REPUBLIC OF KENYA
MINISTRY OF ENVIRONMENT
WATER AND NATURAL RESOURCES
(MEWNR)

COAST WATER
SERVICES BOARD
(CWSB)

Water and Sanitation Service Improvement Project (WaSSIP)

Loan Nos.: IDA 4376-KE and CKE3010-1

Consultancy Services for Water Supply Master Plan for Mombasa and Other Towns Within Coast Province

Volume I
Water Supply Master Plan
Main Report

December 2013

KE-24890-R14-179

TAHAL GROUP

in association with

BHUNDIA associates

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List of Abbreviations

AFD	Agence Française de Développement (French Agency for Development)
ASAL	Arid and semi-arid lands
AV	Air valve
BH	Borehole
BOQ	Bill of quantities
BP	Bank Procedures (WB)
BPT	Break-pressure tank
BWSS	Bulk water supply system
CAPEX	Capital expenditures
CBO	Community-based organization
CBR	California bearing ratio
CDA	Coast Development Authority
CES	Consulting Engineering Services Ltd.
CI	Cast iron
CPR	Common property resource
CWSB	Coast Water Services Board
D	Diameter
DAC	District Area Coordinator
DC	District Commissioner
DDO	District Development Officer
DI	Ductile iron
Dia.	Diameter
DN	Nominal diameter
DOL	Direct-on-line
EAME	Eastern African Marine Ecoregion
EIA	Environmental impact assessment
EIRR	Economic Internal Rate of Return
EMCA	Environmental Management and Coordination Act
EMP	Environmental Management Plan
ENPV	Economic Net Present Value
EPC	Engineering, procurement and construction
Eta	Efficiency *(name of Greek letter: η)*
FEWS NET	Famine Early Warning Systems Network
Fig.	Figure
FS	Feasibility study
GoK	Government of Kenya
HDPE	High-density polyethylene

HLP	High-lift pump
HLPS	High-lift pumping station
HQ	Headquarters
IBA	Important Bird Area
IC	Individual connection
ICM	Integrated Coastal Management
ICZM	Integrated Coastal Zone Management
ID	Inner diameter
IEC	Information, Education and Communication
IFC	International Finance Corporation
IRR	Internal rate of return
JICA	Japan International Cooperation Agency
JPC	Japan Port Consultants
JV	Joint venture
KFS	Kenya Forest Service
KIMAWASCO	Kilifi-Mariakani Water and Sewerage Company
KNBS	Kenya National Bureau of Statistics
KWAWASCO	Kwale Water and Sewerage Company
KWS	Kenya Wildlife Service
LAPSSET	Lamu Port, South Sudan, Ethiopia Transport
LAWASCO	Lamu Water and Sewerage Company
LS	Lump sum
LV	Low-voltage
M&E	Monitoring & evaluation
MALWASCO	Malindi Water and Sewerage Company
MDG	Millennium Development Goals
MEWNR	Ministry of Environment, Water and Natural Resources
MoRDA	Ministry of Regional Development Authorities
MOWASCO	Mombasa Water and Sewerage Company
MPA	Marine Protected Area
MRS	Monthly runoff simulation
NDVI	Normalized Difference Vegetation Index
NEMA	National Environment Management Authority
NGO	Non-governmental organizations
NMT	New Mwache Tank
No.	Number
NOAA	National Oceanic Atmospheric Administration
NPV	Net present value
NRV	Non-return valve

NRW	Non-revenue water
NTE	Not to exceed
NWCPC	National Water Conservation and Pipeline Corporation
NWMP	National Water Master Plan
NWSS	National Water Services Strategy
O&M	Operations and maintenance
OP	Operation Policy (WB)
OPEX	Operational expenditures
PAC	Project-affected community
PAF	Project-affected family
PAH	Project-affected household
PAP	Project-affected person/people
PN	Nominal pressure
PPT	Project preparation team
PS	Pumping station
PVC	Polyvinyl chloride
Qty	Quantity
R&R	Rehabilitation and resettlement
RAP	Resettlement Action Plan
RC	Reinforced concrete
RDA	Regional Development Authority
RHC	Radial horizontal collector *(a type of well)*
RIU	RAP Implementation Unit
RSC	Resettlement Steering Committee
RWH	Rainwater Harvesting
SCADA	Supervisory control and data acquisition
SCF	Standard Conversion Factor
Sec.	Section
SV	Section valve
SWRO	Seawater reverse osmosis
TARDA	Tana and Athi Rivers Development Authority
TAVEVO	Taveta-Voi Water and Sewerage Company
TAWASCO	Tana Water and Sewerage Company
TDH	Total dynamic head *(of pumps)*
TKN	Total Kjeldahl nitrogen
ToR	Terms of reference
TRT	Treatment
TWL	Tank water level
UCBWSS	Unconnected to bulk water supply system

UfW	Unaccounted-for water
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USAID	U.S. Agency for International Development
USGS	U.S. Geological Survey
uPVC	Unplasticized polyvinyl chloride
VSP	Variable speed pump
WAB	Water Appeal Board
WaSSIP	Water and Sanitation Service Improvement Project
WB	World Bank
WFP	World Food Programme
WO	Water overflow
WRMA	Water Resources Management Authority
WSB	Water Services Board
WSMP	Water Supply Master Plan
WSP	Water service provider
WSRB	Water Services Regulatory Board
WSS	Water supply and sanitation
WSTF	Water Services Trust Fund
WT	Water tank
WTP	Water treatment plant
WV	Washout valve
WW	Waterworks
WWAP	World Water Assessment Programme
WWF	World Wide Fund for Nature

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Units:

A	ampere
BCM	billion cubic metres
d	day
h	hour
km	kilometre
KSh	Kenyan shilling
kVA	kilovolt-ampere
kVAr	kilovolt-ampere reactive
kW	kilowatt
kWh	kilowatt-hour
lpcd	litres per capita per day
m	metre
masl	metres above sea level
MCM	million cubic metres
mm	millimetre
MVA	megavolt-ampere
m^3	cubic metre
m^3/d	cubic metres per day
m^3/h	cubic metres per hour
m^3/s	cubic metres per second
MΩ	mega-ohm
rpm	revolutions per minute
US$	United States dollar
y	year

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Executive Summary

Water Supply Master Plan for Mombasa and Other Towns within Coast Province – Water Supply Master Plan

A – Objectives and Scope

This Water Supply Master Plan (WSMP) is the final document of the "consultancy for preparation of a Water Supply Master Plan for Mombasa and other towns within the Coast Province" for the Coast Water Services Board (CWSB) under the Water and Sanitation Service Improvement Project (WaSSIP).

The project is funded through credit and grant by the International Development Association (IDA) of the World Bank (WB) and Agence Française de Développement (AFD). The terms of reference (ToR) for the preparation of the WSMP was initially published by the CWSB in January 2011. The contract was awarded to TAHAL Consulting Engineers, and the final agreement was signed on 19 November 2011.

The general objectives of the WSMP are to increase access to reliable, affordable and sustainable water supply services in the Coast Province, and satisfy the growing water demand of the region, thereby achieving the water supply coverage set out in the **Millennium Development Goals (MDG)** and **Kenya Vision 2030**, both of which have priorities in terms of development and economic viability. In particular, the objectives of the WSMP are to:

- Identify potential water sources in the CWSB area of jurisdiction.
- Conduct hydraulic, hydrological, geotechnical, socioeconomic and environmental assessments of these resources, and recommend strategies for their development.
- Consider possibilities of recycling and use of treated wastewater to ease the stress on the fresh water resources of the region.
- Prepare water demand projections for the Coast Province up to the year 2035, and explore any relevant demand management options, such as pricing.
- Prepare both short-term and long-term investment needs to address gaps in water supply.
- Prepare environmental and social impact assessments.
- Carry out pre-feasibility studies for all options, full feasibility for the recommended four strategies and preliminary designs for the recommended option.
- Prepare a sequence of development for the preferred water resources and supply schemes based on the recommended development strategies.
- Develop a 25-year implementation schedule, in 5-year increments, and in line with the National Water Master Plan.

Numerous documents and reports were reviewed and analyzed during the study. The full list can be found in Section 1.3.2 of the main report. The WSMP was coordinated closely with the CWSB, Consulting Engineering Services (CES), Coast Development Authority (CDA), Water Resources Management Authority (WRMA), county administrations (Mombasa, Kwale, Kilifi, Taita Taveta, Lamu and Tana River), WB, AFD and the JICA study team, to share/incorporate data and findings from previous studies into the WSMP.

B – The Water Sector

Water resources management in Kenya is undertaken mainly on four levels – the national level, the regional level, the catchment area level and the watershed management level.

The Water Services Boards (WSBs) – in different regions of the country and under license from the Water Services Regulatory Board (WASREB) – are responsible for the provision of water services and development of related assets within their area of jurisdiction. The Water Service Providers (WSPs) – with a Service Provision Agreement (SPA) from the WSB – are responsible for the provision of water services at the local level on behalf of the WSB.

The Coast Development Authority (CDA) is one of the six Regional Development Authorities under the Ministry of Regional Development Authorities (MoRDA) in Kenya.

The Coast Water Services Board (CWSB), one of eight Water Service Boards in Kenya, is a parastatal organization created under the Water Act 2002, and established through Gazette Notice No. 1328 of 27th February 2004. The CWSB's main responsibility is the provision of efficient and economical water and sanitation services to the people of the Coast Province. Its area of jurisdiction, which coincides with the administrative boundaries of the Coast Province, cover six counties – Mombasa, Kwale, Kilifi, Lamu, Tana River and Taita Taveta. Within the six counties, there are seven contracted WSPs under the CWSB, as follows:

- Mombasa Water and Sewerage Company (MOWASCO)
- Malindi Water and Sewerage Company (MAWASCO)
- Kilifi-Mariakani Water and Sewerage Company (KIMAWASCO)
- Taveta-Voi Water and Sewerage Company (TAVEVO)
- Lamu Water and Sewerage Company (LAWASCO)
- Kwale Water and Sewerage Company (KWAWASCO)
- Tana Water and Sewerage Company (TAWASCO)

The area of the Coast Province falls under two surface water catchment areas managed by WRMA – Tana Catchment area and Athi Catchment area. The Coast Province is located downstream of both catchments. The WRMA Catchment Management Strategies (2008) set clear strategies for short- and medium-term water resources development in both catchments.

Groundwater aquifers in Kenya in general and the Coast Province in particular, are managed on an ad hoc basis. Water allocation is not based on a formal system of assessment or with an allocation plan in mind. Many wells and boreholes (BH) are not regulated or controlled. Seawater penetration occurs widely and semi salty water in the coast is prevalent.

Despite guidelines for groundwater conservation zones in the Water Act 2002, no groundwater conservation zones have been defined for the Coast Province or Kenya as a whole. A majority of the may groundwater users do not have abstraction permits, and they are not documented or regulated. Management of groundwater resources is carried out independently of land management and other land-based resources. Decision-making in connection with groundwater management is largely centralized, with minimal involvement on the part of stakeholder water resource management units.

C – The Project Area

The project area covers the entire CWSB jurisdiction which is the administrative boundaries of the Coast Province (see Fig. Exec-1). The Coast Province is located on the eastern side of Kenya, adjoining the Indian Ocean, with Somalia at its northern end and Tanzania to the south. Total area of the province is 83,040 km^2.

Six counties are included within the province – Mombasa, Kwale, Kilifi, Taita Taveta, Lamu and Tana River. The six counties are divided into 13 districts. Population projections for the Coast Province were done to the district level. The water demand calculations were done at the district level, and presented at both the province level and for the 20 main townships and urban centres.

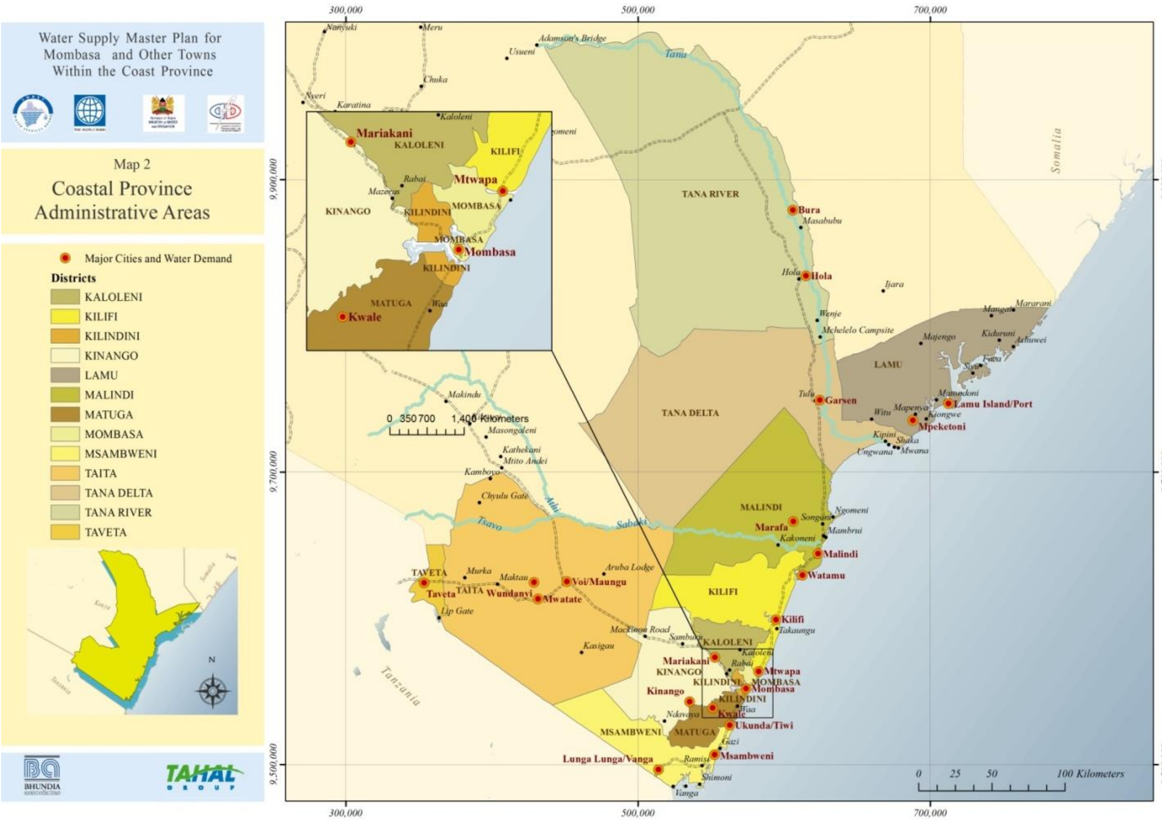


Fig. Exec-1: Coast Province Administrative Area

The total population of the coastal area has been estimated at over 3.3 million in 2009 (2009 population census), and is projected to increase to over 7.5 million by 2035, the target year of the master plan. The population of Mombasa County is projected to more than double, from 0.93 million in 2013 to 2.23 million in 2035.

The WSMP study originally targeted the whole province. Since the development plan for new water resources and supply schemes must address target townships, it was decided in a joint

Consultant-Client-Donor meeting in June 2012, that 20 townships located in six counties would be selected for inclusion in the WSMP scope of work, as follows:

- **Mombasa County** – Mombasa city, including Mombasa Island, North Mainland, South Mainland and West Mainland
- **Kwale County** – the 5 townships of Kwale, Kinango, Msambweni, Ukunda/Tiwi and Lunga Lunga/Vanga
- **Kilifi County** – the 5 townships of Mariakani, Kilifi, Malindi/Watamu, Marafa and Mtwapa
- **Taita Taveta County** – the 4 townships of Taveta, Mwatate, Wundanyi and Voi/Maungu
- **Lamu County** – the 2 townships of Mpeketoni and Lamu Island/Port
- **Tana River County** – the 3 townships of Garsen, Hola and Bura

Later in the study, an additional township was added to the above list – Gongoni township in Kilifi County (located north of Malindi/Watamu along the shore). While Gongoni township was not included in the provincial water balance, it does appear in the supply schemes for the Immediate Phase.

Three physiographic zones are observed in the Coast Province (see maps in Volume II of the WSMP), as follows:

- The **Nyika** lies at 600 masl, and represents the higher ground covered by the Duruma sandstone series and older rocks to the west.
- The **Foot Plateau** occurs at an elevation between 140 and 600 masl, coinciding with the relatively younger Jurassic rocks.
- The **Coastal Plain**, the lowest step, rises from sea level to 140 masl. On average, this belt increases from a few kilometres wide in the southern sector, to over 40 km wide in the north (UNEP, 1998).

The **physiographic features by county** (see maps in Volume II of the WSMP) are as follows:

- **Kwale County** has four major topographical features namely the coastal plain, the Foot Plateau, the Coastal Uplands and The Nyika Plateau. Altitudes range from sea level to 462 masl in Shimba Hills.
- **Kilifi County** has four major topographical features. coastal plain, the foot plateau, the coastal range, and the plateau. Two major physical features dominate this county, they are the Indian Ocean and the Sabaki River. The Sabaki River flows through the area in an easterly direction and is the source of water for Malindi/Watamu, Kilifi and Mombasa. Altitudes range from sea level to 462 masl in Shimba Hills.
- **Lamu County's** main topographical features include the coastal plains, island plains, Dodori River plain and the sand dunes while the most common rock formation are residual coral limestone and columns of sand. The country is generally flat and lies between zero and 50 masl,

- **Taita Taveta County** is divided into three major topographical zones. These are the upper zone, lower zone and volcanic foothills. The major rivers in the county are the Tsavo, Voi and Lumi rivers. The major lakes are Lake Jipe and Lake Challa.
- **Tana River County** is generally dry and prone to drought. Rainfall is erratic, with rainy seasons in March-May and October-December. Periodic disputes over access to water occur between the farmers and the nomadic groups. Flooding is also a regular problem, caused by heavy rainfall in upstream areas of the Tana River. The Tana River is the largest river in Kenya, stretching over a total length of 1,000 km.

The **climate** in the coastal areas of Kenya, which is lying within the equatorial latitudes, is characterized by a distinctive hot and humid climate. From December to early March the coast is dominated by the North East Monsoon (Kazkazi) which is comparatively dry. During March and April, the monsoon winds blow east to southeast (Kuzi) which brings in air from the Indian Ocean and heavy rains. Between May and August, the South East Monsoon brings in more stable weather, more clouds and comparatively cooler temperatures. Mombasa and the main coastal townships of Malindi/Watamu and Lamu generally have similar climatic patterns.

The region experiences **two distinct rainy seasons**: the long rains in April and May and the short rains in October and November. The driest months are January and February. Total annual rainfall usually exceeds 1,000 mm.

The **temperatures** in Mombasa and most of the Coastal Region remain steadily hot for most of the year. Temperatures range between 26 °C during the cooler months of July to August (after the long rainy season) to 32 °C in the warmer months of January to March (following the short rainy season). Nighttimes temperatures are usually below 20 °C.

Annual **evaporation** is around 1,800 mm. It is higher than the normal annual total rainfall and creates a freshwater deficit during the dry seasons. Monthly evaporation levels vary between a low of 138 mm in July to a high of 221 mm in March.

D – Methodologies Employed in the WSMP

The methodologies employed in each of the studies carried out during the execution of the WSMP are concisely described here. The finding and results of the studies are described separately further below.

Socioeconomic Survey

The study was conducted using four broad methodologies:

- Direct observation
- Review of available data and information
- Questionnaires
- Interviews of key individuals

Water Demand Forecast

Population projection

The population growth rates and long-term projections were determined based on the population censuses of the years 1969, 1979, 1989, 1999 and 2009.

The intercensal population growth rates for the 1969–2009 period were estimated at the level of sub-location (sub-location being the smallest population cluster), location, division and district. The upper level of administrative area is a county.

A population projection for the entire Coast Province was performed by calculating each district population separately, and then adding them. Out of the district projections, projections for the 20 main townships and urban centres were performed and used as the basis for the WSMP demand projections.

Population projections for the Coast Province and all clusters were performed for three growth-rate scenarios – low, medium and high. The medium projection scenario was used as the basis for the future demand calculations

The population projection calculations were prepared with two different scales, as follows:

- The Coast Province population projection by district
- Population projections for the 20 townships

The results of the province-level population forecast calculations for the target year are presented in Table Exec-1.

Table Exec-1: Population Projections for the Coast Province

Scenario	2009	2015	2020	2025	2030	2035
Low	3,316,346	3,792,231	4,207,960	4,623,689	5,039,419	5,455,148
Medium	3,316,346	4,010,574	4,698,892	5,505,343	6,450,201	7,557,222
High	3,316,346	4,293,595	5,182,370	6,255,121	7,549,931	9,112,768

The results of the population forecasts for the 20 townships (medium-growth scenario) are presented in Table Exec-2.

Table Exec-2: County-Level Population Projections based on Projections for the 20 Townships

County	Population Projections					
	2012	2015	2020	2025	2030	2035
Mombasa	1,051,268	1,163,066	1,386,173	1,624,076	1,902,809	2,229,380
Kwale	157,394	188,823	219,787	257,508	301,703	353,483
Kilifi	347,298	424,751	499,867	585,657	686,171	803,936
Taita Taveta	115,454	131,551	152,450	178,614	209,269	245,185
Lamu	16,515	119,012	280,484	429,280	590,370	738,717
Tana River	33,542	39,355	45,309	53,086	62,197	72,871
TOTAL	1,721,471	2,066,559	2,584,071	3,128,222	3,752,519	4,443,573

Water demand forecast

The total population was divided into an urban sector (symbol "U") and a rural sector (symbol "R"). The differentiation between the two was made on the basis of the "Kenya County Fact Sheets" (Commission on Revenue Allocation, 2011). These Fact Sheets set out the population from the 2009 Census, clearly identified for the major urban centres in the region and, therefore, allow derivation of the rural population.

The U sector was further divided into the low (L), middle (M) and high (H) classes, according to the MWI design standards. The L class was split into consumers with individual connections (IC) and without individual connections (non-IC).

It should be noted that out of the 20 main townships and urban centres, 10 are connected to bulk water supply system (**BWSS**) schemes, and 10 are unconnected to any of the BWSS schemes (**UCBWSS**). Within the framework of the WSMP, 4 of the townships that are currently UCBWSS are slated for connection. To the 20 above townships, one more was added as part of the Immediate Phase execution – the township of Gongoni, which is currently unconnected. The BWSS supply scheme to Gongoni is beyond the scope of this master plan study. The scheme was planned by a local consultant, and appears in the WSMP as per the Client's request.

Table Exec-3 summarizes the projection water demand for the 20 townships, which presents the core of water supply development plan.

Table Exec-3: Projected Water Demand for the 20 Main Townships and Urban Centres

	County	Urban Centre	Urban Water Demand (m^3/d)				
			2012	2015	2020	2025	2035
Southern Area (Mainland)	Mombasa	Mombasa	137,611	152,302	184,372	238,874	312,554
		Total Mombasa	**137,611**	**152,302**	**184,372**	**238,874**	**312,554**
	Kwale	Kwale	3,786	4,162	4,945	6,000	8,676
		Kinango	1,775	1,951	2,365	2,949	4,489
		Msambweni	1,976	2,171	2,665	3,252	4,809
		Ukunda/Tiwi	11,098	12,250	14,676	19,671	28,453
		Lunga Lunga/Vanga	4,761	5,230	6,445	7,903	11,709
		Total Kwale	**23,397**	**25,764**	**31,097**	**39,776**	**58,136**
	Kilifi	Mariakani	4,036	4,441	5,421	6,884	10,150
		Kilifi	5,167	5,686	7,090	9,014	13,240
		Malindi/Watamu	18,694	20,574	25,616	32,067	46,064
		Marafa	1,287	1,417	1,803	2,303	3,402
		Mtwapa	8,539	9,398	11,686	14,822	21,699
		Total Kilifi	**37,723**	**41,515**	**51,615**	**65,090**	**94,555**
	Taita Taveta	Taveta	2,972	3,573	4,265	5,121	7,228
		Mwatate	2,127	2,350	2,758	3,332	4,665
		Wundanyi	2,178	2,406	2,823	3,411	4,777
		Voi/Maungu	7,501	8,286	9,708	11,630	16,358
		Total Taita Taveta	**14,778**	**16,615**	**19,554**	**23,493**	**33,028**
Northern Area	Lamu	Mpeketoni	1,800	2,753	3,272	4,263	6,749
		Lamu Island/Port	2,500	15,815	34,190	57,805	109,811
		Total Lamu	**4,300**	**18,568**	**37,462**	**62,068**	**116,559**
	Tana River	Garsen	1,456	1,567	1,866	2,269	3,302
		Hola	750	1,246	1,524	1,558	2,707
		Bura	1,391	1,527	1,817	2,209	3,213
		Total Tana River	**3,597**	**4,340**	**5,206**	**6,036**	**9,222**
	Total Urban Water Demand: Southern Area		**213,509**	**236,196**	**286,637**	**367,233**	**498,273**
	On-Line Water Kiosk Demand		**–**	**–**	**13,333**	**26,666**	**40,000**
	Total Urban Water Demand: Southern Area + On-Line Water Kiosk Demand		**213,509**	**236,196**	**299,970**	**393,899**	**538,273**
	Total Urban Water Demand: Northern Area		**7,897**	**22,908**	**42,668**	**68,103**	**125,781**
	Total Urban Water Demand		**221,406**	**259,104**	**342,638**	**462,002**	**624,053**

Water Resources Study

The methodology employed in respect of the water resources of the Coast Province included:

- Assessment of current water resources yields based on a review of dozens of reports, technical papers and documents relating to the development of water resources in the Coast Province.
- An analysis of 11 water basins draining to the Indian Ocean was conducted, and the annual potential water volumes that can be accumulated in reservoirs was quantified. This included a preliminary assessment of the available water flows in the Sabaki River near the Baricho site.
- Analysis of groundwater potential was conducted in Tiwi, Msambweni and other regional aquifers. The analysis included the structuring and running of a groundwater model to estimate the annual potential taking into consideration the possibilities of seawater intrusion and rapidly declining water levels.
- Existing information of deep groundwater potential of the Neogenic aquifer, as a potential deep-water aquifer was analyzed. This aquifer could constitute a substantial water source for the region. Recommendations were given for further investigation of this aquifer.
- Preliminary analyses of potential grey water reuse were performed, considering the advances of local treatment and reuse of wastewater from regional treatment plants.
- Preliminary analyses of the rainfall harvesting as potential source of water was conducted.
- Preliminary analysis of desalination potential was carried out, and its associated impacts evaluated.

Formulation and Phasing of the Development Scenarios

Five development scenarios were considered in the full feasibility study. In formulating the development scenarios, considerations were given to technical feasibility, sustainability and robustness, balancing the water supply and socio-economic and financial viability. A multicriteria analyses comparing the different scenario was applied.

In staging the development scenarios, four phases were considered, as follows:

- **Immediate Phase** (to be completed by 2016) – Expansion of the Baricho Scheme by an additional 20,000 m^3/d (also called immediate supply improvement to Mombasa)
- **Phase I** (to be completed by 2020)
- **Phase II** (to be completed by 2025)
- **Phase III** (to be completed by planning horizon year of 2035)

Financial and Economic Analysis

The financial and economic analysis of the WSMP is based on a comparison between the net benefit flows from water delivery to the cost of developing and operating and maintaining of the water supply schemes for each of the development scenarios.

The indicators computed, analyzed and presented included:

- Net present value (NPV)
- Internal rate of return (IRR)
- Economic net present value (ENPV)
- Economic internal rate of return (EIRR)
- Sensitivity and risk analysis

Selection of the Proposed Development Scenario

A multicriteria methodology was applied for the selection of the preferred development scenario. Four main fields of interest were identified and classified – engineering, economic, environmental and sociopolitical. Each was assigned a different weight, as follows:

- A 30%/40% weighting between the engineering and economic parameters
- A 40%/30% weighting between the engineering and economic parameters
- A 40%/25% weighting between the economic and environmental parameters

Environmental Impact Assessment (EIA)

The Environmental Management Plan, which is an integral part of the assessment, was developed based upon the impacts identified for this project.

The analysis of impacts has been done through the development of a matrix where various project activities have been measured against identified appropriate environmental parameters. A range of indicators have been developed to assess impacts against. Criteria for the impact analysis indicators were based on a number of checklists and other environmental guidelines used.

A further analysis of the impacts was also made available through the analysis of alternatives. In this assessment, different alternate scenarios for the project and its design were prepared.

Resettlement Action Plan (RAP)

The RAP describes the procedures required and actions that will have to be taken to properly resettle and compensate households and communities that will be affected by the programs and projects that originate from the WSMP study.

The RAP methodology included the following steps:

- Identification of project-affected peoples (PAPs) and communities (PACs)
- Preliminary mapping and GIS positioning
- Inventory of persons, households, assets and resources
- Identification of causes that impact the PAPs
- Identification of the impacts of the WSMP and the proposed projects
- Consultations with affected people

- Analysis and description of the resettlement sites
- Mechanisms of participatory processes for host communities
- Identification of the agencies responsible for each resettlement activity and the overall coordinating agency
- Analysis of the capacity of these agencies and mechanisms to improve the capacity and commitment, if required
- Housing/land allocation
- Valuation of losses
- Preparation of the required budget, including costing of all resettlement needs
- Determination of the sources of funds and responsibility for their allocation
- Monitoring and evaluation

The last step, which includes appropriate planning, policy measures and management, have to be set out in order to assure successful and sustainable achievement of the resettlement goals.

Development Phases and Action Plan

Following the division of the implementation period into four development phases, and the establishment of the works to be completed in each of these phases, it became necessary to build a project management schedule, listing project milestones, activities, and deliverables. This was done from two points of view:

- The first one looked at the components of the project along the time scale, starting from present time and ending in the planning horizon year. This was summarized in a bar chart listing, by source of water, supply schemes and project components, the schedule of the actions to be taken along the time coordinate in order to meet the project milestones.
- The second one looked at the components of the project according to their geographic location by county. This was done in order to enable decision-makers at the county level to be keenly aware of the required facilities required in each county as part of the development of the bulk water supply system.

Kenya's new constitution empowers the counties with more mandates to perform development projects compared to previous time. It is important to note that the development and operation of water supply schemes is a cross-boundary task. Thus, only the completion of the schemes enables the people to consume water. The division of the development into counties does not mean that each county will lead its development separately. Rather, all works should be done in coordination between the counties. Section 8.3 describes the components that fall within each county. This may serve the design and statutory procedures required in order to execute construction permits within each county separately.

E – Water Resources Assessment

Objectives

Assessment of the regional water resources plays a major role in the development of the provincial bulk water supply for the CWSB.

The following objectives were set out for the water resources assessment:

- Review of current water resources and their future potential
- Identification and analysis of new surface water resources and their potential
- Analysis of groundwater potential in Tiwi, Msambweni and other areas
- Analysis of deep groundwater potential of the Neogenic layer, and guidelines to further investigate this source
- Preliminary considerations for the use of grey water reuse potential
- Preliminary considerations for the reuse of treated water from regional WTPs
- Preliminary analysis of the use of desalinated seawater

Surface Water Potential

The analysis of surface water comprised four assignments, as follows:

- Review of previous and ongoing studies on dams and direct intakes in the Coast Province
- Analysis of monthly and annual flows of 11 river basins draining to the Indian Ocean, including Mwache, Kombeni and Rare
- Analysis of low flows in the Sabaki River near the Baricho Wellfield site
- Analysis of low flows in the Tana River near the Garsen site

The 11 river basins, marked A to K in Fig. Exec-2, have no streamflow records except for Mwache Hydrometric Station 3MA03 (River Basin H). This available monthly streamflows, together with available monthly rainfall records (see Fig. Exec-3) was applied to the MRS monthly rainfall-runoff model (see Annex 4 in Volume III of the WSMP) to simulate the monthly flows for the Mwache River. Extrapolation of the simulated Mwache River monthly streamflows to the other rivers was performed by using transfer coefficients.

The Coast Province has a high potential for development of surface water sources. Analysis of seasonal rivers shows that the mean annual flows in Mwache River and Rare River are 120 and 190 MCM, respectively. These rivers have very high potential for dam construction.

Analysis of the Sabaki River near the Baricho Wellfield site shows a minimum flow (100%) of 2.6 m^3/s and a 95% flow of 3.58 m^3/s. Current abstraction at the Baricho waterworks is 1 m^3/s. Additional abstraction from Baricho Wellfield or adjacent new sites is possible.

Tana River is the longest river in Kenya. Analysis of the river shows a minimum flow (100%) of 8.5 m^3/s and sustainable flow (95%) of 44.7 m^3/s. The Tana River can constitute a highly viable resource, particularly for Lamu and Tana River counties.

Table Exec-4 shows the mean annual calculated flows of the 11 seasonal rivers according to basin, numbered A to K.

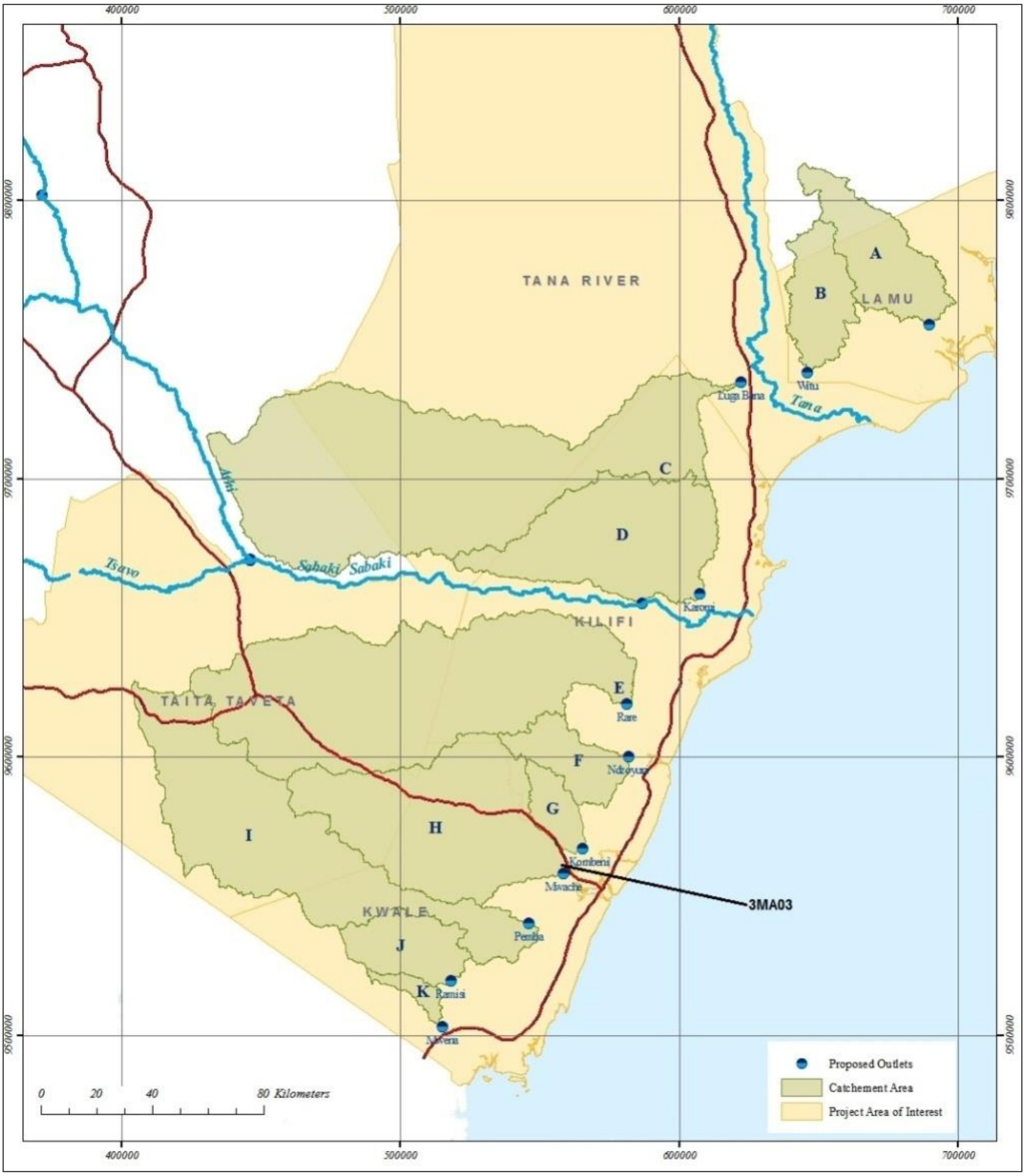


Fig. Exec-2: Location of River Basins in the Coast Province

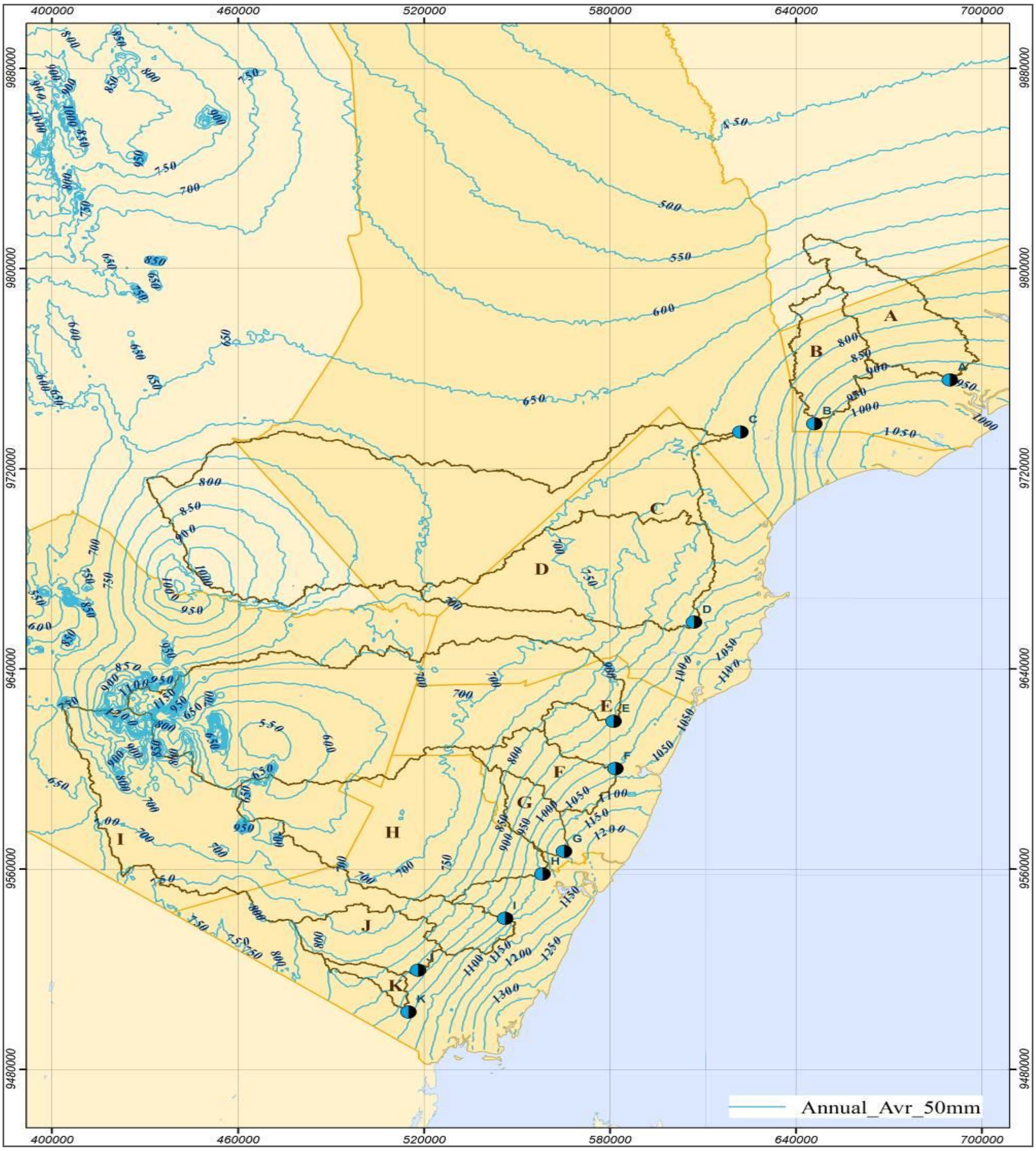


Fig. Exec-3: Mean Multi-Annual Isohyets Map of the 11 River Basins

Table Exec-4: Major Characteristics and Mean Annual Flows of the 11 River Basins (A-K)

Basin	River Name	Area (A)	Rainfall (R)	CN	Contribution to Surface Runoff (SR)	Annual Flow
Dimension		(km^2)	(mm)		(%)	(MCM/y)
A		1,356	775.2	59.7	86.3	**34.9**
B		946	806.3	67.8	81.5	**27.1**
C		7,475	756.7	70.4	89.2	**228.7**
D	Koromi	2,743	748.8	60.5	88.1	**70.5**
E	Rare	6,138	690.1	74.9	93.8	**191.7**
F	Ndzovuni	749	913.4	67.7	90.4	**27.0**
G	Kombeni	422	961.4	81.2	90.1	**19.1**
H	Mwache	3,605	721.3	76.0	94.1	**119.8**
I	Pemba	620	757.6	74.3	95.2	**21.4**
J	Ramisi	865	793.1	70.4	93.4	**29.1**
K	Mwena	177	812.1	75.6	93.5	**6.5**

Groundwater Potential

Southern Coast

The analysis of groundwater potential along the southern coast included the following stages:

- Review of previous studies and available data for the hydrogeology of the study area
- Identification of data gaps
- Construction and primary calibration of a regional groundwater flow model

The groundwater flow region model was used to:

- Assess seawater intrusion corresponding to different pumping scenarios for a time period of 20 years, both for the Tiwi and Msambweni aquifers.
- Estimate the flow regime in the Tiwi and Msambweni aquifers under conservative conditions to evaluate its minimum annual sustainable yield.

The conclusions regarding groundwater potential in the South Coast were:

- Groundwater potential determined for Tiwi and Msambweni aquifers is approximately 20,000 m^3/d (7.5 MCM/y) and 30,000 m^3/d (11 MCM/y), respectively.
- The analysis indicates additional wellfields can be developed south of Msambweni.
- Major data gaps exist. It is proposed that an action plan for further groundwater investigation be carried out preserve the aquifer water quality and to avoid seawater penetration.

- It is recommended that the supply from the Tiwi and Msambweni aquifers to the BWSS will be 13,000 m^3/d (4.7 MCM/y) and 20,000 m^3/d (7.5 MCM/y), respectively, until further investigation of the sustainable yield of these aquifers is conducted.

Deep Groundwater

Data from deep oil and gas exploration wells in Kenya were reviewed in order to assess whether potential deep groundwater exists in the Coast Province. This analysis is based on the assumption that the Coast Province in Kenya may share the same hydrogeological characteristics with the Tanzania Coast area (near Dar es Salaam), where a deep and highly productive aquifer of immense volume and excellent quality was recently (2005) discovered and investigated.

General and detailed geological information was collected from 13 deep wells in Kenya. A cross-section along four of these deep wells located along the Tana River revealed a Neogene sequence of 400–500 m thick inland increasing to 1,000–1,500 m close to the coastline. The depth to this potential aquifer varies from several meters (about 5–30 m) to 150–200 m.

Potential recharge of freshwater to this aquifer is not clearly understood in terms of quantities and mechanisms. However, the location near Tana River is promising, as the river may serve as a source of recharge to the aquifer in this area.

Recommendation for further investigation of this potential aquifer was suggested by drilling of deep wells in three alternative locations, two in the Lamu area and one along the Tana River. This investigation has been budgeted for the Immediate Phase of the WSMP.

Desalination

Desalination of seawater can complement the supply from natural water resources. The major constraints of desalination water are environmental impacts, high energy demand and cost (CAPEX and OPEX). The Kenyan coastline is rich in marine life and marine reserves, and the large number of eco-sensitive areas leaves only a very few potential locations, if any, for desalination plants.

It was recommended that energy costs and availability and the wide range of environmental aspects, associated with seawater desalination, should be carefully investigated before water supply from this option is to be considered. Initial investigations by the consultant indicate that a large desalination plant will not be viable at this time due to the high electricity tariffs. Hence it is advisable to utilize all conventional water resources before a desalination plant is considered (unless major reductions in energy costs are evident).

Recycled Water

A prerequisite for any recycling efforts should be an efficiently operating wastewater system, conveying wastewater via gravity and/or pressure pipelines, a wastewater treatment plant and a recycling supply scheme. It is assumed that parallel to the horizon year (2035), treated wastewater will be available for recycling for urban use.

In Mombasa and some other neighbouring towns, recycled water can be used for gardening within the urban/domestic sector. This will have a positive effect on the reduction of the total urban water demand. From the resources point of view, only in the horizon year (2035) the recycled water was considered in the water balance for the greater Mombasa area and for new house types.

Rainfall Roof Harvesting

Promotion and construction of rainfall harvesting technology is deemed suitable in the coastal areas, and it is recommended as a means of augmenting the availability of water. The effectiveness of this activity is high because there are two rainy seasons.

In rural areas, under appropriate guidance and training regarding the correct use and maintenance of the facilities, rooftop harvesting can also be a viable and effective water source. However, the use of this resource will be negligible and will not affect the planned future water supply infrastructure.

Summary of Water Resources Potential

The Coast Province total water resources potential is summarized in Table Exec-6 in Part G of this Executive Summary.

F – Existing Water Supply Schemes

Overview

The purpose of the water supply assessment was to ascertain the existing and potential water supply situation in the area, as this forms the basis of the study and development of the Water Supply Master Plan (WSMP).

The existing water supply schemes were evaluated for the 20 townships and urban centres. Each main township is comprised of the township and adjacent settlements. Data and information from various institutions were analyzed to obtain an overview of the existing situation in the area.

As mentioned earlier, the Coast Province falls within the Athi and Tana catchments:

- The **Athi Catchment** is bounded by the Athi, Galana and Sabaki rivers to the north and the Kenya–Tanzania border to the south. This covers the counties of Kwale, Mombasa, Kilifi and Taita Taveta.
- The **Tana Catchment** is bounded by the Sabaki River Catchment to the south and by the Somali border to the north. This covers the counties of Lamu and Tana River.

The Coast Province mostly depends on bulk water supply system (BWSS) schemes. These schemes presently comprise Mzima Pipeline, Marere Pipeline, Tiwi Boreholes and Sabaki-Mombasa Pipeline, supplying Mombasa and 13 townships in Kwale, Kilifi and Taita Taveta counties (see Fig. Exec-4). The remaining 6 townships are supplied from local sources. The Coast Development Authority (CDA) is promoting the design of Mwache Dam as an additional key BWSS for domestic water supply and irrigation.

The southern area of the province is characterized by a significant gap between available water resources to the projected demand, due mainly to water scarcity over time as well as high evapotranspiration rates, leading to heavy reliance on groundwater. The uncontrolled pumping of water as well as the lack of groundwater management result in quality degradation and some boreholes have become saline.

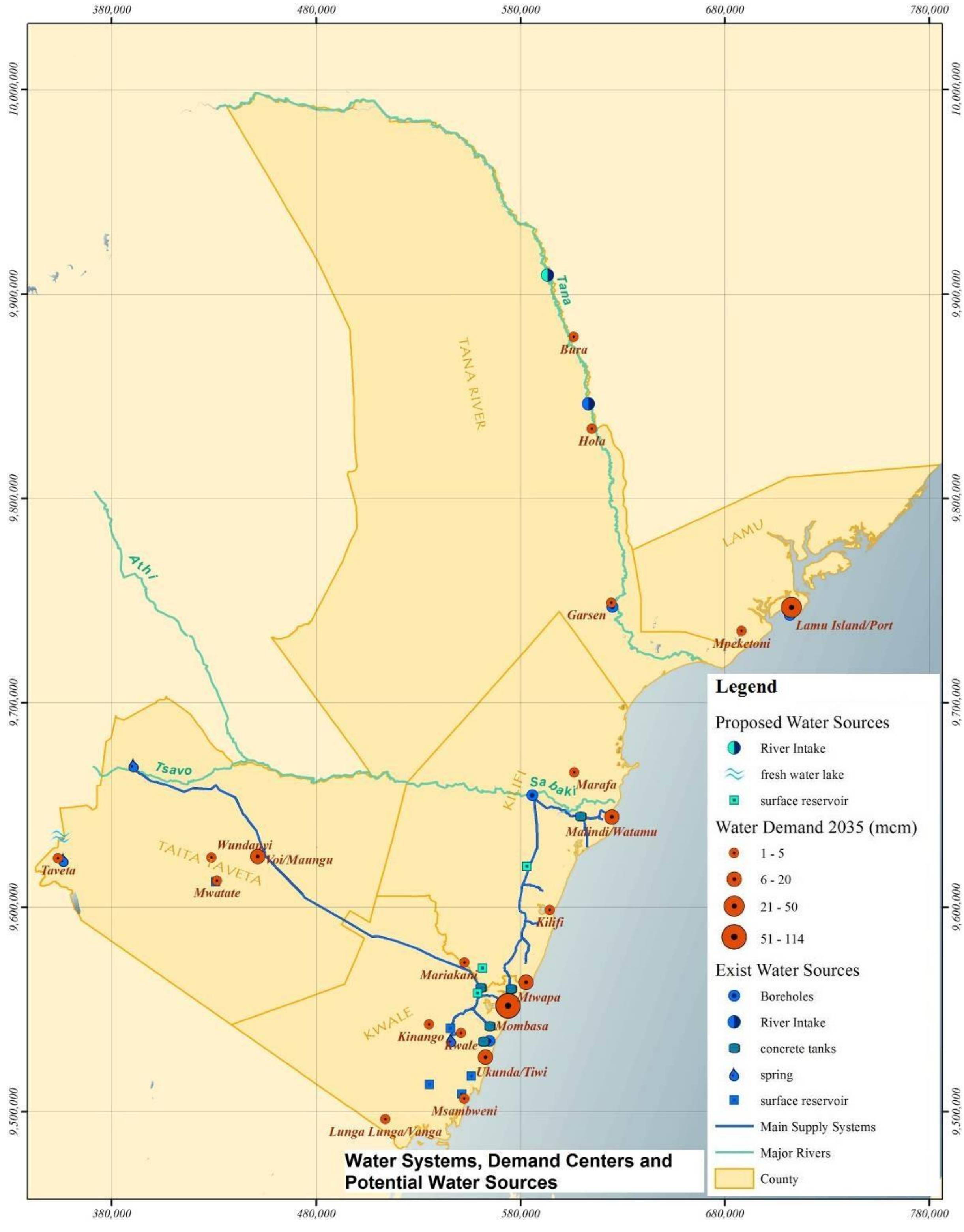


Fig. Exec-4: Water supply schemes, demand centres and water sources

The assessment of the existing water supply schemes was accordingly divided into two sections – schemes providing water to townships unconnected to any BWSS scheme (**UCBWSS schemes**) and townships served by **BWSS schemes**.

UCBWSS schemes:

The UCBWSS townships are presently supplied from the following local water resources:

- **Taveta Springs (known locally as the Njoro Kubwa Springs):**
  - The Njoro Kubwa Springs emerge from the Kilimanjaro Aquifer, and eventually reaches Lake Challa.
  - The springs supply water to Taveta township in Taita Taveta County.
  - As the Njoro Kubwa Springs' safe yield is so much greater than the projected demand in the Planning Horizon Year (2035), it appears that there should be no difficulties whatsoever to meet the future water demand of Taveta township from the Njoro Kubwa Springs.
- **Shella Wellfield**:
  - The Shella Wellfield, located within the Lamu Island, is apparently the only fresh water source in the area, as groundwater in other parts of the area is mostly saline.
  - The Shella Wellfield serves Lamu township, Gadeni, Manda Island and Shella village.
- **Mpeketoni Wellfield:**
  - The Mpeketoni Wellfield is the only source of water for Mpeketoni township.
  - The aquifer is recharged from Lake Kenyatta.
  - The water from the boreholes should be treated since they are contaminated.
- **Lake Kenyatta:**
  - The Lake Kenyatta water level has been slowly declining.
  - However, it is not likely to reach critical levels up to the year 2035, so that supply of water from the present boreholes is reliable.
- **Tana River:**
  - Tana River, the longest river in Kenya, is highly fluctuating, with severe floods occurring every few years. These floods and heavy siltation pose engineering obstacles for building simple river intakes on the river.
  - According to Vision 2030 and WRMA Catchment Management Plan, a few medium- to large-size reservoirs are to be built on the Tana River upstream of Garissa, including the High Grand Falls (HGF) Dam. These reservoirs are expected to moderate the floods and siltation problems in the downstream areas, making the Tana River a sustainable water source for Tana River and Lamu counties.
  - The Tana Water and Sewerage Company (TAWASCO) serves Bora township with water from the Tana River. Other schemes are Hola in Galole District, and Garsen and Ngao in Tana River County.
  - Upon completion of an ongoing rehabilitation scheme for Hola, funded by the World Bank, the projected water demand for Hola up to the target year of 2030 will be met.
- **Garsen Wellfields (Ngao Scheme):**
  - The Garsen Wellfields supply water to the Garsen township in Tana River County to augment the supply from the surface intake on the Tana River (Garsen Scheme).
  - The production in these wellfields is limited due to frequent electricity failures.

BWSS schemes:

The **BWSS townships** presently receive their supply mostly from the following water resources:

- **Baricho Wellfield:**
  - The Baricho Wellfield waterworks are located in Kilifi County.
  - The Baricho Wellfield abstracts water from the Sabaki Aquifer, which is composed of the old Baricho River Channel (palaeochannel), underlying the present riverbed. This aquifer is mainly recharged from the Baricho River.
  - The Baricho BWSS supplies water to Mombasa, Kilifi and Malindi/Watamu townships in Kilifi County.
  - The conveyance system from Baricho to Mombasa is approaching the carrying capacity of the existing pipeline (800 mm 95 km 600 mm 12 km); thus, any further transmission of water to Mombasa from this source will have to include additional boreholes, expansion of the high-lift pumping station (HLPS) and a new water conveyance system, the second Sabaki Pipeline.
  - Operation of the Sabaki-Mombasa Pipeline is costly since the water is pumped to 24 bar pressure along 107 km.
- **Mzima Springs:**
  - The Mzima Springs which are recharged from rainfall on the Chyulu Hills, are located in the Taita Taveta County.
  - The springwater flows through three large pools (Hippo, Long and Chalk Beach Pools) before discharging to the Mzima River some 4 km upstream of its junction with the Tsavo River.
  - Maximum, mean and minimum outflows measured records from the springs were 5.9, 2.6 and 3.6 m^3/s, respectively. Significantly, flows less than 3 m^3/s have been recorded only one in 4 years, and even then merely in a few days of each year.
  - The spring's sub-surface weir-intake consists of a sheet pile cutoff wall. The sheet pile is emplaced at depth within the regolith loams for the full cross-section of the saturated impermeable lava.
  - The weir is connected with an upstream trench to divert the groundwater to a collection chamber.
  - The total water abstracted from the Mzima Springs reaches Mombasa by an 800 mm concrete gravity pipeline. The total distance along the pipeline route from the springs' intake to the Mazeras Water Tanks is 218.5 km, of which the headworks transmission line, consisting of pipelines and tunnels, is only some 3 km long. This resource is shared by several towns along the pipeline, in Taita Taveta (at present, only the township of Voi/Maungu is connected to the BWSS from the Mzima Pipeline), Kilifi and Mombasa counties. While it has a mean sustainable flow of 3.5 m^3/s, the current rate of abstraction is only about 0.4 m^3/s. This flowrate is limited by the capacity of the Mzima Pipeline. The available supply to Mombasa has been declining over time due to the rise in demand in the upstream towns as well as leaks and bursts along the pipeline.

   - By 2030, the Mzima Pipeline will be over 65 years old and will have passed its useful and efficient lifespan. This calls for laying of a new pipeline (Mzima 2).
- **Marere Springs:**
   - The Marere Springs are located in the foot of the Shimba Hills Game Reserve in Kwale County.
   - While the daily yield from these springs is 12,000 m^3, only 8,000 m^3/d is currently abstracted. The resource is shared by both Kwale and Mombasa counties. Some of the water is pumped from the pipe to the local supply system of Kwale District. The current abstraction is limited due to the connecting 425 mm gravity pipeline, which limits the flow to about 350 m^3/h. The available supply to Mombasa has been declining over time due to a rise in demand in Kwale County. Within the WaSSIP program, a new 500 mm pipe is currently under construction, replacing the old pipe.
- **Tiwi Aquifer** (known also as the **Coastal Aquifer**):
   - The Tiwi Aquifer is located in Kwale County, between the Ukunda and Ngombeni areas.
   - There are 12 boreholes in the wellfield, with a total production of approximately 8,000–10,000 m^3/d. The current maximum yield after the WaSSIP rehabilitation of the borehole equipment is approximately 13,000 m^3/d
   - Groundwater potential in the Tiwi and Msambweni areas are approximately 20,000 m^3/d (7.5 MCM/y) and 30,000 m^3/d (11 MCM/y), respectively. Analysis indicates additional wellfields may be developed south of Msambweni.
   - Much of this potential in the Msambweni area is not utilized today because of the presence of the titanium mine in the area. The water from the Msambweni Aquifer will be incorporated in the BWSS only towards the horizon year (2035), when the mining activities will be finished. The CWSB should prepare the required procedures for allocation of the water after termination of water use by the mine industry.
   - The Tiwi Aquifer is shared by both Kwale and Mombasa counties. Some of the water is diverted to the Tiwi area and Diani Beach, while the rest flows to Mombasa (through the Likoni Pipeline, 250 mm). The Tiwi Wellfield is under massive rehabilitation activities fund by the WaSSIP program.
   - The available water supply to Mombasa has been declining over time due to the rise in water demand in Kwale County, mostly due to the rapid development of the hotel industry in the Diani and Tiwi beach areas.
- **Mkurumudzi Dam:**
   - The **Mkurumudzi Dam**, which is being built on the Mkurumudzi River, originates in the Shimba Hills and flows southeast to the Indian Ocean. It drains a catchment area of about 200 km^2, and recharges the Coastal Aquifer in the Msambweni area.
   - The purpose of the Mkurumudzi Dam is to supply water for the new titanium mine owned by the Australian company Base Titanium. The quantity of titanium in the mine is assumed to suffice for 15 years of mining operations. During this period, the water from the Coastal Aquifer in the Msambweni area and from the Mkurumudzi Dam will not be available for water supply to other consumers in the area.

G – Proposed Development of Water Supply Schemes

In many water resource development projects, project execution is spread over a long timespan. In order to facilitate the presentation of the development process over time, the following four phases of development were selected and agreed upon:

- **Immediate Phase** (to be completed by 2016)
- **Phase I** (to be completed by 2020)
- **Phase II** (to be completed by 2025)
- **Phase III** (to be completed by planning horizon year of 2035)

Availability of Water Resources

Table Exec-6 summarizes the availability of water resources in the Coast Province.
(Please note that rounded numbers have been used in Table Exec-6.)

Table Exec-6: Current Water Supply Capacity and Future Potential Yield

Resource / System	Status	Current Capacity* (m^3/d)	Potential Yield* (m^3/d)	Comments
Mzima Springs	Existing	35,000	105,000	Surpluses of Mzima reach Baricho
Baricho Wellfield	Existing	83,000	180,000	
Tiwi Wellfield	Existing	10,000	15,000	
Marere Springs	Existing	8,000	12,000	
Taveta Springs **	Existing	3,000	100,000	Surpluses used for irrigation
Shella Aquifer	Existing	1,800	N/A	Not analyzed
Tana River	Existing	1,400	N/A	Not analyzed; low flow is 8 m^3/s
Mkanda Dam	Existing	2,000	5,900	Used by local communities
Mwache Dam	Detailed design	–	220,000	Only 186,000 m^3/d are reserved for water supply.
Rare Dam	Feasibility study	–	200,000	Initial figures
Mkurumudzi Dam	Detailed design	–	19,000	Will be used by Base Titanium Ltd.
Msambweni Aquifer	EPC contract	N/A	20,000	Currently being used by Base Titanium Ltd. In the future, it will be used for the BWSS.
Desalination	–	–	N/A	Economic and environmental limitations
Deep groundwater	–	–	N/A	
Total		~145,000	**~877,000**	**Without desalination, Tana River and deep groundwater**

* rounded numbers
** known locally as the **Njoro Kubwa Springs**

The water resources potential discussed above is far from being utilized today. For various reasons, the total daily water production in 2013 was estimated at 135,000–140,000 m^3/d. Following the WaSSIP project and rehabilitation of the Baricho pumping station, the total yield of the current BWSS is around 160,000 m^3/d, still far less than the calculated real water demand in the Coast Province. However, the difference between the current yield and the current potential is huge (potential to current ratio is ~ 5.5:1), which indicates the enormous potential for water supply development in the Coast Province.

The huge water resources potential in the Coast Province may play a role in the determination of principles for any future development:

- As long as natural water resources can be developed with environmental sustainability, the Coast Province may benefit from these waters compared to the development of new high-cost water, such as desalinated seawater, desalinated brackish water and fully recycled wastewater (for non-potable use).
- The planning strategy of the WSMP calls for the water resources (new and existing) to be developed in such a way as to meet the projected demand in the mid- and long-term phases of the development plan.

Fig. Exec-5 shows the increase in water demand vs. the increase in water availability under the proposed water resources and supply scheme.

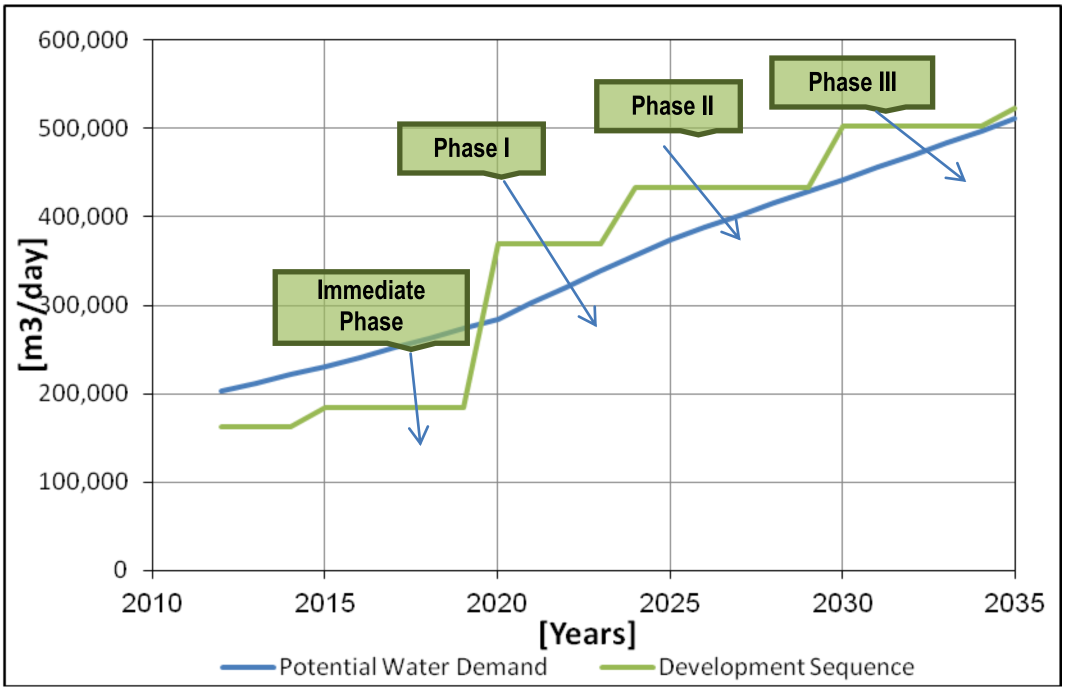


Fig. Exec-5: Development of water resources vs. demand

The sequence of development for the current WSMP is presented in Table Exec-7 as a matrix by phase, counties and water source.

Table Exec-7: WSMP Water Supply Development Matrix (by phase)

County	Source	Proposed Water Production (m^3/d)	Supply Scheme and Pipeline Connected	Required Infrastructure
Immediate Phase				
Kilifi	**Baricho**	• Additional production of 20,000 m^3/d by adding two vertical type boreholes	• Rehabilitation of 600 mm pipe segment in Sabaki-Mombasa Pipeline, 800 mm/32", 12 km, PN 8 • Construction of Kakuyuni-Kilifi Pipeline, 500 mm/20", 51 km • Construction of Gongoni-Malindi Pipeline, 300 mm/12", 25 km	• Works under additional WB & AFD financing for "emergency works to improve supply to Mombasa" • New Kakuyuni Water Tank, 2,500 m^3 • New Kilifi Water Tank, 5,000 m^3 • New Gongoni Water Tank, 1,000 m^3
Taveta	**Taveta Springs (Njoro Kubwa Springs)**	• Spring intake rehabilitation to enable 7,228 m^3/d production *Subject to budget availability. If not, these works would be carried out during Phase I.*	• Rehabilitation of the force main supplying Taveta to 20"	• Rehabilitation of Taveta Scheme to be executed in Immediate Phase, as long as WB & AFD additional financing allow.
Phase I				
Kwale	**Mwache Dam**	• Full abstraction of 186,400 m^3/d for the CWSB potable water allocation for the BWSS • This includes construction of: - 65 m high dam + the outfall - WTP - PS for water delivery	• Three main supply schemes: • NMT Scheme - Supply to NMT with connecting pipe, 1,000 mm/40", 4.5 km - Connecting NMT to Nguu Tatu Water Tank, 1,000 mm/40", 35 km • Chamgamwe Scheme - Supply to Chamgamwe Water Tank, 700 mm/28", 15 km • Kaya Bombo Scheme: - Supply to Kaya Bombo Water Tank, 800 mm/32", 22 km - Connecting Kaya Bombo with Tiwi Pipeline, 500 mm/20", 20 km - Connecting Likoni, 500 mm, 11 km	• Construction of the pumping array at the Mwache PS: - Pumps to +120 NMT, 5+1 units, 865 m^3/h, 110 m TDH - Pumps to Chamgamwe Water Tank, 5+1 units, 600 m^3/h, 65 m TDH - Pumps to Kaya Bombo Water Tank, 5+1 units, 865 m^3/h, 70 m TDH • Construction of new water tanks: - Tank at the WTP outfall, 20,000 m^3 - New Mwache Tank (NMT), 20,000 m^3 - Kaya Bombo Water Tank, 10,000 m^3
Phase II				
Kilifi	**Baricho**	• Development of additional 75,000 m^3/d abstraction to total yield of 175,000 m^3/d (80,000 m^3/d at 2013 + 20,000 m^3/d for Immediate Phase + 75,000 m^3/d for Phase II)	• 4 new RHC-type boreholes, each 900 m^3/h, 22 h/d • Construction of second Sabaki Pipeline, 800 mm/32", 107 km • Construction of second Malindi Pipeline, 600 mm/24", 45 km	• Extension of Baricho delivery pumping facility by adding new building for PS and dividing the pumping arrays to: - Mombasa pumps (in the existing building) and

County	Source	Proposed Water Production (m^3/d)	Supply Scheme and Pipeline Connected	Required Infrastructure
			• Construction of new Marafa Pipeline, 300 mm/12", 20 km • Rehabilitation and upgrade of local water tanks at Kisimani (2,000 m^3), Kisauni (2,500 m^3) and Marafa (1,500 m^3)	Malindi pumps (in the new building) - Pumps to Mombasa (1+1) units, 833 m^3/h, 245 m TDH - Pumps to Malindi/Watamu, 2+1 units, 700 m^3/h, 110 m TDH - Booster pumps to Marafa, 1+1 units, 120 m^3/h, 120 m TDH - Construction of Module B of chlorination contact tank at Baricho.
Tana River and Lamu	**Garsen**	• Garsen intake to provide 120,000 m^3/d, including structures and low-lift pump, WTP and main PS	• Construction of force main from Garsen to Lamu Water Tank, 1,200 mm/48", 78 km	• Garsen delivery pumping station, 6+2 units, 800 m^3/h, 135 m TDH • New Lamu Water Tank, 20,000 m^3
Phase III				
Taveta	**Mzima**	• Additional abstraction of 70,000 m^3/d to total supply of 105,000 m^3/d	• New Mzima 2 Pipeline, 1,200 mm/48" to Voi/Maungu, 78 km and 1,000 mm/40" to Mazeras, 142 km • Mwatate and Wundanyi supply: - New Voi-Mwatate Pipeline, 400 mm/16", 30 km - New Voi-Mwatate Pipeline, 250 mm/10", 12 km	• Expansion of Mzima Waterworks by new 48" pipe, 1.3 km upstream of the existing tunnel • Rehabilitation and expansion of chlorination contact pond • New booster pump for Voi-Mwatate supply, 2+1 units, 470 m^3/h, 350 m TDH • Wundanyi booster pump • New Mwatate Water Tank, 1,500 m^3 • New Wundanyi Water Tank, 1,000 m^3
Tana River	**Hola**	• Local intake from the Tana River to the supply scheme	• Rehabilitation of local water supply scheme for 2,707 m^3/d in 2035	
Tana River	**Bura**	• Local intake from the Tana River to the supply scheme	• Rehabilitation of local water supply scheme for 3,213 m^3/d in 2035	
Kwale	**Msambweni**	• Develop Msambweni Wellfield to 20,000 m^3/d and connect to the BWSS • Drilling new deep boreholes after aquifer investigation	• Connecting Tiwi to Msambweni and Ukunda and further south: - Replacing current 250 mm/10" Tiwi-Msambweni Pipeline with new pipeline, 500 mm/20", 35 km - New Msambweni-Lunga Lunga Pipeline, 300 mm/12", 46 km	• New Msambweni Water Tank, 10,000 m^3 • New booster pump for Lunga Lunga/Vanga supply, 170 m^3/h, 160 m TDH

The following is a brief description of the sequence of development and the water balance for each phase.

Immediate Phase (to be completed by 2016)

This phase comes under the Emergency Action for which financing was already secured. Entire implementation should end by January 2016.

For the UCBWSS townships and urban centres:

Please note: *There will be no activity for the UCBWSS townships and urban centres during the Immediate Phase unless there is a budget made available for supply to Taveta township.*

- Subject to funds availability, the development in this phase will include enhancing the Taveta Springs works (known locally as the Njoro Kubwa Springs), plus the rehabilitation of the main supply line, thereby improving the supply to Taveta township. The yield of the Njoro Kubwa Springs are significant, as there are no other alternatives for water supply to Taveta township.
- A water balance shows that a deficit of some 21,700 m^3/d will still exist in the UCBWSS townships and urban centres at the end of the Immediate Phase. This deficit will be partially covered by local water sources.

For the BWSS townships and urban centres:

- The development in this phase will include enhancing only the Baricho Scheme, thereby improving the supply to Mombasa and to Malindi/Watamu and Kilifi townships in Kilifi County.
- A water balance shows that a deficit of some 71,400 m^3/d will still exist in the BWSS townships and urban centres at the end of the Immediate Phase. This deficit will be partially covered by local water sources.
- With regards to the activities to improve supply to Mombasa – defined as the core objective of the Immediate Phase investments – it is important to mention that although Mombasa has been defined as the prime consumer for the supply upgrade, other townships will benefit from the construction of new infrastructure during the Immediate Phase. More water will be available to communities and townships located along the BWSS pipelines, enabling increased availability of water for other consumers. In addition, Kilifi water supply will be improved during the Immediate Phase, when the Kilifi Pipeline will be constructed, thereby ensuring water supply to Kilifi that is no longer dependent on the existing Sabaki-Mombasa Pipeline to Mombasa. As a result, the impact of the supply improvement to Mombasa will affect the supply to others consumers, mainly in Kilifi township.
- In this phase, some 20,000 m^3/d from Baricho will be added to the BWSS.

Phase I (to be completed by 2020)

For the UCBWSS townships and urban centres:

- If not already carried out during the Immediate Phase, the development in this phase will include enhancing the Njoro Kubwa Springs works, plus the rehabilitation of the main supply line, thereby improving the supply to Taveta township.
- A water balance shows that in Phase I the deficit in the UCBWSS townships and urban centres will increase to some 41,100 m^3/d, since the demand will increase and the development of the water supply schemes for these townships and urban centres will not catch up until the end of this phase. However, this deficit will be partially covered by local water sources.

For the BWSS townships and urban centres:

- In this phase, the Mwache Dam water supply scheme will be completed, bringing about a major change to the water supply situation in the province, mostly to Mombasa County and the southern area. The proposed Mwache Multipurpose Dam is located on Mwache River, a few kilometres before the river drains into the Indian Ocean at Port Reitz. The proposed dam has a potential of supplying 220,000 m^3/d of water upon construction. 80% of the water from the dam, or some 186,000 m^3/d is dedicated to augment Mombasa's water supply via three main pipelines.
- Due to this development, the Phase I water balance for the BWSS townships and urban centres will decrease to some 34,800 m^3/d, in spite of the fact that demand is expected to increase considerably in this period. Part of this deficit will be covered by local water sources.
- In this phase, ~186,400 m^3/d will be added to the BWSS from the new Mwache Dam.

Phase II (to be completed by 2025)

For the UCBWSS townships and urban centres:

- In this phase, the Garsen-Lamu Scheme will be implemented for a total daily capacity of 120,000 m^3/d. Due to the relative proximity of the townships of Garsen, Mpeketoni and Lamu Island/Port, these three townships will be integrated and benefitted from the Garsen-Lamu Scheme.
- Because of this development, the water balance for Phase II for the BWSS townships and urban centres will decrease substantially to a manageable amount of only ~2,200 m^3/d.

For the BWSS townships and urban centres:

- During Phase II, construction of the Baricho 2 Scheme will be undertaken, reaching total production of ~175,000 m^3/d. This development will considerably enhance the supply to Mombasa and the townships of Kilifi, Malindi/Watamu and Marafa in Kilifi County
- Due to the expected sizeable increase in demand during this period, and in spite of this development of the Baricho 2 Scheme, the water balance for Phase II for the BWSS townships and urban centres will increase to some 44,400 m^3/d.

Phase III (to be completed by planning horizon year of 2035)

For the UCBWSS townships and urban centres:

- A water balance shows that in Phase III the total water demand for the six UCBWSS townships and urban centres will be ~133,000 m^3/d (see Table 8-1 in main report). The total deficit will increase slightly to some 3,200 m^3/d (see Table 8-11 in main report)., This amount is manageable and can be covered by local water sources or demand management.

For the BWSS townships and urban centres:

- During Phase III, the construction of the Mzima 2 Scheme will be undertaken, increasing the abstraction from the Mzima Springs to a total of 105,000 m^3/d. This development will enhance the supply to Mombasa and the townships of Mwatate, Wundanyi and Voi/Maungu in Taita Taveta County.
- In addition, during this phase, a new 12"/300 mm, 46 km pipeline will serve the southern coast supply branch, from Msambweni to Lunga Lunga/Vanga. At the same time, the Msambweni Aquifer will also be developed, with a target capacity of 20,000 m^3/d. All these improvements will enhance supply to the townships of Msambweni and Lunga Lunga/Vanga.
- These developments drive the balance between the projected water demand and water supply for Phase III, for the BWSS townships and urban centres, which was the WSMP main planning strategy in the first place.
- For Phase III, the final phase of development, at the horizon year of 2035 – the total water demand for the BWSS consumers will be some 538,273 m^3/d for Mombasa and another 13 townships.
- During this phase, it is proposed to implement the Mzima 2 Pipeline (to convey some 105,000 m^3/d) and decommission the existing Mzima Pipeline. As in the Immediate Phase of the development, the more water will be supplied to Mombasa, the less Mombasa will be dependent on a single source. Thus, more water will be available to other consumers from other BWSS resources. In Phase III, this will be exactly the case for Voi/Maungu, Mwatate and Wundanyi, as these townships will be able to abstract water from the new Mzima 2 Pipeline, without affecting Mombasa supply.

