400	67.96	0.54	0.897
731	P-196	46	250	16.75	0.34	0.66
603	P-37(2)(2)	885	150	34.092	1.93	29.725
604	P-187	26	150	-34.092	1.93	29.728
189	P-48	2,589	150	30.001	1.7	23.459
485	P-40(1)	3,762	100	10.999	1.4	26.361
718	P-195	10	400	-75.092	0.6	1.065
626	P-4(1)(2)(2	4,055	200	42.971	1.37	11.239
681	P-21(2)(2)(	1,942	250	75.2	1.53	10.685
683	P-194	252	250	-75.2	1.53	10.686
640	P-6(2)	5	150	10	0.57	3.055
643	P-106(2)	5	150	10	0.57	3.069
646	P-10(2)(2)	6	150	19.6	1.11	10.669
655	P-4(2)(2)(2	5	150	20.5	1.16	11.614
658	P-14(2)	7	150	20	1.13	11.063
661	P-114(2)	3	100	10	1.27	22.088
664	P-27(2)	2	250	10	0.2	0.287
667	P-29(2)	3	250	10	0.2	0.237
676	P-12(2)(2)	5	200	10	0.32	0.762
679	P-24(2)	5	200	10	0.32	0.76
682	P-21(2)(2)(	4	250	75.2	1.53	10.698
649	P-32(1)(2)	3	250	3.4	0.07	0
687	P-42(2)	6	100	10	1.27	22.095
690	P-83(2)	5	100	10	1.27	22.112
693	P-84(2)	7	100	10	1.27	22.1
696	P-63(2)	4	150	10	0.57	3.059
699	P-64(2)	7	150	10	0.57	3.064
702	P-85(2)	10	100	10	1.27	22.107
705	P-90(2)	8	100	10	1.27	22.102
708	P-78(2)	8	200	10	0.32	0.758
711	P-49(2)	6	150	10	0.57	3.061
714	P-50(2)	6	150	10	0.57	3.074
717	P-51(2)	8	150	10	0.57	3.074
721	P-41(2)	8	100	10	1.27	22.097
724	P-39(2)	8	100	11.85	1.51	30.251
727	P-38(2)	9	100	11.85	1.51	30.273
730	P-148(2)(2	9	150	3.53	0.2	0.445
734	P-47(2)(2)	13	150	3.53	0.2	0.451
737	P-144(2)	4	75	5	1.13	24.85
740	P-44(2)	4	150	3.53	0.2	0.434
743	P-20(2)(2)	7	150	3.53	0.2	0.451
746	P-59(2)	2	100	10	1.27	22.07
753	P-197	8	150	6.941	0.39	1.561
757	P-116(1)(1	1,847	150	6.941	0.39	1.56
758	P-199	9	150	-6.941	0.39	1.566
761	P-145(2)	20	150	0	0	0
765	P-53(2)	7	200	-10	0.32	0.728
768	P-16(1)(2)(	360	150	16.2	0.92	7.494
773	P-16(2)(2)	5	150	16.2	0.92	7.517
776	P-35(2)	5	80	0.5	0.1	0.249
779	P-18(2)	16	150	10	0.57	3.069
783	P-203	29	100	0.001	0	0
793	P-204(1)	324	80	2	0.4	3.326
786	P-205	11	100	0.001	0	0
790	P-206(1)	933	100	10	1.27	22.1
791	P-206(2)	5	100	10	1.27	22.093
794	P-204(2)	6	80	2	0.4	3.307
799	P-65(2)	1,763	150	36.826	2.08	34.291
828	P-210(1)	1,630	100	0.001	0	0
833	P-15(2)(2)(	710	100	0.001	0	0
813	P-10(2)(1)(	1,199	150	19.6	1.11	10.664
940	P-212(1)	750	100	30.473	3.88	174.021
817	P-66(2)	441	150	0	0	0
819	P-213	425	100	0	0	0
824	P-13(2)	582	150	2.73	0.15	0.277
826	P-215	239	152.4	0	0	0
829	P-210(2)	246	152.4	0.001	0	0
831	P-216	688	152.4	0.001	0	0
834	P-15(2)(2)(	280	100	0.001	0	0
836	P-217	1,839	80	0.001	0	0
841	P-108(2)	559	200	8.1	0.26	0.511
843	P-219	287	200	0.001	0	0
846	P-105(2)	192	100	9.78	1.25	21.208
848	P-220	736	100	0	0	0
854	P-10(2)(1)(	1,506	150	50.073	2.83	60.578
856	P-222	363	100	0	0	0
859	P-32(2)(2)	926	250	-6.6	0.13	0.118
861	P-223	8	100	0	0	0
864	P-92(1)(2)	455	160	0.001	0	0
866	P-224	52	152.4	0.001	0	0
869	P-26(2)(2)	2,133	250	20	0.41	0.919
871	P-225	416	90	0.001	0	0
878	P-227(2)	603	152.4	0.001	0	0
880	Pamtsho2_	824	152.4	0.001	0	0
886	P-99(2)	17	200	10.1	0.32	0.774
888	P-230	698	90	0	0	0
891	P-61(2)	982	150	7.61	0.43	1.849

893	P-231	1,007	90	0	0	0
896	P-57(2)	61	150	31.248	1.77	25.297
898	P-232	17	152.4	0	0	0
901	P-151(2)(2	578	150	1.097	0.06	0.051
903	P-233	197	90	0	0	0
906	P-81(2)	754	150	30	1.7	23.458
908	P-234	16	90	0	0	0
913	P-160(2)	1,690	100	3.88	0.49	3.827
915	P-236	31	90	0	0	0
920	P-75(2)(2)	56	100	0	0	0
922	P-238	81	80	0	0	0
927	P-66(1)(2)	79	150	0.001	0	0
929	P-240	88	150	0.001	0	0
932	P-67(2)(2)	1,944	100	-10.284	1.31	23.276
934	P-241	74	100	0.001	0	0
946	P-245	81	80	-1.69	0.34	2.435
941	P-212(2)	116	100	30.472	3.88	174.014
945	P-244	9	90	0	0	0
944	P-221(2)	129	90	0	0	0

ARUP

Job No. 289551 | Sheet No. Sheet number | Rev.
Member/Location: Member/Location
Drg. Ref. Drawing reference
Made by LZ | Date 26/05/2023 | Chd. IF
Job Title: Thimphu Water Services Masterplan
Calculation

2032 Scenario: Node pressure

ID	Label	X (m)	Y (m)	Elevation (m)	Demand (L/s)	Pressure (m H2O)
63	J-11	764,118.88	3,037,859.93	2,306.25	0	222.82
67	J-13	764,994.75	3,037,477.71	2,379.98	0	161.95
70	Olakha 2_PC2	764,091.47	3,038,212.79	2,393.29	1.12	148.59
72	J-15	764,722.36	3,036,334.19	2,757.00	0	-162.63
78	Debsi_PC1	760,439.73	3,037,252.66	2,475.54	2.89	180.74
115	J-27	763,086.87	3,039,176.30	2,367.53	0	156.57
128	J-31	761,550.64	3,039,496.04	2,390.52	0	95.61
131	J-32	761,528.39	3,039,306.87	2,430.19	0	58.13
134	Olokha 1	763,053.53	3,039,189.09	2,358.75	11.81	5.22
136	Olakha1a	763,062.80	3,039,176.63	2,359.47	11.81	4.51
138	J-35	763,268.30	3,038,052.00	2,304.86	0	181.09
143	J-37	761,385.95	3,036,513.60	2,288.11	0	370.17
146	J-38	763,209.68	3,033,510.97	2,640.00	0	19.57
151	J-39	760,566.79	3,048,382.11	2,500.38	0	20.05
155	J-41	760,444.69	3,048,527.23	2,523.06	0	53.99
159	J-43	760,458.67	3,048,463.66	2,515.64	0	5.24
165	J-44	758,318.59	3,041,995.88	2,590.85	0	235.71
171	J-45	760,218.30	3,040,087.93	2,479.05	0	37.31
179	J-46	759,066.26	3,044,620.53	2,465.35	0	6.61
188	J-48	759,642.77	3,041,906.29	2,437.68	0	370.81
200	J-50	760,321.97	3,044,993.07	2,361.50	0	178.21
204	J-51	761,309.09	3,043,589.71	2,423.13	0	29.3
206	J-52	761,148.08	3,043,618.75	2,399.27	0	48.43
214	Upper Taba	760,952.29	3,045,755.26	2,404.68	7.91	122.46
218	J-54	761,780.43	3,041,091.48	2,402.77	0	40.36
224	J-55	762,556.72	3,039,587.05	2,327.92	0	1.39
226	J-56	761,786.39	3,041,087.77	2,402.80	0	2.18
227	Changdelo_PC1	760,679.73	3,040,887.03	2,351.08	0	53.8
232	J-58	762,528.51	3,039,581.26	2,323.98	0	4.94
233	J-59	760,087.09	3,041,513.77	2,371.39	0	3.62
244	Changjiji Demand_PC1	762,151.61	3,039,520.56	2,279.98	0.01	48.92
246	Bhutan Hospital	762,631.99	3,039,641.73	2,362.94	0	41.67
249	J-63	759,655.78	3,041,927.41	2,436.39	0	83.46
254	J-64	760,076.99	3,041,131.75	2,396.54	0	15.19
257	J-65	760,523.56	3,040,395.63	2,391.35	0	9.38
269	J-66	760,331.89	3,042,137.06	2,359.01	0	17.94
275	J-67	762,568.91	3,039,091.00	2,291.44	0	72.39
277	J-68	762,337.84	3,039,309.18	2,289.19	0	74.64
279	J-69	762,913.17	3,038,694.17	2,279.63	0	84.18
281	J-70	763,384.81	3,038,634.82	2,343.90	0	20.05
283	J-71	762,706.39	3,039,285.77	2,316.26	0	47.62
286	Dangrina_PC1	760,802.11	3,047,749.34	2,425.87	6.42	50.37
288	Dangrina proposed	760,513.32	3,048,483.79	2,514.90	9.3	5.84
290	Satellite Town_PC1	761,562.99	3,047,981.72	2,380.91	0.46	17.05
292	Lower Taba_PC1	760,912.88	3,045,807.98	2,402.46	6.87	126.99
294	Lango Residents 1	761,024.89	3,043,672.81	2,384.74	2.7	16.44
298	Langho Res1_PC1	760,484.04	3,043,685.87	2,314.94	0	111.44
300	YHS Residents	761,605.40	3,041,158.13	2,387.08	7.74	15.03
302	Changjiji Residents Demar	761,992.32	3,039,937.83	2,310.59	12.74	15.18
304	Above Old Highway Dema	762,388.78	3,036,764.87	2,385.80	6.42	8.87
307	J-82	763,000.28	3,037,793.73	2,308.10	0	156.18
311	Bebesa Left Demand 2	763,192.43	3,038,106.06	2,294.68	12.86	11.69
313	Bebesa Left_PC1	761,850.25	3,037,311.43	2,264.80	6.43	41.6
315	J-85	763,819.94	3,036,963.52	2,587.49	0	-17.78
318	Simtokha E4 Demand	763,896.40	3,037,056.79	2,559.08	3.5	10.52
320	Simtoka Upper 1_PC1	763,331.45	3,037,349.05	2,458.12	0.87	62.65
322	Simtokha Upper 1_PC2	762,708.09	3,037,403.33	2,308.64	0.87	211.76
325	Lango Res1_PC2	761,047.61	3,043,598.41	2,386.85	0.01	14.37
331	Bangdu Residents_PC1	761,578.82	3,039,158.04	2,428.10	2.17	3.82
334	J-92	761,343.57	3,039,430.31	2,488.86	0	-0.39
349	Changzamtog Demand 2	761,399.49	3,039,558.15	2,427.70	8.12	56.41
351	Hejo& Kawajangsa_PC2	760,407.82	3,043,922.64	2,316.24	2.72	82.45
357	J-97	761,054.17	3,044,126.19	2,377.18	0	85.51
361	J-98	760,396.89	3,044,941.82	2,356.19	0	3.8
374	J-100	760,450.15	3,044,936.23	2,353.70	0	47.2
380	J-101	760,379.99	3,044,955.61	2,356.68	0	3.28
383	J-102	760,386.72	3,044,930.46	2,357.32	0	32.34
399	J-104	760,553.00	3,040,398.73	2,387.11	0	5.98
404	J-105	760,054.26	3,041,482.39	2,370.63	0	3.26
415	J-108	758,382.11	3,042,032.19	2,583.62	0	-1.84
422	Taba / Dotena	761,474.11	3,045,679.81	2,533.35	0	6.7
424	J-112	760,297.08	3,045,020.63	2,360.81	0	165.11
429	Pamtsho_PC1	760,303.74	3,046,709.65	2,564.66	6.5	-82.15
434	J-117	759,745.29	3,043,709.89	2,451.02	0	-1.71
439	J-119	759,776.42	3,043,705.43	2,436.35	0	12.89
442	Hejo & Kawajangsa_PC1	760,046.89	3,044,313.59	2,417.12	2.72	31.87
445	Kawajangsa and Zilukha_I	759,590.95	3,043,424.69	2,451.37	4.17	-9.24
447	J-122	759,741.74	3,042,529.17	2,446.23	0	94.46
449	Town Area 1 Demand	759,934.58	3,042,599.10	2,393.55	6.01	141.23
452	Norzin Wog_PC1	760,434.23	3,042,234.65	2,351.90	16.49	-1.06
454	J-125	761,264.69	3,040,163.06	2,305.76	0	24.85
457	Changzamtog Demand 1	761,272.04	3,040,131.04	2,305.95	8.12	24.17
460	Changedaphu & UChangz	760,897.74	3,039,985.82	2,382.90	23.48	85.29
463	Changbangdu - BHs	761,353.45	3,039,416.84	2,488.98	0	-0.28
467	Jungshina	760,376.27	3,044,970.08	2,357.77	0	2.22
468	Ziluka _PC1	760,603.51	3,043,112.32	2,314.12	0.42	86.63
470	J-136	759,674.27	3,042,093.32	2,430.89	0	89.08
473	Town Area 1_PC1	760,375.62	3,042,631.67	2,347.52	6.01	163.1
475	Town Area 2a	760,492.18	3,041,462.19	2,335.14	4.16	36.27
477	Town Area 2_PC2	760,924.41	3,041,040.67	2,313.18	4.16	37.82
479	J-140	759,676.62	3,041,912.72	2,432.94	0	5.9
480	Town Area 2c	760,287.79	3,041,682.73	2,356.47	4.16	78.18
482	Upper Mothiang Demand	758,872.79	3,041,988.83	2,522.41	20.29	9.68
484	J-143	759,923.06	3,040,755.22	2,453.51	0	112.17
487	Above RICB Demand	759,943.07	3,040,768.73	2,452.84	4.42	112.72
489	Above RICB Tank a	760,062.17	3,041,105.88	2,399.98	2	2.01
491	J-146	760,241.64	3,040,092.09	2,477.61	0	2.27
492	Changedaphu & UChangz	761,619.05	3,040,031.16	2,287.55	11	185.04
494	J-148	760,556.76	3,040,397.66	2,387.04	0	5.69
497	Changdelo_PC2	761,335.27	3,040,377.10	2,290.78	6.65	91.06
499	Changdelo Demand 2	760,659.45	3,040,786.44	2,353.19	6.65	25.39
501	J-151	761,619.09	3,040,392.20	2,314.22	0	90.3
510	Bangdu Area left_PC1	762,090.51	3,038,962.40	2,405.02	4.11	-15.52
516	Bebesa Right_PC1	761,598.56	3,036,529.10	2,329.80	3.74	3.85
518	J-157	761,375.13	3,036,330.99	2,305.19	0	353.14
521	Gangchey Nyezergang_P(	760,866.82	3,036,196.70	2,252.43	4.75	402.87
532	J-160	760,847.04	3,039,952.85	2,410.33	0	64.4
548	J-162	763,275.08	3,033,563.22	2,644.00	0	15.49
575	Bebena 1_PC1	760,350.72	3,044,483.92	2,345.83	0.01	120.23
578	Bebena 1a Demand	759,260.84	3,044,773.37	2,441.47	10.73	24.17
601	J-168	757,564.56	3,042,096.37	2,675.00	0	193.37
605	J-169	757,550.83	3,042,074.31	2,682.00	0	187.6
624	J-172	767,183.67	3,033,559.92	2,915.00	0	-12.72
632	J-173	767,809.18	3,035,688.01	2,792.00	0	-3.04
651	Simtoka Upper 2b_PC	763,016.48	3,036,669.73	2,537.68	2.99	19.42
750	J-176	761,147.43	3,043,624.77	2,399.49	0	1.71
755	J-177	760,395.40	3,044,933.85	2,356.20	0	33.52
766	J-178	760,123.92	3,048,687.37	2,573.00	0	6.84
782	Luding Demand 1	763,846.55	3,039,059.53	2,634.50	2.63	10.42
785	Lubding Demand 2	763,921.25	3,038,737.26	2,513.27	2.63	5.7
797	J-182	761,599.65	3,040,713.58	2,396.84	0	-7.06
804	J-185	761,061.79	3,036,909.98	2,290.16	0	367.93
807	Rama _PC2	759,847.66	3,035,658.15	2,244.00	0	414
809	Town Area 1.1	760,491.21	3,041,163.14	2,357.57	6.01	66.77
811	J-188	762,165.23	3,035,991.09	2,498.29	0	127.01
815	J-189	761,100.29	3,040,938.84	2,299.88	0	104.89
818	Changdelo 1a	761,184.30	3,040,535.49	2,305.04	0	99.74
822	J-191	764,380.46	3,037,901.85	2,346.00	0	195.81
825	Olakha 2_PC1	764,178.80	3,037,879.71	2,307.88	0	233.86
827	J-193	759,800.25	3,035,899.49	2,274.00	0	384.06
830	Rama_PC1	759,218.61	3,036,266.35	2,381.00	0	277.28
832	J-195	760,642.46	3,037,372.92	2,463.08	0	193.79
835	Debsi_PC2	760,435.22	3,036,250.18	2,249.97	0	406.47
837	Bebesa Right_PC2	761,369.59	3,036,912.39	2,263.39	3.74	68.15

2032 Scenario: Pipeline hydraulics

ID	Label	Length (Scaled) (m)	Diameter (mm)	Flow (L/s)	Velocity (m/s)	Headloss Gradient (m/km)
68	P-11(1)	2,096.00	350.00	192.302	2	11.808
321	P-110	411.00	100.00	0.87	0.11	0.24
323	P-111	702.00	100.00	0.87	0.11	0.24
845	P-105(1)	149.00	100.00	6.42	0.82	9.727
979	P-6(1)(1)	5.00	150.00	10	0.57	3.062
517	P-176	95.00	100.00	3.74	0.48	3.576
838	P-218	650.00	100.00	3.74	0.48	3.576
116	P-12(1)	1,871.00	200.00	20	0.64	2.726
974	P-26(1)(1)	569.00	250.00	171.182	3.49	49.022
69	P-11(2)	1,090.00	350.00	191.182	1.99	11.681
823	P-13(1)	852.00	150.00	1.12	0.06	0.053
316	P-4(2)(1)	1,112.00	200.00	61.63	1.96	21.916
657	P-14(1)	1,664.00	150.00	29.011	1.64	22.046
652	P-193	199.00	152.40	2.99	0.16	0.304
287	P-96	684.00	100.00	6.42	0.82	9.726
1009	P-264(1)	941.00	200.00	9.54	0.3	0.692
576	P-46(1)	1,807.00	160.00	0.01	0	0
675	P-12(2)(1)	9.00	200.00	10	0.32	0.748
678	P-24(1)	17.00	200.00	10	0.32	0.75
135	P-30	20.00	200.00	11.812	0.38	1.03
1003	P-266	253.00	100.00	0.001	0	0
137	P-31	13.00	200.00	11.81	0.38	1.029
332	P-115	211.00	100.00	2.17	0.28	1.305
660	P-114(1)	757.00	100.00	10	1.27	22.1
132	P-28	217.00	200.00	(N/A)	(N/A)	(N/A)
938	P-243	402	152.4	0	0	0
666	P-29(1)	3	250	10	0.2	0.243
863	P-92(1)(1)	139	160	0.002	0	0
282	P-95	664	200	0	0	0
648	P-32(1)(1)	456	250	167.931	3.42	47.312
868	P-26(2)(1)	669	250	0.001	0	0
805	P-15(2)(1)	614	150	2.891	0.16	0.308
519	P-33(1)	3664	250	7.641	0.16	0.155
558	P-184	84	250	21.1	0.43	1.017
637	P-192	87	250	-28.742	0.59	1.798
289	P-97	94	150	9.3	0.53	2.682
770	P-202	36	150	10	0.57	3.07
775	P-35(1)	1137	80	0.5	0.1	0.255
947	P-245	99	80	5.321	1.06	20.373
778	P-18(1)	966	150	10	0.57	3.066
291	P-98	81	150	0.46	0.03	0.011
873	P-226	188	90	0	0	0
772	P-16(2)(1)	28	150	16.2	0.92	7.492
161	P-17(2)	136	150	10	0.57	3.066
177	P-43	3877	100	20.045	2.55	80.116
723	P-39(1)	19	152.4	11.85	0.65	3.888
726	P-38(1)	14	100	11.85	1.51	30.271
686	P-42(1)	9	100	10	1.27	22.094
720	P-41(1)	15	100	10	1.27	22.089
987	P-256	13	100	15.765	2.01	51.336
821	P-214	20	100	4.818	0.61	5.711
579	P-45(1)	240	160	10.73	0.53	2.552
435	P-47(1)	1700	110	9.78	1.03	13.331
739	P-44(1)	7	150	3.53	0.2	0.434
742	P-20(2)(1)	11	150	3.53	0.2	0.446
736	P-144(1)	207	75	5	1.13	24.858
710	P-49(1)	8	150	10	0.57	3.042
713	P-50(1)	9	150	10	0.57	3.054
716	P-51(1)	13	150	10	0.57	3.064
537	P-181	23	100	5.136	0.65	6.43
905	P-81(1)	407	150	30	1.7	23.458
352	P-124	1081	100	2.72	0.35	1.983
375	P-52(1)(1)(1)	1,565	150	0	0	0
529	P-151(1)	16	100	0.514	0.07	0.095
219	P-62	3403	200	20	0.64	2.726
895	P-57(1)	125	150	31.248	1.77	25.296
213	P-60	238	100	21.248	2.71	89.244
745	P-59(1)	3	100	10	1.27	22.119
295	P-100	150	150	2.7	0.15	0.272
328	P-113	105	80	0.01	0	0
299	P-102	969	63	0	0	0
425	P-77(1)	1505	200	19.05	0.61	2.491
764	P-53(1)	4	200	-10	0.32	0.75
885	P-99(1)	768	200	6.87	0.22	0.377
890	P-61(1)	332	150	7.91	0.45	1.986
695	P-63(1)	4	150	10	0.57	3.058
698	P-64(1)	10	150	10	0.57	3.063
248	P-76	6	150	8.802	0.5	2.413
924	P-239	50	80	0	0	0
798	P-65(1)	444	150	36.83	2.08	34.297
241	P-71	7	100	14.689	1.87	45.055
242	P-72	8	100	13.795	1.76	40.105
243	P-73	20	100	8.346	1.06	15.815
301	P-103	207	100	7.74	0.99	13.751
502	P-75(1)	828	100	1.061	0.14	0.347
926	P-66(1)(1)	732	150	0.002	0	0
245	P-74	692	150	0.01	0	0
238	P-68	16	100	-4.322	0.55	4.678
239	P-69	22	100	-3.647	0.46	3.416
240	P-70	30	100	-3.049	0.39	2.451
303	P-104	651	150	12.74	0.72	4.802
455	P-67(1)	2043	100	-1.723	0.22	0.851
264	P-86	27	100	13.37	1.7	37.843
265	P-87	40	100	10.815	1.38	25.552
396	P-135	29	80	2.092	0.42	3.613
397	P-136	19	80	2.603	0.52	5.416
476	P-159	577	100	4.161	0.53	4.356
707	P-78(1)	5	200	10	0.32	0.735
258	P-82	995	150	20	1.13	11.07
701	P-85(1)	13	100	10	1.27	22.092
490	P-164	9	100	2	0.25	1.118
689	P-83(1)	7	100	10	1.27	22.116
692	P-84(1)	12	100	10	1.27	22.107
495	P-166	23	100	6.943	0.88	11.241
496	P-167	27	100	6.357	0.81	9.548
273	P-91	801	250	34.029	0.69	2.46
704	P-90(1)	8	100	10	1.27	22.104
453	P-154	164	100	16.49	2.1	55.806
912	P-160(1)	359	100	4.16	0.53	4.355
278	P-93	318	110	0	0	0
280	P-94	529	110	0	0	0
285	P-92(2)	239	160	0.001	0	0
312	P-107	505	200	12.86	0.41	1.203
840	P-108(1)	986	200	6.43	0.2	0.333
642	P-106(1)	8	150	10	0.57	3.058
858	P-32(2)(1)	651	250	157.93	3.22	42.226
319	P-109	121	150	3.5	0.2	0.439
654	P-4(2)(2)(1)	605	150	58.13	3.29	79.858
340	P-118	17	100	-7.715	0.98	13.66
989	P-258	185	150	10	0.57	3.067
350	P-123	185	100	8.12	1.03	15.028
964	P-253	79	80	1.49	0.3	1.927
359	P-56(2)	666	200	51.248	1.63	15.574
360	P-126	2393	150	31.619	1.79	25.855
363	P-52(2)	35	150	0	0	0
373	P-127	18	100	0	0	0
378	P-129	14	100	0	0	0
370	P-52(1)(2)	15	100	0	0	0
377	P-128	39	100	0	0	0
379	P-130	40	100	0	0	0
376	P-52(1)(1)(2)	39	100	0	0	0
387	P-89(2)(1)(1)	12	250	0	0	0
391	P-131	15	152.4	0	0	0
393	P-133	13	152.4	29.43	1.61	20.96