H – Preliminary Design

The final selection for the best option was made out of five scenarios. In developing the scenarios, the following precautions were observed:

- For each scenario, the water demand must be met as close as possible.
- To reduce high capital expenses, high-cost water schemes were postponed as much as possible into the future. (Please see further explanation regarding this in Chapter 11 of the Main Report – "Financial and Economic Analysis".)
- The selected water supply schemes should be highly reliable, sustainable and robust, both in term of the water resources as well as the conveyance systems.

Under conditions, restrictions and constraints of the existing supply scheme, the Consultant developed a tailored approach to development, exploitation and management of new water resources and supply schemes (see Fig. Exec-6). The outcome of the preliminary design is the following list of projects for implementation during the four development phases.

Immediate Phase ("emergency works to improve supply to Mombasa")

Under the additional financing awarded to the CWSB, (with total investments of approximately US$ 35 million), additional water from Baricho will be pumped and supplied towards Mombasa. Abstraction will be done via two new boreholes (of the same borehole type as the current ones). In addition, a pipe segment along the Baricho-Nguu Tatu Pipeline will be rehabilitated, enabling an increase in supply to Mombasa of about 20,000 m^3/d. With construction of the new Kilifi Pipeline (500 mm, 51 km) and a new Kilifi Water Tank (5,000 m^3/d), some 16,000 m^3/d could be diverted from the Sabaki-Mombasa Pipeline to Kilifi. This will decrease the load on the existing pipeline. By rehabilitating the 12 km, 400 mm pipeline (downstream of the Lower Ribe Water Tank), an additional capacity of ~4,000 m^3/d will be delivered, thereby bringing a total of about 20,000 m^3/d to be available for Mombasa. Hydraulic modelling showed that the additional amount can be supplied without exceeding 24 bar pressure in the PN 24 Sabaki-Mombasa Pipeline downstream of the Baricho delivery pumps.

The following projects will be implemented during the Immediate Phase:

- Drilling of two new boreholes in Baricho, adding new manifolds connecting to the main delivery pipe up to the treatment tank. A 470 m^3/h pump will be installed for each borehole, enabling a total production of 10,340 m^3/d. The pumps will be connected to the current manifolds system at the Baricho site.
- Upgrading the 12 km Lower Ribe-Nguu Tatu parallel force main pipe (a segment of the Baricho-Nguu Tatu Pipeline) from 600 to 800 mm, upstream of the Nguu Tatu Water Tank. The pipe used will have a PN 8 pressure rating.
- Construction of the Kakuyuni-Kilifi Pipeline (51 km, 500 mm)
- Connecting Gongoni to the Malindi Pipeline (25 km, 300 mm) with a connection at the Kakuyuni Water Tank, allowing +120 m head for the Gongoni Pipeline
- Construction of the new Kakuyuni Water Tank, 2,500 m^3 at +120 masl
- Construction of the new Kilifi Water Tank, 5,000 m^3 at +60 masl

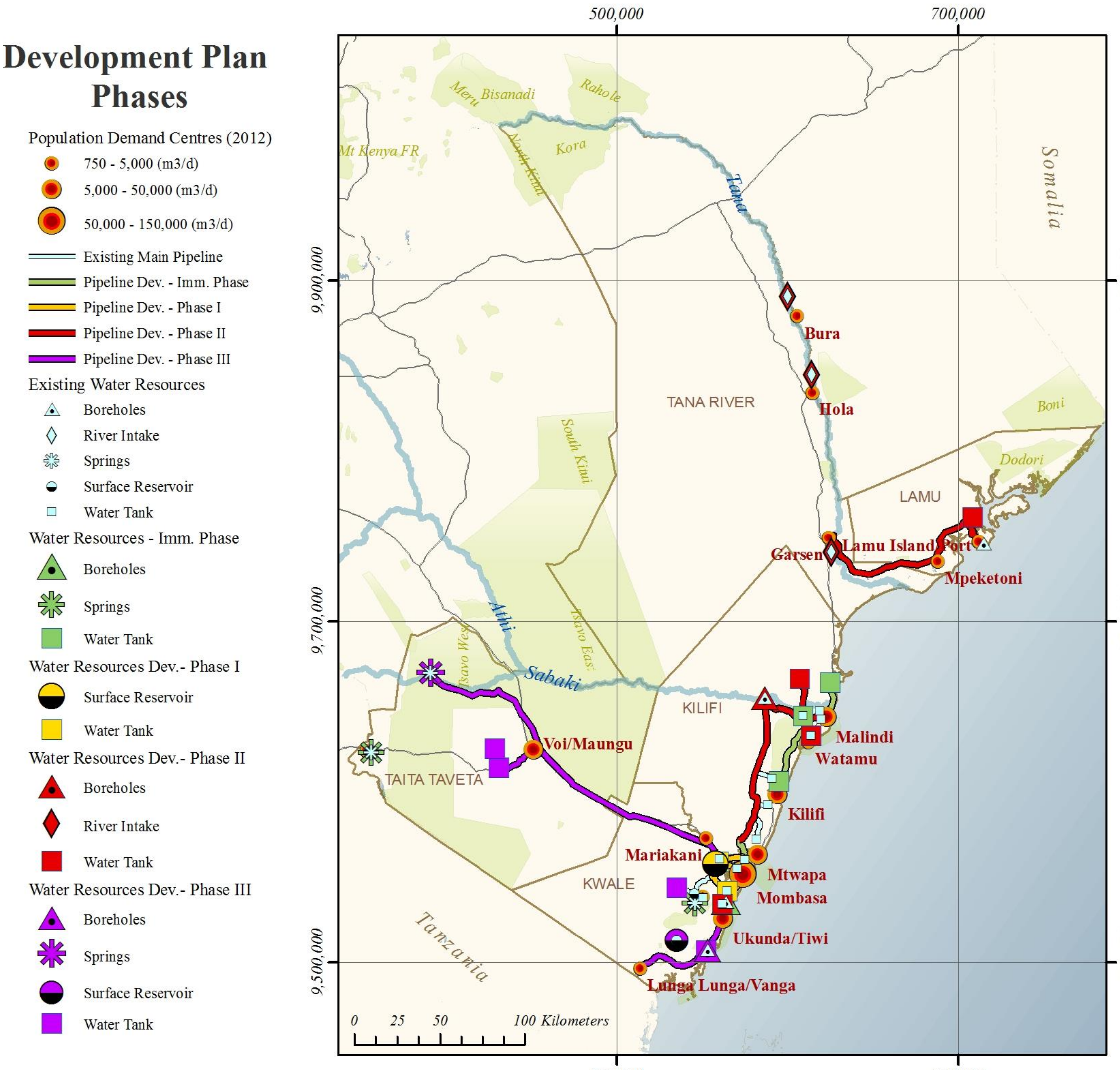


Fig. Exec-6: Layout map of development by phases

Phase I (2020)

The importance of this phase lies in the major changes it will effect with respect to the availability of water in the region (due to the contribution from Mwache Dam), mainly in Mombasa city and vicinity, where water shortages are severe. In this phase, some rehabilitation works will be also executed at the Njoro Kubwa Springs in Taita Taveta County.

The following works will be implemented during Phase I:

- Completing the Mwache Dam, the treatment facilities and the delivery water tank
- Construction of a new pumping station downstream of the treatment plant
- Construction of three arrays of pumps from the Mwache Dam to:
  - +120 New Mwache Tank (NMT) [6 new pumps (5 duty, 1 standby), 865 m^3/h at 110 m head, with 440 kW motor each]
  - Chamgamwe Water Tank [6 new pumps (5 duty, 1 standby), 600 m^3/h at 65 m head, with 180 kW motor each]
  - The southern area (Kaya Bombo) [6 new pumps (5 duty, 1 standby), 865 m^3/h at 70 m head, with 280 kW motor each]
- Laying new water mains to supply water for Mombasa and the southern area:
- Toward Mombasa:
  - Connecting Mwache Pumping Station to the +120 NMT, via 1,000 mm pipeline, 4.5 km long
  - Connecting Mwache Pumping Station to the Chamgamwe Water Tank, via 700 mm pipeline, 15 km long
  - Connecting the +120 NMT to Nguu Tatu Water Tank, via 1,000 mm pipeline, 35 km long
- Toward southern region:
  - Connecting Mwache Pumping Station to the south, by connecting to the Kaya Bombo Water Tank, via 800 mm pipeline, 22 km long
  - Connecting Likoni to the Kaya Bombo Water Tank via 500 mm pipeline, 11 km long
  - Connecting the Tiwi Pipeline to the Kaya Bombo-Likoni Pipeline in the southern region via 500 mm pipeline, 20 km long
- New 20,000 m^3 Mwache Water Tank ("NMT") at +120 masl
- New 10,000 m^3 Kaya Bombo Water Tank at, +70 masl (attached to the current tank)
- Rehabilitation work at the Njoro Kubwa Springs to supply Taveta township, including rehabilitation of the main supply line

Phase II (2025)

Phase II will be devoted to expanding the BWSS and improving supply reliability. This phase will include both the development of new resources for the region, with further extension of the supply network to new areas, some of which are UCBWSS.

For the Lamu and Tana River counties the plan calls for the Garsen-Lamu Scheme to be executed during this phase, to meet the increasing demand for water in the region. Local supply scheme will provide an additional amount of water to Garsen township, whereas Bura and Hola will be supplied solely from independent local schemes.

The following works will be implemented during Phase II:

- Boost the Baricho Wellfield abstraction capacity to a total of 175,000 m^3/d by adding five new RHC-type boreholes, having a capacity of 900 m^3/h each.
- Construction of a new PS at Baricho, including new electrical and administrative buildings.
- Shift the Malindi pumps to a new PS, and adding three new delivery pumps to Malindi (2 duty, 1 standby, 700 m^3/h, TDH 110 m). Using the freed space in the existing PS to add two new delivery pumps to Mombasa (1 duty, 1 standby, 833 m^3/h, TDH 245 m).
- Construction of the second Baricho-Nguu Tatu Pipeline, 800 mm, 107 km long (with pipe pressure ratings ranging from PN 12 to PN 40).
- Construction of the second Baricho-Kakuyuni Pipeline, 600 mm, 45 km long (with pipe pressure ratings of PN 12 and PN 16).
- Upgrade the water tanks at Kisimani (2,000 m^3) and Kisauni (2,500 m^3).
- Construction of the new Marafa supply line, 300 mm, 20 km long (with pipe pressure ratings ranging from PN 12 to PN 24).
- Installation of a new booster pump near Kakuyuni Water Tank, to supply Marafa, 170 m^3/h, TDH 120 m.
- Construction of the new Marafa Water Tank, 1,500 m^3.
- Construction of a new pipeline from the second Sabaki Pipeline to Ubaoni Water Tank, to enable more water to be delivered from the second Sabaki Pipeline toward Mtwapa.
- For the Lamu and Tana River counties water supply scheme:
  - Construction of a water intake on Tana River, with a capacity of about 120,000 m^3/d.
  - Construction of a WTP and PS for the Garsen-Lamu Scheme (total capacity of 4,800 m^3/h, against a TDH of 115 m).
  - Construction of Garsen-Lamu Pipeline, 1,200 mm, 78 km long (with pipe pressure ratings ranging from PN 8 to PN 24).

Phase III (2035)

During this phase, the plan calls for construction of the Mzima 2 Pipeline and decommissioning of the existing Mzima Pipeline due to its advanced age and deteriorating condition. The new 220 km line, 1,200/1,000 mm in diameter, will convey 105,000 m^3/d from Mzima Springs to Mombasa (via the Mazeras Water Tanks), and, in Taita Taveta County, to Voi/Maungu, Mwatate (by pumping) and Wundanyi (by a booster pump).

In addition, water demand along the Voi-Mazeras section was projected to be some 15,000 m^3/d. To meet the demand, partial expansion of the abstraction chamber of the Mzima Springs is required. This will be achieved by replacing the existing 30" diameter pipeline with a new 48" diameter pipeline.

The following works will be implemented during Phase III:

- Expansion of the Mzima Waterworks by installing a 48" diameter pipeline upstream of the existing Mzima Tunnel (replacing the existing, 1.3 km long, 30" diameter pipeline).
- Rehabilitating and upgrade the existing disinfection facility to cope with the increased abstraction
- Installing the 1,200 mm Mzima 2 Pipeline from Mzima Springs to Voi Junction (78 km), and 1,000 mm pipeline to the Mazeras Water Tanks in Mombasa (142 km). Pressure rating of the pipelines will be PN 12.
- Construction of the 30 km 400 mm pipeline to Voi-Mwatate
- Construction of the 12 km 250 mm pipeline to Mwatate-Wundanyi
- Construction of the 1,500 m^3 Mwatate Water Tank
- Construction of the 1,250 m^3 Wundanyi Water Tank
- Construction of the Wundanyi PS, 240 m^3/h, TDH 645 m, booster pump
- Construction of the Mwatate booster pump, 470 m^3/h, TDH 350 m (2 duty, 1 standby)
- Reinforcing the South Coast supply branch from Mwache, including a 35 km 500 mm supply line from Tiwi to Msambweni and further south via a 46 km 300 mm supply line to Lunga Lunga/Vanga
- Construction of the new 10,000 m^3 Msambweni Water Tank and pumping station
- Development of the Msambweni Aquifer, to a capacity of 20,000 m^3/d, connecting the wellfield to the Msambweni Water Tank
- Adding 2 pumps (1 duty, 1 standby) to the PS at Baricho to augment the supply to Malindi/Watamu, with capacity and TDH identical to the existing ones

I – Financial and Economic Analysis

Table Exec-9 sets out the total costs of implementing all works of the WSMP in its entirety. Detailed BOQs are presented in Annex 5 in Volume III of the WSMP.

Table Exec-9: Total Costs of Implementing All Works of the WSMP (excluding the Mwache Dam and Treatment Plant)

Phase	BOQ Sec.	Project Description	Total Cost (US$)
Immediate Phase	1	Baricho Waterworks extension	2,160,274
	2	Baricho-Nguu Tatu Pipeline (segment rehabilitation)	9,591,949
	3	Kakuyuni-Kilifi and Malindi-Gongoni pipelines	22,382,174
	4	Deep Neogenic aquifer investigation in the Lamu Region	2,500,000
Total for Immediate Phase – emergency works to improve supply to Mombasa			**36,634,396**
Phase I	1	Mwache Waterworks	50,538,222
	2	Mwache Transmission Pipelines	87,742,124
	3	Taveta Springs* rehabilitation + Taveta local water supply scheme	5,129,419
Total for Phase I (excluding Mwache Dam + WTP)			**143,409,768**
Phase II Baricho 2 expansion + supply schemes	1	Baricho Waterworks – Baricho 2 expansion + supply schemes	14,087,923
	2	Baricho-Nguu Tatu Pipeline	67,239,631
	3	Baricho-Kakuyuni Pipeline	28,470,078
	4	Kakuyuni-Marafa Pipeline	7,024,704
	Total for Baricho 2 expansion + supply schemes		**116,822,334**
Phase II Lamu and Tana River Counties	1	Garsen-Lamu water supply scheme	181,027,526
	2	Hola local water supply scheme	1,285,070
	3	Bura local water supply scheme	1,290,940
	Total for water supply to Lamu and Tana River counties		**182,223,445**
Total for Phase II			**299,045,700**
Phase III	1	Mzima Waterworks + Mzima 2 Pipeline	374,931,688
	2	Voi-Wundanyi-Mwatate branch	13,544,938
	3	Msambweni Waterworks + connection to bulk water supply system	24,790,177
Total for Phase III			**413,266,803**
Grand total for bulk water supply development plan (excluding Mwache Dam + WTP)			**893,750,333**
Investment estimation for Mwache Dam + WTP			**168,291,000**
Grand total for bulk water supply development plan (including Mwache Dam + WTP)			**1,062,041,333**

* known locally as the **Njoro Kubwa Springs**

Financial Analysis

Financial analysis was conducted from the perspective of water utilities firm, namely the CWSB.

Table Exec-10 presents the main financial indicators of the WSMP development program. (The detailed analysis is included in Annex 6 in Volume III of the WSMP).

Table Exec-10: Main Financial Indicators of the Development Program

Average Capital Cost (US$/m³)	Average Energy Cost (US$/m³)	Average O&M Cost (US$/m³)	NPV (US$ millions)	IRR (%)	Water Cost (US$/m³)
0.15	0.09	0.06	17.7	32.7%	0.3

- The financial internal rate of return (**IRR**) was calculated at over **32.7%**. This is high and indicates that precise and efficient implementation of the projects will generate impressive returns.
- The computed net present value (**NPV**) resulted in **US$ 17.7 million**.
- The **cost of supplied water** amounts to approximately **0.3 US$/m^3** (price to the utilities firms). This cost is composed of US$0.146 attributed to the average capital outlays per m^3, US$0.09 attributed to the energy expenses and US$0.06 due to O&M expenses. This water cost is an aggregation of all investments and O&M expenses of: development of the water resources, conveyance, treatment and storage per m^3 supplied.

Economic Analysis

The economic analysis of the WSMP program examined the feasibility and viability of the water supply schemes from the perspective of the entire provincial and national economy.

Table Exec-11 presents the main indicators of the economic analysis.

Table Exec-11: Main Economic Indicators of the Development Program

Average Capital Cost (US$/m³)	Average Energy Cost (US$/m³)	Average O&M Cost (US$/m³)	ENPV (US$ millions)	EIRR (%)	Economic Water Cost (US$/m³)
0.45	0.08	0.06	-139.5	1.5%	0.58

- The economic internal rate of return (**EIRR**) was calculated at **1.5%**.
- The economic net present value (**ENPV**) was calculated at **- US$ 139.5 million**.
- The resulting **cost (to the national economy) of supplied water** will amount to approximately **0.58 US$/m^3**.

J – Development Phases and Action Plan

As mentioned earlier, the entire development program for the water supply schemes was divided into the following four phases:

- **Immediate Phase (2016):** This phase comes under the Emergency Action for which financing was already secured. It will include enhancing the Baricho water supply scheme (thereby improving the supply to Mombasa, Malindi/Watamu and Kilifi) as well as rehabilitating the Njoro Kubwa Springs works to improve supply to Taveta township (subject to budget availability). The total additional daily production is expected to be 20,000 m^3/d, where all the water will be pumped to Mombasa via the existing Sabaki-Mombasa Pipeline, with upgrade of 400 mm section upstream of the Nguu Tatu Water Tank.
- **Phase I (2020):** In this phase, the Mwache Dam water supply scheme will be completed, bringing about a major change to the water supply situation in the province, mostly to Mombasa County and the southern area. It is proposed that three main supply pipelines will be constructed, pumping water to the New Mwache Tank (NMT) at elevation +120 masl; to southern water supply toward Kaya Bombo Water Tank at elevation +120 masl; and to Chamgamwe Water Tank (+70 masl). This phase will also include rehabilitating the Njoro Kubwa Springs works to improve supply to Taveta township, if not already carried out during the Immediate Phase.
- **Phase II (2025):** This phase will be dedicated to expanding the water supply scheme, and improve the supply reliability. In the Baricho Scheme the capacity of the Baricho Wellfield will be enlarged by adding 5 new RHC-type boreholes, the existing wells will be replaced by RHC-type boreholes and the Baricho 2 Pipeline will be laid. These works will further improve the water supply to Mombasa County and to Malindi/Watamu and Marafa townships in Kilifi County. This phase will also include the construction of the Garsen-Lamu Offtake and conveyance system, thus improving the water supply to Garsen in Tana River County, as well as Lamu Island/Port and Mpeketoni township in Lamu County.
- **Phase III (2035):** In this last phase, additional improvements will be made to the water supply schemes in order to cope with the increasing water demand in the Coast Province. In the Mzima Scheme, the abstraction from the Mzima Springs will be augmented by improving the Mzima Springs waterworks, and laying down the Mzima 2 Pipeline. These works will further improve the water supply to Mombasa County, Voi/Maungu, Mwatate and Wundanyi townships in Taita Taveta County. The Mwache Dam water supply scheme will be expanded to increase the water supply to the southern area – Msambweni and Lunga Lunga/Vanga in Kwale County. The Msambweni Aquifer will be developed, and, jointly with the supply from the Mkurumudzi Dam, will improve water supply to Kwale County. In the Baricho Scheme, the PS will be expanded to increase water supply to Malindi/Watamu in Kilifi County.

Fig. Exec-7 summarizes the development action plan by year of development and by water source.

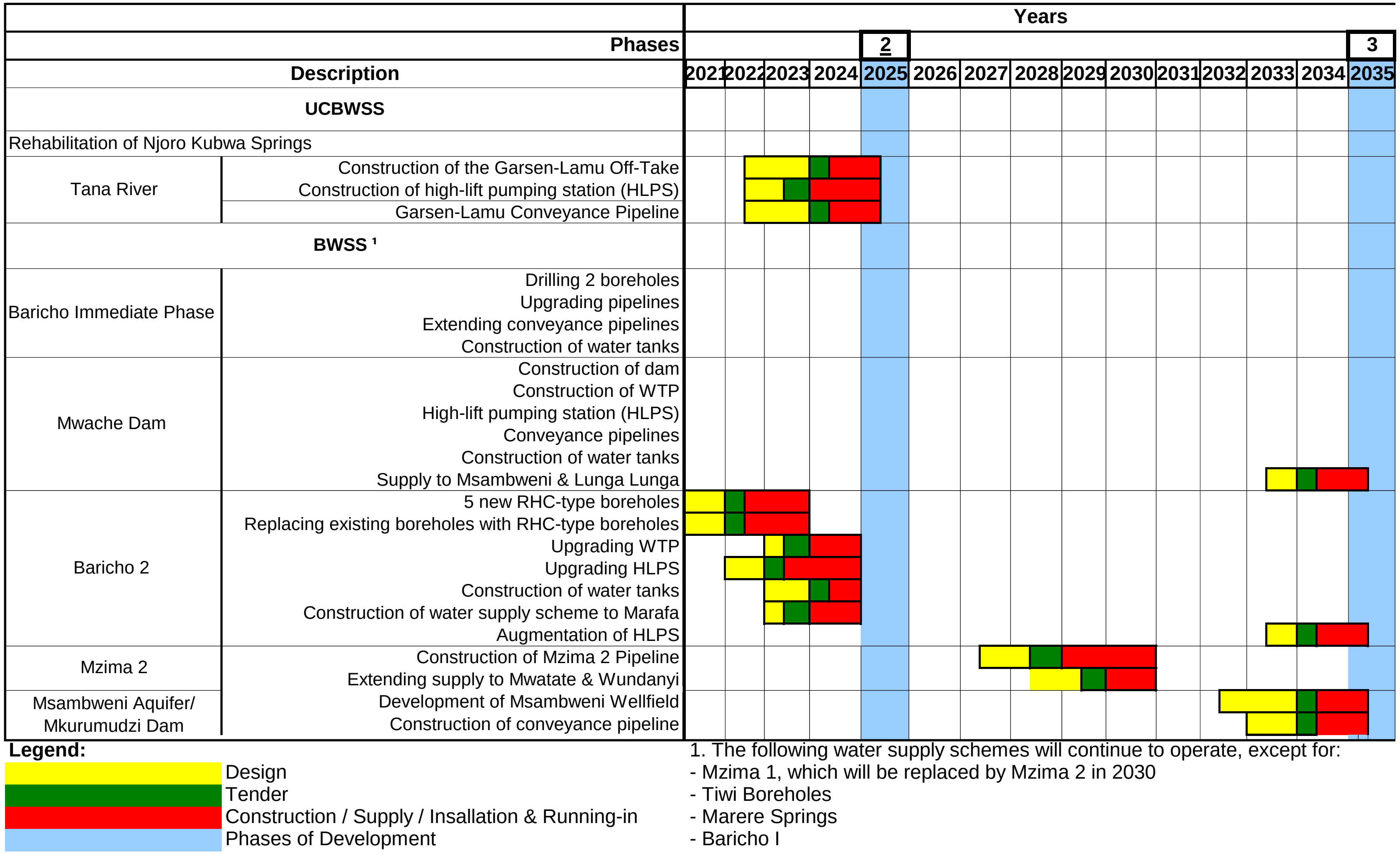


Fig. Exec-7: Action Plan

Water Supply Master Plan

Water Supply Master Plan for Mombasa and Other Towns within Coast Province

1. Introduction

1.1 Background

The contract for providing consultancy services for preparation of the "Water Supply Master Plan (WSMP) for Mombasa and Other Towns within the Coast Province" for the Coast Water Services Board (CWSB) under the Water and Sanitation Service Improvement Project (WaSSIP) was awarded to TAHAL Consulting Engineers Ltd. in association with Bhundia Associates. The contract was signed on 19 October 2011.

Funding for the Consultancy Services is being provided by the Government of Kenya (GoK) with the assistance of the World Bank's International Development Association (IDA) and Agence Française de Développement (AFD).

Preparation of a WSMP requires the Consultant to chart and examine all aspects of the water resources and water supply systems under the jurisdiction of the CWSB. This includes:

- Investigation of the resources and their sustainability over time
- Identification and quantification of new water resources, including both surface water and groundwater, as well as water quality aspects
- Financial aspects, in terms of both capital costs and operational costs
- Integration of the proposed main pipelines to the existing pipelines and to the delivery points of the water service providers (WSPs)

According to the ToR and a clarifying letter dated 28 May 2012, the WSMP will cover **20 townships**:

- The city of **Mombasa and the other 13 townships connected to the BWSS** – Kilifi, Kinango, Kwale, Lunga Lunga/Vanga, Malindi/Watamu, Mariakani, Msambweni, Mtwapa, Mwatate, Marafa, Ukunda/Tiwi, Voi/Maungu, and Wundanyi. These 14 townships will hereinafter be referred to as the **BWSS townships**.
- The **6 townships unconnected to the BWSS** – Bora, Garsen, Hola, Lamu Island/Port, Mpeketoni and Taveta. These 6 townships will hereinafter be referred to as the **UCBWSS townships**.

Note: While the Immediate Phase of the WSMP includes Gongoni township's connection to the BWSS, the design of this pipeline is being carried out by a local consultant.

1.2 Objectives of the Study

The general objectives of the WSMP are to increase access to reliable, affordable and sustainable water supply services in the Coast Province, and satisfy the future growing water demand of the Coast Province, thereby achieving the water supply coverage set out in the **Millennium Development Goals (MDG)** and in **Kenya Vision 2030**, both of which have priorities in terms of development and economic viability.

In particular, the objectives of the WSMP are to:

- Identify potential water resources in the CWSB area of jurisdiction.
- Conduct hydraulic, hydrological, geotechnical, socioeconomic and environmental assessments of these resources, and recommend strategies for their development.
- Examine future possibilities of recycling and use of treated wastewater for public utilities.
- Prepare water demand projections for the Coast Province up to the year 2035, and explore any relevant demand management options, such as pricing.
- Prepare both short-term and long-term investment needs, to address gaps in water supply.
- Prepare environmental and social impact assessments.
- Carry out pre-feasibility studies for all options, full feasibility study for the recommended four strategies and preliminary designs for the recommended option.
- Prepare a sequence of development for the preferred water resources and supply schemes based on the recommended development strategies.
- Develop a 25-year implementation action plan, in 5-year increments, in line with the National Water Master Plan.

1.3 Previous Reports and Related Studies

1.3.1 Previous Reports Submitted by the Consultant

As of October 2013, the following reports and working papers have been submitted by the Consultant:

• Inception Report	December 2011
• Low Flow Analysis of Major Rivers (Athi, Tsavo, Tana)	March 2012
• Draft Water Demand and Supply Assessment Report	April 2012
• Final Water Demand and Supply Assessment Report	July 2012
• Draft Pre-Feasibility Study for all Options Report	August 2012
• Final Pre-Feasibility Study for all Options Report	October 2012
• Draft Water Resources Report	October 2012

• Final Water Resources Report	December 2012
• Feasibility Study – key issues for discussions	December 2012
• Draft Full Feasibility Study Report	December 2012
• Special report: Alternatives for Additional Finance: The Expansion of Baricho Waterworks	January 2013
• Final Full Feasibility Study Report	February 2013
• Revised Final Full Feasibility Study Report	April 2013
• Draft Preliminary Design Report	May 2013
• Draft RAP Report	May 2013
• Draft EIA Report	May 2013
• Final RAP Report	July 2013
• Final EIA Report	August 2013
• Final Preliminary Design Report	October 2013
• Draft Final Master Plan Report	December 2013

1.3.2 Related Studies Reviewed by the Consultant

The following documents, as listed in the ToR, were received and reviewed during the study:

- WaSSIP Project Appraisal Document (PAD)
- AFD Aide Mémoire of mission of assessment of the MWSSIP project
- Feasibility Study, JV BRL and GIBB, 2008
- The Water Act 2002
- The Local Government Act, Cap 265
- The State Corporation Act, Cap 446
- Sessional Paper No. 1 of 1999, National Water Policy
- Environment Act, Cap 8
- Review of Options for Private Sector Participation in the Provision of Water Supply and Sewerage Services in Mombasa and the Coastal Region – Final Report on Preferred Option, Pricewaterhouse Coopers, December 2002
- Serving All Urban Consumers – Book 4: Sample strategic marketing plan for Mombasa and Coastal Region, WEDC, NWCPC, 2004
- The Vision 2030
- The National Water Services Strategy Policy,2007
- The National Water Master Plan 1992, JICA
- The Second Mzima Pipeline Studies, 1996 (Second Mombasa and Coastal Water Supply Rehabilitation Project), Sincat/Atkins
- The Second Mombasa and the Coastal Water Supply Rehabilitation Project, Sincat/Atkins and Seureca/Mangat
- Mwache Dam Water Resources Study, 2008, Samez Consultants
- Feasibility Study for Marere Pipeline, 1992, YIT

- Rehabilitation of Mzima Pipeline and Rationalization of the Sabaki Pipeline Transmission Systems,1998, H. P. Gauff
- Detailed Designs for Rehabilitation Works for Mzima, Baricho & Tiwi projects, 2009, BRLi/GIBB
- Mzima Pipeline Hydraulic Performance Assessment and Hydropower Generation Study 2010, BRL/GIBB
- Detailed Designs for Rehabilitation Works for 6 WSPs – Mzima, Baricho & Tiwi projects, 2010, H. P. Gauff
- Expansion/Rehabilitation of the Marere System Study, H. P. Gauff
- Oil and gas well information from the Ministry of Energy
- The 2009 National Census Data
- The Second Mombasa and the Coastal Water Supply Rehabilitation Project, Modular three dimensional finite-difference ground water flow model of the Sabaki aquifer, H. P. Gauff
- Feasibility Study and Detailed Design of the Mwache Multipurpose Dam Development Project, CES/APEC

In addition to the above documents, four important studies impacting the Coast Province are in preparation:

- **National Water Master Plan 2030 (NWMP)** – A Japan International Cooperation Agency (JICA) study team is preparing the NWMP for year 2030. Work on the NWMP began in 2010, covering the entire area of Kenya. The plan will indicate water resources to be developed, some of which will influence the availability of water for the Coast Province. The JICA study team presented their Interim Report on 3 August 2012. The draft report was submitted to GoK in June 2013.
- **Chyulu Hills Aquifer Study** – The World Bank is funding a hydrological study to investigate the groundwater system of the Chyulu Hills. This aquifer is the source for Mzima Springs and other smaller springs (Umani, Mtito Andei, Kiboko, Makindu, Mangelete and others).
- **Mwache Multipurpose Dam** – The Coast Development Authority (CDA) is promoting the design of the Mwache Dam for domestic water supply and irrigation. The study and the detailed design are being carried out by CES/APEC, and they indicate that the Mwache Dam is a key resource for the Coast Province. The Mwache Dam Feasibility Report was approved by MWI and CDA in February 2013, and authorization was granted to begin the detailed design.
- **Kilimanjaro Aquifer Study** – The World Bank has issued a tender to study replenishment mechanisms for the Kilimanjaro Aquifer, in order to better estimate annual water yield from this source.

The present study was coordinated closely with the JICA study team, CES, CDA, WRMA, the World Bank and AFD to share and incorporate the data and findings from these studies in the WSMP.

1.4 Kenya Vision 2030

Among the documents mentioned above, Kenya Vision 2030 has served as guideline to the present study.

Kenya's Vision 2030 is the country's new development blueprint covering the period 2008 to 2030. It aims to transform Kenya into a newly industrializing "*middle-income country providing a high quality life to all its citizens by the year 2030*" – a fact that is expected to provide a huge impetus to development of water resources to meet the various goals for water demand as per the vision.

Flagship projects have been identified in various sectors, whose development has a substantial effect on water sector development, both directly and indirectly. These projects include:

- **22 Medium-Size Dams** – Multipurpose dams with a total capacity of 2 billion m^3 to supply water for domestic, irrigation and livestock use in the arid and semi-arid areas of the country. The projects are promoted by the Ministry of Regional Development Authorities (MoRDA) and the National Water Conservation and Pipeline Corporation (NWCPC). Two dams fall under the area covered by the CWSB – Mwache Multipurpose Dam near Mombasa, and Rare Dam near Kilifi.
- **High Grand Falls (HGF)** – Multipurpose dam on the Tana River for hydropower production and flood mitigation. The location of the dam is behind the area of the Coast Province but will influence flows in the Tana River. The feasibility study for HGF is currently being carried out under MoRDA.
- **LAPSSET Corridor** – The Lamu-Southern Sudan-Ethiopia Transport Corridor will develop the area of Lamu and transform it into a major metropolis, including development of transportation, industrialization, tourism, and urban areas. This major development is expected to increase the water demand of Lamu County from less than 10,000 m^3/d in 2012 to more than 100,000 m^3/d in the horizon year of 2035. One of the proposed new sources is the Tana River. A suggested waterworks from the Nanighi intake on the Tana River via a 180 km pipeline to Lamu was considered in the framework of the master plan of the new port in 2010.

1.5 Structure of the Water Supply Master Plan Report

The present report is the final report of the WSMP. As such, it sums up, recaps and integrates all the preceding studies and findings of the WSMP in three volumes – Volume I (Main Report), Volume II (Maps and Geographic Data) and Volume III (Annexes).

The report includes the following chapters in Volume I:

- **Chapter 1: Introduction** – This chapter presents the background, objectives and structure of the WSMP Report.

- **Chapter 2: The Water Sector –** This chapter presents the structure of the water sector in Kenya, in general, and in the Coast Province, in particular. It also describes briefly the strategies employed by the water authorities for the development and management of the surface water and groundwater resources and catchments.

- **Chapter 3: The Project Area** – This chapter describes the various attributes of the Coast Province, including geography, topography, climate, geology, demography and economic activities. Special emphasis is given to the description and analyses of the potential development of the water resources in the province – surface, groundwater and unconventional water resources.

- **Chapter 4: Methodologies Employed in the WSMP** – This chapter introduces the methodologies employed in the different studies carried out during the execution of the WSMP. The concept was to describe the methodologies separately from the findings and conclusions of each of the studies. The findings, conclusions of the various studies and their integration into a WSMP are presented in Chapters 5–12.

- **Chapter 5: Socioeconomic Survey** – This chapter summarizes the various characteristics of Coast Province population, and lays the groundwork for the population projections, especially the breakdown between urban and rural populations.

- **Chapter 6: Water Demand Forecast** – This chapter summarizes the population projections for the entire Coast Province in general, and for the 20 main townships and urban centres - the objective of the present WSMP. Using the methodology described in Chapter 4 and the population projection, the water demand for the 20 main townships and urban centres are forecast for each of the four phases of development, as defined in Chapter 4.

- **Chapter 7: Existing Water Supply Schemes** – In this chapter, the existing water supply schemes were analyzed and evaluated with regard to current abstraction from the resources and existing supply infrastructure. Table 7-1 maps the resources that can potentially meet the projected demand.

- **Chapter 8: Proposed Water Supply Schemes** – The planning strategy of the WSMP calls for the water resources (new and existing) to be developed in such a way as to meet the projected demand in the mid- and long-term phases of the development plan. The assessment was divided into two sections – schemes connected to the bulk water suppy system (**BWSS**) and schemes providing water to townships unconnected to the bulk water supply system

(**UCBWSS**). Accordingly, a **water balance**, showing source and destination, is presented for the 20 main townships and urban centres for each section and for each development phase.

- **Chapter 9: Preliminary Design** – This chapter comprises comprehensive calculation with regard to the water supply shemes and their engineering components. Several schematics are presented in this chapter to show the layout of the main waterworks of the phased development plan.

- **Chapter 10: Climate Change** – This chapter cover the climate change impacts in Kenya in general, and a statistical analysis of climate change for the Coast Province in particular. As a result of the climate change analysis, some very conclusive recommendations are given.

- **Chapter 11: Financial and Economic Analysis** – This chapter presents the principles, assumptions and results of the financial and economic analysis of the selected scenario.

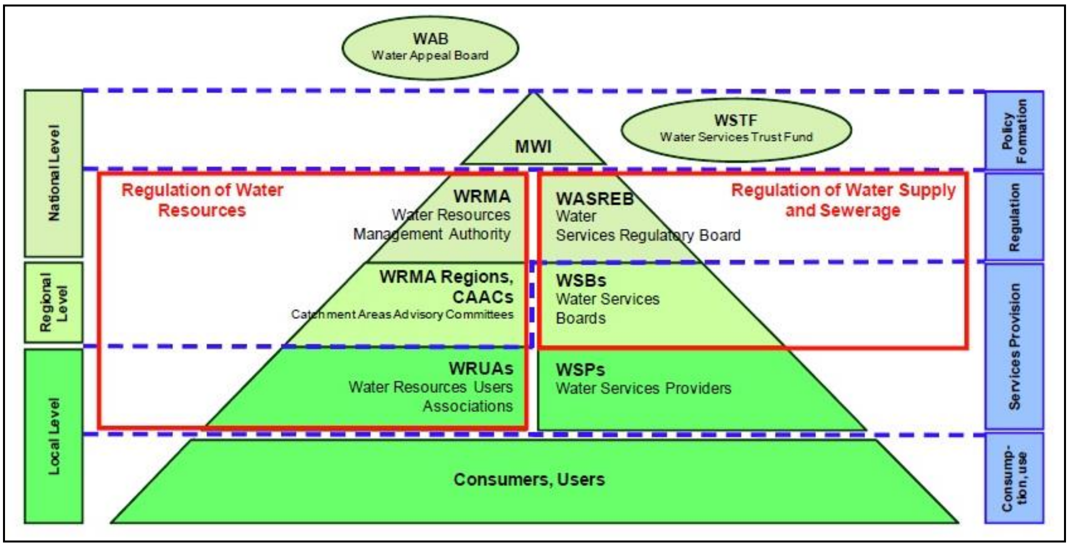
- **Chapter 12: Resettlement Action Plan (RAP)** – This chapter reviews the policy, legislation and administrative framework associated with the resettlement issue resulting from the proposed water supply schemes. It then defines the project-affected population (PAP) for each of the schemes in each of the development phases, and describes the impact of the proposed development on the PAP. Finally, a rational program for the resettlement planning of all persons and communities affected by the proposed water supply schemes is defined.

- **Chapter 13: Environmental Impact Analysis (EIA)** – This chapter reviews the policy, legislation and administrative framework associated with the environmental impact resulting from the proposed water supply schemes. The EIA then identified possible impacts from various project components and stages (design and location, construction and operation and maintenance) for each of the schemes in each of the development phases. For the adverse impacts, mitigation measures are suggested and recommendations are presented for appropriate implementation actions, as well as capacity needs that have to be developed, to ensure the possible implementation of identified management actions to safeguard the environment.

2. The Water Sector

2.1 General

Under the Kenya Water Act of 2002, the institutional framework for water resources management and utilization is as shown in Fig. 2-1, and described below.



Source: WRMA and NWMP

Fig. 2-1: Water Act 2002 institutional framework

2.2 Water Resources Management

2.2.1 Overview

Water resources management in Kenya is undertaken mainly on four levels. The Ministry of Environment, Water and Natural Resources (MEWNR) is involved mainly in the capacity of policymaker. Under the MWI, the Water Resources Management Authority (WRMA) regulates, at both the national and regional levels, the management of the water resources in the country. At the catchment level, the Catchment Area Advisory Committees (CAACs) act as the advisors to WRMA, while the Water Resource Users Associations (WRUAs) constitute regulators at the local level.

Responsibility for flood control is not completely clear according to the Water Act 2002 (whether under MWI or WRMA). Catchment protection is under WRMA, although it is not clear if catchment protection includes flood control.

Watershed management is part of catchment protection while water quality management is also conducted to a partial extent by WRMA.

In the future the water resources management framework will have to consider present and future needs of various water-related sectors, policy and non-policy measures and requirements, alternative measures, and an appropriate balance between policies and measures.

2.2.2 Water Service Management

The water services sector under the Ministry of Environment, Water and Natural Resources (MEWNR) still undertakes policymaking, while regulation and management of the water services is carried out nationally by the Water Services Regulatory Board (WASREB). The Water Services Boards (WSBs), in different regions of the country and under licence from WASREB, are responsible for the provision of water services and development of related assets within their area of jurisdiction. The Water Service Providers (WSPs), with a Service Provision Agreement (SPA) from the WSB, are responsible for the provision of water services at the local level on behalf of the WSB.

2.2.3 Water Appeals Board

The Water Appeals Board was established under the Water Act 2002 to adjudicate disputes of any nature arising within the water sector. The Water Appeals Board can hear and determine appeals arising from the decisions of the MWI, the WARSEB and WRMA in respect to the issuance of permits or licences under the Water Act 2002. The Water Appeals Board can also adjudicate complaints between a customer and a WSP, or any organisation within the setup, or vice versa.

2.2.4 Water Services Trust Fund (WSTF)

The Water Services Trust Fund (WSTF) was established under the Water Act 2002 for funding development of the long-term objective of disseminating water and sewerage services in areas of Kenya lacking supply of these services. Its main objective is to assist in the financing of capital costs for provision of water services to communities without adequate water and sanitation, with priority given to the poor and disadvantaged groups, such as the urban informal settlements.

2.2.5 National Water Conservation & Pipeline Corporation (NWCPC)

The National Water Conservation and Pipeline Corporation (NWCPC) was established under the State Corporations Act Chapter 446 of the Laws of Kenya Vide Legal Notice 270 of 24th June 1988. It is mandated under the Water Act 2002 to develop state schemes – construction of dams and water pans; development of canals; flood control works; and drilling of boreholes. In the Coast Province, it is initiating a study of the Rare River for possible construction of a dam about 4 km upstream of Kilifi Town.

2.2.6 Coast Development Authority (CDA)

The Coast Development Authority (CDA) is one of the six Regional Development Authorities under the Ministry of Regional Development Authorities in Kenya. As part of the Ministry's adapted multi-sectorial/integrated development approach for regional economic growth, the CDA is involved in the development of Mwache Dam and water pans in the Coast Province, among other projects. The dam projects undertaken by the Ministry of Regional Development Authorities (MoRDA) are mostly multipurpose in nature, with water supply being one of the components. Therefore MoRDA and CDA play a significant role in the development of water resources in Kenya.

2.2.7 Coast Water Services Board (CWSB)

The Coast Water Services Board (CWSB), one of eight Water Service Boards in Kenya, is a parastatal (Government owned and autonomous) organization created under the Water Act, 2002, and established through Gazette Notice No. 1328 of 27th February 2004.

The Board's main responsibility is the provision of efficient and economical water and sanitation services to the people of the Coast Province. Its area of jurisdiction, which coincides with the administrative boundaries of the Coast Province, is approximately 83,040 km^2. This area covers six counties – Mombasa, Kwale, Kilifi, Lamu, Tana River and Taita Taveta.

There are currently seven contracted WSPs under the CWSB, namely:

- Mombasa Water and Sewerage Company (MOWASCO)
- Malindi Water and Sewerage Company (MAWASCO)
- Kilifi-Mariakani Water and Sewerage Company (KIMAWASCO)
- Taveta-Voi Water and Sewerage Company (TAVEVO)
- Lamu Water and Sewerage Company (LAWASCO)
- Kwale Water and Sewerage Company (KWAWASCO)
- Tana Water and Sewerage Company (TAWASCO)

2.3 WARMA Surface Water Management Strategies

2.3.1 Background

The area of the Coast Province falls under two catchment areas managed by WRMA – Tana Catchment area and Athi Catchment area.

The Coast Province is located downstream of both catchments and it is therefore essential to understand the development strategies for the catchment as a whole.

The WRMA Catchment Management Strategies (2008) set short- and medium-term strategies for water resources development.

2.3.2 Athi Catchment Area Strategies

WRMA management strategies for the Athi Catchment area, with an annual average rainfall of 739 mm, include development of surface water storage, in the framework of which the region will adopt a micro (household level) and macro (state level) strategy, promoting:

- Construction of large dams
- Rehabilitation of small dams/pans
- Construction of water harvesting facilities

Water storage can be improved through the enhancement of groundwater storage, performed by encouraging development of groundwater recharge infrastructure. Targets in terms of water resources development include:

- Development of plans to meet 150,000 m^3 capacity groundwater storage
- Development of 1.9 MCM storage in small-scale reservoirs by 2013
- Promotion of 1.62 BCM storage on Athi River by 2013, as well as at Munyu, Fourteen Falls, Site A13, Mavindini and Yatta Bridge

2.3.3 Tana Catchment Area Strategies

The Tana Catchment area is home to the largest dam and reservoir capacity in Kenya. Among the existing dams are Kindaruma (1968), Kamburu (1975), Gitaru (1978), Masinga (1981), Kiambere (1988) and Sasumua (1956). There is a plan to construct the High Grand Falls Dam. In addition, many small dams/pans have been constructed by private individuals, institutions and communities.

WRMA management strategies for the Tana Catchment area, with an annual average rainfall of 679 mm, include the utilization of underexploited natural aquifers. In considering the development of additional groundwater storage, artificial groundwater recharge techniques will be one way to ensure better use of water resources.

The region expects to carry out planned activities during the next 10 years, including:

- Two dams, each of 1 MCM capacity
- A dam of 4–5 BCM capacity
- Five small dams, each of 0.2 MCM capacity
- Five sand dams / check dams / pans / rock catchments, each of 100–1,000 m^3 capacity
- Groundwater survey and mapping
- Rainwater harvesting in ~1,000 households/institutions

2.4 Existing Groundwater Management

Aquifers in Kenya in general, and the Coast Province in particular, are managed on an ad-hoc basis. Water allocation is not based on a formal system of assessment nor with an allocation plan in mind.

Groundwater management decision-making is sector-based and ad hoc in nature, with no mechanism for coordination or encouragement of multi-sector linkages. Management of groundwater resources is carried out independently of land management and other land-based resources. Decision-making in connection with groundwater management is largely centralized, with minimum involvement, if any, on the part of stakeholder water resource management units.

Despite provision for groundwater conservation zones in the Water Act 2002, no groundwater conservation zones have been gazetted for the Coast Province, nor for Kenya as a whole. A majority of the numerous groundwater users does not have abstraction permits, and, hence, essentially they are not documented. Groundwater management is therefore weak and largely lacking in any strategic focus.

2.5 Constitutional Reform in Kenya, as related to Water Sector Development

Following the adoption of a new Constitution in 2010 and the 2013 elections, significant administrative and legislative changes have taken place at the federal and county levels in Kenya. These transformations present development opportunities and challenges for WSMP implementation.

Kenya is divided into 47 counties. Six are included within the CWSB area of jurisdiction. Decentralization policies and legislation have transferred development functions and powers from the National Government to the counties.

The decentralized functions include, inter alia, planning and development authority. Counties can now enter into contracts and acquire, purchase or lease land. They can also borrow and receive grants from development partners, subject to the approval of the National Government). They also have direct responsibility for the development of agriculture; county public works; policy implementation; soil and water conservation; etc. Water supply infrastructures clearly fall into this category.

Implementation of projects within the CWSB area of jurisdiction and WSMP guidelines will have to be initiated, coordinated and implemented by (or with) the county administrations.

3. The Project Area

3.1 Location and Topography

3.1.1 General

The Coast Province is one of the eight provinces of Kenya, located on the eastern side of Kenya, adjoining the Indian Ocean, with Somalia at its northern end and Tanzania to the south.

Three physiographic zones are observed in the Coast Province, as follows:

- The **Nyika** lies at 600 masl, and represents the higher ground covered by the Duruma sandstone series and older rocks to the west.
- The **Foot Plateau** occurs at an elevation between 140 and 600 masl, coinciding with the relatively younger Jurassic rocks.
- The **Coastal Plain**, the lowest step, rises from sea level to 140 masl. On average, this belt increases from a few kilometres wide in the southern sector, to over 40 km wide in the north (UNEP, 1998).

In the following sections, a county-by-county description of the physiographic features is presented (see maps in Section I of Volume II of the WSMP).

3.1.2 Mombasa

Mombasa is the capital of the Coast Province and the second largest city in Kenya. In term of economic activity, the city leads the Kenyan business sector in two dominant activities:

- The port of Mombasa – the largest port along the east African coast – which serves many inland countries
- The tourism industry, which stretches along the southern coast from Diani and Msambweni in the south to Malindi/Watamu in the north, with concentration of hotels and resorts around Mombasa

The importance of these economic activities to the entire country justifies the need for sustainable and highly reliable infrastructures, such as water supply, sanitation services, electricity and communications.

With its urban character, Mombasa has the highest rate of population growth in the province, expected to increase from over 1 million inhabitants in 2012 to 1.64 million inhabitants in 2025 and up to 2.22 million in the horizon year of 2035. The total water demand will increase from 137,611 m^3/d in 2012 to 312,554 m^3/d in the horizon year of 2035 – a 230% increase in a period of less than 25 years.

Mombasa is located on an island, with two main bridges that connect the island to the mainland and the surrounding neighbourhoods, as follows:

- To the south – the neighbourhood of Likoni is separated from the mainland by the port of Mombasa, where crossing the port channel is possible only via ferry.
- To the north – the Nialy Bridge connects the island to the northern neighbourhoods and to the roads leading north to Malindi/Watamu
- To the east – the mainland bridge connects the island to Chamgamwe and the airport area where the beginning of the road to Nairobi starts. The elevation of the island range from sea level to +33 masl. The total area of the island is ~15 km^2. The island is divided into several subzones, mainly for administrative purposes.

3.1.3 Kwale County

Kwale County has four major topographical features – the Coastal Plain, the Foot Plateau, the Coastal Uplands and the Nyika Plateau – with altitudes ranging from sea level to 462 masl in Shimba Hills.

The Coastal Plain is a narrow belt, varying in width from 3 km to 20 km, and lies below 30 masl, extending 10 km inland. The extent of this feature, which is the coastline in Kwale County, is about 250 km.

The Foot Plateau, which is behind the Coastal Plain, lies at an altitude of between 60 and 135 masl. This zone is composed of Jurassic and sandy hills consisting of Magarini sands.

The Coastal Uplands, commonly known as Shimba Hills rises steeply from the foot plateau to an altitude of 150–462 masl. They are composed of the Mazeras sandstones. The hills include the Shimba Hills (420 masl), Tsimba (350 masl) and Dzombo (462 masl). This is an area of medium to high agricultural potential.

The Nyika Plateau, also referred to as the hinterland, rises gradually from about 180 masl to about 300 masl on the western boundary of the district. The region is underlain by basement rock system. The main economic activity here is livestock rearing.

3.1.4 Kilifi County

Kilifi County has four major topographical features. The first one is a narrow belt, which forms the coastal plain, varying in width from 3 km to 20 km. The coastal plain lies below 30 masl, with a few prominent peaks on the western boundary, including hills like Mwembetungu. Across this plain run several creeks resulting in the natural creation of marine swamps. These swamps are endowed with mangrove forests and present good conditions for potential growth of marine culture.

To the west of the coastal plain lies the Foot Plateau characterized by slightly undulating terrain. The plateau falls between 60 masl and 150 masl, and slopes towards the sea. A number of dry watercourses traverse the surface with underlying Jurassic sediments consisting of shells, sandstones and clays. In this zone, grassland and stunted vegetation prevails.

The coastal range falls beyond the Foot Plateau, and has a distinct low range of sandstone hills, ranging between 150 masl and 500 masl. These hills include Simba, Kiwava and Mwangea. The Nyika Plateau, which occupies about two-thirds of the area, rises from 100 masl to 340 masl and occupies the lower-lying ground along the western side. The plateau has less population than the hills, with a thin vegetation cover, shallow depressions and gently undulating terrain. This is an arid and semi-arid zone, which is suitable for ranching.

The drainage pattern for Kilifi County is formed by seasonal rivers, which drain into the Indian Ocean through the various creeks along the coastline. The rivers and streams are Nzovuni, Rare, Goshi and Wimbi.

In Malindi/Watamu and Magarini, there are two major physical features – the Indian Ocean and the Sabaki River. The Indian Ocean is a major feature in the county, bordering the county on the east. The coastline is 155 km, extending from Mida Creek in the south to Ungwana in the north. The ocean supports fisheries, tourism and the salt manufacturing industry.

The Sabaki River flows through the area in an easterly direction, and is the source of water for Malindi/Watamu, Kilifi and Mombasa. It enters the area at Chakama and flows for a distance of 150 km up to its estuary. The river affects human settlement, as it provides water for both humans and livestock, and also supports freshwater fisheries.

3.1.5 Lamu County

Lamu County is generally flat and lies between sea level and 50 masl, which makes some parts of the county flood during the rainy seasons. Other areas that are near the sea experience floods during high tides. Other important features in the county are rock outcrops, which occur on the islands of Manda and Kiwayuu, and sand dunes, which are found mostly in Lamu Island and parts of Mkokoni in Kiunga Division.

The main topographical features include the coastal plains, island plains, Dodori River plain and the sand dunes, while the most common rock formations are residual coral limestone and columns of sand.

The major catchments areas in the county are Dodori and the coastal zone; Duldul and the Lamu Bay drainage; and Tana River. Lake Kenyatta in Mpeketoni Division is the only permanent open water body in the county, although it has been known to dry out during exceptionally dry years. Several swamp sites exist throughout the county, with the main ones located in Dodori; BeleBele in Hindi; Ziwa la Magarini; Chomo Ndogo–Chomo Kuu along the Hindi-Bargoni Road; Luimshi and Kenza on Nairobi Ranch; and Kitumbini and Ziwa la Gorjji in Witu.

3.1.6 Taita Taveta County

Taita Taveta County is divided into three major topographical zones – the upper zone, the lower zone and the volcanic foothills. The upper zone is suitable for horticultural farming. Precious gemstones are found and mined in the lower plain, while the volcanic foothills, covering Taveta District, have potential for underground water and springs emanating from the Taita Hills and Mt. Kilimanjaro. The major rivers in the county are the Tsavo, Voi and Lumi rivers. Small springs and streams in the county include Njuguini, Sanite, Njokubwa Kitobo, Maji Wadeni, Humas Springs and Lemonya Springs.

There are two lakes – Lake Jipe and Lake Challa – both found in Taita Taveta Division. Lake Challa is a crater lake with little economic exploitation, while Lake Jipe is slightly exploited through small-scale irrigation and fishing. Both lakes are served by springs emanating from Mt. Kilimanjaro.

3.1.7 Tana River County

The Tana River is generally dry and drought-prone. Rainfall is erratic, with rainy seasons in March-May and October-December. Conflicts over access to water have occurred between farmers and nomadic peoples. Flooding is also a regular problem, caused by heavy rainfall in upstream areas of the Tana River.

Tana River is the largest river in Kenya, stretching over a total length of 1,000 km. It originates from Mt. Kenya and Aberdares in central Kenya, with a catchment area of about 95,000 km^2, which is approximately 17% of Kenya's land mass. For most of its course, the river flows across semi-arid and arid regions, while meandering through an alluvial floodplain, with width varying from 2 km in the middle river reaches to 42 km in the lower delta areas. The river forms the Tana Delta, which is the largest deltaic ecosystem in Kenya, stretching over 180,000 km^2 before entering into the Indian Ocean through Kipini.

3.2 Climate

3.2.1 General

The coastal areas of Kenya, lying within the equatorial latitudes, are characterized by a distinctive hot and humid climate. From December to early March, the coast is dominated by the North East Monsoon (Kazkazi), which is comparatively dry. During March and April, the monsoon winds blow east to southeast (Kuzi), which brings in air from the Indian Ocean and heavy rains. Between May and August, the South East Monsoon brings in more stable weather, more clouds and comparatively cooler temperatures. Mombasa and the main coastal towns Malindi Mombasa and Lamu generally have similar climatic patterns.

3.2.2 Precipitation

The region experiences two distinct rainy seasons – the long rains in April and May, and the short rains in October and November. The driest months are January and February. Total annual rainfall usually exceeds 1,000 mm.

Fig. 3-1 presents the precipitation patterns in the region.

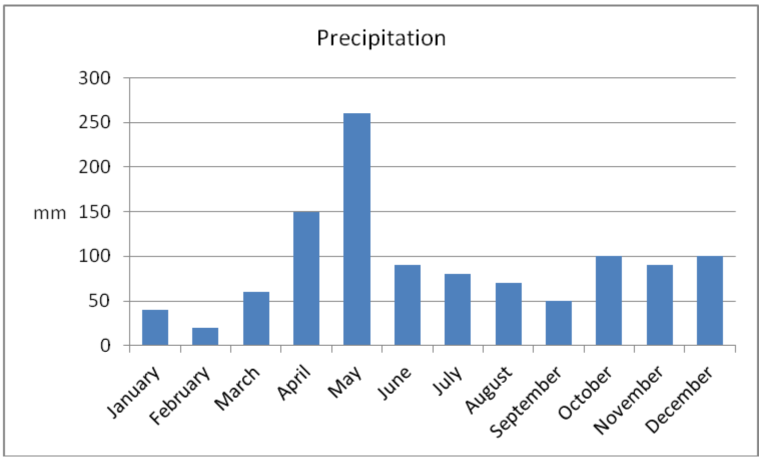


Fig. 3-1: Average monthly precipitation for the coastal region

3.2.3 Temperatures

The temperatures in Mombasa and most of the Coastal Region remain steadily hot for most of the year. Temperatures range between 26 °C during the cooler months of July to August (after the long rainy season) to 32 °C in the warmer months of January to March (following the short rainy season). Nighttimes temperatures are usually below 20 °C.

Fig. 3-2 presents the monthly minimum, maximum and average temperatures for the coastal region.

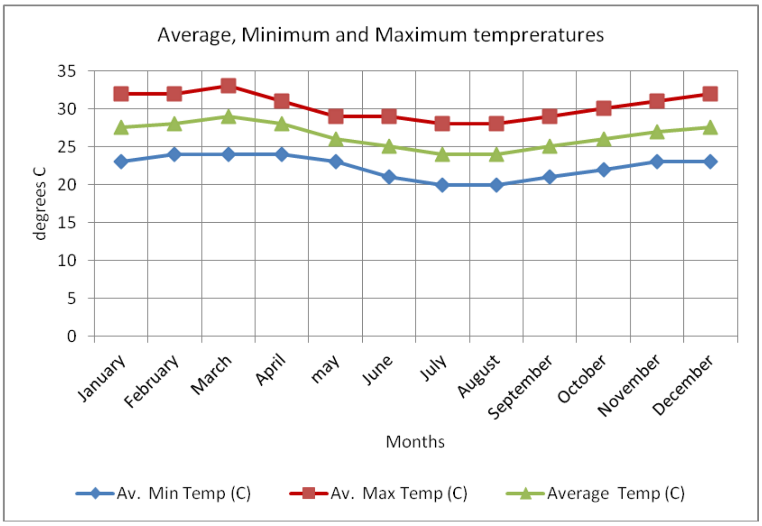


Fig. 3-2: Monthly temperature variation for the coastal region

3.2.4 Evaporation

Annual evaporation is around 1,800 mm. It is higher than the normal annual total rainfall, and creates a freshwater deficit during the dry seasons. Monthly evaporation levels vary between 138 mm in July to 221 mm in March.

3.2.5 Winds

Wind speeds are generally between levels 3 to 4 on the Beaufort scale (10–16 kph). Fig. 3-3 presents average monthly recorded wind speeds.

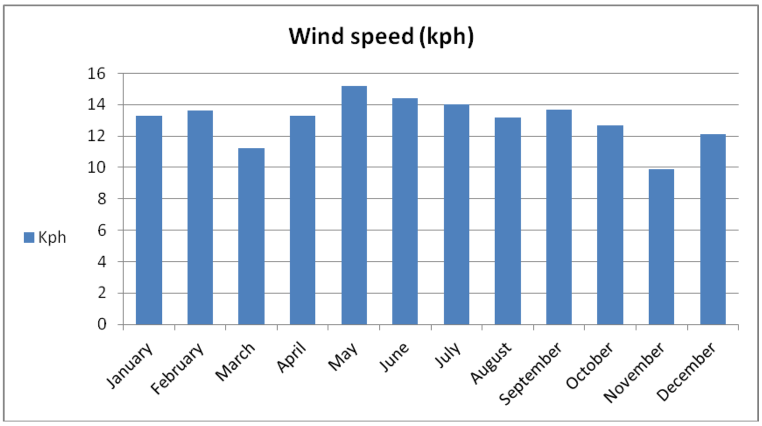


Fig. 3-3: Average monthly wind speed in Mombasa

3.3 Water Resources

3.3.1 General

Water supply in the Coast Province is based mostly on bulk water supply systems deriving their water from the Mzima and Marere springs and the Tiwi and Sabaki aquifers. These bulk water systems supply Mombasa, Kwale, Kilifi and Taita Taveta counties.

It should be noted that all four of the abovementioned major water sources are located outside of Mombasa County.

It is estimated that with the rise of the urban population, the extraction of water from the bulk systems will increase, thereby aggravating the already existing stress on bulk systems.

Smaller water supply schemes, which are unconnected to the bulk systems include:

- Taveta township and the surrounding villages, which are supplied from the Njoro Kubwa Springs
- The settlement of Lamu, which is supplied from the local Shella Aquifer
- Hola township, which abstracts water directly from the Tana River

In the following sections, a description of the various water resources available to the Coast Province will be presented. These will include surface water, springwater and groundwater resources.

In Chapter 7 below, the existing and potential water supply schemes will be described and enumerated.

3.3.2 Hydrogeological Background

3.3.2.1 Aquifers in the Region

The CWSB area of jurisdiction falls within two water catchment areas – Tana Catchment area (the main one) and Athi Catchment area. While they provide both recharge and major alluvial deposits, they are also sources of floods and silt.

There are a number of aquifers located in strategic geological areas that have great potential for full economic exploitation. The major aquifers and their underlying hydrogeological environments are indicated in Table 3-1.

These strategic geological localities of interest in the CWSB area of jurisdiction are backed up by the geology that features mainly major alluvial and coastal plain sediments; consolidated sedimentary formations; recent coastal calcareous formations; and extensive volcanic terrains as per the geological maps of Kenya presented in Volume III of the WSMP.

Table 3-1: Major Aquifers in the Region

Hydrogeological Environment	Lithology	Description and Source	Extent and Dimension	Examples
Unconsolidated / Semi-Consolidated Aquifers				
Major alluvial & coastal plain sediments	Gravel, sand, silt & clay	Unconsolidated material deposited by major rivers or in deltas & shallow seas; primary porosity & permeability usually high	Can be extensive in area and of significant thickness.	• Lamu sand dunes aquifer • Magarini Sands • Tiwi aquifer • Baricho aquifer
Consolidated Aquifers				
Consolidated sedimentary aquifers	Sandstone (mudstones & shales)	Marine/continental sediments, compacted & cemented to form consolidated rocks; consolidation generally increases	Form extensive beds of substantial thickness, but relatively poor aquifer	Coastal carboniferous to Jurassic sediments

Hydrogeological Environment	Lithology	Description and Source	Extent and Dimension	Examples
		with depth and age of deposition. Primary porosity is moderate to poor, secondary porosity from fractures of tectonic origin may be significant	characteristics. Often encountered in intercalated beds of limestones, sandstones, mudstones & siltstones.	
	Limestone	Deposited organic carbonates (shell fragments, reefs) in shallow seas. Solution enlargement of fractures may develop into karst features		Coastal carboniferous to Jurassic sediments
Recent coastal calcareous formations	Limestone & calcareous sand	Composed of coral limestones, sandy back-reef deposits, shellbanks, oolites & calcareous oozes; generally loosely cemented; porosity & permeability can be very high, especially if solution features are present	Limited area, often forming narrow aquifers that fringe coastline/form oceanic islands.	Southern coast limestones, Mombasa Crag, Nyali Hinterland. Vipingo, Lake Kenyatta/Hindi limestones
Extensive volcanic terrains	Lava, tuff & ash intercalations	Flows from flood-erupted, mainly basaltic lavas; or large explosive eruptions of ash. Primary porosity of thick flows is often poor but flow junctions can be very permeable where weathered (old land surfaces). Extremely variable potential; permeability tends to decrease with age	Flood basalts, extensive and thick. In Kenya these are very often intercalated with tuffs or other pyroclastics, these often being significant aquifers. May be faulted/fractured. Widespread.	The Kilimanjaro (Lake Challa) aquifer

3.3.2.2 Aquifer Classification

Based on the country's geological and hydrogeological formations, the Water Resources Management Authority (WRMA) has put in place an aquifer classification system to the country's groundwater resources to rank their importance in each of the major catchment areas and nationally (see Table 3-2). This is an essential tool for management strategy.

The classification system recognizes the value of aquifers in quantities and qualities terms as well as in terms of social and economic values the society attaches to groundwater resources. This recognition allows monitoring resources to be earmarked to those aquifers under stress (over-abstraction, and saline intrusion or pollution), in turn allowing development of strategies to reverse or slow down deterioration.

Table 3-2: Classification of Aquifers

Item	Class	Description	Example
1	Strategic aquifer	Aquifer used to supply significant amounts/ proportions of water in a given area and for which there are no available alternative resources, or where such resources would take time and money to develop; significant transboundary aquifers	Baricho, Tiwi, Lamu Island, Nairobi, Central Merti, Nakuru, Kabatini, Lake Naivasha
2	Major aquifer	High-yield aquifer systems with good quality water	Daua and Elgon volcanics
3	Minor aquifer	Moderate-yield aquifer systems with variable water quality	Mandera Jurassics
4	Poor aquifer	Low- to negligible-yield aquifer systems with moderate to poor water quality.	Basement system
5	Special aquifer	Aquifer systems designated as such by WRMA	Isinya in Kajiado Central
		Transboundary aquifer – high yields recently established	Lake Challa in Taveta

3.3.2.3 Transboundary Aquifers

The aquifer basins are limited to the south by Precambrian Basement Mountains. To the west, the aquifer system is bounded by the eastern slopes of Mount Meru. Towards the north, the basin is bounded by basement rocks and the Chyulu Hills. These hills consist of a series of recent volcanic cones, some only a few hundred years old, with lava flows that extend down to the lower ground of the Amboseli Basin. To the east are fresh Precambrian Basement rocks covered by expansive sisal estates.

3.3.3 Surface Water Resources

As mentioned earlier, the area of the Coast Province is located downstream of two catchment areas – Athi Catchment area and Tana Catchment area.

3.3.3.1 Athi Catchment Area

Rivers

- **Athi Sabaki River**
  - The Athi/Sabaki River Catchment area is 37,836 km^2 (see Fig. 3-4).
  - There are numerous hydrometric stations on the river – Stations 3F02, 3HA01, 3HA02, 3HA03, HA05, 3HA06, 3HA08, 3HA09, 3HA010, 3HA011, 3HA012 and 3HA013.
  - Data for Station 3F02, located about 200 km upstream of the confluence of the Sabaki and Tsavo rivers, is available for the 1952–1995 period, albeit with significant gaps. The other stations for which data are partly available are Station 3HA08 (1973–1982), and Station 3HA12 (1980–1987). For the rest of the stations, data are not available.

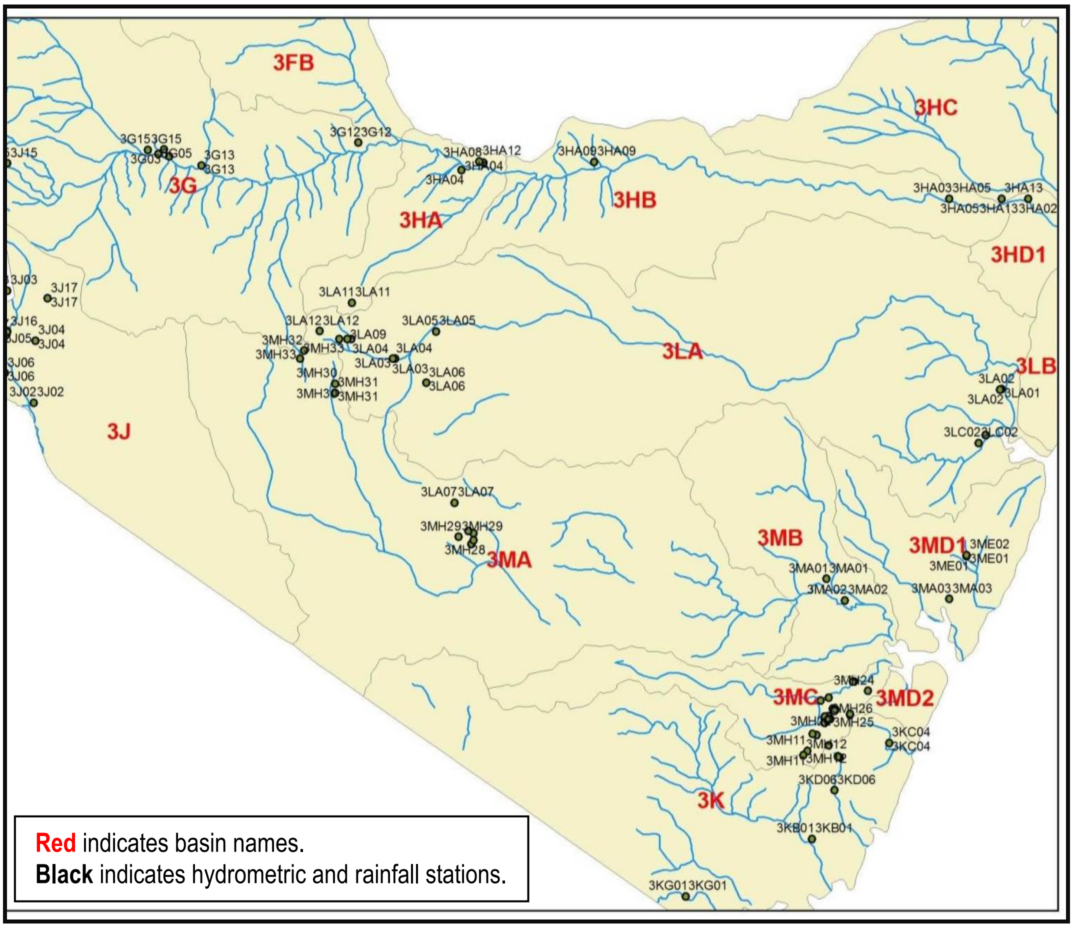
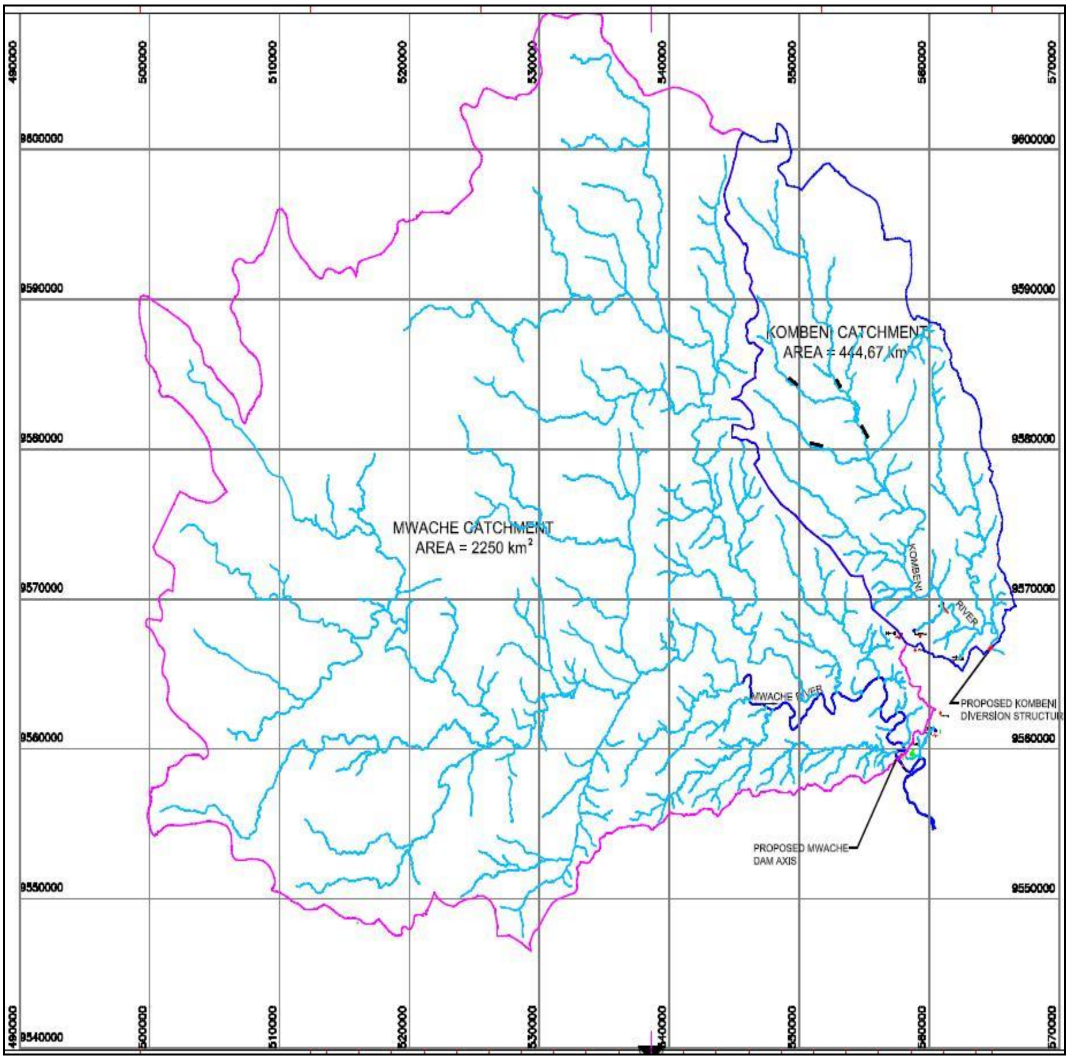


Fig. 3-4: River basins and hydrometric stations in Athi Catchment area

- **Mwache River / Kombeni River**
  - The Mwache River Basin covers an area of approximately 2,000 km^2 (see Fig. 3-5). Two hydrometric stations exist on the Mwache River – Station 3MA02 and Station 3MA03. Data for Station 3MA03 are partly available for the 1976–1990 period. The minimum and maximum annual flow (June to May) during this 14-year period were 75 MCM and 186 MCM, respectively. Data are not available for Station 3MA02.
  - Kombeni River (see Fig. 3-5) lies to the northeast of Mwache River, and is adjacent to it.
  - The Mwache and Kombeni rivers drain directly into the Indian Ocean. The two river systems are adjacent and drain areas of similar geographical features. Kombeni River drains to the Indian Ocean through Tudor Creek, which lies immediately to the north of Mombasa Island. Kombeni River Basin lies northeast of Mwache River Basin.



Source: Feasibility Study and Detailed Design of the Mwache Multipurpose Dam, 2011, CES/APEC

Fig. 3-5: Mwache and Kombeni catchments

- **Rare River**
  - The Rare River, located in Kilifi District, is a seasonal river with a catchment area of about 7,729 km^2.
  - The river has two hydrometric stations – Stations 3LA01 and 3LA02. Data are not available.