839	J-198	762,294.91	3,037,371.34	2,280.85	0	25.77
842	Bebesa Left_PC2	762,320.58	3,037,187.46	2,311.27	0	-4.58
844	J-200	762,361.42	3,036,884.43	2,377.91	0	18.6
847	Above Old Highway Dema	761,726.57	3,037,092.61	2,264.04	0	132.25
850	Serbithang_PC1	761,670.37	3,036,462.73	2,345.02	0.75	279.79
852	J-204	762,779.65	3,034,747.27	2,519.65	0	122.88
855	Serbithang_PC2	763,021.62	3,035,017.70	2,634.70	0.75	8.05
857	J-206	762,632.60	3,037,430.70	2,305.97	0	130.86
860	Simtokha Upper 2b_PC2	762,637.10	3,037,436.71	2,305.16	0	131.67
862	J-208	763,002.65	3,039,314.24	2,344.38	0	19.56
865	J-209	763,050.22	3,039,335.70	2,367.75	0	-3.76
867	J-210	762,978.88	3,038,534.41	2,280.10	0	205.8
870	Olakha 1_PC1	762,916.19	3,038,370.99	2,274.50	0	211.39
872	Satellite Town_PC2	761,574.68	3,048,215.92	2,393.49	0	4.5
874	Pamtsho_PC2	760,513.38	3,045,930.64	2,338.45	0	106.18
876	J-214	760,382.60	3,046,047.78	2,359.60	0	85.07
879	Pamtsho 2_PC1	760,595.12	3,045,476.93	2,331.83	3.04	93.78
882	Pamtsho2_PC2	759,907.65	3,045,359.03	2,473.73	3.04	-46.28
884	J-218	760,929.45	3,045,813.00	2,403.78	0	125.68
887	Lower Taba_PC2	760,672.26	3,046,292.66	2,360.23	0	169.14
889	J-220	761,567.35	3,045,903.46	2,498.77	0	30.51
892	Upper Taba_PC	761,151.31	3,046,515.51	2,391.94	0	137.12
894	J-222	761,188.38	3,043,585.34	2,406.91	0	42.34
897	Lang 2_PC1	761,192.29	3,043,601.97	2,407.48	0	41.77
899	J-224	759,867.39	3,043,014.07	2,416.91	0	123.72
902	Kawajangsa and Zilukha_I	760,038.10	3,043,112.02	2,357.72	0	182.8
904	J-226	759,835.02	3,041,718.68	2,410.42	0	19
907	Upper Motihang_PC	759,819.36	3,041,716.77	2,412.82	0	16.61
909	Upper Motihang_PC2	758,333.90	3,041,893.22	2,594.83	0	-13.03
911	J-229	760,282.72	3,041,787.46	2,364.11	0	-5.66
914	Town Area 2_PC1	760,304.24	3,041,798.22	2,363.23	0	-4.79
916	Norzin Wog_PC2	761,111.67	3,041,238.63	2,298.01	0	73.33
918	J-232	762,581.84	3,039,665.86	2,361.98	0	42.63
923	YHS Res_PC1	761,805.84	3,041,140.16	2,408.97	0	-3.96
925	J-235	761,175.06	3,040,950.54	2,301.85	0	102.93
928	YHS Res_PC2	761,201.33	3,040,866.96	2,293.33	0	111.43
930	J-237	761,164.94	3,040,228.87	2,315.68	0	17.58
933	Changdelo_PC	761,197.65	3,040,162.27	2,311.94	0	21.3
935	Changedaphu & UChangz	761,285.73	3,039,394.71	2,493.83	1.49	-6.97
937	Bangdu Residents_PC2	761,743.06	3,039,281.11	2,358.47	0	127.59
939	J-241	761,556.09	3,036,390.81	2,354.33	0	270.54
942	J-242	761,558.29	3,036,399.08	2,371.99	0	252.92
946	J-243	760,538.51	3,048,562.02	2,516.00	0	2.98
948	Community supply_PC1	760,478.33	3,048,648.25	2,515.00	2.84	3.31
950	Community supply_PC2	761,541.10	3,048,250.52	2,398.00	2.48	115.55
952	J-246	762,949.84	3,039,668.76	2,369.00	0	-52.9
954	Changjiji 2_PC1	762,988.69	3,039,501.02	2,410.00	3.42	-95.36
956	Changjiji 2_PC2	763,890.80	3,040,384.21	2,594.00	3.42	-288.05
966	J-250	766,583.83	3,034,289.98	2,872.42	0	-145.33
969	J-251	766,639.62	3,035,362.09	2,650.58	0	35.32
973	J-252	763,587.01	3,038,043.30	2,305.36	0	195.86
976	J-253	763,402.87	3,038,166.20	2,310.00	3.25	190.71
984	J-254	760,231.35	3,040,087.41	2,477.16	0	38.53
990	J-255	761,792.67	3,048,878.67	0	0	2,513.91
992	Community supply PC1	762,079.55	3,048,775.52	2,568.00	0	-48.92
994	Community supply PC2	761,615.39	3,049,036.61	2,410.00	0	108.76
1000	J-259	759,642.18	3,043,289.82	0	0	2,453.05
1002	J-260	763,307.27	3,039,096.98	0	0	2,359.24
1004	J-261	763,835.90	3,038,189.29	0	0	2,359.24
1006	J-262	763,841.06	3,039,027.36	0	0	2,359.24
1008	J-263	760,298.52	3,046,713.53	2,460.27	0	22.04
1014	YHS2_PC2	762,022.63	3,040,765.35	2,520.00	0	-115.07
1016	YHS2_PC1	761,704.77	3,040,176.10	2,280.00	1.06	124.44

385	P-89(2)(2)	3214	250	44.029	0.9	3.965
388	P-89(2)(1)(2)	14	250	0	0	0
392	P-132	16	152.4	0	0	0
394	P-134	14	152.4	29.43	1.61	20.96
401	P-138	19	80	2.499	0.5	5.022
402	P-139	25	80	2.196	0.44	3.956
410	P-137(1)	30	80	4.695	0.93	16.156
411	P-137(2)	1490	80	4.695	0.93	16.155
416	P-141	2795	80	-8.093	1.61	44.284
1001	P-265	24	152.4	0	0	0
417	P-142	57	80	-17.149	3.41	177.939
418	P-143	54	80	-16.73	3.33	169.963
483	P-162	606	100	20.29	2.58	81.937
910	P-235	235	152.4	0.001	0	0
201	P-54	1,516	200	0.001	0	0
358	P-56(1)	2,036	200	82.867	2.64	37.924
877	P-227(1)	475	150	3.04	0.17	0.338
883	P-229	763	63	3.04	0.98	23.125
471	P-77(2)(1)	3380	200	16.01	0.51	1.806
760	P-145(1)	1179	150	3.04	0.17	0.338
440	P-148(1)	31	150	6.25	0.35	1.283
733	P-47(2)(1)	25	150	3.53	0.2	0.441
443	P-149	755	150	2.72	0.15	0.275
729	P-148(2)(1)	255	150	3.53	0.2	0.446
446	P-150	142	150	4.17	0.24	0.607
450	P-152	228	80	6.01	1.2	25.522
451	P-153	1891	80	-5.496	1.09	21.629
458	P-155	33	100	8.12	1.03	15.029
931	P-67(2)(1)	122	100	-9.843	1.25	21.461
341	P-119	22	100	-7.715	0.98	13.67
381	P-89(1)	15	250	29.431	0.6	1.882
469	P-157	1151	100	-0.42	0.05	0.062
472	P-77(2)(2)	173	200	10	0.32	0.755
474	P-158	1,069	100	6.01	0.77	8.607
917	P-237	1398	152.4	0.001	0	0
481	P-161	928	100	4.16	0.53	4.355
538	P-182	24	100	-5.034	0.64	6.197
810	P-211	1670	100	6.01	0.77	8.607
486	P-40(2)	968	100	15.72	2	51.078
488	P-163	24	100	4.42	0.56	4.882
493	P-165	1,893	150	11	0.62	3.659
536	P-180	13	100	-6.182	0.79	9.065
498	P-168	1033	100	6.65	0.85	10.381
500	P-169	458	80	6.65	1.32	30.783
919	P-75(2)(1)	1258	100	0	0	0
1015	P-271	550	152.4	0	0	0
1017	P-272	232	152.4	1.06	0.06	0.038
511	P-173	124	100	4.11	0.52	4.258
520	P-33(2)	187	200	2.891	0.09	0.075
522	P-177	526	100	4.75	0.6	5.567
900	P-151(2)(1)	845	150	0.514	0.03	0.013
534	P-117(2)	996	100	-7.715	0.98	13.668
535	P-179	60	100	23.48	2.99	107.38
853	P-10(2)(1)(1)(1)	1370	150	21.1	1.19	12.225
769	P-201	19	150	16.2	0.92	7.494
762	P-200	21	400	92.868	0.74	1.604
754	P-198	13	400	29.43	0.23	0.189
731	P-196	46	250	16.84	0.34	0.67
603	P-37(2)(2)	885	150	43.746	2.48	47.17
604	P-187	26	150	-43.746	2.48	47.176
189	P-48	2589	150	30.001	1.7	23.459
485	P-40(1)	3762	100	20.14	2.56	80.819
718	P-195	10	400	-93.887	0.75	1.628
967	P-4(1)(2)(2)(1)	1094	200	180.535	5.75	160.407
683	P-194	252	250	-214.915	4.38	74.71
970	P-21(2)(2)(1)(1)	1215	250	214.915	4.38	74.71
640	P-6(2)	5	150	10	0.57	3.055
643	P-106(2)	5	150	10	0.57	3.069
646	P-10(2)(2)	6	150	19.6	1.11	10.669
655	P-4(2)(2)(2)	5	150	58.129	3.29	79.848
658	P-14(2)	7	150	29.012	1.64	22.046
661	P-114(2)	3	100	10	1.27	22.088
667	P-29(2)	3	250	10	0.2	0.237
676	P-12(2)(2)	5	200	10	0.32	0.762
679	P-24(2)	5	200	10	0.32	0.76
682	P-21(2)(2)(2)	4	250	304.809	6.21	142.724
649	P-32(1)(2)	3	250	167.93	3.42	47.297
687	P-42(2)	6	100	10	1.27	22.095
690	P-83(2)	5	100	10	1.27	22.112
693	P-84(2)	7	100	10	1.27	22.1
696	P-63(2)	4	150	10	0.57	3.059
699	P-64(2)	7	150	10	0.57	3.064
702	P-85(2)	10	100	10	1.27	22.107
705	P-90(2)	8	100	10	1.27	22.102
708	P-78(2)	8	200	10	0.32	0.758
711	P-49(2)	6	150	10	0.57	3.061
714	P-50(2)	6	150	10	0.57	3.074
717	P-51(2)	8	150	10	0.57	3.074
721	P-41(2)	8	100	10	1.27	22.097
724	P-39(2)	8	152.4	11.85	0.65	3.886
727	P-38(2)	9	100	11.85	1.51	30.273
730	P-148(2)(2)	9	150	3.53	0.2	0.445
734	P-47(2)(2)	13	150	3.53	0.2	0.451
737	P-144(2)	4	75	5	1.13	24.85
740	P-44(2)	4	150	3.53	0.2	0.434
743	P-20(2)(2)	7	150	3.53	0.2	0.451
746	P-59(2)	2	100	10	1.27	22.07
753	P-197	8	150	-14.598	0.83	6.17
757	P-116(1)(1)(2)	1847	150	-14.598	0.83	6.179
758	P-199	9	150	14.598	0.83	6.183
761	P-145(2)	20	150	3.04	0.17	0.335
765	P-53(2)	7	200	-10	0.32	0.728
768	P-16(1)(2)(2)	360	150	16.2	0.92	7.494
773	P-16(2)(2)	5	150	16.2	0.92	7.517
776	P-35(2)	5	80	0.5	0.1	0.249
779	P-18(2)	16	150	10	0.57	3.069
783	P-203	29	100	2.63	0.33	1.864
793	P-204(1)	324	80	2	0.4	3.326
786	P-205	11	100	2.63	0.33	1.853
790	P-206(1)	933	100	10	1.27	22.1
791	P-206(2)	5	100	10	1.27	22.093
794	P-204(2)	6	80	2	0.4	3.307
799	P-65(2)	1763	150	36.83	2.08	34.297
828	P-210(1)	1630	152.4	0.001	0	0
833	P-15(2)(2)(1)	710	100	2.89	0.37	2.218
813	P-10(2)(1)(2)	1199	150	19.6	1.11	10.664
940	P-212(1)	750	100	0.75	0.1	0.183
817	P-66(2)	441	150	0	0	0
819	P-213	425	152.4	0	0	0
824	P-13(2)	582	150	1.12	0.06	0.053
826	P-215	239	152.4	0	0	0
829	P-210(2)	246	152.4	0.001	0	0
831	P-216	688	152.4	0.001	0	0
834	P-15(2)(2)(2)	280	100	2.89	0.37	2.218
836	P-217	1839	80	0.001	0	0
841	P-108(2)	559	200	6.43	0.2	0.333
843	P-219	287	152.4	0	0	0
846	P-105(2)	192	100	6.42	0.82	9.726
848	P-220	736	152.4	0	0	0
854	P-10(2)(1)(1)(2)	1506	150	20.35	1.15	11.432
856	P-222	363	152.4	0.75	0.04	0.023
859	P-32(2)(2)	926	250	157.93	3.22	42.226
861	P-223	8	152.4	0	0	0
864	P-92(1)(2)	455	160	0.002	0	0
866	P-224	52	152.4	0	0	0
869	P-26(2)(2)	2132	250	0	0	0
871	P-225	416	90	0	0	0
878	P-227(2)	603	75	0	0	0

880	Pamtsho2_PC	824	63	3.04	0.98	23.125
886	P-99(2)	17	200	6.87	0.22	0.378
888	P-230	698	90	0	0	0
891	P-61(2)	982	150	7.91	0.45	1.986
893	P-231	1007	90	0	0	0
896	P-57(2)	61	150	31.248	1.77	25.297
898	P-232	17	152.4	0	0	0
901	P-151(2)(2)	578	150	0.514	0.03	0.012
903	P-233	197	90	0.001	0	0
906	P-81(2)	754	150	30	1.7	23.458
908	P-234	16	90	0	0	0
913	P-160(2)	1690	100	4.16	0.53	4.355
915	P-236	31	90	0	0	0
920	P-75(2)(2)	56	100	0.001	0	0
927	P-66(1)(2)	79	150	0.001	0	0
929	P-240	88	152.4	0.001	0	0
932	P-67(2)(2)	1944	100	-9.843	1.25	21.464
934	P-241	74	152.4	0	0	0
945	P-244	9	152.4	0.75	0.04	0.035
982	P-212(2)(1)	110	100	0	0	0
944	P-221(2)	129	90	0.75	0.12	0.305
949	P-246	105	80	2.84	0.56	6.366
951	P-247	1050	80	2.48	0.49	4.954
991	P-259	1294	152.4	0.001	0	0
955	P-249	172	80	3.42	0.68	8.984
957	P-250	1182	80	3.42	0.68	8.984
958	P-251	401	80	-6.84	1.36	32.431
968	P-4(1)(2)(2)(2)	2965	200	90.641	2.89	44.776
972	P-254	1074	200	89.894	2.86	38.018
971	P-21(2)(2)(1)(2)	728	250	304.808	6.21	142.705
975	P-26(1)(2)	323	250	167.932	3.42	47.312
977	Workshop	221	100	3.25	0.41	2.376
980	P-6(1)(2)	1205	150	10	0.57	3.067
983	P-212(2)(2)	6	90	0	0	0
986	P-117(1)(2)	797	100	15.765	2.01	51.35
993	P-260	305	152.4	0.001	0	0
995	P-261	237	152.4	0.001	0	0
1005	P-267	1050	80	0.001	0	0
1007	P-268	538	80	0.001	0	0
1013	P-270	7	152.4	6.5	0.36	1.099
1019	P-264(2)(1)	840	250	3.04	0.06	0.028
1020	P-264(2)(2)	23	200	3.04	0.1	0.084
627	P-190	61	200	180.535	5.75	160.406

Job No. 289551 | Sheet No. Sheet number | Rev.
Member/Location | Drawing reference
Drg. Ref. | Made by LZ | Date 26/05/2023 | Chd. IF
Job Title: Thimphu Water Services Masterplan
Calculation

ARUP

2047 Scenario: Node pressure

ID	Label	X (m)	Y (m)	Elevation (m)	Demand (L/s)	Pressure (m H2O)
63	J-11	764,118.88	3,037,859.93	2,306.25	0	220.68
67	J-13	764,994.75	3,037,477.71	2,379.98	0	160.48
70	Olakha 2_PC2	764,091.47	3,038,212.79	2,393.29	1.86	147
72	J-15	764,722.36	3,036,334.19	2,757.00	0	-164.01
78	Debsi_PC1	760,439.73	3,037,252.66	2,475.54	14.75	114.27
115	J-27	763,086.87	3,039,176.30	2,367.53	0	154.44
128	J-31	761,550.64	3,039,496.04	2,390.52	0	90.22
131	J-32	761,528.39	3,039,306.87	2,430.19	0	58.13
134	Olokha 1	763,053.53	3,039,189.09	2,358.75	19.28	5.19
136	Olakha1a	763,062.80	3,039,176.63	2,359.47	19.28	4.49
138	J-35	763,268.30	3,038,052.00	2,304.86	0	176.42
143	J-37	761,385.95	3,036,513.60	2,288.11	0	359
146	J-38	763,209.68	3,033,510.97	2,640.00	0	19.13
151	J-39	760,566.79	3,048,382.11	2,500.38	0	20.05
155	J-41	760,444.69	3,048,527.23	2,523.06	0	53.99
159	J-43	760,458.67	3,048,463.66	2,515.64	0	5.24
165	J-44	758,318.59	3,041,995.88	2,590.85	0	235.49
171	J-45	760,218.30	3,040,087.93	2,479.05	0	33.59
179	J-46	759,066.26	3,044,620.53	2,465.35	0	6.6
188	J-48	759,642.77	3,041,906.29	2,437.68	0	370.81
200	J-50	760,321.97	3,044,993.07	2,361.50	0	178.21
204	J-51	761,309.09	3,043,589.71	2,423.13	0	29.3
206	J-52	761,148.08	3,043,618.75	2,399.27	0	48.43
214	Upper Taba	760,952.29	3,045,755.26	2,404.68	14.5	117.06
218	J-54	761,780.43	3,041,091.48	2,402.77	0	40.36
224	J-55	762,556.72	3,039,587.05	2,327.92	0	1.39
226	J-56	761,786.39	3,041,087.77	2,402.80	0	2.16
227	Changdelo_PC1	760,679.73	3,040,887.03	2,351.08	0	53.78
232	J-58	762,528.51	3,039,581.26	2,323.98	0	4.67
233	J-59	760,087.09	3,041,513.77	2,371.39	0	3.54
244	Changjiji Demand_PC1	762,151.61	3,039,520.56	2,279.98	0.01	48.92
246	Bhutan Hospital	762,631.99	3,039,641.73	2,362.94	0	41.65
249	J-63	759,655.78	3,041,927.41	2,436.39	0	76.67
254	J-64	760,076.99	3,041,131.75	2,396.54	0	15.19
257	J-65	760,523.56	3,040,395.63	2,391.35	0	9.38
269	J-66	760,331.89	3,042,137.06	2,359.01	0	17.87
275	J-67	762,568.91	3,039,091.00	2,291.44	0	72.36
277	J-68	762,337.84	3,039,309.18	2,289.19	0	74.61
279	J-69	762,913.17	3,038,694.17	2,279.63	0	84.15
281	J-70	763,384.81	3,038,634.82	2,343.90	0	20.03
283	J-71	762,706.39	3,039,285.77	2,316.26	0	47.59
286	Dangrina_PC1	760,802.11	3,047,749.34	2,425.87	12.19	35.23
288	Dangrina proposed	760,513.32	3,048,483.79	2,514.90	19.92	5.06
290	Satellite Town_PC1	761,562.99	3,047,981.72	2,380.91	0.99	17.05
292	Lower Taba_PC1	760,912.88	3,045,807.98	2,402.46	12.58	126.38
294	Lango Residents 1	761,024.89	3,043,672.81	2,384.74	5.03	16.35
298	Langho Res1_PC1	760,484.04	3,043,685.87	2,314.94	0	111.44
300	YHS Residents	761,605.40	3,041,158.13	2,387.08	13.2	10.23
302	Changjji Residents Demand	761,992.32	3,039,937.83	2,310.59	21.48	9.82
304	Above Old Highway Demand_PC1	762,388.78	3,036,764.87	2,385.80	12.19	1.33
307	J-82	763,000.28	3,037,793.73	2,308.10	0	152.6
311	Bebesa Left Demand 2	763,192.43	3,038,106.06	2,294.68	23.39	10.46
313	Bebesa Left_PC1	761,850.25	3,037,311.43	2,264.80	11.69	40.56
315	J-85	763,819.94	3,036,963.52	2,587.49	0	-19.87
318	Simtokha E4 Demand	763,896.40	3,037,056.79	2,559.08	5.84	8.34
320	Simtoka Upper 1_PC1	763,331.45	3,037,349.05	2,458.12	1.44	62.5
322	Simtokha Upper 1_PC2	762,708.09	3,037,403.33	2,308.64	1.44	211.5
325	Lango Res1_PC2	761,047.61	3,043,598.41	2,386.85	0.01	14.37
331	Bangdu Residents_PC1	761,578.82	3,039,158.04	2,428.10	3.69	3.36
334	J-92	761,343.57	3,039,430.31	2,488.86	0	-0.45
349	Changzamtog Demand 2	761,399.49	3,039,558.15	2,427.70	14.64	50.92
351	Hejo& Kawajangsa_PC2	760,407.82	3,043,922.64	2,316.24	5.04	77.88
357	J-97	761,054.17	3,044,126.19	2,377.18	0	85.51
361	J-98	760,396.89	3,044,941.82	2,356.19	0	3.8
374	J-100	760,450.15	3,044,936.23	2,353.70	0	47.2
380	J-101	760,379.99	3,044,955.61	2,356.68	0	3.28
383	J-102	760,386.72	3,044,930.46	2,357.32	0	32.3
399	J-104	760,553.00	3,040,398.73	2,387.11	0	5.98
404	J-105	760,054.26	3,041,482.39	2,370.63	0	3.26
415	J-108	758,382.11	3,042,032.19	2,583.62	0	-9.68
422	Taba / Dotena	761,474.11	3,045,679.81	2,533.35	0	6.7
424	J-112	760,297.08	3,045,020.63	2,360.81	0	162.83
429	Pamtsho_PC1	760,303.92	3,046,710.20	2,564.66	13.78	-83.38
434	J-117	759,745.29	3,043,709.89	2,451.02	0	-7
439	J-119	759,776.42	3,043,705.43	2,436.35	0	7.59
442	Hejo & Kawajangsa_PC1	760,046.89	3,044,313.59	2,417.12	5.04	26.11
445	Kawajangsa and Zilukha_PC1	759,590.95	3,043,424.69	2,451.37	6.38	-9.34
447	J-122	759,741.74	3,042,529.17	2,446.23	0	77.34
449	Town Area 1 Demand	759,934.58	3,042,599.10	2,393.55	11.59	110.34
452	Norzin Wog_PC1	760,434.23	3,042,234.65	2,351.90	32.79	-24.58
454	J-125	761,264.69	3,040,163.06	2,305.76	0	15.57
457	Changzamtog Demand 1	761,272.04	3,040,131.04	2,305.95	14.64	13.91
460	Changedaphu & UChangzamtok2	760,897.74	3,039,985.82	2,382.90	23.48	83.73
463	Changbangdu - BHs	761,353.45	3,039,416.84	2,488.98	0	-0.31
467	Jungshina	760,376.27	3,044,970.08	2,357.77	0	2.22
468	Ziluka _PC1	760,603.51	3,043,112.32	2,314.12	0.62	86.56
470	J-136	759,674.27	3,042,093.32	2,430.89	0	82.29
473	Town Area 1_PC1	760,375.62	3,042,631.67	2,347.52	11.59	134.5
475	Town Area 2a	760,492.18	3,041,462.19	2,335.14	8.39	29.59
477	Town Area 2_PC2	760,924.41	3,041,040.67	2,313.18	8.39	14.07
479	J-140	759,676.62	3,041,912.72	2,432.94	0	5.54
480	Town Area 2c	760,287.79	3,041,682.73	2,356.47	8.39	67.07
482	Upper Mothiang Demand	758,872.79	3,041,988.83	2,522.41	32.7	-68.53
484	J-143	759,923.06	3,040,755.22	2,453.51	0	105.18
487	Above RICB Demand	759,943.07	3,040,768.73	2,452.84	5.24	105.69
489	Above RICB Tank a	760,062.17	3,041,105.88	2,399.98	2	2.01
491	J-146	760,241.64	3,040,092.09	2,477.61	0	2.27
492	Changedaphu & UChangzamtok_PC1	761,619.05	3,040,031.16	2,287.55	11	185.04
494	J-148	760,556.76	3,040,397.66	2,387.04	0	5.23
497	Changdelo_PC2	761,335.27	3,040,377.10	2,290.78	11.64	71.12
499	Changdelo Demand 2	760,659.45	3,040,786.44	2,353.19	11.64	-0.71
501	J-151	761,619.09	3,040,392.20	2,314.22	0	90.28
510	Bangdu Area left_PC1	762,090.51	3,038,962.40	2,405.02	7.26	-16.5
516	Bebesa Right_PC1	761,598.56	3,036,529.10	2,329.80	6.57	3.23
518	J-157	761,375.13	3,036,330.99	2,305.19	0	342.92
521	Gangchey Nyezergang_PC1	760,866.82	3,036,196.70	2,252.43	8.48	387.03
532	J-160	760,847.04	3,039,952.85	2,410.33	0	62.84
548	J-162	763,275.08	3,033,563.22	2,644.00	0	15.05
575	Bebena 1_PC1	760,350.72	3,044,483.92	2,345.83	0.01	120.23
578	Bebena 1a Demand	759,260.84	3,044,773.37	2,441.47	20.39	22.77
601	J-168	757,564.56	3,042,096.37	2,675.00	0	193.36
605	J-169	757,550.83	3,042,074.31	2,682.00	0	187.6
624	J-172	767,183.67	3,033,559.92	2,915.00	0	-12.74
632	J-173	767,809.18	3,035,688.01	2,792.00	0	-3.05
651	Simtoka Upper 2b_PC	763,016.48	3,036,669.73	2,537.68	4.83	19.33
750	J-176	761,147.43	3,043,624.77	2,399.49	0	1.71
755	J-177	760,395.40	3,044,933.85	2,356.20	0	33.47
766	J-178	760,123.92	3,048,687.37	2,573.00	0	6.84
782	Luding Demand 1	763,846.55	3,039,059.53	2,634.50	4.41	10.34
785	Lubding Demand 2	763,921.25	3,038,737.26	2,513.27	4.41	5.67
797	J-182	761,599.65	3,040,713.58	2,396.84	0	-7.06
804	J-185	761,061.79	3,036,909.98	2,290.16	0	344.12
807	Rama _PC2	759,847.66	3,035,658.15	2,244.00	13.47	380.97
809	Town Area 1.1	760,491.21	3,041,163.14	2,357.57	11.59	32.34
811	J-188	762,165.23	3,035,991.09	2,498.29	0	124.42
815	J-189	761,100.29	3,040,938.84	2,299.88	0	104.87
818	Changdelo 1a	761,184.30	3,040,535.49	2,305.04	0	99.72
822	J-191	764,380.46	3,037,901.85	2,346.00	0	194.28
825	Olakha 2_PC1	764,178.80	3,037,879.71	2,307.88	0	232.32
827	J-193	759,800.25	3,035,899.49	2,274.00	0	352.24
830	Rama_PC1	759,218.61	3,036,266.35	2,381.00	0	245.45
832	J-195	760,642.46	3,037,372.92	2,463.08	0	139.38
835	Debsi_PC2	760,435.22	3,036,250.18	2,249.97	0	352.06
837	Bebesa Right_PC2	761,369.59	3,036,912.39	2,263.39	6.57	63.88
839	J-198	762,294.91	3,037,371.34	2,280.85	0	25.11
842	Bebesa Left_PC2	762,320.58	3,037,187.46	2,311.27	0	-5.25
844	J-200	762,361.42	3,036,884.43	2,377.91	0	15.3
847	Above Old Highway Demand_PC2	761,726.57	3,037,092.61	2,264.04	0	128.95
850	Serbithang_PC1	761,670.37	3,036,462.73	2,345.02	1.22	276.95
852	J-204	762,779.65	3,034,747.27	2,519.65	0	121.03
855	Serbithang_PC2	763,021.62	3,035,017.70	2,634.70	1.22	6.2
857	J-206	762,632.60	3,037,430.70	2,305.97	0	128.76
860	Simtokha Upper 2b_PC2	762,637.10	3,037,436.71	2,305.16	0	129.57
862	J-208	763,002.65	3,039,314.24	2,344.38	0	19.53
865	J-209	763,050.22	3,039,335.70	2,367.75	0	-3.79
867	J-210	762,978.88	3,038,534.41	2,280.10	0	200.96
870	Olakha 1_PC1	762,916.19	3,038,370.99	2,274.50	0	206.54
872	Satellite Town_PC2	761,574.68	3,048,215.92	2,393.49	0	4.5
874	Pamtsho_PC2	760,513.38	3,045,930.64	2,338.45	0	105.76
876	J-214	760,382.60	3,046,047.78	2,359.60	0	84.65
879	Pamtsho 2_PC1	760,595.12	3,045,476.93	2,331.83	6.09	43.54
882	Pamtsho2_PC2	759,907.65	3,045,359.03	2,473.73	6.06	-91.87

2047 Scenario: Pipeline hydraulics

ID	Label	Length (Scaled) (m)	Diameter (mm)	Material	Flow (L/s)	Velocity (m/s)	Headloss Gradient (m/km)
68	P-11(1)	2,096.00	350.00	Ductile Iron	198.39	2.06	12.51
321	P-110	411.00	100.00	Ductile Iron	1.44	0.18	0.611
323	P-111	702.00	100.00	Ductile Iron	1.44	0.18	0.611
845	P-105(1)	149.00	100.00	Ductile Iron	12.19	1.55	31.893
979	P-6(1)(1)	5.00	150.00	Ductile Iron	10	0.57	3.062
517	P-176	95.00	100.00	Ductile Iron	6.57	0.84	10.151
838	P-218	650.00	100.00	Ductile Iron	6.57	0.84	10.151
116	P-12(1)	1,871.00	200.00	Ductile Iron	20	0.64	2.726
974	P-26(1)(1)	569.00	250.00	Ductile Iron	176.53	3.6	51.896
69	P-11(2)	1,090.00	350.00	Ductile Iron	196.53	2.04	12.293
823	P-13(1)	852.00	150.00	Ductile Iron	1.86	0.11	0.136
316	P-4(2)(1)	1,112.00	200.00	Ductile Iron	62.604	1.99	22.562
657	P-14(1)	1,664.00	150.00	Ductile Iron	28.42	1.61	21.221
652	P-193	199.00	152.40	Ductile Iron	4.83	0.26	0.738
287	P-96	684.00	100.00	Ductile Iron	12.19	1.55	31.891
1009	P-264(1)	941.00	200.00	Ductile Iron	16.82	0.54	1.978
576	P-46(1)	1,807.00	160.00	Ductile Iron	0.01	0	0
675	P-12(2)(1)	9.00	200.00	Ductile Iron	10	0.32	0.748
678	P-24(1)	17.00	200.00	Ductile Iron	10	0.32	0.75
135	P-30	20.00	200.00	Ductile Iron	19.282	0.61	2.549
1003	P-266	253.00	100.00	Ductile Iron	0.001	0	0
137	P-31	13.00	200.00	Ductile Iron	19.28	0.61	2.55
332	P-115	211.00	100.00	Ductile Iron	3.69	0.47	3.488
660	P-114(1)	757.00	100.00	Ductile Iron	10	1.27	22.1
132	P-28	217.00	200.00	Ductile Iron	(N/A)	(N/A)	(N/A)
663	P-27(1)	16	250	Ductile Iron	10	0.2	0.251
938	P-243	402	152.4	Ductile Iron	0	0	0
666	P-29(1)	3	250	Ductile Iron	10	0.2	0.243
863	P-92(1)(1)	139	160	Ductile Iron	0.002	0	0
282	P-95	664	200	Ductile Iron	0.001	0	0
648	P-32(1)(1)	456	250	Ductile Iron	163.279	3.33	44.913
868	P-26(2)(1)	669	250	Ductile Iron	10.001	0.2	0.255
805	P-15(2)(1)	614	150	Ductile Iron	28.22	1.6	20.946
519	P-33(1)	3664	250	Ductile Iron	36.7	0.75	2.83
558	P-184	84	250	Ductile Iron	22.04	0.45	1.102
637	P-192	87	250	Ductile Iron	-58.741	1.2	6.761
289	P-97	94	150	Ductile Iron	19.92	1.13	10.987
770	P-202	36	150	Ductile Iron	10	0.57	3.07
775	P-35(1)	1137	80	Ductile Iron	0.5	0.1	0.255
947	P-245	99	80	Ductile Iron	7.401	1.47	37.532
778	P-18(1)	966	150	Ductile Iron	10	0.57	3.066
291	P-98	81	150	Ductile Iron	0.99	0.06	0.042
873	P-226	188	90	Ductile Iron	0	0	0
772	P-16(2)(1)	28	150	Ductile Iron	16.2	0.92	7.492
161	P-17(2)	136	150	Ductile Iron	10	0.57	3.066
177	P-43	3877	100	Ductile Iron	20.167	2.57	81.02
723	P-39(1)	19	152.4	Ductile Iron	11.85	0.65	3.888
726	P-38(1)	14	100	Ductile Iron	11.85	1.51	30.271
686	P-42(1)	9	100	Ductile Iron	10	1.27	22.094
720	P-41(1)	15	100	Ductile Iron	10	1.27	22.109
987	P-256	13	100	Ductile Iron	15.316	1.95	48.691
821	P-214	20	100	Ductile Iron	4.818	0.61	5.711
579	P-45(1)	240	160	Ductile Iron	20.39	1.01	8.379
435	P-47(1)	1700	110	Ductile Iron	10.953	1.15	16.443
739	P-44(1)	7	150	Ductile Iron	3.53	0.2	0.457
742	P-20(2)(1)	11	150	Ductile Iron	3.53	0.2	0.446
736	P-144(1)	207	75	Ductile Iron	5	1.13	24.858
710	P-49(1)	8	150	Ductile Iron	10	0.57	3.079
713	P-50(1)	9	150	Ductile Iron	10	0.57	3.054
716	P-51(1)	13	150	Ductile Iron	10	0.57	3.064
537	P-181	23	100	Ductile Iron	10.089	1.28	22.466
905	P-81(1)	407	150	Ductile Iron	30	1.7	23.458
352	P-124	1,081	100	Ductile Iron	5.04	0.64	6.213
375	P-52(1)(1)(1)	1565	150	Ductile Iron	0	0	0
529	P-151(1)	16	100	Ductile Iron	5.451	0.69	7.186
219	P-62	3403	200	Ductile Iron	20	0.64	2.726
895	P-57(1)	125	150	Ductile Iron	31.248	1.77	25.296
213	P-60	238	100	Ductile Iron	21.248	2.71	89.244
745	P-59(1)	3	100	Ductile Iron	10	1.27	22.119
295	P-100	150	150	Ductile Iron	5.03	0.28	0.859
328	P-113	105	80	Ductile Iron	0.01	0	0
299	P-102	969	63	Ductile Iron	0	0	0
425	P-77(1)	1505	200	Ductile Iron	24.63	0.78	4.009
764	P-53(1)	4	200	Ductile Iron	-10	0.32	0.75
885	P-99(1)	768	200	Ductile Iron	12.58	0.4	1.155
890	P-61(1)	332	150	Ductile Iron	14.5	0.82	6.102
695	P-63(1)	4	150	Ductile Iron	10	0.57	3.058
698	P-64(1)	10	150	Ductile Iron	10	0.57	3.063
248	P-76	6	150	Ductile Iron	14.262	0.81	5.921
924	P-239	50	80	Ductile Iron	0	0	0
798	P-65(1)	444	150	Ductile Iron	36.83	2.08	34.297
241	P-71	7	100	Ductile Iron	14.689	1.87	45.055
242	P-72	8	100	Ductile Iron	13.795	1.76	40.105
243	P-73	20	100	Ductile Iron	8.346	1.06	15.815
301	P-103	207	100	Ductile Iron	13.2	1.68	36.956
502	P-75(1)	828	100	Ductile Iron	1.061	0.14	0.347
926	P-66(1)(1)	732	150	Ductile Iron	0.002	0	0
245	P-74	692	150	Ductile Iron	0.01	0	0
238	P-68	16	100	Ductile Iron	-9.893	1.26	21.664
239	P-69	22	100	Ductile Iron	-8.348	1.06	15.819
240	P-70	30	100	Ductile Iron	-6.978	0.89	11.351
303	P-104	651	150	Ductile Iron	21.48	1.22	12.635
455	P-67(1)	2043	100	Ductile Iron	3.739	0.48	3.574
264	P-86	27	100	Ductile Iron	12.813	1.63	34.973
265	P-87	40	100	Ductile Iron	10.365	1.32	23.614
396	P-135	29	80	Ductile Iron	2.092	0.42	3.613
397	P-136	19	80	Ductile Iron	2.603	0.52	5.416
476	P-159	577	100	Ductile Iron	8.39	1.07	15.968
707	P-78(1)	5	200	Ductile Iron	10	0.32	0.796
258	P-82	995	150	Ductile Iron	20	1.13	11.07
701	P-85(1)	13	100	Ductile Iron	10	1.27	22.092
490	P-164	9	100	Ductile Iron	2	0.25	1.118
689	P-83(1)	7	100	Ductile Iron	10	1.27	22.116
692	P-84(1)	12	100	Ductile Iron	10	1.27	22.107
495	P-166	23	100	Ductile Iron	12.153	1.55	31.71
496	P-167	27	100	Ductile Iron	11.127	1.42	26.932
273	P-91	801	250	Ductile Iron	34.079	0.69	2.467
704	P-90(1)	8	100	Ductile Iron	10	1.27	22.104
453	P-154	164	100	Ductile Iron	32.79	4.17	199.317
912	P-160(1)	359	100	Ductile Iron	8.391	1.07	15.968
278	P-93	318	110	Ductile Iron	0	0	0
280	P-94	529	110	Ductile Iron	0	0	0
285	P-92(2)	239	160	Ductile Iron	0.001	0	0
312	P-107	505	200	Ductile Iron	23.39	0.74	3.644
840	P-108(1)	986	200	Ductile Iron	11.69	0.37	1.008
642	P-106(1)	8	150	Ductile Iron	10	0.57	3.058
858	P-32(2)(1)	651	250	Ductile Iron	153.279	3.12	39.952
319	P-109	121	150	Ductile Iron	5.84	0.33	1.13
654	P-4(2)(2)(1)	605	150	Ductile Iron	56.764	3.21	76.418
340	P-118	17	100	Ductile Iron	-8.164	1.04	15.184
989	P-258	185	150	Ductile Iron	10	0.57	3.067
350	P-123	185	100	Ductile Iron	14.64	1.86	44.768
964	P-253	79	80	Ductile Iron	1.49	0.3	1.927
359	P-56(2)	666	200	Ductile Iron	51.248	1.63	15.574
360	P-126	2393	150	Ductile Iron	31.619	1.79	25.855
363	P-52(2)	35	150	Ductile Iron	0	0	0
373	P-127	18	100	Ductile Iron	0	0	0
378	P-129	14	100	Ductile Iron	0	0	0
370	P-52(1)(2)	15	100	Ductile Iron	0	0	0
377	P-128	39	100	Ductile Iron	0	0	0
379	P-130	40	100	Ductile Iron	0	0	0
376	P-52(1)(1)(2)	39	100	Ductile Iron	0	0	0
387	P-89(2)(1)(1)	12	250	Ductile Iron	0	0	0
391	P-131	15	152.4	Ductile Iron	0	0	0
393	P-133	13	152.4	Ductile Iron	29.45	1.61	20.983
385	P-89(2)(2)	3214	250	Ductile Iron	44.079	0.9	3.973
388	P-89(2)(1)(2)	14	250	Ductile Iron	0	0	0
392	P-132	16	152.4	Ductile Iron	0	0	0
394	P-134	14	152.4	Ductile Iron	29.45	1.61	20.981
401	P-138	19	80	Ductile Iron	2.499	0.5	5.022
402	P-139	25	80	Ductile Iron	2.196	0.44	3.956
410	P-137(1)	30	80	Ductile Iron	4.695	0.93	16.156
411	P-137(2)	1490	80	Ductile Iron	4.695	0.93	16.155
416	P-141	2,795	80	Ductile Iron	-7.812	1.55	41.476
1001	P-265	24	152.4	Ductile Iron	0	0	0
417	P-142	57	80	Ductile Iron	-23.325	4.64	314.513
418	P-143	54	80	Ductile Iron	-23.326	4.64	314.55
483	P-162	606	100	Ductile Iron	32.7	4.16	198.305
910	P-235	235	152.4	Ductile Iron	0.001	0	0
201	P-54	1,516	200	Ductile Iron	0.001	0	0
358	P-56(1)	2036	200	Ductile Iron	82.867	2.64	37.924
877	P-227(1)	475	150	Ductile Iron	6.09	0.34	1.224

884	J-218	760,929.45	3,045,813.00	2,403.78	0	125.08
887	Lower Taba_PC2	760,672.26	3,046,292.66	2,360.23	0	168.54
889	J-220	761,567.35	3,045,903.46	2,498.77	0	29.14
892	Upper Taba_PC	761,151.31	3,046,515.51	2,391.94	0	135.76
894	J-222	761,188.38	3,043,585.34	2,406.91	0	42.34
897	Lang 2_PC1	761,192.29	3,043,601.97	2,407.48	0	41.77
899	J-224	759,867.39	3,043,014.07	2,416.91	0	107.17
902	Kawajangsa and Zilukha_PC2	760,038.10	3,043,112.02	2,357.72	0	166.25
904	J-226	759,835.02	3,041,718.68	2,410.42	0	19
907	Upper Motihang_PC	759,819.36	3,041,716.77	2,412.82	0	16.61
909	Upper Motihang_PC2	758,333.90	3,041,893.22	2,594.83	0	-20.87
911	J-229	760,282.72	3,041,787.46	2,364.11	0	-9.82
914	Town Area 2_PC1	760,304.24	3,041,798.22	2,363.23	0	-8.95
916	Norzin Wog_PC2	761,111.67	3,041,238.63	2,298.01	0	66.65
918	J-232	762,581.84	3,039,665.86	2,361.98	0	42.61
923	YHS Res_PC1	761,805.84	3,041,140.16	2,408.97	0	-3.96
925	J-235	761,175.06	3,040,950.54	2,301.85	0	102.91
928	YHS Res_PC2	761,201.33	3,040,866.96	2,293.33	0	111.41
930	J-237	761,164.94	3,040,228.87	2,315.68	0	8.83
933	Changdelo_PC	761,197.65	3,040,162.27	2,311.94	0	12.56
935	Changedaphu & UChangzamtok_PC2	761,285.73	3,039,394.71	2,493.83	1.49	-6.97
937	Bangdu Residents_PC2	761,743.06	3,039,281.11	2,358.47	0	122.2
939	J-241	761,556.09	3,036,390.81	2,354.33	0	267.76
942	J-242	761,558.29	3,036,399.08	2,371.99	0	250.13
946	J-243	760,538.51	3,048,562.02	2,516.00	0	1.28
948	Community supply_PC1	760,478.33	3,048,648.25	2,515.00	3.7	1.19
950	Community supply_PC2	761,541.10	3,048,250.52	2,398.00	3.7	108.15
952	J-246	762,949.84	3,039,668.76	2,369.00	0	-71
954	Changiji 2_PC1	762,988.69	3,039,501.02	2,410.00	5.48	-115.62
956	Changiji 2_PC2	763,890.80	3,040,384.21	2,594.00	5.48	-320.93
966	J-250	766,583.83	3,034,289.98	2,872.42	0	-145.67
969	J-251	766,641.72	3,035,359.96	2,650.58	0	35.23
973	J-252	763,587.01	3,038,043.30	2,305.36	0	192.09
976	Workshop	763,402.87	3,038,166.20	2,310.00	3.25	186.94
984	J-254	760,231.35	3,040,087.41	2,477.16	0	34.84
990	J-255	761,792.67	3,048,878.67	0	0	2,512.21
992	Community supply PC1	762,079.55	3,048,775.52	2,568.00	0	-50.61
994	Community supply PC2	761,615.39	3,049,036.61	2,410.00	0	107.07
1000	J-259	759,642.18	3,043,289.82	0	0	2,453.05
1002	J-260	763,307.27	3,039,096.98	0	0	2,359.24
1004	J-261	763,835.90	3,038,189.29	0	0	2,359.24
1006	J-262	763,841.06	3,039,027.36	0	0	2,359.24
1008	J-263	760,298.52	3,046,713.53	2,460.27	0	20.83
1014	YHS2_PC2	762,022.63	3,040,765.35	2,520.00	0	-115.09
1016	YHS2_PC1	761,704.77	3,040,176.10	2,280.00	1.06	124.42