- **Pemba River**
  - The Pemba River is located in the east part of Shimba Hills on the southern part of the Coast Province, and drains to the Indian Ocean at Port Reitz.
  - The catchment area of Pemba River is about 637 km^2.
  - The river has only one hydrometric station – Station 3MH10. Data available for the river relate to the 1947–1978 period (with gaps corresponding to periods when data were not recorded).

- **Ramisi River / Mkanda River**
  - The Ramisi River, draining an area of about 1,610 km^2, has four hydrometric stations – Station 3KB01 on the river itself; Station 3KC01 on Ndoro, Station 3KC03 on Cheruka and Station 3KC04 on Mwachema tributaries. Data are available only for Station 3KB01 for the 1978–1991 period (with gaps).
  - The Mkanda River, which is a tributary of the Ramisi River, is a non-perennial stream. However, the river receives heavy rain from the Shimba Hills Forest. The river flows over a distance of about 15 km before draining to the saline Ramisi River, and does not have a hydrometric station.

- **Mwachema River**
  - The Mwachema River flows along the eastern side of the Shimba Hills.
  - The catchment area is about 2,000 km^2 and borders the catchments of the Pemba and Mkurumuji rivers.
  - The river drains into Mombasa Bay near Port Reitz, south of Mombasa Island.
  - The data available from the one hydrometric station – Station 3KC04 – relates to the 1978–1991 period (with gaps).

- **Lumi River**
  - The main water resource in Taita Taveta District, the Lumi River originates in the southern slopes of Mt. Kilimanjaro.
  - It drains an area of approximately 590 km^2 and drains into the swamps of Lake Jipe.
  - The Lumi River has five hydrometric stations – Stations 3J01, 3J04, 3J06, 3J07 and 3J15. Data are available only for Station 3J15 for the 1961–1994 period (with gaps).

- **Tsavo River**
  - The Tsavo River has its origin in the Mzima Springs area and flows eastward from the foothills of Mt. Kilimanajro, draining an area of 7,140 km^2.
  - It is the largest tributary of the Athi River.
  - The Tsavo River Basin has seven hydrometric stations on its several tributaries – Mzima, Nolturesh Springs, Ngong Naroko, Kitendeni, and Simeki streams. The hydrometric stations are Stations 3G02, 3G04, 3G05, 3G06, 3G012, 3G013 and 3G014.
  - Data are available for Stations 3G02 (for the 1949–1991 period), 3G04 (for the 1949–1997 period), 3G05 (for the 1951–1979 period) and 3G06 (for the 1951–1989 period). All data for these stations have gaps when no measurements were recorded.

- **Mkurumudzi River**
  - The Mkurumudzi River originates in the Shimba Hills, and drains a catchment area of about 200 km^2.
  - It has three hydrometric stations – Stations 3KD04, 3KD05 and 3KD05. However, data for the stations are not available.

- **Voi River**
  - The Voi River originates in the Taita Hills and drains into the Rare River.
  - It is a seasonal river with three hydrometric stations – Stations 3LA03, 3LA04 and 3LA05. Data are available at Station 3LA03 for the 1961–1981 period, and at Station 3LA05 for the 1969–1992 period (data for both stations having gaps).

- **Umba River**
  - The Umba River originates in Tanzania.
  - It has one hydrometric station on the Kenya side – Station 3KG01 – with data available spanning the 1966-1968 period.

Spring Water Resources

- **Mzima Springs**
  - The Mzima Springs Basin lies northwest of Mombasa, with the source located on the fringes of Chyulu Hills. The springs are located west of Chyulu Hills in Tsavo West National Park, at an elevation of ~680 masl.
  - The springs are connected to Mazeras Water Tanks by a pipeline totalling 215 km in length. Together with the 3 km source works tunnel, the distance along the pipeline to Mazeras Water Tanks is 218 km. Half of the pipeline is laid within the Tsavo National Park.
  - The springwater flows through three large pools (Hippo, Long and Chalk Beach Pools) before discharging to the Mzima River some 4 km upstream of its junction with the Tsavo River

- The three pools are in sequence and cascade one into the other (see Fig. 7-2 in Chapter 7 below). The difference in level between the Hippo Pool and the Chalk Beach Pool is about 3.7 m. The total length of the three pools is about 2 km; the longest is Long Pool, which is about 1.2 km.
- Water from Mzima Springs is measured in Station 3G03 before discharging into Tsavo River. Data for the 1951-1990 period are available for this station, with gaps for periods with no recorded data.
- From the flow-duration curve (see Fig. 3-6 below). it can be seen that maximum outflow measured was 5.9 m^3/s and minimum was 2.6 m^3/s ("100% exceedence flow"), with a mean value of 3.6 m^3/s. Significantly, flows of less than 3 m^3/s have been recorded only once in 4 years, and, even then, merely in a few days of each year.
- WRMA has recently applied through the World Bank for a study of the Chiulu Hills Aquifer in order to ascertain the sustainable yield of Mzima and other springs (Umani, Mtito Andei, Kiboko, Makindu, Mangelete and others) originates from the Chiulu Hills, in light of the climatic changes in the region. WRMA published a request for Expressions of Interest for this contract in August 2012. This study will play a major role in understanding the real potential of this source as well as other sources. The actual potential of Mzima Springs will be determined following this in-depth study.

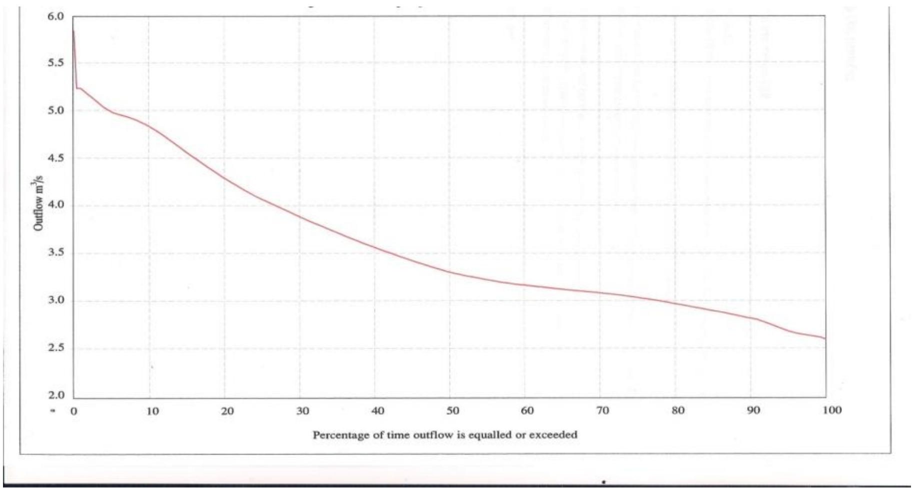


Fig. 3-6: Mzima Springs – flow-duration curve

- **Marere Springs**
  - Marere Springs, which are located in Kwale County southwest of Mombasa, originate from Shimba Hills Game Reserve and are the source of the oldest piped water supply to Mombasa. The resource is shared by both Kwale and Mombasa counties (see Fig. 3-7).
  - The sources of Marere Springs are three springs – Marere, Votia and Mwaluganje. The springs have seven hydrometric stations – Stations

3MH01, 3MH02, 3MH03, 3MH09, 3MH25, 3MH26 and 3MH14. Votia Spring, a tributary of Mwalolo River, has three hydrometric stations – Stations 3MH06, 3MH15 and 3MH16. Mwadabara and Mkomba streams/springs have three hydrometric stations – Stations 3MH17, 3MH08 and 3MH21, while Kitanzi Spring has one hydrometric station – Station 3MH23. Data are not available for any of these stations.

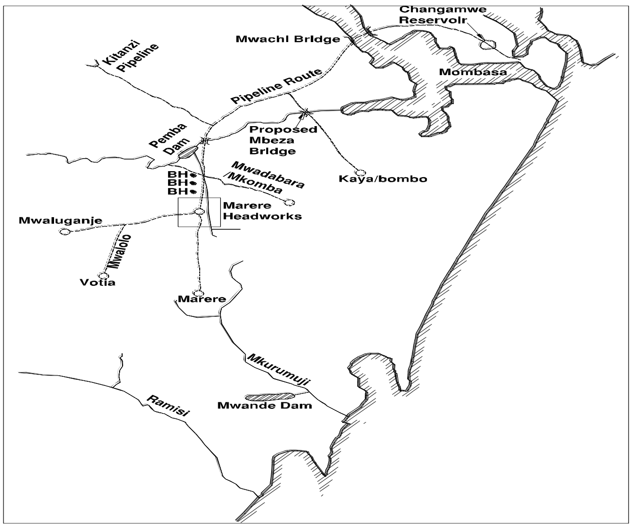


Fig. 3-7: Marere Springs and pipeline layout

Njoro Kubwa Springs

– Njoro Kubwa Springs emerge in a pool beside the right bank of the Lumi River, about 3 km southeast of Taveta township. The group of springs includes two other springs – Njoro Ndogo 1 and Njoro Ndogo – emerging 100 m upstream. Njoro Kubwa Springs are utilized for irrigation water supply to sisal estates. They have one hydrometric station, 3J05, whose data are not available.
– The estimated average flow according to previous studies (Sincat-Atkins, 1996) of the springs is 5.6 m^3/s and the safe yield is 4.5 m^3/s.

Lake Water Resources

- **Lake Jipe**
  – Lake Jipe is a shallow water body located on the Kenya-Tanzania border, with about one quarter of it lying within Tsavo West National Park. Lake Jipe is fed mainly by rainfall from the slopes of Mt. Kilimanjaro, perennially by runoff from the Lumi River and ephemerally by the Mbaro River to the south. The lake is drained by the Rovu River, which flows out from the northwestern corner of the lake. The Rovu River has one hydrometric station, 3J02, for which data are not available.

- **Lake Challa**
  - Lake Challa on the slopes of Mount Kilimanjaro is a freshwater lake shared by Kenya and Tanzania (the border passing through its middle). The source of water to the lake is assumed to be groundwater from the Kilimanjaro Aquifer.
  - Lake Challa occupies the site of an old volcanic caldera, The surface area of the lake is 4.21 km^2, the volume of water stored is in excess of 400 M m^3 and the crater is some 140 m deep. Water depth ranges from 85 to 91 m. Data are not available from the one hydrometric station, 3J03.

3.3.3.2 Tana Catchment Area

The Tana River Basin, with a catchment area of about 94,700 km^2, can be divided into three sections:

- Upper 9,520 km^2 area, consisting of streams from Mt. Kenya and the Aberdares
- Middle 15,480 km^2 area
- Lower Tana 69,700 km^2 area

While the WSMP is based on the Lower Tana area, it is affected by activities in the entire catchment. The Tana River has several hydrometric stations, among them 4G01 (Garissa), 4G02 (just upstream of Garsen) and 4G04 (just upstream of Hola). Station 4G01 has data for the 1941–1994 period, 4G02 for the 1950–1998 period and 4G04 for the 1962–1993 period, all displaying some gaps corresponding to periods when data were not recorded.

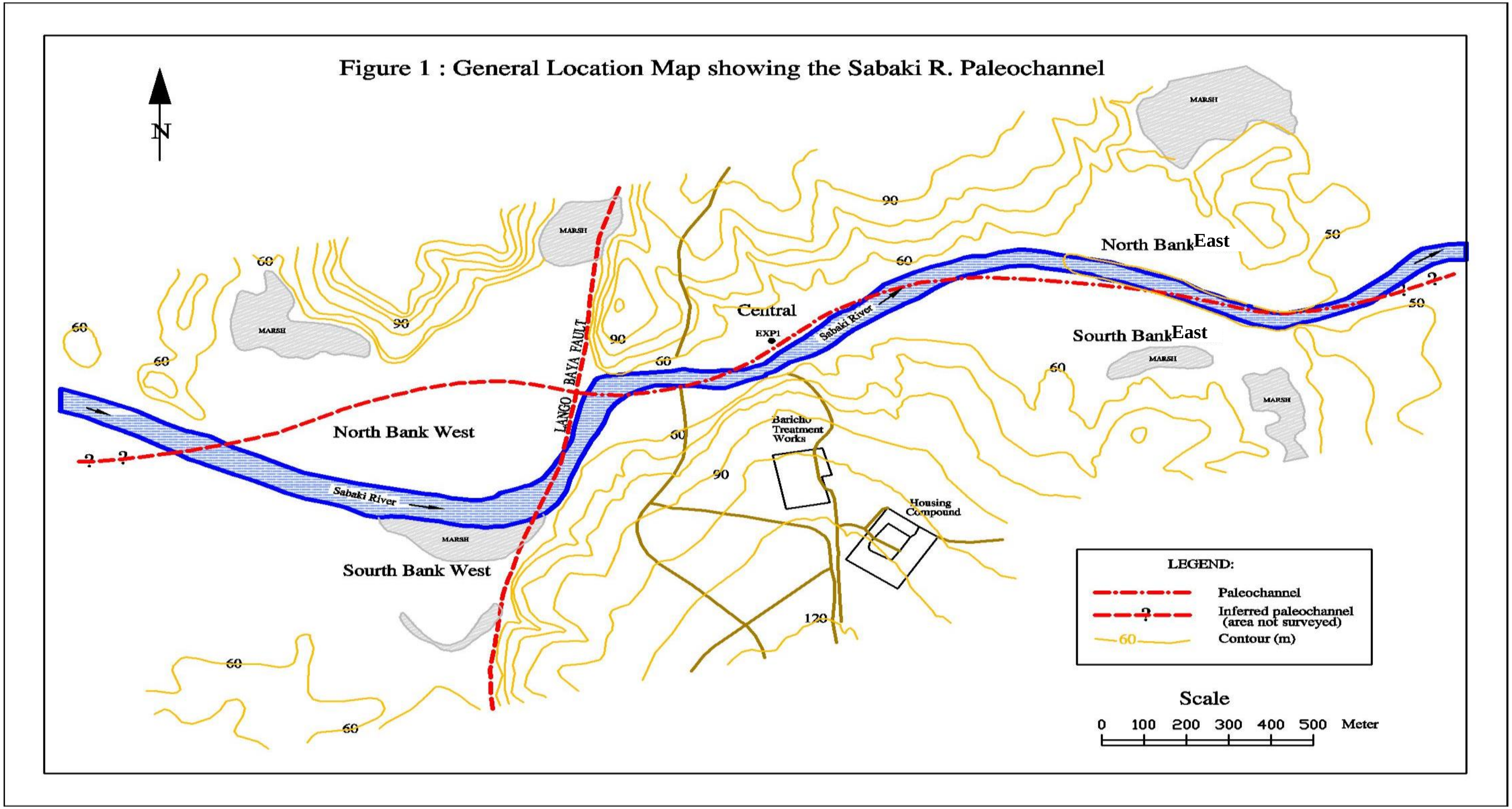
Tana River originates in the Aberdare Mountains area and is the longest river in Kenya. According to a current study, the lowest measured flow (100% exceedence) in the past 60 years is 8.5 m^3/s, and the sustainable flow is 43 m^3/s (95% exceedence).

In addition to the Tana River itself, there are several seasonal rivers in the area, found in the area west of the Tana River, in the northeastern part of the delta. These rivers, popularly known as "lagas", flow in a west-east direction, draining into the Tana River and eventually into the Indian Ocean.

3.3.4 Groundwater Resources

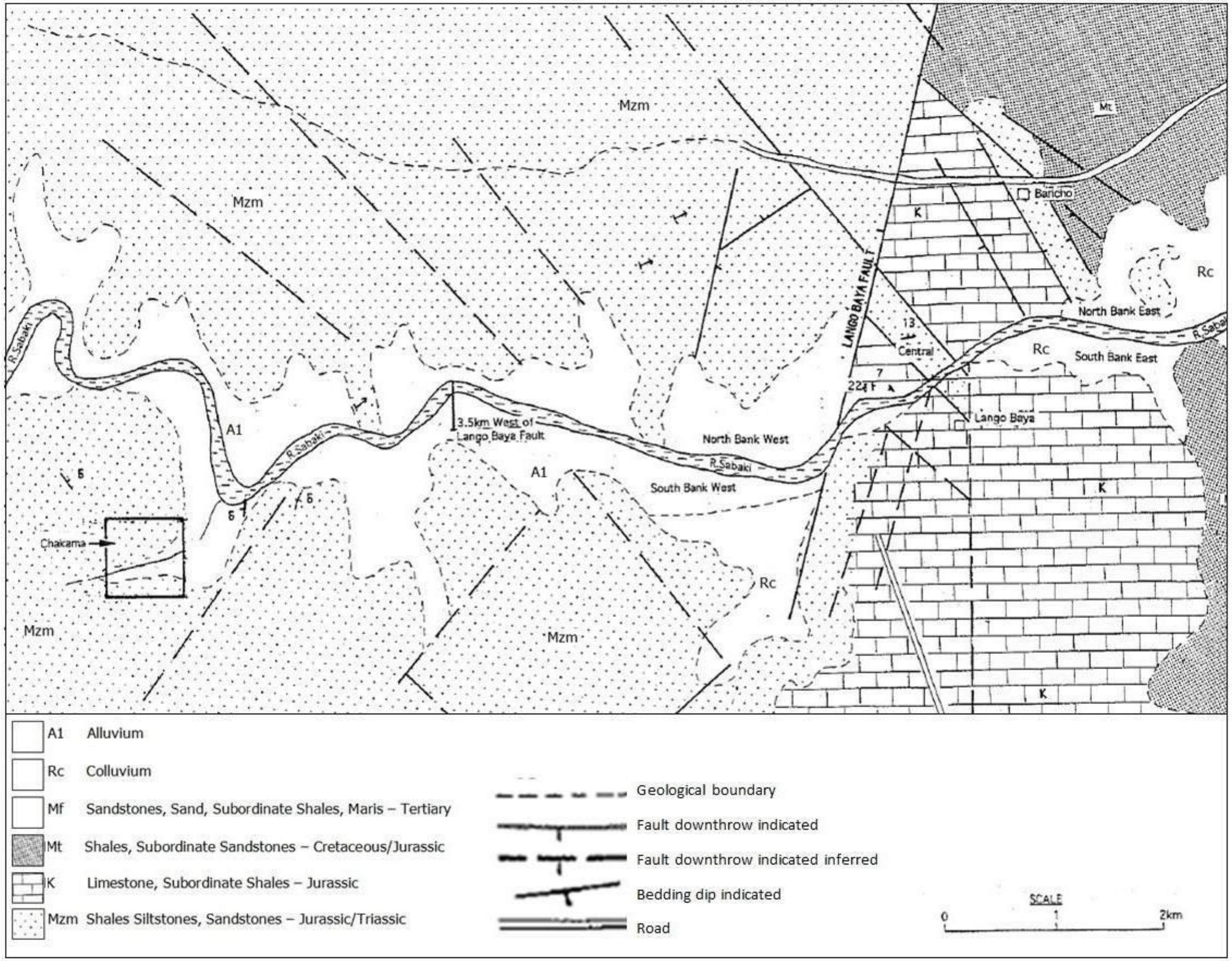
3.3.4.1 Aquifers

- **Sabaki Aquifer**
  - Studies conducted along the Sabaki River in Kilifi County have pointed to the enormous groundwater potential in the buried Sabaki River palaeochannel (see Fig. 3-8), locally known as the Sabaki Aquifer. This ~50 m deep alluvial aquifer, composed of sands, sandstones grits and gravels intercalated with silts and clay, is recharged mainly by the Sabaki River through permeable horizons within the river flood plain. Yields of 1,000 m/h and aquifer transmissivity of 7,000 m^2/d obtained from production boreholes drilled along the Sabaki River Banks have proven this aquifer to be an important groundwater source for the Coast Province.
  - Seismic and resistivity sounding surveys indicated that the palaeochannel extends over 50 km west of Baricho waterworks (see Fig. 3-9). However, accurate delineation of the Sabaki Aquifer depth-to-bedrock was obtained only in the South Bank East Area of Sabaki River.
  - The Baricho Wellfield consists of eight production boreholes, which were drilled in the South Bank East Area of Sabaki River in 1995, and is shared by Mombasa and Kilifi counties.
  - The yield of Baricho Wellfield is estimated to be a maximum of 175,000 m^3/d. This proposed abstraction from Baricho Wellfield could be sustained even at the minimum flow in the Sabaki River of 2.6 m^3/s, which occurs in the month of January and is exceeded 99.9% of the time.



Source: Gauff JBG Ingenieure, Seismic and Resistivity Survey, September 1995

Fig. 3-8: General location map of the area showing the palaeochannel



Source: Seismic & Resistivity Survey, H. P. Gauff, 1993

Fig. 3-9: Map showing the geology of the area near Baricho

- **Tiwi Aquifer**
  - Tiwi Aquifer (known also as the Coastal Aquifer), located in Kwale County some 60 km south of Mombasa. The aquifer is estimated to be ~40 km in length and some 8–15 km wide (see Fig. 3-10). However, the most permeable unit with a significant aquifer thickness is in the 5–7 km adjacent to the shore. The aquifer narrows inland (see Fig. 3-11).

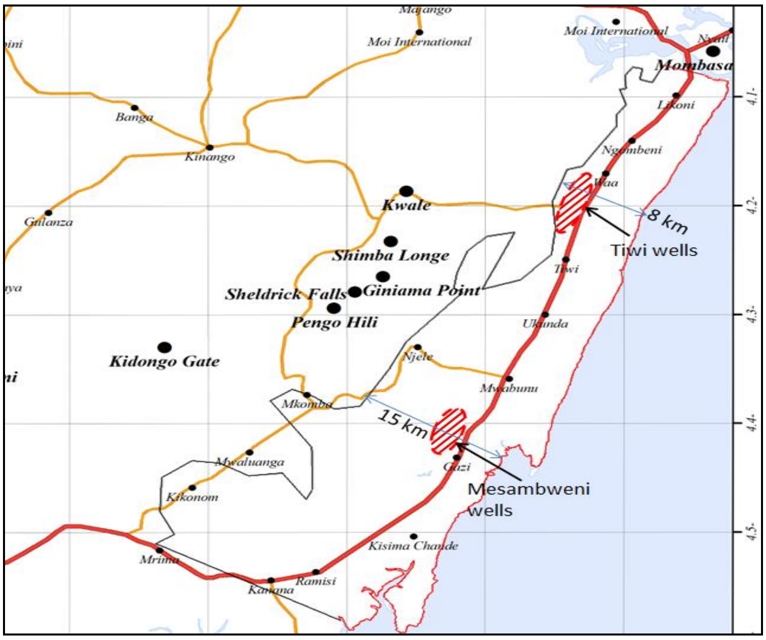


Fig. 3-10: Location map of Tiwi and Msambweni wellfields

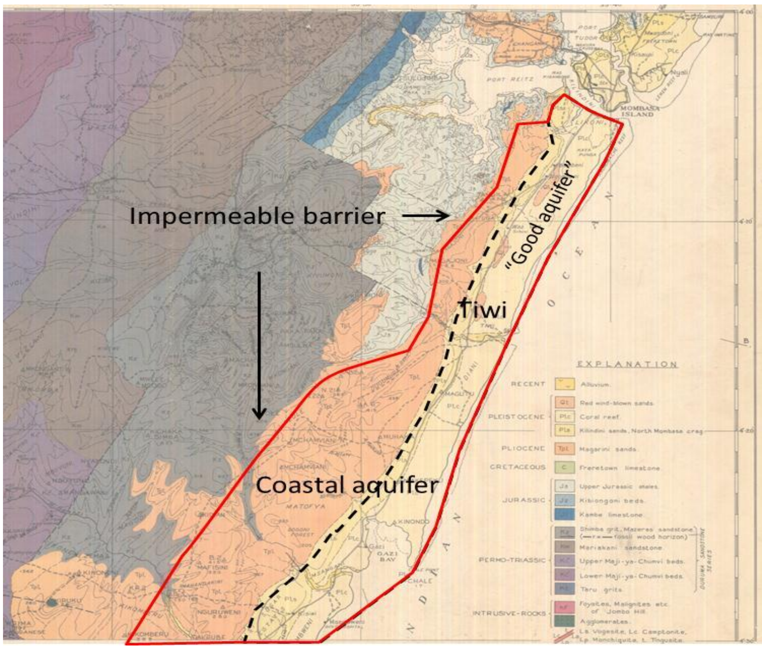


Fig. 3-11: Location map of Coastal Aquifer

– The Tiwi aquiferous complex (see Fig. 3-12) comprises sediments, reefal (coral) limestone and Sands. This complex, which is unconsolidated, is known to exhibit the best aquifer properties and is the dominant one in the Tiwi Aquifer, although only about 70–90 m thick. Some 20 km south of the Tiwi Aquifer, the southern part of the Coastal Aquifer is known as the Msambweni Aquifer.Two main boreholes are currently in operation. Evidence regarding water quality (no actual measurments were done) claim the water to be of good quality.

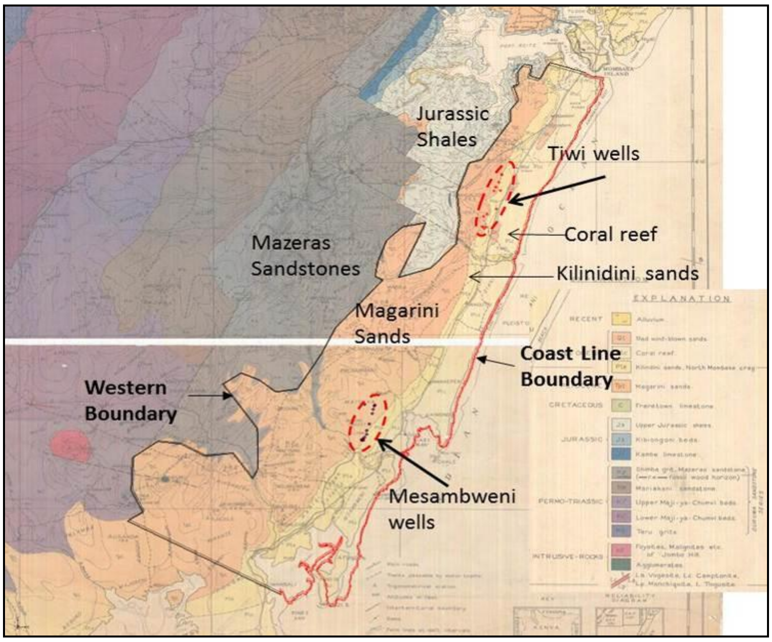


Fig. 3-12: Geology of Tiwi Aquifer

– The resource is shared by both Kwale and Mombasa counties. Some of the water is diverted to the Tiwi area and Diani Beach, while the rest flows to Mombasa. The available supply to Mombasa has been declining over time due to the rise in demand in Kwale County, mostly because of the rapid development of the hotel industry in the Diani and Tiwi beach areas.

– Tiwi Aquifer, which has a total of 18 boreholes, has two wellfields – north and south. They are known as Kaya Bombo in the north and Magodzoni in the south. There are 13 old boreholes drilled in the 1970s. About 400 shallow boreholes, equipped with jack-pumps, have been constructed in the area, 340 of which are considered to be operative at present, providing access to potable water for about 40% of the local population (numbering 300,000).

– Not much data are available for the Msambweni Aquifer. Two deep (100–110 m) production wells were drilled and tested. It appears that they can provide a sustainable yield of 120 and 60 m^3/h. All other wells are shallow piezometers, most of them driiled and operated by locals.

- The Coastal Aquifer in the Tiwi area is narrower (7–8 km wide) than the width in the Msambweni area (~15 km wide). Therefore, the recharge evaluated for the Msambweni area is about 60,000 m^3/d, while for the Tiwi area recharge was assumed to be about 30,000 m^3/d.
- Altough the southern part of the aquifer is wider and has a better replenishment then the northern part, fewer wells abstract water from the Msembweni area, leaving higher potentail for future development of this source. The water stress in the southern area is severe as the hotel industry is growing and its water demand keeps increasing, while at the same time, there has been no additional water production.
- A groundwater model for the Tiwi Aquifer was created and computed. Its objective is to quantify the future water potential of the aquifer, while maintaiing the aquifer boundary far from the seawater, thereby preventing the intrusion of saltwater into the water body.
- The conclusions from the groundwater model runs are:
  - The analysis indicates that additional wellfields may be developed south of Msambweni.
  - The groundwater potential determined for the Tiwi Aquifer is about 20,000 m^3/d (7.5 MCM). The groundwater potential determined for the Msambweni Aquifer is about 30,000 m^3/d (11 MCM).
  - Analysis of the groundwater flow regime in the Coastal Aquifer indicates that the groundwater potential (safe yield) of this region may be greater than current abstraction. However, careful attention should be given to the possible risk of seawater intrusion at high wellfield abstractions.
- Major data gaps were identified, and a plan of required actions and further investigation was outlined. It is emphasized that the required actions are mandatory before any new wellfield is developed, or any significant changes in pumping policy are decided upon. The most critical parts of the required actions include:
  - Drilling of deep exploratory/monitoring wells for detecting the seawater-freshwater interface location and depth
  - Performance of an accurate well survey
  - Performance of short- and long-term water level measurements
  - Performance of short- and long-term water quality measurements
  - Survey of pollution sources
- The investigation of the aquifer nature and future development of the Msambwebi Aquifer will increase availability of water in the region. However, the huge increase in water demand will not be balanced only by local resources. Additional water from Mwache Dam will be supplied to the southern area, and will enhance southern region supply.

- **Hindi Magogoni Aquifer**
  - Five boreholes have been drilled in the Hindi Magogoni Aquifer. These boreholes jointly produce 14 m^3/h for local consumers, without negatively affecting the aquifer or the environment.

– The aquifer is about 12 km long and 2 km wide. The thickness of the aquifer is about 5–15 m. Saltwater interface was detected in the aquifer at a depth of some 20 m.
– Considering that the estimated natural recharge of the aquifer is about 1.6 MCM/y,[1] there is room for studious and cautious drilling of a considerable number of additional boreholes in this aquifer.

- **Shella Aquifer**
  – The Shella Aquifer, located within the Lamu Island (see Fig. 3-13), presently supplies about 1,350 m^3/d. The wellfield consists of some 30 wells with a total approximate capacity of 1,800 m^3/d.
  – The Shella Aquifer is the only source of water for Lamu Island/Port. The Shella Aquifer is apparently the only fresh water source in the area as groundwater in other parts of the area are mostly saline, leaving Shella Aquifer as the only potential source for good quality water.. The Shella boreholes serve Lamu town, Gadeni, Manda Island and Shella village. Water rationing is frequent at Lamu, as demand exceeds the daily supply.

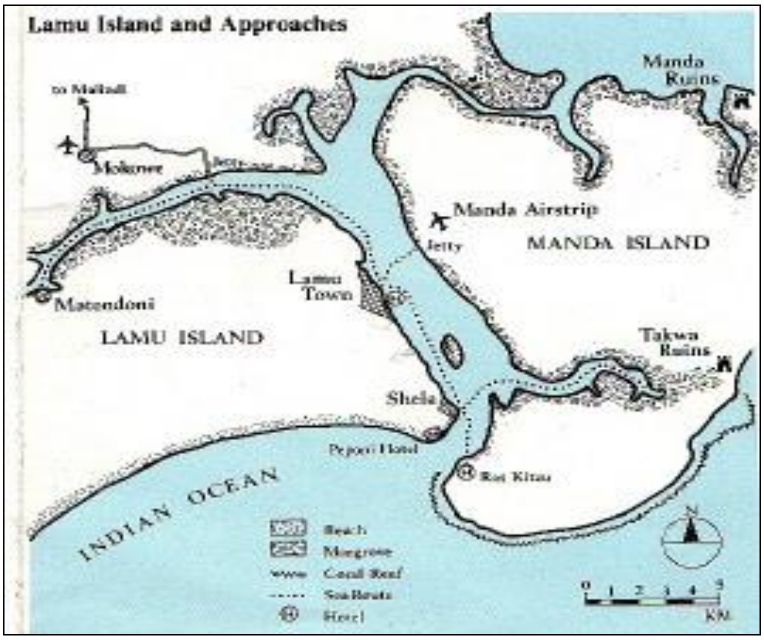


Fig. 3-13: Shella Aquifer location map

- **Mpeketoni Aquifer**
  – Five boreholes have been sunk into the Mpeketoni Aquifer. The boreholes contain hydrogen sulphide, which is easily treated by aeration. However, the water is also contaminated with *e coli* and general coliforms, which should be treated as well. The source of recharge to this aquifer is Lake Kenyatta It is estimated that the amount of water that can be withdrawn from the aquifer is 1,000 m^3/d.

[1] Final Completion Report, C. M. Gicheru, September 2000

  - Lake Kenyatta water level has been slowly declining. However, it is estimated that, given the current intensity of pumpage, it is not likely to reach critical levels up to the year 2035, so that supply of water from the present boreholes is reliable.

- **Witu Aquifer**
  - Three sub-aquifers exist in Witu Aquifer – Munuji, Witu East and Witu North. Their estimated safe yields are 475 m^3/d, 1,900 m^3/d, and 320 m^3/d, respectively.
  - These aquifers are currently not used, except for Witu East, which has only two boreholes in operation to supply local consumers.
  - There is a need to drill into these sub-aquifers and perform pumping tests in order to ascertain the reliability of the above estimated figures.

- **Garsen Aquifer**
  - Three boreholes have been sunk next to Tana River into the Garsen Aquifer. The amount of 50 m^3/h, which is pumped from the boreholes, is used for water supply to Garsen town. Production in these boreholes is limited due to electricity failures.
  - Due to its remote location and its estimated relative low production potential, the practicability of connecting this water source to any bulk water supply in the region is assumed to be limited.

3.3.4.2 Deep Groundwater

Data from deep oil and gas exploration wells in Kenya were reviewed in order to assess whether potential deep groundwater exists (see Fig. 3-14). This analysis is based on the assumption that the Coast Province in Kenya may share the same hydrogeological characteristics with the Tanzania Coast area (the area of Dar es Salaam), where a deep and highly productive aquifer of immense volume and excellent water quality was recently discovered and investigated.

General and detailed geological information was collected from the data reviewed for 13 of the deep wells in Kenya. Information included stratigraphy, top and base of the Neogene sequence, thickness and depth to the Neogene sequence, etc.

A cross-section along four deep wells located along the Tana River from inland to the coast adjacent to the Lamu area revealed a Neogene sequence of 400–500 m thickness inland, increasing to 1,000–1,500 m close to the coastline. The depth to this potential aquifer varies from several metres (about 5–30 m) near Tana River to 150–200 m in other locations.

The lateral continuity of the Neogenic aquifer was mapped and related to the location of the Lamu Rift Basin. The potential aquifer units extend into the Lamu area to the north, and narrow southwards, towards Mombasa.

Potential recharge of freshwater to this aquifer should be thoroughly investigated. It is possible that locations in the vicinity of the Tana River play a major role in aquifer replenishment in this area.

Further investigation of this potential aquifer is recommended by drilling deep wells to a depth of about 600 m. Three alternative locations are proposed – two in the Lamu area and one along the Tana River (see Fig. 3-14). The Mombasa area appears to be less promising regarding the existence of a deep aquifer due to the limited presence of Neogenic formations south of Malindi/Watamu.

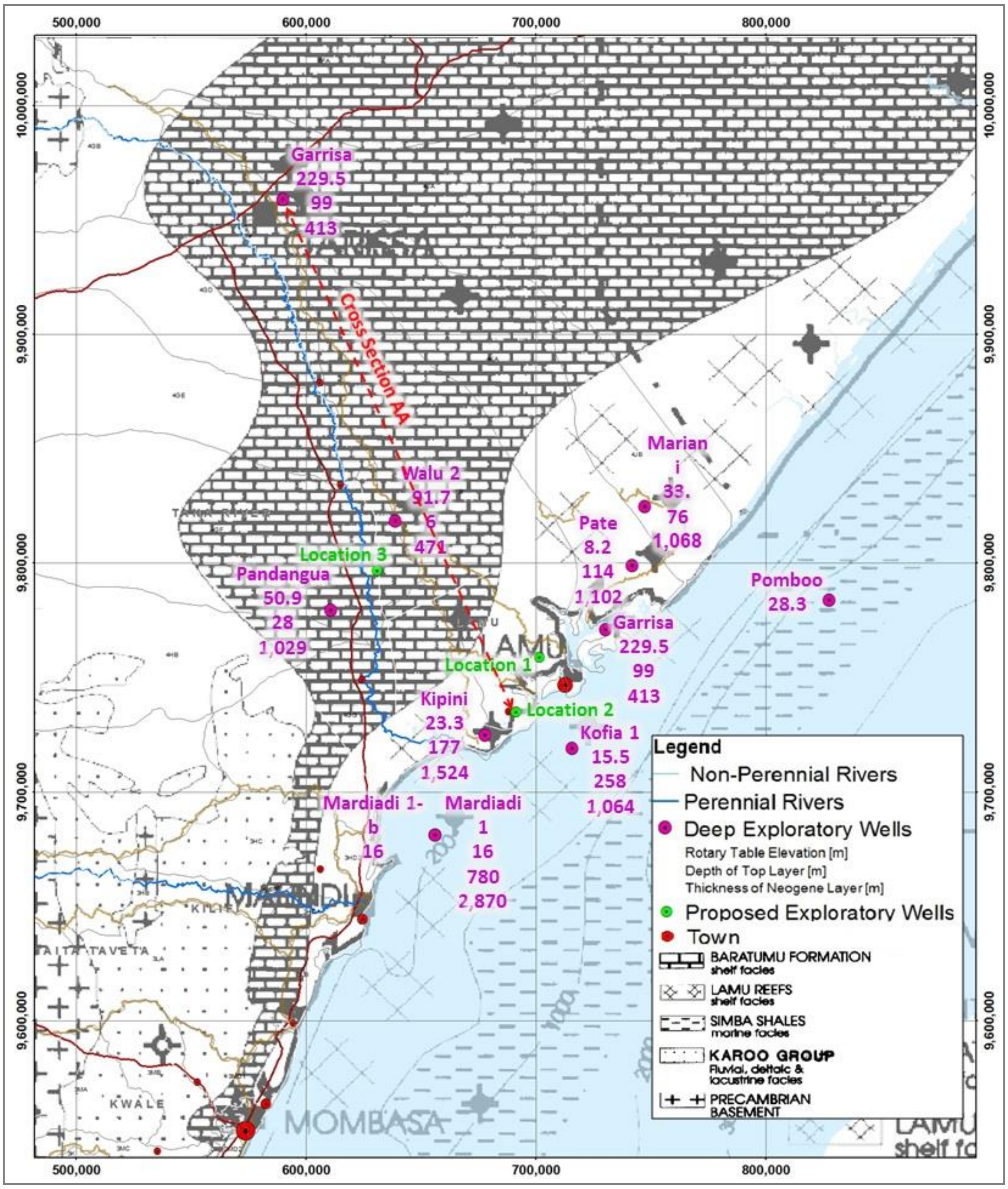


Fig. 3-14: Location map of deep exploration wells

In view of the future water demand in the Lamu region, the existence of water potential in the Neogenic layer presents an opportunity not to be missed. Inherent in Lamu Port and the future project of the corridor to the Ethiopian border is a massive demand for water, in a semi-arid zone where water is scare. Desalinated water may be found too expensive to afford by localities. Thus, the Neogenic water potential must be further investigated from the geological viewpoint and by adding exploratory drills to clarify the nature of this water source.

3.3.5 Other Potential Water Sources

3.3.5.1 Desalination

Desalinated seawater can make up the deficit of natural water resources and meet the entire potable water demand, or part of the demand of the Coast Province, irrespective of the availability of other natural water sources. Furthermore, seawater desalination plants can be erected near demand centres, eliminating the need for long pipelines.

Major constraints of desalination are environmental impacts and high energy cost:

- The Kenyan coastline is rich in marine life and marine reserves, and the large number of eco-sensitive areas allows very few potential locations for desalination plants.
- Energy costs in Kenya depend on rainfall, as most of the energy production in the country is based on hydropower.

For the economic analysis, the variance in electricity tariffs was considered for calculation of the real production cost. (See Chapter 10 below.)

A study undertaken of the desalination option showed that the unit cost of desalination in Kenya is relatively high. The estimated cost for 1 m^3 at the gate of the desalination plant will be around US$ 1.45, comprising the following:

- Electricity cost: 0.88 US$/$m^3$
- O&M costs: 0.17 US$/$m^3$
- Investment costs: 0.40 US$/$m^3$

In addition to these relatively high costs, seawater desalination involves the following severe environmental impacts:

- The plant must be erected near the coast, possibly preventing other uses of the same coastline.
- The seawater intake structure could have an adverse effect on the coral reef.
- The resultant brine effluent from the desalination plant can affect marine life.
- The relatively high energy consumption will result in increased air pollution.

Energy costs, energy availability and the wide range of environmental aspects can constitute serious obstacles and need to be carefully investigated in the future. At this point, weighing the pros and cons of desalination as a source of water to the Coast Province, the Consultant does not recommend this source of water as a part of the overall solution to the water supply to the Coast Province.

3.3.5.2 Recycled Water

There is no doubt that recycling of wastewater has many advantages, such as the following:

- Improves sustainability and water security
- Reduces stress on environmental sources.
- Residual organic matter in recycled water is beneficial for agricultural production.
- Provides opportunities where they are currently lacking.

In Mombasa and some other neighbouring towns, utilization of recycled water could be used only for gardening within the urban/domestic sector (in addition to agriculture in the rural areas). This will have a positive effect on per capita water demand, reducing the total urban water demand.

However, wastewater recycling must overcome traditional perceptions and gain community acceptance, and, most important, requires dual infrastructure and piping systems, with the resultant capital investment. Therefore, a prerequisite for any recycling efforts should be an efficiently operating gravity wastewater system, a treatment plant and a recycling plant, none of which will be in operation during Phase I of the WSMP. Consequently, initiation, design and establishment of a recycling system in CWSB's area of jurisdiction can be considered only followinf Phase II of the WSMP.

It is the Consultant's recommendation that defining the principles of recycling should be included in the Sewage Master Plan for the Coast Province.

3.3.5.3 Rainwater Harvesting

Promotion and construction of rainfall harvesting technology is deemed suitable in the coastal areas and recommended as a means of augmenting the amount of water available. Advantages of rainwater harvesting include the following:

- Construction of a rooftop rainwater catchment system is simple, for which local residents can easily be trained, minimizing its cost.
- The technology is flexible: poor households can start with a single small tank and add more tanks when they can afford them.

- Running costs are low.
- Rainwater harvesting could provide a source of water at the point where it is needed. It is owner-operated and -managed.
- It can provide an essential reserve in emergencies and/or during breakdown of public water supply systems.

However, it should be remembered that the success of rainfall harvesting depends upon the frequency and amount of rainfall; therefore, it is not a dependable water source in times of dry weather or prolonged drought. In addition, rainwater harvesting involves the following severe environmental impacts:

- Storing water for long periods will cause deterioration in its quality, thus limiting its uses.
- Private consumption of this water is difficult to control and regulate, and may result in inappropriate use of water.
- Cisterns and storage tanks can be unsafe for small children if proper protection is not provided.
- Possible contamination of water may result if the tanks are not protected.
- Cisterns can be a breeding ground for mosquitoes.

CWSB's area of jurisdiction has potential for construction and operation of rooftop harvesting systems. Precipitation averages 800–1,200 mm/y (excluding Lamu) and most rural water supply systems are based on community water kiosks. Promoting and construction of the technology is deemed suitable and recommended as a means of augmenting the amount of water available.

In public buildings (offices, schools, clinics, etc.) water use can be controlled; hence, it is recommended to consider government support. This water will serve the needs of flushing and gardening, resulting in a decrease in the use of potable water for those facilities.

In rural households, under appropriate guidance and training in the correct use and maintenance of the facilities, rooftop harvesting can be viable and effective.

Then again, per capita use of this source is estimated to be a small percentage of the total demand. Hence, it will not affect significantly the need for future infrastructure design derived from the regional water balance.

It should be borne in mind that the possibility of controlling the use of water collected in rooftop tanks and its quality is very limited. Water will inevitably be used also for drinking without means of quality control, raising the probability of water-related illnesses. Only a backing in the form of appropriate education programs will lead to efficient use of this water without affecting the health of the population.

3.4 Demographics and Economic Activities

Mombasa County, the second most populated county in the Coast Province, is a cosmopolitan region in Kenya, having a population comprising Africans, Asians, Arabs and Europeans. Of this, Africans are the largest group, consisting of both indigenous and migrant groups. Among locals, Mijikenda's are the largest ethnic group that is indigenous in the region. Also native to the region is the Swahili group, from whom the Kiswahili language originated.

To learn more about the demographics and economic activities in the Coast province, a socioeconomic survey was conducted, with the participation of over 600 respondents.

The areas covered by the survey included the following:

- Gender
- Gender of head of household
- Number of persons per household
- Marital status
- Education level
- Employment
- Household income
- Household expenditure
- Sources and uses of water
- Monthly consumption of water
- Volumes of water billed/purchased and amounts paid
- Willingness to pay for private connection and consumption
- Service provision by WSPs, etc.

Details of the socioeconomic survey and results are presented in Chapter 5 below.

4. Methodologies Employed in the WSMP

4.1 General

This chapter introduces the methodologies employed in the different studies carried out during the execution of the WSMP. In the following sections, the findings, conclusions and integration of the various studies will be presented.

4.2 Socioeconomic Survey

The main objective of the socioeconomic survey was to assess the socioeconomic situation with regards to the water supply situation in the project area and to probe the possible socio-cultural effects and the economic implications of the project.

The following specific objectives were set to be accomplished by the study:

- To review social setups, family sizes, and the current water supply situation
- To analyze and review the various socioeconomic benefits that may be derived from the project
- To determine willingness and ability to pay for water and their expected consumption rates

The study was conducted using four broad methodologies:

- **Direct observation** – The Consultant observed, measured, recorded and monitored all relevant aspects including sources of water and their uses, water supply systems, sanitation infrastructure and operation, economic activities and housing patterns.
- **Review of available data and information** – Data and information from various institutions were analyzed to obtain an overview of the existing situation in the area. These included production volumes, water demand, water supply coverage, and consumption volumes. They were obtained from:
  - Mombasa Water and Sewerage Company, MOWASCO
  - Malindi Water and Sewerage Company, MAWASCO
  - Lamu Water and Sewerage Company, LAWASCO
  - Kilifi-Mariakani Water and Sewerage Company, KIMAWASCO
  - Kwale Water and Sewerage Company, KWAWASCO
  - TAVEVO Water and Sewerage Company, TAVEVO
  - Tana Water and Sewerage Company, TAWASCO
- **Questionnaires** – The Consultant administered questionnaires to randomly selected household units, institutions and kiosks (water vendors) within the project area as the primary consumers. Households were selected from three major levels: higher income, middle income and low income. The institutions

sampled included industries, hotels, schools, mosques and hospitals, these were categorized as major consumers.

- **Interviews of key individuals** – Interviews were used primarily in order to gain an understanding of the underlying reasons and motivations for people's attitudes, preferences or behaviour. This method is based on obtaining information, over time, from the community residents who understand the societal setup and needs/demands in order of priority. The persons selected to be the key informants must therefore have a broad knowledge of the society, its people, services and development.

4.3 Water Demand Forecast – Methodology

4.3.1 Population Projection

The population growth rates and long-term projections were determined based on the population censuses of the years 1969, 1979, 1989, 1999 and 2009.

The intercensal population growth rates for 1969–2009 were estimated at the level of sub-location (sub-location being the smallest population cluster), location, division and district.

A population projection for the entire Coast Province was performed by calculating each district population separately, and then adding them. Out of the district projections, projections for the 20 main townships and urban centres were performed and used as the basis for the WSMP demand projections.

It should be emphasized that over a time span of 40 years between the first and last population censuses, the geographical and administrative subdivisions of the Coast Province have changed, as have the boundaries of the administrative units. Sub-locations have been moved from one district to another, while the number of districts has also changed. In addition, several new sub-locations/villages have been created during the above period.

The consequences of these changes are inconsistencies in the data at specific locations over time. While the 1999 and 2009 data are generally consistent, the data from the three other census reports, particularly the first two, show inconsistencies that result in negative figures and division by zero when estimating growth rates between two censuses.

Nonetheless, the total population has been maintained as per the censuses at the level of divisions and districts, giving here more significant growth rate figures. In other words, at the level of divisions and districts, the calculated growth rate per period shows positive figures and enables the use of those numbers as a key growth rate for the projection. Thus, the overall regional growth rates in the censuses are consistent, as the boundaries of the regions have remained practically unchanged during all of the censuses.

Because of the inconsistencies in the data, the Consultant has adopted a special procedure, which is described below, to analyze and derive the growth rates for the Coast Province population projections.

There are two main approaches to performing population projections for an area with a large population (i.e., country/state/province):

- **Bottom-up (from the part up to the whole)** – A projection is performed for each settlement/city (primary level) that is included in the large area, and summarized for each of the required clusters and for the entire area.
- **Top-down (from the whole down to the part)** – A projection is first performed for the entire area population, and the population projection for each settlement or cluster of settlements is calculated as a portion/percentile of the larger area's population projection.

Experience from other WSMP projects shows that projections for communities with large population are usually more accurate than projection for communities with small population; this is mainly due to the absence of internal immigration dynamics in the smaller communities.

Therefore, a top-down approach was chosen, i.e., a population projection for the entire Coast Province was performed first, and was subsequently used for the population projection for each district. The district projections were then used to calculate the projections for each division, and so on, down to the main townships and urban centres.

It should be noted that according to the requirement of the ToR and the clarification letter defining the scope of the WSMP, the water balance, and consequently the corresponding population and demand projection, will be evaluated for only the 20 main townships and urban centres.

Within the six counties The 20 main townships and urban centres considered were:

- **Mombasa County** – Mombasa city, including Mombasa Island, North Mainland, South Mainland and West Mainland
- In **Kwale County** – the 5 townships of Kwale, Kinango, Msambweni, Ukunda/Tiwi and Lunga Lunga/Vanga
- In **Kilifi County** – the 5 townships of Mariakani, Kilifi, Malindi/Watamu, Marafa and Mtwapa
- In **Taita Taveta County** – the 4 townships of Taveta, Mwatate, Wundanyi and Voi/Maungu
- In **Lamu County** – the 2 townships of Mpeketoni and Lamu Island/Port
- In **Tana River County** – the 3 townships of Garsen, Hola and Bura

Population projections for large sub-locations (>20,000) were calculated by trend analysis. However, no clear trend was found or insufficient data was available for all of these sub-locations (particularly for sub-locations with <5,000); thus, projections for small sub-locations were performed using the top-down approach.

Population projections for the Coast Province and all clusters were performed for three growth rates scenarios – **low**, **medium** and **high**.

4.3.2 Population Projections for the Coast Province

The most widely acceptable mathematical function for describing large population changes over time is an S-shaped function, starting with exponential growth, continuing with linear growth (which is usually the longest phase) and gradually reaching a saturation point in the third phase.

A graphical presentation of the Coast Province population data for the years 1969–2009 did not clearly indicate whether the province population is at the exponential phase or at the linear phase, since both types of regressions exhibited excellent correlation parameters (see Table 4-1).

Table 4-1: Coast Province Population – Regression Parameters

Parameter	Type of Regression	
	Exponential	Linear
R2	0.998	0.998
F-Statistic	1,549	436
Probability:		
F > 1,549	$1.2 * 10^{-6}$	–
F > 436	–	0.002

By trying to match a constant rate of growth to the population growth curve, the result demonstrated low correlation, where R2 < 0.67.

For the cases of linear and exponential regressions, R2 exhibited values of very high significance, i.e., both of the calculation procedures explain the rate growth well.

However, the exponential regression suggests an annual growth rate of 3.83%, which is significantly higher than the average annual growth rate in the 1999–2009 period (3.22%). On the other hand, the linear extrapolation results in a rapid reduction of the average growth rate, reaching 2% around the year 2020.

Therefore, the Coast Province population projection up to the planning horizon year of 2035 was estimated as follows:

- For the low and high scenarios, a continuation of the linear and exponential trends were considered, respectively.
- For the medium scenario, the projection was calculated according to the average annual growth rate during the 1999–2009 period for the entire Coast Province.
- For the special cases of Mombasa and Lamu Port free economic trade zones, which may attract immigration, a "block" of demand was added to the balance above the local growth rate.

See Chapter 6 for the detailed results of the population projections for the entire Coast Province.

4.3.3 Population Distribution by District

For each of the districts of the Coast Province (13), the projected population was calculated as a proportion of the province population. The percentage proportion of population of the districts was estimated using the following criteria:

- A district for which the proportion of population [population out of the province population (district population / province population)] showed a constant trend during the 1989–2009 period was assumed to exhibit this behaviour up to 2030.
- For a district for which the population dynamics showed a positive trend as compared with the population of the province (i.e., the population within the district increased more than the province average), it was assumed that the trend will continue in the same manner, and with about the same rate of change, up to 2025, and will then remain constant up to 2035.

The population projections by divisions, locations and sub-locations were performed according to the top-down approach, using the district population projection as the highest level. The percentage proportion of the division population out of the district population taken from the 2009 census data was assumed to be applicable for the years 2015–2035. The same percentage proportion for the division was taken to be applicable to the locations and the sub-locations forming the division.

The "Kenya County Fact Sheets" (Commission on Revenue Allocation, 2011) were used to support the allocation of the population data for the districts, locations and sub-location into the main townships and urban centres. This categorization contributed to a more accurate calculation of the water demand.

The population for each district, as a percentage of the total Coast Province population, is presented in Table 4-2.

See Chapter 6 for the detailed results of the population projections for the entire Coast Province.

Table 4-2: District Populations as Percentage of Total Coast Province Population

District	1989 *	1999 *	2009 *	2015	2020	2025	2030	2035
Mombasa + Kilindi	25.3	24.7	28.3	29	29.5	29.5	29.5	29.5
Kwale	5.2	4.9	4.6	4.5	4.4	4.4	4.4	4.4
Kinango	7.6	7.2	6.3	6.0	5.8	5.8	5.8	5.8
Msambweni	7.7	8.8	8.7	8.7	8.7	8.7	8.7	8.7
Kilifi	12.2	14.1	13.8	13.8	13.8	13.8	13.8	13.8
Kaloleni	8.6	7.9	7.4	7.2	7.0	7.0	7.0	7.0
Malindi	11.5	11.7	12.1	12.4	12.6	12.6	12.6	12.6
Tana River	5.4	4.7	4.3	4.1	4.0	4.0	4.0	4.0
Tana Delta	2.1	2.8	2.9	3.0	3.0	3.0	3.0	3.0
Lamu	2.2	3.0	3.1	3.2	3.2	3.2	3.2	3.2
Taita	9.3	8.1	6.5	6.2	6.1	6.1	6.1	6.1
Taveta	2.7	2.2	2.0	1.9	1.9	1.9	1.9	1.9
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

* Source: Kenya Population Census, 2009.

4.3.4 Water Demand Forecast

As water demand patterns are not similar for the different locations within the Coast Province, a clear methodology was required in order to determine the adequate water demand. For this purpose, the Ministry of Environment, Water and Natural Resources (MEWNR) standards were used, dividing the entire population into urban and rural groups.

The following summarizes the procedure applied to determine future water demand of each population group.

The total population was divided into an urban sector (symbol "U") and a rural sector (symbol "R"). The differentiation between the two was made on the basis of the "Kenya County Fact Sheets" (Commission on Revenue Allocation, 2011). These Fact Sheets have the population from the 2009 Census clearly identified for the major urban centres in the region and, therefore, allow derivation of the rural population.

The U sector was further divided into the low (L), middle (M) and high (H) classes, and the L class was split into consumers with individual connection (IC) and without individual connection (non-IC). Table 4-3 shows the MWI's Standards for water use for the U sector for the abovementioned divisions.

Table 4-3: Kenya MWI Standards for Per Capita Water Use

Sector	Socioeconomic Level	Home Type as MWI	Water Use (lpcd)
U	Class H	Home Type 1	**250 ***
U	Class M	Home Type 2/3	**150**
U	Class L (IC)	Home Type 4/5	**75**
U	Class L (non-IC)	Home Type 4/5	**40**
R	IC	Rural	**60**
R	non-IC	Rural	**20**

Note: The figure for water use includes domestic water use + UfW.
* It has been assumed that Mombasa will use in the year 2035 a dual system for potable and grey water, reducing water use to 180 lpcd.

Table 4-4 and Table 4-5 present the percentage of consumers with IC connection by district and connection to the bulk water supply system in the rural sector, respectively.

Table 4-4: Consumers with IC – Average by District (%)

District	2015	2020	2025	2030	2035
Mombasa	40	50	60	80	100
Kilindini	40	50	60	80	100
Kwale	25	40	55	65	80
Kinango	25	40	55	65	80
Msambweni	25	40	55	65	80
Kilifi	25	40	55	65	80
Kaloleni	25	40	55	65	80
Malindi	25	40	55	65	80
Tana River	25	40	55	65	80
Tana Delta	25	40	55	65	80
Lamu	25	40	55	65	80
Taita	25	40	55	65	80
Taveta	25	40	55	65	80

Table 4-5: Connections to Bulk Water Soppy System in the Rural Sector (%)

	2015	2020	2025	2030	2035
All Districts	30	30	50	50	80
Kilindini	30	30	50	50	80
Kwale	30	30	50	50	80
Kinango	30	30	50	50	80
Msambweni	30	30	50	50	80
Kilifi	30	30	50	50	80
Kaloleni	30	30	50	50	80
Malindi	30	30	50	50	80
Tana River	30	30	50	50	80
Tana Delta	30	30	50	50	80
Lamu	30	30	50	50	80
Taita	30	30	50	50	80
Taveta	30	30	50	50	80

The total water demand projection by county, as calculation based on the MWI standards, including institutional demand and mega-projects, is presented in the water demand summary in Section 6.3 below.

To account for rural consumers who will be supplied water at kiosks along the main pipelines, an estimate of on-line water kiosk demand was made considering the following:

- High reliability – Abstracting water from a bulk water pipe ensures high reliability (i.e., water will be available at all times)
- High quality – The water quality in the bulk water pipe is very high, due to the high standards of treatment plants in the bulk water supply system.

It was assumed that a distance of 5 km, roughly equivalent to one hour of walking, is the maximum distance that people will consider to walk in order to get water of adequate quality and high reliability. Thus, the total area served by 1 km of main pipeline is 10 km^2.

In the calculation process, the population density is determined in each one of the districts/divisions. The density is then multiplied with the length of the bulk water supply systems (existing + proposed) in each district. The result is the total population in each area that are located near the main pipeline and should be considered as water demand population. In order to determine the water demand, the total population was multiplied by the lpcd for the rural sector. The results – by districts –are then added to the water demand table and to the water balance, increasing the total urban demand in the Coast Province by ~7.5%. Detailed results are presented in Chapter 6 below.

4.4 Water Resources Study

4.4.1 General

The following reviews/analyses were taken in respect of the water resources of the Coast Province:

- Review of the exploitation of current water resources and their future potential
- Identification and analysis of new surface water resources and their potential
- Analysis of groundwater potential in Tiwi, Msambweni and other areas
- Analysis of existing information of deep groundwater potential of the Neogenic layer and recommendations for further investigation
- Preliminary analyses of potential grey water reuse, as local treatment and reuse of wastewater from regional treatment plants is advanced
- Preliminary analysis of desalination potential and its associated impacts

More specifically, the methodology included:

- Assessment of current water resources yields based on a review of dozens of reports, technical papers and documents relating to the development of water resources in the region, which were made available to the Consultant by the CWSB and other agencies.
- A study was conducted to locate new water resources –both surface and groundwater – that could be incorporated into the water supply systems of the province, contributing additional sustainable volumes of water. The investigation was divided into three sets:
  - In the first set, a preliminary analysis of 11 water basins draining to the Indian Ocean was conducted, and the annual potential water volumes that can be collected in dams and reservoirs was quantified; this included a preliminary assessment of the available water flows in the Sabaki River near Baricho site.
  - The second set focused on regional aquifers, and included the structuring and running of a groundwater model to estimate the annual potential taking into consideration the possibilities of seawater intrusion and rapidly declining water levels.
  - In the third set, the possibility of adding desalinated water to the water balance of the region was considered, emphasizing local constraints such as availability of electricity, site locations along the coast and reliability.

Additionally, the nature of the Neogenic aquifer as a potential deep-water aquifer was analyzed. This aquifer could constitute a substantial water source for the region. In order to assess the existence of a Neogenic aquifer and its water potential in Kenya, it is essential to perform further investigations by drilling deep exploratory/production wells.

4.4.2 Approach to the Assessment

In parallel with the population and water demand projections, the existing water supply schemes for the 20 main townships and urban centres – Mombasa plus another 19 townships and urban centres – were also evaluated.

Each main township comprises the township and adjacent settlements. These townships are shown in Fig. 6-2 in Chapter 6 below. For the Immediate Phase, the township of Gongoni was added to the WSMP, although this township was not included in the initial list.

The Coast Province mostly depends on bulk water supply system (BWSS) schemes. These waterworks presently comprise – from the most important ones to the marginal ones – Mzima, Sabaki-Mombasa Pipeline, Marere Pipeline and the Tiwi Boreholes, which supply 15 of the 20 townships in Mombasa, Kwale, Kilifi and Taita Taveta counties. The other 5 townships depend on local water resources. Also, the Coast Development Authority (CDA) is promoting the design of the Mwache Dam, a multipurpose reservoir, as an additional resource for BWSS domestic water supply and irrigation. The study and the detailed design are being carried out by CES/APEC, and they indicate Mwache Dam as a key resource for the Coast Province.

4.4.3 Guidelines for Water Resources Management

The increasing emphasis on environmental and ecological protection, the role of water in preserving natural resources, and the several regional catastrophes that took place during the 1990s due to faulty management of wastewater and mines, causing contamination of water sources, have resulted in a pressing need for effective water resources management.

The following major elements for the effective management of water resources were dealt in the present study, and recommendations were introduced accordingly:

- Judicious management of water consumption, utilizing tools and techniques, some of which are outside the sphere of engineering
- Long-term study of water source features, as well as ways to ensure sustainability
- Introduction and implementation of metering and monitoring systems
- Incorporation of modern tools and techniques, for the preparation of short- and long-term programs for the development, operation and maintenance of water supply schemes

In particular, the following measures are recommended for surface water and groundwater resources management in the CWSB's area of jurisdiction:

- Enhancement of hydrometric measurements of rivers and streams within the Coast Province, including establishment of new hydrometric stations where necessary, and setting up of measurement timetables to ensure the collection of adequate data
- Determination of environmental flows for all perennial rivers and streams in the province in order to protect the aquatic environment both inland and in the delta region
- Determination of the reserve for each of the water resources in accordance with the 2006 Water Resources Management Rules, in order to guarantee equitable utilization between the various competing demands
- Ensuring viable programs are in place for conservation of each catchment against degradation
- Introduction of aquifer management and protection/conservation programs, focusing on the following aspects:
  - Incorporation of the subject of groundwater management into CWSB policy and planning
  - Improvement of the knowledge base on aquifers within the Coast Province by improving both institutional and human resources in the relevant institutions responsible for water resources management
  - Implementation of suitable monitoring programs for aquifers within the Coast Province
  - Improvement in data collection, management, storage and dissemination
  - Improving the active involvement of groundwater users in aquifer management

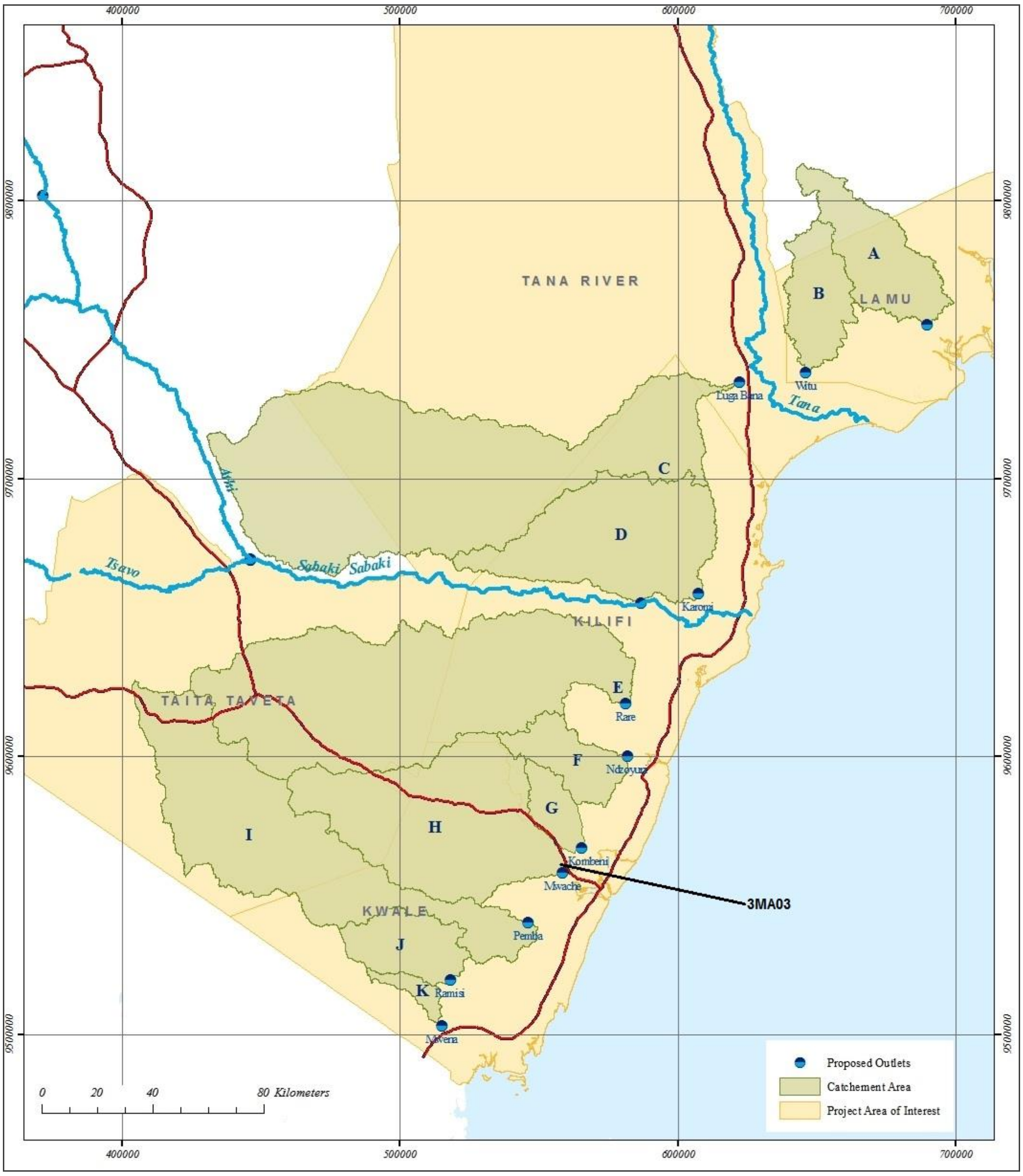
4.4.4 Surface Water Resources Study

The analysis of surface water resources included:

- Review of previous and ongoing studies on dams and direct river intakes in the Coast Province
- Analysis of monthly and annual flows of 11 rivers draining to the Indian Ocean, including the Mwache, Kombeni and Rare rivers
- Analysis of low flows in the Sabaki River near Baricho site
- Analysis of low flows in the Tana River near Garsen site

The available monthly streamflows measured at the abovementioned Mwache River Hydrometric Station 3MA03 (see 4Fig. 4-1 below) were applied using the MRS monthly rainfall-runoff model, developed by the Consultant, and calibrated for the period of available records (1976/77–1989/90). Five rainfall stations, having monthly data for the period 1958/59–2008/2009, were expanded, based on the Theissen procedure, and used as input to the MRS model. Following completion of calibration, the MRS model was applied to simulate monthly flows.

Conversion of the simulated Mwache River monthly streamflows to the other rivers was performed by using transfer coefficients based on the ratios of basin areas, basin mean annual rainfalls, basin mean runoff coefficients (being a function of soils and soil cover) and basin mean contribution to surface runoff (being a function of lithological and geological characteristics) to their corresponding values in the 3MA03 hydrometric station basin.



4Fig. 4-1: Location of hydrometric station 3MA03 (Mwache/Basin H) and river basins A–K

4.4.5 Groundwater Potential

The analysis of groundwater potential along the southern coast included the following steps:

- Review of previous studies and available data for the hydrogeology of the study area
- Identification of data gaps
- Construction of a regional groundwater flow model based on the existing data, with simplifying assumptions
- Model calibration and assessment of seawater intrusion according to different pumping scenarios

Step 1 model runs studied the general flow regime and the parameters affecting seawater intrusion for the Tiwi and Msambweni areas as part of the southern region. The parameters affecting seawater intrusion were analyzed specifically for the Tiwi area and included the following:

- Amount of recharge to the aquifer (two scenarios – high and low)
- Amount of pumping (two scenarios – high and low)
- Distance from the ocean

Step 2 model runs studied the flow regime in the Tiwi and Msambweni areas assuming conservative conditions – lower topography and lower recharge. A transient run simulated the effect of high pumping and seawater intrusion rate for a period of 20 years, in both the Tiwi and Msambweni areas.

4.5 Formulation and Phasing of the Development Scenarios

Five development scenarios were considered in the full feasibility stage of the present study.

In formulating the development scenarios, priority was given to the following considerations:

- Expansion/rehabilitation of presently utilized resources
- Achievement of water balance
- Sustainable and robust schemes
- Development options having favourable economic/financial results
- Deferment of high capital investment schemes to later phases
- Proximity of the consumers to the coastline
- Satisfying the demand of 14 out of the 20 main townships and urban centres via the BWSS

- Small-scale sources (boreholes, small desalination systems, etc.) that will continue to exist in the future, supplying some 5% of the total demand
- Immediate expansion of the Baricho Scheme to be included in all of the development scenarios

In staging the development scenarios, four phases were considered, as follows:

- **Immediate Phase** (to be completed by 2016) – expansion of the Baricho Scheme by an additional 20,000 m^3/d
- **Phase I** (to be completed by 2020)
- **Phase II** (to be completed by 2025)
- **Phase III** (to be completed by planning horizon year of 2035)

The **Immediate Phase** is common to all of the scenarios, except for Development Scenario B3 (see Table 4-6).

The development scenarios considered (excluding the development in the Immediate Phase) are presented in Table 4-6.

Table 4-6: Years of Introduction of Water Supply Scheme for each Development Scenario

Water Supply Scheme	Development Scenario				
	B1	B1.1	B3 *	B5	C2
Baricho 2 (85,000 m^3/d)			2016		
Mwache Dam (186,000 m^3/d)	2020	2020	2020	2020	2020
Baricho 2 (63,000 m^3/d)	2024	2024			2026
Rare Dam (180,000 m^3/d)				2024	
Mzima 2 (105,000 m^3/d)	2030				
Rare Dam (100,000 m^3/d)		2030	2031		
Desalination (100,000 m^3/d)			2032–2034		
Msambweni Aquifer / Mkurumudzi Dam (20,000 m^3/d)	2035	2035	2035	2035	2035

* This development scenario does not include the Immediate Phase.

Note:

+Years refer to commencement of water production, and not to commencement of construction

The different development scenarios do not differ substantially from each other, as can be observed from Table 4-6; they are mostly different sequences of development of the same resources.

4.6 Financial and Economic Analysis and Selection of the Proposed Development Scenario

4.6.1 Financial and Economic Analysis

The main objective of the financial and economic analysis was to provide the CWSB and other policymakers and stakeholders with all necessary information needed for informed decision-making regarding the implications of development of the water sector and the selection of the preferred development scenario out of the proposed projects and programs. The final outcome of evaluation was to present the financial and economic outcomes of implementing the WSMP.

The financial and economic analysis of the WSMP is generally based on a comparison between the net benefit flows from water delivery to the cost of developing and operating the systems.

The basic elements analyzed included:

- Costs of designing, procuring and construction of each of the water supply schemes (each as a standalone project and as an integral part of the entire water supply system)
- Detailed operations and maintenance (O&M) costs
- Detailed energy requirements and costs for each project and for the complete water supply system
- Detailed discounted cash flows

Moreover, the following values per m^3 of water supplied were considered:

- Total cost per m^3 of water delivered
- Total investment per m^3
- Energy and O&M costs per m^3
- The total water cost per m^3 delivered to the utility firm

The indicators computed, analyzed and presented included:

- Net present value (NPV)
- Internal rate of return (IRR)
- Economic net present value (ENPV)
- Economic internal rate of return (EIRR)
- Sensitivity and risk analysis

General assumption for the evaluation included:

- Costs were expressed at September 2012 costs, and considered constant.
- Project lifespan was set at 50 years, while for the various engineering components (e.g., electromechanical and civil), the lifespan was taken from known international standards.
- Investments relate only to the additional infrastructure needed to be developed.
- An annual discount rate of 10% has been tentatively set for the analysis.
- Investments include all components from the water source, all the way up to the final connection point to the water utility company.
- Average capital, O&M and energy costs were calculated for only the additional infrastructure needed to be developed, and were determined as a constant rate set at 1% per annum of the total accumulated investments.
- O&M expenditures reflect an annual investment of 0.5% of accumulated investments for rehabilitation purposes.
- Government policies regarding water prices will remain unchanged. Policy shifts may cause corresponding changes in the results of the analysis.
- Different water prices have been set for the Mombasa area and the Lamu area, reflecting the differing costs of water production and supply between the two areas.
- Investments for each phase are divided equally by the anticipated number of years of the component implementation (relevant for economic analysis).
- A standard conversion factor (SCF) of 0.9 was determined in order to reflect additional (or decreased) benefits (or costs) to the National economy (relevant for economic analysis).
- Funding costs are computed according to the terms of loans of the water utilities – 10-year grace period with annual interest rate of 1%, and additional 30 years of loans' refund with an annual interest rate of 3% (relevant for financial analysis).

4.6.2 Selection of the Proposed Development Scenario

Multicriteria methodology was used for the selection of the proposed development scenario. Four main criteria/parameters were identified and classified for the multicriteria analysis – engineering, economics, environmental aspects and social & politics.

A grade (on a 0–100 scale) was linked to each scenario and associated with the indicators in each field of significance. The economic indicators were arithmetically calculated, and grades for the other indicators were assigned according to similar projects and the Consultant's experience. Each criterion/parameter was classified with a percentile weight, reflecting its importance for the decision-making.

Table 4-7 summarizes the results of the basic multicriteria analysis for all the development scenarios considered.

Table 4-7: Multicriteria Analysis for the Development Scenarios

Item	Criteria / Parameter	Classification	Inner Weighting	Scenario				
				B1	B1.1	B3	B5	C1
1.0	**Engineering Sustainability**	30%						
1.1	Feasibility of implementation		40%	80	70	50	65	50
1.2	Reliability of Resources		30%	90	70	70	60	90
1.3	Diversity of Resources		30%	90	80	80	20	100
	Engineering Summary			86	73	65	50	77
2.0	**Economic Considerations**	40%						
2.1	NPV		20%	47	13	0	100	26
2.2	IRR		35%	80	31	19	100	0
2.3	O&M Costs		10%	83	76	85	100	31
2.4	Calculated Water Cost		35%	86	79	78	100	79
	Economic Summary			76	49	42	100	36
3.0	**Environmental Issues**	15%						
3.1	Water Quality		30%	90	70	70	50	95
3.2	Downstream Impact		30%	60	60	70	50	60
3.3	Energy Consumption		30%	90	70	70	80	50
3.4	Construction Effects		10%	60	60	70	80	50
	Environmental Summary			78	66	70	62	67
4.0	**Social & Political Aspects**	15%						
4.1	Supply Coverage		30%	100	80	80	80	80
4.2	Resettlement / Income Loss		40%	80	70	70	50	60
4.3	Political acceptability		30%	100	90	50	50	30
	Social Summary			**60**	**51**	**39**	**39**	**33**
	Total	**100%**		**76.8**	**59.0**	**52.8**	**70.2**	**52.4**
	Rank			**1**	**3**	**4**	**2**	**5**

Three different cases for the weighing the different criteria/parameters were examined:

- A 30%/40% weighting between the engineering/economic parameters
- A 40%/30% weighting between the engineering/economic parameters
- A 40% weighting for the economic parameter and a 25% weighting for the environmental parameter

The results clearly indicate that Scenario B1 maintains its leading position in each of the three cases. It is followed by B1.1. While both are strong in the economic and environmental parameters, but Scenario B1.1 is inferior in the engineering parameters. This led to the selection of B1 as the preferred development scenario.

4.7 Environmental Impact Assessment (EIA)

The EIA for the project uses both primary and secondary data. Secondary data sources include existing project documents, research papers and other documents on the project areas and official government information. Primary data collection includes data collected through discussions with various stakeholders. These include government officials at the local, county and provincial level and other agencies such as research agencies and NGOs.

The assessment has reviewed existing legislation of relevance for the project the institutional system with reference to the water and environment landscape. The review of legislation has been undertaken to identify required environmental clearances and other legal needs under the project. Since this project has applied for funding through the World Bank, the Banks safeguard procedures have also been reviewed for significance.

Since it is yet to be made clear what the final institutional setup for implementing the project will be, the identified grievance redressal system and the capacity building actions are broadly identified, and would need to be refined once the institutional system for the project is detailed.

The Environmental Management Plan, which is an integral part of the assessment, is developed based upon the impacts identified for this project. The aim of the EMP is to enhance positive impacts of the project and to identify methods to reduce and if possible find alternatives to ensure adverse impacts from the project do not occur.

The analysis of impacts has been done through the development of a matrix where various project activities have been measured against identified appropriate environmental parameters. The assessment of environmental impacts is based on best professional judgment and follows conventional wisdom.

A range of indicators have been developed to assess impacts against. These indicators have been used to identify short- and long-term effects and where possible cumulative impacts too. Impacts have been classified into basic three types – positive, adverse and negligible. According to possible periodicity of impacts, they have been classified as permanent, temporary and intermittent. For areas where there is insufficient information at present, unknown has been marked. Where possible, impacts have been classified according to spread as localized or widespread.

A further analysis of the impacts is also available through the analysis of alternatives. This section precedes the section of the impact matrix. In this section, a brief assessment of different alternate scenarios for the project and its design has been made. This also includes a business as usual scenario where there is no new project developed, but the population continues to grow at project rates.

Criteria of indicators for impact analysis are based on a number of checklists and other environmental guidelines used. Due to the complexity of the existing environment the indicators and activities have been modified to suit the need of the project environment and therefore it is not necessary that only conventional indicators are used or standard parameters have been applied for the analysis.

4.8 Resettlement Action Plan (RAP)

The RAP describes the procedures required and actions that will have to be taken to properly resettle and compensate households and communities that will be affected by the programs and projects that originate from the WSMP study.

It should be noted that, by its nature, a master plan study is all-embracing, comprehensive and inclusive. The exact details of each project and component have yet to be decided. Hence, location of structures, pipeline routes and reservoirs are not final and the concurrent RAP, land acquisition and compensation can only be done in general terms. The basic assumption of the Consultant is that each and every project will require a more comprehensive and detailed RAP and a compensation program during each project's feasibility study and detailed design stages.

The RAP methodology included the following steps:

- Identification of the impacts of the WSMP and the proposed projects
- Preliminary mapping and GIS positioning
- Review of socioeconomic surveys, asset inventories and censuses
- Review of World Bank RAP guidelines (specifically Operational Procedures OP 4.12) and the GoK resettlement policies
- Census of persons and households
- Identification of causes that impact the affected peoples
- Identification of project-affected peoples (PAPs) and communities (PACs)
- Identification of potential project impacts
- Inventory of assets and resources
- Consultations with affected people
- Analysis and description of the resettlement sites
- Mechanisms of participatory processes for host communities
- Identification of the agencies responsible for each resettlement activity and the overall coordinating agency
- Analysis of the capacity of these agencies and mechanisms to improve the capacity and commitment if required
- Housing/land allocation
- Valuation of losses
- Preparation of the required budget, including costing of all resettlement needs
- Determination of the sources of funds and responsibility for their allocation

- Monitoring and evaluation

The last step, which includes appropriate planning, policy measures and management, have to be set out in order to assure successful and sustainable achievement of the resettlement goals. Otherwise, as is often the case in numerous involuntary resettlement schemes in Africa and elsewhere, long-term hardships for the affected populations and environmental damage are the inadvertent results.

4.9 Action Plan

The main objective of the action plan is to review each of the implementation actions of the projects, specifying the project management schedules, activity milestones and deliverables. This will enable the client and the water the water utility firms to plan, prepare and budget each of the projects well in advance. Indicating on a calendar type timetable the periods for budgeting, procurement, design and construction of each project so that full operational levels are achieved according to the water demand requirements in each area.

This was done from two points of view:

- The first one looked at the components of the project along the time scale, starting from present time and ending in the planning horizon year. This was summarized in a bar chart listing, by source of water, supply schemes and project components, the schedule of the actions to be taken along the time coordinate in order to meet the project milestones.
- The second plan of action was arranged by source of water. Thus, although a certain water supply scheme is scheduled to be developed in more than one phase, the development by phases of this water supply scheme is shown sequentially. For example, if a certain water supply scheme is planned to be developed in two phases, both developments will be shown sequentially under this water supply scheme.

5. Socioeconomic Survey

5.1 Objectives of the Socioeconomic Survey

The main objectives of the socioeconomic survey was to assess the socioeconomic situation in regard to the supply of water in the Project area and to probe the possible socio-cultural consequences and the economic implications of the Project.

The following specific objectives were set to be accomplished by the survey:

- To assess the socioeconomic situation in regard to water supply situation in the Project area
- To review social setups, family sizes, and water supply situation
- To evaluate the various socioeconomic benefits that may be derived from the Project
- To determine water consumption rates

To accomplish these objectives, the Consultant compiled information on the following:

- Household socioeconomic status
- Sources and uses of water
- Monthly consumption of water
- Volumes of water billed/purchased and amounts paid
- Willingness to pay for private connection and consumption
- Service provision by WSPs, etc.

5.2 Methodology

The methodology employed in the socioeconomic survey – including direct observation; review of available data and information; questionnaires administered to household units, institutions and water vendors; and interviews of key individuals –is described in Section 4.2 above.

5.3 Sample Distribution

A sample size of 0.0186% of the total population was used giving a respondent base of 633 respondents distributed in each county (see Fig. 5-1) and 2.5% of the total number of institutions consuming water.

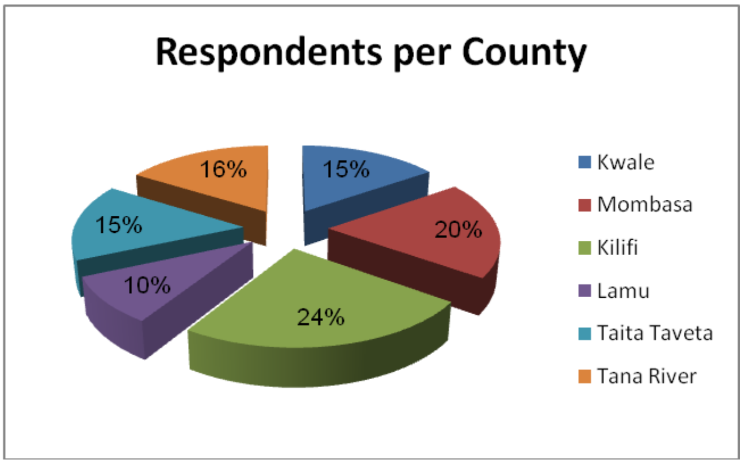


Fig. 5-1: Socioeconomic survey – respondents per county

5.4 Demography, Household Information and Economic Activity

5.4.1 *Gender of Respondents*

The survey totalled 633 respondents, of which 43% were female. This is attributed to the multiple roles of women, who handle a wide variety of activities in and outside the home. Among the respondents interviewed, 93% of the households were headed by males.

5.4.2 *Household Size*

The average number of persons per households in the project area is five. However, 54% of the households are less than five persons in the household, 42% have between 6 and 10 people and 4% have more than ten persons in the household, as shown in Fig. 5-2.

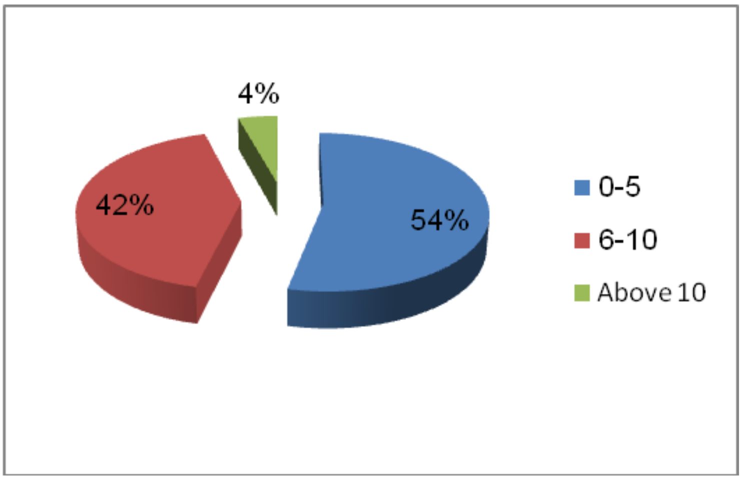


Fig. 5-2: Socioeconomic survey – household size of respondents

5.4.3 Marital Status

The survey on marital status of the respondents in the Project area was based on five categories – married, single, divorced, widowed and separated. The survey revealed that 83% of the respondents were married, 11% single, 1% divorced, 4% widowed, and 1% separated, as shown in Fig. 5-3.

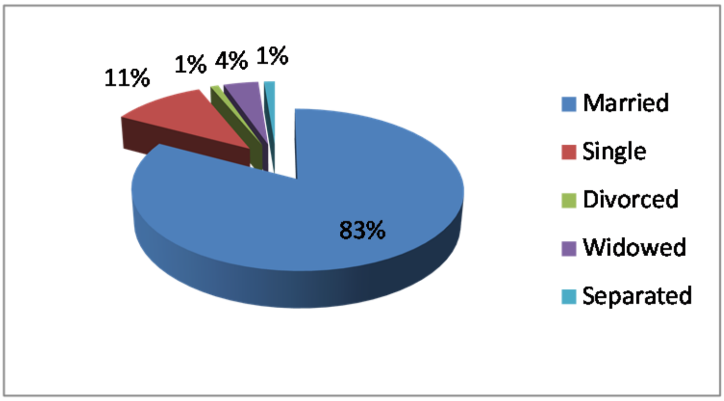


Fig. 5-3: Socioeconomic survey – marital status of respondents

5.4.4 Education Status

Education attainment is an important indicator of socioeconomic development and the capacity of people to participate in development activities. The ratio of boys to girls in primary school is 1:3, whereas the teacher-student ratio is at 1:82. According to the survey, 56% of the population had attended school to primary level, 31% to secondary level, 7% had diploma qualification, 1% had degree qualification, 3% had tertiary education and 2% indicated "others". This distribution is presented in Fig. 5-4.

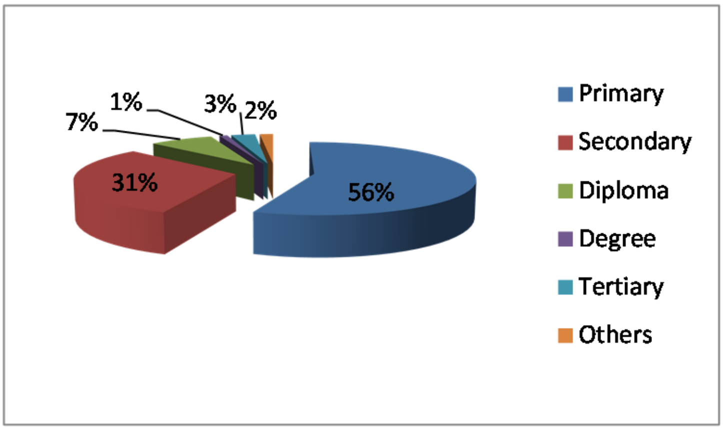


Fig. 5-4: Socioeconomic survey – education level of respondents

5.4.5 Economic Activities

Most of the local population practice mixed farming, industrial activities, pastoralism, tourism and commercial activities. During the survey, it was established that ~51% of the respondents are unemployed, 35% are self-employed and 14% of the population are employed by others, as shown in Fig. 5-5.

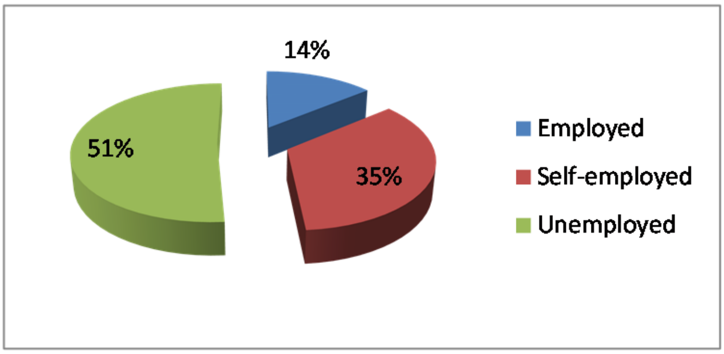


Fig. 5-5: Socioeconomic survey – employment status of respondents

5.4.6 Monthly Household Income and Expenditure

The local population earns their income from subsistence farming, tourism, trade and industry. The socioeconomic survey revealed that 14% of the households earn below KSh 5,000 per month; 27% earn KSh 5,001–10,000; 37% earn KSh 10,001–15,000 and 22% earn more than KSh 15,000 per month. The income distribution is presented in Fig. 5-6. The average household income is about KSh 9,000 per month, which amounts to approximately KSh 300 per day.

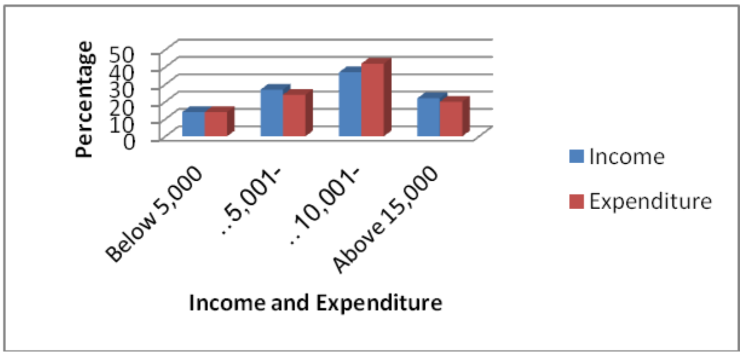


Fig. 5-6: Socioeconomic survey – household income and expenditure of respondents

The survey also established that the monthly household expenditure varies considerably, with 14% spending less than KSh 5,000, 24% spending KSh 5,001–10,000, 42% spending KSh 10,001–15,000 and 20% spending above KSh 15,000. The average household expenditure is some KSh 9,600 per month, which amounts to approximately KSh 320 per day. This distribution is also presented in Fig. 5-6.

5.5 County-by-County Survey

The survey covered in detail each of the six Coast Province counties – Mombasa, Kwale, Kilifi, Lamu, Tana River and Taita Taveta.

Fort each county, the following parameters were established:

- Location of the county in the study area
- Population characteristics of the county
- Physiographic and natural conditions of the county
- Climatic information of the county
- Socioeconomic activities and poverty estimates
- Socioeconomic indicators of the county
- Physical infrastructure of the county
- Water supply and sanitation of the county
- Challenges and recommendations
- Challenges facing water sources

As a result of the county-by-county survey, the following challenges were registered as common to the residents in the entire Project area:

- **Inadequate Water Supply**
  - Inadequate water, as evidenced by water rationing, is widespread across the entire Coast Province. Water rationing is rampant in urban areas due to high populations that consume the limited supply, making it impossible to supply all users at the same time.
  - High demand for water that supersedes the available supply is another factor. The increased demand is largely attributed to the increasing population, both rural and urban.
  - Leakages and pipe breaks, mainly due to aged facilities, lead to high levels of unaccounted-for water (UfW).
  - Low rainfall levels and salinity of water sources have also led to water inadequacy.
  - Power rationing has greatly affected the supply of water in the Coast Province by rendering electric pumps useless, while water in the existing inadequate reservoirs is quickly exhausted

- **Unreliable Water Vendors**
  - Water vendors are not reliable. They may decide not to provide water on a particular day, regardless of the demand.
  - Vendors are also known to charge exorbitant prices for water, especially if there is water scarcity and residents have no alternative source.
  - The vendors' source of water is not known, putting doubts on the quality of the water they sell.

- **Water Vandalism**
  - Theft and vandalism of the existing water supply infrastructure (e.g., pipes, valves and storage tanks) leads to loss of water through leakage and wastage, causing water scarcity in the intended points of supply and loss of revenue for the water supplier.
  - Pipelines – Baricho, Marere, Mzima and others – face a great deal of ruptures along the way by people cutting pipe sections for scrap metals and illegal connections.

- **Illegal Connections**
  - Illegal connections and tampering with water meters have led to loss of water though leakage at illegal connection points.
  - Tampering with meters leads to underpayment or nonpayment for water services, reducing revenues, which result in poor maintenance and operation, and consequently to more breakdowns.

- **Long Distances to Water Sources**
  - The majority of residents in the Coast Province, especially in rural areas without piped water, travel up to 5 km to receive water. This leads to misuse of time that could be better used for other important work.

5.6 Recommendations for Improved Water Supply

The following recommendations were made by the respondents to counter the water situation in the area:

- **Reduction in the Water Charges** – Respondents recommended reduction of water charges. This supposedly will make water more affordable to residents. However, while considering a reduction in water charges the costs of operation and maintenance of the infrastructure should be borne in mind.

- **Improvement of the Water Supply Infrastructure** – Improvement of the water supply infrastructure (e.g., WTPs, pipelines, pumps and storage tanks) to reduce the distance travelled to fetch water. This can also be achieved through locating water sources nearer to consumer centres, through drilling of boreholes and construction of djabias for water harvesting.

- **Timely Payment of Water Bills** – Timely payment of water bills by consumers will enable the water supplier to meet operation and maintenance costs of the water supply facilities and ensure efficiency in water supply. To enhance payment of bills, the supplier should impose penalties for late payments and charge high reconnection fees.

- **Community Involvement** – Increase security measures by community mobilization. These measures will help reduce vandalism and illegal connections, and help maintain water meters to avoid blockage and inaccuracy in metre readings.

6. Population and Water Demand Forecast

6.1 General

The water demand forecast, expressed in m^3/d and in MCM/y is the product of litres per capita per day (lpcd), times the population forecast and the level of services. The per capita water use was divided according to urban and rural sectors, with subdivision according to type of housing, and then multiplying by the percentage of individual connections. Thus, existing water resources and the required new water resources, in terms of location and potential, will be developed to strike a water balance.

Using past population censuses of the Coast Province, the latest being the 2009 Census, three population growth rates and population forecasts were derived for the five target years of 2015, 2020, 2025, 2030 and 2035.

6.2 Population Projection

6.2.1 Population Projection for the Coast Province

The database for the population projections for the Coast Province comprised the five census datasets (sub-location-wise) for the years 1969, 1979, 1989, 1999 and 2009. The population was projected using three different models – **low**, **medium** and **high**. However, based on the 2009 census, the medium growth rate was found to be the best fit for the historical data.

Coast Province population projections by district are presented in Table 6-1. The projected Coast Province population up to the planning horizon year of 2035 is summarized in Table 6-2, and Fig. 6-1 is a graph of the population curves. See Chapter 4 above for additional details regarding the methodology used for the population projections.

Table 6-1: Coast Province Population Projections by District

District	Scenario	2009	2015	2020	2025	2030	2035
Mombasa	Low	523,283	599,172	664,858	730,543	796,228	861,913
	Medium	523,283	633,671	742,425	869,844	1,019,132	1,194,041
	High	523,283	678,388	818,814	988,309	1,192,889	1,439,817
Kilindini	Low	416,187	500,574	576,491	633,445	690,400	747,355
	Medium	416,187	529,396	643,748	754,232	883,678	1,035,339
	High	416,187	566,755	709,985	856,952	1,034,341	1,248,449
Kwale	Low	151,978	170,650	185,150	203,442	221,734	240,027
	Medium	151,978	180,476	206,751	242,235	283,809	332,518
	High	151,978	193,212	228,024	275,225	332,197	400,962

District	Scenario	2009	2015	2020	2025	2030	2035
Kinango	Low	209,560	227,534	244,062	268,174	292,286	316,399
	Medium	209,560	240,634	272,536	319,310	374,112	438,319
	High	209,560	257,616	300,577	362,797	437,896	528,541
Msambweni	Low	288,393	329,924	366,093	402,261	438,429	474,598
	Medium	288,393	348,920	408,804	478,965	561,168	657,478
	High	288,393	373,543	450,866	544,196	656,844	792,811
Kilifi	Low	456,297	523,328	580,699	638,069	695,440	752,810
	Medium	456,297	553,459	648,447	759,737	890,128	1,042,897
	High	456,297	592,516	715,167	863,207	1,041,891	1,257,562
Kaloleni	Low	243,825	273,041	294,557	323,658	352,759	381,860
	Medium	243,825	288,761	328,922	385,374	451,514	529,006
	High	243,825	309,139	362,766	437,858	528,495	637,894
Malindi	Low	400,552	470,237	530,203	582,585	634,967	687,349
	Medium	400,552	497,311	592,060	693,673	812,725	952,210
	High	400,552	532,406	652,979	788,145	951,291	1,148,209
Tana River	Low	143,411	155,481	168,318	184,948	201,577	218,206
	Medium	143,411	164,434	187,956	220,214	258,008	302,289
	High	143,411	176,037	207,295	250,205	301,997	364,511
Tana Delta	Low	96,664	113,767	126,239	138,711	151,183	163,654
	Medium	96,664	120,317	140,967	165,160	193,506	226,717
	High	96,664	128,808	155,471	187,654	226,498	273,383
Lamu	Low	101,539	121,351	134,655	147,958	161,261	174,565
	Medium	101,539	128,338	150,365	176,171	206,406	241,831
	High	101,539	137,395	165,836	200,164	241,598	291,609
Taita	Low	216,992	235,118	256,686	282,045	307,405	332,764
	Medium	216,992	248,656	286,632	335,826	393,462	460,991
	High	216,992	266,203	316,125	381,562	460,546	555,879
Taveta	Low	67,665	72,052	79,951	87,850	95,749	103,648
	Medium	67,665	76,201	89,279	104,602	122,554	143,587
	High	67,665	81,578	98,465	118,847	143,449	173,143
Total	**Low**	**3,316,346**	**3,792,231**	**4,207,960**	**4,623,689**	**5,039,419**	**5,455,148**
	Medium	**3,316,346**	**4,010,574**	**4,698,892**	**5,505,343**	**6,450,201**	**7,557,222**
	High	**3,316,346**	**4,293,595**	**5,182,370**	**6,255,121**	**7,549,931**	**9,112,768**

The medium population projection to year 2035 shows that the Coast Province population will be more than 7.5 million inhabitants of which the greater portion will live in urban areas.

Table 6-2 summarizes the population forecast.

Table 6-2: Coast Province – Past Population Data and Projections to 2035

Year	Low	Medium	High
	Linear	Geometric	Exponential
1969	745,877	745,877	745,877
1979	1,108,974	1,108,974	1,108,974
1989	1,653,429	1,653,429	1,653,429
1999	2,415,917	2,415,917	2,415,917
2009	3,316,346	3,316,346	3,316,346
2015	3,792,231	4,010,574	4,293,595
2020	4,207,960	4,698,892	5,182,370
2025	4,623,689	5,505,343	6,255,121
2030	5,039,419	6,450,201	7,549,931
2035	5,455,148	**7,557,222**	9,112,768

It should be noted that the medium total projected population for the Coast Province for the horizon year of 2035 reaches an estimated value of over 7.5 million. This is the number of people for which water supply facilities should be provided by the year 2035.

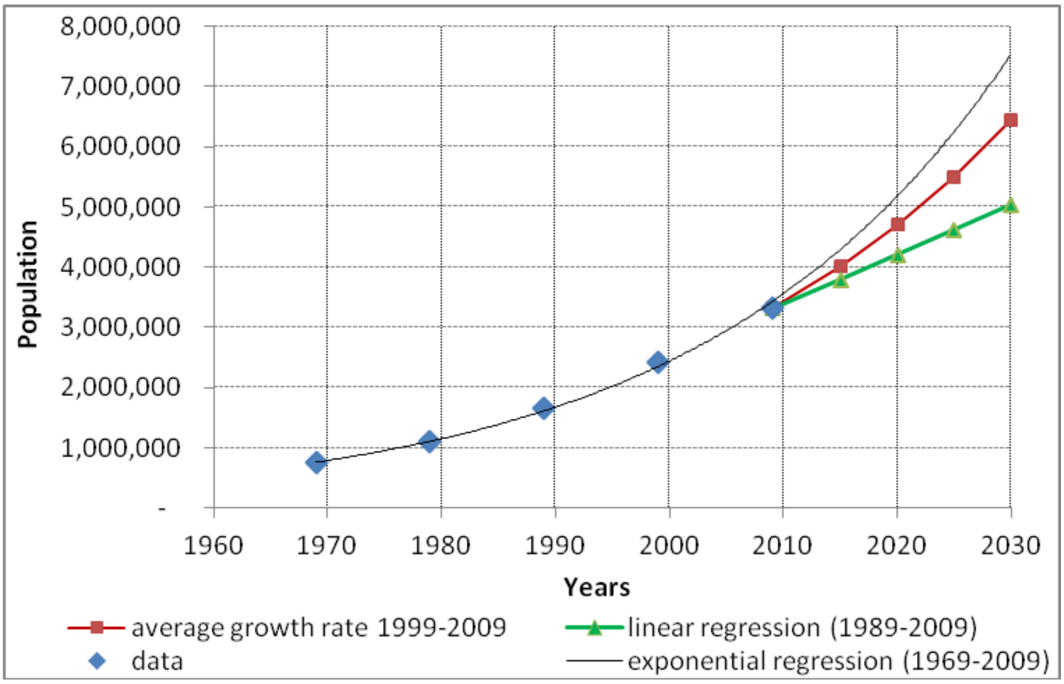


Fig. 6-1: Coast Province population – past and projected

6.2.2 Population Projection for the Main Townships and Urban Centres

Following a meeting with the Client, a clarification letter was issued to define the scope of the WSMP. It was determined that the population and demand projections, and consequently the water balance, will be evaluated for the 20 main townships and urban centres (see Fig. 6-2 for location map).

For each of the townships, the projected population for each year was calculated as a proportion of the province population for the target years. The population projected was based on the medium growth rate. Obviously, the total province population is much larger than the population considered under the present WSMP, which is focussed on the water supply to only the main townships and urban centres as presented in Table 6-3.

Table 6-3: Population Projections for the 20 Main Townships and Urban Centres

County	Townships	Population Projections					
		2012	2015	2020	2025	2030	2035
Mombasa	**Mombasa**	**1,051,268**	**1,163,066**	**1,386,173**	**1,624,076**	**1,902,809**	**2,229,380**
Kwale	Kwale	18,719	22,229	25,465	29,836	34,956	40,956
	Kinango	19,256	22,111	25,043	29,341	34,376	40,276
	Msambweni	17,394	21,045	24,656	28,888	33,846	39,655
	Ukunda/Tiwi	73,475	88,896	104,152	122,028	142,971	167,508
	Lunga Lunga /Vanga	28,550	34,542	40,470	47,416	55,554	65,088
	Subtotal	**157,394**	**188,823**	**219,787**	**257,508**	**301,703**	**353,483**
Kilifi	Mariakani	43,199	51,160	58,276	68,278	79,996	93,725
	Kilifi	53,114	64,424	75,481	88,435	103,613	121,396
	Malindi *	126,031	156,476	186,288	218,260	255,719	299,606
	Watamu *	25,982	32,258	38,404	44,995	52,718	61,766
	Marafa	13,483	16,740	19,929	23,350	27,357	32,052
	Mtwapa	85,489	103,693	121,489	142,340	166,769	195,391
	Subtotal	**347,298**	**424,751**	**499,867**	**585,657**	**686,171**	**803,936**
Taita Taveta	Taveta	37,919	42,702	50,031	58,618	68,678	80,465
	Mwatate	14,508	16,625	19,164	22,453	26,307	30,822
	Wundanyi	14,439	16,546	19,073	22,346	26,182	30,675
	Voi/Maungu	48,588	55,678	64,182	75,197	88,103	103,223
	Subtotal	**115,454**	**131,551**	**152,450**	**178,614**	**209,269**	**245,185**
Lamu	Mpeketoni	9,475	11,976	14,031	16,439	19,261	22,566
	Lamu Island/Port	7,040	107,036	266,453	412,841	571,109	716,151
	Subtotal	**16,515**	**119,012**	**280,484**	**429,280**	**590,370**	**738,717**
Tana River	Garsen	9,133	11,368	13,319	15,605	18,283	21,421
	Hola	12,424	14,245	16,283	19,078	22,352	26,188
	Bura	11,985	13,742	15,708	18,403	21,562	25,263
	Subtotal	**33,542**	**39,355**	**45,309**	**53,086**	**62,197**	**72,871**
	Total	**1,721,471**	**2,066,559**	**2,584,071**	**3,128,222**	**3,752,519**	**4,443,573**

*** Note:** Malindi and Watamu townships were considered to be a single urban centre – Malindi/Watamu – in other parts of the WSMP.

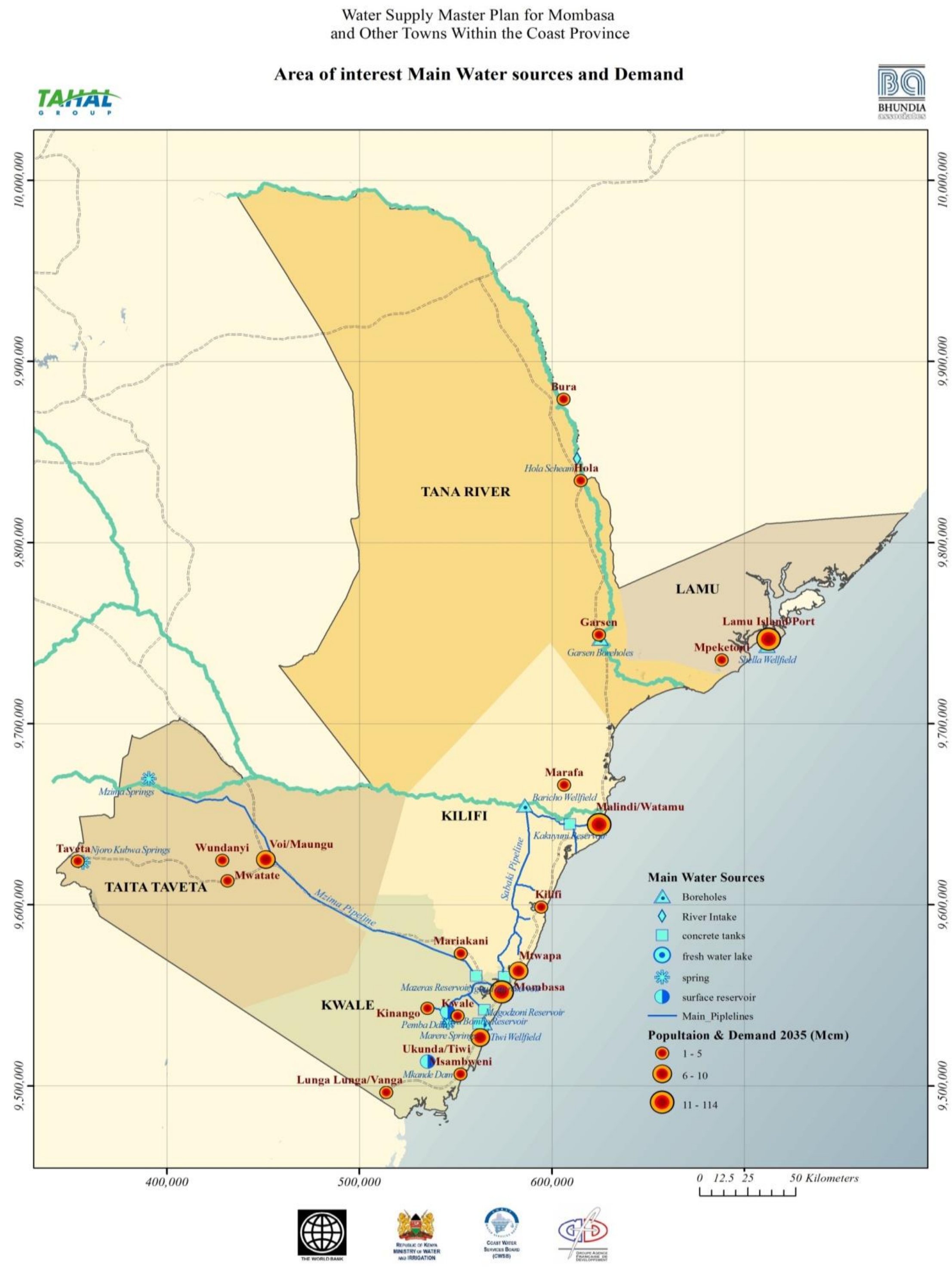


Fig. 6-2: Coast Province – main townships and urban centres

6.3 Water Demand Projection

6.3.1 Water Demand Projection for the Coast Province

Following the population projection calculation and the calculation of the per capita water demand (by class of residence, by IC and non-IC connection, and by percent of rural and urban distribution), the projected water demand for the province was calculated. A summary of the future water demand is presented in Table 6-4.

Table 6-4: Summary of Water Demand Projections (m^3/d) by County for Entire Coast Province
(based on MWI Standards)

County	2015	2020	2025	2030	2035
Mombasa	152,302	184,372	238,874	288,918	312,554
Kwale	50,535	59,566	76,769	90,701	119,910
Kilifi	84,597	103,160	133,443	159,856	210,047
Lamu	22,204	41,681	67,556	104,763	125,186
Tana River	25,194	29,492	36,981	43,486	55,739
Taita Taveta	29,411	34,430	42,789	50,366	63,817
Total	**364,243**	**452,701**	**596,413**	**738,090**	**887,253**

6.3.2 Water Demand Projection for the 20 Main Townships and Urban Centres

Water demand projections for the townships were calculated using several different coefficients (see Chapter 4 above for additional details). The primary calculation was based on current average consumption in each location. This was then compared to the water demand calculation using Ministry of Environment, Water and Natural Resources (MEWNR) design standards. To reach the overall demand, institutional consumptions were also calculated and added, based on current consumption and MWI design standards. On top of that, the demand of special purpose projects, such as Lamu Port and the commercial free zone, as well as industrial and livestock demands were also added to the above sum. Therefore, the total water demand forecasted is the sum of the following:

- Domestic water demand, including water losses in distribution systems
- Institutional and other public water demand
- Industrial demand
- Livestock water demand in the rural sector
- Water demand of mega-projects, as reflected in the development documents

An amount of 13,333 m^3/d was added to the projection for the years 2020, 2025 and 2035 as "On-Line Water Kiosk Demand", based on the methodology in Section 4.3.4 above.

The total water demand for each of the development phases was projected at two different levels – for the overall Coast Province population by county (see Table 6-4 above) and for the 20 target townships and urban centres (see Table 6-5).

The final water demand projections for the 20 townships are shown in Table 6-5.

Comparing the present installed capacities of the existing water sources in the Coast Province (see also Chapter 7 below), which stands roughly at some 145,000 m^3/d (not all of which is yet being exploited), to the projected demand for as closely as the year 2015 (some 260,000 m^3/d), it is clear that the immediate gap between the needs and the availability is massive. Closing current and future gaps will require a sizeable and long development effort with its consequential need for large investment of resources.

As expected, the total water demand projection for the entire province is greater than the total water demand forecast for the main townships and urban centres.

Table 6-5: Projected Water Demand for the 20 Main Townships and Urban Centres (based on MWI Standards)

	County	Urban Centre	Urban Water Demand (m^3/d)				
			2012	2015	2020	2025	2035
Southern Area (Mainland)	Mombasa	Mombasa	137,611	152,302	184,372	238,874	312,554
		Total Mombasa	**137,611**	**152,302**	**184,372**	**238,874**	**312,554**
	Kwale	Kwale	3,786	4,162	4,945	6,000	8,676
		Kinango	1,775	1,951	2,365	2,949	4,489
		Msambweni	1,976	2,171	2,665	3,252	4,809
		Ukunda/Tiwi	11,098	12,250	14,676	19,671	28,453
		Lunga Lunga/Vanga	4,761	5,230	6,445	7,903	11,709
		Total Kwale	**23,397**	**25,764**	**31,097**	**39,776**	**58,136**
	Kilifi	Mariakani	4,036	4,441	5,421	6,884	10,150
		Kilifi	5,167	5,686	7,090	9,014	13,240
		Malindi/Watamu	18,694	20,574	25,616	32,067	46,064
		Marafa	1,287	1,417	1,803	2,303	3,402
		Mtwapa	8,539	9,398	11,686	14,822	21,699
		Total Kilifi	**37,723**	**41,515**	**51,615**	**65,090**	**94,555**
	Taita Taveta	Taveta	2,972	3,573	4,265	5,121	7,228
		Mwatate	2,127	2,350	2,758	3,332	4,665
		Wundanyi	2,178	2,406	2,823	3,411	4,777
		Voi/Maungu	7,501	8,286	9,708	11,630	16,358
		Total Taita Taveta	**14,778**	**16,615**	**19,554**	**23,493**	**33,028**
Northern Area	Lamu	Mpeketoni	1,800	2,753	3,272	4,263	6,749
		Lamu Island/Port	2,500	15,815	34,190	57,805	109,811
		Total Lamu	**4,300**	**18,568**	**37,462**	**62,068**	**116,559**
	Tana River	Garsen	1,456	1,567	1,866	2,269	3,302
		Hola	750	1,246	1,524	1,558	2,707
		Bura	1,391	1,527	1,817	2,209	3,213
		Total Tana River	**3,597**	**4,340**	**5,206**	**6,036**	**9,222**
	Total Urban Water Demand: Southern Area		**213,509**	**236,196**	**286,637**	**367,233**	**498,273**
	On-Line Water Kiosk Demand		**–**	**–**	**13,333**	**26,666**	**40,000**
	Total Urban Water Demand: Southern Area + On-Line Water Kiosk Demand		**213,509**	**236,196**	**299,970**	**393,899**	**538,273**
	Total Urban Water Demand: Northern Area		**7,897**	**22,908**	**42,668**	**68,103**	**125,781**
	Total Urban Water Demand		**221,406**	**259,104**	**342,638**	**462,002**	**624,053**

7. Existing Water Supply Schemes

7.1 Background

Water supply and resources assessment was carried out for the Coast Water Services Board's region in Kenya. The region covers all six counties of the Coast Province. The purpose of the assessment was to ascertain the existing water resources and their future potential, as well as the water supply situation in the area, including the current schemes. This formed the basis of the study and development of the WSMP.

As mentioned earlier, the Coast Water Services Board falls within two WRMAs – Athi Catchment and Tana Catchment (see maps in Section II of Volume II of the WSMP):

- The Athi Catchment is bounded by the Athi, Galana and Sabaki rivers to the north and the Kenya–Tanzania border to the south. This covers the counties of Kwale, Mombasa, Kilifi and Taita Taveta.
- The Tana Catchment is bounded by the Sabaki River Catchment to the south and by the Tana River Catchment to the north. This covers the counties of Lamu and Tana River.

The Coast Province is located downstream of both catchments, and, therefore, it is essential to understand the development strategies for the catchment as a whole.

In the Athi Catchment, the estimated annual renewable fresh water availability was estimated to be 162 m^3 per capita in 2006, which indicates that the Athi Catchment is a seriously water-scarce area.

The Tana Catchment had an estimated annual renewable fresh water availability of 724 m^3/per capita in 1999. This value has declined to an estimated 387 m^3/per capita by 2006, which is considered, for semi-arid areas, to be at the lower level for water scarcity status.

The southern zone of the region is characterized by surface water scarcity in time and space, as well as high evapotranspiration rates, leading to heavy reliance on groundwater. In some areas in the south (Ramisi River, delta of Umba River), groundwater have already turned saline due to the nature of the geological formations, low recharge rate and over pumping without adequate control on pumping rate. Other challenges facing the groundwater in the region include seawater intrusion (due to high pumping rate over many years), pollution of groundwater due to inadequate sanitation infrastructure, poor management of domestic waste disposal, lack of control and supervision on contaminated activities (garages, fuel stations, etc.).

Data and information from various institutions were analyzed to obtain an overview of the existing situation in the area. Data and information regarding current production volumes, water demand, water supply coverage, and consumption volumes were obtained from the following institutions:

- Mombasa Water and Sewerage Company (MOWASCO)
- Malindi Water and Sewerage Company (MALWASCO)
- Lamu Water and Sewerage Company (LAWASCO)
- Kilifi-Mariakani Water and Sewerage Company (KIMAWASCO)
- Kwale Water and Sewerage Company (KWAWASCO)
- Taveta-Voi Water and Sewerage Company (TAVEVO)
- Tana Water and Sewerage Company (TAWASCO)

For this study, knowledgeable and resourceful persons who were used as key information sources include the following:

- District Area Coordinators (DAC)
- District Development Officers (DDO)
- District Commissioners (DC)
- Water Service Provider (WSP) Managing Directors
- WSP Technical Services Managers
- WSP Commercial Managers

The following townships are currently **unconnected to the BWSS**:

- **Taveta** township and the surrounding villages in Taita Taveta County, which are supplied with water from the Njoro Kubwa Springs
- **Mpeketoni** and **Lamu Island/Port** in Lamu County, which depend on the local Shella Aquifer
- In Tana River County:
  - The townships of **Hola** and **Bura**, which abstract water directly from the Tana River
  - **Garsen** township, which uses water from the Garsen Wellfield

The assessment of the existing water supply schemes was accordingly divided into two sections – schemes connected to the **BWSS**, and schemes providing water to townships unconnected to the BWSS, which will be referred to as **UCBWSS**.

Wherever relevant, the following water supply issues were also considered:

- Water scarcity
- Old infrastructure or low level of infrastructure development
- Inadequate storage facilities or lack of storage
- Groundwater salinity and seawater intrusion
- Decline in spring and river flows
- Water use conflicts
- Destruction and encroachment of water catchment areas

7.2 Existing Water Resources for the UCBWSS Townships

7.2.1 Njoro Kubwa Springs

The Njoro Kubwa Springs, which emerge from the Kilimanjaro Aquifer, surface in a pool beside the right bank of the Lumi River, at an elevation of +730 masl, about 3 km southeast of Taveta township. The group of springs includes two other springs – Njoro Ndogo 1 and Njoro Ndogo – emerging 100 m upstream of the main spring. The water flows downstream and eventually reaches Lake Challa.

From the Njoro Kubwa Springs, water is supplied to Taveta township, and is also utilized for irrigation of Sisal Estates.

Only sparse data on the yield of the Njoro Kubwa Springs is available. The estimated average flow of the springs, according to previous studies (Sincat-Atkins, 1996), is 5.6 m^3/s and the safe yield is 4.5 m^3/s (some 390,000 m^3/d), where the present abstraction of water is only about 3,000 m^3/d.

As the projected demand in the planning horizon year (2035) was estimated to be some 7,228 m^3/d, and the Njoro Kubwa Springs' safe yield is so much greater, it appears that there should be no difficulties whatsoever to meet the future water demand of Taveta township and the villages around the township from the Njoro Kubwa Springs.

7.2.2 Shella Aquifer

The Shella Wellfield located within the Lamu Island, supplies presently about 1,350 m^3/d. The wellfield consists of some 30 wells with a total approximate capacity of 1,800 m^3/d. Most of the wells are shallow, and seawater intrusion risk is high.

The Shella Wellfield is currently the only source of water for Lamu Island/Port. The Shella Wellfield is apparently the only fresh water source in the area as groundwater in other parts of the area are mostly saline, leaving Shella Wellfield as the only potential source for good quality water. The Shella Wellfield serves Lamu town, Gadeni, Manda Island and Shella village. It is obvious that the Shella Wellfield cannot meet the future demand of water in that region.

7.2.3 Mpeketoni Aquifer

The Mpeketoni Wellfield is the only source of water for Mpeketoni township. Five boreholes have been sunk into the Mpeketoni Aquifer. The boreholes contain hydrogen sulphide, which is easily treated by aeration. However, the water is also contaminated with e coli and general coliforms, which should be treated as well. The source of recharge to this aquifer is Lake Kenyatta. It is estimated that the amount of water that can be withdrawn from the aquifer, in a sustainable manner, is 1,000 m^3/d.

Lake Kenyatta water level has been slowly declining. It is estimated that, given the current intensity of pumpage, it is not likely to reach critical levels up to the year 2035, so that supply of water from the present boreholes is reliable. Furthermore, with the development of the new supply scheme to Garsen, the main supply source will be the regional BWSS, and, therefore, there will be less dependency on Lake Kenyatta.

7.2.4 Hindi Magogoni Aquifer

Five boreholes have been drilled in the Hindi Magogoni Aquifer. These boreholes jointly supply to local consumers 14 m^3/h (some 280 m^3/d assuming operation of 20 h/d), without negatively affecting the fragile aquifer or the environment.

The aquifer is about 12 km long and 2 km wide. The thickness of the aquifer is about 5–15 m. Saltwater interface was detected in the aquifer at a depth of some 20 m.

A previous study (Final Completion Report, C. M. Gicheru, September 2000) estimated the natural recharge of the aquifer to be about 1,600,000 m^3/y (on average, some 4,000 m^3/d). There is room for studious and cautious drilling of a considerable number of additional boreholes in this aquifer.

7.2.5 Tana River

The Tana River is the longest river in Kenya. The lowest flow (100% exceedence) measured in Tana River in the past 60 years was 8.5 m^3/s, and the sustainable flow (95% exceedence) was 43 m^3/s.

The flow regime in this river is highly fluctuating, with severe floods occurring every few years. These floods and heavy siltation pose engineering obstacles for building simple river intakes on the Tana River. In the past, river intake that was built to abstract water for Garsen was abandoned due to the heavy operational costs of the local WTP.

According to Vision 2030 and the WRMA Catchment Management Plan, a few medium-to-large-size reservoirs are to be built upstream of Garissa [namely, High Grand Falls (HGF)]. These reservoirs are expected to moderate the floods and siltation problems in the downstream areas, making the Tana River a more sustainable water source for Tana River and Lamu counties. However, there is no indication for execution of this project.

Presently, there are only a few intakes around the towns of Hola and Bura. The Tana Water and Sewerage Company (TAWASCO), which operates three schemes in the county, serves Hola township with water from the Tana River. The other schemes – Hola in Galole District, and Garsen and Ngao in Tana Delta District – are all local.

Hola township receives an average of 1,200 m^3/d of water from the company. There is an ongoing program funded by the World Bank to rehabilitate the system. This upon completion will inject an additional 1,200 m^3/d of water, which will only meet the demand up to the target year of 2030 (with projected demand of 22,352 m^3/d). Future water supply will rely on this source.

7.2.6 Garsen Wellfield

The township of Garsen in Tana River County receives water from both the Garsen Wellfields – three boreholes located in the Garsen Aquifer along the banks of the Tana River (Ngao Scheme), and a surface intake on the Tana River (Garsen Scheme). The Garsen Scheme supplies up to 250 m^3/d, and the Ngao Scheme supplies approximately 170 m^3/d. The installed capacity of the Garsen Wellfield amounts to some 50 m^3/h (some 1,000 m^3/d, assuming operation of 20 h/d). However, production in these boreholes is limited due to electricity failures

7.3 Existing Water Resources for the BWSS Townships

7.3.1 Baricho Wellfield

The Baricho Waterworks, located in Kilifi County, consists of eight boreholes with an approximate total potential yield of 83,000 m^3/d (8 boreholes of 470 m^3/h, with 22 h/d operation). The Baricho Waterworks abstract water from the Sabaki Aquifer, which is composed of the old Baricho River Channel (palaeochannel), underlying the present riverbed. This aquifer is mainly recharged from the Baricho River. In fact, the close location of the boreholes (differentiated into two groups – one with 5 boreholes and the other with 3 boreholes) to the riverbank, makes the palaeochannel act as a filter prior to the borehole pumps.

Several problems of rapid drawdown of the water level near the boreholes were reported during 2013, mainly after the first operation of the new borehole pumps, which were installed as part of the WaSSIP project. Although water levels were sustained, pumping rate should be carefully monitored in order to avoid what happened during February 2013, when rapid drawdown caused pumps to shut down.

The waterworks comprise the following components, as shown in Fig. 7-1:

- Eight boreholes, which are equipped with KSB electro-submersible pumps rated at 470 m^3/h. Total borehole production capacity (for 24 h/d operation) is therefore about 90,240 m^3/d. For 22 h/d operation, which is more likely the case, the total capacity is 82,720 m^3/d. However, according to the Monthly Report for Baricho for December 2012, the average production per day for the period August–December 2012 was only 68,046 m^3/d, corresponding to an average of 17 h/d of operation for each borehole.
- Each borehole is connected with a 16" pipe to the main manifold.
- The borehole water is pumped to a 2,000 m^3 contact tank at the site, where the water is chlorinated.
- After chlorination, the water flows into an attached 3,000 m^3 balancing tank.
- From the balancing tank, the water flows to a water sump, with a capacity of 3,000 m^3, from which the water is pumped directly to Malindi District in Kilifi County by a HLPS equipped with three deep-well turbine pumps (2 duty, 1 standby) running at 583 m^3/h, or at about 28,000 m^3/d.
- On the inlet pipe to the 3,000 m^3 sump, the water is pumped directly to Mombasa via the Sabaki-Mombasa Pipeline, using five vertical split-casing pumps (3 duty, 2 standby) running at 833 m^3/h, or at about 60,000 m^3/d.

The present HLPS is capable of pumping some 88,000 m^3/d (some 60,000 m^3/d to Mombasa, and some 28,000 m^3/d to Malindi). Therefore, the number of operational hours per day for each well could be immediately increased to approach at least the standard 22 h/d of operation. However, this would depend on the total water production from the boreholes.

Of the present total abstraction of 68,000 m^3/d, some 53,000 m^3/d is transmitted to Mombasa. The city of Kilifi receives its supply today from the Sabaki-Mombasa Pipeline as well (i.e., part of the 53,000 m^3/d). This conveyance to Mombasa can increase to 65,000 m^3/d if the wellfield operational hours are increased. This 65,000 m^3/d is also approaching the carrying capacity of the existing 800 mm pipeline (installed in 1982). Therefore, in the future, any additional transmission of water to Mombasa from this source would have to include not only additional boreholes and expansion of the HLPS, but also a new water conveyance system.

For Kilifi County, Malindi/Watamu and the other townships, the current supply, via a 600 mm pipeline, is about 15,000 m^3/d (today, two pumps can deliver some 583 m^3/h x 2 = 1,150 m^3/h). The total volume that can be conveyed to these townships can increase to 30,000 m^3/d if the wellfield operational hours are increased to yield some 1,500 m^3/h more than their current yield. Thus, this transmission pipeline to Kilifi County is capable of conveying even larger quantities (under good hydraulic conditions).

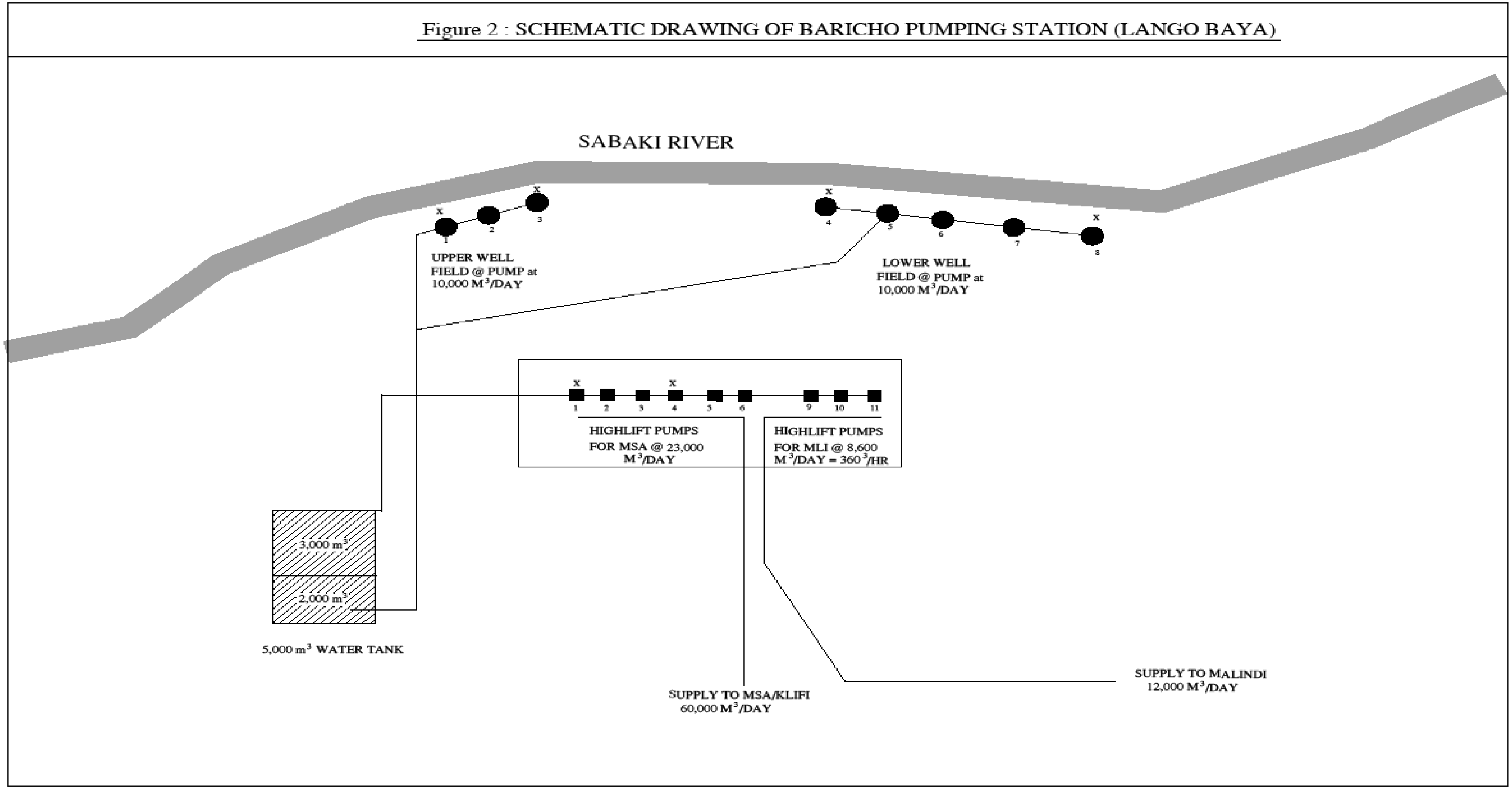


Fig. 7-1: Baricho Waterworks, current status, 2013

7.3.2 Mzima Springs

The Mzima Springs are located in Taita Taveta County, southwest of the Chyulu Hills in Tsavo National Park. The Mzima Springs outflow is a consequence of rainfall on the Chyulu Hills and percolating recharge over and through the volcanic mass overlaying the Chyulu Hills bedrock floor.

The springwater flows through three large pools (Hippo, Long and Chalk Beach pools) before discharging to the Mzima River some 4 km upstream of its junction with the Tsavo River. The three pools are in sequence and cascade one into the other (see Fig. 7-2 below).

Spring outflows have been measured at the Mzima River since 1951. A flow-duration curve is shown in Fig 7-3. From the figure, it can be observed that the maximum outflow measured was 5.9 m^3/s and the minimum 2.6 m^3/s ("100% exceedence flow"), the mean value being 3.6 m^3/s. Significantly, flows of less than 3 m^3/s have been recorded only once in 4 years, and, even then, merely in a few days of each year.

Changes of flow are slow from month to month, with the variation over any 12-month period about 1 m^3/s. The response-time between rainfall on the Chyulu Hills and outflow at Mzima is 3–4 years. Therefore, it is possible to predict spring flows in advance, with relative accuracy.

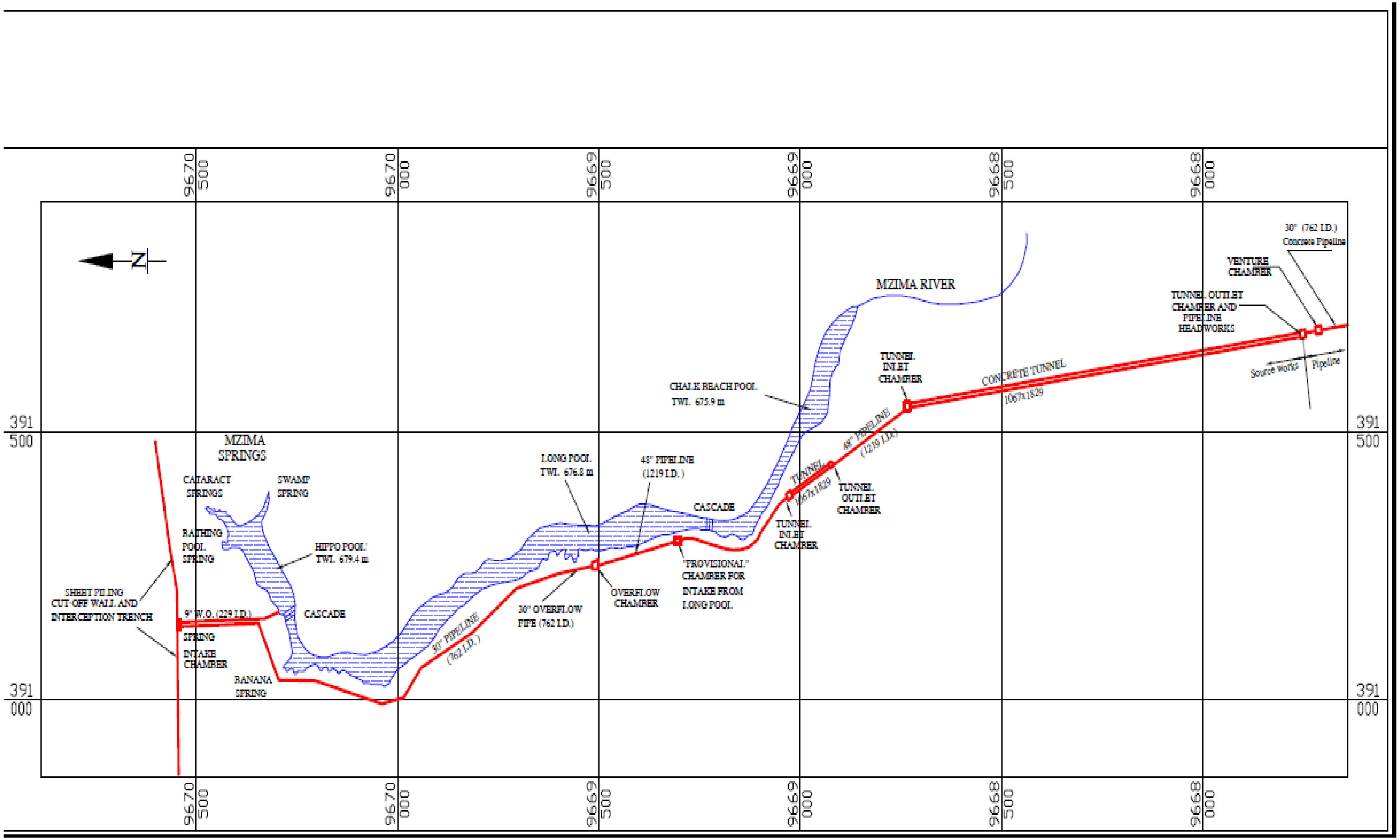
Construction of the existing headworks (named Mzima 1) was completed in 1956. The intake consists of a 672 m long subsurface weir, consisting of a sheet pile cutoff wall upstream of the Hippo Pool, having an elevation of 684.58 masl at the top. The sheet pile is emplaced at depth within the regolith loams for the full cross-section of the saturated lava; the regolith loams are regarded as having negligible permeability. The weir is connected with an upstream trench to divert the groundwater to a collection chamber.

Approximately 1.1 m^3/s gravitates from this intake to an overflow chamber located some 850 m from the head of the Long Pool, or some 1,300 m from the Collection Chamber. At the overflow chamber some 0.7 m^3/s is returned to the Mzima River system, and about 0.4 m^3/s is diverted to the Sabaki-Mombasa Pipeline. Excess water from the Mzima Springs flows over the top of the cutoff wall and discharges to the Hippo Pool and to the upper end of the Long Pool.

As it stands now, the total water released from the Mzima Springs to the Mzima River system is = {(the flow over the weir) + 0.7 m^3/s}. Therefore, the minimum amount released to the river system is {(2.6 – 1.1) + 0.7} = 2.2 m^3/s, where 2.6 is the minimum spring outflow. This is well in excess of the 1.4–1.6 m^3/s, which is the Minimum Allowable Environmental Discharge. Analysis of the flow through the headworks and pipe interception trench, upstream of the sheet pile cutoff wall, indicates that the present headworks might sustain the additional abstraction required, as indicated below.

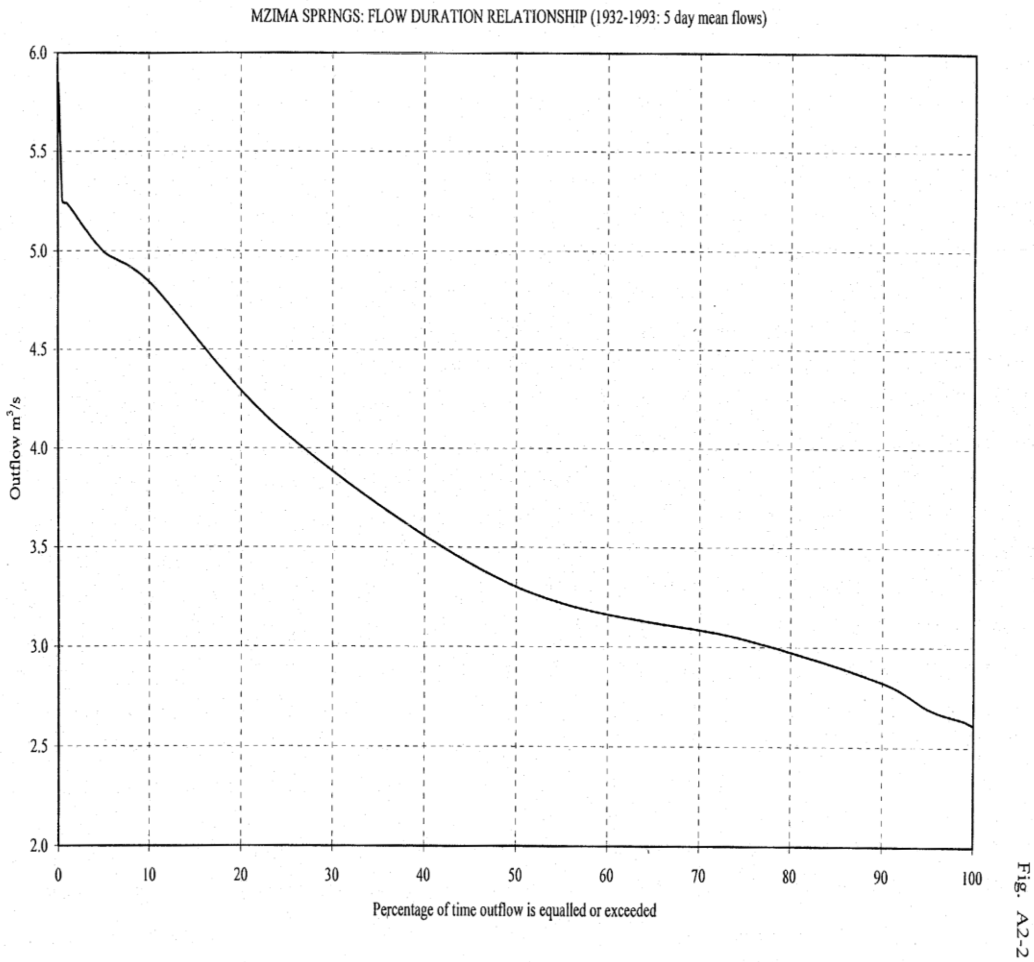
The total water abstracted from the Mzima Springs reaches Mombasa by gravity. The total distance along the pipeline route from the springs' intake to the Mazeras Water Tanks is 218.5 km, of which the headworks transmission line, consisting of pipelines and tunnels, is only some 3 km long. This resource is shared by several towns along the pipeline, in Taita Taveta (at present, only the township of Voi/Maungu is connected to the BWSS from the Mzima Pipeline), Kilifi and Mombasa counties (see Fig. 7-4). While the spring has a mean sustainable flow of 3.5 m^3/s, the current rate of abstraction is only about 0.4 m^3/s (equal to 35,000 m^3/d).

According to documents recently presented to the CWSB (Preparation of Investment Plan & Associated Feasibility Studies Feasibility studies/Identification of institutional support, BRL Ingenierie/GIBB Africa Ltd 2008), the current flowrate is limited by the capacity of the Mzima Pipeline. With the hydraulic study made along the pipe, it was found that there is a bottleneck that limits the conveyance to only some 35,000 m^3/d. According to this study, only some 70% of the total potential daily volume from the pipeline reaches the Mazeras Water Tanks, as the rest of the water is either lost, leakage or consumed by upstream consumers. The available supply to Mombasa has been declining over time due to the rise in demand in the upstream towns. Most of these demands are not metered, so it is impossible to evaluate this water abstraction and its trend. Current plans by the Taveta-Voi Water and Sewerage Company (TAVEVO) to abstract an additional 2,500 m^3/d of water from the Mzima Pipeline will further worsen the situation in Mombasa.



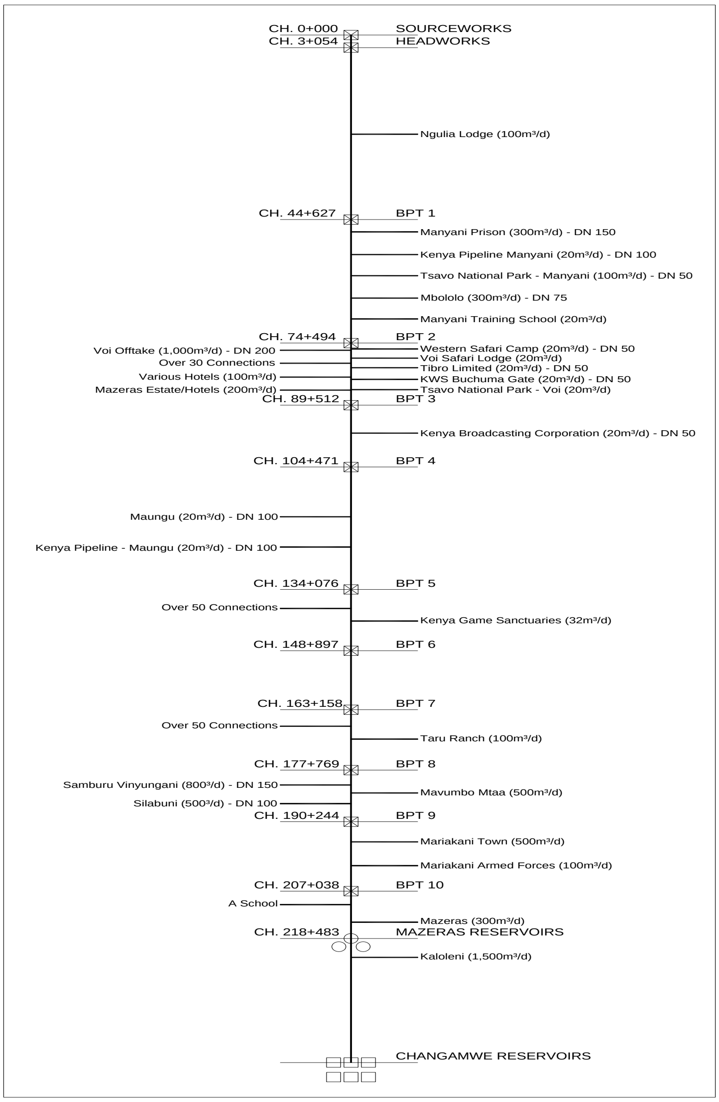
Source: The Second Mzima Pipeline – Alternative Engineering Designs, Sincat-Atkins, 1996

Fig. 7-2: Mzima Springs – existing waterworks and pools



Source: The Second Mzima Pipeline – Alternative Engineering Designs, Sincat-Atkins, 1996

Fig. 7-3: Mzima Springs – flow-duration curve



Source: Preparation of Investment Plan & Associated Feasibility Studies Feasibility studies/Identification of institutional support, BRL Ingenierie/GIBB Africa Ltd 2008

Fig. 7-4: Abstraction along Mzima Pipeline

7.3.3 Marere Springs

Marere Springs is located in the foot of the Shimba Hills Game Reserve in Kwale County. While the daily yield from these springs is 12,000 m^3, only 8,000 m^3/d is currently abstracted. The resource is shared by both Kwale and Mombasa counties. Some of the water is pumped from the pipe to the local supply system of Kwale District (to a local water tank). The current abstraction is limited due to the connecting 425 mm gravity pipeline, which limits the flow to about 350 m^3/h. Under the WaSSIP project, some segments of the pipeline, as well as the intake structure near the springs, are to be replaced and repaired. The available supply to Mombasa has been declining over time due to a rise in demand in Kwale County. The new Marere Pipeline will be part of the BWSS of the southern region, as it will convey water from the Mwache Dam to the Kaya Bombo Water Tank in the south, utilize the downstream section of the Marere Pipeline.

7.3.4 Tiwi Wellfield

The Tiwi Aquifer (known also as the Coastal Aquifer) is located in Kwale County, between the Ukunda and Ngombeni areas. There are 12 boreholes in the wellfields, with a total production of approximately 10,000–12,000 m^3/d.

The Tiwi Aquifer is shared by both Kwale and Mombasa counties. Some of the water is diverted to the Tiwi area and Diani Beach, while the rest flows to the Likoni neighbourhood of Mombasa. The Tiwi Wellfield is under massive rehabilitation activities at present, as part of the WaSSIP project. Within this framework, a renewal of all current equipment is being carried out, including the drilling of several new boreholes. These boreholes are located close to the current ones, within the same yard. The average flow of each borehole in this field is around 35–40 m^3/h, and the total actual abstraction can be as low as 8,000 m^3/d, due to operational difficulties.

The Tiwi Wellfield is divided into two groups of boreholes, as follows:

- The southern group, supplying water through the Magodzoni Water Tank, in which most of the water goes to the local villages, the Tiwi area and Diani Beach
- The northern group, supplying water through the Kaya Bombo Water Tank, in which most of the water is conducted to Mombasa via a 250 mm pipeline. It should be emphasized that this 250 mm pipeline supplies water up to Likoni District only.

The available water supply to Mombasa has been declining over time due to the rise in water demand in Kwale County, mostly due to the rapid development of the hotel industry in the Diani and Tiwi beach areas.

According to the Water Resources Report prepared by the Consultant, there is additional abstraction potential. The analysis indicates that additional wellfields may be developed south of Msambweni. However, in order to sustain the proposed yield of the two aquifers, a more detailed groundwater demand study is required. Such a study should be based on a monitoring plan that will serve as the basis for the analysis.

7.4 Present Installed Capacities

Table summarizes the present installed capacities of the main water supply schemes in the Coast Province.

Table 7-1: Present Installed Capacities

Water Source	Status	Installed Capacity* (m^3/d)	Remarks
Mzima Springs	Existing	35,000	
Marere Springs	Existing	8,000	
Baricho Wellfield	Existing	83,000	
Tiwi Wellfield	Existing	10,000	
Msambweni Aquifer	Under development	0	To be used by Base Titanium.
Mkurumudzi Dam	Detailed design	0	To be used by Base Titanium.
Mwache Dam	Detailed design	0	Only about 186,000 are reserved for water supply
Taveta Springs**	Existing	3,000	
Tana River	Existing	1,400	
Shella Aquifer	Existing	1,800	
Mkanda Dam	Existing	2,000	Used by local communities
	Total	**144,200+**	

* rounded numbers
** known locally as the **Njoro Kubwa Springs**

7.5 Additional Surface Water Potential

The Coast Province is abounding with surface water sources. Analysis of Mwache River and Rare River show that their mean annual flows are 120 and 190 MCM/y (average daily flow of 330,000 and 520,000 m^3/d), respectively. These rivers have very high potential for dam construction.

Analysis of the Sabaki River near the Baricho site shows a minimum flow (100% exceedence) of 2.6 m^3/s and a sustainable flow (95%) of 3.58 m^3/s. Current abstraction at the Baricho waterworks is only 1 m^3/s. Pumping an additional amount of 1 m^3/s will double the supply potential, and will still maintain a minimum flow of 1.58 m^3/s to the Sabaki River Delta.

Tana River is the longest river in Kenya. Analysis of the river shows a minimum flow (100%) of 8.5 m^3/s and a sustainable flow (95%) of 44.7 m^3/s. As the High Grand Falls project is expected to reduce turbidity and sediment loads in the river and moderate floods, the Tana River can constitute a highly viable potable water source.

Monthly and annual flows of 11 rivers draining to the Indian Ocean, marked A to K (see 4), were analyzed. These rivers have no streamflow records (calibrated and reliable) except for Basin H, which includes Mwache Hydrometric Station 3MA03.

Table 7-2 shows the calculated mean annual flows of the 11 rivers by basin (designated A–K).

Table 7-2: Calculated Mean Annual Flows (MCM/y)

Basin	A	B	C	D	E	F	G	H	I	J	K
River	*	*	*	Koromi	Rare	Ndzovuni	Kombeni	Mwache	Pemba	Koromi	Ramisi
Flow	34.9	27.1	228.7	70.5	191.7	27.0	19.1	119.8	21.4	29.1	6.5

* Basins without names

8. Proposed Water Supply Schemes

8.1 Background

In the present chapter, the design of the proposed water supply development schemes is introduced in a broad manner, without going into details. In Chapter 9 below ("Preliminary Design of the Proposed Development Schemes"), a more detailed description of the development schemes is presented.

The region's water resources vary in terms of intensity, location and availability over time. The huge area under CWSB jurisdiction, together with the variety in water resources, affect the utilization of the resources for different water supply schemes. Not all water schemes will be supplied from all resources, and, at the same time, some major water resources will not be connected to the BWSS. For example, the vast Njoro Kubwa Springs, located near Taveta township, will not serve the BWSS due to its remote location. One may ask the reason for not connecting this resource to the BWSS; this issue was indeed examined as part of the feasibility report of the WSMP. As a result, it should be noted that some water demand centres and townships will be supplied from the BWSS and thus will be connected to the main resources, while others categorized as UCBWSS will be supplied from local sources. The Lamu Scheme will be a special case, as it was declared as UCBWSS although the scheme will be supplied from a central water source, namely the Garsen water intake (120,000 m^3/d, including supply to Garsen and Mpeketoni townships).

For the horizon year, when all water resources will be deployed, 14 of the 20 townships will be connected to the BWSS, hence benefitting from the massive development. It is assumed that water availability for the BWSS connected customers will be 24/7. Table 8-1 maps all the consumers of the BWSS with the resources and matches each consumer with the specific source from which its water supply will be received.