883	P-229	763	63	Ductile Iron	6.06	1.94	82.974
471	P-77(2)(1)	3380	200	Ductile Iron	21.59	0.69	3.141
760	P-145(1)	1179	150	Ductile Iron	3.04	0.17	0.338
440	P-148(1)	31	150	Ductile Iron	8.57	0.48	2.305
733	P-47(2)(1)	25	150	Ductile Iron	2.383	0.13	0.218
443	P-149	755	150	Ductile Iron	5.04	0.29	0.862
729	P-148(2)(1)	255	150	Ductile Iron	3.53	0.2	0.446
446	P-150	142	150	Ductile Iron	6.38	0.36	1.334
450	P-152	228	80	Ductile Iron	11.59	2.31	86.123
451	P-153	1,891	80	Ductile Iron	-6.139	1.22	26.549
458	P-155	33	100	Ductile Iron	14.64	1.86	44.769
931	P-67(2)(1)	122	100	Ductile Iron	-10.901	1.39	25.929
341	P-119	22	100	Ductile Iron	-8.164	1.04	15.175
381	P-89(1)	15	250	Ductile Iron	29.45	0.6	1.882
469	P-157	1151	100	Ductile Iron	-0.62	0.08	0.128
472	P-77(2)(2)	173	200	Ductile Iron	10	0.32	0.755
474	P-158	1069	100	Ductile Iron	11.59	1.48	29.045
917	P-237	1398	152.4	Ductile Iron	0.001	0	0
481	P-161	928	100	Ductile Iron	8.39	1.07	15.966
538	P-182	24	100	Ductile Iron	-9.891	1.26	21.653
810	P-211	1,670	100	Ductile Iron	11.59	1.48	29.045
486	P-40(2)	968	100	Ductile Iron	15.149	1.93	47.696
488	P-163	24	100	Ductile Iron	5.24	0.67	6.682
493	P-165	1893	150	Ductile Iron	11	0.62	3.659
536	P-180	13	100	Ductile Iron	-6.182	0.79	9.065
498	P-168	1033	100	Ductile Iron	11.64	1.48	29.278
500	P-169	458	80	Ductile Iron	11.64	2.32	86.813
919	P-75(2)(1)	1258	100	Ductile Iron	0	0	0
1015	P-271	550	152.4	Ductile Iron	0.001	0	0
1017	P-272	232	152.4	Ductile Iron	1.06	0.06	0.038
511	P-173	124	100	Ductile Iron	7.26	0.92	12.213
520	P-33(2)	187	200	Ductile Iron	28.22	0.9	5.159
522	P-177	526	100	Ductile Iron	8.48	1.08	16.285
900	P-151(2)(1)	845	150	Ductile Iron	5.451	0.31	0.997
534	P-117(2)	996	100	Ductile Iron	-8.164	1.04	15.177
535	P-179	60	100	Ductile Iron	23.48	2.99	107.38
853	P-10(2)(1)(1)(1)	1370	150	Ductile Iron	22.04	1.25	13.252
769	P-201	19	150	Ductile Iron	16.2	0.92	7.494
762	P-200	21	400	Ductile Iron	92.867	0.74	1.604
754	P-198	13	400	Ductile Iron	29.45	0.23	0.189
731	P-196	46	250	Ductile Iron	18.013	0.37	0.757
603	P-37(2)(2)	885	150	Ductile Iron	43.868	2.48	47.414
604	P-187	26	150	Ductile Iron	-43.868	2.48	47.405
189	P-48	2589	150	Ductile Iron	30.001	1.7	23.459
485	P-40(1)	3762	100	Ductile Iron	20.389	2.6	82.681
718	P-195	10	400	Ductile Iron	-94.258	0.75	1.657
967	P-4(1)(2)(2)(1)	1094	200	Ductile Iron	180.712	5.75	160.7
683	P-194	252	250	Ductile Iron	-214.998	4.38	74.764
970	P-21(2)(2)(1)(1)	1213	250	Ductile Iron	214.998	4.38	74.764
640	P-6(2)	5	150	Ductile Iron	10	0.57	3.055
643	P-106(2)	5	150	Ductile Iron	10	0.57	3.069
646	P-10(2)(2)	6	150	Ductile Iron	19.6	1.11	10.669
655	P-4(2)(2)(2)	5	150	Ductile Iron	56.764	3.21	76.439
658	P-14(2)	7	150	Ductile Iron	28.42	1.61	21.202
661	P-114(2)	3	100	Ductile Iron	10	1.27	22.088
664	P-27(2)	21	250	Ductile Iron	10	0.2	0.252
667	P-29(2)	3	250	Ductile Iron	10	0.2	0.237
676	P-12(2)(2)	5	200	Ductile Iron	10	0.32	0.762
679	P-24(2)	5	200	Ductile Iron	10	0.32	0.76
682	P-21(2)(2)(2)	4	250	Ductile Iron	304.686	6.21	142.589
649	P-32(1)(2)	3	250	Ductile Iron	163.279	3.33	44.932
687	P-42(2)	6	100	Ductile Iron	10	1.27	22.095
690	P-83(2)	5	100	Ductile Iron	10	1.27	22.112
693	P-84(2)	7	100	Ductile Iron	10	1.27	22.1
696	P-63(2)	4	150	Ductile Iron	10	0.57	3.059
699	P-64(2)	7	150	Ductile Iron	10	0.57	3.064
702	P-85(2)	10	100	Ductile Iron	10	1.27	22.107
705	P-90(2)	8	100	Ductile Iron	10	1.27	22.102
708	P-78(2)	8	200	Ductile Iron	10	0.32	0.758
711	P-49(2)	6	150	Ductile Iron	10	0.57	3.061
714	P-50(2)	6	150	Ductile Iron	10	0.57	3.074
717	P-51(2)	8	150	Ductile Iron	10	0.57	3.074
721	P-41(2)	8	100	Ductile Iron	10	1.27	22.097
724	P-39(2)	8	152.4	Ductile Iron	11.85	0.65	3.886
727	P-38(2)	9	100	Ductile Iron	11.85	1.51	30.273
730	P-148(2)(2)	9	150	Ductile Iron	3.53	0.2	0.445
734	P-47(2)(2)	13	150	Ductile Iron	2.383	0.13	0.213
737	P-144(2)	4	75	Ductile Iron	5	1.13	24.85
740	P-44(2)	4	150	Ductile Iron	3.53	0.2	0.434
743	P-20(2)(2)	7	150	Ductile Iron	3.53	0.2	0.451
746	P-59(2)	2	100	Ductile Iron	10	1.27	22.07
753	P-197	8	150	Ductile Iron	-14.629	0.83	6.206
757	P-116(1)(1)(2)	1847	150	Ductile Iron	-14.629	0.83	6.203
758	P-199	9	150	Ductile Iron	14.629	0.83	6.199
761	P-145(2)	20	150	Ductile Iron	3.04	0.17	0.335
765	P-53(2)	7	200	Ductile Iron	-10	0.32	0.728
768	P-16(1)(2)(2)	360	150	Ductile Iron	16.2	0.92	7.494
773	P-16(2)(2)	5	150	Ductile Iron	16.2	0.92	7.517
776	P-35(2)	5	80	Ductile Iron	0.5	0.1	0.249
779	P-18(2)	16	150	Ductile Iron	10	0.57	3.069
783	P-203	29	100	Ductile Iron	4.41	0.56	4.852
793	P-204(1)	324	80	Ductile Iron	2	0.4	3.326
786	P-205	11	100	Ductile Iron	4.41	0.56	4.85
790	P-206(1)	933	100	Ductile Iron	10	1.27	22.1
791	P-206(2)	5	100	Ductile Iron	10	1.27	22.093
794	P-204(2)	6	80	Ductile Iron	2	0.4	3.307
799	P-65(2)	1763	150	Ductile Iron	36.83	2.08	34.297
828	P-210(1)	1630	152.4	Ductile Iron	13.47	0.74	4.928
833	P-15(2)(2)(1)	710	100	Ductile Iron	14.75	1.88	45.395
813	P-10(2)(1)(2)	1199	150	Ductile Iron	19.6	1.11	10.664
940	P-212(1)	750	100	Ductile Iron	1.22	0.16	0.449
817	P-66(2)	441	150	Ductile Iron	0.001	0	0
819	P-213	425	152.4	Ductile Iron	0.001	0	0
824	P-13(2)	582	150	Ductile Iron	1.86	0.11	0.136
826	P-215	239	152.4	Ductile Iron	0	0	0
829	P-210(2)	246	152.4	Ductile Iron	13.47	0.74	4.928
831	P-216	688	152.4	Ductile Iron	0	0	0
834	P-15(2)(2)(2)	280	100	Ductile Iron	14.75	1.88	45.393
836	P-217	1839	80	Ductile Iron	0.001	0	0
841	P-108(2)	559	200	Ductile Iron	11.69	0.37	1.008
843	P-219	287	152.4	Ductile Iron	0.001	0	0
846	P-105(2)	192	100	Ductile Iron	12.19	1.55	31.891
848	P-220	736	152.4	Ductile Iron	0	0	0
854	P-10(2)(1)(1)(2)	1,506	150	Ductile Iron	20.82	1.18	11.926
856	P-222	363	152.4	Ductile Iron	1.22	0.07	0.058
859	P-32(2)(2)	926	250	Ductile Iron	153.278	3.12	39.952
861	P-223	8	152.4	Ductile Iron	0	0	0
864	P-92(1)(2)	455	160	Ductile Iron	0.002	0	0
866	P-224	52	152.4	Ductile Iron	0.001	0	0
869	P-26(2)(2)	2132	250	Ductile Iron	10.001	0.2	0.255
871	P-225	416	90	Ductile Iron	0.001	0	0
878	P-227(2)	603	75	Ductile Iron	0	0	0
880	Pamtsho2_PC	824	63	Ductile Iron	6.09	1.95	83.737
886	P-99(2)	17	200	Ductile Iron	12.58	0.4	1.152
888	P-230	698	90	Ductile Iron	0.001	0	0
891	P-61(2)	982	150	Ductile Iron	14.5	0.82	6.102
893	P-231	1007	90	Ductile Iron	0	0	0
896	P-57(2)	61	150	Ductile Iron	31.248	1.77	25.297
898	P-232	17	152.4	Ductile Iron	0.001	0	0
901	P-151(2)(2)	578	150	Ductile Iron	5.451	0.31	0.997
903	P-233	197	90	Ductile Iron	0	0	0
906	P-81(2)	754	150	Ductile Iron	30	1.7	23.458
908	P-234	16	90	Ductile Iron	0	0	0
913	P-160(2)	1,690	100	Ductile Iron	8.39	1.07	15.966
915	P-236	31	90	Ductile Iron	0	0	0
920	P-75(2)(2)	56	100	Ductile Iron	0	0	0
927	P-66(1)(2)	79	150	Ductile Iron	0.001	0	0
929	P-240	88	152.4	Ductile Iron	0.001	0	0
932	P-67(2)(2)	1944	100	Ductile Iron	-10.901	1.39	25.93
934	P-241	74	152.4	Ductile Iron	0	0	0
945	P-244	9	152.4	Ductile Iron	1.22	0.07	0.07
982	P-212(2)(1)	110	100	Ductile Iron	0	0	0
944	P-221(2)	129	90	Ductile Iron	1.22	0.19	0.751
949	P-246	105	80	Ductile Iron	3.7	0.74	10.394
951	P-247	1050	80	Ductile Iron	3.7	0.74	10.393
991	P-259	1294	152.4	Ductile Iron	0.001	0	0
955	P-249	172	80	Ductile Iron	5.48	1.09	21.511
957	P-250	1182	80	Ductile Iron	5.48	1.09	21.511
958	P-251	401	80	Ductile Iron	-10.96	2.18	77.655
968	P-4(1)(2)(2)(2)	2965	200	Ductile Iron	91.024	2.9	45.127
972	P-254	1072	200	Ductile Iron	89.688	2.85	37.857
971	P-21(2)(2)(1)(2)	730	250	Ductile Iron	304.687	6.21	142.6
975	P-26(1)(2)	323	250	Ductile Iron	173.28	3.53	50.141
977	Workshop	221	100	Ductile Iron	3.25	0.41	2.377
980	P-6(1)(2)	1205	150	Ductile Iron	10	0.57	3.067
983	P-212(2)(2)	6	90	Ductile Iron	0	0	0

986	P-117(1)(2)	797	100	Ductile Iron	15.316	1.95	48.674
993	P-260	305	152.4	Ductile Iron	0.001	0	0
995	P-261	237	152.4	Ductile Iron	0.001	0	0
1005	P-267	1050	80	Ductile Iron	0.001	0	0
1007	P-268	538	80	Ductile Iron	0.001	0	0
1013	P-270	6	152.4	Ductile Iron	13.78	0.76	4.432
1019	P-264(2)(1)	840	250	Ductile Iron	3.04	0.06	0.028
1020	P-264(2)(2)	23	200	Ductile Iron	3.04	0.1	0.084
627	P-190	61	200	Ductile Iron	180.712	5.75	160.7

Appendix E

Begana-Rama Trunk Main Calculations

ARUP

Job Title	Thimphu Water Services Masterplan
Job Number	289551-00
Made By	OVT
Checked By	LZ
Date	08/06/2023
Description of spreadsheet	Begana Rama trunkmain high level hydraulic assessment
Sheet Number prefix	Sheet number prefix
Member/Location	Member/Location
Drawing Reference	Drawing reference
Filename	Filename

Contents of Spreadsheet

Sheet	Description
Cover	Cover page
Notes	Notes, assumptions and basis of calculations
Hydraulic design	Design flow and hydraulic design calculations
Supply pressure assessment	High level assessment for DMA supply pressure from proposed trunk main
Community supply press	High level assessment for Community supply DMA supply pressure from proposed trunk main

Authorisation of latest version

Type and method of check		
Signatures & dates:	Made by	
	Checked	

Revisions

Current Revision

Rev.	Date	Made by	Checked	Description
P01	08/06/2023	OVT	LZ	High level hydraulic calculations for strategic trunk mains

(1) Purpose of spreadsheet

Begana Rama trunk main high level hydraulic assessment

(2) Key Assumptions

1 Top Water Level of the existing Taba tank considered as trunkmain initial head
2 Pipeline to follow utility corrridor
3 Ductile iron pipe used (roughness coefficient= 120)
4 For each area considered in the flow breakdown, the unit head loss is considered constant in the trunk main portion
5 From the end of the Rama DMA onwards, there are no more head losses

(3) Basis of calculations

1 Hazen Williams Equation for headloss calculations
2 The derived hydraulic grade line was used to assess the adequacy of supply pressure to the existing DMAs

(4) Sources of data & Links to other spreadsheets

Date	File path / URL	Description

(5) Special features

(6) Diary of development, including checking

(if supplement is needed to Cover page)

Date	Who	Description

Best Practice Guide

1. Don't duplicate raw data in the spreadsheet i.e. use cell references where possible.
2. Use colours to distinguish between fixed data, user-variable data, calculations and results.
3. Explicitly define constants to be used in equations, using named cells where appropriate.
4. Avoid password use unless essential and documented (to avoid loss of work with loss of password).
5. Ensure extracts copied to other documents can be traced back to the spreadsheet.
6. Plot to engineering scale whenever sensible to do so, and make units obvious.
7. For charts, use colours/patterns which will be distinguishable if printed or photocopied in black & white.
8. Give sheets & workbooks descriptive names.
9. Use comments to describe the purpose of individual cells and ranges of cells.
10. Use the revision facility on the cover page and maintain the diary where further details required.

Methodology

1. Design flow calculated for each demand area.
2. Hydraulic design using H-W equation to limit pipeline velocity to less than 1m/s
3. Design included sections of two or three parallel pipelines for greater system resiliency.
4. The total head loss along the utility corridor determined the hydraulic grade line slope.

Table 1: Design flow calculation for each demand area

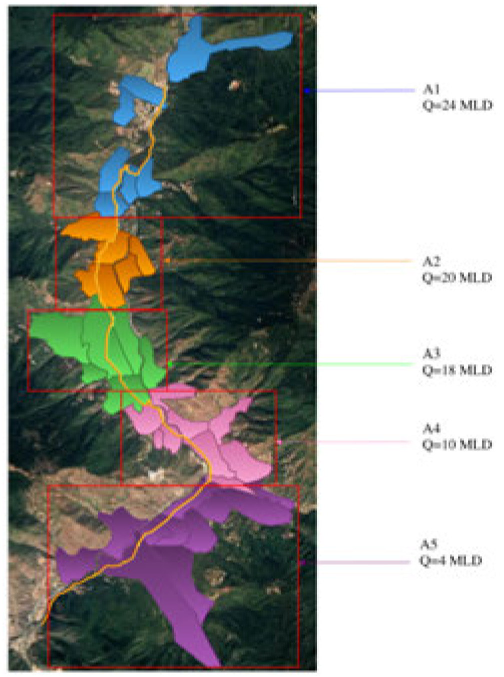
Demand area	DMA	Current Demand	2032 Demand	2047 Demand
		MLD	MLD	MLD
	Community Supply	0.566	0.429	0.306
	Dangrina left and right	0.684	0.828	0.759
	Dangrina proposed	0.908	0.804	0.825
	Pamtsho 1	0.383	0.562	0.571
	Pamtsho 2	0.762	0.525	0.504
	Satellite town	0.053	0.040	0.041
	Taba Lower	0.873	0.593	0.521
A1	Taba Upper	0.658	0.683	0.601
	Babena 1	1.000	0.927	0.844
	Hejo and Kawajangsa	0.455	0.470	0.418
	Kawajangsa and Zilukha	0.471	0.360	0.264
	Lango Residents 1	0.591	0.234	0.208
	Lango Residents 2	0.067	0.246	0.221
A2	Zilukha	0.025	0.036	0.026
	Above RICB	0.207	0.281	0.300
	Changdelo	1.003	1.149	0.964
	Changedaphu and Upper Changzamtok	2.047	2.029	1.667
	Norzin Wog	0.805	1.425	1.358
	Town Area 1	1.661	1.559	1.440
	Town Area 2	1.005	1.077	1.043
	Upper Motihang	2.230	1.753	1.354
A3	YHS Residents	0.532	0.668	0.547
	Bangdu area (left)	0.705	0.349	0.301
	Bangdu Residents	0.147	0.187	0.153
	Changiji Residents	1.439	1.101	0.890
	Changiji 2	0.945	0.591	0.454
	Changzamtog	1.883	1.403	1.213
	Lubding	0.274	0.455	0.365
	Olakha 1	2.349	2.040	1.597
	YHS 2	0.213	0.192	0.183
A4	Workshop	0.442	0.280	0.224
	Above old highway	0.845	0.555	0.505
	Babesa Left	1.399	1.111	0.969
	Babesa Right	0.904	0.646	0.544
	Debsi	0.378	0.249	0.611
	Gangchey Nyezergang	0.491	0.411	0.351
	Olakha 2	0.236	0.096	0.077
	Rama	-	-	0.558
	Serbithang	0.205	0.129	0.101
	Simtoka E4	0.214	0.303	0.242
	Simtoka Upper 1	0.237	0.150	0.120
A5	Simtoka Upper 2	0.363	0.258	0.200
			total	24.438

Table 2: Hydraulic design

Demand area	Area demand (MLD)	Total pipes flows (MLD)	Total pipes flows (LS)	D1 (mm)	D2 (mm)	D3 (mm)	v (m/s)	Unitary headloss (m/km)	Length (m)	Headloss (m)
			-							
A1	4.13	24	283	450	450		0.89	1.98	4,525	9
A2	1.98	20	235	400	400		0.94	2.49	2,310	6
A3	8.67	18	212	300	300	300	1.00	3.94	3,477	14
A4	5.38	10	112	300	300		0.79	2.56	2,940	8
A5	4.28	4	50	200	200		0.79	4.14	4,830	20
								total	18,082	56

Comment: High headloss in area A5

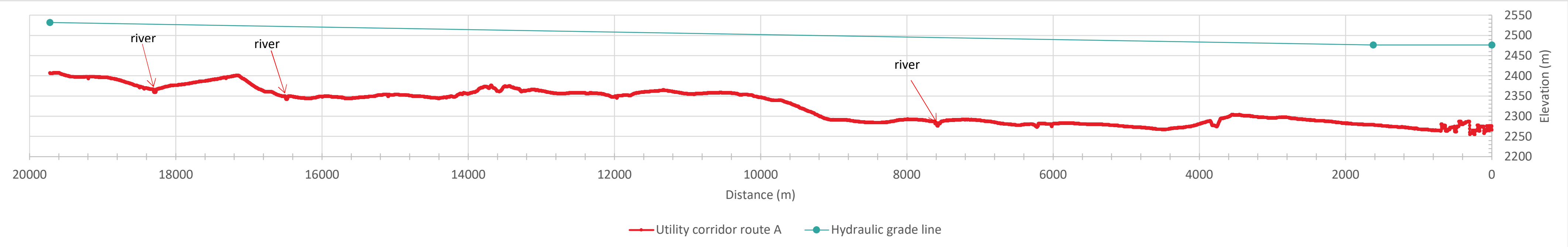
Title: **Plan and profile of Begana Rama trunkmain**



Hydraulic grade line

	distance (m)	elevation (m)
	0	2476
	1621.679	2476
tank position	19721.68	2532

slope	0.003
intercept	2471



Methodology

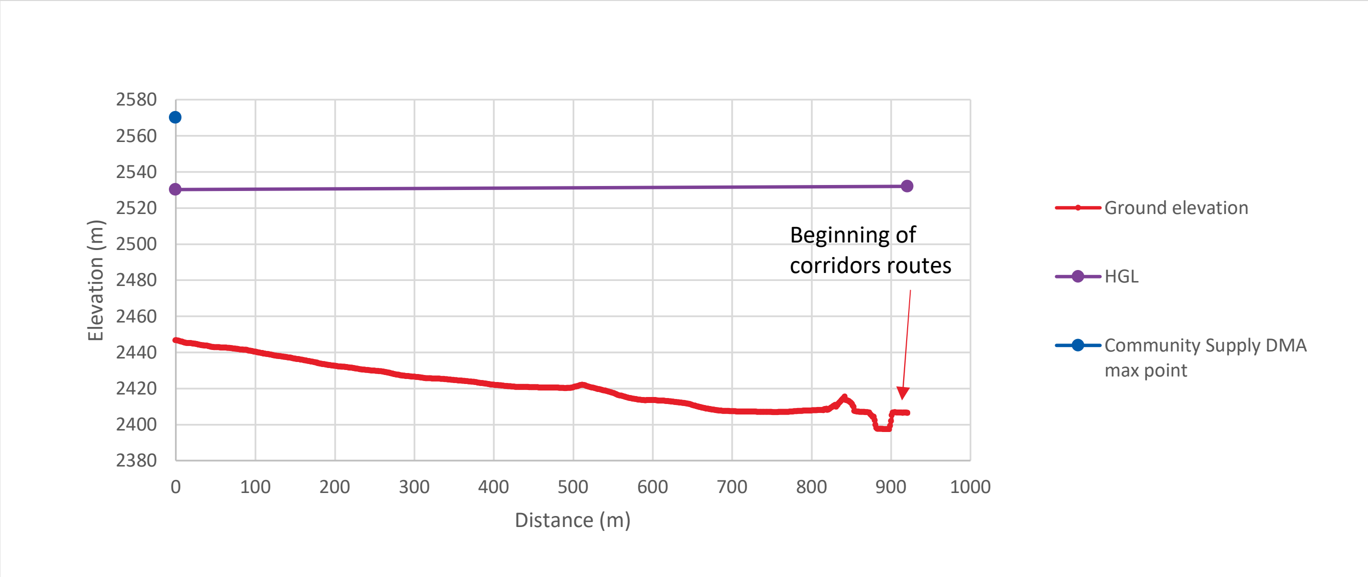
HGL compared with each DMA highest point (pressure critical) to assess hydraulic feasibility of supplying from the trunk main with no pumping.