The maps in Section II of Volume II of the WSMP present schematically the main water resources for the region, and indicate the water sources and the corresponding townships that can be potentially supplied by each source. Table 8-1 summarizes the above.

Table 8-1: Townships that can Potentially be Supplied from BWSS and non-BWSS Sources

County	Townships	Projected Demand 2035	BWSS					
			Baricho	Mzima	Marere	Tiwi	Mwache	Msambweni Aquifer / Mkurumudzi Dam
Mombasa	Mombasa	**312,554**	X	X	X		X	
Kwale	Kwale	8,676			X	X	X	X
	Kinango	4,489			X			
	Msambweni	4,809				X	X	X
	Ukunda/Tiwi	28,453				X	X	X
	Lunga Lunga/Vanga	11,709				X	X	X
Kilifi	Mariakani	10,150		X				
	Kilifi	13,240	X					
	Malindi *	36,851	X					
	Watamu *	9,213	X					
	Marafa	3,402	X					
	Mtwapa	21,699	X					
Taita Taveta	Taveta*	7,228						
	Mwatate	4,665		X				
	Wundanyi	4,777		X				
	Voi/Maungu	16,358		X				
			UCBWSS (unconnected to BWSS)					
			Njoro Kubwa Springs	**Shella Aquifer**	**Garsen intake**	**Hola intake**	**Bura intake**	
Taita Taveta	Taveta	7,228	X					
Lamu	Mpeketoni	6,749			X			
	Lamu Island/Port	109,811		X	X			
Tana River	Garsen	3,302			X			
	Hola	2,707				X		
	Bura	3,213					X	

* **Note:** Malindi and Watamu townships were considered to be a single urban centre – Malindi/Watamu – in other parts of the WSMP.

8.2 Proposed Water Resources for the BWSS

8.2.1 Baricho System

The Baricho Waterworks are based on eight boreholes, which are equipped with KSB electro-submersible pumps rated at 470 m^3/h, with a total potential daily production of 90,240 m^3/d.

A major extension is proposed for the Baricho site throughout the development plan up to the horizon year. In order to address the water demand and the infrastructure development for water transmission, it is recommended to develop water production facilities in two phases – Immediate Phase and Phase II – while the installation of pumping equipment will also be done in Phase III where additional water demand will be needed. Generally, it is proposed to extend the total water production using two main borehole pumping methods:

- For the Immediate Phase – installation of two additional vertical-type boreholes similar to the current units and to utilize the existing delivery pumps with no change in the current delivery arrays.
- For Phase II – installation of a new type RHC-type borehole with a higher capacity per borehole. In Phase II, the total additional daily water production will be 90,000 m^3/d, for a total production of 175,000 m^3/d.

For supply improvement during the Immediate Phase (2014-2015), two new boreholes will be drilled and installed. They will produce approximately 470 m^3/h at 20 h/d, for an additional amount of 20,680 m^3/d.

At the end of Phase II, most of the production load will be carried by the new borehole pumps, while the existing borehole pumps will carry less of the production load than they carry today. Furthermore, it should be noted that in 2025, the time benchmark for Phase II, the borehole pumps installed in 2012 under WaSSIP will be 13 years old, and may be less efficient at that time. Thus, there is a strong recommendation that around 2022–2023 the entire pumping array will be re-evaluated, in order to set strategy for the rehabilitation of the old pumping equipment (rehabilitate or replace with new RHC-type).

Groundwater abstraction for the future development of the Baricho Wellfield considers the construction and installation of five RHC-type boreholes. Each RHC-type borehole consists of a central shaft with several horizontal collector wells drilled into the aquifer of the palaeochannel. Groundwater will be drawn into the central collector shaft caisson through radial horizontal well screens, where it will be pumped to a ground-level chlorination tank and balancing tank. This type of well can achieve extremely high yield by penetrating horizontally to the most conductive layer of the aquifer. The proposal is to add a total daily volume of 90,000 m^3/d, for a grand total of 175,000 m^3/d.

Table 8-2 below summarizes the total production of water as designated to the horizon year after full development of the Baricho Wellfield.

Table 8-2: Baricho Wellfield Production to End of Phase II

Production Period	No. of Boreholes	Borehole Type	Capacity per Borehole (m^3/h)	Duty Cycle (h/d)	Production (m^3/d)	Comment
Current 2013 – potential	8	vertical	470	22	82,720	
2015, after immediate works	8 + 2	vertical	470	8 x 22 2 x 22	102,720	Adding ~20,000 m^3/d for Mombasa
2025, end of Phase II	10	vertical	470	(8 + 2) x 18	84,600	Total production: **174,600**
	5	RHC	900 **	5 x 20	90,000	

8.2.2 *Mwache Multipurpose Dam*

The proposed Mwache Multipurpose Dam on Mwache River has a potential of supplying 220,000 m^3/d of water upon construction. According to the Coast Development Authority (CDA), the water will be used to augment Mombasa's water supply as well as for irrigated agriculture. About 80% of the water from the dam, or some 186,000 m^3/d is destined for water supply, which will dramatically improve the water supply to the city of Mombasa. Therefore, the Government of Kenya selected Mwache Dam to be a flagship project as part of Vision 2030.

The Ministry of Regional Development Authorities (MoRDA) awarded Consulting Engineering Services (India) Private Limited (CES), in association with APEC Consortium Ltd., the assignment of carrying out the feasibility study and detailed design for the Mwache Multipurpose Dam Development Project. The study commenced in June 2010 and is currently in its final stages. It was also agreed that the MoRDA project will include the reservoir soil works as well as the WTP, so that the CWSB will receive potable quality water in the holding tank.

The dam is located some 5 km from the Mazeras Water Tanks and a few kilometres before the river drains into the Indian Ocean at Port Reitz. It was initially designed to a height of 85 m above ground level, with a gross capacity of 200 MCM and dead storage of 4 MCM. After discussions with World Bank experts, the dam height was lowered to 65 m above ground level, with a gross capacity of 120 MCM and dead storage of 20 MCM.

8.2.3 Mzima System

The Mzima Springs source is a key source for the Mombasa water supply. The current yield of the spring represents some 25% of all available water resources in the region (35,000 m^3/d out of 145,000 m^3/d) and more than 40% of all supplied daily volume to the city of Mombasa. Yet the system has become old with the years. From year to year, less water is available to Mombasa due to various reasons, among them pipe leakages and unauthorized water consumption by communities located alone the pipeline.

The age of the existing Mzima Pipeline should be considered, as the pipeline was laid in the late 1950s and is about 60 years old at present. The pipeline is of a locally manufactured prestressed concrete gravity pipeline and ranges in diameter from 30" (upstream) to 21" (downstream) (i.e., from DN 760 to DN 530). The total distance along the pipeline route is 215 km. Together with the 3 km source works tunnel, the distance along the pipeline to the Mazeras Water Tanks is 218 km; half of the pipeline is laid within the Tsavo National Park. Pipeline pressures are controlled by 10 break-pressure tanks.

With the consideration of the Mzima 2 Pipeline as part of the development plan, it was assumed that the current Mzima Pipeline will not be able deliver water after the year 2025 (at that time, the pipe age will be 65 years). It was assumed that the new Mzima 2 Pipeline will be constructed to meet the full daily abstraction from the spring.

The WSMP calls for the increase of the supply to Mombasa from Mzima Springs from the present 0.4 m^3/s (34,560 m^3/d) to 105,000 m^3/d (1.22 m^3/s) starting from year 2030. By 2030, the current pipe will be over 65 years old and will have passed its useful and efficient lifespan. This calls for laying of a new pipeline (Mzima 2). The new Mzima 2 Pipeline will have to deliver the total required daily volume of 105,000 m^3/d.

For such an increase in supply, the existing 1,300 m, 30" (762 mm) pipeline, between the intake and the overflow chamber, will have to be replaced as well with a new 48" (1,219 mm) pipeline. This replacement will allow the capacity of the Mzima Waterworks to increase to 1.5 m^3/s, well above the 1.22 m^3/s supply required by the plan, and will leave an additional 0.28 m^3/s to be released from the overflow chamber to the Mzima River system. The total proposed water abstraction from the Mzima Pipeline to the downstream consumers, with a total daily volume of 105,000 m^3/d (an additional 70,000 m^3/d) requires full coordination with the WRMA of the Athi River Authority so the CWSB water allocation will be approved.

In addition to Mombasa city, the new Mzima 2 Pipeline will also serve the townships of Voi/Maungu, Mwatate and Wundanyi. Additional consumers along the Mzima 2 Pipeline will consume some 35,000 m^3/d (including Mariakani), allowing Mombasa to enjoy some 54,000 m^3/d from the Mzima Springs.

8.2.4 Tiwi and Msambweni Wellfields (Coastal Aquifer)

According to the Water Resources Report prepared by the Consultant, the groundwater potential determined for the aquifer in the Tiwi and Msambweni areas are approximately 20,000 m^3/d (7.5 MCM) and 30,000 m^3/d (11 MCM), respectively. The analysis indicates that additional wellfields may be developed south of Msambweni. However, in order to sustain the proposed yield of the two aquifers, a more detailed groundwater demand study is required. Such a study should be based on a monitoring plan that will serve as the basis for the analysis.

It should be noted that much of this potential in the Msambweni area is not utilized today because of the presence of the titanium mine in the area. The water from the Msambweni Aquifer will be incorporated in the BWSS only towards the horizon year (2035), when the mining activities will be finished.

Fig. 8-1 shows the boundary of the Tiwi and Msambweni aquifers and the current location of the existing boreholes. Future additional borehole locations will be determined following completion of the aquifer study with regard to the annual replenishment, salt intrusion boundary and the sustainable annual yield. It is recommended that each borehole will have a capacity similar to those of the existing Tiwi boreholes (~60-65 m^3/h) in order to avoid rapid drawdown in water levels while pumping.

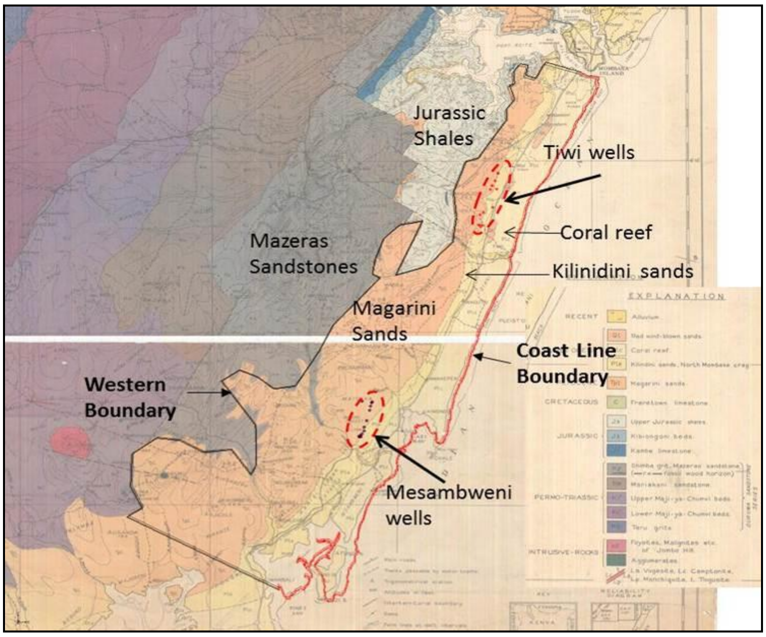


Fig. 8-1: Boundaries of Tiwi and Msambweni aquifers

For purposes of the WSMP water balance, it is recommended that the supply from the Tiwi and Msambweni aquifers to the BWSS will be 13,000 m^3/d (4.7 MCM/y) and 20,000 m^3/d (7.5 MCM/y), respectively, until further investigation of the sustainable yield of these aquifers is conducted.

8.2.5 Mkurumudzi Dam

The Mkurumudzi River originates in the Shimba Hills and flows southeast to the Indian Ocean. It drains a catchment area of about 200 km^2, and recharges the Coastal Aquifer in the Msambweni area.

The purpose of the Mkurumudzi Dam, which is being built on the Mkurumudzi River, is to supply water for the new titanium mine owned by the Australian company Base Titanium. The quantity of titanium in the mine is assumed to suffice for 15 years of mining operations. During this period, the water from the Coastal Aquifer in the Msambweni area and from the Mkurumudzi Dam will not be available for water supply to other consumers in the area.

The main parameters of the Mkurumudzi Dam are as follows: [2]

- Purpose: Mining
- Catchment area 125 km^2
- Gross storage 8.0 MCM
- Flooded area 140 ha
- Daily yield (min/max) 19,000/28,000 m^3/d
- Annual yield (min/max) 6.94/10.22 MCM/y

8.2.6 Umba River

For the southern region of the CWSB, several local water resources were examined to be utilized as part of the regional water resources. Out of the 11 basins in the region that were investigated, three – Pemba, Ramisi and Mwena – are in the southernmost portion of the southern region. All the sources were found to be small and limited in production. The biggest of all those resources is the Umba River. In considering the catchment basin of the river, the Consultant observed that the major part of the basin is located in Tanzania, where, in any event, the CWSB has no control on the activities and the protection of the watershed and the flows in the basin. Therefore, as pollution of the surface water can occur in any time, it is strongly recommended that this kind of water source not be part of the potable water resources for the BWSS. That is why the proposed design in the WSMP is not to utilize the Umba River as a resource, but rather to connect the southern township of Lunga Lunga/Vanga to the BWSS during Phase III.

[2] Borehole and Completion Report, Msambweni Area, Kwale, South Coast, Tiomin Resources Inc., June 2005

8.2.7 Potential Production

Table 8-3 summarizes the potential production of the main water supply resources in the Coast Province.

Table 8-3: Future Potential Production in the Coast Province

Water Source	Status	Potential Production* (m^3/d)	Remarks
Mzima Springs	Existing	105,000	
Marere Springs	Existing	12,000	
Baricho Wellfield	Existing	180,000	
Tiwi Wellfield	Existing	15,000	
Msambweni Aquifer	EPC contract	20,000	To be used by Base Titanium.
Mkurumudzi Dam	Detailed design	19,000	To be used by Base Titanium.
Mwache Dam	Detailed design	220,000	Only about 186,000 m^3/d are reserved for water supply
Rare Dam	Feasibility study	200,000	Was not recognized as an attractive water source for development
Njoro Kubwa Springs	Existing	100,000	
Tana River	Existing	Relatively unlimited	
Shella Aquifer	Existing	N/A	
Mkanda Dam	Existing	5,900	Used by local communities
Desalination	–	N/A	Economic and environmental limitations
Deep groundwater	–	N/A	
	Total	**876,900 +**	**Without desalination, Tana River and deep groundwater**

* rounded numbers

8.3 Proposed Water Resources Development by Counties

8.3.1 Overview

Under the new constitution in Kenya, more power was given to the counties in order to decentralize the authority of the National Government. Therefore, it is required to present the development of the BWSS not only by time sequence, but also by county (see Table 8-5 in Section 8.3.8 below). This table will support decision-makers and key persons from the county administrations to be aware of the development activities that will take place in their area of jurisdiction.

Although the table summarizes the water resources development for each county, one must bear in mind that water resources does not only supply water to the consumers in the vicinity of the source. The Coast Province of Kenya is characterized by large distances between the centres of water demand (mainly in Mombasa and along the coast) and the origin of the water resources. Thus, the discussion on the development of water resources per county will have no meaning without connecting those resources via transmission mains to the places where the demand exists.

The "Water Resources Matrix" (as requested by the CWSB in the comments documents dated 06.2014) presents the linkage between resource location, proposed development (time of development and intensity of water production), supply scheme that will be supplied from the source and time for implementation, according to the phase of development. Please refer to the Water Resources Matrix presented as Table Exec-7 in the Executive Summary. The information in this table is also presented in Table 8-5 in Section 8.3.8 below

Sections 8.3.2–8.3.7 below summarize the development by county.

8.3.2 Mombasa County

The city of Mombasa, the major water demand centre for the CWSB, does not have any water sources that are located within the city boundary. All water supply to Mombasa will be supplied from various sources and through several transmission mains.

The city has three major water tanks – Chamgamwe Water Tank, Nguu Tatu Water Tank and Mazeras Water Tank. All the water will be supplied to water tanks and from the water tanks to the city distribution network.

8.3.3 Kwale County

8.3.3.1 Overview

Within Kwale County, several new water resources and schemes are proposed:

- During Phase I – Mwache Dam
- During Phase III – Further development of Msambweni Wellfield and the Msambweni Scheme

8.3.3.2 Mwache Dam

Under the proposed development plan, a new dam will be constructed on the Mwache River, some 3 km upstream of the river delta near Port Ritz in Mombasa Bay. The height of the dam is planned to be some 65 m, and the total capacity of the storage reservoir is 140 MCM. According to the agreement between the CDA and the CWSB, a total daily volume of 186,600 m^3 of water will be dedicated to the potable water system and will be distribute through three main supply lines, unlike the original supply scheme of the Mwache Dam. The current WSMP recommends that Mwache water be supplied not only to Mombasa, but also to the southern area (Kwale County), improve supply to Tiwi and Msambweni area and – in Phase III – even to the remote township of Lunga Lunga/Vanga, where there is severe stress on water availability today.

The waterworks will comprise three major components:

- The dam
- The water treatment plant
- The delivery pumping station and the main pressure pipelines

For the transmission pipeline and the pumping set for each scheme, please refer to the preliminary design in Chapter 9.8 for further details. In brief, the total daily water and hourly water volume that will abstracted from the reservoir to the target areas are presented in Table 8-4.

Table 8-4: Summary of Mwache Dam Water Supply Scheme

	Unit	South Supply	+120 NMT	Chamgamwe Supply
Total daily delivery	m^3/d	69,200	69,200	48,200
Total hourly operation	h/d	16 *	16	16
Total hourly capacity	m^3/h	4,320	4,320	3,000
Pump configuration	No. x m^3/h	(5+1) x 865	(5+1) x 865	(5+1) x 600
Water supply to:		South scheme	New Mwache Tank	Mombasa Island through Chamgamwe
Cumulative volume	m^3/d	69,200	138,400	186,600

Important points to note are:

- The dam and the dam piping will be built to their full size from phase 1 under the CDA project. Coast water service board will not be the owner of the reservoir thus does not budget it.
- The WTP construction will be under the responsibility of the CWSB and budgeted within this master plan.
- The pumping house will be built for its full dimension parallel to the construction of the dam and the WTP. Pumping installation piping and accessories will be installed gradually in order to meet the demand and to ease on investments at the time of construction. (Please refer to Section 9.8 below.)
- The supply pipelines will be constructed according their final diameters.
- The order of implementing the transmission pipes should be consider separately: In order to supply water to Mombasa as soon as possible after the dam, WTP and PS are completed, the connection between the Mwache and the new NMT at +120 m masl should be executed. In addition, the supply to the north mainland of Mombasa where current water consumers are supplied from the Nguu Tatu Water Tank, the completion of the transmission main connecting the NMT at +120 m masl to the Nguu Tatu Water Tank (+70 masl) is essential. By completing this infrastructure, Mombasa city will be able to benefit from Mwache water in all subareas.

8.3.3.3 Tiwi and Msambweni Wellfields

For the second phase of development, the Tiwi and Msambweni wellfields will be extended in order to support the increasing water demand in the southern region. The Tiwi Wellfield is a key water source in the region today. According to the proposed water resources development plan, the water abstraction will be increased from 12,000 m^3/d (total of 12 boreholes) to some 13,000 m^3/d. The water is pumped from the wells to the Kaya Bombo Water Tank, with a current volume of 1,500 m^3. The Kaya Bombo Water Tank will be extended in the future to 10,000 m^3 by building a new water tank attached to the existing one. The new water tank will receive water also from the Mwache Dam via the Mwache-Kaya Bombo Pipeline (diameter 800 mm, length 22 km).

8.3.3.4 Msambweni Supply Scheme

During Phase III, the Msambweni Aquifer and the Msambweni Scheme will be included in the development plan for Kwale County. The Msambweni Waterworks will include the Msambweni Water Tank (5,000 m^3), the connection main pipeline between Ukunda and Msambweni and the South Scheme, extended from Msambweni to Lunga Lunga/Vanga. Although found to be one of the most expensive schemes in the BWSS, the current situation of water availability in the extreme south is very poor while the demand projection for the region is calculated to increase dramatically(mainly due to the hotel industry development). That is why the Consultant recommends that in Phase III of the development plan, when water availability will improve, the southern region will be connected to the BWSS.

For the above purpose (both Phase II and Phase III), the following infrastructure will be needed (all fall within Kwale County):

- Improving the equipment and the operation of the Tiwi Wellfield
- Drilling new boreholes in the Msambweni Aquifer and installing borehole pumps. This should be done only after investigation of the local aquifer as recommended in Section 3.3.4 above.
- Extension of the Kaya Bombo Water Tank to 10,000 m^3.
- Construction of the Tiwi-Ukunda Pipeline, Ukunda-Msambweni Pipeline and lastly the Msambweni-Lunga Lunga/Vanga Pipeline
- Construction of the regional water storage facility at Msambweni, with a 5,000 m^3 water tank
- Construction of the Msambweni booster pump to supply to southern Lunga Lunga/Vanga with a capacity of 170 m^3/h and TDH of 160 m
- Share the development and the construction of the Mwache-Kaya Bombo water supply line (800 mm, 22 km length)
- Several additional pipelines connecting Tiwi to Kaya Bombo and connecting Likoni (neighbourhood in Mombasa)
- Rehabilitation of the Marere Pipeline (currently 450 mm) to 500 mm pipe between the Marere Springs and the Chamgamwe Water Tank (some segments are already under rehabilitation under the WaSSIP program)

8.3.4 Kilifi County

Baricho Waterworks is the main water source in Kilifi County, serving the Kilifi townships as well as Mombasa. The current production from the Baricho Wellfield is some 68,000 m^3/d. Out of this, some 53,000 m^3 supplies Mombasa through the Sabaki-Mombasa Pipeline to the Nguu Tatu Water Tank and to Mombasa. Yet, even from this 53,000 m^3 /d, a certain amount is consumed by other townships connected to the Sabaki-Mombasa Pipeline, so the real supply to Mombasa is even less. Two key parameters characterize the current Baricho Waterworks production:

- By adding some operation hours, more water can be abstracted with the existing equipment, extending the total daily production to 80,000 m^3/d with no additional infrastructures.
- The 600 mm Malindi supply line convey today some 15,000 m^3/d with hourly flow of 625 m^3/h. The pipe can convey today nearly double this figure, i.e., additional supply toward Malindi is possible without adding new pipe.

For the two reasons above, the Consultant recommends that the Baricho extension be part of the Immediate Phase of development, for improvement of supply to Mombasa.

The Baricho water source and its associated infrastructures holds major potential for the Kilifi County townships. When the Mwache Dam will be in operation and supply water, Mombasa will be less dependent on Baricho water, thus leaving more water potential to the Kilifi townships.

Four major elements will be implemented in Kilifi County during the Immediate Phase and Phase II:

- Drilling two new boreholes identical to the current borehole types in Baricho and connecting the boreholes to the existing manifolds
- Upgrade the 400 mm section of the Sabaki-Mombasa Pipeline near Nguu Tatu Water Tank to 600 mm to enable easier flow of water to the tank (ease the existing bottleneck in the pipe)
- Laying the new 20" 50 km Kilifi line to supply Kilifi direct from the Malindi line
- Construction of the new Kakuyuni Water Tank to 2,500 m^3 in volume to support both future supply to Malindi (by gravity), Kilifi (by gravity) and Marafa (pumping via Marafa booster pump).

During Phase I, no further work is proposed in Kilifi County.

During Phase II, the gradual extension of the Baricho site is proposed. Within this phase, three major works will have to take place, enable the Baricho water work to achieve total daily water production of 174,600 m^3/d, the second biggest water facility for the CWSB. New type of borehole is proposed to installed in the site, called RHC (radial horizontal collectors). Prime evaluation of the RHC shows that the overall capacity of each shaft will be some 900 m^3/h. a total number of 4 RHC will be installed in the site. At the time, it is recommended that the current vertical pumps will be examined for their efficiency in order to consider additional RHC-type boreholes instead of the vertical ones (that will be 10 years old at that time).

The delivery pumping station will change its current function. A new pumping station will be built in order to accommodate the future housing for the Malindi (and Kilifi) supply. The existing pump of the Malindi Pipeline will be removed to the new pumping station leaving more space for the future additional pumps to Mombasa. At the end of this phase, there will be two pumping stations at the Baricho site, each one comprising of a separate pumping array.

The third component will be the second Sabaki Pipeline. This line will be able to deliver some 2,500 m^3/h a total daily volume of 55,000 m^3/d to extend the Mombasa supply. Additional water supply will be provided to consumers along the way, e.g., Upper Ribe and Lower Ribe pressure zone consumers.

One should note that because of the increasing water demand between Phase II and the horizon year, it is recommended that the delivery pumps for both Mombasa and Malindi/Watamu be installed during the 2025–2035 period, as the demand will steadily increase. In the preliminary design, (see Section 9.10 below), the Baricho works are subdivided into stages A–D, each one includes the additional delivery capacity required so that the operation of the facility will best meet demand.

8.3.5 Taita Taveta County

Two major springs exist in Taita Taveta County – Njoro Kubwa Springs and the Mzima Springs:

The Njoro Kubwa Springs are located near Taveta township and far beyond any other township in the county. After analyzing several supply options to Taveta township it was concluded that only Taveta township will be supplied from the local spring, while Mwatate, Wundanyi and Voi/Maungu will be connected to the BWSS through the new Mzima 2 Pipeline.

The Taveta water intake, booster pump and the force main pipe transmit the water to the local distribution system will be deployed in Phase I. It is recommended that the intake and the pipe will address future demand in Taita Taveta County, calculated to be 7,228 m^3/d.

Subject to the availability of budget during the Immediate Phase, the rehabilitation works in the Njoro Kubwa Springs will be executed in their entirety, with no further construction required in later phases.

The Mzima 2 Pipeline is addressed to be developed during Phase III. According to the water balance, some additional 70,000 m^3/d will be abstracted from the spring and transmitted toward urban use in Mwatate, Wundanyi, Voi/Maungu and others consumers along the way. Under the assumption that the existing Mzima Pipeline will no longer be able to convey water around 2025, it is recommended that the Mzima 2 Pipeline will deliver a daily amount of 70,000 m^3/d +35,000 m^3/d, for a total daily amount of 105,000 m^3/d (1.215 m^3/s). This abstraction still needs to be coordinated and agreed to by the KWF, as the additional abstraction of water compared to the current yield will reduce the water flow to the Mzima River. Some extensions will be required in the headworks where the current water tunnel (made of concrete) found to be adequate for the future flow, but the connecting pipe of 36" will have to be replaced and extended to 48".

Lastly, for the Taita Taveta County the connection of Voi/Maungu, Mwatate, and Wundanyi to the BWSS will be executed. It is strongly recommended that this extension of the supply to the remote location of Mwatate and Wundanyi will be constructed after the operation of the Mzima 2 Pipeline, so an additional amount of water will be available at the Voi Junction, thus not affecting the supply to Mombasa.

8.3.6 Tana River County

As proposed in the WSMP, the Lamu area will be supplied form a central water supply scheme although disconnected to the BWSS. The relative distance of the Lamu area from the current water resources and the existence of the Tana River – the largest river in Kenya – on the boundary of the county, cause the calculation to show very clearly that the most viable option for the Lamu Scheme is to abstract water from the Tana River at Garsen and transmit the water via a 78 km pipe line (1,200 mm 48" diameter). The entire water supply scheme is recommended to develop during Phase II due to the plans of the major development in the Lamu Port and attached project. The proposed water supply scheme will be also supply the Mpeketoni township community and the Garsen township located near to the riverbanks.

Calculation of the required pressure to force the water to the 78 km pipe showed that the TDH of the delivery pumps will be some 240 m, while the nearby Mpeketoni and Garsen schemes can use 40–50 m of discharge pressure. That is why the pumping station for the Garsen intake will be divided into two pump arrays. For further details on the Garsen intake and the Lamu Scheme, please refer to Section 9.11 below.

An additional two local water supply schemes will be developed within Tana River County – Hola and Bura. Both will be local supply without any interface with any other potable water scheme.

8.3.7 Lamu County

No water resources to develop within this county.

8.3.8 Summary

Table 8-5 on the following pages presents the required developments by county.

The information in this table also appears in Table Exec-7, broken out by phase of development.

Table 8-5: WSMP Water Supply Development Matrix (by county)

Source	Proposed Water Production (m^3/d)	Supply Scheme and Pipeline Connected	Required Infrastructure
Kwale County			
Mwache Dam (Phase **I**)	• Full abstraction of 186,400 m^3/d for the CWSB potable water allocation for the BWSS • This includes construction of: - 65 m high dam + the outfall - WTP - PS for water delivery	• Three main supply schemes: • NMT Scheme - Supply to NMT with connecting pipe, 1,000 mm/40", 4.5 km - Connecting NMT to Nguu Tatu Water Tank, 1,000 mm/40", 35 km • Chamgamwe Scheme - Supply to Chamgamwe Water Tank, 700 mm/28", 15 km • Kaya Bombo Scheme: - Supply to Kaya Bombo Water Tank, 800 mm/32", 22 km - Connecting Kaya Bombo with Tiwi Pipeline, 500 mm/20", 20 km - Connecting Likoni, 500 mm, 11 km	• Construction of the pumping array at the Mwache PS: - Pumps to +120 NMT, 5+1 units, 865 m^3/h, 110 m TDH - Pumps to Chamgamwe Water Tank, 5+1 units, 600 m^3/h, 65 m TDH - Pumps to Kaya Bombo Water Tank, 5+1 units, 865 m^3/h, 70 m TDH • Construction of new water tanks: - Tank at the WTP outfall, 20,000 m^3 - New Mwache Tank (NMT), 20,000 m^3 - Kaya Bombo Water Tank, 10,000 m^3
Msambweni (Phase III)	• Develop Msambweni Wellfield to 20,000 m^3/d and connect to the BWSS • Drilling new deep boreholes after aquifer investigation	• Connecting Tiwi to Msambweni and Ukunda and further south: - Replacing current 250 mm/10" Tiwi-Msambweni Pipeline with new pipeline, 500 mm/20", 35 km - New Msambweni-Lunga Lunga Pipeline, 300 mm/12", 46 km	• New Msambweni Water Tank, 10,000 m^3 • New booster pump for Lunga Lunga/Vanga supply, 170 m^3/h, 160 m TDH
Kilifi County			
Baricho (Immediate Phase)	• Additional production of 20,000 m^3/d by adding two vertical type boreholes	• Rehabilitation of 600 mm pipe segment in Sabaki-Mombasa Pipeline, 800 mm/32", 12 km, PN 8 • Construction of Kakuyuni-Kilifi Pipeline, 500 mm/20", 51 km • Construction of Gongoni-Malindi Pipeline, 300 mm/12", 25 km	• Works under additional WB & AFD financing for "emergency works to improve supply to Mombasa" • New Kakuyuni Water Tank, 2,500 m^3 • New Kilifi Water Tank, 5,000 m^3 • New Gongoni Water Tank, 1,000 m^3
Baricho (Phase **II**)	• Development of additional 75,000 m^3/d abstraction to total yield of 175,000 m^3/d (80,000 m^3/d at 2013 + 20,000 m^3/d for Immediate Phase + 75,000 m^3/d for Phase II)	• 4 new RHC-type boreholes, each 900 m^3/h, 22 h/d • Construction of second Sabaki Pipeline, 800 mm/32", 107 km • Construction of second Malindi Pipeline, 600 mm/24", 45 km • Construction of new Marafa	• Extension of Baricho delivery pumping facility by adding new building for PS and dividing the pumping arrays to: - Mombasa pumps (in the existing building) and Malindi pumps (in the new

Source	Proposed Water Production (m^3/d)	Supply Scheme and Pipeline Connected	Required Infrastructure
		Pipeline, 300 mm/12", 20 km • Rehabilitation and upgrade of local water tanks at Kisimani (2,000 m^3), Kisauni (2,500 m^3) and Marafa (1,500 m^3)	building) - Pumps to Mombasa (1+1) units, 833 m^3/h, 245 m TDH - Pumps to Malindi/Watamu, 2+1 units, 700 m^3/h, 110 m TDH - Booster pumps to Marafa, 1+1 units, 120 m^3/h, 120 m TDH - Construction of Module B of chlorination contact tank at Baricho.
Tana River County			
Garsen (Phase II)	• Garsen intake to provide 120,000 m^3/d, including structures and low-lift pump, WTP and main PS	• Construction of force main from Garsen to Lamu Water Tank, 1,200 mm/48", 78 km	• Garsen delivery pumping station, 6+2 units, 800 m^3/h, 135 m TDH • New Lamu Water Tank, 20,000 m^3
Hola (Phase III)	• Local intake from the Tana River to the supply scheme	• Rehabilitation of local water supply scheme for 2,707 m^3/d in 2035	
Bura (Phase III)	• Local intake from the Tana River to the supply scheme	• Rehabilitation of local water supply scheme for 3,213 m^3/d in 2035	
Taveta County			
Taveta Springs (Njoro Kubwa Springs) (Immediate Phase)	• Spring intake rehabilitation to enable 7,228 m^3/d production *Subject to budget availability. If not, these works would be carried out during Phase I.*	• Rehabilitation of the force main supplying Taveta to 20"	• Rehabilitation of Taveta Scheme to be executed in Immediate Phase, as long as WB & AFD additional financing allow.
Mzima (Phase III)	• Additional abstraction of 70,000 m^3/d to total supply of 105,000 m^3/d	• New Mzima 2 Pipeline, 1,200 mm/48" to Voi/Maungu, 78 km and 1,000 mm/40" to Mazeras, 142 km • Mwatate and Wundanyi supply: - New Voi-Mwatate Pipeline, 400 mm/16", 30 km - New Voi-Mwatate Pipeline, 250 mm/10", 12 km	• Expansion of Mzima Waterworks by new 48" pipe, 1.3 km upstream of the existing tunnel • Rehabilitation and expansion of chlorination contact pond • New booster pump for Voi-Mwatate supply, 2+1 units, 470 m^3/h, 350 m TDH • Wundanyi booster pump • New Mwatate Water Tank, 1,500 m^3 • New Wundanyi Water Tank, 1,000 m^3

8.4 Proposed Water Resources Development by Phases of Development

In order to facilitate the presentation of the development process over time, the following four phases of development where selected and agreed upon:

- **Immediate Phase** (to be completed by 2016)
- **Phase I** (to be completed by 2020)
- **Phase II** (to be completed by 2025)
- **Phase III** (to be completed by planning horizon year of 2035)

8.4.1 Meeting the Projected Demand

A huge gap can be observed when one compares the projected demand and the present installed capacity. The gap is even greater if one considers the actual supply figures, which are considerably lower still. This is already true for the Immediate Phase (2015) where the projected demand of Mombasa and the 19 townships amounts to about 260,000 m^3/d (see Table 6-5 above), while the present installed capacity is less than 145,000–150,000 m^3/d (see Table 7-1 in Section 7.4 above).

As the development of the water resources and the conveyance systems takes considerable time, there is no realistic option to develop the resources as well as water supply schemes to suit the demand during the Immediate Phase. In other words, the development in the Immediate Phase will ease some of the existing shortages of water in the area; however, lack of water will still prevail in some of the townships.

Despite the gradual development of the total available water, as in any water project, structures and pipes will be developed and implemented according to their final dimensions, even if the required resources are not yet available.

However, the planning strategy of the WSMP calls for the water resources (new and existing) to be developed in such a way as to best meet the projected demand in the mid- and long-term phases of the development plan.

Therefore, the development of water resources by phases, as described in Sections 8.4.2–8.4.5 below are dedicated to the description of the proposed waterworks development, in such a way that all waterworks will be suited to the flows and capacities calculated for the horizon year. The sections are organized according to the sequence of development (i.e. Immediate Phase, followed by Phases I, II and III) and with inner order where the UCBWSS waterworks and water supply schemes are described first, followed by the water supply schemes of the BWSS.

8.4.2 Proposed Water Resources Development for the Immediate Phase

8.4.2.1 For the UCBWSS Townships and Urban Centres

Key settlements to benefits from this phase are as follows:

- **Taveta**
  - Njoro Kubwa Springs supply water to Taveta township in Taita Taveta County, and is also utilized for irrigation of Sisal Estates.
  - As the demand of the Taveta township in the Immediate Phase (2015) was projected to be some 3,573 m^3/d (see Table 6-5 above), and the Njoro Kubwa Springs' safe yield is so much greater, it appears that there should be no difficulties whatsoever to meet the Immediate Phase water demand of Taveta township and the villages around the township from the Njoro Kubwa Springs. Major rehabilitation works will be required at the source intake, including the main supply line.
  - Upon the request of the CWSB, the rehabilitation works of the Njoro Kubwa Springs will be included in the Immediate Phase of the development program, subject to budget availability, as mentioned in Section 8.3.5 above. The abundance of this water resource, as well as the remote location of Taveta township justifies this investment, enabling the township to benefit from the spring water in the Immediate Phase.
  - Under the proposed waterworks, it is recommended that the following activities take place:
    - Rehabilitation works in the intake structures including the design and construction of second module for the intake
    - Upgrading and extension of the facility electric board, including enlargements of the current electric grid connection
    - Adding two new submersible water pump to meet the projected demand for the year 2025 for total daily capacity of 5,220 m^3/d.
    - Laying a new supply pipeline from the spring water work to connect the water distribution system. The pipe will be 20"/500 mm.
    - Additional works, including accessories, pipe fittings, etc.

- **Lamu Island/Port**
  - Water rationing is frequent at Lamu Island/Port, Lamu County, as demand already exceeds the daily supply. The demand projected for the year 2015 is 15,815 m^3/d (see Table 6-5 above).
  - The current water supply is based on the shallow, limited yield Shella Aquifer. The intense development on the Lamu area, with its soon to be developed port, presents one of the biggest water deficits of the District.
  - In order to close the gap in the water balance for Lamu Island/Port it is possible to expand the small aquifers near Lamu. This option is feasible only for the immediate term. The capacity of expansion of the Hindi, Mpeketoni and Shella aquifers is limited, and can sustain only the immediate phase of building the new Lamu Port.

- **Mpeketoni township**
  - The demand projected for the Mpeketoni township in Lamu County for the year 2015 is 2,753 m^3/d (see Table 6-5 above).
  - In order to close the gaps in the water balance in the Mpeketoni area it is possible to expand the small aquifers near Lamu. This option is feasible only for the immediate term. The capacity of expansion of the Hindi, Mpeketoni and Shella aquifers is limited, and can sustain only part of the immediate demand.

- **Garsen, Hola and Bura townships**
  - The township of Garsen in Tana River County receives water from both the Garsen Wellfields (Ngao Scheme) – three boreholes located in the Garsen Aquifer along the banks of the Tana River – and a surface intake on the Tana River (Garsen Scheme). The demand projected for Garsen township for the year 2015 is 1,567 m^3/d (see Table 6-5 above). The Garsen Scheme supplies presently up to 250 m^3/d, and the Ngao Scheme supplies approximately 170 m^3/d. The installed capacity of the Garsen Wellfield amounts to some 50 m^3/h (or about 1000 m^3/d for a 20 h/d operation). However, production in these boreholes is limited due to electricity failures.
  - Presently there are only a few intakes around the towns of Hola and Bura in Tana River County. The Tana Water and Sewerage Company (TAWASCO) supplies the towns of Hola and Bura with water from the Tana River via local intakes.
  - Hola township receives an average of 1,200 m^3/d of water from the company. There is an ongoing program funded by the World Bank to rehabilitate the system. This upon completion will inject an additional 1,200 m^3/d of water, which will easily meet the projected demand of 1,246 m^3/d (see Table 6-5 above) for the year 2015.
  - The demand projected for the year 2015 for Garsen, Hola and Bura are 1,567, 1,246 and 1,527 m^3/d respectively.

Table 8-6 presents the water balance for the Immediate Phase for the UCBWSS townships.

Table 8-6: Water Balance (m³/d) for the UCBWSS Urban Centres and Townships, Immediate Phase (2015),

County	Townships	Projected Demand (2015)[1]	Water to be Supplied						Deficit/ Surplus[2]
			Njoro Kubwa Springs	Shella Aquifer	Mpeketoni Aquifer	Hindi Aquifer	Tana River	Total	
Taita Taveta	Taveta	3,573	3,573	0	0	0	0	3,573	0
	Subtotal	**3,573**	**3,573**	**0**	**0**	**0**	**0**	**3,573**	**0**
Lamu	Mpeketoni	2,753	0	0	0	0	0	0	-2,753[2]
	Lamu Island/Port	15,815	0	0	0	0	0	0	-15,815[2]
	Subtotal	**18,568**	**0**	**0**	**0**	**0**	**0**	**0**	**-18,568[2]**
Tana River	Garsen	1,567	0	0	0	0	0	0	-1,567[2]
	Hola	1,246	0	0	0	0	1,246	1,246	0
	Bura	1,527	0	0	0	0	0	0	-1,527[2]
	Subtotal	**4,340**	**0**	**0**	**0**	**0**	**1,246**	**1,246**	**-3,094[2]**
Total		**26,481**	**3,573**	**0**	**0**	**0**	**1,246**	**4,819**	**-21,662[2]**

Notes:
1. Demand includes 20% unaccounted-for water (UfW).
2. This deficit will be partially covered by local water sources.

8.4.2.2 For the BWSS

- Key townships to benefit from this phase are Mombasa, plus Kilifi and Malindi in Kilifi County (enhancement of Baricho Scheme):
  - The main objective of the Immediate Phase is to improve the supply of water to Mombasa. Analyzing three options for the above purpose, it was found that enhancing the daily water production of the Baricho Scheme by drilling two new boreholes in the wellfield and extending the operation time of the existing HLPS is the most effective solution for the supply improvement.
  - Of the present total abstraction of 68,000 m^3/d from the Baricho Wellfield, some 53,000 m^3/d are transmitted to Mombasa and the city of Kilifi (via the Sabaki-Mombasa Pipeline). This conveyance to Mombasa can increase to 65,000 m^3/d, if the wellfield operational hours are increased. This 65,000 m^3/d is also approaching the carrying capacity of the existing 800 mm pipeline. Therefore, any further transmission of water to Mombasa from this source will have to include not only additional boreholes and expansion of the HLPS, but also a new water conveyance system.
  - For the township of Malindi/Watamu, the current supply, via a 600 mm pipeline, is about 15,000 m^3/d. The hourly flow to the Malindi Pipeline is 681 m^3/h, assuming 22 h/d operation. As indicated above, the current 600 mm pipeline can convey up to 1,500 m^3/h under good hydraulic conditions, i.e., the total potential for the Malindi Pipeline is double the current daily transferred volume.

- The present HLPS in Baricho Waterworks is capable of pumping some 89,000 m^3/d (some 66,000 m^3/d to Mombasa and some 23,000 m^3/d to the township of Malindi in Kilifi County). The number of operational hours per day for each well could be immediately increased to approach at least the standard 22 pumping hours per day. This calculation is for a normal day; on days where maintenance activities are required, the total daily volume will be slightly less. This will raise the daily production of the wellfield to about 89,000 m^3/d, and will cause no difficulty for the existing HLPS.
- The demand for Mombasa for the year 2015 was projected to be some 152,300 m^3/d (see Table 6-5 above).
- The conveyance to the Malindi Pipeline (with the diversion to the new Kilifi Pipeline and the Gongoni section) can increase to 23,000 m^3/d if the wellfield operational hours are increased. This 600 mm transmission pipeline to Kilifi County is capable of conveying even larger quantities.
- The demands for the townships of Kilifi and Malindi for the year 2015 were projected to be 5,686 and 16,459 m^3/d respectively (see Table 6-5 above).
- For the Immediate Phase, it is proposed to abstract additional water from Baricho Wellfield. This will be accomplished by drilling and installation of two new vertical boreholes. As rapid drawdown has been reported recently, the Consultant recommends that the new boreholes be similar to the existing ones. The new boreholes will be identical to the existing ones, producing approximately 470 m^3/h each, operating up to 20 h/d, pumping some 18,800 m^3/d.
- The extension of the Baricho site for the Immediate Phase was analyzed for "*improving water supply to Mombasa"*. Several alternatives were examined with a total investment of around US$ 30 million. The WB and other financiers established the relief of water stress in the city of Mombasa as a key target of the given budget. From the analyses, it was concluded that both infrastructure improvement and additional water production are the best alternative solution in this case. Therefore, since not one of the future water sources were relevant for development at short and urgent notice and within the budget limitation (neither Mwache Dam nor Mzima 2 Pipeline), the results of the investment to production shows that additional water should be abstracted from Baricho because the pipe installations are already there (with upgraded equipment installed as part of the WaSSIP project) and the rehabilitation of only one section of the Sabaki-Mombasa Pipeline plus the new Kilifi Pipeline, will augment Mombasa with approximately 20,000 m^3/d.
- It is important to note that part of the Immediate Phase investments will upgrade as well the supply to Kilifi township with the disconnection of the Kilifi Pipeline from the Sabaki-Mombasa Pipeline. More water will flow to Mombasa, ease the hydraulic load on the current 800 mm Sabaki-Mombasa Pipeline. At the same time, through the new Kilifi Pipeline (500 mm) water will be transmitted directly to Kilifi, utilizing the

Malindi Pipeline (600 mm) and the Baricho–Kakuyuni-Kilifi Pipeline. No rehabilitation activities will be required in this section.

- The components required for the implementation of these works during the Immediate Phase are:
  - Drilling of two new boreholes in Baricho, and adding new manifolds connecting to the main delivery pipe up to the regulation tank
  - Replacing a 12 km section of the 400 mm pipeline upstream of Nguu Tatu with an 800 mm pipeline
  - Connecting Gongoni to the Malindi water supply by laying 20 km of a new 300 mm pipeline. The connection will be upstream of the Kakuyuni Water Tank.
  - Laying 50 km of a new 500 mm pipeline from Kakuyuni to Kilifi
  - Construction of the new water tanks at Kakuyuni and Kilifi

Table 8-7 presents the water balance for the Immediate Phase for the BWSS due to the anticipated enhancement of the Baricho Scheme.

Since there is neither rehabilitation works nor development in any other scheme in the BWSS in the Immediate Phase, there will be no change with regards to the state of demand and supply, i.e., water deficit will remain as is.

Table 8-7: BWSS Water Balance (m^3/d) for the Immediate Phase (2015)

County	Townships	Projected Demand[1]	Water to be Supplied						Deficit/ Surplus
		2015	Baricho	Mzima	Marere	Tiwi	Mwache	Total	
Mombasa	**Mombasa**	**152,302**	**79,855**	**16,714**	**7,956**	**10,919**	**0**	**115,444**	**-36,858**
Kwale	Kwale	4,162	0	0	2,081	2,081	0	4,162	0
	Kinango	1,951	0	0	1,951	0	0	1,951	0
	Msambweni	2,171	0	0	0	0	0	0	-2,171
	Ukunda/Tiwi	12,250	0	0	0	0	0	0	-12,250
	Lunga Lunga /Vanga	5,230	0	0	0	0	0	0	-5,230
	Subtotal	**25,764**	**0**	**0**	**4,032**	**2,081**	**0**	**6,113**	**-19,651**
Kilifi	Mariakani	4,441	0	0	0	0	0	0	-4,441
	Kilifi	5,686	5,686	0	0	0	0	5,686	0
	Malindi	16,459	16,459	0	0	0	0	16,459	0
	Watamu	4,115	0	0	0	0	0	0	-4,115
	Marafa	1,417	0	0	0	0	0	0	-1,417
	Mtwapa	9,398	0	0	0	0	0	0	-9,398
	Subtotal	**41,516**	**22,145**	**0**	**0**	**0**	**0**	**31,543**	**-14,930**
Taita Taveta	Taveta[1]	3,573	0	0	0	0	0	0	N/A [2]
	Mwatate	2,350	0	0	0	0	0	0	N/A [2]
	Wundanyi	2,406	0	0	0	0	0	0	N/A [2]
	Voi/Maungu	8,286	0	8,286	0	0	0	8,286	N/A [2]
	Subtotal	**16,615**	**0**	**8,286**	**0**	**0**	**0**	**8,286**	N/A [2]
Lamu	Mpeketoni[1]	2,753	0	0	0	0	0	0	N/A [2]
	Lamu Island/Port[1]	15,815	0	0	0	0	0	0	N/A [2]
	Subtotal	**18,568**	**0**	**0**	**0**	**0**	**0**	**0**	N/A [2]
Tana River	Garsen[1]	1,567	0	0	0	0	0	0	N/A [2]
	Hola[1]	1,246	0	0	0	0	0	0	N/A [2]
	Bura[1]	1,527	0	0	0	0	0	0	N/A [2]
	Subtotal	**4,340**	**0**	**0**	**0**	**0**	**0**	**0**	N/A [2]
Other demands along pipeline		**20,000**	**10,000**	**10,000**	**0**	**0**	**0**	**20,000**	N/A [2]
Total[2]		**252,624[2]**	**112,000**	**35,000**	**12,000**	**12,000**	**0**	**172,000**	**-71,439[3]**

Notes:
1. Demand includes 20% unaccounted-for water (UfW).
2. Total sum of projected demand does not include the UCBWSS townships of Taveta, Mpeketoni, Lamu Island/Port, Garsen, Hola and Bura.
3. This deficit will be partially covered by local water sources.

8.4.3 Proposed Water Resources Development for Phase I (2020)

8.4.3.1 For the UCBWSS Townships and Urban Centres

- **Taveta township**
  - The demand of the Taveta township in Phase I was projected to be some 4,265 m^3/d (see Table 6-5 above), and the Njoro Kubwa Springs' safe yield is so much greater, it is proposed to rehabilitate the springs' works to supply the entire demand of Taveta township. As proposed in the Immediate Phase for the Taveta supply, all required infrastructures for the Taveta horizon water supply will be upgraded in the Immediate Phase, leaving no additional activities in this source to the horizon year, subject to budget availability, as mentioned in Section 8.3.5 above.

- **Lamu Island/Port**
  - The demand projected for the Mpeketoni township in Lamu County for the year 2020 is 34,190 m^3/d (see Table 6-5 above).
  - The long-term solution for Lamu Island/Port in Lamu County involves the construction of additional small/local intakes along the Tana River, for the townships of Tana River County. This option is feasible, especially after the flow in the Tana River will be moderated (see Section 7.2.5 above).
  - It is likely that the development of the Lamu Port and the LAPSSET corridor will precede the development of the Garsen-Lamu Scheme, which intents to meet the total water demand in the Lamu County. In order to close this gap in Phase I a solution, using local water resources, will have to be improvised.
  - As a result of the need to meet the demand in the Mombasa-Malindi area, it was concluded that the Garsen-Lamu Scheme will be postponed to Phase II of the development plan. Hence, with no additional water to be produced and no scheme to be executed, no change in the water supply is expected in the Lamu region by 2020.
  - However, as noted in the Executive Summary, it is possible that in order to meet the rapid increase in demand that will emerge from the Lamu Port construction, a local desalination plant may be considered, with a limit capacity of a few hundred m^3/d. This small-scale plant would not only help increase the availability of water, but would also help prevent overpumping from the Shella Aquifer, thereby reducing the potential of seawater penetration into the freshwater body.

- **Mpeketoni township**
  - The demand projected for the Mpeketoni township in Lamu County for the year 2020 is 3,272 m^3/d (see Table 6-5 above).
  - The long-term solution for the Mpeketoni area in Lamu County involves the construction of additional small/local intakes along the Tana River, for the townships of Lamu and Tana River counties. This option is

feasible, especially after the flow in the Tana River will be moderated (see Section 7.2.5).
- The short distance from the Lamu area (including the port development with its relatively large demand projection), calls for the integration of the two water supply schemes of Mpeketoni and Lamu, namely the Garsen-Lamu Scheme.

- **Hola and Bura townships in Tana River County**
  - Presently there are only a few intakes around the towns of Hola and Bura.
  - The Tana Water and Sewerage Company (TAWASCO), which operates three schemes in the county, serves Hola township with water from the Tana River. The other schemes are Hola in Galole District and Garsen and Ngao in Tana Delta District.
  - Hola township receives an average of 1,200 m^3/d of water from the company. There is an ongoing program funded by the World Bank to rehabilitate the system. This upon completion will inject an additional 1,200 m^3/d of water, which will easily meet the Projected Demand of 1,524 m^3/d (see Table 6-5 above) for the year 2020.
  - The demand projected for Bura township for the year 2020 is 1,817 m^3/d (see Table 6-5 above).
  - Closing the gap in the water balance for the township of Bura involves the construction of additional small/local intakes along the Tana River for the towns of Tana River County. This option is feasible, especially after the flow in the Tana River will be moderated. No significant change in the state of the water supply/deficit is projected in the region, as most of the extension works, in the intake and in the water supply scheme were postponed to Phase II.

- **Garsen township in Tana River County**
  - Presently the township of Garsen receives some 420 m^3/d of water (some 250 and 170 m^3/d from the Garsen Scheme and the Ngao Scheme, respectively). The installed capacity of the Garsen Wellfield amounts to some 50 m^3/h (equivalent to some 1,000 m^3/d for 20 h/d operation). However, production in these boreholes is limited due to electricity failures. The demand projected for Garsen township for the year 2020 is 1,866 m^3/d (see Table 6-5 above).
  - Closing this gap in the water balance involves the full exploitation of the Garsen Wellfield and the construction of additional small/local intakes along the Tana River. As mentioned earlier, this option is feasible, especially after the flow in the Tana River will be moderated. As in the previous case, here also no significant change in the state of the water supply/deficit is projected in the region, as most of the extension works, in the intake and in the water supply scheme were postponed to Phase II.

Table 8-8 presents the development proposed for each of the water resources in Phase I.

Table 8-8: Water Balance (m^3/d) for the UCBWSS Urban Centres and Townships, Phase I (2020)

County	Townships	Projected Demand[1] (2020)	Water to be Supplied						Deficit/ Surplus
			Njoro Kubwa Springs	Shella Aquifer	Mpeketoni Aquifer	Hindi Aquifer	Tana River	Total	
Taita Taveta	Taveta	4,265	4,265	0	0	0	0	4,265	0
	Subtotal	**4,265**	**4,265**	**0**	**0**	**0**	**0**	**4,265**	**0**
Lamu	Mpeketoni	3,272	0	By local	0	0	0	0	-3,272[2]
	Lamu Island/Port	34,190	0	0	By local	0	0	0	-34,190[2]
	Subtotal	**37,462**	**0**	**0**	**0**	**0**	**0**	**0**	**-37,462[2]**
Tana River	Garsen	1,866	0	0	0	0	0	0	-1,866[2]
	Hola	1,524	0	0	0	By local	1,524	1,524	0
	Bura	1,817	0	0	0	By local	0	0	-1,817[2]
	Subtotal	**5,207**	**0**	**0**	**0**	**0**	**1,524**	**1,524**	**-3,683[2]**
Total		**46,934**	**4,265**	**0**	**0**	**0**	**1,524**	**5,789**	**-41,145[2]**

Notes:
1. Demand includes 20% unaccounted-for Water (UfW).
2. This deficit will be partially covered by local water sources.

8.4.3.2 *For the BWSS*

- The key township to benefit from this phase is Mombasa,
- Mombasa City (launching of the Mwache Dam water supply scheme)
  – The following components relating to Mwache Dam and the water supply to Mombasa and the southern area will be implemented during Phase I:
    - Completing the Mwache Dam, the treatment facilities and the regulating water tank
    - Construction of a new pumping station downstream of the treatment plant
    - Construction of an NMT at an elevation of +120 masl, having a capacity of 20,000 m^3
    - Construction of 3 sets of pumps from the Mwache Dam, which will deliver water to:
      • NMT Water Tank – This set will include 6 (5 duty, 1 standby) pumps, each having a capacity of 875 m^3/h, and supply the water via a 5 km long 1,000 mm/40" pipeline to be constructed. The total potential volume will be 69,200 m^3/d.
      • Mombasa Island through Chamgamwe Water Tank – This set will include 6 (5 duty, 1 standby) pumps, each having a capacity of 600 m^3/h, and supply the water via a 15 km long 700 mm/28" pipeline to be constructed. The total potential volume will be 48,000 m^3/d.
      • The southern area – This set will include 6 (5 duty, 1 standby) pumps, each having a capacity of 865 m^3/h, and supply the water via a 22 km long 800 mm/32" pipeline to be constructed,

connecting Likoni and the Kaya Bombo Water Tank. The total potential volume will be 69,200 m^3/d

- The demand for Mombasa for the year 2020 was projected to be some 184,372 m^3/d (see Table 6-5 above).

Table 8-9 presents the water balance for the BWSS for Phase I as the result of the incorporation of Mwache Dam into the BWSS.

Table 8-9: BWSS Water Balance (m^3/d) for Phase I (2020)

County	Townships	Projected Demand[1] (2020)	Water to be Supplied						Deficit/ Surplus
			Baricho	Mzima	Marere	Tiwi	Mwache	Total	
Mombasa	**Mombasa**	**184,372**	**55,805**	**15,292**	**7,135**	**10,555**	**95,585**	**184,372**	**0**
Kwale	Kwale	4,945	0	0	2,500	2,445	0	4,945	0
	Kinango	2,365	0	0	2,365	0	0	2,365	0
	Msambweni	2,665	0	0	0	0	0	0	-2,665
	Ukunda/Tiwi	14,676	0	0	0	0	0	0	-14,676
	Lunga Lunga /Vanga	6,445	0	0	0	0	0	0	-6,445
	Subtotal	**31,096**	**0**	**0**	**4,865**	**2,445**	**0**	**7,310**	**23,786**
Kilifi	Mariakani	5,421	0	0	0	0	0	0	-5,421
	Kilifi	7,090	7,090	0	0	0	0	7,090	0
	Malindi	20,493	20,493	0	0	0	0	20,493	0
	Watamu	5,123	5,123	0	0	0	0	5,123	0
	Marafa	1,803	1,803	0	0	0	0	1,803	0
	Mtwapa	11,686	11,686	0	0	0	0	11,686	0
	Subtotal	**51,616**	**46,195**	**0**	**0**	**0**	**0**	**46,195**	**-5,421**
Taita Taveta	Taveta	4,265	0	0	0	0	0	0	N/A [2]
	Mwatate	2,758	0	0	0	0	0	0	-2,758
	Wundanyi	2,823	0	0	0	0	0	0	-2,823
	Voi/Maungu	9,708	0	9,708	0	0	0	9,708	0
	Subtotal	**15,289**	**0**	**9,708**	**0**	**0**	**0**	**9,708**	**-5,581**
Lamu	Mpeketoni	3,272	0	0	0	0	0	0	N/A [2]
	Lamu Island/Port	34,190	0	0	0	0	0	0	N/A [2]
	Subtotal	**37,462**	**0**	**0**	**0**	**0**	**0**	**0**	**N/A [2]**
Tana River	Garsen	1,866	0	0	0	0	0	0	N/A [2]
	Hola	1,524	0	0	0	0	0	0	N/A [2]
	Bura	1,817	0	0	0	0	0	0	N/A [2]
	Subtotal	**5,207**	**0**	**0**	**0**	**0**	**0**	**0**	**N/A [2]**
Other demands along pipeline		**20,000**	**10,000**	**10,000**	**0**	**0**	**0**	**20,000**	**0**
Total[2]		**302,373[2]**	**112,000**	**35,000**	**12,000**	**13,000**	**95,585**	**267,585**	**-34,788[3]**

Notes:

1. Demand includes 20% unaccounted-for water (UfW).
2. Total sum of projected demand does not include the UCBWSS townships of Taveta, Mpeketoni, Lamu Island/Port, Garsen, Hola and Bura.
3. This deficit will be partially covered by local water sources.

8.4.4 Proposed Water Resources Development for Phase II

8.4.4.1 For the UCBWSS Townships and Urban Centres

Key townships to benefit from this phase are the township of Lamu Island/Port, as well the townships of Garsen and Mpeketoni (Garsen intake and the Garsen-Lamu Scheme).

- **Taveta township**
  - The demand of the Taveta township in Phase II was projected to be some 5,121 m^3/d (see Table 6-5 above)
  - Since the Njoro Kubwa Springs' safe yield is so much greater, it is recommended to rehabilitate the Springs' work to supply the entire demand of Taveta township.
  - As this work will be done in either the Immediate Phase (subject to budget availability) or in Phase I, no additional infrastructure needs to be developed in this phase.

- **Lamu Island/Port and Mpeketoni in Lamu County and Garsen township in Tana River County**
  - The demands of the Lamu Island/Port, Mpeketoni and Garsen townships in Phase II were projected to be 57,805, 4,263 and 2,269 m^3/d respectively (see Table 6-5 above).
    The short distances from the Lamu area (including the port development with its relatively large water demand projection), calls for the integration of the three water schemes of Lamu, Mpeketoni and Garsen.
  - Two intake sites on the Tana River were considered for Garsen-Lamu Scheme. The first intake site is in the Nanighi area near Hola township at an estimated distance of 180 km from Lamu Island/Port. The second intake site is near Garsen Bridge, further downstream at a distance of about 78 km from Lamu. Analysis of the total CAPEX and OPEX in each alternatives done as part for the Lamu Scheme, shows that the Garsen location is the preferred one, mainly because of the shorter distance of the Garsen site to the Lamu area.
  - In fact is it proposed that for the horizon year the Garsen water works will be designed for a total daily capacity of 120,000 m^3/d.
  - The following components relating to the Garsen-Lamu Scheme will be implemented during Phase II:
    - Construction of the Garsen-Lamu offtake structure and the main pumping station
    - Construction of a new 75 km long main pipeline from Garsen to Lamu, with an extension to Mpeketoni

Table 8-10 presents the water balance for the UCBWSS for Phase II.

Table 8-10: Water Balance (m^3/d) for the UCBWSS Urban Centres and Townships, Phase II (2025)

County	Townships	Projected Demand (2025)	Water to be Supplied						Deficit/ Surplus
			Njoro Kubwa Springs	Shella Aquifer	Mpeketoni Aquifer	Hindi Aquifer	Tana River	Total	
Taita Taveta	Taveta	5,121	5,121	0	0	0	0	5,121	0
	Subtotal	**5,121**	**5,121**	**0**	**0**	**0**	**0**	**5,121**	**0**
Lamu	Mpeketoni	4,263	0	0	0	0	4,263	4,263	0
	Lamu Island/Port	57,805	0	0	0	0	57,805	57,805	0
	Subtotal	**62,068**	**0**	**0**	**0**	**0**	**62,068**	**62,068**	**0**
Tana River	Garsen	2,269	0	0	0	0	2,269	2,269	0
	Hola	1,558	0	0	0	0	1,558	1,558	0
	Bura	2,209	0	0	0	0	0	0	-2,209
	Subtotal	**6,036**	**0**	**0**	**0**	**0**	**3,827**	**3,827**	**-2,209**
	Total	**73,225**	**5,121**	**0**	**0**	**0**	**65,895**	**71,016**	**-2,209**

Notes:
1. Demand includes 20% unaccounted-for water (UfW).
2. This deficit will be partially covered by local water sources.

8.4.4.2 For the BWSS

Key townships to benefit during this phase are Mombasa, Kilifi, Malindi/Watamu and Marafa in Kilifi County.

- **Mombasa and the townships of Kilifi, Malindi/Watamu and Marafa in Kilifi County (second enhancement of the Baricho Scheme):**
  - During Phase II, the construction of the Baricho 2 Scheme will be undertaken in order to enhance the supply to Mombasa, the townships of Kilifi, Malindi/Watamu and Marafa in Kilifi County, reaching a total amount of 175,000 m^3/d. However, the Consultant recommends that the total delivery capacity of the HLPS be developed gradually. See Chapter 8 below for details regarding the staged development of the delivery pumps. This should not be confused with the Consultant's recommendation that the introduction of RHC-type boreholes also be done gradually. For that purpose, Phase II of the WSMP was divided into three major stages (A, B and C). Each one of them is detailed in Chapter 9 below.
  - The demands for Mombasa, Kilifi, Malindi/Watamu and Marafa for the year 2025 were projected to be some 238,874, 9,014, 32,067 and 2,303 m^3/d, respectively (see Table 6-5 above).
  - The components required for the implementation of the second enhancement works of the Baricho Scheme during Phase II are:

- Extension of Baricho abstraction capacity to a total of 175,000 m^3/d by adding 5 new RHC-type boreholes, having a capacity of 900 m^3/h each
- Construction of a new pumping station at the Baricho site, and shifting the Malindi pumps to the new pumping station, to enable the installation of additional Mombasa pumps in the existing pumping station
- Adding 2 new pumps to Mombasa (1 duty, 1 standby) and 3 new pumps to Malindi (2 duty, 1 standby) in the new pumping station
- Construction of the second Baricho Nguu Tatu Pipeline (107 km long, 800 mm)
- Construction of the second Baricho Kakuyuni Pipeline (45 km long, 600 mm)
- Construction of a 300 mm, 30 km pipeline to Marafa
- Construction of a new booster pump to supply Marafa
- Construction of a 1,000 m^3 Marafa Water Tank

Table 8-11 presents the water balance for the BWSS for Phase II as the result of the second enhancement of the Baricho Scheme.

Table 8-11: BWSS Water Balance (m^3/d) for Phase II (2025)

County	Townships	Projected Demand[1] (2025)	Water to be Supplied						Deficit/ Surplus
			Baricho	Mzima	Marere	Tiwi	Mwache	Total	
Mombasa	**Mombasa**	**238,874**	**106,594**	**13,370**	**6,051**	**10,000**	**102,859**	**238,874**	**0**
Kwale	Kwale	6,000	0	0	3,000	3,000	0	6,000	0
	Kinango	2,949	0	0	2,949	0	0	2,949	0
	Msambweni	3,252	0	0	0	0	0	0	-3,252
	Ukunda/Tiwi	19,671	0	0	0	0	0	0	-19,671
	Lunga Lunga/Vanga	7,903	0	0	0	0	0	0	-7,903
	Subtotal	**39,775**	**0**	**0**	**5,949**	**3,000**	**0**	**8,949**	**-30,826**
Kilifi	Mariakani	6,884	0	0	0	0	0	0	-6,884
	Kilifi	9,014	9,014	0	0	0	0	9,014	0
	Malindi	25,654	25,654	0	0	0	0	25,654	0
	Watamu	6,413	6,413	0	0	0	0	6,413	0
	Marafa	2,303	2,303	0	0	0	0	2,303	0
	Mtwapa	14,822	14,822	0	0	0	0	14,822	0
	Subtotal	**65,090**	**58,206**				**0**	**58,206**	**-6,884**
Taita Taveta	Taveta	5,121	0	0	0	0	0	0	0
	Mwatate	3,332	0	0	0		0	0	-3,332
	Wundanyi	3,411	0	0	0	0	0	0	-3,411
	Voi/Maungu	11,630	0	11,630	0	0	0	11,630	0
	Subtotal	**18.373**	**0**	**11,630**	**0**	**0**	**0**	**11,630**	**-6,743**
Lamu	Mpeketoni	4,263	0	0	0	0	0	0	0
	Lamu Island/Port	57,805	0	0	0	0	0	0	0
	Subtotal	**62,068**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Tana River	Garsen	2,269	0	0	0	0	0	0	0
	Hola	1,558	0	0	0	0	0	0	0
	Bura	2,209	0	0	0	0	0	0	0
	Subtotal	**6,036**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Other demands along pipeline		**20,000**	**10,000**	**10,000**	**0**	**0**	**0**	**20,000**	**0**
Total[2]		**382,112[2]**	**174,800**	**35,000**	**12,000**	**13,000**	**102,859**	**337,659**	**-44,453[3]**

Notes:

1. Demand includes 20% unaccounted-for water (UfW).
2. Total sum of projected demand does not include the UCBWSS townships of Taveta, Mpeketoni, Lamu Island/Port, Garsen, Hola and Bura.
3. This deficit will be partially covered by local water sources.

8.4.5 Proposed Water Resources Development for Phase III

8.4.5.1 For the UCBWSS Townships and Urban Centres

- **Taveta township**
  - The demand of the Taveta township in Phase II was projected to be some 5,121 m^3/d (see Table 6-5 above)
  - Since the Njoro Kubwa Springs' safe yield is so much greater, it is recommended to rehabilitate the springs' waterworks to supply the entire demand of Taveta township.
  - As this work will be done in either the Immediate Phase (subject to budget availability) or in Phase I, no additional infrastructure needs to be developed in this phase.

Table 8-12 presents the water balance for the UCBWSS for Phase III.

Table 8-12: Water Balance (m^3/d) for the UCBWSS Urban Centres and Townships, Phase III (2035)

County	Townships	Projected Demand[1] (2035)	Water to be Supplied						Deficit/ Surplus
			Njoro Kubwa Springs	Shella Aquifer	Mpeketoni Aquifer	Hindi Aquifer	Tana River	Total	
Taita Taveta	Taveta	7,228	7,228	0	0	0	0	7,228	0
	Subtotal	**7,228**	**7,228**	**0**	**0**	**0**	**0**	**7,228**	**0**
Lamu	Mpeketoni	6,749	0	0	0	0	6,749	6,749	0
	Lamu Island/Port	109,811	0	0	0	0	109,811	109,811	0
	Subtotal	**116,560**	**0**	**0**	**0**	**0**	**116,560**	**116,560**	**0**
Tana River	Garsen	3,302	0	0	0	0	3,302	3,302	0
	Hola	2,707	0	0	0	0	2,707	2,707	0
	Bura	3,213	0	0	0	0	0	0	-3,213
	Subtotal	**9,222**	**0**	**0**	**0**	**0**	**6,009**	**6,009**	**-3,213[2]**
Total		**133,010**	**7,228**	**0**	**0**	**0**	**122,569**	**129,797**	**-3,213[2]**

Notes:
1. Demand includes 20% unaccounted-for water (UfW).
2. This deficit will be partially covered by local water sources.

8.4.5.2 For the BWSS

Key townships to benefit from this phase are Mombasa and townships in Taita Taveta County, as well as the southern area of Kwale County, including the remote township of Lunga Lunga/Vanga.

- For Mombasa and the townships of Voi/Maungu, Mwatate and Wundanyi in Taita Taveta County (construction of the Mzima 2 Scheme)
  - During Phase III, the construction of the Mzima 2 Scheme will be undertaken in order to enhance the supply to Mombasa and the townships of Mwatate and Wundanyi and Voi/Maungu in Taita Taveta County to a total amount of 105,000 m^3/d.
  - The demand for Mombasa, Voi/Maungu, Mwatate and Wundanyi for the year 2035 was projected to be some 312,554, 16,358, 4,665 and 4,777 m^3/d, respectively (see Table 6-5 above).
  - The components required for the implementation of the Mzima 2 Scheme during Phase III are:
    - Replacing the current 30" pipeline of the Mzima Springs Waterworks by installing a new 48" pipeline downstream of the Mzima Tunnel
    - Laying of a 1,200 mm pipeline (Mzima 2 Pipeline) from the Mzima Springs Waterworks to Voi Junction (some 78 km in length)
    - Connecting Mwatate and Wundanyi to Voi Junction via a 400 mm pipeline, some 30 km in length
    - Abstraction from the Mzima 2 Pipeline and pumping of the water to Mwatate and Wundanyi
    - The pumping rate will be the same (393 m^3/h) while the Taveta location will be supplied from the Njoro Kubwa Springs. The TDH to lift the water to Mwatate will be 335 m, as the line to Mwatate is only 30 km. but the elevation difference is 260 m.

- **For the townships of Msambweni and Lunga Lunga/Vanga in Kwale County:**
  - The demands for Msambweni and Lunga Lunga/Vanga in Kwale County for the year 2035 were projected to be some 4,809, 11,709 m^3/d, respectively (see Table 6-5 above).
  - In order to enhance the supply to Msambweni and Lunga Lunga the following components will be constructed during Phase III:
    - Developing the southern coast supply branch from Mwache, including the laying of a 500 mm/20" pipeline to Msambweni and a 300 mm/12" pipeline to Lunga Lunga.
    - Construction of a new 10,000 m^3 water tank in Msambweni and a booster pump to deliver water to Lunga Lunga/Vanga.
    - Developing the Msambweni wellfield with a target capacity of 20,000 m^3/d and connecting it to the Msambweni Water Tank.

Table 8-13 presents the Phase III water balance for the BWSS.

Table 8-13: BWSS Water Balance (m³/d) for Phase III (2035)

County	Townships	Projected Demand[1] 2035	Water to be Supplied							Deficit/ Surplus
			Baricho	Mzima	Marere	Tiwi	Mwache	Msambweni Aquifer/ Mkurumudzi Dam	Total	
Mombasa	Mombasa	**312,554**	**80,395**	**59,050**	**3,173**	**8,662**	**145,838**	**15,191**	**312,309**	**-245**
Kwale	Kwale	8,676	0	0	4,338	4,338	0	0	8,676	0
	Kinango	4,489	0	0	4,489	0	0	0	4,489	0
	Msambweni	4,809	0	0	0	0	0	4,809	4,809	0
	Ukunda/Tiwi	28,453	0	0	0	0	28,453	0	28,453	0
	Lunga Lunga / Vanga	11,709	0	0	0	0	11,709	0	11,709	0
	Subtotal	**58,136**	**0**	**0**	**8,827**	**4,338**	**40,162**	**4,809**	**58,136**	**0**
Kilifi	Mariakani	10,150	0	10,150	0	0	0	0	10,150	0
	Kilifi	13,240	13,240	0	0	0	0	0	13,240	0
	Malindi	36,851	36,851	0	0	0	0	0	36,851	0
	Watamu	9,213	9,213	0	0	0	0	0	9,213	0
	Marafa	3,402	3,402	0	0	0	0	0	3,402	0
	Mtwapa	21,699	21,699	0	0	0	0	0	21,699	0
	Subtotal	**94,555**	**84,405**	**10,150**	**0**	**0**	**0**	**0**	**94,555**	**0**
Taita Taveta	Taveta	7,228	0	0	0	0	0	0	0	0
	Mwatate	4,665	0	4,665	0	0	0	0	4,665	0
	Wundanyi	4,777	0	4,777	0	0	0	0	4,777	0
	Voi/Maungu	16,358	0	16,358	0	0	0	0	16,358	0
	Subtotal	**33,028**	**0**	**25,800**	**0**	**0**	**0**	**0**	**25,800**	**0**
Lamu	Mpeketoni	6,749	0	0	0	0	0	0	0	0
	Lamu Island/Port	109,811	0	0	0	0	0	0	0	0
	Subtotal	**116,560**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Tana River	Garsen	3,302	0	0	0	0	0	0	0	0
	Hola	2,707	0	0	0	0	0	0	0	0
	Bura	3,213	0	0	0	0	0	0	0	0
	Subtotal	**9,222**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Other Demands along Pipeline		**20,000**	**10,000**	**10,000**	**–**	**–**	**–**	**–**	**20,000**	**0**
Total[2]		**511,045**	**174,800**	**105,000**	**12,000**	**13,000**	**186,000**	**20,000**	**510,800**	**-245[3]**

Notes:

1. Demand includes 20% unaccounted-for water (UfW).
2. Total sum of projected demand does not include the UCBWSS townships of Taveta, Mpeketoni, Lamu Island/Port, Garsen, Hola and Bura.
3. This small deficit will be supplied from existing local water resources.

8.5 Effects of the Upgraded Bulk Water Supply System on Wastewater Volumes

8.5.1 Increase in Quantities of Wastewater Generated

Enhanced water supply to the city and consumption by urban users will, in a short time (1–2 years), lead to an increase in the quantities of wastewater generated. This increase will be phased, in accordance with the phased increase in water demand.

Initially, the increased water use will be attributed mainly to drinking and cooking – uses that produce relatively small quantities of wastewater. Once the convenience of water use is established and the level of system reliability rises, water use will spread to include washing, as a result of which the quantities of wastewater produced will increase.

In considering full use of water (domestic use for all purposes, including sanitary use) it is customary to assume that about 60–70% of the water enters the wastewater system. The part that does not end up as wastewater is assumed to be water that does not result in flows to the wastewater system. Even if a minimum contribution to wastewater is assumed in the initial years of main system development – of the order of magnitude of 10–20 lpcd – the total contribution to wastewater is expected to be thousands of cubic metres per day in small communities, to tens and hundreds of thousands of cubic metres per day in large communities, not to mention Mombasa and neighbouring towns.

8.5.2 Long-Term Planning of the Wastewater Collection System

Due attention must be given at present to the need for long-term planning of the wastewater collection system, as follows:

In the absence of a proper wastewater collection system, most of the wastewater will continue to flow to percolating pits, causing contamination of the groundwater and aquifer systems. There are already areas where the groundwater underlying urban areas is experiencing increased levels of pollution, precluding its use.

The absence of wastewater collection systems creates a potential for the outbreak of diseases and epidemics in built-up areas. The lack of proper wastewater removal systems as an underlying cause of diseases and epidemics worldwide is well known. Based on the common assumption that discharge of wastewater to percolating pits in the ground is not a solution, there is an increasingly acute need for preparing and implementing a plan for collection of wastewater in parallel with the increase in use of water by the population.

Collection of wastewater by means of gravity systems constitutes merely the first link in a wastewater recycling system for reuse in agriculture in Kenya. For this purpose it is necessary to prepare a plan that takes a holistic view of the issue of water recycling:

- Design and construction of gravity wastewater collection systems in the urban domain
- Preparation of a general regional plan with respect to the location of wastewater treatment plants and discharge of all the wastewater to these plants
- Determination of criteria and standards for recycled water quality and recognition of this water as a resource
- Planning of recycled water supply systems for agriculture, ensuring congruity between the quality of the water and the end uses

Preparation of a regional plan for collection, treatment, reclamation and reuse of wastewater in the area of jurisdiction of the Coast Province in Kenya has become a cardinal need and all the necessary resources must be directed towards this end. Failure to prepare such a plan will not only result in continued pressure on water sources and abstraction of fresh water from natural sources for agricultural use but will also cause further contamination of groundwater due to the rise in water use and increased contribution to wastewater.

Collection and treatment of wastewater serving no useful purpose in order to reuse it in agriculture will allow greater quantities of water to be made available for the agricultural sector, improve cultivation conditions for the farmers by supplying additional quantities of water that are not rainfall-dependent, and at the same time raise sanitary levels in the urban sector.

The distance between the main population centres in the area will call for preparation of a regional master plan for wastewater treatment centres and transfer points for diversion of water to the agricultural sector, including weighting of the costs of wastewater conveyance over long distances (it is not customary to pump wastewater over distances exceeding 10–12 km). On the other hand, due consideration must also be given to the number of wastewater treatment plants planned as they entail high operating costs in addition to the initial investments.

9. Preliminary Design

9.1 Overview

The vast amount of engineering components that need to be implemented within the development plan, which will be implemented over a 20-year period, requires the CWSB to adopt clear design criteria. Those design criteria will apply to all stages of development and should be consistent all along.

The Preliminary Design Report describes all the engineering attributes of the proposed water supply schemes for both the BWSS and the UCBWSS. Pipe and accessory specifications, pump specifications, and all other infrastructure specifications – including pressure ratings, pump capacities, flow, TDH, energy operation hours per day and others attributes – are all listed in this chapter. The chapter structure tracks the proposed sequence of development and is mainly focused on the BWSS and the Lamu Scheme, where most of the waterworks construction will be executed.

Chapter 9 structure is as follows:

- **Section 9.2** presents the **approach** to preliminary design that was done as part of the WSMP. It contains the major **design criteria** for the proposed water supply schemes, including pipes, pumps, water tanks, valve criteria, air valves, pressure rating and pressure relief valves, accessories, etc.
- **Section 9.3** deals with the **water quality** standards of the proposed water supply schemes (considering the main purpose of the water is for drinking water).
- **Section 9.4** presents criteria for additional elements.
- **Section 9.5** describes the **principles for the simulation** done in order to size the main transmission pipelines of the BWSS, including the calculation of hydraulic attributes of the proposed system.
- **Sections 9.6–9.14** details the **sequence of development** of the water resources and water supply schemes. It describes in detail the required activities in each phase and in each scheme to be implemented. It contains schematic diagrams of the pumping array and the pumping station needed. A list of all water tanks is also included in these sections.
- **Section 9.15** presents the Development Action Plan, which summarizes the WSMP by year of development and by source of water.
- **Section 9.16** presents additional requirements for the development programs and detailed design.

9.2 Design Criteria

9.2.1 Approach to the Design

Under the conditions, restrictions and constraints of the Coast Province, the Consultant elaborated his approach to the development, exploitation and management of the water resources and the water supply. The water resources supply concept is based on two main components:

- A regional bulk water supply system for transfer of water and combined operation of storage reservoirs
- Conservation and augmentation of the resources, including new water sources, deep groundwater exploitation, desalination, wastewater reuse, etc.
- Balancing water demand and availability for each phase separately

The proposed approach is to reach a fully integrated interconnected system for transfer of water in space and time and conjunctive use of surface and groundwater.

In such an integrated system, the bulk water supply system is the backbone and "carrier" for water transmission from the sources/storage to the supply areas.

The study of the system is based on a simulative study of multiannual operation of the proposed interconnected system, following a similar study for each scheme alone, in order to evaluate the potential for additional supply by the interconnection and the best practice for implementation. The results of the various operational studies served as input for the Consultant's recommendations.

- Proposed operation of the system
- Proposed modifications and additions to the physical system
- Evaluation of benefits in terms of water quantities and reliabilities as parts of the proposed system and its operation

The engineering design of the systems is primarily based on MWI's *Practice Manual for Water Supply Services in Kenya* (December 2005). Where the design guidelines are silent, other design standards, guidelines or previous experience of project specialists are used in consultation with appropriate stakeholders. Where appropriate, the design criteria may deviate from the abovementioned guidelines to fit the realities of particular locations (see Table 9-1).

Table 9-1: Guidelines for Water Service Level

Service Aspect	Guideline
Hours of service	Continuous – 24 hours per day
Water quality	Water supplied should comply with World Health Organization (WHO) guidelines for drinking water. Deviations may be made where the standards are difficult to achieve, provided such deviations are not injurious to health, and provided consumers are notified of any precautions to be taken.
Reliability	To provide service to all consumers for at least 99% of the time, and limit interruptions to the supply to no more than 12 hours for any one interruption
Metering	All production, treatment and consumers should have a metered supply.

9.2.2 Pipelines

Transmission mains will be designed to have minimum slopes of 0.3% for DN ≤ 200 mm and 0.2% for DN > 200 mm.

Flow velocities in transmission mains will be between 0.6 m/s and 2 m/s, and will be lower in smaller diameter pipes and higher in larger diameter pipes. The maximum operating velocity will be 2 m/s to ensure safe operation of the pipeline.

Transmission mains will be designed using the Hazen-Williams formula for pipeline head losses. Given that the pipelines will have to perform according to the required ultimate demand for planning years, the following C factors are recommended to be used for this project:

- Steel or ductile iron (DI) pipe materials: C = 100
- PVC and HDPE pipe materials: C = 130

Working pressure will be limited to 70% of the test pressure of the pipe. The residual pressure will be maintained at a minimum of 10 m, except for sections downstream of break-pressure tanks.

9.2.3 Pumping Stations

Given that the pipes will have to perform according to the required ultimate demand for planning years, the following C factors are recommended to be used for this project:

- Minimum pump efficiency 80%
- All pumping stations will be equipped with variable frequency drive
- The manifold will be sized with one diameter larger than the impeller's diameter.
- All pumping stations will be built and equipped with a minimum of a two pump array (distance >2 m)
- The required capacity of standby pumps will be calculated using the following equation: *% standby capacity = (1 / total no. of duty pumps)*
- It is recommended that pumps and impellers be installed vertically in dry installations (also called surface installation).

9.2.4 Service Reservoirs

Service storage within a bulk water supply system is generally intended to perform some or all of the following functions:

- Compensation for fluctuations in water consumption during the day where water is delivered into the system at a constant rate
- Provision of emergency reserve in case of interruptions due to mechanical and electrical failures, or shutdown of supply main for repair or maintenance
- Provision of reserve for firefighting
- Equalization of pressures in the distribution system
- Stabilization of pumping heads

The efficiency with which these functions are performed by the service reservoirs is determined by the capacity, location and elevation of the reservoirs. The capacity required to compensate for fluctuations in water consumption is related to the size and pattern of variation of water consumption during the day and to the rate and duration of pumping and size of pumping main, such that this capacity needs to be determined on an individual basis.

However, experience has shown that adequate compensating capacity lies between 15% and 30% of the average daily demand. If there are reliable data on variations in consumption in the project areas, this percentage range will be updated.

The size of emergency reserve in case of interruptions in supply is determined from a number of factors, including reliability of electric power supply, availability of standby pumping equipment and the speed with which burst pipes and other repair and maintenance works on the supply side can be attended to. The controlling factor in actual situations is the speed with which repairs can be carried out on mechanical and electrical equipment.

For obvious economic reasons, emergency storage will be provided as follows:

- 6 hours per day in cities
- 12 hours per day in townships
- 24 hours per day in small townships and rural communities

To ensure proper equalization of distribution system pressures and stabilization of pumping heads to ensure efficient operation of pumping stations, the siting of service reservoirs with respect to location and elevation will be determined with careful consideration for all systems.

9.3 Water Quality Standards & Water Treatment

9.3.1 Water Quality Standards

The drinking water standards in use in Kenya (or WHO international standards, as shown in Table 9-2) will be adopted for all water sources of the bulk water supply system.

In order to minimize pollution of the sources, new surface water sources will be located upstream of town/villages, and away from areas of known contamination.

Catchment basin protection is a key water management activity following the development of new water resources, especially surface water resources. In order to sustain the water quality in the catchment basin, the CWSB, together with other institutions, must initiate a program that promotes the importance of maintaining land use control, erosion protection and contamination control in order to protect the water that will be collected and stored in the dam. Those responsible for the quality of the raw water, primarily the CDA, should already be concerned about the effect of human activities within the boundaries of the catchment basin. A program to control the sources of contamination within the Mwache Basin must be an integral part of the development of the Mwache Dam. Basically, it is important to note that the more the catchment area is protected from being polluted, the higher the quality of the raw water, thus minimizing both CAPEX and OPEX investment in water treatment plants.

For urban use, chlorination and disinfection will always be a "must" before supplying potable water to consumers.

Table 9-2: WHO Water Quality Standards

Substance	Maximum Acceptable Concentration	Maximum Allowable Concentration
Total solids	500	1,500
Colour	5 units	50 units
Turbidity	5 units	25 units
Taste	Unobjectionable	–
Odour	Unobjectionable	–
Iron	0.3	1
Manganese	0.1	0.5
Copper (Co)	1	1.5
Zinc (Zn)	5	15
Calcium (Cu)	75	200
Magnesium (Mg)	50	150
Sulphate (SO_4)	200	400
Chloride (Cl)	200	600
pH range	7.0–8.5	6.5–9.2
Magnesium & sodium sulphate	500	1,000
Phenolic substances (as phenol)	0.001	0.002
Carbon chloroform extract (CCE) (from organic pollutants)	0.2	0.5
Alkyl benzyl sulfonate	0.5	1

Note: Unless otherwise noted, units are in mg/L.

9.3.2 Treatment of Surface Water

Conventional water treatment processes comprising coagulation with aluminium sulphate, sedimentation (clarification), rapid gravity sand filtration (or pressure filtration), pH correction with lime or soda ash and chlorination with chlorine gas or sodium hypochlorite (bleaching powder) are applicable to all the surface water sources. There is no reason to change the method of treatment at any of the existing surface water treatment plants and as the types of chemicals in use have been proved from experience to be the most appropriate they will be maintained.

9.3.3 Treatment of Borehole Water

It is acknowledged that most borehole waters in the study area meet the drinking water standards. Treatment of borehole water consists of aeration. Chlorination of borehole waters will be provided for large borehole systems.

9.3.4 Water Quality Monitoring

Existing regional water laboratories are sufficient for periodic monitoring of borehole waters but each surface water treatment plant should have its own facility for monitoring the quality of both the raw water and the processed water at different stages of treatment. Well-equipped chemical laboratories will be provided for the large treatment plants and appropriate test kits will be provided for the smaller treatment plants.

The following methods of water treatment are considered to be suitable, used in different combinations as necessary to achieve the desired results:

- Screening or straining
- Roughing or pretreatment filters
- Primary sedimentation
- Chemical coagulation, flocculation and secondary settling
- Filtration either by slow sand or rapid gravity filtration
- Disinfection
- Control of algae
- Taste and odour control
- Softening
- Removal of iron and manganese
- De-fluoridation of water

Minimum treatment will be disinfection for groundwater sources and some form of filtration followed by disinfection for surface water sources. The most feasible option (technically and financially) will be developed for each town/source individually.

9.4 Criteria for Additional Components

Section valves (symbolized "SV") will be installed for facilitating maintenance of the system:

- Maximum 10 km distance between devices
- Critical points

Air valves (symbolized AV) will be installed:

- Maximum 0.7 km distance between devices
- High topographical points
- Severe change and critical points in hydraulic gradient

Washout valves (symbolized "WV") will be installed at low points and sized to ensure drainage of the pipe sections.

Surge protection valves (symbolized "SPV") and cathodic protection equipment will be designed and installed according to detailed analysis by suitable experts.

Bulk water meters will be installed in offtakes of the main water resources and the entry to the supply system of each WSP. Since the delivery of water from the bulk water supply system to the network grids will be done through the local water tanks, it is recommended that a water meter of the bulk supply type be installed upstream of each tank, thereby allowing CWSB staff to measure incoming volume to the WSP's water tank and then calculate water balance along the main water supply lines. This will support the CWSB in the future with better understanding of the nature of water losses, and will allow the CWSB to track water losses.

9.5 Hydraulic Simulations

The principles of establishing and running a successful hydraulic model are the correct incorporation of two types of data, as follows:

- Physical data of the water network (pipes, elevations, diameters, demand centres, etc.) – variables that are not time dependent
- Dynamic network data (water consumption, water supply, condition and state of the water resources, etc.) – time-dependent variables that may change within short periods, measured in minutes or hours

For the master plan study – which includes the development program for each one of the phases, and in parallel, the range of operational options – the hydraulic simulation tool can answer both, as the software combines both the physical layer of the development as well as the dynamic operations layer.

For any hydraulic simulation, the first necessary step is the compilation of the physical data of the existing system, thus creating the model foundation.

Combining these two levels, the physical and the dynamic, enables simulations of the flows in the water pipeline systems and residual water pressure readings at the demand centres.

Water pressure readings at the demand centres are an essential operational variable of the system. Water delivery utilities are obligated to operate the system within specific directives and parameters. Low water pressure can result in consumer complaints regarding low quality of services, whereas excess pressure may result in pipe bursts and increased leakages.

Hence, the main objective of the hydraulic simulation is to compute the water pressures in the various demand centres of the network and in relation to each one or each group, to specify if there is sub-pressure (less than 15 m) or excess pressure (for which pressure-reducing valves may be required).

The hydraulic simulation model can be utilized for both design needs as well as for the evaluation of different states of system operations. When design is the main target, the simulation is used in order to identify the parameters of the hydraulic components. Basic assumptions are drafted with regard to the size and capacity of the components (valves, pumps, etc.) and solutions to the flow system are conducted. This enables the performance of a mathematical appraisal of the components selected and the specifications of different parameters in relation to the supply system in order to achieve optimal results.

When directing the analysis of the operational aspects of the system, all physical parameters of the system are given and are not open for change. The operational simulation is mostly needed to appraise different alternatives for operation of pumping equipment and/or filling tanks in order to achieve optimal operational efficiency that uses a minimum amount of energy.

For efficient running of the hydraulic model, the following layers have been prepared:

- Input of topographical data, based on GIS mapping information, elevations and other contours, with elevation resolution of 10 m
- Input of the current water system capacity – current water lines, water components/facilities, water production facilities
- Input of data on other components – sluice valves, pressure valves, etc.
- Verification, based on field staff observations, with regard to the gaps between water systems mapped on the formal maps and the actual situation on the ground
- Input of population data and water demand proposed according to population and demand projections
- Dynamic data:
  - Input of relevant data on the operations of the water system, specifically for Baricho Wellfield, which provides water to Mombasa and the various storage facilities along the main conveyance system
  - Data on water facilities, pumps and boosters
- Apply water demand to the hydraulic model (hydraulic loads)

9.6 Sequence of Development

9.6.1 Overview

As the demand for water will increase over the years, it becomes obvious that the development of water resources will be gradual, matching the demand with the supply at each one of the phases. It was therefore concluded that not only will the phase of the development play a role in selection of the preferred option, but also the ***sequence of development*** will be a key issue with regard to future activities.

Following the completion of the feasibility study, Scenario B1 was selected to be the "preferred scenario". For this scenario, the development of the water resources is presented, followed by the need for new water supply schemes and infrastructure that will allow water to be delivered from the resources to the demand centres. Prior to this phase, the Immediate Phase will be executed, using the funds earmarked for emergency supply to Mombasa..

The main phases of development and their main activities are as follows:

- ***Immediate Phase***
  - Baricho production extension
  - New Kilifi Pipeline
  - Sabaki-Mombasa Pipeline segment rehabilitation
  - To be completed by January 2016, per WB direction
  - *Subject to funds availability:* Rehabilitation of the Taveta Springs (known locally as the Njoro Kubwa Springs), and development of local water supply scheme for Taveta township

- ***Phase I***
  - Development of the Mwache Dam, including water treatment plant, pumping station, main transmission pipelines and the New Mwache Tank (NMT)
  - Rehabilitation of the Taveta Springs (known locally as the Njoro Kubwa Springs), and development of local water supply scheme for Taveta township *(if not already carried out during the Immediate Phase)*

- ***Phase II***
  - Baricho full development water production
  - New Sabaki-Mombasa and Malindi pipelines
  - Connection of south region of Ukunda and Msambweni to the south branch supply from Mwache
  - Development of the water supply scheme to Lamu and Tana River counties, including complete local schemes for Hola and Bura
  - This phase will be the dominant one out of all three phases.

- ***Phase III***
  - Increasing water abstraction from the Mzima Springs, plus upgrade of intake conveyor from 30" to 48" diameter
  - Construction of the Mzima 2 Pipeline from the springs to Mazeras, including the secondary supply lines to Voi/Maungu, Mwatate and Wundanyi

Fig. 9-1 shows the timing of the phases vs. the water demand.

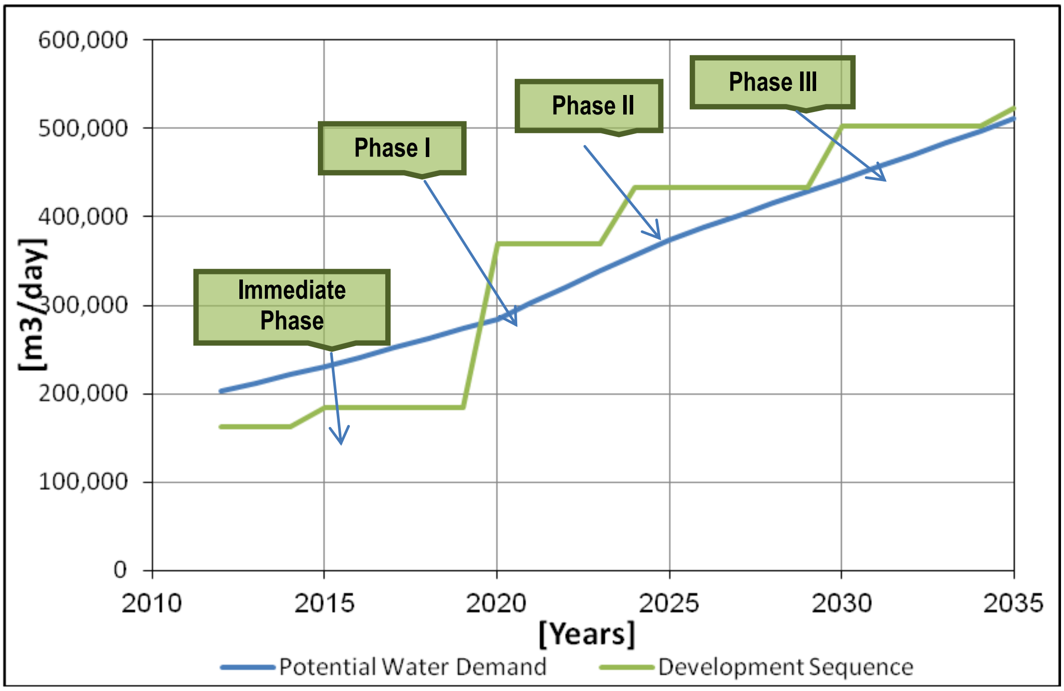


Fig. 9-1: Development of water resources vs. demand

Table 9-3 summarizes the total projected available water of the design plan and the balance between abstraction and supply for each phase, i.e., 2020, 2025 and the horizon year of 2035, for the BWSS. According to the preferred scenario, the table also summarizes the total BWSS demand for water in each development phase (presented in five-year intervals, with the proposed water resources to meet the demand).

Red boxes indicate unbalanced periods when the total demand for water will be greater than the potential of water from the resources. Green boxes indicate years when the total availability of water from the resources will be greater than the demand, and water will be supplied to all consumers, according to their calculated demand, and as long as they will be connected to the BWSS.

Table 9-3: BWSS Water Demand and Resource Development by Phase

Phase			Immediate		I	II		III
Target Year			**2012**	**2015**	**2020**	**2025**	**2030**	**2035**
Population Projection			2,907,067	3,521,284	4,130,325	4,839,196	5,669,727	6,642,798
Total Water Demand (m³/d) *			213,509	242,696	299,637	394,233	465,753	538,273
Target Water Demand (m³/d) **			**202,834**	**230,561**	**284,655**	**374,521**	**442,465**	**511,359**
Existing Capacity (m³/d)								
Water Source	**Year Developed**		**2012**	**2015**	**2020**	**2025**	**2030**	**2035**
Tiwi Boreholes ***	1980		13,000	13,000	13,000	13,000	13,000	13,000
Marere Springs	1923		12,000	12,000	12,000	12,000	12,000	12,000
Mzima Springs ****	1957		35,000	35,000	35,000	35,000	0	0
Baricho Wellfield *****	1980		83,000	83,000	83,000	83,000	68,000	68,000
Others – local resources	various		12,000	12,000	12,000	12,000	12,000	12,000
Total Existing Capacity, **m³/d**			**155,000**	**155,000**	**155,000**	**155,000**	**105,000**	**105,000**
Expected Water Deficit, **m³/d**			-47,834	-75,561	-129,655	-219,521	-337,465	-406,359
Capacity following Implementation of Scenario B1 (m³/d)								
Water Source			**2012**	**2015**	**2020**	**2025**	**2030**	**2035**
Baricho – immediate expansion			–	20,000	20,000	20,000	17,000	17,000
Mwache Dam			–	–	186,000	186,000	186,000	186,000
Baricho 2 – full expansion			–	–	–	70,000	90,000	90,000
Mzima 2 ***			–	–	–	–	105,000	105,000
Msambweni Aquifer / Mkurumudzi Dam			–	–	–	–	–	20,000
Total Available Water Resources			**155,000**	**175,000**	**361,000**	**431,000**	**503,000**	**523,000**
Surplus / Deficit			-47,834	-55,561	76,345	56,479	60,535	11,641

* Includes 25% NRW + rural demand along the main pipelines
** Less 5% where people will continue to use local sources
*** Figures for Tiwi are the proposed yield for the wellfield
**** The Mzima 2 Scheme will supply 105,000 m³/d, and will replace the old scheme.
***** Total production of vertical-type boreholes will decrease due to decreased duty cycle.

9.6.2 Phasing and Projects

- **Immediate Phase** ("emergency works to improve supply to Mombasa" – to be completed by 2016):
  - Extension of Baricho water production by adding two new boreholes
  - Segment rehabilitation of Sabaki-Mombasa Pipeline
  - New Kakuyuni-Kilifi Pipeline
  - New supply pipeline to Gongoni plus Gongoni Water Tank
  - Extension of existing Kakuyuni Water Tank
  - *Subject to budget availability:* Taveta Springs (known locally as the Njoro Kubwa Springs) rehabilitation and development of Taveta local water supply scheme

- **Phase I** (to be completed by 2020):
  - For the development of Mwache Dam, the entire reservoir and conveyance system will be deployed, including the water treatment plant downstream of the dam.
  - The main pumping station will lift the water through a 40" main pipeline to the New Mwache Tank (NMT) at +120 masl. No water will be pumped to the Mazeras Water Tanks.
  - The new pumping station will lift the water through a 28" main pipeline to the Chamgamwe Water Tank at +70 masl.
  - The new pumping station will lift the water through a 28" main pipeline to the Kaya Bombo Water Tank at +70 masl.
  - Implementation of Mwache Dam
  - Taveta Springs (known locally as the Njoro Kubwa Springs) rehabilitation and development of Taveta local water supply scheme *(if not already carried out during the Immediate Phase)*

- **Phase II** (to be completed by 2025):
  - Full development of the Baricho Wellfield
  - This phase will require implementation of the second Baricho Pipeline, parallel to the existing one, with an 800 mm diameter, as well as extension of the Baricho water production.
  - This will include activities along the southern shore of the Sabaki River to locate new sites for pumping facilities in order to add the required water volumes to the bulk water supply system.
  - Connection of south region of Ukunda and Msambweni to the south branch supply from Mwache
  - Development of the water supply scheme to Lamu, as well as complete local schemes for Bura and Hola

- **Phase III** (to be completed by project horizon year of 2035):
  - Development of the Mzima 2 Pipeline, which will deliver 105,000 m^3/d via a new 220 km pipeline (abstraction of an additional 70,000 m^3/d from this source)
  - Msambweni Aquifer and Mkurumudzi Dam will be available after the completion of mining works, and the development of transmission works will add 20,000 m^3/d.
  - Supplementary development of Msambweni Aquifer and connection of Lunga Lunga to the bulk water supply system

Fig. 9-2 presents a block diagram of the proposed bulk water supply system. Demand summaries are shown in the lower boxes, the resources are shown in the upper boxes. The existing system is represented in black, and Phases I–III are indicated via different colours.

Fig. 9-3 presents the layout of the proposed system and the geographical locations of the demand centres.

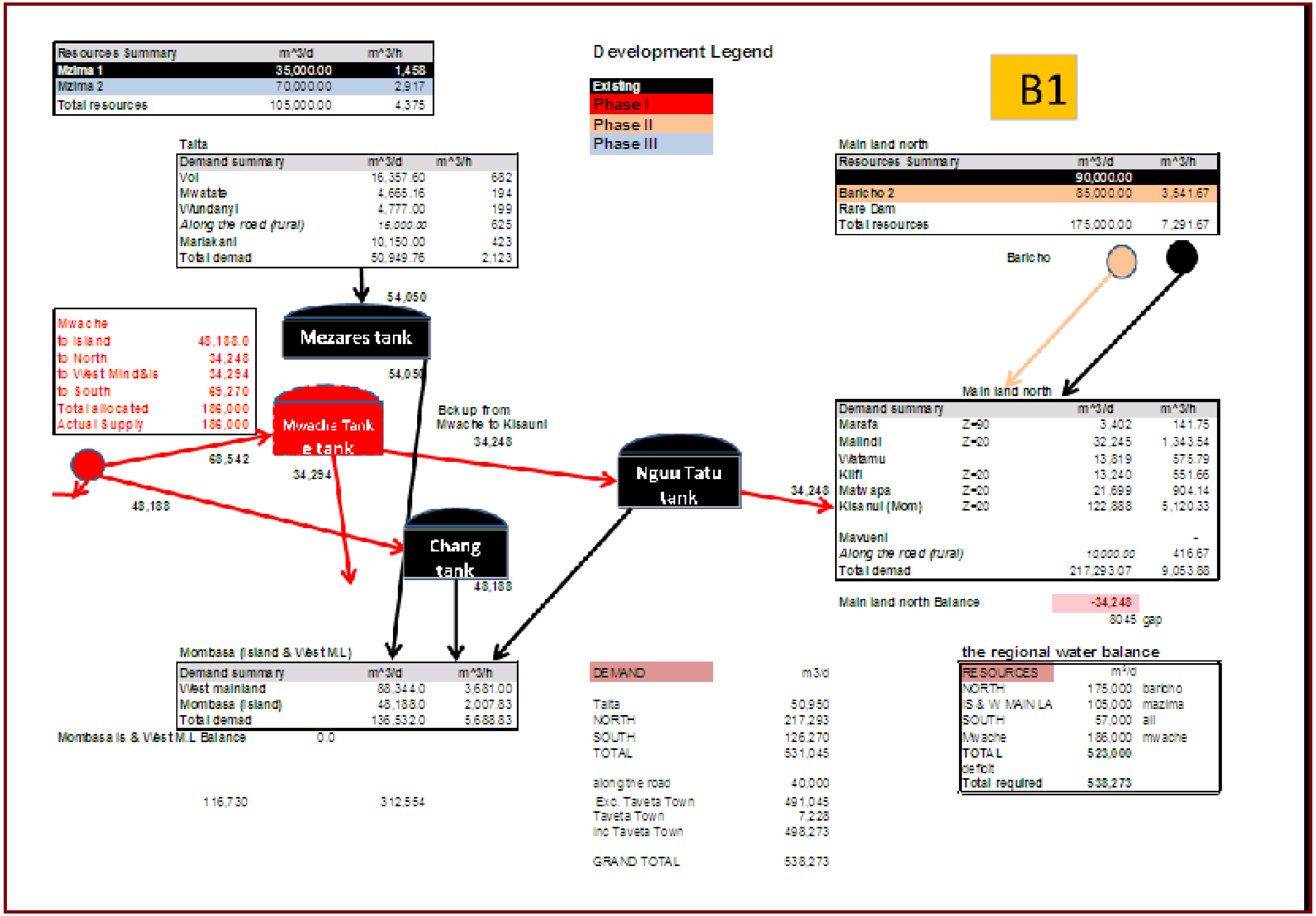


Fig. 9-2: Block diagram – proposed development

Fig. 9-3: **Layout map of sequential water resources development**

9.7 Immediate Phase

9.7.1 Additional Financing for Immediate Improvements in Water Supply to Mombasa

The WB and AFD have earmarked additional funds to the CWSB for immediate investment within the CWSB area. The main target of these funds is to carry out immediate improvements in water supply in the region, with focus on increased supply to the city of Mombasa. According to the donor requirements, the above budget must fulfil the following constraints:

- The proposed project must realize an increase in supply volume to the region, with focus on Mombasa.
- The funds must be allocated so as to maximize water availability.
- The proposed project must be completed and in operation no later than January 2016.
- As much as possible, the investment should comply with the WSMP.

Subject to budget availability, this phase will also include rehabilitation and development of Taveta Springs (known locally as the Njoro Kubwa Springs) for local water supply scheme for Taveta township.

9.7.2 Proposed Alternatives

With the above constraints, three main alternatives were suggested. Alternatives 1 and 2 were discussed briefly in the meeting held at the offices of the World Bank on 15 January 2013, and a third alternative was examined by the Consultant following analysis of the first two alternatives. Alternative 3 were found to be the best in term of cost per m^3, and was therefore chosen to be recommended for execution. Its main characteristics are as follows:

- Augmentation of 17,000 m^3/d to Mombasa
- Augmentation of 5,000 m^3/d to the area of Malindi, Gongoni & Kilifi
- Reducing the energy costs of water supply to Kilifi by supplying via a new gravity main
- Main components:
  - Drilling two additional boreholes in Baricho
  - Connecting the new boreholes to the water treatment facility at Baricho
  - Construction of gravity main, Kakuyuni-Kilifi (500 mm / 50 km)
  - Construction of gravity main, Malindi-Gongoni (300 mm / 20 km)
  - Construction of parallel force main, Lower Ribe-Nguu Tatu (800 mm / 12 km)
  - Diverting the supply to Kilifi to the new gravity main and reducing the loads on Baricho-Nguu Tatu Pipeline

The master plan recommendation is for development of "Baricho 2" and the construction of an 800 mm parallel pipeline from Baricho to Nguu Tatu, in parallel to the existing Baricho Pipeline. This alternative proposes to lay sections of the future pipeline during the Immediate Phase. The new 800 mm section will be in parallel to the two existing 600 mm sections, of which only the 800 mm section and one of the 600 mm sections will be used for conveyance to Mombasa. The third section will be used for the Lower Ribe Water Tank consumers. This will increase the capacity of the Baricho-Nguu Tatu Pipeline and improve the supply to Mombasa. This recommendation is in accordance with the WSMP.

9.7.3 Conclusions

The key objective of the Immediate Phase is to increase the water supply from Baricho toward Mombasa. Following the reinforcements of the bottleneck sections of the Sabaki-Mombasa Pipeline with the new 800 mm segment, as well as the diversion of the Kilifi water supply, the result will be an additional supply to Mombasa of about 20,000 m^3/d, using the existing delivery pumps. In order to provide this daily volume, two new vertical-type boreholes, identical to the existing boreholes, will be required at the Baricho Waterworks, thereby enabling 20,000 m^3/d, while operating 21 h/d (see Fig. 9-4).

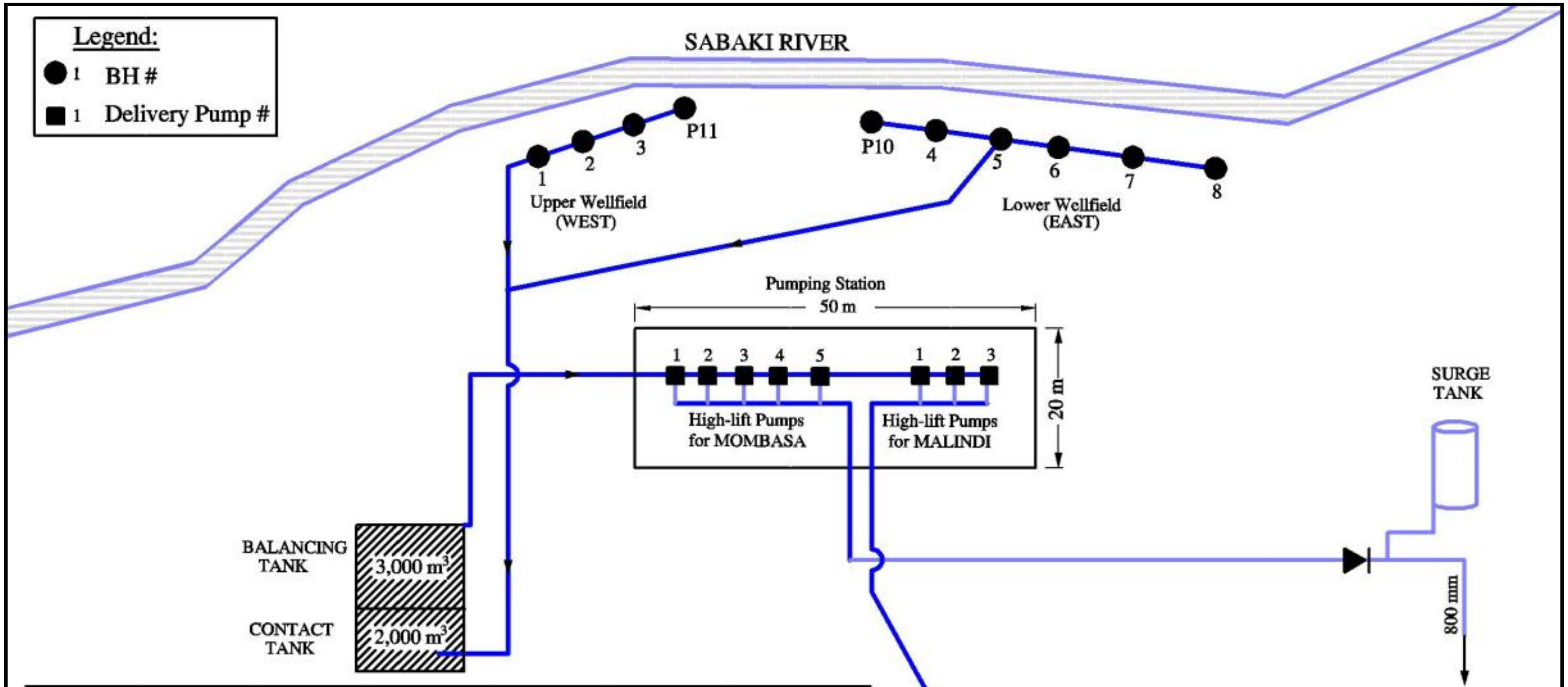
In this alternative, the water supply will be conveyed using the existing 600 mm pipe from Baricho to the Kakuyuni Water Tank, and from there with a new 500 mm pipeline toward Kilifi. It was calculated that the existing 600 mm Baricho-Malindi Pipeline can convey an additional volume of about 15,000 m^3/d. Out of this 15,000 m^3/d, Kilifi will receive some 10,000 m^3/d via the new Kilifi Pipeline and Malindi will receive some 5,000 m^3/d via the existing Baricho-Malindi Pipeline. This will allow some more 20,000 m^3/d to be pumped from Baricho toward Mombasa to increase the supply to the city.

Significant energy savings will be realized as most of the Kilifi supply will pumped through the Malindi pipe (TDH of 80 m) compare to the Mombasa line (TDH of 240 m). The energy savings was estimated to be 5,000–6,000 kWh/d, which translates into a cost savings of KSh 160,000–190,000 per day.

9.7.4 Summary of the Engineering Components of Baricho Waterworks Extension and Transmission Pipelines

Table 9-4 presents a preliminary BOQ with engineering components required for the Immediate Phase.

Please note that the BOQ for the Taveta Springs (Njoro Kubwa Springs) rehabilitation is presented as part of the Phase I BOQs (see Table 9-19).



	Existing+ New	Q (m³/h)	Head	Hours	Daily (m³)	Operation
BH	8+2	470	65	~18	84,500	
Mombasa Delivery	5	833	245	~20	66,000	4 duty + 1 standby
Malindi Delivery	3	583	100	16	18,500	2 duty + 1 standby

Fig. 9-4: Schematic drawing of Baricho Waterworks – Immediate Phase

Table 9-4: Immediate Phase – Engineering Components of Baricho Waterworks Extension and Transmission Pipelines

1			Baricho Waterworks Extension	Unit	Qty
	1.1		**Civil engineering works**		
		1.100	Drilling new boreholes at the Baricho site, 5 m diameter	No.	2
		1.101	Concrete works for the borehole cover and pump installation	LS	2
		1.102	Conducting geohydrological study to determine civil engineering works needed for future abstraction of water from the buried Sabaki River palaeochannel	LS	1
		1.103	Civil construction works for new non-asphalt access road to site, and upgrade of existing non-asphalt road	km	0.5
	1.2		**Electromechanical works**		
		1.200	Supply of borehole pumps, 480 m³/h, 60 m head	No.	2
		1.201	Installation of the above borehole pumps	No.	2
		1.202	Electrical installation for pumps	LS	2
	1.3		**Pipe and manifolds**		
		1.300	Pipes to borehole pump manifolds, steel, 16", DN400	m	40
		1.301	Pipe for main manifolds from borehole pumps to main conveyer, steel, 20", DN500	m	300
		1.302	Main gate valve for borehole manifolds, 12", DN300	No.	2
		1.303	Main non-return valve for borehole manifolds, 12", DN300	No.	2
		1.304	Suction chamber main valve, 24", DN600	No.	1
		1.305	Suction chamber secondary valve, 12", DN300	No.	3
	1.4		**Accessories**		
		1.400	Air valve, static + dynamic, 6", DN150	No.	4
		1.401	Air valve, static + dynamic, 4", DN100	No.	2
		1.402	Air valve, static + dynamic, 3", DN80	No.	2
		1.403	Surge rapid pressure release valve, 12," DN300	No.	2
		1.404	Surge rapid pressure release valve, 10", DN250	No.	2
		1.405	Surge rapid pressure release valve, 6", DN150	No.	4
		1.406	Pressure sustain valve, 16", DN400	No.	2
		1.407	Pressure sustain valve, 12", DN300	No.	1
		1.408	Pressure sustain valve, 10", DN250	No.	1
		1.409	Flowmeter for each borehole, DN400	No.	2
		1.410	Gate valve for flowmeters, DN400	No.	4

2			Baricho-Nguu Tatu Pipeline (segment rehabilitation)	Unit	Qty
	2.1		**Pipe and manifolds**		
		2.100	Rare-Jaribuni parallel force main pipe, steel, DN800, PN 25	m	600
		2.101	Lower Ribe-Nguu Tatu parallel force main pipe, steel, DN800, PN 16	m	12,000

2			Baricho-Nguu Tatu Pipeline (segment rehabilitation)	Unit	Qty
	2.2		**Accessories**		
		2.200	Air valve, static + dynamic, 6", DN150	No.	42
		2.201	Gate valve for the main pipeline, 32", DN800	No.	10
		2.202	Drain valve for the main pipeline, 8", DN200	No.	9
	2.3		**Water distribution chambers**		
		2.300	Gate valve chamber for main valve, 32", 2 m x 3 m	No.	42
		2.301	Air valve chamber, 1.5 m x 1.5 m	No.	10
		2.302	Chamber for drainage valves, 2 m x 3 m	No.	9
2			**Total – Section 2**		

3			Kakuyuni-Kilifi and Malindi-Gongoni Pipelines	Unit	Qty
	3.1		**Pipe and manifolds**		
		3.100	New Kakuyuni-Kilifi gravity main, PE pipe, DN500, PN 10	m	50,500
		3.101	New Malindi-Gongoni gravity main, PE pipe, DN300, PN 10	m	25,000
	3.2		**Accessories**		
		3.200	Air valve, static + dynamic, 6", DN150	No.	62
		3.201	Gate valve for the main pipe, 20", DN500	No.	10
		3.202	Gate valve for the main pipe, 12", DN300	No.	5
	3.3		**Water distribution chambers**		
		3.300	Gate valve chamber for main valves, 20", 2 m x 3 m	No.	10
		3.301	Gate valve chamber for main valves, 12", 2 m x 3 m	No.	5
		3.302	Air valve chamber, 1.5 m x 1.5 m	No.	62
	3.4		**Water tanks**		
		3.400	New water tank at Kakuyuni	m^3	2,500
		3.401	New water tank at Kilifi	m^3	5,000
		3.402	New water tank at Gongoni	m^3	1,000
	3.5		**Water pumps**		
		3.500	New pumping station at the Gongoni Water Tank (150 m^3/h, 40 m)	LS	1

9.8 Phase I – Mwache Dam Water Supply Scheme

9.8.1 General

The Mwache Dam is a key water source for the region. Its close vicinity to the hub of water demand around the greater Mombasa area and the intensity of this source makes it a significant water source for the region. Balancing the water demand and supply in the southern region (namely Kwale, Diani and towards Tiwi, Ukunda and Msambweni) confirms that there is a substantial lack of supply in this area. A new water supply scheme will connect the Mwache site with the Kaya Bombo Water Tank that serves the Likoni neighbourhood, and along the southern coast to the Kwale settlements and to Diani and Ukunda. This supply scheme (Mwache South Supply Scheme) is a modification from the original Mwache Dam Feasibility Report, which proposes that all water from the dam be conveyed towards the Mazeras Water Tanks.

9.8.2 Mwache Dam Water Treatment Plant

9.8.2.1 Overview

The water treatment plant consist of the intake and raw water mains, coagulant mixing unit, flocculation units, sedimentation tanks, rapid sand filters, clear water storage tanks, and associated infrastructure such as backwash water system, chemical storage and dosing units, administration buildings, living quarters, access roads and packing, flow control facilities, pipeworks, etc.

The data and information in this section are based on the Draft Detailed Design Report prepared by CES.

9.8.2.2 Design of Water Treatment Plant

Water treatment plant design criteria are as follows:

- **General:**
  - Plant design capacity:
    6 parallel streams, each 32,640 m³/d = **195,790 m³/d**
    (6 parallel flocculators, 18 sedimentation basins and 36 rapid sand filter units)
  - Treated water used for backwashing of filters and domestic use at site (approximately 5%): 9,790 m³/d
  - **Net treated water available for bulk transmission: 186,000 m³/d**

- **Distribution chamber & pH correction with soda ash – V-notch flow measurement weir:**
  - Type: Hydraulic
  - Point of application: Downstream of flow measurement weir
  - Storage: 30 days
  - Dosing method: Gravity solution feeders
  - Dosing rate: 20–40 mg/l
  - Detention time (T): 10–60 s
  - Velocity gradient: 500–1,000 m/s
  - Mixing head: 0.6–1.2 m

- **Rapid mixing/flow measurement weir:**
  - Type: Hydraulic
  - Point of application: Downstream of flow measurement weir
  - Storage: 30 days
  - Dosing method: Gravity solution feeders
  - Dosing rate: 40–80 mg/l
  - Detention time (T): 10–60 s
  - Velocity gradient: 500–1,000 m/s
  - Mixing head: 0.80–1.5 m

- **Flocculation:**
  - Type: Horizontal flow around-the-end baffled channel flocculation (3 compartments)
  - Maximum velocity at inlet: 0.4 m/s
  - Maximum velocity at outlet: 0.2 m/s
  - Detention time (T): 15–30 minutes
  - Velocity gradient (G): 20–100 S^{-1}
  - GT value: 20,000– 200,000

- **Sedimentation:**
  - Type: Horizontal flow (rectangular) without mechanical sludge removal
  - Surface loading rate: 20 – 40 $m^3/m^2/h$
  - Maximum velocity at inlet: 0.20 m/s
  - Maximum velocity outlet: 0.40 m/s
  - Detention time: 2–6 hours
  - Sludge accumulation: 25% of settling volume
  - Length/Width ratio (L/W): 1:2 to 1:8
  - Effective water depth: >2.0 m (2–4 m)
  - Tank floor slope: From outlet end to inlet end: 5–8%; From sidewalls to centreline: 10%
  - Desludging: Manually
  - Outlet of sedimentation tank: Launders – with V-notches

- **Filtration:**
  - Type: Conventional – Rapid Gravity Sand Filters
  - Rate of filtration: 4–8 $m^3/m^2/h$
  - Rate of backwash water (with water alone): 50 – 120 $m^3/m^2/h$
  - Backwash time: 10–20 minutes
  - Rate of filtration control: Manually controlled valve

- **Disinfection and pH correction:**
  - Disinfection by either hypochlorite powder or chlorine gas:
    - Form: Fine granular material
    - Storage: 30 days
    - Dosing method: Gravity solution feeders
    - Dosing rate: 2.0–15.0 mg/l
    - pH correction by soda ash

- **Clear water (retention) tank – at treatment works:**
  - Retention time: 30–90 minutes

- **Chemical storage mixing building:**
  - Aluminium sulphate [$Al_2 (SO_4)^3$, $18H_20$]
    - Form: Powder
    - Storage: 30 days (minimum)
    - Dosing method: Gravity solution feeders
    - Dosing rate: Average 50 mg/l
  - Soda ash [Na_2CO_3]
    - Form: Powder
    - Storage: 30 days (minimum)
    - Dosing method: gravity solution feeders
    - Dosing rate: Average 40 mg/I

- **Mechanical equipment:**
  - Standby generator
    - Number: 1
    - Capacity: 1
  - Recirculation pumps
    - Number: 2 (1 duty, 1 standby)
    - Flowrate: 815.9 m^3/h (12 hr pumping)
    - Dynamic head: 18 m
    - Electric motor: 100 kW
    - Total power for working pumps: 99.83 kW
  - Instrumentation equipment for flow measurement, etc.:
    - Incoming raw water – distribution chamber
    - Treated water from new treatment works
    - Recirculate backwash water

- Pumped supply
  - To Mwache high level tanks
  - To community – 3.5 km from the site and to be used by scheme village and neighbours
- Alarm system for overflow from stilling well, filters, etc., for information, including a display board

- **Administration building offices for:**
  - Scheme Manager
  - Secretary
  - General Store / Registry
  - Operators Rooms Central Recording Room for Instrumentation
  - Reception
  - Laboratory
  - Board Room
  - Water Engineers Room
  - Washrooms (Ladies/Gents)
  - Staff Quarters (spread in works area)
  - Guard Rooms (spread in works area)

9.8.2.3 Raw Water Intake Works

- **Intake system**

The intake works will consist of an intake tower complete with bridge access located in the impounded dam water. The maximum dam water level is 82.5 masl and the minimum drawdown is 45 masl (based on dam design). For 99% water supply reliability, the intake system should be able to draw water at the entire dam height between 82.5.masl and 45 masl. The intake flow system should be made for gravity flow and based on the site topography, the treatment works are at about 46.5 masl. The draw of system lowest level is thus set at 47 masl.

For purposes of creating redundancy, the intake will thus be made up of two vertical pipe draw-offs with several inlets over the water column and will flow by gravity to the Water Supply Treatment Plant. Therefore there will be need to construct an intake tunnel for water to flow by gravity and also regulate the amount of water and the top water level entry to the treatment works downstream the intake.

It is proposed that each intake draw-off pipe be made of coated steel pipe with three number inlet pipes spread on the vertical columns supported by an intake tower. The inlets are so places so that at any given time, the open inlet is not more than 15 m head for safety and operational purposes. The intakes will be fitted with Sluice valves with operating spindle on the intake tower platform. The intake pipe is sized for the entire 186,000 m³/d plus 5% backwash water (total 195,790 m³/d) there is no peaking factor for this flow as the redundancy is provided at 100%. The intake pipe is for twin DN 1100 of total length of about 410 m.

The intake tower shall be constructed of reinforced concrete frame and a platform for operations. The beams a placed such that the intake pipe is supported on them and an access ladder to the inlets for purposes of cleaning of course screens.

One of the components to be introduced to the intake is fish screens/barriers so that fish are not "sucked" into the water treatment plant. This can effectively be done by having the rack screens of such a size that would deter passage of fish into the intake pipe.

Critical facilities are the access bridge to the intake tower, pressure reducing valves to ensure that there is no overflow in the downstream facilities with the varying dam levels of 37 m head. The two pipes will be interconnected through a sluice valve just before the pressure reducing valves to allow for maintenance of the pressure reducing valves.

- **Distribution chamber**

The distribution chamber will be composed of 2 chambers in series, the first chamber will collect the water from the inlet pipe and send it to three (3) number "in parallel" V-notch weirs for equal flow distribution between the 3 process pairs. The first chamber is so sized so that it will also allow the hydraulic performance of the V-notch weirs allowing for proper measurement.

Up-flow velocity is limited at 0.1 m/s in the first chamber to allow the measurement in the V-Notch sharp crested weirs.

After flow distribution, a "3 compartments" second chamber will collect the water from the V-notch weirs and send it to the WTP lines via a 3 x DN 700 lines. Detailed hydraulics calculations (TWorks – calculation sheets) are included in Annex 4 in Volume III of the WSMP.

9.8.2.4 Water Treatment Units

The water treatment plant is sized for the entire water demand of **195,790 m³/d**. However, the treatment units are sized for six treatment streams that can be used for phased construction (modular units). Each treatment stream is able to treat 32,640 m³/d, which allows for 5% of the throughput as backwashing water.

The treatment plant units are sized based on the raw water quality, the water demand and output water quality. The treatment stream is composed of a rapid mixer (for coagulant dosing), a flocculation unit, three number parallel sedimentation tanks, six number parallel rapid sand filters and an appropriate combined flow clear water storage tank with chlorination unit after filtration. The backwash water effluents are stored into a lagoon for settlement and the supernatant water is pumped back into the system to join the treatment stream at the rapid mixing chamber unit.

The units have also been sized for ease of construction trying to maintain the overall outside width of each treatment stage same throughout to achieve a rectangular shape of combined units.

Recommended maximum velocity is 3 m/s for DN 350 valves and above. Velocity below 1.5 m/s will be considered at water treatment plant inlet and all other pipework.

Summary of the treatment plant units is as follows:

- **Rapid mixing**
  - Rapid mixing adopted is weir type with minimum 10 seconds detention time. The Coagulant is dosed at the hydraulic jump formed. It should be noted that there might be need for pH correction of Soda Ash to facilitate coagulation, based on the sampled water in the seasonal river. However, the extent of this pH correction would be confirmed based on the quality of the raw water after impoundment in the dam.
  - The raw water, supernatant from filter backwashing and coagulant are feed into the rapid mixing chamber. The weir is such designed to measure the flows from the raw water pipe.
  - Adopted criteria on the sizing:
    - Type: Hydraulic
    - Point of application: Downstream of flow measurement weir
    - Detention time (T): 10 seconds
    - Velocity gradient (G): 1,000 m/s
    - Mixing head: 1.03 m
  - From the chemical mixing and dosing building, dosed water is conveyed through a 450/400 mm diameter pipe to feed the raw water at the hydraulic jump. The same is also fed with the recirculating backwash water from the settlement ponds.
  - Both the dosed water and flocculated water channels will be covered with precast concrete slabs to serve as walkways and recesses provided for lifting up of these slabs for cleaning and maintenance purposes.

- **Flocculation basin**
  - A hydraulic flocculation system achieved by means of horizontal flow baffled basins has been designed. This system was adopted due to its advantage of ease of operation, cleaning and draining operations. For each treatment stream, one flocculation basin has been provided having overall plan dimensions of 13.20 m x 24.7 m. Each basin is divided into three sections separated by 250 mm thick reinforced concrete walls, with 90 mm, 120 mm and 150 mm thick rounded reinforced concrete baffle walls at 480 mm, 729 mm and 922 mm clear spacing respectively. The

varying baffle wall spacing was designed to provide a tapering velocity gradient within each basin, thereby enhancing the efficiency of the floc formation process. The fact that there are six treatment streams allows for flexibility in operations so that when one stream is put out of operation there is continuity of service.

- For periodic removal of settled flocs, each basin, as well as the dosed water channel, has been provided with a 150 mm diameter draw-off pipe. These sludge draw-off pipes will operate under the hydrostatic pressure in the basins and dosed water channel to discharge into a common chamber provided as part of the overall onsite draw off/overflow drainage system that flows to the waste/wastewater ponds.
- The round the end baffled hydraulic flocculation is adopted to avoid mechanical stirrers. There are three compartments for the mixing to ensure that flocs are of sufficient sizes as indicated in Table 9-5.

Table 9-5: Summary of Design of Hydraulic Flocculation Units Gt Values

Compartment	1	2	3
G-value range, /s	100 – 65	65 – 30	30 – 10
Chosen G-value, /s	80	45	30
Applied Gt-value	48,000	27,000	18,000
Total Gt-value (1 + 2 + 3)	93,000		

- **Sedimentation basin**
  - From the flocculated water channel, the water enters another covered channel 1.2 m wide x 1.7 m deep running across the width of four horizontal flow sedimentation tanks adjacent to each other. This channel is used to distribute the flocculated water to all three Sedimentation Tanks. Each Sedimentation Tank has internal plan dimensions of 35.20 m x 7.75 m and is 3.5 m effective depth for clear water depth but provided with 33% of volume as sludge storage. Therefore the depth at the deepest point is 4.58 m. The L/B 5:1 ration is selected to ensure that the total width of the combined settlement tanks fits into the flocculation basin overall length (of 35.2 m) while ensuring that the criteria is within range of 2-8.
  - Horizontal flow sedimentation tanks were adopted due to their ease of operation and maintenance. They can take large variations in flows and temperatures with no adverse effect on their performance. Provision of three parallel tanks per treatment stream allows economy in designs and gives flexibility in operation and maintenance.
  - Water enters each tank from the flocculated water channel through two 450 mm x 450 mm penstock-controlled square openings into a 600 mm wide x1800 mm deep inlet channel and then into the settling zone through eleven 350 mm diameter orifices spaced at 700 mm centres at the base of each inlet channel.

- Three reinforced concrete channels troughs, each 8.8 m long, with V-notch galvanized mild steel decanters are provided near the top of each tank to decant water after settlement and empty into a 1.2 m wide x1.8 m deep settled water channel from which the water enters the rapid sand filters. The troughs are held in position by clamps, brackets and bolts fixed to supporting reinforced concrete and steel beams and to the walls of the sedimentation tanks. Provision has been made to allow adjustment of the levels of the troughs when necessary with the help of bolts and nuts on V-notch plate (the holes are elongated for this purpose).
- Each sedimentation tank has a 2 m x 2 m sludge collection sump at the base (approximately 1/3 of length). The base of each tank is laid to varying slopes to assist the settled sludge flow and collect into the sump. A 350 mm pipe is provided for the periodic draw-off of sludge from each tank. The pipes act under the hydrostatic pressure in the tanks to discharge the accumulated sludge into a sludge draw-off chamber. One sludge draw-off chamber is provided to serve each set of 3 sedimentation tanks. The sludge is then drained into waste / backwash water ponds for settlement and finally to four sludge drying beds provided on site.
- Access walkways with hand railing have been provided, running along the length of the tanks. The settled water channel is covered with precast concrete slabs, which also serve as a walkway to provide access to the filters.
- Other features of the sedimentation tank are:
  - Surface loading rate: 18.45 $m^3/m^2/d$
  - Assumed weir loading rate: 204.89 $m^3/m/d$ – replaced with orifices
  - Detention time: 11.38 minutes

- **Filtration – rapid sand filter**
  - For the throughput, it is recommended that rapid sand filters be employed. The criteria also take is to as much as possible employ manual controls such as hand operated valves and thus a declining rate option is selected. This is also selected so that each filter can be operated independent of the other filters.
  - The filters plan layout L/B ration are selected to ensure that they are streamlined with the overall width of the sedimentation basin. From the design calculations, there are 6 parallel filter units each with an overall internal plan dimensions of 3.8 m x 9.9 m.
  - Water enters each tank from the flocculated water channel through one 450 mm x 450 mm penstock-controlled square openings into a 600 mm wide x 1800 mm deep inlet channel and then into the settling zone through five 350 mm diameter orifices spaced at 700 mm centres at the base of each inlet channel.
  - Other features of the filter are as follows:
    - Depth of the filter bed: 1.10 m
    - Specific diameter: from 0.8 to 1.2 mm, density 2.65 kg/m^3
    - Porosity of clean bed, 0.43
    - Porosity of clogged filter, 0.35

  - Uniform coefficient: < 1.5, preferably 1.3
  - Filtration rate, 6 m/h
  - Water depth above filter during filtration, 0.5 m
  - Backwash water depth (including fluidized bed) 2 m deep
  - Backwash water flow rate, 4.9 m³/m²/h
- The filter galleries are thus designed for this throughput. They are as follows:
  - Filtered water pipe individual filter
  - Filtered water combined pipe
  - Backwash water main
  - Backwash water feed to each filter
  - Backwash wastewater pipe outlet
  - Filtered water flow to clear water tank after chlorination
- The filter pipe galleries are operated from 1st floor of the filter gallery house with access to the gallery chamber for individual maintenance and operations.
- Filter bottom is 200 thick with the filtered water chamber being 450 mm thick.

- **Chlorination – rapid mix chamber**
  - Inside the filter gallery ground floor, a rapid mix chamber with the same characteristics as the raw water rapid mix is provided.
  - The chlorinated water is thereafter gravitated through a combined 700 mm pipe to the clear water tank.

- **Clear water tank**
  - A clear water tank is located centrally for ease of gravity flow from the three treatment streams.
  - Each stream is provided with a float valve as it enters the clear water tank.
  - The tank is constructed of reinforced concrete. Other features of the tank are:
    - Chlorine contact time, min 30 minutes (provided one hour),
    - Internal dimensions are 45 m x 45 m x 4.5 m deep.

- **Backwash wastewater / drainage pond storage and recirculation**
  - All the water collected from the dam that is already containing any chemicals (either as settled or liquid) is collected into a lagoon from where solids/suspensions are allowed to settle while the supernatant water flows to another pond from which it is pumped back to the raw water rapid mix tank to mix with the raw water.
  - The final sizing of the holding ponds would be determined when the final raw water quality is determined after impoundment of the dam.

- **Works buildings and facilities**
  - For purposes of operation and maintenance of the treatment works, the following are the additional infrastructure required in the system:
    - Scheme Managers Office and Living Quarters
    - Deputy Scheme Managers Office and Living Quarters
    - Operators Houses
    - Mechanical and Electrical Engineers Office and Living Quarters
    - Support, Junior staff offices and Living Quarters
    - Pumping station buildings: High lift, Backwashing and chemical mixing units
    - Workshops and pipe yard
    - Works road network
    - Fencing of all the works
    - Communication facilities
    - Plant operation monitoring system – a dashboard which would be monitored on a 24-hour basis
    - Proposed police station – as this is a security installation

9.8.3 Pumping from the Mwache Dam's Water Treatment Plant

9.8.3.1 Overview

The pumping station of the Mwache delivery facility will contain three major pump arrays, and will be able to deliver the total water allocation from the Mwache Dam to the urban supply (agreed to be 186,000 m^3/d). A holding tank at the outlet of the water treatment plant is required. The volume of the tank was calculated at 10% of the total supplied water per day (approximately 20,000 m^3). This water tank will not serve as the regulation volume for the supply, but will serve as a holding tank for the treated water to allow retention of two hours for chlorination dispersion. The pump arrays will abstract water from a common manifold.

Each of the delivery sets will pump the water to different directions, as well as different flows and delivery heads. All of the pumps will be installed in the same pumping station.

The three major pumping arrays are summarized in Table 9-6.

Table 9-6: Future Water Delivery to Mombasa and Vicinity

	Unit	South Supply	+120 NMT	Chamgamwe Supply
Total daily delivery	m³/d	69,200	69,200	48,200
Total hourly operation	h/d	16 *	16	16
Total hourly capacity	m³/h	4,320	4,320	3,000
Pump configuration	No. x m³/h	(5+1) x 865	(5+1) x 865	(5+1) x 600
Water supply to:		South Scheme	New Mwache Tank	Mombasa Island through Chamgamwe
Cumulative volume	m³/d	69,200	138,400	186,600

* The pump operation time per day in the proposed plan assumes a maximum operation time of 16 h/d. This was assumed due to the future option of having varied electricity tariff during daytime, thus making it economical to operate only during nighttime hours and not running the pumps during daytime hours.

The diagram in Fig. 9-5 sets out the main bulk water supply system topology from the Mwache Waterworks to Mombasa and the southern region.

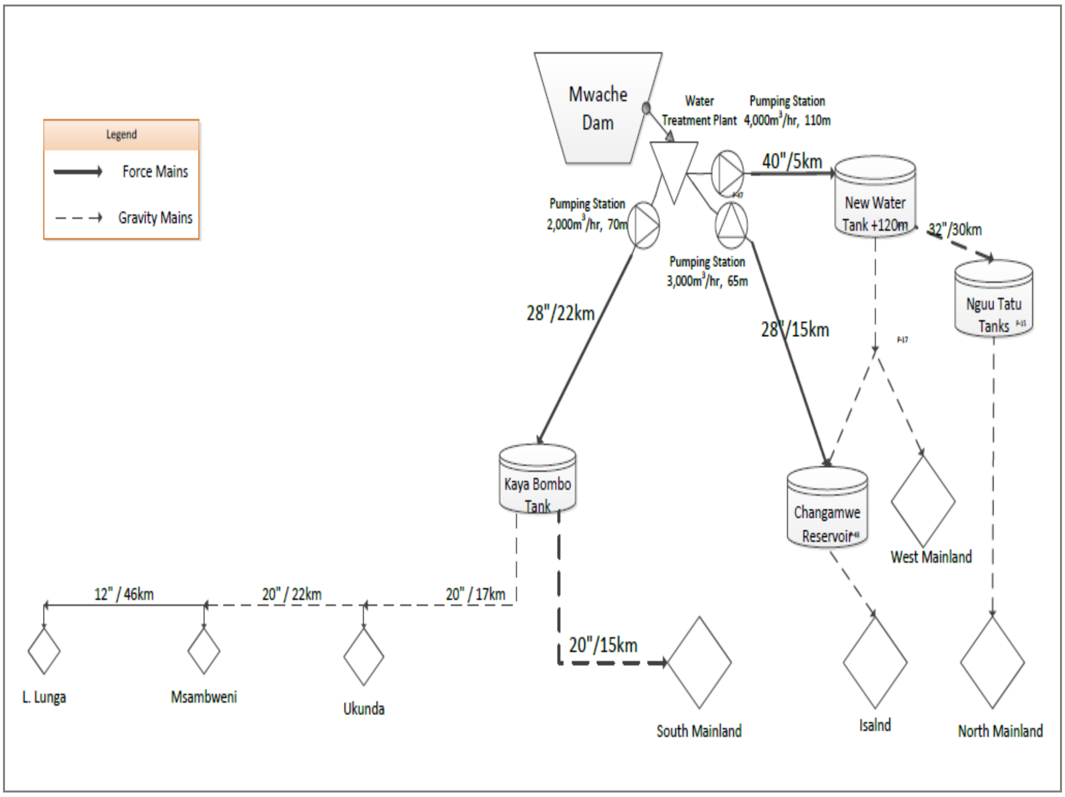


Fig. 9-5: Block diagram – proposed development of Mwache Scheme

Table 9-7 presents the sources for the Mombasa water supply. Total Mombasa supply is 312,780 m^3/d.

Table 9-7: Mombasa Water Supply by Sources and Schemes

	Unit	West Mainland	Mombasa Island	South Mainland	North Mainland
Source of water		Mwache Dam	Mwache Dam / Mzima Springs	Mwache Dam	Mwache Dam / Baricho Wellfield
Supply from tank		+120 NMT	Chamgamwe and Mazeras Water Tanks	Kaya Bombo Water Tank	Nguu Tatu Water Tank
Total daily delivery	m^3/d	34,600	48,180 / 54,050	53,150	34,600 / 88,200
Total Mombasa from Mwache	m^3/d	34,600	48,180	53,150	34,600
Total Mombasa from Baricho	m^3/d	–	–	–	88,200
Total Mombasa from Mzima	m^3/d	–	54,050	–	–
Total Mombasa	m^3/d	34,600	102,230	53,150	122,800
Total Mombasa cumulative	m^3/d	**34,600**	**136,830**	**189,900**	**312,780**

9.8.3.2 Northern Branch – New Mwache Tank (NWT)

New pumping stations proposed at the outlet of the water treatment plant. The treated water flowing from the treatment plant will be stored in a holding tank. The required volume for pumping towards the northern areas will be part of the Mombasa supply.

Total daily volume to be pumped from Mwache to Mombasa will amount to 69,200 m^3/d (i.e., to Mombasa's West Mainland and North Mainland neighbourhoods). The total daily volume will be supplied from two different pump arrays:

- Towards Mombasa's western mainland, at an average elevation of +70 masl, the daily volume of 34,600 m^3/d will be pumped directly to the New Mwache Tank (NMT), and from there will gravitate to the distribution networks.
- Towards Mombasa's northern mainland, a total daily volume of 34,600 m^3/d will be transferred to the regional Nguu Tatu Water Tank. This supply line will be a gravity force main.

For the new pump array to the +120 masl tank (NMT), it is recommended that six new vertical high-efficiency pumps be installed, each with a capacity of 865 m^3/h and a TDH of 110 m. The total contribution of this pump array to the supply will be provided by five duty pumps, operating 16 h/d, for a total of 69,200 m^3/d.

The pumps will deliver a total of 4,325 m^3/h through a 40" (1,000 mm) diameter pipe. The pipe length will be 4 km. At the end of the pipe, the water will be stored at the NMT tank at an elevation of +120 masl. The total supply in this direction will be 37% of the total water abstraction from the Mwache Dam.

The static head of each pump will be 85 m (from +35 masl to +120 masl), and the dynamic head (the friction loss) will be approximately 8–10 m. The TDH of each pump will be approximately 105–110 m. The design calls for connection of the new Mwache Pipeline at the top of the tanks.

The pumping station will consist of six pumping units in parallel (5 duty, 1 standby), each with a capacity of 865 m^3/h. This will enable the pumping station to work at full capacity with six units simultaneously. The design calls for backup capacity at a level of 20%; i.e., the total installed standby capacity will be 865 m^3/h.

Estimated power consumption for the pump operation is 5,200 kWh/d, based on 16 h/d operation and pump efficiency of 80%.

Table 9-8 summarizes the operational data of the pumping units to the new + 120 NMT.

Table 9-8: Pumping Array and Operation Data for New +120 Mwache Tank (NMT)

Delivery Pump ID number	Status	Q (m^3/h)	H (m)	T (h)	Volume (m^3)	Eta (Pump Efficiency Coefficient)	Power (hp)	Energy (kWh)	Energy (kWh/d)
PD-newT-01	New	865	110	16	13,840	0.8	441	324	5,187
PD-newT-02	New	865	110	16	13,840	0.8	441	324	5,187
PD-newT-03	New	865	110	16	13,840	0.8	441	324	5,187
PD-newT-04	New	865	110	16	13,840	0.8	441	324	5,187
PD-newT-05	New	865	110	16	13,840	0.8	441	324	5,187
PD-newT-06 (standby)	New	865	110	0	0	0.8	441	324	0
Total					**69,200**		**2,643**	**1,945**	**25,937**

9.8.3.3 Chamgamwe Supply

Direct supply from the Mwache Dam to Mombasa Island will be diverted through a new 30" diameter pipeline. This pipeline will be laid in parallel to the existing 20" diameter pipeline, conveying water from the Marere Springs to the Chamgamwe Water Tank. Since the current water supply to the Greater Mombasa area is divided into the western mainland + Chamgamwe area and Mombasa Island – the two areas are supplied with different heads – it is suggested that the water from the Marere Springs and the Mwache Dam that arrive at Chamgamwe Water Tank be directly conveyed to consumers on the island. The head of the water at the Chamgamwe Water Tank is +70 masl, and the majority of consumers in the island area are located at an elevation of +0–+30 m. Thus, the static pressure for the island consumers will be around 40 m while the dynamic pressures will range between 20 m and 30 m.

The total daily volume to be pumped from Mwache to Chamgamwe will be 48,200 m^3/d, with an average hourly discharge of 600 m^3/h, considering 16 h/d operation.

The new pump array to Chamgamwe will include installation of six new high-efficiency vertical pumps, each with a capacity of 600 m^3/h and a TDH of 65 m. Total contribution of this array to the supply will be provided by five duty pumps, operating 16 h/d, for a total 48,200 m^3/d.

The pumps will deliver a total of 3,000 m^3/h through a 32" (800 mm) pipeline, 15 km in length. At the end of the pipeline, the water will be stored in the Chamgamwe Water Tank at an elevation of +75 masl. Total supply in this direction will be 26% of the total water abstraction from the Mwache Dam.

The static head of each pump will be 40 m (from +35 masl to +75 masl), and the dynamic head (the friction loss) will be approximately 20–25 m. The TDH of each pump will be approximately 65 m. The design calls for connection of the new Mwache Pipeline at the top of the tanks.

The pumping station will consist of six pumping units in parallel (5 duty, 1 standby), each with a capacity of 600 m^3/h. This will enable the pumping station to work at full capacity with six units simultaneously. The design calls for backup capacity at a level of 20%, i.e., the total installed standby capacity will be 600 m^3/h.

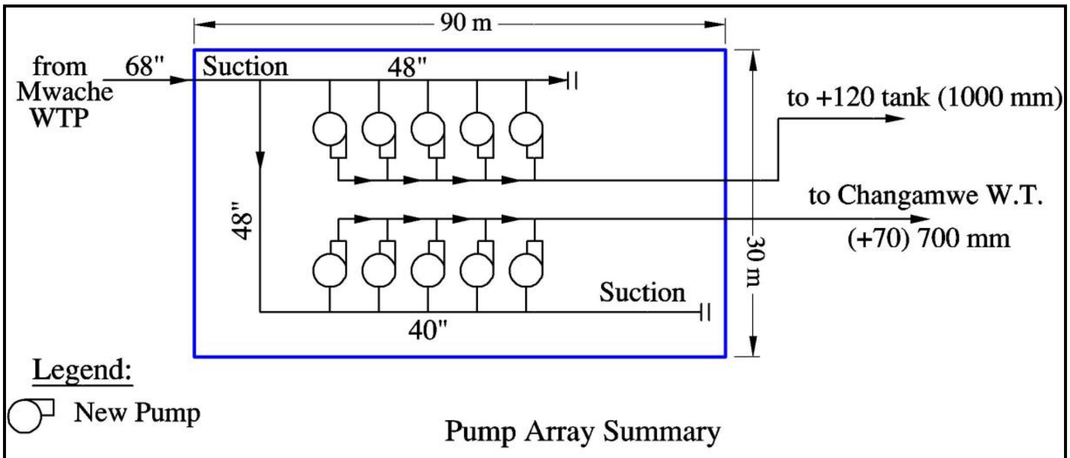
Estimated power consumption for pump operation is 10,600 kWh/d, based on 16 h/d operation and pump efficiency of 80%.

Table 9-9 summarizes the operational data of the pumping units to the Chamgamwe Water Tank.

Table 9-9: Pumping Array and Operational Data for Chamgamwe Water Tank

Delivery Pump ID No.	Status	Q (m^3/h)	H (m)	T (h)	Volume (m^3)	Eta (Pump Efficiency Coefficient)	Power (hp)	Energy (kWh)	Energy (kWh/d)
PD-chan-01	New	600	65	16	9,600	0.8	181	133	2,126
PD-chan-02	New	600	65	16	9,600	0.8	181	133	2,126
PD-chan-03	New	600	65	16	9,600	0.8	181	133	2,126
PD-chan-04	New	600	65	16	9,600	0.8	181	133	2,126
PD-chan-05	New	600	65	16	9,600	0.8	181	133	2,126
PD-chan-06 (standby)	New	600	65	0	0	0.8	181	133	0
Total					**48,000**		**1,083**	**797**	**10,631**

Fig. 9-6 presents the primary works to be carried out for Mwache Waterworks during Phase I.



Pump Array Summary

	Existing +New	Q (m^3/h)	Head	Hours	Daily (m^3)	Remarks
+120 tank	5	865	90	16	55,360	4 duty + 1 standby
Changamwe	5	600	65	16	38,400	4 duty + 1 standby

Fig. 9-6: Schematic drawing of Mwache Waterworks – Phase I, primary works

9.8.3.4 Southern Scheme

The Mwache Dam will be the supply source to the south mainland (Likoni). Water will delivered further south towards Kwale and the coastal towns and resorts. In this area, the supply will be at the head of the Kaya Bombo Water Tank (+70 masl). In the event of supply over demand (mainly during nighttime), the tank will be filled. Due to the increase in supply and demand, the Kaya Bombo Water Tank will have to be expanded.

The southern branch of the water supply scheme will consist of a 32" (800 mm), 20 km new pipe that will connect the Mwache Dam with the current Likoni-Kaya Bombo Scheme. In order to meet the water demand in the south coast, a new water pipe will be laid along the main road from Likoni to Ukunda. This pipe will be referred to as the "south coast water conveyer", and it will be the main means of supply for the region in the coming years. Only by the horizon year of 2035, after additional water resources will be developed (abstraction from the Msambweni Aquifer and/or the Mkurumudzi Dam), will it be possible to increase supply in this area without abstracting more water from the dam.

The static head of the pump will be at 35 m (from +35 masl to +70 masl) and the dynamic head at approximately 55–60 m. The new water pipe will be connected to the Likoni local water supply distribution system as well as to the current Kaya Bombo–Likoni Pipeline. Extension of the current 250 mm southern line is required.