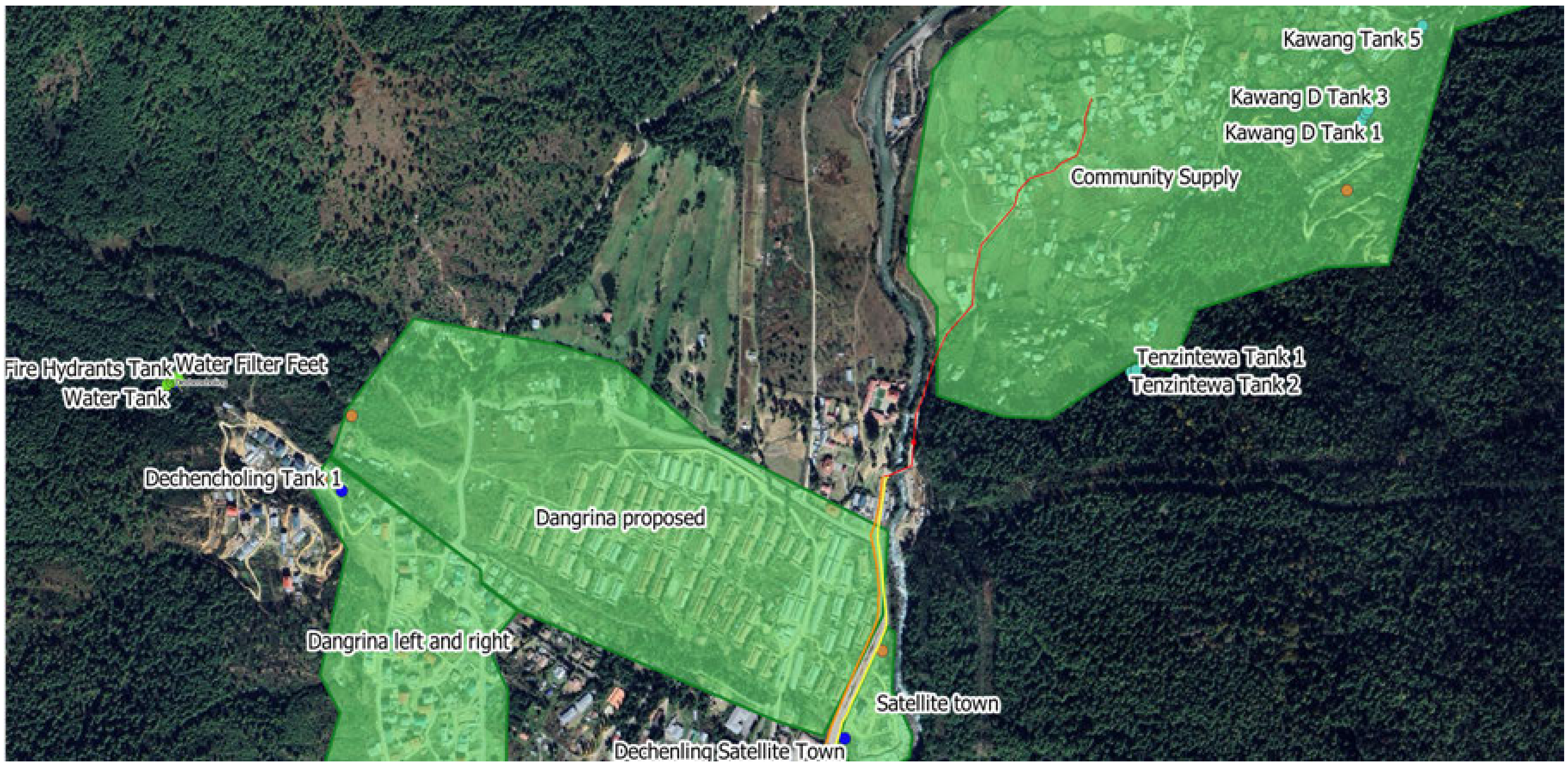
DMA	Location on the trunkma	Abscisse (m)	Highest point elevation (m)	HGL (m)	Result	Minimum pumping head required (m)
Above old highway	14771	5229	2390	2487	ok	-
Above RICB	9095	10905	2540	2505	insufficient pressure	35
Babena 1	4963	15037	2460	2518	ok	-
Babesa Left	14472	5528	2310	2488	ok	-
Babesa Right	15446	4554	2330	2485	ok	-
Bangdu area (left)	11977	8023	2410	2496	ok	-
Bangdu Residents	11492	8508	2430	2497	ok	-
Changdelo	9222	10778	2350	2504	ok	-
Changedaphu and Upper Changzamtok	9909	10091	2480	2502	ok	-
Changiji Residents	11926.4	8074	2390	2496	ok	-
Changjiji 2	10533	9467	2590	2500	insufficient pressure	90
Changzamtog	11164	8836	2490	2498	ok	-
Dangrina left and right	136	19864	2520	2532	ok	-
Dangrina proposed	85	19915	2520	2533	ok	-
Debsi	15446	4554	2480	2485	ok	-
Gangchey Nyezergang	16070	3930	2640	2483	insufficient pressure	157
Hejo and Kawajangsa	5466	14534	2420	2516	ok	-
Kawajangsa and Zilukha	6431.3	13569	2450	2513	ok	-
Lango Residents 1	6232	13768	2390	2514	ok	-
Lango Residents 2	6232	13768	2410	2514	ok	-
Lubding	12422	7578	2620	2494	insufficient pressure	126
Norzin Wog	7726	12274	2350	2509	ok	-
Olakha 1	12140	7860	2370	2495	ok	-
Olakha 2	13100	6900	2390	2492	ok	-
Pamtsho 1	2270	17730	2560	2526	insufficient pressure	34
Pamtsho 2	4236	15764	2470	2520	ok	-
Rama	17707	2293	2380	2478	ok	-
Satellite town	350	19650	2390	2532	ok	-
Serbithang	15670	4330	2630	2484	insufficient pressure	146
Simoka Upper 1	13726	6274	2470	2490	ok	-
Simtoka E4	13365	6635	2500	2492	insufficient pressure	8
Simtoka upper 2	14472	5528	2540	2488	insufficient pressure	52
Taba Lower	3778	16222	2400	2521	ok	-
Taba Upper	3778	16222	2500	2521	ok	-
Town Area 1	8016	11984	2440	2508	ok	-
Town Area 2	8179	11821	2360	2508	ok	-
Upper Motihang	8016	11984	2590	2508	insufficient pressure	82
Workshop	13125	6875	2310	2492	ok	-
YHS Residents	9095	10905	2410	2505	ok	-
YHS2	9553	10447	2520	2503	insufficient pressure	17
Zilukha	6309	13691	2355	2513	ok	-

Methodology
1. Calculation of hydraulic gradeline from upstream of corridor (Taba Tanks) to Community supply
2. HGL vs Ex. Ground level to assess hydraulic feasibility of supplying by gravity

Distance (m)	HGL (m)	Community supply max point (m)	Minimum head needed (m)
0	2530	2570	40
921.0247102	2532		

Title: **Plan and profile view of the corridor extended route**





Conclusion
HGL at highest elevation = 2530 mAOD and EGL = 2570 mAOD. Therefore system unable to supply high elevation properties without pumping.
There is sufficient head to supply low elevation properties.

Appendix F

Wastewater Supply Maps

Figure 5-1: Extension to Existing Wastewater Network

Figure 5-2: Route Option 1

Figure 5-3: Route Option 2

Figure 5-4: Route Option 3

Figure 5-5: Route Option 4

Figure 5-6: Sewer Network Phasing

Figure 5-7: Sewer Network Sizing for Design Year 2047

Figure 5-8: High Flow Scenario Check

Appendix G

Upgrades to Existing WWTPs

Wastewater Treatment Plants

ARUP

WWTP	Operational	Capable to Run until 2032 2B
Dechencholing	X	X
Taba	✓	X
Jungshina	X	X
Langjophakha	✓	✓
Lungtenzampa	X	✓
Babesa	✓	X

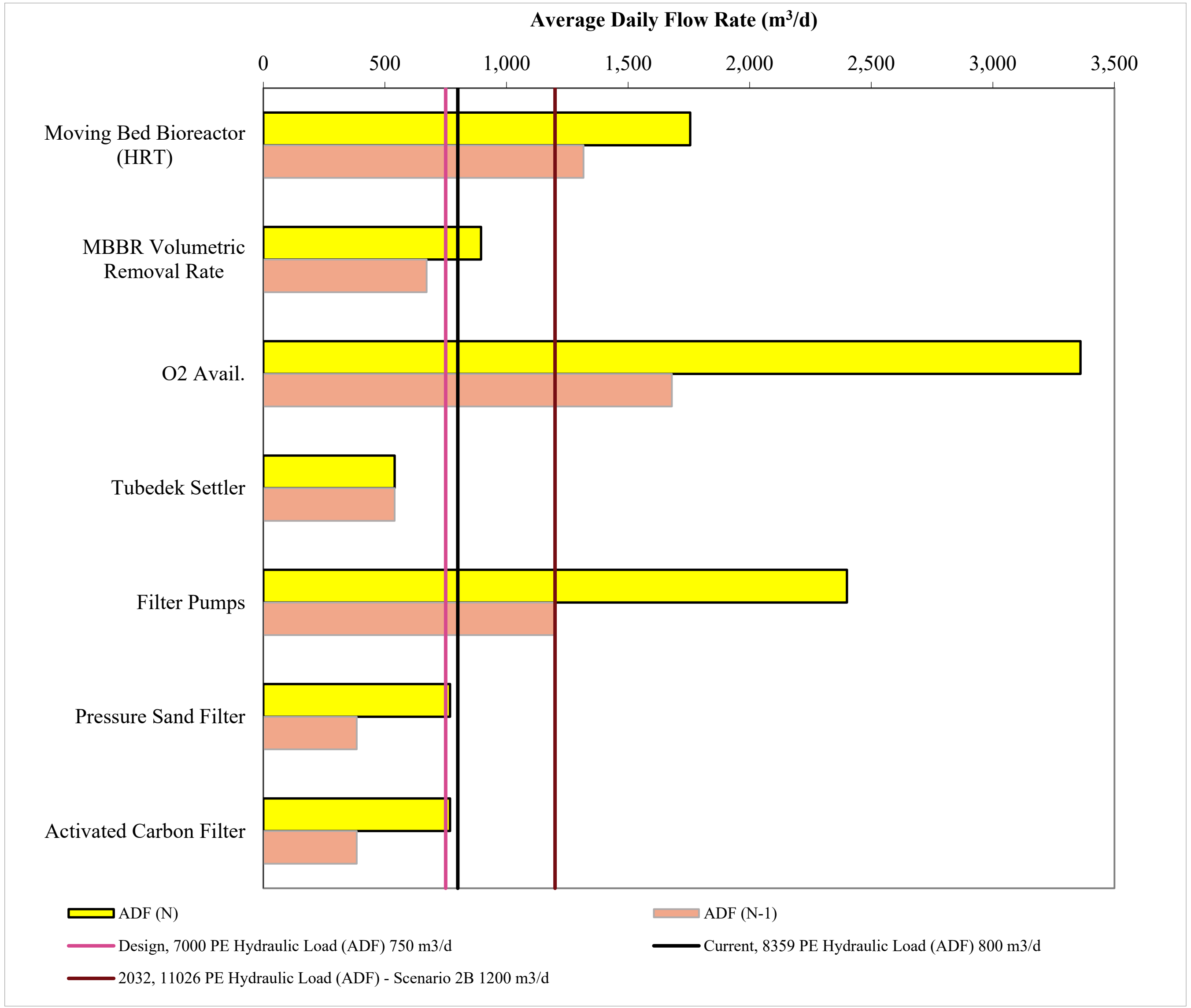
Dechencholing WWTP

Design Capacity: 0.75 MLD

Current Capacity: 107% of design capacity

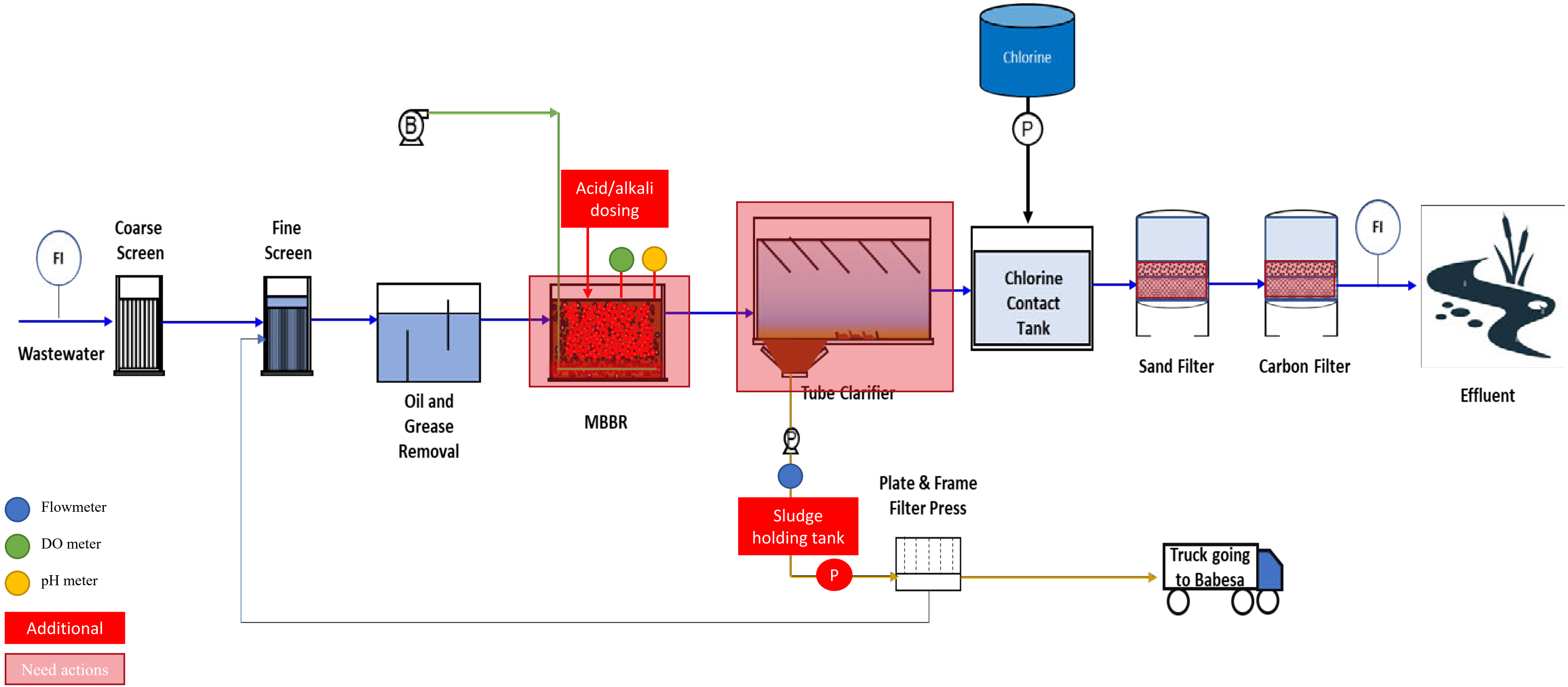
General Remarks:

- Insufficient capacity to cater 2032 flow
- Not operational since 2019/2020



Dechencholing WWTP

Recommended Upgrades



ARUP

Dechencholing WWTP

Design Capacity: 0.75 MLD

Current Capacity: 107% of design capacity

Issues Identified	Basis/Assumptions	Recommendation	Criticality Rating
• Plant is not functional due to multiple mechanical failures. • In 2032, mechanical components will reach their design life (2027)	• It is not operational for almost three years. • Assumed that the mechanical components were not changed and started to run on 2012	Further assess each equipment not functioning as per design specification or process which has mechanical failure and provide a service report.	HIGH
		Consider checking the electrical line cable, instrumentation, and pipeline if still in good condition that there is leak/damage and clogging.	HIGH
		Refurbish/replace all the equipment that cannot be recovered based on the service report/assessment to ensure compliance.	MEDIUM
		Establish regular preventive maintenance program plan for all equipment	LOW
• Possible clogging in diffusers • Reached its design life (2017)	• Water is much lower than the diffusers which solid may already accumulated. • Assumed that the diffusers were not changed since the plant was constructed on 2012	Replacement of the diffusers	HIGH

Dechencholing WWTP

ARUP

Design Capacity: 0.75 MLD

Current Capacity: 107% of design capacity

Issues Identified	Basis/Assumptions	Recommendation	Criticality Rating
• Possible insufficient quantities/specific surface area of media • Possible degradation of media	Long time of being shut down	Assess the condition of media as well its total amount.	**HIGH**
		If the amount of media present in the tank is already insufficient based on the investigation, replenish up to design volume of the media	**MEDIUM**
		If the media can still recover, it needs to wash out or clean the media by removing the sludge. If not, it needs to be replaced.	**MEDIUM**
Possible toxic gases (i.e. hydrogen sulphide) are produced in the aeration chamber	• No air in the biological treatment led to growth of anaerobic bacteria • Discoloration of wastewater into black	Have a safety plan before recommissioning it	**MEDIUM**
• Insufficient capacity of MBBR • No alkali/acid dosing	• 60 g PE/d • 4 hrs HRT • 1.7 kg/m^3/d	Further investigate the performance of the processes in terms of BOD removal once the plant is running while assuring the operating conditions are met like its target pH and dissolved oxygen (DO).	**HIGH**
		Provide an alkali/acid dosing.	**HIGH**
		If it is not reaching its effluent BOD quality, provide additional media	**MEDIUM**
		If it is not reaching its effluent BOD quality, increase the air flow if possible.	**MEDIUM**
		If above is still not achieving its target or it is not possible, consider add a unit of MBBR	**LOW**

Dechencholing WWTP

Design Capacity: 0.75 MLD

Current Capacity: 107% of design capacity

Issues Identified	Basis/Assumptions	Recommendation	Criticality Rating
Insufficient capacity of Tubedek Settler	• 1 unit of Tubedek Settler • 2.5 $m^3/m^2/h$	Further investigate the TSS before and after the settler. If possible, revisit the settler's design.	**HIGH**
		If the efficiency of the settler is less than the design removal percentage, consider check if its possible to change the configuration of settler like the slope in order to increase the settling area.	**MEDIUM**
		If above is still not achieving its target or it is not possible, consider adding one unit of the settler especially there is no additional unit that can handle the flow if this chamber is in downtime	**LOW**
		Have a frequent preventive maintenance of the unit to ensure the continuity of services	**MEDIUM**
• Missing media inside the filters • Reached the design life (2022) of activated carbon • Insufficient capacity of Sand and Activated Carbon Filters	• Based on the discussion with the client. • Activated carbon media has typical design life of 10 years only • Capacity of 16 m^3/hr	Further assess it by checking the size of the filter vessels as well as the plan on how to add the filter media to identify if it's worth salvaging.	**HIGH**
		If the size of the vessels are still suitable, replace only the media specially the activated carbon. On the other hand, replace whole units if it's not worth recovering them.	**HIGH**
• Insufficient to no historical data for all parameters required in effluent • No influent quality data	Only effluent's turbidity and pH data received	Develop a sampling plan and testing procedure for internal and third-party laboratory testing and analysis for all required parameters to ensure compliance and identify its influent quality.	**HIGH**
		Influent characteristics should be established so that it could be used as a basis in constructing a centralized WWTPs	**MEDIUM**

Dechencholing WWTP

ARUP

Design Capacity: 0.75 MLD

Current Capacity: 107% of design capacity

Issues Identified	Basis/Assumptions	Recommendation	Criticality Rating
Possible no sludge holding tank	Sludge holding tank is required since the treatment used for dewatering sludge is plate and frame filter press, which is a batch process. The sludge holding tank should be able to store the sludge for a certain time.	Check if there's a sludge holding tank before subjecting it to the plate and frame filter press and its capacity if its has enough storage time to hold the sludge when it cannot be feed the sludge in plate and frame filter press	HIGH
		If there's none, provide a sludge holding tank with sufficient capacity.	MEDIUM
• Have no removal for biological nutrient.	• MBBR requires longer aeration time with suitable pH of wastewater for nitrification. There is no anoxic tank for denitrification. • No anaerobic or chemical treatment to remove phosphorus.	Investigate if the capacity of the aeration tank is enough to further nitrify the wastewater to reach its target quality.	MEDIUM
		If the existing tank is not enough for nitrification, consider exploring possible options to remove the ammonia up to its target quality such as the following: • Addition unit for the MBBR tanks and other auxiliaries like blower and provide an alkali/acid dosing • Addition of biological aerated filter • Addition of clay-based filter that can adsorb ammonia • May retrofit it with other secondary treatment technologies like Step-feed, SBR, MLE.	MEDIUM
		Investigate if the existing component of the plant can biodegrade the phosphorus of the wastewater up to its target effluent quality.	LOW
		If not, provide a chemical (metal salts or polymer e.g. $FeCl_3$ or PAC) that can precipitate the phosphorus and examine if the existing setter is suitable to efficiently remove the precipitates. If not, consider to add another unit of settler.	LOW

ARUP

Dechencholing WWTP

Design Capacity: 0.75 MLD

Current Capacity: 107% of design capacity

Issues Identified	Basis/Assumptions	Recommendation	Criticality Rating
Odor nuisance in WWTPs	No odor control unit	Provide a good ventilation and OCU in the treatment plant since the plant has nearby school	LOW
		Consider adding a trash bin with the lid and have a proper disposal method for the screenings.	LOW
Possible difficulty in operating the plant	No SCADA and other instruments.	Install online pH and DO analysers, and the associated SCADA control and monitoring.	LOW
No enough skilled personnel (i.e. Plant Manager, Process Engineer or Electro-mechanical Engineer)		Provide this skilled personnel to ensure the continuous operation of the plant as well as be certain that the effluent is conforming to the standard.	LOW
No operation and maintenance manual.	Assume there is no O&M manual or incomplete information	Develop an operation and maintenance manual that comprised of the standard procedures of operating and maintaining each equipment/process with health and safety measures. It also includes the following: • Detailed Design Criteria; • Process controls monitoring system; • Emergency operations plan and troubleshooting; • Schedule of routine inspection and preventive maintenance; • Sampling and/or water quality monitoring plan; • Inventory of equipment, chemicals and other supplies needed; and • Safe handling, storing and proper disposal of chemicals used.	MEDIUM

ARUP

Taba WWTP

Design Capacity: 1 MLD

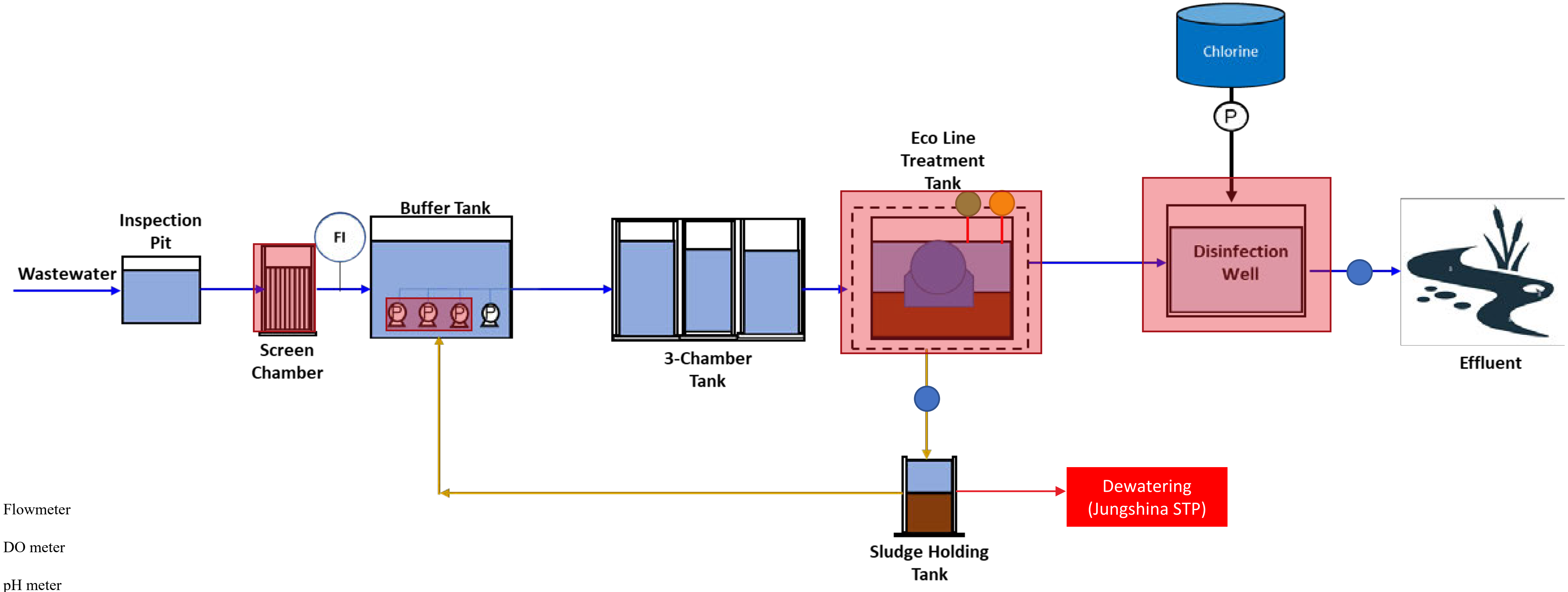
Current Capacity: 108% of design capacity

General Remarks:

- Hydraulic and Biological assessment not done due to missing information
- Design capacity is insufficient to cater 2032 flow.