The pumping station will consist of six pumping units in parallel (5 duty, 1 standby), each with a capacity of 865 m^3/h. This will enable the pumping station to work at full capacity with five units simultaneously. It is suggested that the backup capacity will be at a level of 20%, i.e., the total installed standby capacity in the pumping station will be 865 m^3/h.

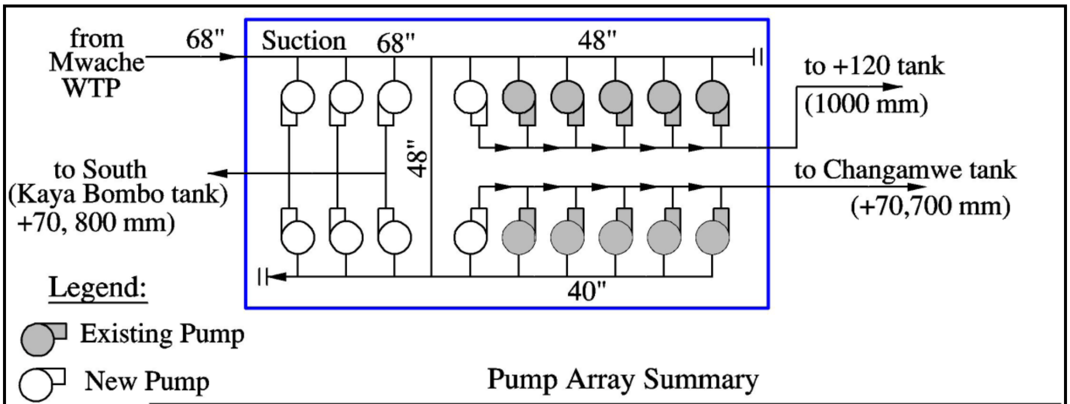
The estimated power consumption for the pump operation is 16,500 kWh/d, based on 16 h/d operation and pump efficiency of 80%.

Table 9-10 summarizes the operational data of the pumping units to the Kaya Bombo Water Tank.

Table 9-10: Pumping Array and Operation Data for Kaya Bombo Water Tank

Delivery Pump ID number	Status	Q (m^3/h)	H (m)	T (h)	Volume (m^3)	Eta (Pump Efficiency Coefficient)	Power (hp)	Energy (kWh)	Energy (kWh/d)
PD-newS-01	New	865	110	16	13,840	0.8	280	206	3,301
PD-newS-02	New	865	110	16	13,840	0.8	280	206	3,301
PD-newS-03	New	865	110	16	13,840	0.8	280	206	3,301
PD-newS-04	New	865	110	16	13,840	0.8	280	206	3,301
PD-newS-05	New	865	110	16	13,840	0.8	280	206	3,301
PD-newS-06 (standby)	New	865	110	0	0	0.8	280	206	0
Total					**69,200**		**1,682**	**1,238**	**16,505**

Fig. 9-7 presents the additional secondary works to be carried out for Mwache Waterworks during Phase I.



Pump Array Summary

	Existing +New	Q (m^3/h)	Head	Hours	Daily (m^3)	Remarks	Total
+120 tank	5+1	865	90	16	69,200	5 duty + 1 standby	186,400
Changamwe	5+1	600	65	16	48,000	5 duty + 1 standby	
South	6	865	70	16	69,200	5 duty + 1 standby	

Fig. 9-7: Schematic drawing of Mwache Waterworks – Phase I, secondary works

9.8.4 Pumping Stations of Mwache Scheme

9.8.4.1 HLPS to New Mwache Tank (NMT)

The prime pumping set in the Mwache Pumping Station will include a pump array that will supply water to the new +120 NMT.

Array 1 – HLPS to lift the water to the new +120 NMT

Table 9-11 presents the principles for the pump installation and accessories, including key parameters for preparation of the detailed design.

Recommended HLPS design criteria are as follows:

- Pump type: submersible pump, dry install, on legs with elbow pipe at suction inlet
- Suction pipe diameter will be one "D" over the discharge pipe.
- A gate valve of PN 16 will be installed at the suction chamber.
- The electric motor will include liquid cooling system by circulation over the pump motor.
- Pump chart characteristics: Flat curve up to 20% head difference along the scale
- Typical free passage pass: up to 20 mm
- Pump capacity each: 865 m^3/h at working point
- Pump head: 110–115 m
- Station pump design points: 865 m^3/h, 110 m
- Minimum hydraulic efficiency at design point: 80%
- No. of pumps: 5 duty by horizon year 2035, 1 standby
- Percent of standby capacity: 20%, 1 unit out of 5
- Total energy required to deliver the water: 324 kWh
- Electric motor power requirements: 441 hp
- Electric current at steady state: 800 A
- Electric motor (size/rpm): 175 kVA / 1,350 rpm
- Working hours per day: 16 h/d
- Total annual energy consumption: 9,500,000 kWh/y
- Suction manifold material/diameter: steel / 48"
- Suction manifold configuration: one 48" inlet manifold, six outlets (20" each) – three outlets to each side
- Main valves at suction manifold: main 40" valve at suction pipe and six 20" valves at each suction pipe
- Other flow devices: surge relief valves, air valves and rapid pressure relief valves

Table 9-11: Summary of the New +120 NMT Pumping Array

Delivery Pump	Qty	Q (m^3/h)	H (m	T (h)	Volume (m^3)	Eta (Pump Efficiency Coefficient)	Power (hp)	Energy (kWh)	Energy (kWh/y)
Duty	5	865	110	16	69,200	0.8	441	324	9.5 million
Standby	1	865	110	16	–	0.8	441	324	–

- ***HLPS to Chamgamwe Reservoir***

The second pumping set in the Mwache pumping station will include the pump array for the supply of water to Chamgamwe Water Tank at +70 masl.

Array 2 – HLPS to lift water to the Chamgamwe Water Tank

Table 9-12 sets out the principles for the pump installation and accessories, including prime parameters for the process of the detailed design.

Recommended HLPS design criteria:

- Pump type: submersible pump, dry install, on legs with elbow pipe at suction inlet
- Suction pipe diameter: one "D" over the discharge pipe
- A gate valve of PN 16 will be installed at the suction chamber.
- The electric motor will include liquid cooling system by circulation over the pump motor.
- Pump chart characteristics: Flat curve up to 20% head difference along the scale
- Typical free passage pass: up to 20 mm
- Pump capacity each: 600 m^3/h at duty point
- Pump head: 60–65 m
- Station pump design points: 600 m^3/h, 65 m
- Minimum hydraulic efficiency at design point: 80%
- No. of pumps: 5 duty by horizon year 2035, 1 standby
- Percent of capacity on standby: 20%, 1 unit out of 5
- Total power required to deliver the water: 125 kWh
- Electric motor power requirements: 165 hp
- Electric current at steady state: 330 A
- Electric motor size/rpm: 77 kVA / 1,350 rpm
- Working hours per day: 16 h/d
- Total annual energy consumption: 3,600,000 kWh/y
- Suction manifold material/diameter: steel / 36"

- Suction manifold configuration: One 36" inlet manifold, 6 outlets, 16" each, 3 outlets to each side
- Main valves at suction manifold: main valve at suction pipe, 30"; 3 x 16" valves at each suction pipe

Table 9-12: Summary of the Chamgamwe Pumping Array

Delivery Pump	Qty	Q (m^3/h)	H (m)	T (h)	Volume (m^3)	Eta (Pump Efficiency Coefficient)	Power (hp)	Energy (kWh)	Energy (kWh/y)
Duty	5	600	65	16	48,200	0.8	165	125	3.6 million
Standby	1	600	65	16	–	0.8	165	125	–

- ***HLPS to South Coast (Kaya Bombo Water Tank)***

The second pumping set in the Mwache Pumping Station will include a pump array that will supply water to the Kaya Bombo Water Tank at +70 masl.

Array 3 – HLPS to lift water to the Kaya Bombo Water Tank

Table 9-13 presents summarizes the principles for the pump installation and accessories, including prime parameters for the process of the detailed design.

Recommended HLPS design criteria are as follows:

- Pump type: submersible pump, dry install, on legs with elbow pipe at suction inlet
- Suction pipe diameter: one "D" over the discharge pipe
- A gate valve of PN 16 will be installed at the suction chamber.
- The electric motor will include liquid cooling system by circulation over the pump motor.
- Pump chart characteristics: Flat curve up to 20% head difference along the scale
- Typical free passage pass: up to 20 mm
- Pump capacity each: 865 m^3/h at duty point
- Pump head: 70–75 m
- Station pump design points: 865 m^3/h, 70 m
- Minimum hydraulic efficiency at design point: 80%
- No. of pumps: 5 duty by horizon year 2035, 1 standby
- Percent of capacity on standby: 20%, 1 unit out of 5
- Total power required to deliver the water: 206 kWh
- Electric motor power requirements: 280 hp

- Electric current at steady state: 520 A
- Electric motor size/rpm: 115 kVA / 1,350 rpm
- Working hours per day: 16 h/d
- Total annual energy consumption: 6,000,000 kWh/y
- Suction manifold material/diameter: steel / 36"
- Suction manifold configuration: one 36" inlet manifold, 6 outlets, 16" each, 3 outlets to each side
- Main valves at suction manifold: main valve at suction pipe 30", 3 x 16" valves at each suction pipe

Table 9-13: Summary of the Kaya Bombo (South Region) Pumping Array

Delivery Pump	Qty	Q (m^3/h)	H (m	T (h)	Volume (m^3)	Eta (Pump Efficiency Coefficient)	Power (hp)	Energy (kWh)	Energy (kWh/y)
Duty	5	865	75	16	69,200	0.8	280	206	6.0 million
Standby	1	865	75	16		0.8	280	206	

9.8.5 Transmission Works

9.8.5.1 Transmission Mains to Mombasa

The entire daily volume to be pumped will amount to 69,200 m^3/d, and will be divided into two main supply lines:

- Supplying NMT for West Mainland and North Mainland consumers
- Supplying Chamgamwe Water Tank for Mombasa Island consumers

+120 New Mwache Tank (NMT)

- Supplying NMT for West Mainland and North Mainland consumers
  - 34,600 m^3/d will be directly supplied to the consumers within the distribution water network in the western mainland of Mombasa.
  - Most of these consumers are located at ground elevations ranging between +50 masl and +70 masl.
  - This will enable the entire network to be supplied from the +120 NMT.

Table 9-14 presents the characteristics of the main delivery pipeline connecting the new Mwache Waterworks with the new +120 NMT. This pipe will deliver water towards the western mainland and the backup supply to the northern areas of Mombasa.

Table 9-14: Summary of Main Supply Line Connecting Mwache Waterworks to New +120 NMT

Existing Diameter (mm)	New Diameter (mm)	Pipe Pressure Rating	Length (km)	Daily Supply (m^3/d)	Hourly Supply (m^3/h)
none	1,000	PN 16	4.5	69,200	4,325

Transmission Mains to Chamgamwe Reservoir

Table 9-15 presents the characteristics of the main delivery pipeline connecting the new Mwache Waterworks with the existing Chamgamwe Water Tank, at +70 masl. This pipe will deliver water towards consumers on Mombasa Island. The entire daily volume pumped will amount to 48,000 m^3/d, and will reach the existing tank. From there, it will be conveyed by gravity through the two main supply lines – 900 mm and 600 mm – to consumers on the island.

Table 9-15: Summary of Main Supply Line Connecting Mwache WW to Chamgamwe Tank

Existing Diameter (mm)	New Diameter (mm)	Pipe Pressure Rating	Length (km)	Daily Supply (m^3/d)	Hourly Supply (m^3/h)
none	800	PN 10	15	48,000	3,000

9.8.5.2 Transmission Mains to Southern Coast

Table 9-16 presents the characteristics of the main delivery pipeline connecting the new Mwache Waterworks with the southern coast water tank, namely the Kaya Bombo Water Tank. This pipeline will deliver water to meet the demand of the southern coast region. The main consumer for this water will be Likoni, the southern neighbourhood of Mombasa. The entire daily volume that will be pumped – 69,200 m^3/d – will reach the existing Kaya Bombo Water Tank, and from there will be supplied, by gravity, through the new Kaya Bombo-Likoni Pipeline. In order to improve the supply to Likoni, it will be necessary to upgrade the supply to the Kaya Bombo Water Tank.

Table 9-16: Summary of Main Supply Line Connecting Mwache to Kaya Bombo

Existing Diameter (mm)	New Diameter (mm)	Pipe Pressure Rating	Length (km)	Daily Supply (m^3/d)	Hourly Supply (m^3/h)
Mwache WW to Kaya Bombo					
none	800	PN 16	22	69,200	4,325
Kaya Bombo to Likoni					
250	500	PN 10	11	12,000	500
New pipeline to Kaya Bombo Water Tank					
250	600	PN 10	8	14,700	668

9.8.5.3 Transmission Mains to Nguu Tatu Water Tank

One of the main supply improvements suggested in this master plan is the diversion of water from the new +120 NMT to the Nguu Tatu Water Tank. This diversion serves several purposes of the master plan:

- As part of the water supply to the northern area will rely on water from Mwache WW, there is a need to convey water from the Mwache-NMT Scheme to the northern mainland area.
- Less water from Baricho will be pumped towards the Mombasa area, thus enabling more water to be supplied to townships north of Mombasa. This will ease the hydraulic loads on the Sabaki-Mombasa Pipeline.
- More efficient operation is expected, as the water supply will be from a closer source, thereby enabling the CWSB to spend less for the energy costs of the water supply.

The main parameters for the supply line are summarized in Table 9-17.

Table 9-17: Summary of Main Supply Line Connecting New +120 NMT to Nguu Tatu Water Tank

Existing Diameter (mm)	New Diameter (mm)	Pipe Pressure Rating	Length (km)	Daily Supply (m^3/d)	Hourly Supply (m^3/h)
none	1,000	PN 16	35	34,928	1,455

Table 9-18: Phase I – Engineering Components of Mwache Waterworks (excluding dam and water treatment plant works) and Mwache Transmission Pipelines

1			Mwache Waterworks (excluding dam and water treatment plant works)	Unit	Qty
	1.1		**Civil engineering works**		
			Pumping station at Mwache		
		1.100	Construction of new pumping station, 90 m x 30 m x 7 m (L x W x H)	m^2	2,700
		1.101	Construction of new auxiliary building, 30 m x 20 m x 5 m (L x W x H)	m^2	600
		1.102	Construction of new electrical building, 25 m x 15 m x 7 m (L x W x H)	m^2	375
		1.103	Construction of new administration building, 20 m x 15 m x 3 m (L x W x H)	m^2	300
		1.104	Construction of guardhouse, 10 m x 6 m x 3 m (L x W x H)	m^2	60
		1.105	Fire protection system for the new pumping station	LS	1
		1.106	Fire protection system for the new auxiliary building	LS	1
		1.107	Fire protection system with foam for the new electrical building	LS	1
		1.108	Lighting system for all buildings	LS	1
	1.2		**Water tanks and works**		
		1.200	New Mwache Tank (NMT)	m^3	20,000
		1.201	New Nguu Tatu Water Tank (extension)	m^3	40,000
		1.202	New Kaya Bombo Water Tank	m^3	30,000
		1.203	New water tank at Lunga Lunga	m^3	3,000
		1.204	New water tank at Msambweni	m^3	6,000
		1.205	Inlet/outlet flowmeter and regulating valve chamber, 6 m x 3 m x 4 m (L x W x H)	No.	12
		1.206	Outlet valve chamber, 3 m x 2 m x 2.5 m (L x W x H)	No.	5
		1.207	Line valve chamber, 2.5 m x 2 m x 2 m (L x W x H)	No.	44
		1.208	Air valve chamber, 2 m x 2 m x 2.5 m (L x W x H)	No.	316
		1.209	Washout chamber, 3 m x 2 m x 2.5 m (L x W x H)	No.	33
	1.3		**Electromechanical works**		
			Mwache Pumping Station pumps to +120 NMT		
		1.300	Supply of delivery pumps, 865 m^3/h, 110 m head	No.	6
		1.301	Installation of the above delivery pumps	No.	6
		1.302	Electrical installation for pumps	LS	6
		1.303	Accessories for the new +120 delivery pumps	LS	6
		1.304	Accessories installation for the new +120 delivery pumps	LS	6
		1.305	Provide electricity to the site (proportional cost)	LS	1
			Pumps to Chamgamwe		
		1.306	Supply of delivery pumps, 600 m^3/h, 65 m head	No.	6
		1.307	Installation of the above delivery pumps	No.	6
		1.308	Electrical installation for pumps	LS	6
		1.309	Accessories materials for the new +75 delivery pumps	LS	6

1			Mwache Waterworks (excluding dam and water treatment plant works)	Unit	Qty
		1.310	Accessories installation for the new +75 delivery pumps	LS	6
		1.311	Provide electricity to the site (proportional cost)	LS	1
			Pumps to Kaya Bombo		
		1.312	Supply of delivery pumps, 865 m^3/h, 70 m head	No.	6
		1.313	Installation of the above delivery pumps	No.	6
		1.314	Electrical installation for pumps	LS	6
		1.315	Accessories materials for the Kaya Bombo delivery pumps	LS	6
		1.316	Accessories installation for the Kaya Bombo delivery pumps	LS	6
		1.317	Provide electricity to the site (proportional cost)	LS	1

2			Mwache Transmission Pipelines	Unit	Qty
	2.1		**Transmission pipe**		
		2.100	Pipe (Mwache-Kaya Bombo), steel, DN800	m	22,000
		2.101	Pipe (Kaya Bombo-Likoni), steel, DN500	m	11,000
		2.102	Pipe (Kaya Bombo-Tiwi), steel, DN500	m	20,000
		2.103	Pipe (Tiwi-Ukunda), steel, DN400	m	6,000
		2.104	Pipe (Ukunda-Msambweni), steel, DN300	m	22,000
		2.106	Pipe (Mwache-Chamgamwe), steel, DN700	m	15,000
		2.107	Pipe (New Mwache Tank -Nguu Tatu), steel, DN1000	m	35,000
		2.108	Pipe (Mwache-New Mwache Tank), steel, DN1000	m	4,500
		2.109	Pipe for manifold section, steel, DN1000	m	150
		2.109	Pipe for manifold section, steel, DN800	m	150
		2.110	Pipe for manifold section, steel, DN700	m	150
		2.111	Pipe for manifold section, steel, DN500	m	150
		2.112	Pipe for manifold section, steel, DN300	m	150
		2.113	Pipe for manifold section, steel, DN250	m	150
		2.114	Drainage pipe for manifold sections, steel, DN300	m	500
		2.115	Excavation for pipelines	m	135,500
		2.116	Access road, non-asphalt	km	15
	2.2		**Accessories**		
			Flowmeters		
		2.200	Electromagnetic flowmeter, DN800	No.	6
		2.201	Electromagnetic flowmeter, DN700	No.	2
		2.202	Electromagnetic flowmeter, DN500	No.	2
		2.203	Electromagnetic flowmeter, DN300	No.	2
			Accessories		
		2.204	Manual butterfly valve, DN500	No.	45
		2.205	Manual butterfly valve, DN700	No.	3
		2.206	Manual butterfly valve, DN800	No.	27
		2.207	Manual butterfly valve, DN400	No.	2
		2.208	Gate valve (on pipeline and on drain pipes), DN300	No.	3
		2.209	Gate valve (on pipeline and on drain pipes), DN250	No.	37
		2.210	Air valve, DN200	No.	316
		2.211	Pressure-reducing valve for kiosk lines, DN300	No.	32

9.9 Phase I – Water Supply to Taveta Area

The remote location of Taveta township, plus the abundance of water at the Taveta Springs (known locally as the Njoro Kubwa Springs), justifies the examination of a local solution for water supply as opposed to connecting to the bulk water supply system. At the horizon year of 2035, the demand is forecast to be 7,228 m^3/d (~300 m^3/h).

Three different supply options were investigated with regard to the Taveta local water supply, as follows:

- **Mwatate-Taveta Pipeline** – Connecting Taveta to the mainland's bulk water supply system via a 80 km pipeline connecting Mwatate to Taveta, enabling the water to flow from Voi/Maungu to Mwatate, and further east to Taveta
- **New pipeline from the Taveta Springs (first alternative)** – Abstracting water from the Taveta Springs, then first-stage pumping of the water towards Taveta and Mwatate, followed by second-stage pumping to Wundanyi. The length of the pipe, as well as the TDH required to deliver the water, showed that this alternative is not beneficial.
- **New pipeline from the Taveta Springs (second alternative)** – Separating the water supply to Taveta from other townships in Kwale County. The supply to Taveta will rely on the Taveta Springs, while Mwatate and Wundanyi townships will be connected to the bulk water supply system through Voi/Maungu.

The third option above was selected mainly based on its moderate cost and the abundance of water in the Taveta Springs.

Table 9-19 summarizes the engineering components of the rehabilitation works required at the Taveta water source and main supply.

Table 9-19: Phase I – Engineering Components of Taveta Springs Rehabilitation and Taveta Local Water Supply Scheme

3			Taveta Springs* Rehabilitation + Taveta Local Water Supply Scheme	Unit	Qty
	3.1		**Civil engineering works**		
			Water intake system		
		3.100	Intake – civil works	m^3/d	7,300
		3.101	Construction of new pumping station, 25 m x 12 m x 5 m (L x W x H)	m^2	300
		3.102	Construction of new electrical building, 5 m x 12 m x 5 m (L x W x H)	m^2	60
		3.103	Fencing, chain link	m	50
			Water treatment plant		
		3.104	Treatment works, full conventional train – primary sedimentation + coagulation + secondary sedimentation + filtration + disinfection	m^3/d	7,300
		3.105	Fencing, chain link	m	500
		3.106	Construction of new high-lift pumping station (HLPS), 12 m x 25 m x 7 m (L x W x H)	m^2	300
		3.107	Construction of new administration building, 18 m x 12 m x 3 m (L x W x H)	m^2	216
		3.108	Construction of guardhouse, 6 m x 5 m x 3 m (L x W x H)	m^2	30
		3.109	Treated water flowmeter and regulating valve chamber, 6 m x 3 m x 4 m (L x W x H)	No.	1
		3.110	Treated water outlet valve chamber, 3 m x 2 m x 2.5 (L x W x H)	No.	1
		3.111	**Transmission pipe chambers**		
		3.112	Line valve chamber, 2.5 m x 2 m x 2.5 m (L x W x H)	No.	19
		3.113	Air valve chamber, 2 m x 2 m x 2.5 m (L x W x H)	No.	75
		3.114	Washout chamber, 3 m x 2 m x 2.5 m (L x W x H)	No.	15
		3.115	Access road, non-asphalt	km	5
	3.2		**Transmission pipe**		
		3.200	Raw water pump suction pipe, steel, DN300	m	100
		3.201	Raw water pump delivery pipe, steel, DN400	m	150
		3.202	High-lift suction pipe, steel, DN300	m	50
		3.203	Treated water pump delivery pipe to main conveyor, steel, DN400	m	200
		3.204	Transmission pipe, steel, DN500	m	2,500
		3.205	Pipeline excavation	m	3,000
	3.3		**Electromechanical works**		
		3.300	Supply of raw water delivery pumps, 360 m^3/h, 45 m head	No.	6
		3.301	Installation of the above raw water delivery pumps	No.	3
		3.302	Installation of the above treated water delivery pumps	No.	3
		3.303	Electrical installation for pumps	LS	1
		3.304	Provide electricity to the site	LS	1

3			Taveta Springs* Rehabilitation + Taveta Local Water Supply Scheme	Unit	Qty
	3.4		**Accessories**		
		3.400	Air valve, DN200	No.	12
		3.401	Manual gate valve (drain valve), DN300	No.	4
		3.402	Electromagnetic flowmeter, DN400	No.	2

***** known locally as the **Njoro Kubwa Springs**

9.10 Phase II – Baricho 2 Scheme

9.10.1 General

Expansion of the Baricho Wellfield (see Fig. 9-8 location map) is one of the main recommendations of the selected design. This source has been serving the Mombasa water supply system from the late 1980s when the first water boreholes where installed. The main feature of this site is the existence of the palaeochannel formation. These geologic layers, with very high permeability, enable the water to flow laterally through the layers into the pumping shafts. Total potential yield of water with the current equipment at the Baricho site amounts to approximately 90,000 m^3/d. The proposal is to add a total daily volume of 85,000 m^3/d, for a grand total of 175,000 m^3/d.

Water abstraction potential in this site is subject to three main constraints:

- **Availability of water in the Sabaki River** – According to the statistical analyses of the flows in the Sabaki River (duly presented in the Water Resources Report of the WSMP), the minimum flow, based on 50 years of records along the Galana River, is 3.6 m^3/s. The current abstraction of water ranges between 65,000 and 68,000 m^3/d (less than 1 m^3/s).
- **The ability of the palaeochannel to convey water from the river to the pumping shafts through the geological formation** – Currently, the boreholes are located only at the southern bank of the river, dividing it into two groups, three boreholes in the western group and five boreholes in the eastern group. An evaluation of the total potential abstraction of water is presented in the previous studies cited in Section 9.10.2.1 below.
- **Installed capacity** – The total installed capacity should be in accordance with the total yield of water from the palaeochannel.
- The current operation of the production facility in Baricho has just completed major rehabilitation works, which will allow operating time of 22 h/d, assuming all pumping equipment is in good condition.

As long as the development plan is implemented throughout the years, the more boreholes in operation, the less hours per day will be required from each one of the boreholes. As new RHC-type boreholes are more efficient in terms of yield per borehole, the Consultant recommends that during Phase II of the development plan, in 2025, the entire production array be revised, with RHC-type boreholes installed both to increase production, as well as for replacement of some of the existing vertical-type boreholes.

Table 9-20 presents a summary of water production at Baricho from the present through the end of Phase II.

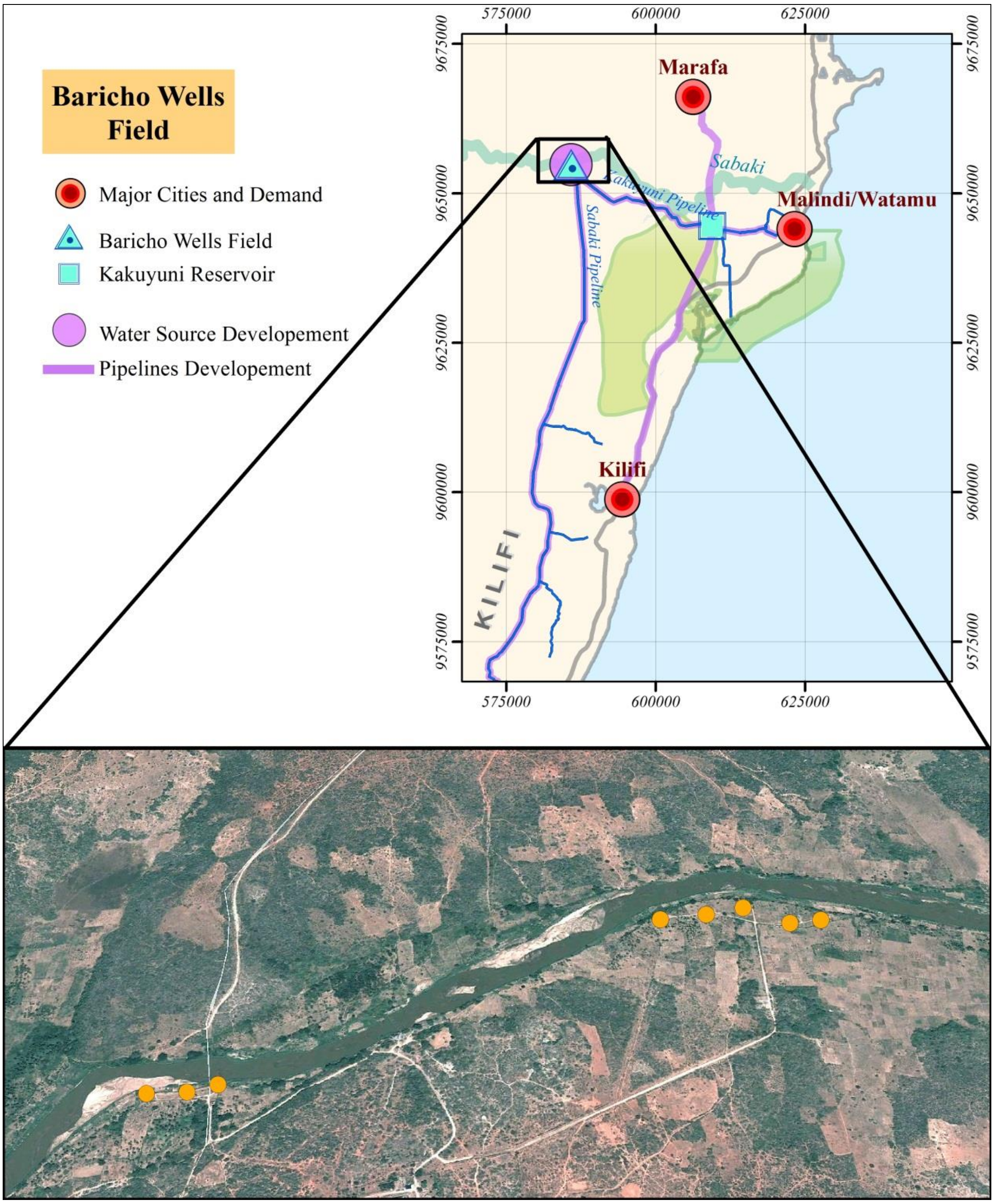


Fig. 9-8: General location of Baricho Wellfield

Table 9-20: Summary of Water Production at Baricho

Production Period	No. of Boreholes	Borehole Type	Capacity per Borehole (m^3/h)	Duty Cycle (h/d)	Production (m^3/d)	Comment
Current 2013 – potential	8	vertical	470	22	82,720	
Current 2013 – actual	8	vertical	470	17–17.5	65,800	
2015, after immediate works	8 + 2	vertical	470	8 x 22 2 x 22	102,720	Adding ~20,000 m^3/d for Mombasa
2025, end of Phase II *	10	vertical	470	(8 + 2) x 18	84,600	Total production: **174,600**
	5	RHC	900 **	5 x 20	90,000	

* At the time of Phase II development, installation of new RHC-type boreholes should be considered. The Consultant strongly recommends that some of the vertical boreholes be decommissioned and new, more effective, RHC-type boreholes, be installed.

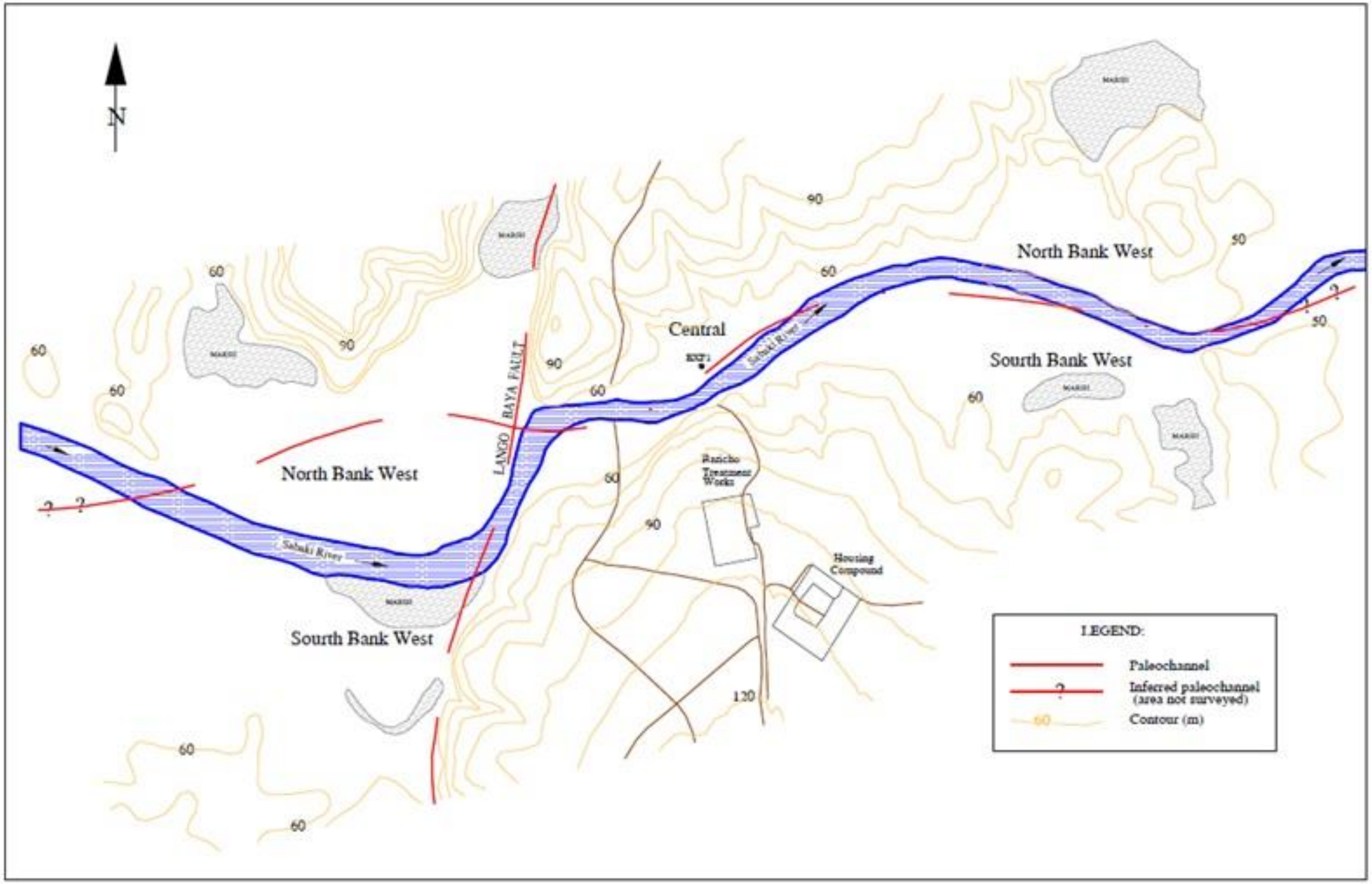
** Based in the Consultant's experience, RHC-type boreholes may produce as much as double that of vertical boreholes. The Consultant has assumed 900 m^3/h per borehole.

9.10.2 Waterworks

9.10.2.1 Overview

Various geological, geophysical and hydrological characteristics of the Baricho Area were reviewed in previous studies, as well as in the Water Resources Assessment Report submitted as part of the current master plan study. The following is a short list of the main studies that were fully focused on the nature of the palaeochannel along the banks of the Sabaki River:

1. Gauff, H. P., JBG Ingenieure (with the assistance of *Groundwater Survey Kenya*), Second Mombasa & Coastal Water Supply Engineering and Rehabilitation Project: Rehabilitation and Augmentation of Sabaki Waterworks, Seismic and Resistivity Survey, 1993.
2. Gauff, H. P., JBG Ingenieure, Second Mombasa & Coastal Water Supply Engineering and Rehabilitation Project: Rehabilitation and Augmentation of Sabaki Waterworks, A modular three-dimensional finite-difference groundwater flow model of the Sabaki Aquifer, September, 1995.
3. Full Feasibility Study Report, Consultancy Services for Water Supply Master Plan for Mombasa and Other Towns within Coast Province, TAHAL, February 2013.



Source: Gauff, H. P., JBG Ingenieure, Seismic and Resistivity Survey Report, September 1995

Fig. 9-9: General location map of the area showing the palaeochannel

These studies, most of which were conducted along the Sabaki River near the Baricho Waterworks, have concluded that there is substantial groundwater potential in the Sabaki palaeochannel (see Fig. 9-9 above), locally known as the Sabaki Aquifer. This ~50 m deep alluvial aquifer is composed of sands, sandstone, grits and gravels, all intercalated with silts and clay. The aquifer is recharged mainly by the Sabaki River through permeable horizontal layers within the river flood plain. Yields of 1,000 m/h flux and aquifer transmissivity of 7,000 m^2/d obtained from production boreholes drilled along the banks of the Sabaki River, have proven this aquifer to be an important groundwater source for the Coast Province. Seismic and resistivity sounding surveys indicate that the palaeochannel extends over 50 km west of Baricho Waterworks. Accurate delineation of the Sabaki Aquifer depth-to-bedrock was obtained for only the eastern group along the south bank of the Sabaki River.

The current situation at the water production site at Baricho consists of eight production boreholes, BH1–BH8. They were drilled in the south bank of the river in 1995. See Table 9-21 and Table 9-22 below for a summary of borehole data for these boreholes.

Due to the intense development proposed for the Baricho site, it is recommended to change the operational pattern and decrease the borehole pump duty cycle over the course of the development period, as follows:

- During the Immediate Phase of improvement of water supply to Mombasa, the Consultant recommends that the eight existing boreholes plus the two new boreholes be operated 22 h/d in order to achieve the maximum available water; i.e., total production will be [(8+2) boreholes x 470 m^3/h x 22 h/d =] 103,000 m^3/d. This figure includes the current potential of about 83,000 m^3/d plus about 20,000 m^3/d from the immediate works.
- For the horizon year, the Consultant recommends that the five new RHC-type boreholes be operated 20 h/d, thereby enabling the bulk water supply system to receive (5 boreholes x 900 m^3/h x 20 h/d =) 90,000 m^3/d, while the existing boreholes are operated more moderately, for only 18 h/d, with a production figure of [(8+2) boreholes x 470 m^3/h x 18 h/d =] 84,600 m^3/d. The total production from Baricho at the end of Phase II will be 174,600 m^3/d, compared to the required volume of 175,000 m^3/d.

Table 9-21: Basic Characteristics of Existing Boreholes at Baricho

Borehole	BH1	BH2	BH3	BH4	BH5	BH6	BH7	BH8
Date of rehabilitation *	7/2012	8/2012	7/2012	3/2012	7/2011	6/2011	7/2009	3/2012
Borehole depth (m)	40	43	32	52	51	48	51	52
Borehole diameter (mm)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Case & screen diameter (mm)	600	600	600	600	600	600	600	600
Capacity (m^3/h)	470	470	470	470	470	470	470	470
Head (m)	70	70	70	70	70	70	70	70
Rated motor power (kW)	180	180	180	180	160	145	145	180
Pump depth (m)	9	15	9	18	13	18	16	18
Insulation resistance (MΩ)	593	1,040	3,330	3,337	1,180	–	–	2,343
Water electrodes level (m)	9	15	9	18	13	18	16	18
Status (as of August 2013)	OK	OK	Dry run	OK	Old pump – OK	Old pump – OK	Old pump – OK	OK
Remarks		Will be re-drilled				Will be re-drilled		

* Date of rehabilitation – as reported by the management of the Baricho site

Sources:
- Monthly Report for Baricho, December 2012.
- Preparation of Investment Plan & Associated Feasibility Studies Feasibility Studies / Identification of Institutional Support, BRL Ingenierie / GIBB Africa Ltd., 2008.

Table 9-22: Baricho Borehole Water Level Details

	BH1	BH2	BH3	BH4	BH5	BH6	BH7	BH8
Static level (m)	2.5	3.25	2.82	4.92	5.25	5.20	5.78	4.39
Dynamic level (m)	7.92	12.62	7.82	12.40	8.14	14.28	12.38	7.12
Drawdown average (m)	5.42	9.37	5	7.48	2.89	9.08	6.6	2.73

Source: Monthly Report for Baricho, December 2012.

9.10.2.2 Existing Situation

The Baricho Waterworks abstract water from the Sabaki Aquifer, which comprises the old Baricho River Channel (palaeochannel) underlying the present riverbed. This aquifer is recharged mainly from the Baricho River. The locations of the eight existing boreholes (BH1–BH8) were presented in Fig. 9-8 above.

The waterworks comprise the following components, as shown in Fig. 7-1 in Chapter 7 above:

The borehole pumps

The eight boreholes are equipped with KSB electro-submersible pumps, rated at 470 m^3/h each (see Table 9-21above). Total borehole production capacity (for 24 h/d operation) is therefore about (8 x470 m^3/h x 24 h/d =) ~90,000 m^3/d. More reasonably, for 22 h/d operation, total water production is about (8 x 470 m^3/h x 22 h/d =) ~83,000 m^3/d.

However, according to the December 2012 Monthly Report for Baricho, the average daily production for the August–December 2012 period was only 68,046 m^3/d, corresponding to less than 17 h/d operation, on the average, for each borehole. The boreholes' water level details, as recorded in the December 2012 Monthly Report for Baricho, are presented in Table 9-22 above.

The boreholes' water is pumped to a 2,000 m^3 contact tank at the site, where the water is chlorinated.

After chlorination, the water flows into a 3,000 m^3 balancing tank.

The works have four 2 MVA 33/3.3 kV transformers, which work at a total of 8 MVA of power capacity availability at the site. The current power utilized by the existing pump installations is 62.5% of the 8 MVA. The balance remaining is about 3 MVA.

Contact tank and balancing tank

The boreholes' water is pumped to a 2,000 m^3 contact tank at the site, where the water is chlorinated. There is a separate chlorination chamber in which the chlorine is prepared as a liquid. From the chamber, chlorine is injected into the water, and the water then flows to the 3,000 m^3 balancing tank.

The delivery pumps (high-lift pumps)

From the balancing tank, the water flows to an 800 mm diameter suction manifold that serves as the suction chamber to the delivery pumps, also known as high-lift pumps (HLPs).

From the balancing tank, the water flows to an 800 mm diameter main suction pipe, from which the water is pumped by a high-lift pumping station.

The first pump array comprises three new KSB pumps. Those pumps replaced the Mather and Platt deep-well turbine pumps that were used before the rehabilitation works under the WaSSIP program. Two of the pumps are duty pumps, 583 m^3/h each, with a daily potential of about (2 x 583 m^3/h x 24 h/d =) ~28,000 m^3/d. The pump details are presented in Table 9-23.

Table 9-23: Details of High-Lift Pumping Station (HLPS) to Malindi

	HLP 1	HLP 2	HLP 3
Capacity (m^3/h)	583	583	583
Delivery head @ duty point (m)	100	100	100
Date of rehabilitation	5/2012	5/2012	3/2012
Rated motor power (hp)	250	250	250
Status (as for 08.2013)	OK	OK	OK

Source: Monthly Report for Baricho, December 2012.

The second pump array utilizes the water to be pumped directly to Mombasa and Kilifi using five vertical split-casing pumps (3 duty, 2 standby), each running at 833 m^3/h, with a daily potential of about (3 x 833 m^3/h x 24 h/d =) ~60,000 m^3/d. The pump details are presented in Table 9-24.

Table 9-24: Details of High-Lift Pumping Station (HLPS) to Sabaki-Mombasa Pipeline

	HLP 1	HLP 2	HLP 3	HLP 4	HLP 5
Capacity (m^3/h)	833	833	833	833	833
Delivery head @ duty point (m)	240	240	240	240	240
Date of rehabilitation	4/2012	4/2012	4/2012	6/2012	6/2012
Rated motor power (hp)	840	840	840	840	840
Status (as for 08.2013)	OK	OK	OK	OK	OK

Source: Monthly Report for Baricho, December 2012.

Actual current production of the Baricho Wellfield is limited to only about 68,000 m^3/d. Moreover, the present HLPS is capable of pumping some 88,000 m^3/d, (60,000 m^3/d to Mombasa, and 28,000 m^3/d to Malindi). Hence, in order to bridge the gap of 22,000 m^3/d and reach the targeted 83,000 m^3/d planned supply, it is proposed to operate the existing boreholes for at least 22 h/d. This will raise daily production of the wellfield to about 83,000 m^3/d, and will apparently cause no difficulty for the existing HLPS. It is important to note that the current duty cycle of 22 h/d is more than the usually accepted duty cycle, and it is intended to be lowered to 18 h/d at the end of Phase II.

9.10.2.3 Proposed Development of Baricho Waterworks

The Baricho Wellfield is a major contributor to the Coast Province water balance. The preferred scenario that was selected to lead the regional water development action plan emphasizes the Baricho Wellfield as one of the three main sources to be developed, together with the proposed Mwache Dam and the Mzima 2 Pipeline.

Development of water production from Baricho is carried out during two phases – Immediate Phase and Phase II. This is the result of the additional financing awarded to the CWSB in order to increase Mombasa supply in a short time (also called "***emergency works to improve supply to Mombasa***"). Thus, development of the production in Baricho will be done partly during the Immediate Phase (2014–2015, mainly upgrades and improvement to the conveyance system). Full development will be implemented during Phase II, according to the sequence set out in this WSMP

The Consultant recommends a monitoring program be started following implementation of the immediate extension. According to the Water Resources Report of the current master plan study, the total calculated water contribution of Baricho to the bulk water supply system will be 175,000 m^3/d, and the total proposed production for Baricho is 174,600 m^3/d (see Table 9-20 above). Approximately 84,600 m^3/d will be abstracted with the current installed equipment and the rest by the new proposed RHC-type boreholes. Upon finalization of development in Phase II (2025), the total annual water abstraction will amount to approximately 62.85 MCM/y.

The balancing between the production of the current vertical boreholes and the new RHC-type boreholes, as part of the development plan, will be clear only in the future. It may be that the current vertical boreholes with the 2012 installed equipment will suffer a decrease in production rate, while the new RHC-type boreholes will realize high production. This will happen in the coming years, when water levels will be measured continuously, and a groundwater model to simulate water level variations due to pumping will be completed. At this time, there is insufficient data to run this kind of model. The design plan calls for approximately 15% of the regional water balance to be abstracted from Baricho by the horizon year of 2035.

In order to avoid events of rapid drawdowns and/or bilateral influence between the new boreholes and the existing ones, the recommendation is for gradual increase in production rate at this site. Development of the Baricho Wellfield (in terms of water production) is proposed within **four inner stages** (as detailed in Table 9-25 below). Previous studies done on the water flows in the Sabaki River and the geological formation indicate that over 200,000 m^3/d can probably be abstracted without harm to the recharge of the aquifer from the river. The design concept elaborated here proposes moderate and measured abstraction amounts that are much lower than the actual potential.

Table 9-25: Proposed Development Stages of Baricho Wellfield Water Production

Development Phase	Proposed Production in South Bank East Sabaki Aquifer							General Design		
	No. of Boreholes	Borehole Capacity (m^3/h)	Operation Period (h/d)	Production Capacity per borehole (m^3/d)	Cumulative Capacity (m^3/d)	Cumulative Annual Production (MCM/y)	Year	Depth (m)	Dia. (mm)	Casing & Screen Diameter (mm)
Current	8 vertical-type	3,760	18	67,680	67,680	24.7	2010	32–52	1,000	600
Immediate Phase	2 vertical-type	940	18	16,920	84,600	30.87	2010	32–52	1,000	600
Phase II Stage A	2 RHC-type	900	20	36,000	120,600	38.14	2020	35	3,000–9,000	600–1,000
Phase II Stage B	1 RHC-type	900	20	18,000	138,600	44.71	2025	35	3,000–9,000	600–1,000
Phase II Stage C	1 RHC-type	900	20	18,000	138,600	50.58	2025	35	3,000–9,000	600–1,000
Phase II Stage D	1 RHC-type	900	20	18,000	174,600	63.73	2025	35	3,000–9,000	600–1,000
Total		**8,260**	**18–20**	**–**	**174,600**	**64**	**2025**			

Proposed abstraction from Baricho Wellfield can be sustained even at the minimum flow in the river. Recorded flowrates of 2.6 m^3/s, which occurred in January, and are exceeded 99.9% of the time. Total production from Baricho Wellfield planned based on the minimum river flow probability of 95%. A flow magnitude of 3.9 m^3/s, with probability of 95% of the time for a data series of 50 years, was observed. This means that the total final production planned from the Sabaki Aquifer, which is equivalent to about 2 m^3/s (174,600 m^3/d), or about 50% of the minimum flow in the river for 95% of the time. For 95% of the time, the remaining flow in the river will be greater than 1.9 m^3/s. For Sabaki flow analyses, see Section 3.3.4 above, as well as Annex 4 in Volume III of the WSMP.

Considering flowrates in the Sabaki River, and a good hydraulic connection between the river and the aquifer, total production planned from the Sabaki Aquifer is rather conservative, and is not anticipated to compromise either the Sabaki River flow or the aquifer in the long run.

Groundwater abstraction during the two development phases – Immediate Phase, plus the four inner stages within Phase II – of the Baricho Wellfield considers the construction and installation of five RHC-type boreholes. Each borehole consists of a central shaft with several horizontal collector tubes drilled into the surrounding aquifer, penetrating the submerged area of the palaeochannel radiating from the bottom of the shaft to act as collection galleries to the central sump. Groundwater will be drawn into the central collector shaft caisson through these radial horizontal well screens, where it will be pumped to a ground-level chlorination tank and balancing tank. This type of borehole can achieve extremely high yield by penetrating horizontally to the most permeable layer of the aquifer, with little effect on groundwater level drawdown in comparison to conventional vertical-type boreholes.

For the Immediate Phase – "***emergency works to improve supply to Mombasa***"– two new boreholes will be drilled and installed onsite. The boreholes will produce approximately 470 m^3/h @ 21 h/d as explained in Section 9.10.2.1 above for a total of about 20,000 m^3/d (while in the horizon phase, they will be operated only 18 h/d).

Due to the lack of historical data on the behaviour of the water level, and due to the fact that rapid drawdown has occurred as a result of overpumping at the current borehole, the Consultant strongly recommends that the boreholes scheduled for implementation during the Immediate Phase be of the **same type as the current ones**. The probability of rapid drawdown will decrease, compared to a situation in which new high-yield RHC-type boreholes – which have a greater effect on water levels – are installed. This will result in less water level fluctuations, as well as more effective control of the pumping rates. (Utilizing RHC-type boreholes will result in higher pumping capacities, and require complex regulation to prevent rapid drawdown.)

According to the WSMP preferred scenario, Phase II will include the residual development of the water production, namely adding 90,000 m^3/d with five new RHC-type boreholes by 2025, the target year for Phase II. It is assumed that during Phase II, more data – with regard to the flow capacity through the palaeochannel, as well as the monitoring of the levels – will be available and analyzed. This will allow the detailed design to optimize the number of additional boreholes and their capacities. Total additional abstraction from two phases of the development program (Immediate Phase and Phase II) will enable the addition of some 83,000 m^3/d to the bulk water supply system. This will bring water production from Baricho to ~175,000 m^3/d (see Table 9-20 and Table 9-25 above), which will meet the forecasted demand for the horizon year of 2035.

Table 9-26 presents details of Baricho borehole operational data.

Table 9-26: Details of Baricho Borehole Operational Data

Boreholes	Status	Capacity (m^3/h)	Head (m)	Duty Cycle (h/d)	Volume (m^3/d)	Eta	Power		Energy (kWh/y)	Remarks
							hp	kWh		
P-BH-01	Exists	470	50	18	8,460	0.82	106	78	570,284	
P-BH-02	Exists	470	50	18	8,460	0.82	106	78	570,284	Will be re-drilled and newly installed
P-BH-03	Exists	470	50	18	8,460	0.82	106	78	570,284	
P-BH-04	Exists	470	50	18	8,460	0.82	106	78	570,284	
P-BH-05	Exists	470	50	18	8,460	0.82	106	78	570,284	
P-BH-06	Exists	470	50	18	8,460	0.82	106	78	570,284	Will be re-drilled and newly installed
P-BH-07	Exists	470	50	18	8,460	0.82	106	78	570,284	
P-BH-08	Exists	470	50	18	8,460	0.82	106	78	570,284	
Total current production					**67,680**					
P10	New, immediate	470	50	18	8,460	0.82	106	78	570,284	Immediate application
P11	New, immediate	470	50	18	8,460	0.82	106	78	570,284	Immediate application
Additional by immediate works					**16,920**					
P21	RHC	900	50	20	18,000	0.85	196	144	842,792	
P22	RHC	900	50	20	18,000	0.85	196	144	842,792	
P23	RHC	900	50	20	18,000	0.85	196	144	842,792	
P24	RHC	900	50	20	18,000	0.85	196	144	842,792	
P25	RHC	900	50	20	18,000	0.85	196	144	–	
Additional by Phase II works (m^3/d)					**90,000**					
Total for Baricho future production (2025) (m^3/d)					**174,600**					

Inner Stages

The recommendation for Phase II of the WSMP includes five RHC-type boreholes designed for a capacity of 900 m^3/h each. The residual development of the RHC-type boreholes will be done in **four inner stages**. The first stage will include two RHC-type boreholes, and the other three stages will include one RHC-type borehole each. The daily production per RHC-type borehole will be (900 m^3/h x 20 h/d =) 18,000 m^3/d.

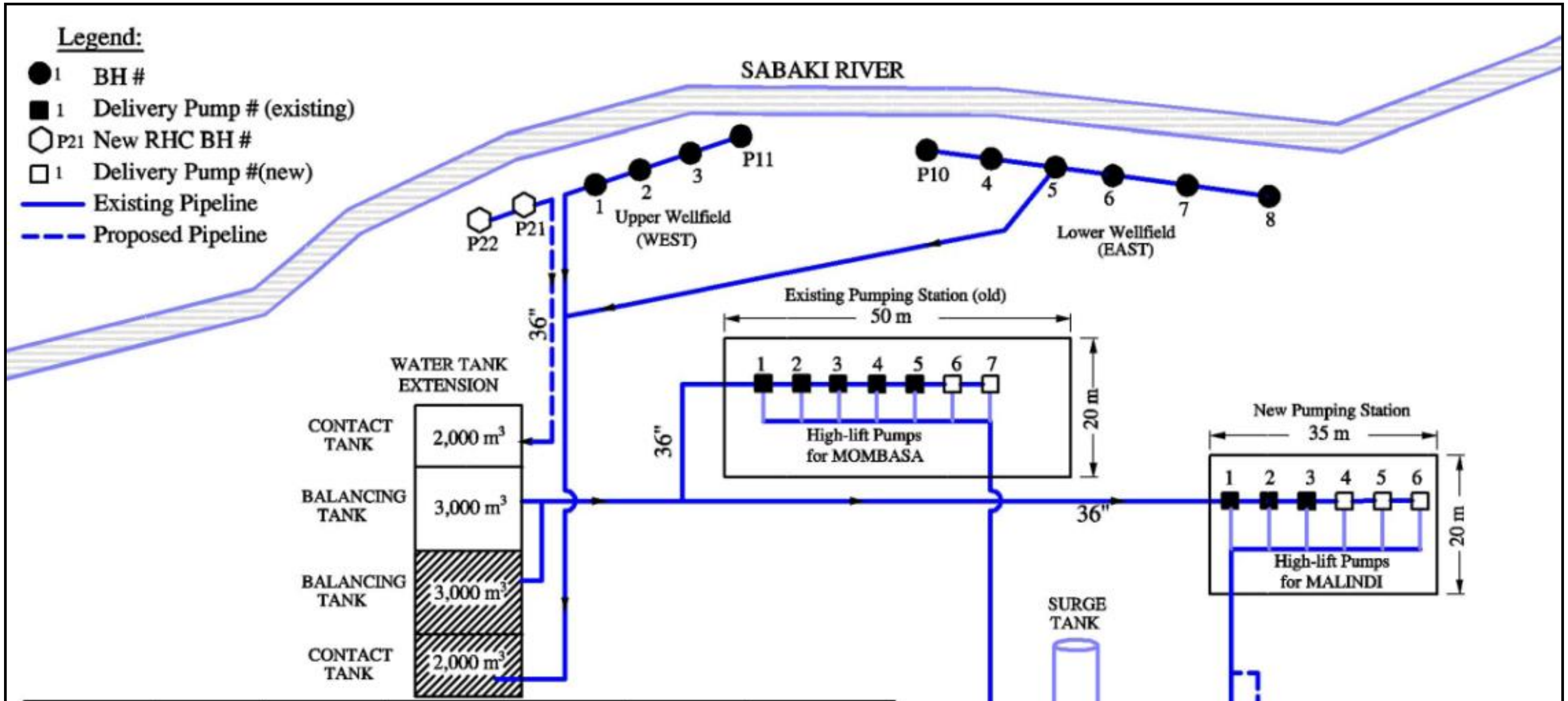
Each RHC-type borehole will operate some 20 h/d in order to achieve a daily capacity of 18,000 m^3/d and annual production of 6.57 MCM/y. By the end of Phase II, (5 x 18,000 m^3/d =) 90,000 m^3/d will be supplied to the bulk water supply system.

Table 9-25 above (development stages) summarizes the water production figures for Phase II. Proposed development stages for the Baricho Wellfield are as follows:

- **Following WaSSIP rehabilitation:** Increasing the duty cycle of the current boreholes (8), to an average of 22 h/d, resulting in total production of about (8 x 470 m^3/h x 22 h/d =) ~83,000 m^3/d (30.3 MCM/y)
- **Immediate Phase:** Additional two boreholes for the emergency supply to Mombasa (2014–2016), 22 h/d, total increase in production of about (2 x 470 m^3/h x 22 h/d =) ~20,000 m^3/d (7.3 MCM/y)
- **Phase II:**
  - Action plan for **Inner Stage A** – Additional development of the Baricho site, 2 RHC-type boreholes, average 20 h/d operation, total production 36,000 m^3/d (13.1 MCM/y)
  - Action plan for **Inner Stage B** – Additional development of the Baricho site, 1 RHC-type borehole, average 20 h/d operation, total production 18,000 m^3/d (6.5 MCM/y)
  - Action plan for **Inner Stage C** – Additional development of the Baricho site, 1 RHC-type borehole, average 20 h/d operation, total production 18,000 m^3/d (6.5 MCM/y)
  - Action plan for **Inner Stage D** – Additional development of the Baricho site, 1 RHC-type borehole, average 20 h/d operation, total production 18,000 m^3/d (6.5 MCM/y)

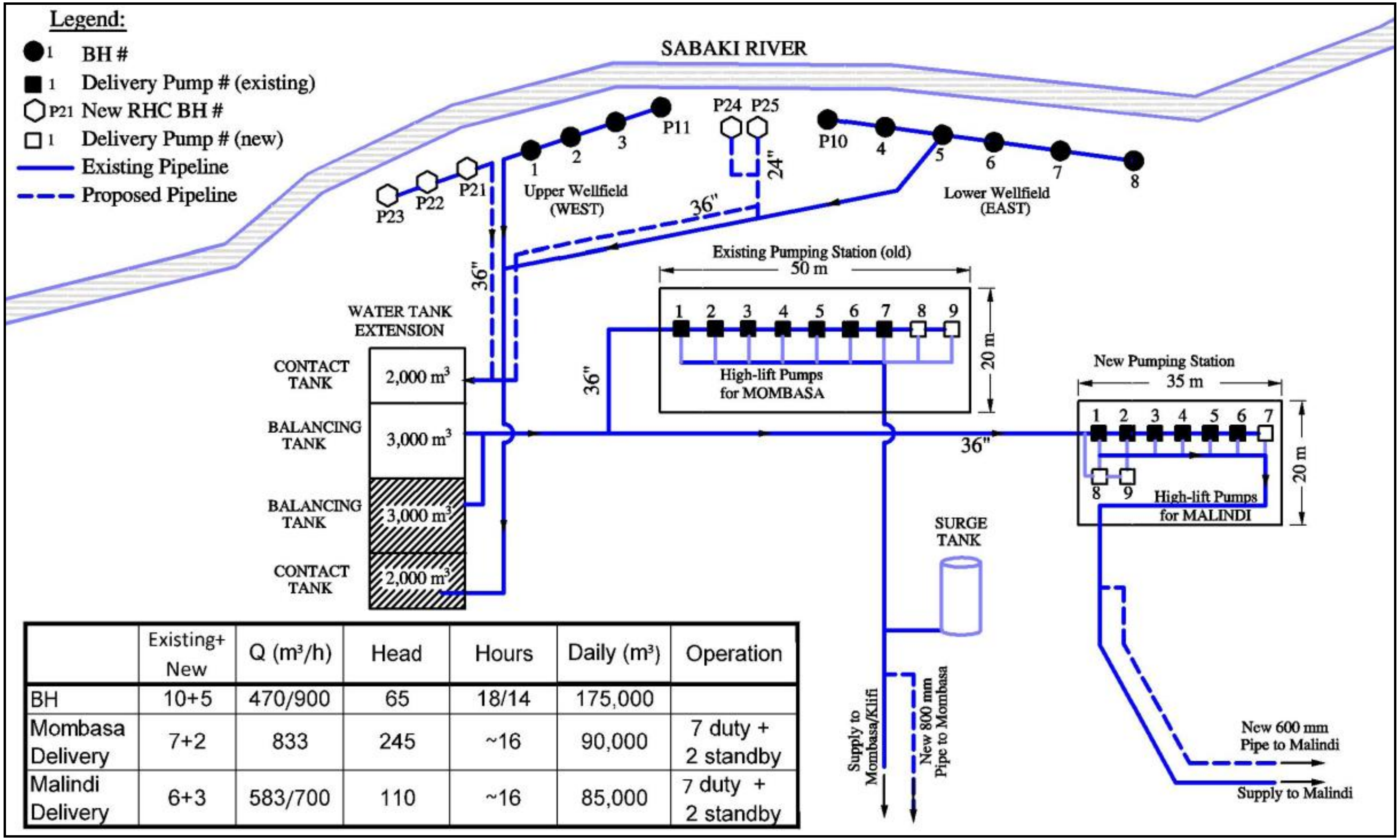
Inner Stages A–D are each anticipated to have a duration of 12 months. Following the end of Phase II, about three years after the target year of 2025, total yield for the Baricho site will be 174,600 m^3/d (63.5 MCM/y).

The total development of the water production facility and the delivery pumping stations for Mombasa and Malindi are schematically presented in Fig. 9-10 and Fig. 9-11 on the following pages. Fig. 9-10 shows the development the end of Inner Stage A, and Fig. 9-11 shows the full development at the end of Inner Stage D.



	Existing+ New	Q (m³/h)	Head	Hours	Daily (m³)	Operation
BH	10+2	470/900	65	18/14	128,000	
Mombasa Delivery	5+2	833	245	~18	90,000	6 duty + 1 standby
Malindi Delivery	3+3	583/700	110	15	38,000	5 duty + 1 standby

Fig. 9-10: Schematic drawing of Baricho Waterworks – Phase II, Inner Stage A



	Existing+ New	Q (m³/h)	Head	Hours	Daily (m³)	Operation
BH	10+5	470/900	65	18/14	175,000	
Mombasa Delivery	7+2	833	245	~16	90,000	7 duty + 2 standby
Malindi Delivery	6+3	583/700	110	~16	85,000	7 duty + 2 standby

Fig. 9-11: Schematic drawing of Baricho Waterworks – Phase II, Inner Stage D

Phase II is proposed to be executed regardless of the condition of existing conventional boreholes BH1–BH8. Following this development phase, it is likely that due to the age of the existing conventional boreholes (8 x 470 m^3/h), which will be over 12 years old, the Consultant assumes that replacement of the existing conventional boreholes will be necessary. The Consultant recommends that the eight conventional boreholes be replaced with five more RHC-type boreholes with capacity of 900 m^3/h each, in addition to the five already included within Phase II. It assumed that each RHC-type borehole will replace about 1.9 conventional boreholes. Total production of these five RHC-type boreholes will reach 90,000 m^3/d, based on 20 h/d of operation. Although these additional works are proposed to be completed by 2030, they could be executed in parallel to Phases II and III, depending on the condition of boreholes BH1–BH8.

From the resources point of view, the total abstraction proposed for the horizon year is 2.02 m^3/s, where recorded Sabaki River flow data, based on 50 years of data monitoring, shows that the minimum flow at 100% probability was 2.6 m^3/s, and 3.9 m^3/s at 95% probability. That is to say, even in the horizon year, when all the infrastructure will be onsite, the total abstraction from the river will allow natural flow to be not less than (3.9 m^3/s – 2.02 m^3/s =) 1.88 m^3/s.

The proposed development plan for Baricho Wellfield must be evaluated in light of the existing groundwater management framework of Sabaki River, considering additional downstream and upstream production. Accordingly, a detailed 3-D numerical groundwater flow model must be set up before implementation of Phase II. The model will be used to examine the effects of the proposed additional production from the Immediate Phase and Inner Stage of Phase II on:

- Groundwater levels and flow pattern in the Sabaki Aquifer, including seasonal effects
- To determine the expected groundwater level drawdown in the vicinity of the new RHC-type boreholes and possible effects on the existing boreholes
- The effects of the RHC-type borehole design and layout on the total yield
- To examine various production scenarios and their effects on aquifer storage, groundwater balance, groundwater levels and long-term water quality (2050)

Field data collected at the RHC-type borehole locations (which will be gathered in a detailed study for construction of the RHC-type boreholes in the Baricho Wellfield) will be integrated with the model for:

- Accurately determining the 3-D source area for the collector well
- Determining in-situ aquifer hydraulic parameters – transmissivity, storativity, hydraulic conductivity, etc.
- Estimating the travel times along path lines towards the well
- Estimating the perimeter fluxes that would result from any particular configuration of lateral wells, spacing and configurations of lateral well

A monitoring well network must be put in place to monitor groundwater level changes due to the additional production from the aquifer. In addition, a comprehensive continuous monitoring plan is recommended in order to measure groundwater level changes in response to present and future groundwater abstraction from the Sabaki Aquifer.

In addition, the model will be used as a decision-making tool for the Kenyan authorities, and will help sustain Sabaki Aquifer production for the long run.

Proposed Location and General Design of RHC-type boreholes

RHC-type boreholes for Phase II are proposed in the area (see Fig. 9-12) where 40–50 m depth-to-bedrock was delineated in a seismic survey (see Report 1, as listed in Section 9.10.2.1 above), while the RHC-type boreholes that may replace the existing wells following Phase II, are proposed to be located adjacent to the existing boreholes, within a narrow strip where the depth-to-bedrock is about 50 m. The spacing between each RHC-type borehole is about 500 m, with the exception of the western group. This is aimed to spread out the production from the Sabaki Aquifer as much as possible in order to mitigate the influence of the RHC-type borehole production on groundwater flow patterns in the vicinity of the existing boreholes, and reduce the total groundwater level drawdown in the aquifer.

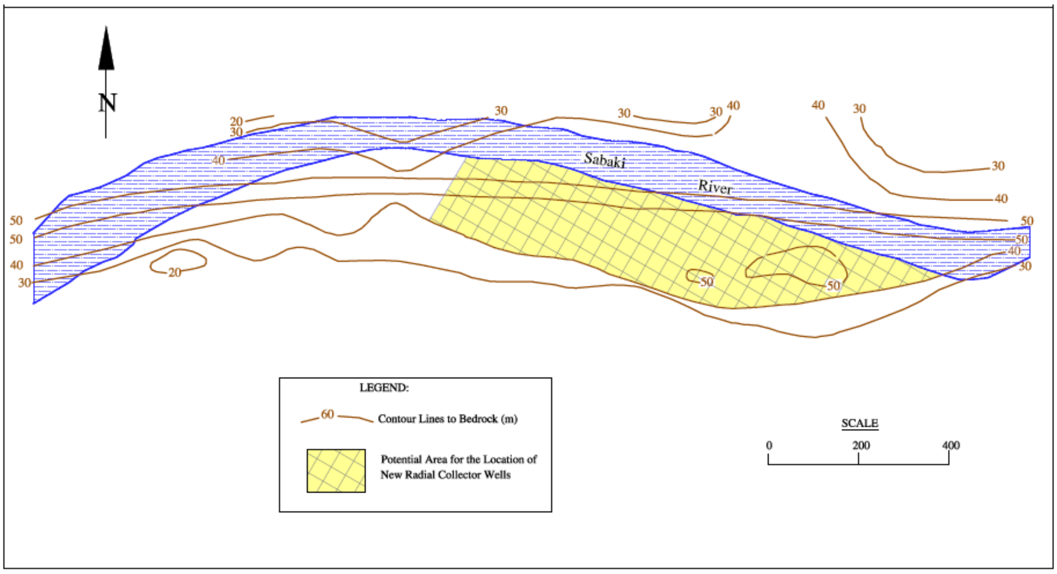


Fig. 9-12: Potential area for RHC-type boreholes

The general design of each RHC-type borehole was set out in Table 9-26 above.

A typical RHC-type borehole cross-section is presented in Fig. 9-13.

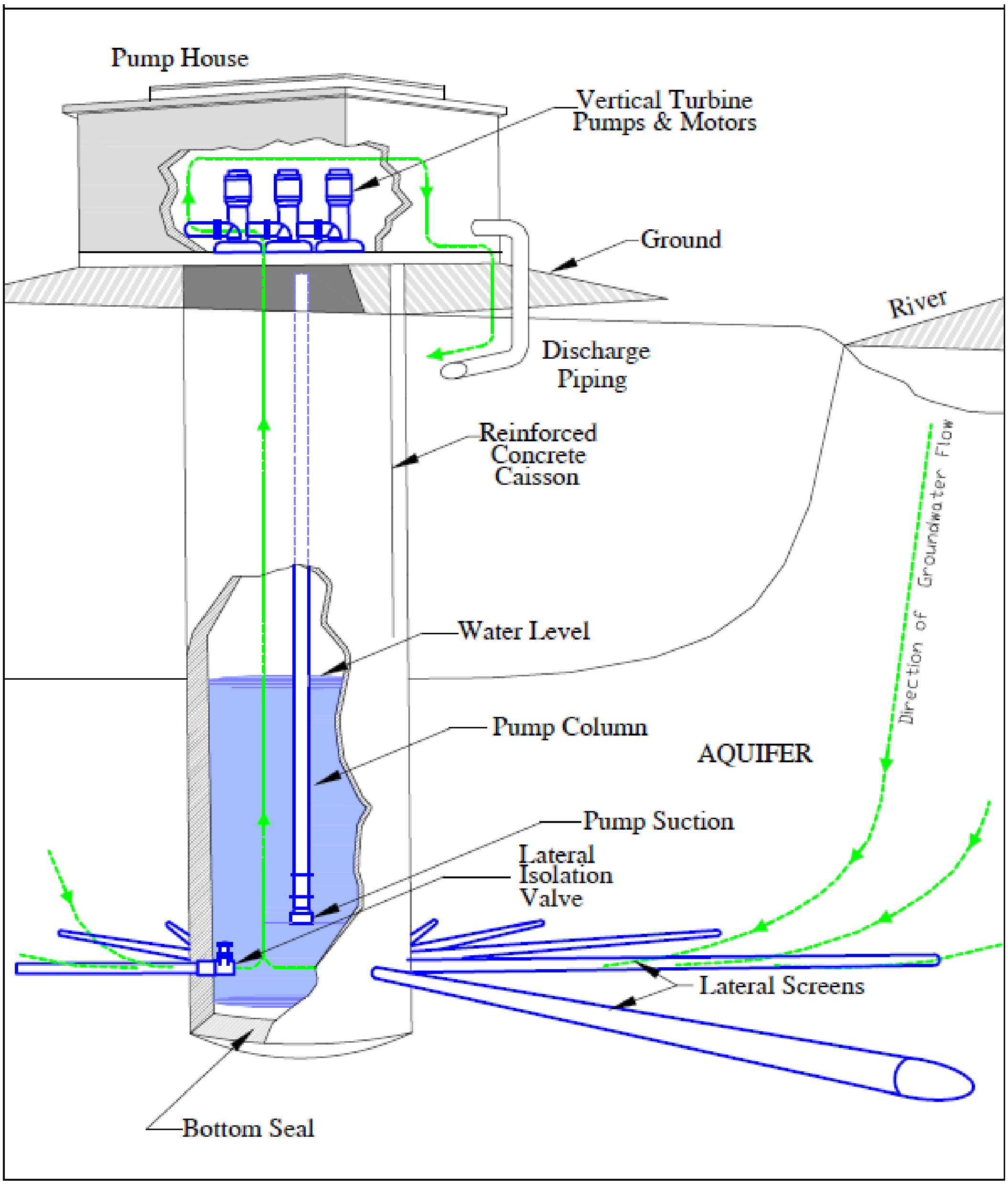


Fig. 9-13: Schematic illustration of RHC-type borehole

RHC-type borehole components are as follows:

- Central caisson shaft with a 3–9 m diameter shaft that extends from the surface and down to 5 m above the base of the aquifer (~35–45 m below ground level)

- Collector room at the bottom of the shaft to accommodate the drilling equipment used to construct a series of horizontal radial tunnels, and to house pumps and pumping appurtenances
- Pumping station, including motors, controls and discharge piping
- Hoist lift
- Several horizontal collector wells or screens extending an estimated 40–60 m laterally from the central shaft, below the water table

The RHC-type boreholes will be drilled/excavated to about 5 m above the base of the aquifer in order to allow flexible drawdown range, considering seasonal groundwater level drop in the Sabaki Aquifer and to avoid the lateral wells/screens to run dry.

The exact location and design of the proposed RHC-type boreholes will be determined based on a detailed study for the construction and installation of RHC-type boreholes. The detailed study will include site-specific investigations confirming the aquifer conditions prior to detailed design and well testing, which may significantly impact technical feasibility and costs of RHC-type borehole construction at the proposed locations. A comparison to other production techniques and alternatives is also recommended.

9.10.2.4 Expansion of the High-Lift Pumping Station (HLPS)

At present, only 65,000–68,000 m^3/d are produced at the Baricho site and supplied to the Mombasa Line and Kakuyuni Water Tank for the Malindi consumers. Out of this daily volume, the estimation is that some 17,500 m^3/d are supplied for the Malindi line and the rest for Mombasa. However, with the completion of the WaSSIP works and the good condition of the borehole pumps, as well the renewal of the delivery pumps, the total potential of water is about 83,000 m^3/d.

The following actual production figures were obtained from onsite CWSB staff:

- Actual supply towards Mombasa amounts to about 49,900 m^3/d, by operating four delivery pumps an average of 15 h/d.
- Actual supply towards Kakuyuni Water Tank (to Malindi), amounts to about 17,500 m^3/d, by operating two delivery pumps an average of 15 h/d.
- Total water delivery amounts to about (49,900 + 17,500 =) ~67,400 m^3/d.

From the figures above, it becomes clear that there is unused water capacity of about (83,000 – 67,400 =) ~15,600 m^3/d.

Along the phases of the development, additional water volumes will be abstracted from the Sabaki River and will flow to the treatment facility at the Baricho site. In each phase, different amounts of water will be supplied to Mombasa and Malindi, due to the regional water balance; i.e., Mombasa will be supplied with additional water from Mwache Dam (Phase I) and Mzima Springs (Phase III), and, therefore, less water from Baricho will be allocated for supplying Mombasa.

An additional amount of 90,000 m^3/d to be abstracted from the Baricho Wellfield at the end of Phase II will be about (174,600 – 84,600 =) ~90,000 m^3/d, as shown in Table 9-20 and Table 9-25 above. Out of the additional daily water volume, some 20,000 m^3/d will be added to the Mombasa water supply in the Immediate Phase, when two new vertical boreholes will be added to the Baricho site, leaving additional abstraction for Phase II to be about 90,000 m^3/d.

The Sabaki-Mombasa Pipeline will receive (by horizon year 2035) a total of about 90,273 m^3/d, while the Malindi Pipeline will receive about 84,730 m^3/d by the end of Phase II.

The reason for the increased additional water to Malindi/Watamu in Phase II is a result of the fact that, at that time, Kilifi and Malindi/Watamu will receive their entire water supply from the new Kilifi Pipeline, rather than from the Sabaki-Mombasa Pipeline. This change in the bulk water supply system is described in Section 8.4.2.2 (Immediate Phase) above.

Table 9-27 summarizes the diversion of water from the Baricho site to each one of the supply lines. (Note: Rounded numbers have been used in Table 9-27.)