Taba WWTP

Recommended Upgrades



Flowmeter
DO meter
pH meter
Additional
Need actions

Taba WWTP

Design Capacity: 1 MLD

Current Capacity: 108% of design capacity

Issues Identified	Basis/Assumptions	Recommendation	Criticality Rating
Screens are hydraulically overloaded	• Current capacity is already exceeding the plant's design capacity. • Failure of some downstream pumps; only one pump is operational. • Based on the picture, the water level is almost reaching the possible allowable freeboard.	• Further investigate the influent TSS, effluent TSS and operation condition. • Evaluate the removal efficiency and check if the solids are accumulated on the chambers that can affect the equipment downstream.	**HIGH**
		If it is already insufficient, consider add a unit of screens.	**MEDIUM**
		Have a frequent maintenance of the screens in order not to accumulate the solids.	**MEDIUM**
3 out of 4 pumps are not working	Based on the discussion with the client	Prepare a service report to assess the condition of each pump if its functioning according to its specification.	**HIGH**
		If the pumps are not recoverable, replace the damaged pumps	**MEDIUM**
		Check the capacity of each pumps if there are still capable to transfer the wastewater from the main tank to the eco-line unit with the 2032 flow.	**MEDIUM**
		If the capacity of each pumps are insufficient to cater 2032 flow, consider add unit or replace the unit with a higher capacity.	**MEDIUM**

ARUP

Taba WWTP

Design Capacity: 1 MLD

Current Capacity: 108% of design capacity

Issues Identified	Basis/Assumptions	Recommendation	Criticality Rating
Insufficient design capacity of eco-line by 136% for 2032	0.5 MLD x 2 train of Eco-line	Further assess the performance of the processes in terms of BOD removal once the plant is running while assuring the operating conditions are met like its target pH and dissolved oxygen (DO).	HIGH
		If it is not reaching its target quality due to pH, add an alkali/acid dosing.	MEDIUM
		If it is not reaching its target quality due to DO, check the capacity of the blower. If it is already insufficient, then additional blower should be considered.	MEDIUM
		If it is still not reaching its target quality, consider add another train of eco-line.	MEDIUM
Insufficient disinfection well	Only 2min of contact time	Investigate the effluent's fecal coliform.	HIGH
		Increase the disinfection dosage if the fecal coliform is not reduced up to its required value.	MEDIUM
		If the fecal coliform is still not meeting its standard, increase the contact time of disinfection well by extending the disinfection well or build another unit with sufficient capacity.	MEDIUM
		If it cannot be done, it can consider used ultraviolet unit if it is fit in the well.	MEDIUM
Possible difficulty in operating the plant	No SCADA and online instruments such as pH, DO, TSS analyzers.	Install online pH and DO analysers, and the associated SCADA control and monitoring.	LOW

ARUP

Taba WWTP

Design Capacity: 1 MLD

Current Capacity: 108% of design capacity

Issues Identified	Basis/Assumptions	Recommendation	Criticality Rating
• Insufficient to no historical data for all parameters required in effluent • No influent quality data	Based on the data given, COD, BOD and TSS are not usually tested unlike pH.	Develop a sampling plan and testing procedure for internal and third-party laboratory testing and analysis for all required parameters to ensure compliance and identify its influent quality.	HIGH
		Influent characteristics should be established so that it could be used as a basis in constructing a centralized WWTP	LOW
Odor nuisance in WWTPs	No odor control unit	Provide a good ventilation and OCU in the treatment plant since the plant has nearby school	LOW
• Have no removal for biological nutrient. • No alkali/acid dosing	• Eco-line requires longer aeration time with suitable pH of wastewater for nitrification. There is no anoxic tank for denitrification. • No anaerobic or chemical treatment to remove phosphorus.	Investigate if the capacity of the eco-line is enough to further nitrify the wastewater to reach its target quality.	MEDIUM
		If the existing train is not enough for nitrification, consider exploring possible options to remove the ammonia up to its target quality such as the following: • Addition unit for the eco-line and other auxiliaries like blower and provide an alkali/acid dosing • Addition of biological aerated filter • Addition of clay-based filter that can adsorb ammonia • Retrofit it with other secondary treatment technologies like Step-feed, SBR, MLE.	MEDIUM
		Investigate if the existing component of the plant can biodegrade the phosphorus of the wastewater up to its target effluent quality.	MEDIUM
		If not, provide a chemical (metal salts or polymer e.g. $FeCl_3$ or PAC) that can precipitate the phosphorus and examine if the existing setter is suitable to efficiently remove the precipitates. If not, consider to add another unit of settler.	MEDIUM

Taba WWTP

Design Capacity: 1 MLD

Current Capacity: 108% of design capacity

Issues Identified	Basis/Assumptions	Recommendation	Criticality Rating
No dewatering unit	Sludge holding tank is only present in the Taba WWTP based on the PFD provided.	Check the dewatering unit of Jungshina if there's an excess capacity	**HIGH**
		Transfer the sludge to Jungshina or provide dewatering unit	**HGH**
No enough skilled personnel (i.e. Plant Manager, Process Engineer or Electro-mechanical Engineer)		Provide this skilled personnel to ensure the continuous operation of the plant as well as be certain that the effluent is conforming to the standard.	**LOW**
No operation and maintenance manual.	Assume there is no O&M manual or incomplete information	Develop an operation and maintenance manual that comprised of the standard procedures of operating and maintaining each equipment/process with health and safety measures. It also includes the following: • Detailed Design Criteria; • Process controls monitoring system; • Emergency operations plan and troubleshooting; • Schedule of routine inspection and preventive maintenance; • Sampling and/or water quality monitoring plan; • Inventory of equipment, chemicals and other supplies needed; and • Safe handling, storing and proper disposal of chemicals used.	**MEDIUM**

ARUP

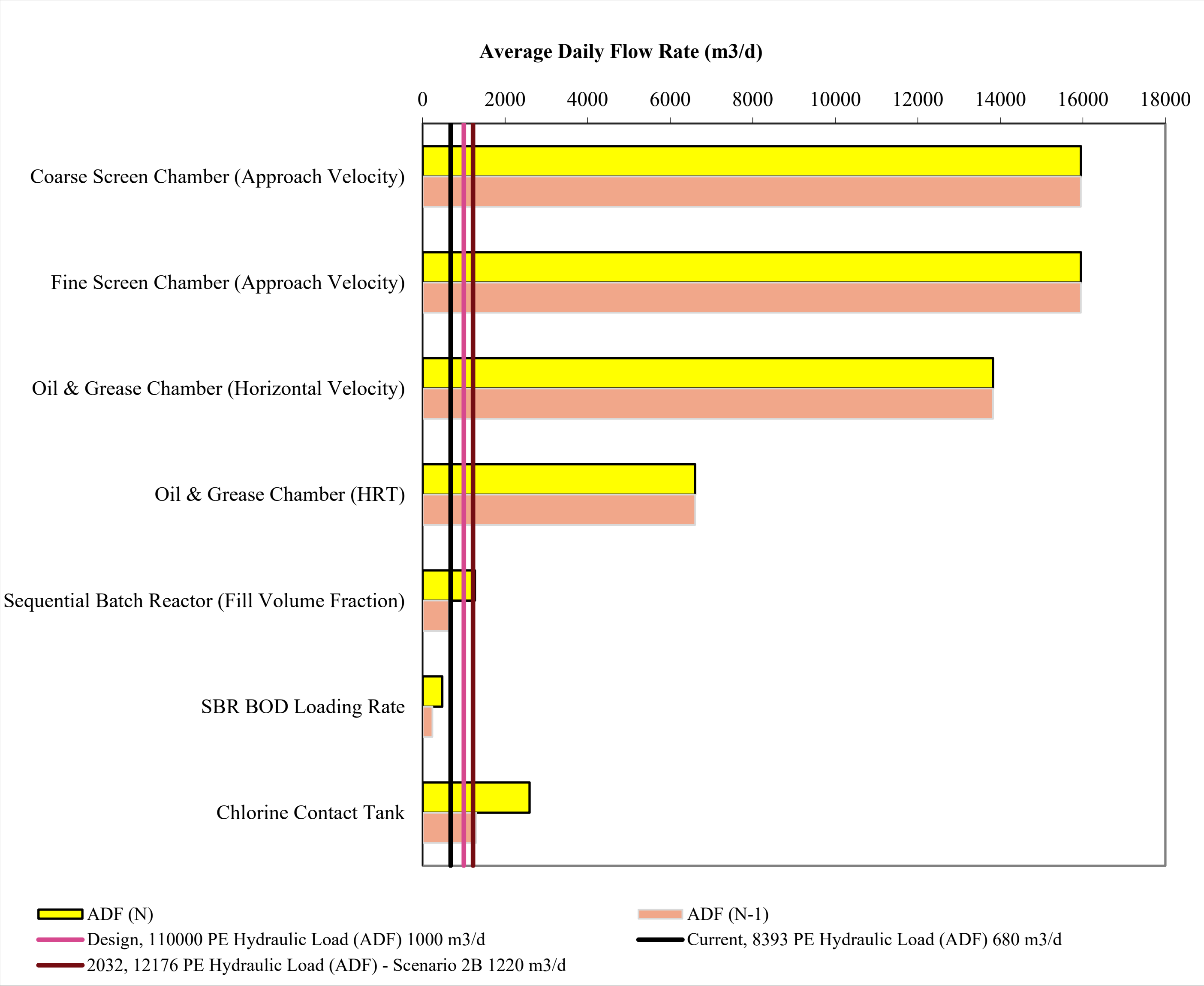
Jungshina WWTP

Design Capacity: 1 MLD

Current Capacity: not yet operational;
- 68% of design capacity based on the network assessment

General Remarks:

- Insufficient capacity to cater 2032 flow
- No diagram since the assessment are based on the provided general drawings only because it is not yet started to operate.



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Jungshina WWTP

Design Capacity: 1 MLD

Current Capacity: 68% of design capacity based on the network assessment

<table>
<tr><th>Issues Identified</th><th>Basis/Assumptions</th><th>Recommendation</th><th>Criticality Rating</th></tr>
<tr><td rowspan="5">Size of the SBR tanks are not enough to biologically treat the wastewater.</td><td rowspan="5">• Assumed total cycle time is 4 hrs with fill and aeration time is 1.5 hrs, settle time is 1 hr, decant time is 1 hr and idle time is 0.5 hr.
• 60 g BOD/PE</td><td>• Further investigate the performance of the biological treatment by checking its removal efficiency.
• Further check the other auxiliaries equipment such as pumps and blowers if they can handle the increase of flow.</td><td>HIGH</td></tr>
<tr><td>If it is not capable meeting the standards, adjust the operation by modifying the intercycle phase duration.</td><td>MEDIUM</td></tr>
<tr><td>If it still not capable meeting the standards, explore replacing the activated sludge by granular sludge.</td><td>MEDIUM</td></tr>
<tr><td>If it still not capable meeting the standards, add additional unit of SBR</td><td>MEDIUM</td></tr>
<tr><td>If the auxiliaries are not enough to cater the 2032 flow, consider add another unit of pumps, blowers and other auxiliaries.</td><td>MEDIUM</td></tr>
<tr><td rowspan="2">Have no removal for biological nutrient</td><td rowspan="2">• Nitrification always happen with sufficient time of aeration as well as with the right pH.
• Treatment plant has additional anoxic tank as well as in the SBR sequence hence, denitrification can be done.
• No anaerobic or chemical treatment to remove phosphorus.</td><td>Investigate if the existing SBR is enough to further nitrify the wastewater to reach its target quality.</td><td>MEDIUM</td></tr>
<tr><td>If the reactor is not enough for nitrification, consider exploring possible options to remove the ammonia up to its target quality such as the following:
• Adjust the operation by modifying the intercycle phase duration.
• Exploring converting activated sludge into granular sludge
• Addition unit of SBR and other auxiliaries like blower
• Addition of biological aerated filter
• Addition of clay-based filter that can adsorb ammonia
• Retrofit it with other secondary treatment technologies like Step-feed, SBR, MLE.</td><td>MEDIUM</td></tr>
</table>

ARUP

Jungshina WWTP

Design Capacity: 1 MLD

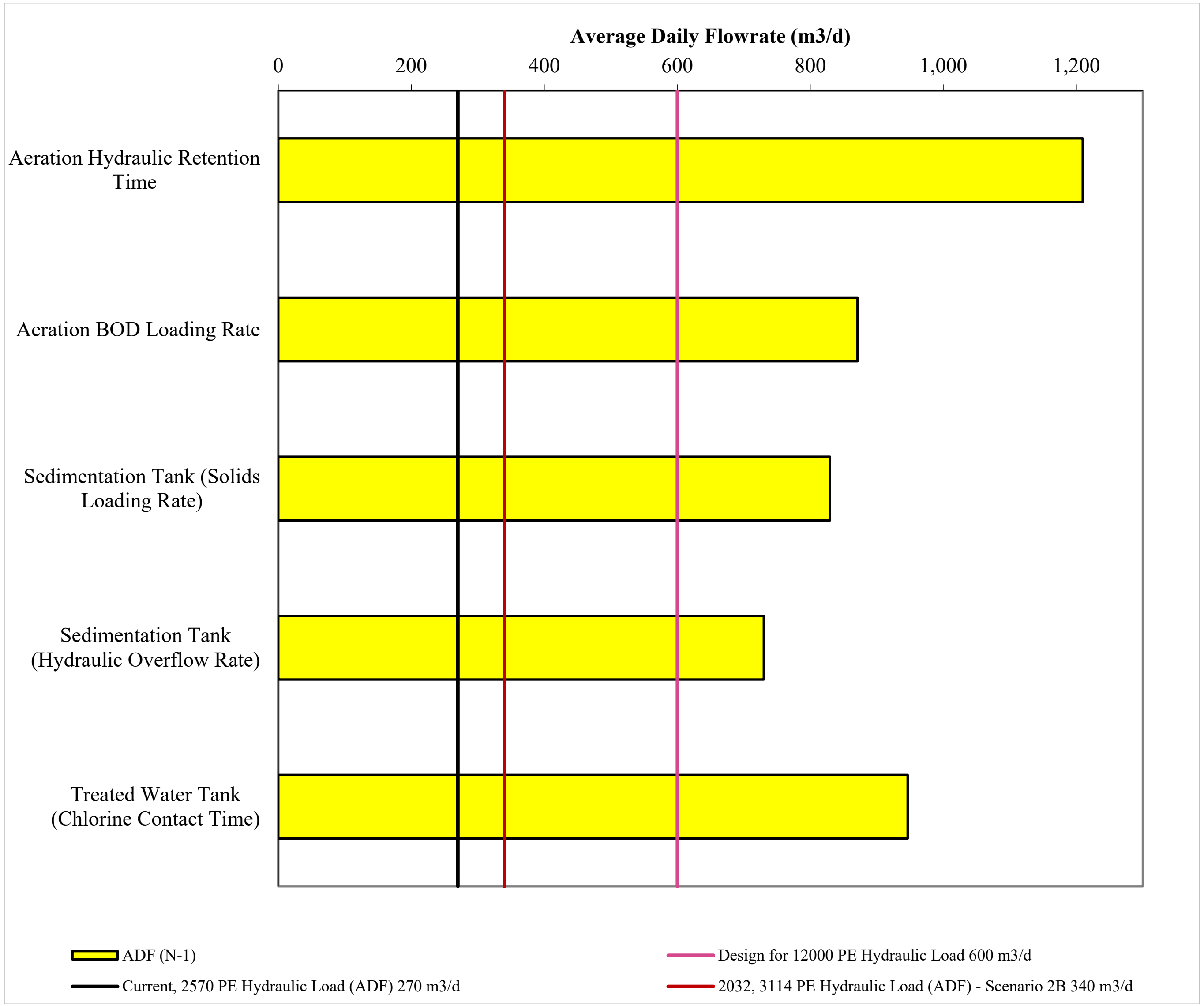
Current Capacity: 68% of design capacity based on the network assessment

Issues Identified	Basis/Assumptions	Recommendation	Criticality Rating
Have no removal for biological nutrient	• Nitrification always happen with sufficient time of aeration as well as with the right pH. • Treatment plant has additional anoxic tank as well as in the SBR sequence hence, denitrification can be done. • No anaerobic or chemical treatment to remove phosphorus.	Investigate if the existing component of the plant can biodegrade the phosphorus of the wastewater up to its target effluent quality.	**MEDIUM**
		If not, provide a chemical (metal salts or polymer e.g. $FeCl_3$ or PAC) that can precipitate the phosphorus and examine if the precipitates can settle within the settling time.	**MEDIUM**
		If precipitate cant settle within the settling time, consider add a filter after reactor in order to remove the precipitates in the effluent.	**MEDIUM**

Lanjophakha WWTP

Design Capacity: 0.6 MLD

Current Capacity: 45% of design capacity

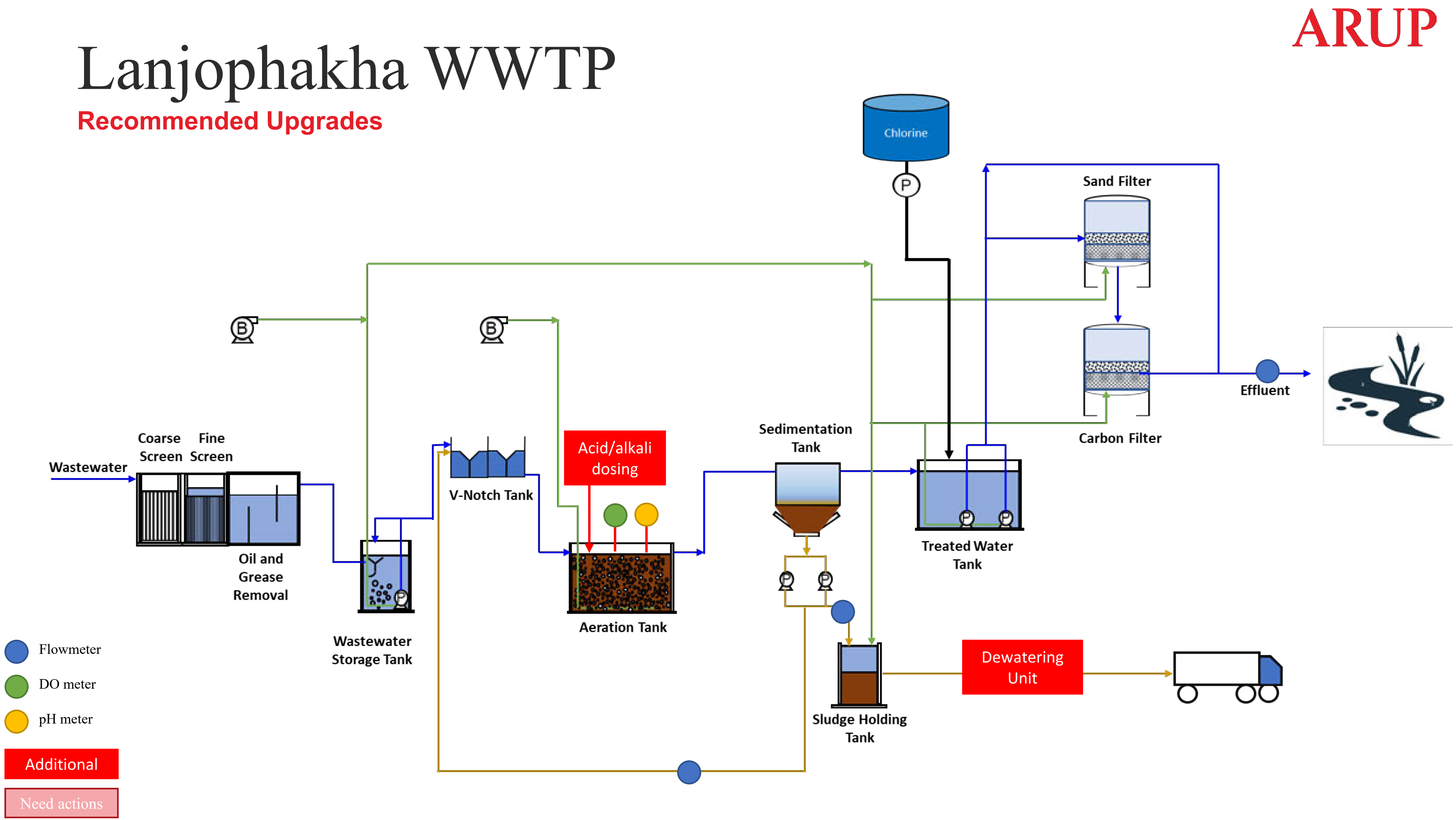


General Remarks:

- All equipment in the graph are hydraulically capable to cater 2032 flow.

Lanjophakha WWTP

Recommended Upgrades



ARUP

Lanjophakha WWTP

Design Capacity: 0.6 MLD

Current Capacity: 45% of design capacity

Issues Identified	Basis/Assumptions	Recommendation	Criticality Rating
Deterioration of screens	Based on the picture captured during site visit	Consider checking the screens on site, if screens are already worn out that will result in ineffective removal of debris from the raw wastewater.	MEDIUM
		Further investigate the effluent TSS as well as frequency of failure of downstream pumps and other equipment.	MEDIUM
		If it is already affecting the effluent as well the performance of other equipment, consider replacing the screens.	MEDIUM
		Have a frequent maintenance of the screens in order not to accumulate the solids.	MEDIUM
		If the screens is already insufficient, consider add another unit of screens.	MEDIUM
Possible short circuiting happens in a Treated Water Tank	Assume that there is no mixer or baffle in the tank.	Investigate the effluent's fecal coliform.	MEDIUM
		If there's a time that effluent exceeds the limit, it requires an addition of baffle or mixer.	MEDIUM
Other components of treatment plant which were not assessed like blowers, pumps and filters may not capable to handle the 2032 flow		Further investigate or check its capacity, if it is not sufficient to cater 2032 flow, provide additional unit of these equipment.	HIGH
Possible difficulty in operating the plant	No SCADA and online instruments such as pH and DO but there is a local PLC in the treatment plant.	Install online pH and DO analysers, and the associated SCADA control and monitoring.	LOW

ARUP

Lanjophakha WWTP

Design Capacity: 0.6 MLD

Current Capacity: 45% of design capacity

Issues Identified	Basis/Assumptions	Recommendation	Criticality Rating
Odor nuisance in WWTPs	Assume there is no odor control unit.	Provide a good ventilation and OCU in the treatment plant since the plant has nearby residences	LOW
		Consider adding a trash bin with the lid and have a proper disposal method for the screenings.	LOW
• Have no removal for biological nutrient. • No alkali/acid dosing	• Activated sludge requires longer aeration time with suitable pH of wastewater for nitrification. There is no anoxic tank for denitrification. • No anaerobic or chemical treatment to remove phosphorus.	Investigate if the capacity of the aeration tank is enough to further nitrify the wastewater to reach its target quality as well as the blowers.	MEDIUM
		If the existing tank is not enough for nitrification, consider exploring possible options to remove the ammonia up to its target quality such as the following: • Addition unit of the aeration tank and other auxiliaries like blower and provide an alkali/acid dosing • Addition of biological aerated filter • Addition of clay-based filter that can adsorb ammonia • Retrofit it with other secondary treatment technologies like Step-feed, SBR, MLE.	MEDIUM
		Investigate if the existing component of the plant can biodegrade the phosphorus of the wastewater up to its target effluent quality.	MEDIUM
		If not, provide a chemical (metal salts or polymer e.g. $FeCl_3$ or PAC) that can precipitate the phosphorus and examine if the existing setter is suitable to efficiently remove the precipitates. If not, consider to add another unit of settler.	MEDIUM

ARUP

Lanjophakha WWTP

Design Capacity: 0.6 MLD

Current Capacity: 45% of design capacity

Issues Identified	Basis/Assumptions	Recommendation	Criticality Rating
No sludge treatment	Sludge holding tank can store the sludge within few hrs	Provide dewatering unit if there's available space	HIGH
• Insufficient to no historical data for all parameters required in effluent • No influent quality data	Based on the data given, COD, BOD and pH are being tested three times per month.	Develop a sampling plan and testing procedure for internal and third-party laboratory testing and analysis for all required parameters to ensure compliance and identify its influent quality.	**HIGH**
		Influent characteristics should be established so that it could be used as a basis in constructing a centralized WWTPs	**LOW**
No enough skilled personnel (i.e. Plant Manager, Process Engineer or Electro-mechanical Engineer)		Provide this skilled personnel to ensure the continuous operation of the plant as well as be certain that the effluent is conforming to the standard.	**LOW**
No operation and maintenance manual.	Assume there is no O&M manual or incomplete information	Develop an operation and maintenance manual that comprised of the standard procedures of operating and maintaining each equipment/process with health and safety measures. It also includes the following: • Detailed Design Criteria; • Process controls monitoring system; • Emergency operations plan and troubleshooting; • Schedule of routine inspection and preventive maintenance; • Sampling and/or water quality monitoring plan; • Inventory of equipment, chemicals and other supplies needed; and • Safe handling, storing and proper disposal of chemicals used.	**MEDIUM**

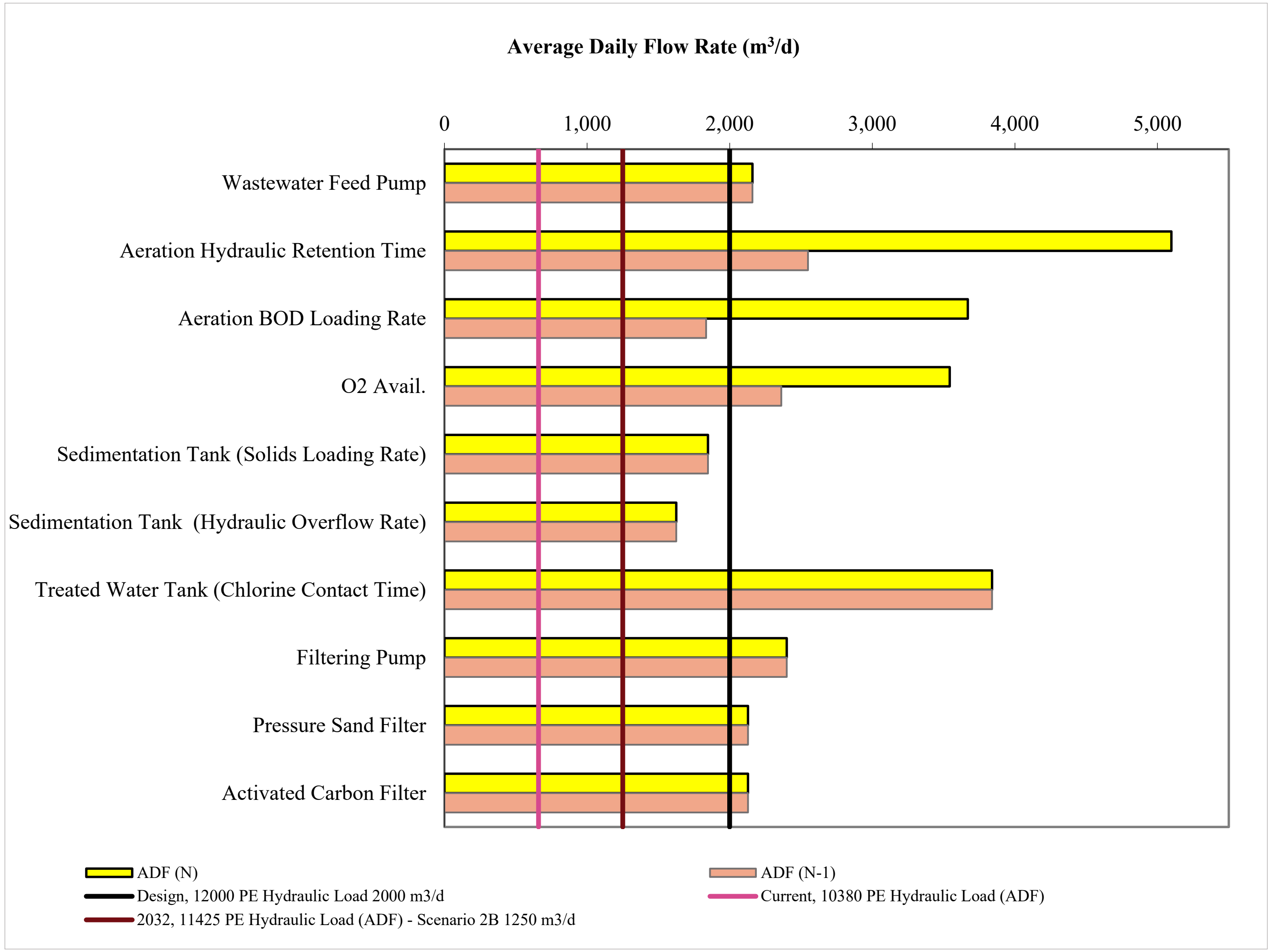
Lungtenzampa WWTP

Design Capacity: 2 MLD

Current Capacity: 33% of design capacity

General Remarks:

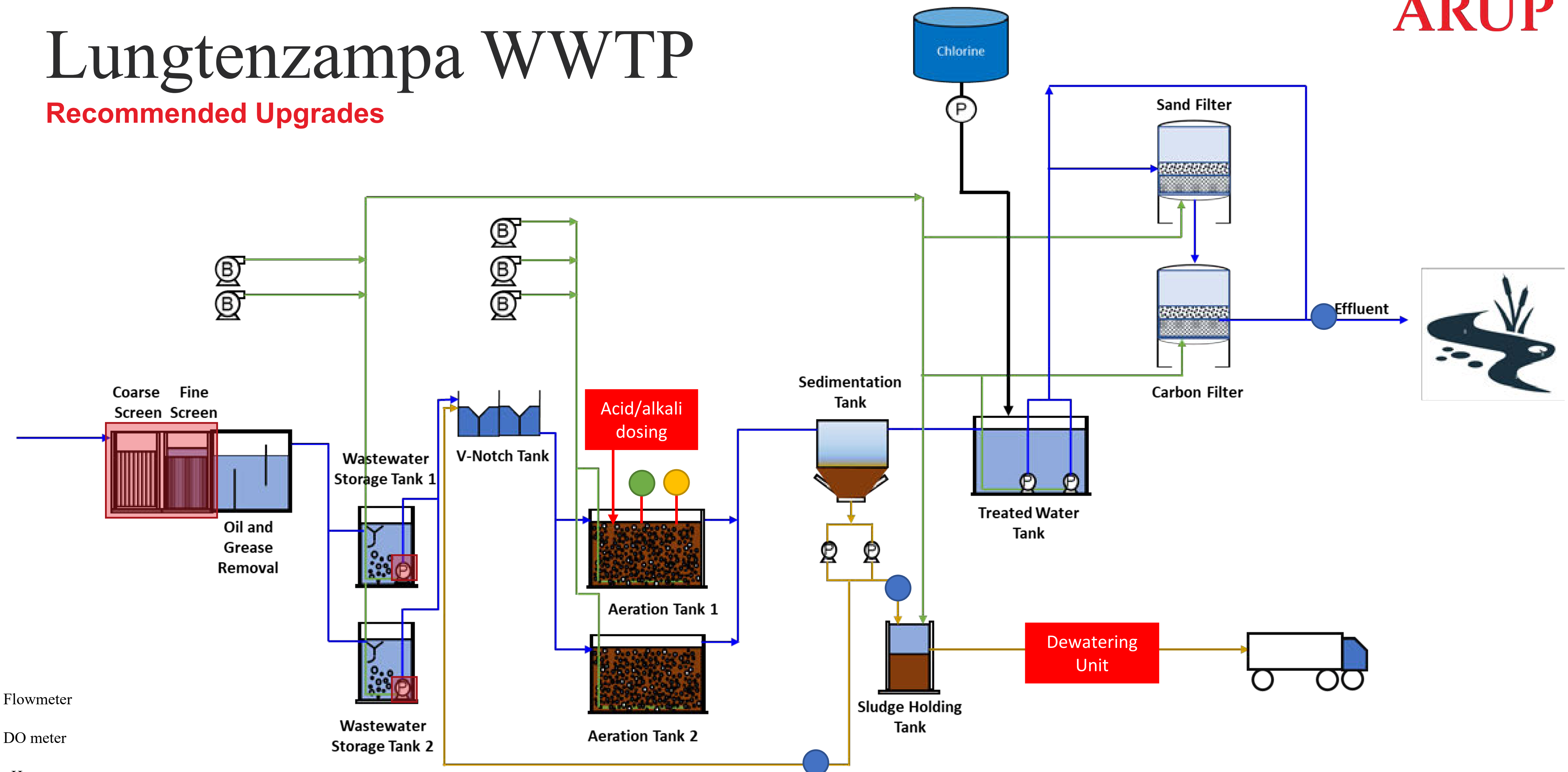
- All equipment in the graph are hydraulically capable to cater 2032 flow but insufficient to cater the design flow.
- Currently, not operational since August 2022



ARUP

Lungtenzampa WWTP

Recommended Upgrades



Flowmeter

DO meter

pH meter

Additional

Need actions

ARUP

Lungtenzampa WWTP

Design Capacity: 2 MLD

Current Capacity: 33% of design capacity

Issues Identified	Basis/Assumptions	Recommendation	Criticality Rating
Plant is not functional due to leaked pumps.	Based on the site visit.	Conduct full maintenance of troubleshooting and assess if equipment condition is acceptable for operation. There are many causes why the pumps are leaking. This could be because of the following: • seal material or bearings is already worn out, • not enough lubrication on the shaft, or • there is too much instability in the operating condition of the pumps like too much pressure drops or spikes.	**HIGH**
		If the pumps are not recoverable, consider replace the damaged pumps	**MEDIUM**
Screens are hydraulically overloaded.	• Failure of some downstream pumps; • Based on the picture, the water level is already reaching the overflow pipe.	• Further investigate the influent TSS, effluent TSS and operation condition. • Evaluate the removal efficiency and check if the solids are accumulated on the chambers that can affect the equipment downstream. • Consider revisiting the maximum allowable side water depth, which should be lower than the invert level of an overflow pipe, to identify if one unit is enough to cater for the design flow.	**HIGH**
		If it is already affecting the effluent quality as well the performance of other equipment, consider replacing the screens.	**MEDIUM**
		If the screens is already insufficient, consider add another unit of screens.	**MEDIUM**

ARUP

Lungtenzampa WWTP

Design Capacity: 2 MLD

Current Capacity: 33% of design capacity

Issues Identified	Basis/Assumptions	Recommendation	Criticality Rating
Possible not functional of other equipment	Few months of being shutdown	Consider checking the equipment which is not running for a long time like pumps and blowers if its effectively running according its design capacity.	HIGH
		Consider checking the electrical line cable, instrumentation, and pipeline if still in good condition that there is leak/damage and clogging.	HIGH
Possible clogging of diffusers in wastewater storage tanks and aeration tanks	It is not operational for few months.	Check its performance during the operation.	HIGH
		If it is already clogged, consider replacement of the diffusers	MEDIUM
Sedimentation tank is not reaching its design capacity.	• 60 g BOD/PE • MLSS = 3000 mg/L • RAS Ratio = 0.6	Further investigate the inlet, outlet TSS of sedimentation tank and effluent characteristics. Check its removal efficiency.	LOW
		If it is affecting the effluent TSS by exceeding the limit, consider add a lamella or provide additional unit.	LOW
Possible short circuiting happens in a Treated Water Tank	Assume that there is no mixer or baffle in the tank.	Investigate the effluent's fecal coliform.	MEDIUM
		If there's a time that effluent exceeds the limit, it requires an addition of baffle or mixer.	MEDIUM
Possible difficulty in operating the plant	No SCADA and online instruments such as pH, DO, turbidity/TSS analyzers but there is a local PLC in the treatment plant.	Install online turbidity/TSS, pH and DO analysers, and the associated SCADA control and monitoring.	LOW

Lungtenzampa WWTP

Design Capacity: 2 MLD

Current Capacity: 33% of design capacity

Issues Identified	Basis/Assumptions	Recommendation	Criticality Rating
Odor nuisance in WWTPs	Assume there is no odor control unit.	Provide a good ventilation and OCU in the treatment plant.	LOW
		Consider adding a trash bin with the lid and have a proper disposal method for the screenings.	LOW
• Have no removal for biological nutrient. • No alkali/acid dosing	• Activated sludge requires longer aeration time with suitable pH of wastewater for nitrification. There is no anoxic tank for denitrification. • No anaerobic or chemical treatment to remove phosphorus.	Investigate if the capacity of the aeration tank is enough to further nitrify the wastewater to reach its target quality as well as the blowers.	MEDIUM
		If the existing tank is not enough for nitrification, consider exploring possible options to remove the ammonia up to its target quality such as the following: • Addition unit of the aeration tank and other auxiliaries like blower and provide an alkali/acid dosing • Addition of biological aerated filter • Addition of clay-based filter that can adsorb ammonia • Retrofit it with other secondary treatment technologies like Step-feed, SBR, MLE.	MEDIUM
		Investigate if the existing component of the plant can biodegrade the phosphorus of the wastewater up to its target effluent quality.	MEDIUM
		If not, provide a chemical (metal salts or polymer e.g. $FeCl_3$ or PAC) that can precipitate the phosphorus and examine if the existing setter is suitable to efficiently remove the precipitates. If not, consider to add another unit of settler.	MEDIUM

ARUP

Lungtenzampa WWTP

Design Capacity: 2 MLD

Current Capacity: 33% of design capacity

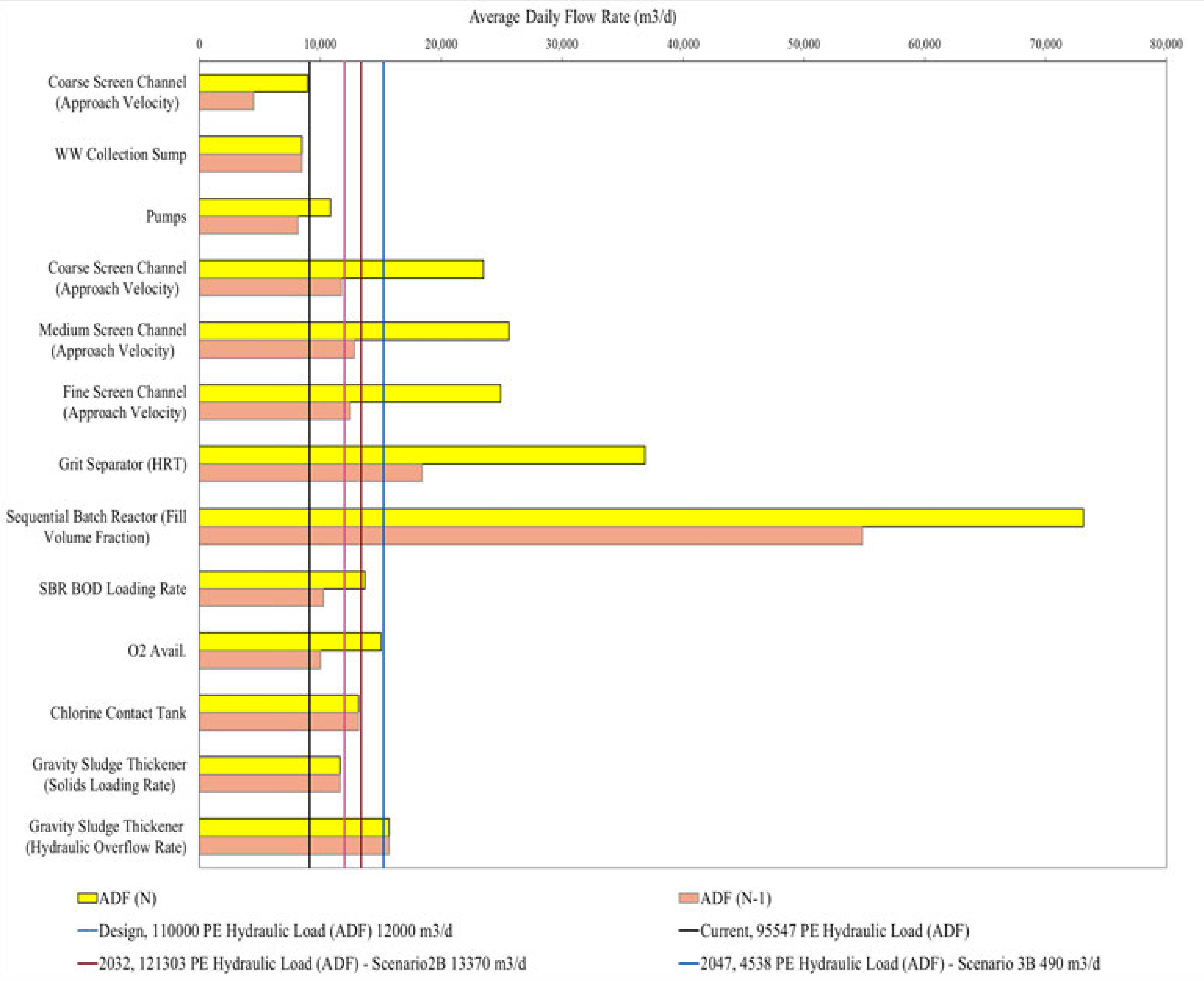
Issues Identified	Basis/Assumptions	Recommendation	Criticality Rating
No sludge treatment	Sludge holding tank can store the sludge within few hrs	Provide dewatering unit if there's available space	HIGH
• Insufficient to no historical data for all parameters required in effluent • No influent quality data	Based on the data given, COD, BOD and pH are being tested three times per month.	Develop a sampling plan and testing procedure for internal and third-party laboratory testing and analysis for all required parameters to ensure compliance and identify its influent quality.	**HIGH**
		Influent characteristics should be established so that it could be used as a basis in constructing a centralized WWTPs	**LOW**
No enough skilled personnel (i.e. Plant Manager, Process Engineer or Electro-mechanical Engineer)		Provide this skilled personnel to ensure the continuous operation of the plant as well as be certain that the effluent is conforming to the standard.	**LOW**
No operation and maintenance manual.	Assume there is no O&M manual or incomplete information	Develop an operation and maintenance manual that comprised of the standard procedures of operating and maintaining each equipment/process with health and safety measures. It also includes the following: • Detailed Design Criteria; • Process controls monitoring system; • Emergency operations plan and troubleshooting; • Schedule of routine inspection and preventive maintenance; • Sampling and/or water quality monitoring plan; • Inventory of equipment, chemicals and other supplies needed; and • Safe handling, storing and proper disposal of chemicals used.	**MEDIUM**

ARUP

Babesa WWTP

Design Capacity: 12 MLD

Current Capacity: 76% of the design capacity

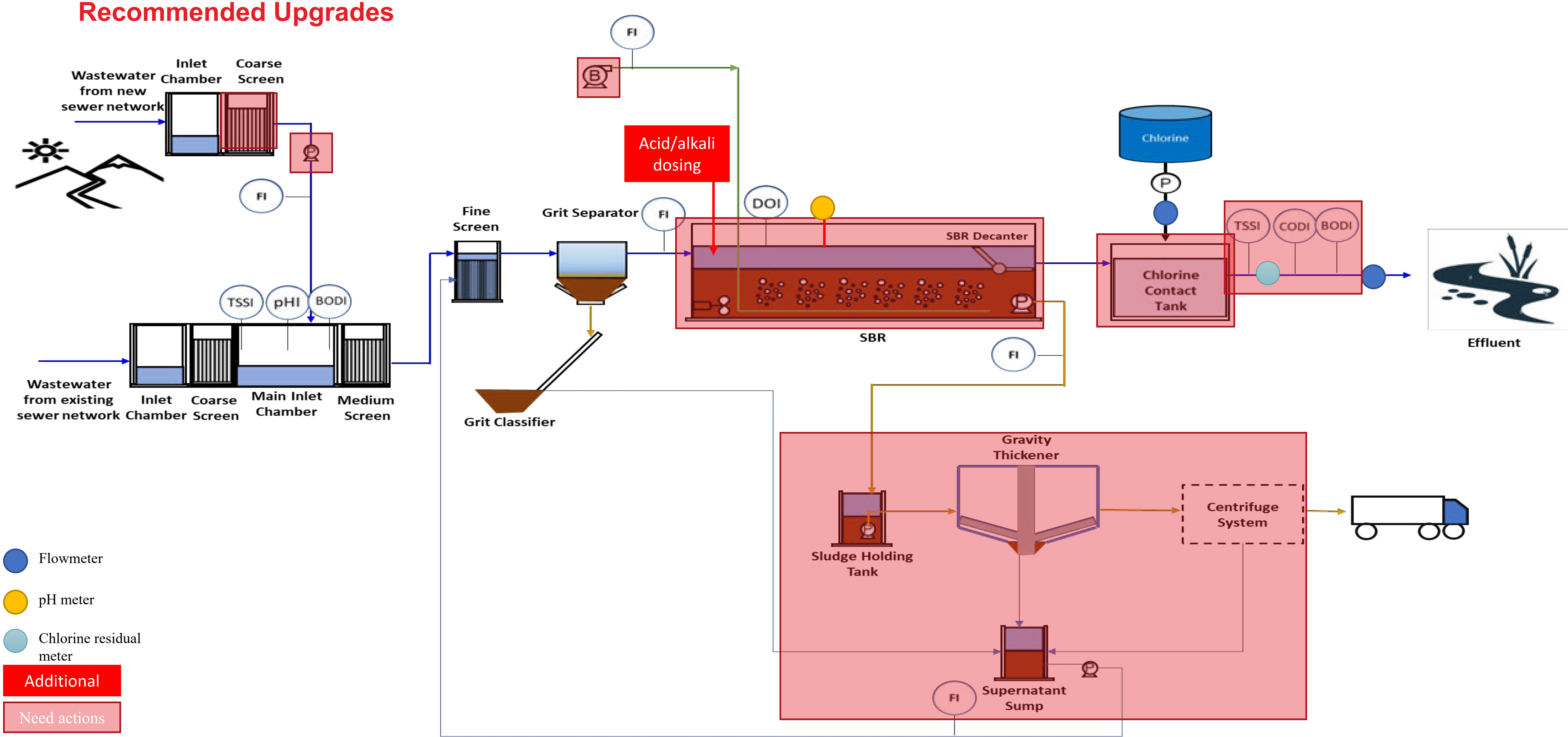


General Remarks:

- Insufficient capacity to cater the 2032 and 2047 flow

Babesa WWTP

Recommended Upgrades



ARUP

Babesa WWTP

Design Capacity: 12 MLD

Current Capacity: 76% of the design capacity

Issues Identified	Basis/Assumptions	Recommendation	Criticality Rating
• Outside coarse screen may be insufficient in receiving the wastewater from new sewer line. • One of the coarse screen is not functional.	• Assumed the flow passing through is 12 MLD. • Ratio of clear opening area/cross-section area of water = 0.5 • Angle of slant (horizontal) = 60^o	• Validate actual flow measures coming from the new sewer line and evaluate with the existing capacity of the coarse screens • Investigate if there is a frequent failure of pumps downstream to check if the screens are sufficient to remove the solids.	HIGH
		If the flow is greater than the capacity of the coarse screen, it needs an additional another chamber with coarse screen.	MEDIUM
		Prepare a service report of the defective coarse screen.	HIGH
		If the defective coarse screen cannot be troubleshoot, replace it with a new one.	MEDIUM
		Properly maintain the screens in order for the solids to not accumulate.	MEDIUM
Insufficient capacity of pump	• Assumed the flow going in and needs to pump is 12 MLD. • Actual each pump capacity is 158.30 m^3/hr with 4 units.	Identify the influent flow for this line. Identify the influent flow for this line. If the pump capacity is not enough, add a unit or replace with higher capacity.	HIGH
Screens (Coarse, Medium and Fine Screens) inside of the preliminary building are insufficient if only 1 Duty+1 Stand-by.	• Assumed the flow passing through is 12 MLD. • Ratio of clear opening area/cross-section area of water = 0.5 • Angle of slant (horizontal) = 60^o	Identify how many flow is going to these screens as well as the removal efficiency of solid from the inlet up to the outlet of fine screens.	MEDIUM
		If the flow is greater than the capacity as well as inefficient of solid removal, consider additional unit of screens.	LOW
		Properly maintain the screens in order for the solids to not accumulate.	MEDIUM

Babesa WWTP

Design Capacity: 12 MLD

Current Capacity: 76% of the design capacity

Issues Identified	Basis/Assumptions	Recommendation	Criticality Rating
Size of the SBR tanks are not enough to biologically treat the wastewater when 3 Duty+1 Stand-by and insufficient by 11% with 2047 flow even if all units are running.	• Total cycle time considered is 4 hrs with fill and aeration time is 1.5 hrs, settle time is 1 hr, decant time is 1 hr and idle time is 0.5 hr. • BOD loading rate used is 0.3 kgBOD/m^3/d. • Fill Volume Fraction is 0.12 from SVI 120 mg/L. • 60 g BOD/PE	Further investigate the performance of the biological treatment by checking its removal efficiency.	**HIGH**
		If it is not capable meeting the standards, adjust the operation by modifying the intercycle phase duration.	**MEDIUM**
		If it still not capable meeting the standards, explore replacing the activated sludge by granular sludge.	**MEDIUM**
		If it still not capable meeting the standards, add additional unit of SBR tank.	**MEDIUM**
		If the auxiliaries are not enough to cater the 2032 flow, consider add another unit of pumps, blowers and other auxiliaries.	**MEDIUM**
Aeration Blower is insufficient when 2D+1S and insufficient by 1% with 2047 flow even if all units are running.	The assumed rated capacity is 740 m^3/hr based on the captured SCADA.	Validate the flow of assumed capacity of the blower. If it is validated that this is insufficient since it is necessary to have stand-by unit of blower, provide additional unit.	**HIGH**
• Insufficient contact time in chlorine tank • Possible short circuiting happens in a Treated Water Tank	• 90 mins HRT • Assume that there is no mixer or baffle in the tank.	Investigate the effluent's fecal coliform.	**HIGH**
		If there's a time that effluent exceeds the limit, adjust the dosing of chlorine since there is no sufficient contact time.	**MEDIUM**
		If there's a time that effluent exceeds the limit, it requires an addition of baffle or mixer.	**MEDIUM**
		If there's a time that effluent exceeds the limit, it requires an addition of baffle or mixer.	**MEDIUM**

ARUP

Babesa WWTP

Design Capacity: 12 MLD

Current Capacity: 76% of the design capacity

Issues Identified	Basis/Assumptions	Recommendation	Criticality Rating
Sludge Holding Tank can only store the sludge for approximately at most hours.	• 24 hrs operating • 60g BOD/PE • Sludge Specific Yield (0.8 kg dry sludge/kg BOD) • 1% concentration of sludge • 1050 kg/m^3 sludge density	Identify the flow of the waste activated sludge and compare it if the sludge holding tank has enough capacity to cater the amount of time when the sludge treatment is in downtime.	HIGH
		If it's insufficient, provide an additional sludge holding tank or extend the existing tank or increase the time of sludge treatment considering that the other equipment is capable to handle that duration via adding unit of the downstream equipment like thickener and dewatering unit.	MEDIUM
Insufficient capacity of Gravity Sludge Thickener as well as the Dewatering Unit to cater the sludges in terms of solids loading rate.		Identify the flow of the waste activated sludge and check if its effectively thickened the sludge up to its desirable moisture content.	HIGH
		If not sufficient, then consider add a polymer or increase the dosing of polymer if its already has polymer dosing or provide additional unit of thickener and centrifuge,	MEDIUM
• Have no removal for biological nutrient. • No alkali/acid dosing	• Nitrification always happen with sufficient time of aeration as well as with the right pH. • Treatment plant has additional anoxic tank as well as in the SBR sequence hence, denitrification can be done. • No anaerobic or chemical treatment to remove phosphorus.	Investigate if the existing SBR is enough to further nitrify the wastewater to reach its target quality.	MEDIUM
		If the reactor is not enough for nitrification, consider exploring possible options to remove the ammonia up to its target quality such as the following: • Adjust the operation by modifying the intercycle phase duration. • Exploring converting activated sludge into granular sludge • Addition unit of SBR and other auxiliaries like blower and alkali/acid dosing • Addition of air stripping system • Addition of ion exchange with zeolite as media • Addition of biological aerated filter • Addition of clay-based filter that can adsorb ammonia • Retrofit it with other secondary treatment technologies like Step-feed, SBR, MLE.	MEDIUM

ARUP

Babesa WWTP

Design Capacity: 12 MLD

Current Capacity: 76% of the design capacity

Issues Identified	Basis/Assumptions	Recommendation	Criticality Rating
Have no removal for biological nutrient	• Nitrification always happen with sufficient time of aeration as well as with the right pH. • Treatment plant has additional anoxic tank as well as in the SBR sequence hence, denitrification can be done. • No anaerobic or chemical treatment to remove phosphorus.	Investigate if the existing component of the plant can biodegrade the phosphorus of the wastewater up to its target effluent quality.	**MEDIUM**
		If not, provide a chemical (metal salts or polymer e.g. $FeCl_3$ or PAC) that can precipitate the phosphorus and examine if the precipitates can settle within the settling time.	**MEDIUM**
		If precipitate cant settle within the settling time, consider add a filter after reactor in order to remove the precipitates in the effluent.	**MEDIUM**
Possible odor problem in a preliminary treatment	Debris is manually collected and placed in the open basin	Consider adding a trash bin with the lid or screen compactors and have a proper disposal method for the screenings. The recovered supernatant from compactors should be directed to the main inlet chamber.	**MEDIUM**
Possible difficulty in operating the plant	With SCADA and online instruments	Identify the online controls that should be monitored and controlled by the plant's current basic SCADA.	**LOW**
		If insufficient to easy to adjust or control the plant, install online instruments and add it in the SCADA.	**LOW**
• Insufficient to no historical data for all parameters required in effluent • Insufficient to no historical data for influent quality	COD, BOD, and TSS parameters can be seen in the analog monitoring	Develop a sampling plan and testing procedure for internal and third-party laboratory testing and analysis for all required parameters to ensure compliance and identify its influent quality.	**HIGH**

ARUP

Babesa WWTP

Design Capacity: 12 MLD

Current Capacity: 76% of the design capacity

Issues Identified	Basis/Assumptions	Recommendation	Criticality Rating
No enough skilled personnel (i.e. Plant Manager, Process Engineer or Electro-mechanical Engineer)	Assume that there is no skilled personnel in 30 personnel	Provide the skilled personnel to ensure the continuous operation of the plant as well as be certain that the effluent is conforming to the standard.	**LOW**
No operation and maintenance manual.	Assume there is no O&M manual or incomplete information	Develop an operation and maintenance manual that comprised of the standard procedures of operating and maintaining each equipment/process with health and safety measures. It also includes the following: • Detailed Design Criteria; • Process controls monitoring system; • Emergency operations plan and troubleshooting; • Schedule of routine inspection and preventive maintenance; • Sampling and/or water quality monitoring plan; • Inventory of equipment, chemicals and other supplies needed; and • Safe handling, storing and proper disposal of chemicals used.	**MEDIUM**

Appendix H

New WWTP Pre-selection

ARUP

JOB TITLE	Thimpu Water Services Masterplan
JOB NUMBER	289551-01
MADE BY	EV
CHECKED BY	PC
DATE	10/05/2023
Description of spreadsheet	New WWTP - Pre-selection Screening
Sheet Number prefix	
Member/Location	
Drawing Reference	
Filename	

CONTENTS OF SPREADSHEET

Sheet	Description
Cover	
Criteria Guide Note Part 1	WWTP Pre-Selection Criteria Guide Note for 1st Stage
Criteria Guide Note Part 2	WWTP Pre-Selection Criteria Guide Note for 2nd Stage
Options Screening	WWTP Pre-Selection Criteria and Scoring

AUTHORISATION OF LATEST VERSION

Type and method of check		
Signatures & dates:	Made by	EV
	Checked	PC

REVISIONS Current Revision 0

Rev.	Date	Made by	Checked	Description
0	10/05/23	EV	PC	Pre-Selection

ARUP

Job No.	Sheet No.	Rev.
289551-01	1	0

Member/Location:

Job Title: Thimpu Water Services Masterplan

Drg. Ref.:

Calculation: Criteria Guide Note Part 1

Made by: EV | Date: 10/05/2023 | Chd.: PC

Stage	Category	Q#	Criteria	Question	MBR	MLE	Oxidation Ditch	SBR	Step-feed	AGS	IFAS	BAF/SAF	FBBR	MBBR	RBC	Trickling Filter
1st Stage Preselection Criteria	Brief Description				Suspended growth process with membrane filtration	Suspended growth process	Suspended growth process with longer Solids Retentioin time (SRTs)	Batch suspended growth process	Plug flow of suspended growth	Granular activated sludge	Suspended growth reactor with attached growth media	Attached growth process with fixed bed filter	Attached growth process with fixed bed biofilm	Attached growth process with moving bed biofilm	Attached growth process with circular disk on horizontal shaft	Attached growth process with fixed bed filter
	High Level MCA Criteria	1	Biological Nutrient Removal Capability	Does the technology - considering proper configuration, without combining with other techs - meet the biological nutrient (nitrogen and phosphorus) removal targets based on the influent characteristics?	Pre-anoxic configuration with Internal Recycle is commonly applied for BNR requirement; <6 mg/L TN effluent is achievable	One of the most common methods used for biological nitrogen removal; < 10 mg/L TN effluent is achievable	Considered as Cyclic Nitrification – Denitrification process typically done in single reactor systems or single reactor compartmentalized systems; <5 mg/L TN is achievable	Mix (Anoxic) and Aerate (Aerobic) can be included in the SBR process cycle; 5 to 8 mg/L TN effluent is achievable	Multi-stage reactors can be configured to anoxic/aerobic set-up <5 mg/L TN effluent is achievable	Simultaneous Nitrification and Denitrification occurs with nitrification in the outer layer of the granules and denitrification in the inner layers. Similar or better effluent quality than other BNR technologies	Nitrifying bacteria can grow on the IFAS media to provide nitrification despite the limited SRT in the suspended growth process.	Can be configured for both nitrification and denitrification process depending on the application if air within the filter; BOD removal and nitrification removal efficiency of ≥85%	Common use has been for nitrification but also capable of biological denitrification in tertiary treatment applications; Can achieve effluent ammonia-N concentration of 0.5 mg/L	Multistage reactors for heterotrophic and nitrifying bacteria can grow on the MBBR media. Effluent total nitrogen < 10 mg/L	Both aerobic nitrifying bacteria and anaerobic denitrifying bacteria can simultaneously live in the attached biofilm	Applications include combined BOD removal and nitrification, however, difficult in accomplishing biological nitrogen and phosphorus removal compared to single-sludge biological nutrient removal suspended growth designs
		2	Weather Adaptability	Does it capable to run in a cold weather condition?	Suitable but potential issues may arise during the cold weather	Suitable but potential issues may arise during the cold weather	Suitable but potential issues may arise during the cold weather	Suitable but potential issues may arise during the cold weather	Suitable but potential issues may arise during the cold weather	Suitable but potential issues may arise during the cold weather	Suitable but potential issues may arise during the cold weather	Suitable but potential issues may arise during the cold weather	Suitable but potential issues may arise during the cold weather	Suitable but potential issues may arise during the cold weather	Protection of the system in a cold climate is difficult	Suitable but potential issues may arise during the cold weather
		3	Space	Does the technology fit in the available area?	Small	Mid	Largest	Relatively small depends on depth	Small	Small	Large	Small	Small	Small	Small	Large
		4	Capacity	Does the technology is suitable in low capacity? Is it usually used for treatment plants with low flow?	Have existing plants and potential suppliers with low capacity	Have existing plants and potential suppliers with low capacity	Have potential suppliers with low capacity	Have existing plants and potential suppliers with low capacity	Generally applicable	Have existing plants and potential suppliers with low capacity	Have potential suppliers with low capacity	Have potential suppliers with low capacity	Generally applicable	Have potential suppliers with low capacity	Have existing plants and potential suppliers with low capacity	Have existing plants and potential suppliers with low capacity

ARUP

Job No.	Sheet No.	Rev.
289551-01	2	0

Member/Location:

Drg. Ref.:

Job Title: Thimpu Water Services Masterplan

Calculation: Criteria Guide Note Part 2

Made by: EV | Date: 10/05/2023 | Chd.: PC

Stage	Category	Question No #	Weighting (0-10 points)	Criteria	Questions	SCORE GUIDE 1 - worst	2	3 - Best
2nd Stage Preselection Criteria	High Level MCA Criteria	5	20	TT experience	Does TT have experience with using such technology?	TT has no experience regarding the operation of this type of process facility	TT has some and/or limited experience with such technology. TT has at least 1 plant with this type of technology	TT has extensive experience with operating this type of technology. It has more than 1 plant of this type of process technology and has more than 5 years experience with using this technology
		6	20	Operation & Maintenance	Is this technology difficult to operate and maintain.	This technology is difficult to maintain, due to factors such as: - requiring permanent personnel onsite, - requiring complex SCADA and controls systems in place to monitor the treatment process. - Requires specialist expertise and knowledge to operate and maintain which skills cannot be easily obtained, procured or trained locally	This technology requires some regular maintenance and factors such as: -requiring some personnel to be dedicated to the operation and management of the plant. - Majority of labor and materials can be sourced and obtained locally with minimal importation of goods and labor required.	This technology is easy to maintain. Such factors to determine this may include: - - Requiring minimal personnel onsite to manage and operate the plant - technology has simple and/or limited SCADA controls and systems required in place to monitor. - The plant essentially can run it self. - All labor and materials to run the plant can be sourced locally or in India
		7	15	Constructability	Is this process easy to construct (i.e. are there a number of flow splits, clarifiers with slope bottom, difficult formwork)?	The process technology is difficult to construct with issues/risks may include: - complex structures, requiring complex formwork - deep pits (>6m) - equipment that cannot be sourced locally and may need to be imported	The process technology is does not have many major risks or issues that are currently known.	The process technology is relatively easy to construct. Overall construction may include; - relatively shallow pits deep pits (<6m), - all electrical mechanical equipment can be sourced locally. - All structures are relatively straightforward and formwork is not complex.
		8	20	Reliability	Is this process reliable and robust?	The process technology is not robust and unreliable. The determination of this is due to the following factors such as - The technology is unproven and with a little performance record in this region and climate - this technology is inflexible and cannot perform with changing conditions (flow, load, concentrations)	The process technology is somewhat reliable and robust. The determination of this is due to the following factors such as - The technology is proven elsewhere and with solid performance record , however it has not been tried and/or has a record of success in this region and/or climate - this technology is flexible and has a limited performance record within changing conditions (flow, load, concentrations), however there are some doubts to the records of success and performance in this region.	The process technology is robust and reliable. The determination of this is due to the following factors such as - The technology is proven and with a solid performance record in this region and climate - this technology is flexible and can perform with changing conditions (flow, load, concentrations)
		9	15	Equipment, Chemicals and other requirements	Is this process using chemicals that are not readily available locally? Are the chemicals expensive? Replacement equipment (pumps, parts etc.)	Determination of this within this category may include factors such as: - chemicals cannot be sourced locally and have to be imported - equipment can be easily replaced and shave to be imported - operating equipment and perishable items needed are expensive and cannot be sourced locally	Determination of this within this category may include factors such as: -Some chemicals cannot be sourced locally and have to be imported - Some equipment can be easily replaced and shave to be imported - Some operating equipment and perishable items needed are expensive and cannot be sourced locally	Determination of this within this category may include factors such as: - chemicals can be sourced locally easily at competitive prices - equipment can be easily replaced and sourced locally - operating equipment and perishable items needed are relatively inexpensive and can be sourced locally
		10	10	Envi & Social Impacts	Does this technology has any types/amounts of treatment residuals not acceptable to TT or have negative environmental impacts? Does this technology have a different level of social impact to the nearby community	This process technology has increased adverse social and environmental impacts. Determination within this category may include: - Increased of higher external air, noise pollution caused by this technology compared to other technologies known in the market - Detrimental disturbance to the nearby community - Increased of higher footprint requirements which may lead to higher area/land requirements of this technology compared to other technologies known in the market - Increased of higher energy consumption requirements leading to an increased carbon footprint of this technology compared to other technologies known in the market	This process technology has social and environmental impacts. Determination within this category may include: - adverse external air, noise pollution caused by this technology compared to other technologies known in the market - adverse disturbance to the nearby community	This process technology has limited or minimal adverse social and environmental impacts. Determination within this category may include: - Minimal external air, noise pollution caused by this technology compared to other technologies known in the market - Minimal disturbance to the nearby community - reduced footprint requirements which may lead to reduced area requirements - reduced energy consumption requirements leading to a smaller carbon footprint
			100					

Note:
Assuming the technology will not be combined with other treatment technologies for preliminary and tertiary.

ARUP	Job No.	Sheet No.	Rev.
	289551-01	3	0
	Member/Location		
Job Title: Thimpu Water Services Masterplan	Drg. Ref.		
Calculation: Options Screening	Made by: EV	Date: 10/05/2023	Chd.: PC

Biological Treatment Comparison

Category	Process	1st Stage Pre Selection Criteria – High Level MCA: Q1 BNR	Q2 Weather Adaptability	Q3 Space	Q4 Capacity	REMARKS	2nd Stage Pre Selection Criteria – High Level MCA: Q5 (20) Thimpu Thromde Experience	Q6 (20) Operation & Maintenance	Q7 (15) Constructability	Q8 (20) Reliability	Q9 (15) Equipment, Chemicals and other requirements	Q10 (10) Envi & Social Impacts	Weighted Score (100)	Rank
Suspended Growth	Membrane Bio-Reactor (MBR)	Y	Y	Y	Y	Smallest space needed; identified existing treatment plants with low capacity but with the highest CAPEX and OPEX								
Suspended Growth	Modified Ludzack-Ettinger (MLE)	Y	Y	Y	Y	Identified existing treatment plants with low capacity; Low CAPEX and OPEX	3	3	3	2	3	2	270	1
Suspended Growth	Oxidation Ditch	Y	Y	Y	Y	Largest space needed; Have potential suppliers with low capacity; Higher CAPEX and OPEX than MLE								
Suspended Growth	Sequencing Batch Reactor (SBR)	Y	Y	Y	Y	Possible small space needed but it depends on the depth of the tank; Identified existing treatment plants with low capacity	2	2	2	2	3	2	215	3
Suspended Growth	Step Feed	Y	Y	Y	Y	Small space needed; Low OPEX but higher CAPEX than MLE								
Granular	Aerobic Granular Sludge (AGS)	Y	Y	Y	Y	Small space needed; Identified existing treatment plants with low capacity; Low OPEX but higher CAPEX than MLE	1	2	2	2	2	3	190	4
Hybrid	Integrated Fixed Film Activated Sludge (IFAS)	Y	Y	Y	Y	Large space needed; Have potential suppliers with low capacity; Higher CAPEX than MLE								
Biofilm	Biological Aerated Filter (BAF) or Submerged Aerated Filter (SAF)	Y	Y	Y	Y	Small space needed; Have potential suppliers with low capacity; Lower OPEX but higher CAPEX than MLE								
Biofilm	Fixed Bed Biofilm Reactor (FBBR)	Y	Y	Y	Y	Small space needed; Lower OPEX but higher CAPEX than MLE								
Biofilm	Moving Bed Biofilm Reactor (MBBR)	Y	Y	Y	Y	Small space needed; Have potential suppliers with low capacity; Lower OPEX but higher CAPEX than MLE	3	2	3	3	3	2	270	1
Biofilm	Rotating Media Reactor	Y	Y	Y	Y	Small space needed; Identified existing treatment plants of low capacity; Protection of the system in a cold climate is difficult								
Biofilm	Trickling Filter (FT)	Y	Y	Y	Y	Possible nutrient removal efficiency is lower as compared to others. Large space needed; Few identified treatment plants of low capacity;								

NOTE - ONLY MLE, SBR, STEP FEED, AGS AND MBRR GET CARRIED THROUGH TO THE 2ND STAGE HIGH LEVEL MCA ANALYSIS

Very suitable
Commonly Suitable
Slightly suitable but with problem

Appendix I

Wastewater Separation Strategy Example

Phase 1 Example: Dechencholing WWTP Catchment

The plan below illustrates the scale of investigation for the Dechencholing catchment wastewater separation strategy. It excludes investigations at the WWTP which will be required as part of the wider Wastewater Masterplan. The local team will need to procure investigation with suitably qualified individuals and organisations with the correct safety systems and hardware to deliver the requirements safely and of suitable quality.

For the more technically challenging surveys wider support and training may be required. Investigations are often adaptive; an initial desk study will form the initial plan (example as below), then during the surveys the plans will adapt depending on findings. For example, if significant levels of infiltration or silt are observed, local CCTV may be required to confirm the extent / source.

Flow survey is often the highest cost element but also at greatest risk of delivering poor data. Experience is needed to select appropriate sites (typically pipes > 225mm, sub-critical flow, lack of turbulence, representative of upstream network, downstream conditions, lack of shifting silt) and to also pro-actively manage the survey weekly.

4. Royal Estate, Education and Religious Facilities

Check connectivity of complex. Conduct drainage area survey for car parks and roof.

2. Residential Area a + b +c

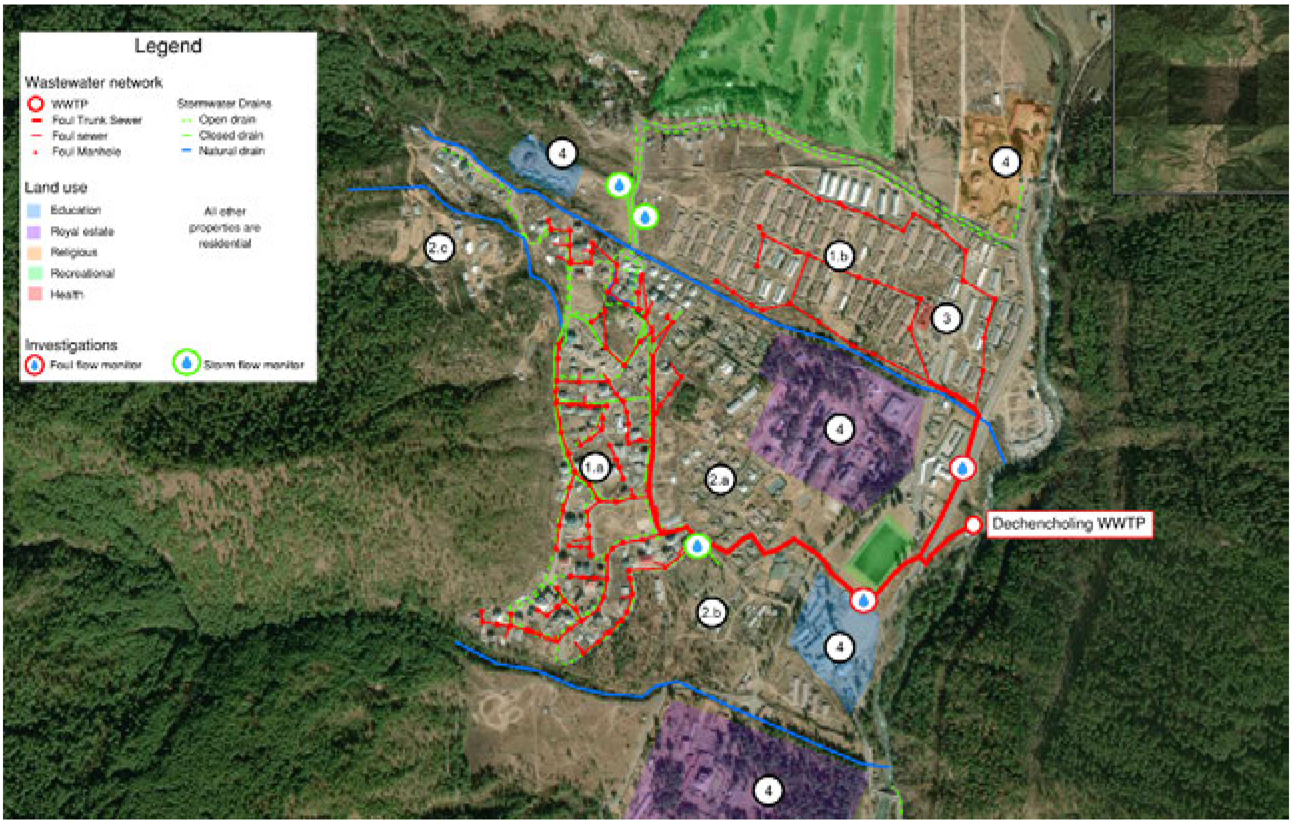
Same as above but, as no drainage information is known for the housing development, conduct the connectivity survey for 1in5 properties.

3. Hospital Complex

Check connectivity of hospital trade flows. Conduct drainage area survey for hospital car park and roof.

1. Residential Area a + b

- Conduct connectivity survey for 1in10 properties. Assume the same connectivity for other properties of same age and housing development. Also identify any abandoned pipes that used to connect greywater to the foul network.
- Conduct drainage area survey for streets, carparks, and large roofs. Also test permeable areas liable to run-off to the network.
- Conduct manhole survey for:
  - Roughly every 50m down the foul trunk sewer and at least one manhole on each side sewer branch.
  - Any manholes containing bifurcations, flow controls, or sharp changes in direction/gradient.
  - Roughly every 50m down closed storm water drains.
- Section details every 100m or at important step changes for open and natural stormwater drains.
- Asset survey for any storage tanks.
- Conduct CCTV along pipes of uncertain connectivity and pipes likely to be in poor state to identify infiltration/blockages/collapses.


Legend
Wastewater network
WWTP
Foul Trunk Sewer
Foul sewer
Foul Manhole
Stormwater Drains
Open drain
Closed drain
Natural drain
Land use
Education
Royal estate
Religious
Recreational
Health
All other properties are residential
Investigations
Foul flow monitor
Storm flow monitor
4
4
1.b
2.c
3
4
1.a
2.a
Dechencholing WWTP
2.b
4
4