Table 9-27: Current and Future Water Delivery from Baricho to Mombasa and Malindi Pipelines

	Unit	Current	2035	Remarks
Total abstraction from borehole	m^3/d	68,000	175,000	
Total delivery from PS	m^3/d	68,000	175,000	
Total daily delivery to Mombasa	m^3/d	49,900	90,273	
Total hourly delivery to Mombasa **Current supply with 4 units, 833 m^3/h each, 15 h/d**	m^3/h	3,326	3,761	- Adding four pumps (3 duty, 1 standby) for Mombasa delivery, 833 m^3/h each - Will be done in stages
Total daily delivery to Malindi	m^3/d	17,500	84,727	
Total hourly delivery to Malindi **Current supply with 2 units, 583 m^3/h each, 15 h/d**	m^3/h	1,166	3,530	- Adding six pumps (5 duty, 1 standby) for Malindi/Watamu delivery, 583 m^3/h each - Will be done in stages

For simplicity of operation and maintenance, it is recommended to install standard HLP equipment, similar to that being operated today. The pumps serving the Malindi Pipeline will be larger in terms of capacity due to the need to add significant volumes for the target years of the master plan.

The development of delivery pump capacity will be as follows:

- **Immediate Phase** – no additional delivery pumps necessary to supply Mombasa and Malindi/Watamu
- **Phase II** – three additional pumps (2 duty, 1 standby) to supply Mombasa, and six additional pumps (5 duty, 1 standby) to supply Malindi/Watamu

Table 9-28 and Table 9-29 present a summary of the required delivery pump configuration for each delivery pipeline according to development phase.

Table 9-28: Summary of the Pump Array of the Delivery Facility at Baricho Site

Description	Unit	Current *	Additional	Remarks
Mombasa delivery pump array				
Number of units (duty + standby)	No.	4 + 1	3 + 1	2 new pumps at Phase II 2 new pumps at Phase III
Capacity for each pump	m^3/d	833	833	
Working hours per day	h/d	22	21	
Total daily delivery	m^3/d	56,644	90,273	Total of 5 duty pumps
Malindi delivery pump array				
Number of units (duty + standby)	No.	2 + 1	5 + 1	In the expansion of the HLPS, 6 new pumps will be installed: - 3 of the 6 will be in Phase II. - The other 3 can be postponed to Phase III.
Capacity for each pump	m^3/h	583	700	
Working hours per day	h/d	20	18.6	
Total daily delivery	m^3/d	23,320	84,730	Total daily delivery volume: **175,000**

* The current data does not refer to the current yield of the Baricho site, but rather to the future capacity of the current equipment.

Table 9-29: Details of High-Lift Pumping Station to Mombasa and Kilifi

	Present		Phase II		Phase III	
	Duty	Standby	Duty	Standby	Duty	Standby
	Mombasa Pumps					
Number of pumps	4	1	1	1	1	1
Pump capacity (m^3/h)	833	833	833	833	833	833
Pump TDH (m)	240	240	240	240	240	240
Pumps installed power (kW)	840	840	840	840	840	840
	Malindi Pumps					
Number of pumps	2	1	2	1	2	1
Pump capacity (m^3/h)	583	583	700	700	700	700
Pump TDH (m)	100	100	110	110	110	110
Pumps installed power (kW)	250	250	300	300	300	300
	Total					
Total newly installed pumps	**–**		**5**		**5**	
Total number of pumps	**8**		**13**		**18**	
Type	**Deep-well vertical trunk centrifugal pumps**					

The current Baricho Waterworks have four 2 MVA 33/3.3 kV transformers, which work at a total of 8 MVA of power capacity availability at the site. The current power utilized by the existing pump installations is 62.5% of the 8 MVA. The balance remaining is 3 MVA.

Hence, no additional transformers will be required for the Immediate Phase or for Phase I. Two new 2 MVA 33/3.3 kV transformers must be installed and connected during Phases II and III.

9.10.3 Transmission Works

A main assumption of the WSMP study is that the current 800 mm, PN 24, steel Sabaki-Mombasa Pipeline, constructed in the late 1980s and currently over 25 years old, has reached its half lifespan. Assuming that it will safely serve for about another 25 years, it has been considered an integral part of the delivery system from Baricho towards Mombasa and other consumers along the main line.

For calculation of the hydraulic performance of the bulk water supply system at the horizon year, the following factors were considered:

- The existing pipeline will continue to convey water for the next 25 years, and will reach a service duration of 50 years, i.e., to 2035.
- The new pipeline will be constructed parallel to the existing one. This will simplify construction in Phase II when the pipe should be implemented, and,

even more so, will facilitate maintenance activities, allowing easier access to the pipes and the chambers of accessories.

- The new pipeline will be designed to operate under the same hydraulic gradient, and the total delivery of water will be done with the same TDH of the existing pumps.
- The new pipeline will have to be of the same grade as the existing one, with a gradual decrease in grade to the downstream of the pipe. Table 9-30 presents the pipe pressure rating (PN) required for each of the pipeline segments, measuring from downstream of the pumping station at Baricho.

Table 9-30: Pipe Pressure Rating Requirements for Baricho-Nguu Tatu Pipeline

Pipe Pressure Rating (PN)	km Required (from Baricho)
32	30
24	30
16	20
10	20
6	7
Total	**107**

According to data received from the CWSB, the existing pipe does not have an 800 mm diameter for its entire length. There are two bottlenecks with narrower pipe segments, as follows:

- A 100 m long pipeline section, 400 mm in diameter, at the extreme downstream of the main line, just before the Nguu Tatu Water Tank
- A 12 km long pipeline section, 600 mm in diameter, between Lower Ribe Junction and the Nguu Tatu Water Tank, in the section that allows the water to flow directly to Nguu Tatu

These two sections will be replaced and upgraded as part of the Immediate Phase of the development plan. The immediate investment will be dedicated to the emergency works for the Mombasa supply improvement, in order to achieve this target.

In addition, works will include construction of a new pipeline from the second Sabaki Pipeline to Ubaoni Water Tank, to enable more water to be delivered from the second Sabaki Pipeline toward Mtwapa

Since there are consumers complaining about low pressure at the area surrounding the Nguu Tatu Water Tank (which happens when the pumps toward Mombasa work against the elevation of the Nguu Tatu Water Tank, thus causing the consumers along the line to experience low pressures), it has been concluded that downstream of the Lower Ribe, two pipes will serve the bulk water supply system. The new 800 mm segment will connect in line with the current Mombasa line, while the existing 400 mm and 600 mm pipe will be used to supply from the Lower Ribe Water Tank to the consumers. Thus, the pressure supplied will be of the head of the Lower Ribe Water Tank, while, at the same time, the new 800 mm pipe will be without consumer connection. In that case, the CWSB should operate the Mombasa line, such that the valve towards Nguu Tatu will be closed for a few hours each day, and the water will be diverted to the Lower Ribe Water Tank for downstream consumers. While doing that, the supply to the Nguu Tatu Water Tank will be suspended, resulting in a decrease in the daily volume delivered to Mombasa. (It is predicted that the filling time of the Lower Ribe Water Tank will be shorter compared to the current situation, as the pumping rate will be greater than the current rate.)

Water abstraction that comes from the two new boreholes will be required in order to increase water productivity.

Operating two additional delivery pumps (out of the existing pumps, without installing any new delivery pumps) in 2014-2015, in parallel with the improvement activities within the Immediate Phase framework, are expected to improve delivery capacity of the pipe and improve supply to Mombasa.

Full analyses of the hydraulic performance of the supply line were calculated using the WaterCAD hydraulic model. For background on use of hydraulic simulation models, please refer to Section 9.5 above.

9.10.4 Summary of the Engineering Components for the Baricho 2 Expansion and Supply Schemes

Table 9-31 presents a preliminary BOQ with engineering components required for Baricho 2 expansion and supply schemes in Phase II.

Table 9-31: Phase II – Engineering Components for Baricho 2 Expansion and Supply Schemes

1			Baricho 2 Scheme (Inner Stages A–D)	Unit	Qty
	1.1		**Civil engineering works**		
		1.100	Drilling new boreholes at the Baricho site, 9 m diameter, RHC-type	No.	5
		1.101	Concrete works for the borehole cover and pump installation	LS	5
		1.102	Horizontal drilling for "gallery"-type suction shaft	No.	5
		1.103	Civil construction works for new non-asphalt access road to site, and upgrade of existing non-asphalt road	km	1
		1.104	Construction of new pumping station, 60 m x 25 m, 7 m (L x W x H)	m^2	1,500
		1.105	Construction on new auxiliary building, 20 m x 15 m x 5 m (L x W x H)	m^2	300
		1.106	Construction of new electrical building, 20 m x 12 m, 7 m (L x W x H)	m^2	240
		1.107	New receiving tank with chlorination chamber	m^3	5,000
	1.2		**Electromechanical works**		
		1.200	Supply of borehole pumps, 900 m^3/h, 60 m head	No.	5
		1.201	Installation of the above borehole pumps	No.	5
		1.202	Supply of delivery pumps, 833 m^3/h, 240 m head	No.	4
		1.203	Installation of the above delivery pumps	No.	4
		1.204	Supply of delivery pumps, 700 m^3/h, 110 m head	No.	6
		1.205	Installation of the above delivery pumps	No.	6
		1.206	Electrical installation for pumps	LS	1
		1.207	Provide electricity to the site	LS	1
	1.3		**Pipe and manifolds**		
		1.300	Pipes to borehole pump manifolds, steel, DN400	m	160
		1.301	Pipe main manifolds from borehole pumps to main conveyer, steel, DN500	m	120
		1.302	Pipe from manifolds to water treatment tank, steel, DN600	m	350
		1.303	Pipe from water treatment tank to suction chamber, steel, DN750	m	150
		1.304	Overflow pipe from treatment tank, steel, DN600	m	200
		1.305	Main gate valve for borehole manifolds, 12", DN300	No.	5
		1.306	Main non-return valve for borehole manifolds, 12", DN300	No.	5
		1.307	Treatment water tank valve, 24", DN600	No.	2
		1.308	Suction chamber main valve, 24", DN600	No.	1
		1.309	Suction chamber secondary valve, 16", DN400	No.	5
		1.310	Suction chamber secondary valve, 12", DN300	No.	3
	1.4		**Accessories**		
		1.400	Air valve static + dynamic, 6", DN150	No.	12
		1.401	Air valve static + dynamic, 4", DN100	No.	5
		1.402	Air valve static + dynamic, 3", DN80	No.	5

1			Baricho 2 Scheme (Inner Stages A–D)	Unit	Qty
		1.403	Surge rapid pressure release valve, 12", DN300	No.	5
		1.404	Surge rapid pressure release valve, 10", DN250	No.	2
		1.405	Surge rapid pressure release valve, 6", DN150	No.	4
		1.406	Pressure sustain valve, 16", DN400	No.	5
		1.407	Pressure sustain valve, 12", DN300	No.	4
		1.408	Pressure sustain valve, 10", DN250	No.	4
		1.409	Flowmeter for each borehole, DN400	No.	5
		1.410	Gate valve for flowmeters, DN400	No.	12
	1.5		**Auxiliary systems**		
		1.500	Surge protection system and all accessories needed – surge protection tank, pressure valves, system control, interface with existing system, etc.	LS	1
		1.502	Fire protection system for the new pumping station	LS	1
		1.503	Fire protection system for the new auxiliary building	LS	1
		1.504	Fire protection system with foam for the new electrical building	LS	1
		1.505	Lighting system for all buildings	LS	1
	1.6		**Treatment systems**		
		1.600	Chlorination system for the disinfection	LS	2

2			Baricho-Nguu Tatu Pipeline	Unit	Qty
	2.1		**Pipe and manifolds (including excavation)**		
		2.100	Parallel force main pipe, steel, DN800, PN 40	m	28,000
		2.101	Parallel force main pipe, steel, DN800, PN 25	m	28,000
		2.102	Parallel force main pipe, steel, DN800, PN 16	m	26,000
		2.103	Parallel force main pipe, steel, DN800, PN 12	m	25,000
		2.104	Branch pipes for connecting kiosks, PE pipe, DN400, PN 25	m	300
		2.105	Branch pipes for connecting other points, PE pipe, DN300, PN 25	m	500
		2.106	Branch pipes for connecting other points, PE pipe, DN250, PN 25	m	500
	2.2		**Accessories**		
		1.200	Air valve, static + dynamic, 6", DN150	No.	50
		1.201	Air valve, static + dynamic, 4", DN100	No.	30
		1.202	Air valve, static + dynamic, 3", DN80	No.	20
		1.203	Surge rapid pressure relief valve, 12", DN300	No.	10
		1.204	Surge rapid pressure relief valve, 10", DN250	No.	8
		1.205	Surge rapid pressure relief valve, 6", DN150	No.	6
		1.206	Pressure sustain valve, 16", DN400	No.	12
		1.207	Pressure sustain valve, 12", DN300	No.	12
		1.208	Pressure sustain valve, 10", DN250	No.	12
		1.209	Gate valve for the main pipe, 24", DN600	No.	15
		1.210	Gate valve for the secondary pipe, 20", DN500	No.	15
		1.211	Gate valve for the secondary pipe, 16", DN400	No.	8
		1.212	Gate valve for the secondary pipe, 12", DN300	No.	12

2			Baricho-Nguu Tatu Pipeline	Unit	Qty
	2.3		**Water distribution chambers**		
		2.300	Gate valve chamber for main valve, 24", 2 m x 3 m	No.	15
		2.301	Gate valve chamber for secondary valves, 20", 2 m x 3 m	No.	15
		2.302	Gate valve chamber for secondary valves, 16", 2 m x 2 m	No.	8
		2.303	Gate valve chamber for main valve, 12", 1 m x 2 m	No.	12
		2.304	Drainage valve for the main line, 12", DN300	No.	20
		2.305	Drainage valve for the secondary lines, 10", DN250	No.	10
		2.306	Drainage valve for the secondary lines, 8", DN200	No.	10
		2.307	Drainage valve for the secondary lines, 6", DN150	No.	10
		2.308	Chamber for drainage valves	No.	50

3			Baricho–Kakuyuni Pipeline	Unit	Qty
	3.1		**Pipe and manifolds (including excavation)**		
		3.100	Parallel force main, PE pipe, DN600, PN 16	m	24,000
		3.101	Parallel force main, PE pipe, DN600, PN 12	m	21,000
		3.102	Branch pipes for connecting kiosks, PE pipe, DN400, PN 12	m	300
		3.103	Branch pipes for connecting other points, PE pipe, DN300, PN 12	m	300
		3.104	Branch pipes for connecting other points, PE pipe, DN250, PN 12	m	300
	3.2		**Accessories**		
		3.200	Air valve, static + dynamic, 6", DN150	No.	20
		3.201	Air valve, static + dynamic, 4", DN100	No.	20
		3.202	Air valve, static + dynamic, 3", DN80	No.	20
		3.203	Surge rapid pressure relief valve, 10", DN250	No.	6
		3.204	Surge rapid pressure relief valve, 6", DN150	No.	6
		3.205	Pressure sustain valve, 12", DN300	No.	6
		3.206	Pressure sustain valve, 10", DN250	No.	6
		3.207	Gate valve for the main pipe, 20", DN500	No.	10
		3.208	Gate valve for the secondary pipe, 12", DN300	No.	8
		3.209	Gate valve for the secondary pipe, 10", DN250	No.	12
	3.3		**Water distribution chambers**		
		3.300	Gate valve chamber for secondary valves, 20", 2 m x 3 m	No.	10
		3.301	Gate valve chamber for secondary valves, 12", 2 m x 2 m	No.	8
		3.302	Gate valve chamber for secondary valves, 10", 2 m x 2 m	No.	12
		3.303	Drainage valve for the main line, 12", DN300	No.	6
		3.304	Drainage valve for the secondary lines, 10", DN250	No.	6
		3.305	Drainage valve for the secondary lines, 8", DN200	No.	4
		3.306	Drainage valve for the secondary lines, 6", DN150	No.	4
		3.307	Chamber for drainage valves	No.	20

4			Kakuyuni-Marafa Pipeline	Unit	Qty
	4.1		**Pipe and manifolds (including excavation)**		
		4.100	Force main, PE pipe, DN300, PN 24	m	10,000
		4.101	Force main, PE pipe, DN300, PN 16	m	6,000
		4.102	Force main, PE pipe, DN300, PN 12	m	4,500
		4.103	Branch pipes for connecting other points, PE pipe, DN300, PN 12	m	300
		4.104	Branch pipes for connecting other points, PE pipe, DN250, PN 12	m	300
	4.2		**Accessories**		
		4.200	Air valve, static + dynamic, 6", DN150	No.	12
		4.201	Air valve, static + dynamic, 4", DN100	No.	10
		4.202	Air valve, static + dynamic, 3", DN80	No.	10
		4.203	Surge rapid pressure relief valve, 10", DN250	No.	4
		4.204	Surge rapid pressure relief valve, 6", DN150	No.	4
		4.205	Pressure sustain valve, 12", DN300	No.	4
		4.206	Pressure sustain valve, 10", DN250	No.	6
		4.207	Gate valve for the main pipe, 12", DN300	No.	10
		4.208	Gate valve for the secondary pipe, 10", DN250	No.	8
	4.3		**Water distribution chambers**		
		4.300	Gate valve chamber for secondary valves, 12", 2 m x 2 m	No.	10
		4.301	Gate valve chamber for secondary valves, 10", 2 m x 2 m	No.	8
		4.302	Drainage valve for the secondary lines, 10", DN250	No.	6
		4.303	Drainage valve for the secondary lines, 8", DN200	No.	8
		4.304	Drainage valve for the secondary lines, 6", DN150	No.	8
		4.305	Chamber for drainage valves	No.	14
	4.4		**Water tanks**		
		4.400	New water tank at Marafa	m^3	1,500
	4.5		**Water booster for Marafa**		
		4.500	Supply booster pump, 50 m^3/h, 60 m head	No.	4
		4.501	Install booster pumps	No.	4
		4.501	Construction of new pumping station, 6 m x 10 m x 7 m (L x W x H)	m^2	60
		4.502	Construction of guardhouse, 6 m x 5 m x 3 m (L x W x H)	m^2	30
		4.504	Electrical system to connect Marafa Pumping Station	LS	1

9.11 Phase II – Water Supply to Lamu and Tana River Counties

9.11.1 Overview

The Garsen-Lamu Supply Scheme will deliver most of the projected water demand for the region. The Lamu Port, as well as the related project of the LAPSSET corridor, is one the Government of Kenya's flagship projects in the coming years. Initiative to already start these projects in 2015 emphasizes the need of water supply to this region where the current resource of water – local shallow boreholes – will not be able to sustain the demand for water.

In the Executive Summary of the Full Feasibility Study Report, it clearly mentioned that there may be a time gap between the need for an increased amount of water in the region and the actual time it will take to execute the Garsen-Lamu Supply Scheme. Hence, a local desalination plant may be the local solution without changing the alternative of supplying water from the Tana River. Only in the case of a large seawater reverse osmosis (SWRO) plant, the water balance for the region will have to be updated, to account for some of the supply coming from desalinated water and some of the supply originating from the Tana River. In both cases, electrical power plays a key role in the cost of water – power for desalination vs. power for delivery from the Tana River. One should also consider the quality of water and sustainability of the source.

The potential of the deep aquifer in the Tana River Delta was discussed in the Water Resources Report. If it should be found in the future, during the proposed Immediate Phase investigation, that the Neogenic aquifer holds an immense amount of water, with high quality, a study will then be required to analyze the alternatives and their feasibility for allowing the bulk water supply system to receive more water from the north and also supplying the settlements along the way.

The distance between Malindi and Lamu County makes the transmission of water between those areas uneconomical. Conveying water from Tana River to Malindi is also not financially viable. Hence, townships in Lamu County will be supplied from local sources in this region.

Due to the remote location of the townships of Hola and Bura, located on the banks of the Tana River some 80 km and 130 km north of Garsen township, respectively, the Consultant has concluded that water will be supplied via local abstraction and distribution schemes.

9.11.2 Water Supply to Lamu Island/Port, Mpeketoni and Garsen

As part of the preparation of the WSMP study, the development of the bulk water supply system has been carried out in two stages – prefeasibility and full feasibility. The Consultant has determined that not only are the OPEX and CAPEX costs significant for long-distance transmission of water from the Tana River to the centres of demand, but also additional economic and environmental aspects should be considered.

Comparing the "linkage" between the water resources of the region and the demand for water indicates that the situation will differ only marginally in the future. This will also affect the contribution of the Tana River to the bulk water supply system. The explanation is as follows:

- **The "game changer" in the water resources of the region is the Mwache Dam.** Since this source will supply roughly 40% of the total water demand for the Greater Mombasa area (some 125,000 m^3/d out the proposed demand of 312,000 m^3/d), the contribution of Baricho Wellfield to meet Mombasa demand will be less significant, leaving more water from the Sabaki River to the Malindi area, including the Gongoni and Marafa townships and others.
- **The more water will be available in the vicinity of Malindi, the less attractive will be the alternative to deliver water from Tana River to the Malindi area.** The result of this understanding was clearly mentioned in the conclusion of the Prefeasibility Study Report of the current master plan study. The Tana River area, although rich in water (of poor quality) will not be connected to the mainland bulk water supply system. It was found that conveying water from Tana River to the mainland is not necessary in order to meet the demand and, at the same time, there is no advantage to deliver water to the north where there is an abundance of local water.

For planning and development considerations, the region was divided into **two main water supply schemes**:

- **Lamu Island township, including the proposed Lamu Port and Mpeketoni:**
  - The consumers in the Greater Lamu area (including Mpeketoni) will be supplied from the main water scheme in this region.
  - Water will be abstracted from the Tana River near Garsen, and will be pumped via a 78 km main pipeline to the Lamu Island township.
  - According to the regional water balance, the total supply of water will be around 119,860 m^3/d at the horizon year of 2035. Out of this, a volume of 116,000 m^3/d will be pumped along the main line toward Lamu city (~97% of the total abstracted water), with an average hourly flow of 4,833 m^3/h, 24 h/d.
  - Preliminary design for the Lamu supply must be supplemented prior to execution of this scheme, as there is a lack of data with regard to the local

  - constraints of this region. (The Consultant did not visit this area due to limitations with regard to security in this region.)
  - The same is relevant regarding the location of the intake from the Tana River, as the Consulted was not granted admission to the area.
  - Thus, the main contribution of the master plan study for Lamu County is the projection of water demand to the horizon year and the alternative comparison made in order to identify the best practice for development of the area's resources (out of three scenarios).
- **From Garsen intake to Garsen township:**
  - The daily volume of water consumption in Garsen township will be 3,860 m^3/d, with hourly flow of 160 m^3/h.
  - The water will be abstracted from the main water intake that will serve the Lamu Supply Scheme.
  - The pumped supply will be carried out by a separate pump array towards the Garsen distribution system.

The daily production volume from the intake will be pumped toward Lamu township and Lamu Port. Both represent the major demand centre in the northern area. The main water supply line will be 1,200 mm in diameter, which will enable a flow of 4,830 m^3/h by 2035.

The key components for the Lamu Supply Scheme will be as follows:

- **Water intake from the Tana River near Garsen:**
  - This will enable the diversion of up to 5,000 m^3/d, with a total daily volume of about 120,000 m^3/d.
  - The Consultant recommends that the water intake consist of five modules for the abstraction of 24,000 m^3/d each, with each module's capacity up to 1,000 m^3/h.
- **Five treatment plant trains for the treatment of raw water from the Tana River:**
  - Each module will comprise a coagulation chamber to achieve contact between the polymer and the suspended solids; settling basin (primary settlings); high rate filtration; and disinfection system.
- **Main pumping station for water delivery to Lamu County:**
  - This pumping station will have the dimensions of 60 m x 25 m, and a height of 7 m.
  - A new electrical building, with dimensions of 20 m x 12 m, and a height of 7 m, will constructed adjacent to the pumping station.
- **Garsen-Lamu main water supply pipeline:**
  - 1,200 mm steel pipe, 78 km in length
  - Designed to convey 4,830 m^3/h for the Greater Lamu area

Table 9-32 presents a preliminary BOQ with engineering components required for the Garsen-Lamu Supply Scheme.

Table 9-32: Engineering Components of Garsen-Lamu Water Supply Scheme

1			Garsen-Lamu Water Supply Scheme	Unit	Qty
	1.1		**Civil engineering works**		
			Water intake system		
		1.100	Intake – civil works	m^3/d	120,000
		1.101	Construction of new pumping station, 65 m x 20 m x 7 m (L x W x H)	m^2	1,300
		1.102	Construction of new electrical building, 20 m x 12 m x 5 m (L x W x H)	m^2	240
		1.103	Construction of new administration building, 20 m x 10 m x 3 m (L x W x H)	m^2	200
		1.104	Fencing, chain link	m	400
		1.105	Fire protection system for the new pumping station	LS	1
		1.106	Fire protection system with foam for the new electrical building	LS	1
		1.107	Fire protection system for the new administration building	LS	1
		1.108	Lighting system for all buildings	LS	1
			Water treatment plant		
		1.109	Treatment works, full conventional train – primary sedimentation + coagulation + secondary sedimentation + filtration + disinfection (Note: 3 trains, 40,000 m^3/d each)	LS	3
		1.110	Fencing, chain link	m	500
		1.111	Construction of new high-lift pumping station (HLPS), 60 m x 25 m x 7 m (L x W x H)	m^2	1,500
		1.112	Construction of new administration building, 18 m x 12 x 3 m (L x W x H)	m^2	216
		1.113	Construction of guardhouse, 12 m x 9 m x 3 m (L x W x H) x 3 No.	m^2	324
		1.114	Fire protection system for the new pumping station	LS	1
		1.115	Treated water flowmeter and regulating valve chamber, 6 m x 3 m x 4 m (L x W x H)	No.	1
		1.116	Treated water outlet valve chamber, 3 m x 2 m x 2.5 m (L x W x H)	No.	1
			Transmission pipe chambers		
		1.117	Line valve chamber, 2.5 m x 2 m x 2.5 m (L x W x H)	No.	19
		1.118	Air valve chamber 2 m x 2 m x 2.5 m (L x W x H)	No.	75
		1.119	Washout chamber 3 m x 2 m x 2.5 m (L x W x H)	No.	15
	1.2		**Transmission pipe**		
		1.200	Raw water pump suction pipe, steel, DN300	m	100
		1.201	Raw water pump delivery pipe, steel, DN400	m	150
		1.202	Raw water main conveyance pipe, steel, DN1200	m	150
		1.203	High-lift suction pipe, steel, DN300	m	50
		1.204	Treated water pump delivery pipe to main conveyor, steel, DN400	m	200

1			Garsen-Lamu Water Supply Scheme	Unit	Qty
		1.205	Transmission pipe, steel, DN1200	m	78,000
		1.206	Pipeline excavation	m	78,000
		1.207	Access road, non-asphalt	km	75
	1.3		**Electromechanical works**		
		1.300	Supply of raw water delivery pumps, 800 m³/h, 135 m head	No.	8
		1.301	Installation of the above raw water delivery pumps	No.	8
		1.302	Supply of treated water delivery pumps, 800 m³/h, 220 m head	No.	8
		1.303	Installation of the above treated water delivery pumps	No.	8
		1.304	Electrical installation for pumps	LS	1
		1.305	Provide electricity to the site	LS	1
	1.4		**Accessories**		
		1.400	Manual butterfly valve (line), DN1200	No.	16
		1.401	Air valve, DN200	No.	150
		1.402	Manual gate valve (drain valve), DN300	No.	15
		1.403	Electromagnetic flowmeter, DN1200	No.	1
		1.404	Pipe, steel, DN1200	m	80
		1.405	Pipe, steel, DN1000	m	80
		1.406	Drainage pipe, steel, DN500	m	500
	1.5		**Auxiliary systems**		
		1.501	Surge protection system and all accessories needed – surge protection tank, pressure valves, system control, interface with existing system, etc.	LS	1

9.11.3 Water Supply to Hola and Bura

Hola and Bura are two local townships within Tana River County. The distance of these towns from the bulk water supply system, coupled with the short distance from Tana River, the main water source in the region, justifies the proposal to develop separate water schemes centred on abstraction and treatment of Tana River waters, as follows:

- From Tana River, by local schemes, water will supplied to Hola and Bura townships. The daily volume of water consumption will be 2,707 m^3/d and 3,213 m^3/d respectively, with hourly flows of 135 m^3/h and 160 m^3/h, respectively.
- The smaller scale of these local water supply schemes does not justify the construction of a local water tank.
- The Consultant recommends that the supply be relayed via a local pumping station with a VSP-type pump, enabling the supply of water directly to the actual demand location without a balancing tank.

Table 9-33 and Table 9-34 presents a preliminary BOQ with engineering components required for the Hola and Bura local water supply schemes, respectively.

Table 9-33: Engineering Components of Hola Water Supply Scheme

2			Hola Local Water Supply Scheme	Unit	Qty
	2.1		**Civil engineering works**		
			Water intake system		
		2.100	Intake – civil works	m^3/d	2,700
		2.101	Pumping station, 16 m x 10 m x 5 m (L x W x H)	m^2	160
		2.102	Construction of new electrical building, 12 m x 5 m x 5 m (L x W x H)	m^2	60
		2.103	Fencing, chain link	m	50
			Water treatment plant		
		2.104	Treatment works, full conventional train – primary sedimentation + coagulation + secondary sedimentation + filtration + disinfection	m^3/d	2,700
		2.105	Fencing, chain link	m	500
		2.106	Administration building, 12 m x 10 m x 3 m (L x W x H)	m^2	120
		2.107	Guardhouse, 8 m x 5 m x 3 m (L x W x H)	m^2	40
		2.108	Treated water flowmeter and regulating valve chamber, 6 m x 3 m x 4 m (L x W x H)	No.	1
		2.109	Treated water outlet valve chamber, 3 m x 2 m x 2.5 m (L x W x H)	No.	1
		2.111	**Transmission pipe chambers**		
		2.112	Line valve chamber, 2.5 m x 2 m x 2.5 m (L x W x H)	No.	19
		2.113	Air valve chamber, 2 m x 2 m x 2.5 m (L x W x H)	No.	75
		2.114	Washout chamber, 3 m x 2 m x 2.5 m (L x W x H)	No.	15
	2.2		**Transmission pipe**		
		2.200	Raw water pump suction pipe, steel, DN300	m	400
		2.201	Raw water pump delivery pipe, steel, DN400	m	150
		2.202	High-lift suction pipe, steel, DN300	m	50
		2.203	Treated water pump delivery pipe to main conveyor, steel, DN400	m	200
		2.204	Installation of manifolds for pumps	LS	1
		2.205	Access road, non-asphalt	km	2
	2.3		**Electromechanical works**		
		2.300	Supply of raw water and treated water delivery pumps, 250 m^3/h, 45 m head	No.	6
		2.301	Installation of the above raw water delivery pumps	No.	3
		2.302	Installation of the above treated water delivery pumps	No.	3
		2.303	Electrical installation for 6 pumps	LS	1
		2.304	Provide electricity to the site	LS	1
	2.4		**Accessories**		
		2.400	Air valve, DN200	No.	10
		2.401	Manual gate valve (drain valve), DN300	No.	4
		2.402	Electromagnetic flowmeter, DN400	No.	1

Table 9-34: Engineering Components of Bura Water Supply Scheme

3			Bura Local Water Supply Scheme	Unit	Qty
	3.1		**Civil engineering works**		
			Water intake system		
		3.100	Intake – civil works	m^3/d	3,300
		3.101	Pumping station, 12 m x 10 m x 5 m (L x W x H)	m^2	120
		3.102	Construction of new electrical building, 12 m x 5 m x 5 m (L x W x H)	m^2	60
		3.103	Fencing, chain link	m	120
			Water Treatment Plant		
		3.104	Treatment works, full conventional train – primary sedimentation + coagulation + secondary sedimentation + filtration + disinfection	m^3/d	3,300
		3.105	Fencing, chain link	m	400
		3.106	Administration building, 12 m x 10 m x 3 m (L x W x H)	m^2	120
		3.107	Guardhouse, 8 m x 5 m x 3 m (L x W x H)	m^2	40
		3.108	Treated water flowmeter and regulating valve chamber, 6 m x 3 m x 4 m (L x W x H)	No.	1
		3.109	Treated water outlet valve chamber, 3 m x 2 m x 2.5 m (L x W x H)	No.	1
			Transmission pipe chambers		
		3.110	Line valve chamber, 2.5 m x 2 m x 2.5 m (L x W x H)	No.	8
		3.111	Air valve chamber, 2 m x 2 m x 2.5 m (L x W x H)	No.	12
		3.112	Washout chamber, 3 m x 2 m x 2.5 m (L x W x H)	No.	5
	3.2		**Transmission pipe**		
		3.200	Raw water pump suction pipe, steel, DN300	m	400
		3.201	Raw water pump delivery pipe, steel, DN400	m	150
		3.202	High-lift suction pipe, steel, DN300	m	50
		3.203	Treated water pump delivery pipe to main conveyor, steel, DN400	m	200
		3.204	Installation of manifolds for pumps	LS	1
		3.205	Access road, non-asphalt	km	2
	3.3		**Electromechanical works**		
		3.300	Supply of raw water and treated water delivery pumps, 250 m^3/h, 45 m head	No.	6
		3.301	Installation of the above raw water delivery pumps	No.	3
		3.302	Installation of the above treated water delivery pumps	No.	3
		3.303	Electrical installation for 6 pumps	LS	1
		3.304	Provide electricity to the site	LS	1
	3.4		**Accessories**		
		3.400	Air valve, DN200	No.	12
		3.401	Manual gate valve (drain valve), DN300	No.	4
		3.402	Electromagnetic flowmeter, DN400	No.	1

9.12 Phase III – Mzima 2 Scheme

9.12.1 Extension of the Mzima Springs – Mzima 2 Pipeline

The Mzima Springs is a major contributor to the bulk water supply system of the CWSB. Development of the Mzima 2 Pipeline considers the actual condition of the current pipeline, dating back to 1956, the year of installation. Previous studies – including the Water Resources Report of the current master plan study – have indicated that this source is one of the most sustainable water sources in the region, with very good flow measurement records.

The WB has recently published a request for a study of the replenishment mechanism of the Kilimanjaro Aquifer in order to predict future changes in the aquifer and their affect on the water yield. This work has not yet been completed.

Following the scenario comparison in the Full Feasibility Study Report of the current master plan study, it was clearly found that the most effective and viable development of this sources will be in Phase III of the development program. The utilization of this source is the most expensive by "standalone" calculation, which makes it the most viable to be implemented last in the development program.

By 2035, the current Mzima Pipeline will be over 70 years old, and will have passed its useful and efficient lifespan. The new Mzima 2 Pipeline will have to deliver the required daily volume of 105,000 m^3/d (1.22 m^3/s) without using the capacity of the current pipeline, which will be decommissioned.

The Mzima 2 Pipeline will serve, in addition to the city of Mombasa, the townships of Voi/Maungu, Mwatate and Wundanyi. Additional water consumers along the Mzima 2 Pipeline will consume some 50,949 m^3/d, allowing the city of Mombasa to enjoy some 54,000 m^3/d from Mzima Springs. The detailed schematic block diagram of the Mzima 2 Pipeline is presented in Fig. 9-17.

9.12.2 Waterworks – Existing Situation

Water for the Mzima supply system is abstracted from the Mzima Springs headworks. The Mzima Springs outflow is a consequence of rainfall on the Chyulu Hills and percolating recharge over and through the volcanic mass overlaying the Chyulu Hills bedrock (crystalline basement) floor.

The springwater flows through three large pools – the Hippo, Long and Chalk Beach Pools – before discharging to the Mzima River some 4 km upstream of its junction with the Tsavo River.

The three pools are in sequence and cascade one into the other (see Fig. 9-14 below). The difference in level between the Hippo Pool and the Chalk Beach Pool is about 3.7 m. The total length of the three pools is about 2 km; the longest is Long Pool, which is about 1.2 km.

Spring outflows have been measured at the Mzima River since 1951. A flow-duration curve was shown in Fig. 7-3 above. From the figure, it can be observed that the maximum outflow measured was 5.9 m^3/s and the minimum 2.6 m^3/s ("100% exceedence flow"), the mean value being 3.6 m^3/s. Significantly, flows less than 3 m^3/s have been recorded only once in 4 years, and, even then, only in a few days of each year.

Flow fluctuation is moderate from month to month; and the variation over any 12-month period is about 1 m^3/s. The response time between rainfall on the Chyulu Hills and outflow at Mzima is 3–4 years. Therefore, it is possible to predict spring flows in advance, with relative accuracy.

Construction of the existing headworks (named Mzima 1) was completed in 1956. The intake consists of a 672 m long subsurface weir, consisting of a sheet pile cutoff wall upstream of the Hippo Pool, having an elevation of 684.58 masl at the top. The sheet pile is emplaced at depth within the regolith loams for the full cross-section of the saturated lava; the regolith loams are regarded as having negligible permeability. The weir is connected with an upstream trench to divert the groundwater to a collection chamber (see Fig. 9-15).

Approximately 1.1 m^3/s gravitates from this intake to an overflow chamber located some 850 m from the head of the Long Pool, or some 1,300 m from the collection chamber. At the overflow chamber, some 0.7 m^3/s is returned to the Mzima River system, and about 0.4 m^3/s is piped to Mombasa. Excess water from the Mzima Springs flows over the top of the cutoff wall and discharges to the Hippo Pool and to the upper end of the Long Pool.

As it stands now, the total water released from the Mzima Springs to the Mzima River system is equal to {(the flow over the weir) + 0.7 m^3/s}. Therefore, the minimum amount released to the river system is [(2.6 – 1.1) + 0.7] = 2.2 m^3/s, where 2.6 is the minimum spring outflow. This is well in excess of the minimum allowable environmental discharge of 1.4–1.6 m^3/s.

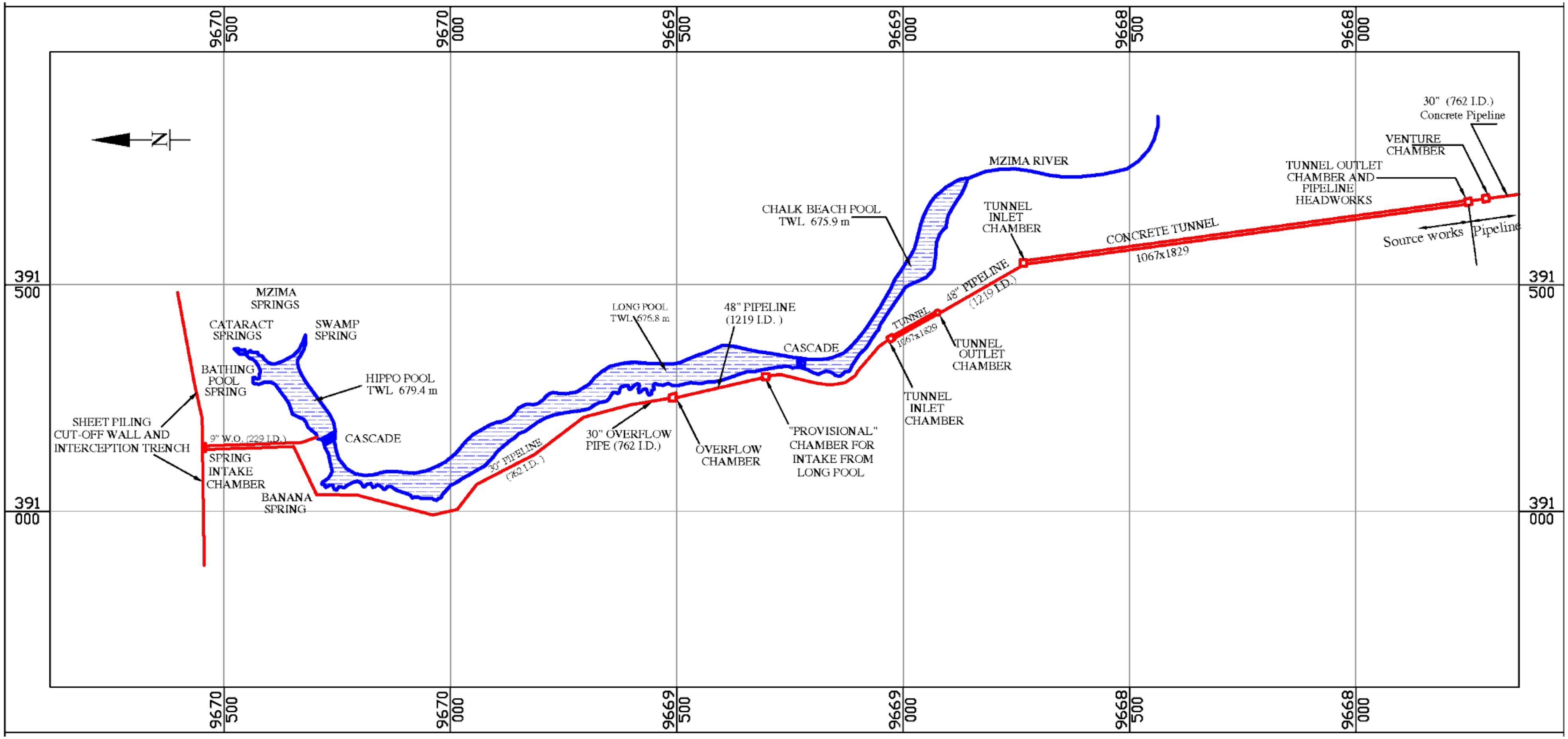


Fig. 9-14: Mzima Springs – existing waterworks and pools

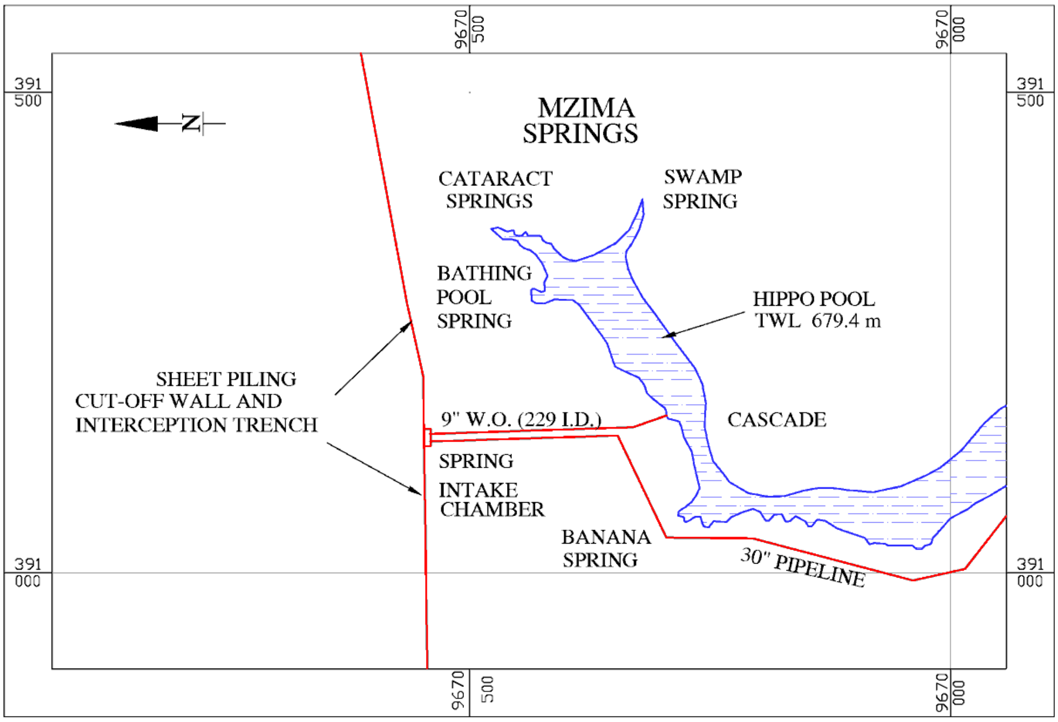


Fig. 9-15: Mzima Springs – existing headworks

9.12.3 Transmission Mains

The total water abstracted from the Mzima Springs reaches Mombasa by gravity. The total distance along the pipeline route from the springs' intake to the Mazeras Water Tanks is 218.5 km, of which the headworks transmission line, consisting of pipelines and tunnels, is only some 3 km long (see Fig. 9-16).

This headworks transmission line includes:

- 30" (762 mm) pipeline extending for 1,800 m, from the springs to the collection chamber along the southern end of the Hippo and Long Pools to the first tunnel inlet
- Overflow chamber, some 1,300 m from the intake
- Provisional intake chamber from Long Pool, some 1,500 m from the intake

The first tunnel, which is 100 m long, has a rectangular cross-section (1,067 mm x 1,829 mm) and a semi-circle top, having a radius of 534 mm.

The exit pipeline from the first tunnel has a diameter of 48" (1,219 mm ID) and runs for 200 m before entering the second tunnel. The second tunnel, which is 950 m long, has a cross-section identical to the first tunnel.

The water level at the intake chamber is 684.6 masl and the water level at the outlet chamber from the second tunnel is 675.4 masl.

The above was inputted to a hydraulic model of the headwork transmission line (according to the existing diameters). It was found that the existing waterworks at Mzima Springs have a maximum capacity of 1.21 m^3/s only, the bottleneck being the existing 30" (762 mm), 1,300 m long pipeline between the intake and the overflow chamber. Since the proposed contribution of the Mzima Springs to the bulk water supply system is 1.22 m^3/s (105,000 m^3/d), it is therefore necessary to extend this pipe for the Mzima expansion in Phase III of the development plan.

Analysis of the flow through the headworks and pipe interception trench, upstream of the sheet pile cutoff wall, indicates that the present headworks might sustain the additional abstraction required, as indicated above.

9.12.4 Proposed Development of the Mzima Waterworks (Mzima 2)

The selected Scenario B1 calls for increase of the supply to Mombasa from Mzima Springs, from the present 0.4 m^3/s (~35,000 m^3/d) to 1.22 m^3/s (~105,000 m^3/d), starting from the year 2030.

For such an increase in supply, the existing 1,300 m 30" (762 mm) pipeline between the intake and the overflow chamber will have to be replaced with a new ϕ48" (1,219 mm) pipeline (see Fig. 9-16). This replacement will allow the capacity of the Mzima Waterworks to increase to 1.5 m^3/s, well above the 1.22 m^3/s supply required by the preliminary design, and will leave an additional 0.28 m^3/s to be released from the overflow chamber to the Mzima River system.

This increased abstraction, and the release of 0.28 m^3/s from the overflow chamber, will, in this case, bring the minimum amount released to the Mzima River system to [(2.60 – 1.50) + 0.28 =] 1.38 m^3/s, where 2.60 is the minimum spring outflow. Although this amount is at the lower end of the 1.4–1.6 m^3/s required as the minimum allowable environmental discharge, it should be remembered that flows from the Mzima Springs of less than 3 m^3/s have been recorded only once in 4 years, and, even then, merely for a few days of each year. Therefore, it is expected that the minimum allowable environmental discharge will be violated very rarely, if at all.

The outlet chamber, which serves in fact as the headworks for the pipeline to Mombasa, will have to be reconstructed at the site of the existing NWCPC compound and will include the headworks chamber, provision of flow regulation apparatus and a connection to the existing water supply.

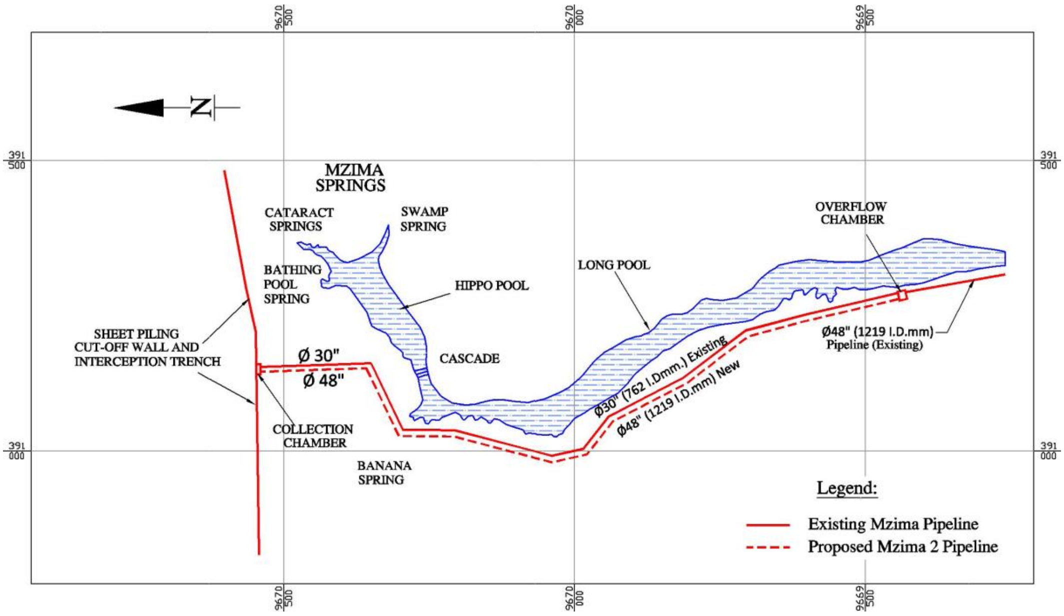


Fig. 9-16: Mzima Springs – augmentation of waterworks to 1.5 m^3/s abstraction (actual abstraction of 1.22 m^3/s in 2035)

A block diagram showing the proposed development of the Mzima 2 Scheme is presented in Fig. 9-17.

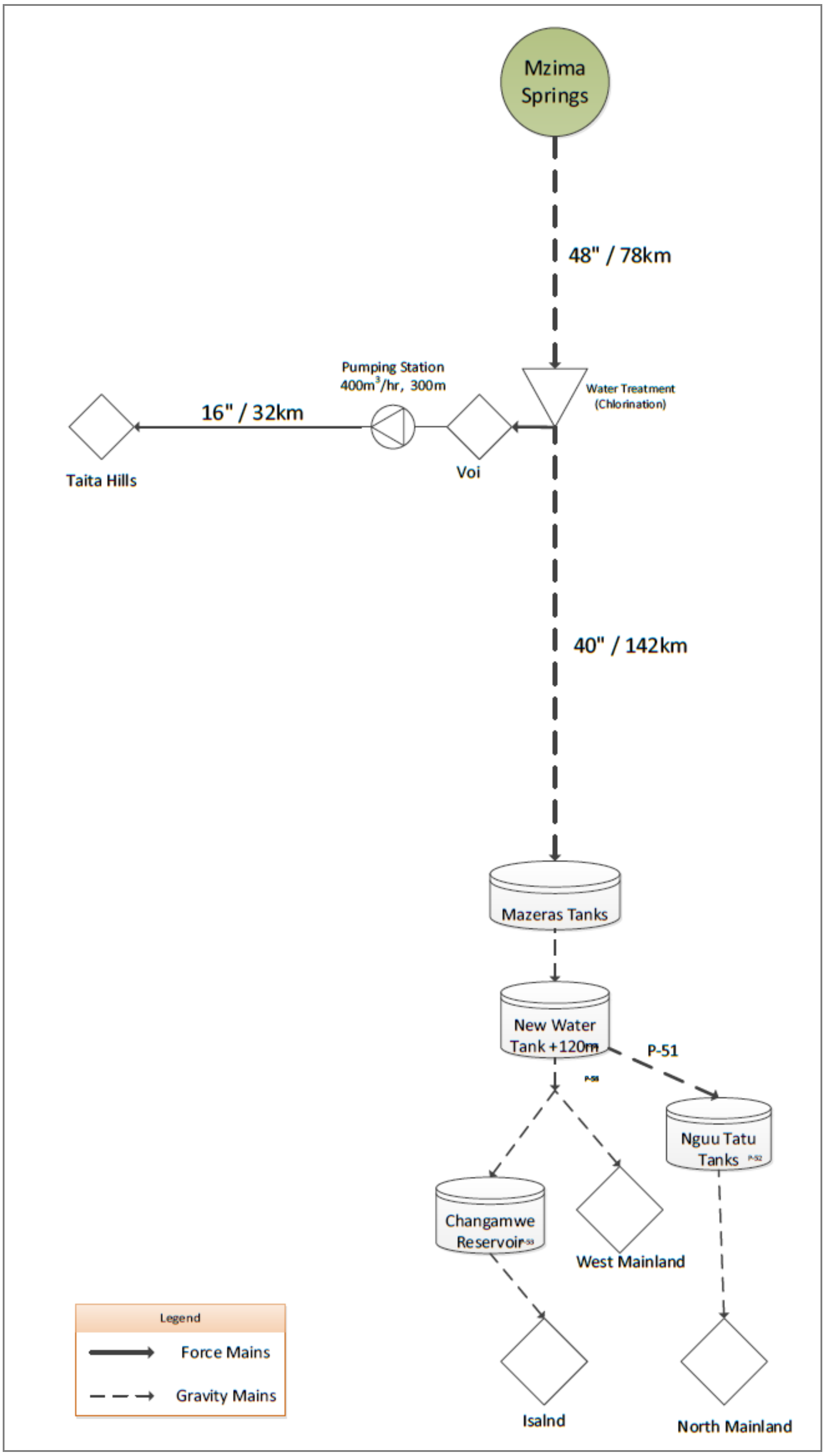


Fig. 9-17: Block diagram showing proposed development of the Mzima 2 Scheme

9.12.5 Summary of the Engineering Components for the Mzima 2 Scheme

Table 9-35 presents a preliminary BOQ with engineering components required for the Mzima 2 Scheme.

Table 9-35: Engineering Components of Mzima 2 Water Supply Scheme

1			Mzima Waterworks + Mzima 2 Pipeline	Unit	Qty
	1.1		**Civil engineering works**		
		1.100	Transmission pipe, steel, DN1200 (48"), including excavation	m	1,300
		1.101	Water tank, rectangular, 2,000 m^3 x 3 No.	m^3	6,000
		1.102	Inlet flowmeter and regulating valve chamber, 6 m x 3 m x 4 m (L x W x H)	No.	4
		1.103	Outlet valve chamber, 3 m x 2 m x 2.5 m (L x W x H)	No.	6
		1.104	Construction of guardhouse, 10 m x 5 m x 3 m (L x W x H)	m^2	50
		1.105	Fencing, chain link	m	305
			Mazeras Water Tanks		
		1.105	Inlet flowmeter and regulating valve chamber, 6 m x 3 m x 4 m (L x W x H)	No.	1
			Transmission pipe chambers		
		1.106	Line valve chamber, 2.5 m x 2 m x 2.5 m (L x W x H)	No.	50
		1.107	Air valve chamber, 2 m x 2 m x 2.5 m (L x W x H)	No.	200
		1.108	Washout chamber, 3 m x 2 m x 2.5 m (L x W x H)	No.	100
	1.2		**Transmission pipeline**		
		1.200	Pipe, steel, DN1200	m	78,200
		1.201	Pipe, steel, DN1000	m	142,028
		1.202	Manual butterfly valve, DN1200	No.	34
		1.203	Manual butterfly valve, DN1000	No.	80
		1.204	Air valve, DN200	No.	450
		1.205	Manual gate valve, DN300	No.	400
		1.206	Pipeline excavation	m	220,000
		1.207	Rehabilitate/supplement existing access road, non-asphalt	km	220
	1.3		**Accessories**		
		1.300	Manual butterfly valve, DN1200	No.	8
		1.301	Manual butterfly valve, DN1000	No.	12
		1.302	Electromagnetic flowmeter, DN1000	No.	5
		1.303	Electromagnetic flowmeter, DN1200	No.	2
		1.304	Pipe, steel, DN1200	m	100
		1.305	Pipe, steel, DN1000	m	200
		1.306	Drainage pipe, steel, DN500	m	500
			Mazeras Water Tanks		
		1.307	Manual butterfly valve, DN1000	No.	4
	1.4		**Water tank rehabilitation**		
		1.400	Water tank rehabilitation	No.	8

9.13 Phase III – Water Supply Scheme to Voi/Maungu, Mwatate and Wundanyi

9.13.1 Existing Situation and Feasible Future Option

Current water supply to the remote townships of Mwatate and Wundanyi utilize local water sources, mainly boreholes and other local rainwater harvesting facilities. Both townships are located in remote areas and with a significant elevation above sea level, challenging the water supply, both in terms of capital costs and operational costs.

Mwatate is located some 30 km southwest of Voi Junction, and has an elevation of +860 masl. Wundanyi is located some 18 km north of Mwatate, and has an elevation of +1450 masl.

Yet the two were included in the CWSB list of 20 townships to be part of the WSMP. The alternatives to the local water supply were first introduced in a Prefeasibility Report, and later summarized in a Full Feasibility Report. Several options for the Mwatate and Wundanyi supply were examined, taking into consideration both capital investment and operational costs. It was found that for these two townships within Taveta County, the preferred water supply scheme is to connect to Voi/Maungu, in which the current and the future Mzima 2 Pipeline will be laid. An alternative to supply Mwatate and Wundanyi from Njoro Kubwa Springs was examined just in case the Mzima 2 Pipeline will not be implemented, thus the limited amounts of water from the existing Mzima Pipeline will be sufficient for the required demand. In any case, Taveta itself will be supplied from the local Njoro Kubwa Springs.

9.13.2 Proposed Development of the Mwatate Scheme

The proposed water supply scheme for Mwatate and Wundanyi will consist of two pumping stations and two force mains. At the end of each supply line, a water tank will be located in order to contain storage volume both for supply and for booster suction.

The first stage of supply will comprise a Voi to Mwatate pumping station and a force main to deliver the water to Mwatate. Preliminary design of the supply line concluded that the line will be laid along the main road from Voi to Mwatate. The pumping station location will be on the west side of Voi, as close as possible to the Mzima 2 Pipeline. In order to utilize the pressure in the Mzima 2 Pipeline, it is suggested that the suction of the pumps will be directly from the pipe, without the use of a balancing tank.

The scheme will be developed in Phase III of the BWSS due to the need to have the Mzima 2 Pipeline as the source for supply. However, it is possible that the works on the Mwatate supply will began in parallel with the Mzima 2 Pipeline. Once the 1,200 mm section of the Mzima 2 Pipeline will be finished and will be able to supply water to Voi Junction, it will be possible to operate the first stage of pumping, until Mwatate.

Table 9-36 presents a summary of water demand for Mwatate and Wundanyi.

Table 9-36: Summary of Water Demand for Mwatate and Wundanyi

Summary of Water Demand	Units	Value
Total water demand, 2035 (Mwatate + Wundanyi)	m^3/d	9,442
	m^3/h	472
Total water demand, 2035 (Wundanyi)	m^3/d	4,777
	m^3/h	240

9.13.3 Pumping Stations

The required pumps for the delivery of water to Mwatate and on the second stage to Wundanyi is summarized in Table 9-37 and Table 9-38.

Table 9-37: Summary of the Voi to Mwatate Pumping Station

Delivery Pump	Qty	Q (m^3/h)	H (m	T (h)	Volume (m^3)	Eta (Pump Efficiency Coefficient)	Power (hp)	Energy (kWh)	Energy (kWh/y)
Duty	2	470	350	20	9,600	0.8	400	300	4.38 million
Standby	1	470	350	20		0.8	400	300	

Table 9-38: Summary of the Mwatate to Wundanyi Pumping Station

Delivery Pump	Qty	Q (m^3/h)	H (m	T (h)	Volume (m^3)	Eta (Pump Efficiency Coefficient)	Power (hp)	Energy (kWh)	Energy (kWh/y)
Duty	1	240	650	20	4,800	0.8	720	550	4.0 million
Standby	1	240	650	20		0.8	720	550	

9.13.4 Transmission Mains for the Mwatate Scheme

Table 9-39 presents the physical parameters of the transmission mains for the Mwatate Scheme.

Table 9-39: Transmission Mains for the Mwatate Scheme

Physical parameters of the supply line	Units	Value
Elevations (average)		
Mwatate	masl	860
Wundanyi	masl	1,450
Voi/Maungu	masl	600
Distances		
Voi-Mwatate	km	30
Mwatate-Wundanyi	km	18
Elevation difference		
Taveta-Mwatate	m	110
Voi-Mwatate	m	260
Mwatate-Wundanyi	m	590
Total dynamic head (TDH)		
Voi-Mwatate	m	350
Mwatate-Wundanyi	m	645
Diameter		
Voi-Mwatate	mm	500
Mwatate-Wundanyi	m	350

9.13.5 Summary of the Engineering Components for the Mwatate Scheme

Table 9-40 presents a preliminary BOQ with engineering components required for the Mwatate Scheme.

Table 9-40: BOQ – Engineering Components Required for the Mwatate Scheme

2			Voi-Mwatate-Wundanyi Branch	Unit	Qty
	2.1		**Civil engineering works**		
		2.100	Construction of new pumping station, 10 m x 10 m x 5 m (L x W x H)	m^2	100
		2.101	Construction of new electrical building, 8 m x 5 m x 5 m (L x W x H)	m^2	40
		2.102	Construction of new administration building, 8 m x 6 m x 3 m (L x W x H)	m^2	48
		2.103	Valve chambers, 3 m x 2 m x 2.5 m (L x W x H)	No.	84
		2.104	Fire protection system for new pumping station	LS	1
		2.105	Lighting system for all buildings	LS	1

	2.2		**Electromechanical works**		
		2.200	Supply and installation of delivery pumps, 470 m^3/h, 350 m head	No.	5
		2.201	Main low-voltage (LV) panel board, complete with a 150 kVAr power factor corrections capacitor, 7-step LOVATO controller and automatic changeover switch, as a complete package	No.	1
		2.202	Transformer, 415 kVA, 11 kV/433 V, and metering equipment for pumping station	LS	1
	2.3		**Pipe and manifolds**		
		2.300	Suction pipe from sump to pumps, steel, DN250	m	100
		2.301	Delivery pipe from pump to main pipeline, steel, DN300	m	100
		2.302	Pipe to Mwatate, steel, DN400, PN 20, including excavation	m	30,000
		2.303	Pipe to Wundanyi, steel, DN250, PN 24, including excavation	m	12,000
	2.4		**Accessories**		
		2.400	Main gate valve for Mwatate Pipeline, DN400	No.	4
		2.401	Main gate valve for Wundanyi Pipeline, DN250	No.	4
		2.402	Air valve, static + dynamic, 4", DN100	No.	60
		2.403	Surge rapid pressure release valve, 6", DN150	No.	6
		2.404	Pressure sustain valve, 12", DN300	No.	4
		2.405	Flowmeter for Mwatate Pipeline, DN400	No.	1
		2.406	Flowmeter for Wundanyi Pipeline, DN250	No.	1
		2.407	Gate valve for Mwatate flowmeters, DN400	No.	2
		2.408	Gate valve for Wundanyi flowmeters, DN250	No.	2
	2.5		**Auxiliary systems**		
		2.500	Surge protection system and all accessories needed – surge protection tank, pressure valves, system control, interface with existing system, etc.	LS	1

9.14 Phase III – Southern Scheme – Msambweni and Lunga Lunga/Vanga

9.14.1 Proposed Development of the Msambweni Water Supply Scheme

The remote areas south of the regional administrative centre of Msambweni do not connect today to the BWSS. The current water supply scheme of the Lunga Lunga/Vanga township is based on local sources, mainly a shallow borehole, with water abstracted from a depth of 5–6 m. The borehole is very sensitive to saline penetration and, in some cases, the saline taste of the water has been reported by the local inhabitants.

The projection for water demand in this area is significant compared to the low water demand today. Balance for the region's water supply shows that the resources cannot sustain the demand for water. Therefore, the area should be connected to a regional water supply system.

The area north of Lunga Lunga/Vanga (some 35–40 km away) is where the Msambweni Aquifer is located. This aquifer is proposed to produce some 20,000 m^3/d in the horizon year. This water will be abstracted partly from the local aquifer (although further study on the local water potential and the replenishment of the aquifer is still needed) and partly from the Mkurumudzi Dam (that are serving today the titanium mine). The dam will be transferred back to the CWSB just after 2030, making it possible to add this water resource to the regional water supply scheme.

All in all, in order to achieve an efficient water supply system, it is proposed under the framework of the WSMP to enable the region south of Msambweni to be supplied from the Msambweni Water Tank. The tank will receive water from two main sources:

- Connecting Tiwi-Ukunda-Msambweni water supply via a 20" pipeline along the coast, dedicated to delivering water from the Mwache Dam through the Kaya Bombo Water Tank to the south
- Local abstraction from the Msambweni Aquifer, where the water will be pumped to the Msambweni Water Tank

The supply scheme to the south will includes:

- Booster pump locates near the Msambweni water tank
- Lunga Lunga/Vanga connecting pipe, 12"/300mm in diameter
- Several water kiosks along the pipeline route to enable local communities to abstract water

All of the above scheme for Lunga Lunga/Vanga is proposed in the WSMP to be executed during Phase III, due to the relative time it will take to develop the area. Although the water supply upgrade to the Tiwi-Ukunda area is proposed in Phase I (extension of the Mwache Dam water supply scheme), because of financial considerations, the Consultant found the southern supply scheme to be viable only in the last phase of development.

9.14.2 Pumping Station

Table 9-41 summarizes the attributes of the supply pumped to Lunga Lunga/Vanga.

Table 9-41: Future Water Delivery to Lunga Lunga/Vanga

	Units	South Supply, 2035
Total daily delivery	m^3/d	11,709
Total hourly operation	h/d	20 *
Total hourly capacity	m^3/h	600
Pump configuration	No. x m^3/h	(3+1) x 200
TDH	m	110
Daily Energy use	kW/h	1530
Annual Energy use	kW/h	558,450
Water supply to:		South Scheme
Cumulative volume	m^3/d	11,709

* The pump operation time per day in the proposed plan assumes a maximum operation time of 20 h/d.

9.14.3 Transmission Mains

The force main connecting pipe from the Msambweni Water Tank to the townships will be 12" with a length of 46 km. The hydraulic gradient in the supply line will be some 0.2%, which will require a pressure of 92 m in order to discharge the water from the Msambweni Water Tank to the consumers.

9.14.4 Summary of the Engineering Components for the Msambweni Scheme

3			Msambweni Waterworks + connection to bulk water supply system	Unit	Qty
	3.1		**Civil engineering works**		
		3.100	Drilling new boreholes at the Msambweni site, 250 mm diameter	No.	15
		3.101	Concrete works for the borehole cover and pump installation	LS	15
		3.102	Civil construction works for tertiary road	km	20
		3.103	Construction of new electricity panel sheds 5 m x 2 m (L x W) x 16 No.	No.	16
		3.104	Valve chambers, 3 m x 2 m x 2.5 m (L x W x H)	No.	116
	3.2		**Electromechanical works**		
		3.200	Supply and install borehole pumps, 55.5 m^3/h, 150 m head	No.	15
		3.201	Supply and install electrical systems for borehole pumps	LS	15
		3.202	Provision of power to the borehole sites (transformer and high-tension transmission cable)	LS	1
	3.3		**Transmission pipeline (including excavation)**		
		3.300	Pipe (Msambweni-Lunga Lunga), steel, DN300	m	46,000
		3.300	Pipe (Tiwi-Msambweni), steel, DN500	m	35,000
	3.4		**Pipe and manifolds (including excavation)**		
		3.400	Pipe to borehole pump manifolds, steel, DN100	m	1,500
		3.401	Main manifold pipe from borehole pumps to main conveyer, steel, DN100	m	150
		3.402	Pipe from manifolds to water treatment tank, steel, DN500	m	1,000
		3.403	Main gate valve for borehole manifolds, DN100	No.	12
		3.404	Main non-return valve for borehole manifolds, DN100	No.	12
		3.405	Treatment water tank outlet valve, DN500	No.	1
		3.406	Pipe from treatment tank to Msambweni Reservoir, steel, DN500	m	6,500
	3.5		**Msambweni Pumping Station to Lunga Lunga**		
		3.500	Supply of delivery pumps, 170 m^3/h, 160 m head	No.	5
		3.501	Installation of the above delivery pumps	No.	5
		3.502	Electrical installation for pumps	LS	1
		3.503	Accessories for the new pumps	LS	5
		3.504	Installation of accessories for the new pumps	LS	5
		3.505	Provide electricity to the site	LS	1
	3.6		**Accessories**		
		3.600	Air valve, static + dynamic, 4", DN100	No.	56
		3.601	Air valve, static + dynamic, 3", DN80	No.	15
		3.602	Flowmeter for each borehole, DN100	No.	15
		3.603	Gate valve for flowmeters, DN100	No.	30

	3.7		**Auxiliary systems**		
		3.700	Surge protection system and all accessories needed – surge protection tank, pressure valves, system control, interface with existing system, etc.	LS	1
	3.8		**Treatment systems**		
		3.800	Construction of receiving tank for chlorination	m^3	500
	3.9		**Auxiliary systems (Msambweni Pumping Station for Lunga Lunga)**		
		3.900	Surge protection system and all accessories needed – surge protection tank, pressure valves, system control, interface with existing system, etc.	LS	1

9.15 Development Action Plan

Fig. 9-18 summarizes the WSMP by year of development and by source of water.

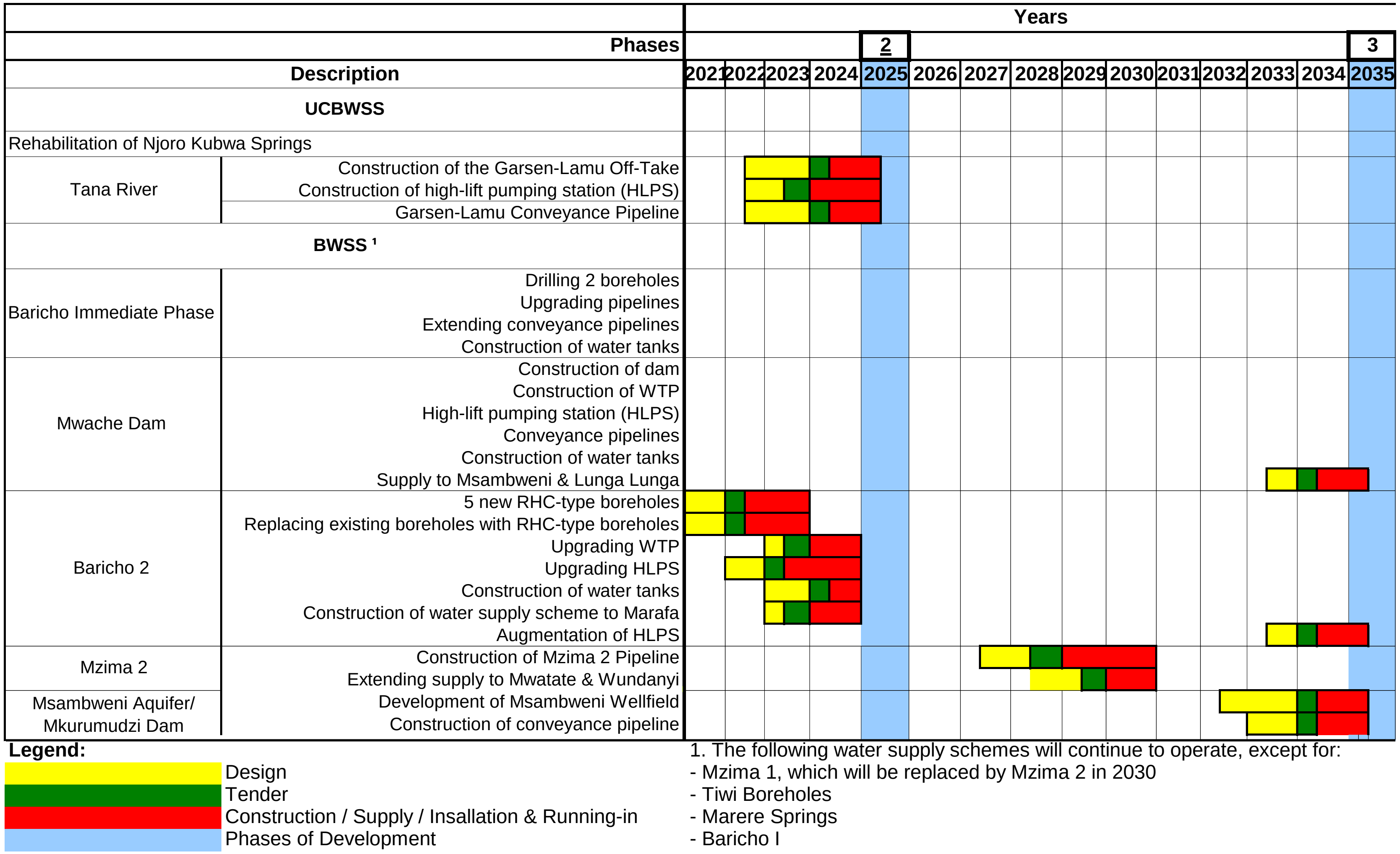


Fig. 9-18: Development Action Plan

9.16 Additional Requirements for the Development Programs and Detailed Design

The preliminary design stage of the study does not replace the need for preparation of a complete detailed design and a fully detailed BOQ. The Consultant recommends undertaking the following activities prior to implementation:

- Topographic mapping of waterworks sites in 1:5,000 scale – all new pumping station and hydraulic structure will be designed at a 1:5,000 scale
- Structures and specific design details prepared at 1:500 scale (or less)
- Topographic mapping for the design of pipelines, including layout and longitudinal sections scaled at 1:1,000
- Specific supplementary surveys to expand production sites. The surveys will cover different aspects of the site expansion. For example:
  - Availability of electrical power connections and requirements for new transformers for proposed bulk water supply system
  - Geological surveys for the proposed structure foundations
  - Access road designs, considering the need to transfer new large pumps to the site
  - Fire protection consultancy for the proposed buildings
  - Security consultancy for the entire site
- Updating of existing bulk water supply system infrastructure survey
- Geotechnical surveys and formulation of guidelines for earthquakes, stabilization and foundations
- Availability of large-diameter pipes and additional devices
- Determination of water measuring standards and recommendations for proposed equipment to be installed
- Guidelines for providing security for bulk water supply system infrastructure
- General guidelines for design and installation of supervisory control and data acquisition (SCADA) systems
- Mapping rural consumers for establishment and connection of water kiosks – number, intensity along the line, size, daily water demand, etc.
- Detailed study of the possibilities of power generation in gravitational lines, including identification of applicable technology and appropriate locations
- Detailed surveys of the rehabilitation works required for connecting the Msambweni Wellfield and the Mkurumudzi Dam to the bulk water supply system
- Detailed surveys of the main water supply line within the distribution system in order to assess and evaluate the required investments for the system's rehabilitation as well as modification for the new volumes expected from the bulk water supply system
- Preparation of a comprehensive study of the current wastewater collection network, followed by the preparation of a wastewater collection network master plan
- Water allocation agreements with WRMA

10. Climate Change

10.1 Overview

The earth's climate is dynamic and is ever-changing as part of a natural cycle. The changes occurring today, however, have been escalated by human activities. These include a reduction in mountain glaciers; landslides; loss of vegetation cover; flooding; sea level changes; variations in temperature; fluctuations in seasonal rainfall; frequent and prolonged droughts; resurgence of pests and diseases; and loss of biodiversity.

The existing climate variability has involved significant economic costs for Kenya, in general, and the coastal regions, in particular. Extreme weather patterns – such as droughts, floods and irregular precipitation – cost the Kenyan economy billions of dollars per year. They also lower GDP per capita growth as a direct result of loss of crops and livestock production, reduced water supply and irrigation, diminished hydropower generation and lessened industrial production. Although research on future impacts generally produces inconsistent conclusions, intensification of extreme events appears to be a probable development. Compounding this is the fact that the coastal region of Kenya already has a complex climate, with wide seasonal variations and disparities.

10.2 Climate Change Impacts in Kenya

10.2.1 General

In addition to the dependency on the weather of water supply for the population needs, it should also be remembered that rainfed agriculture is one of the main sectors of the Kenyan economy. Furthermore, livestock production is central to livelihoods and food security in the coastal areas, the inland areas of the Coast Province and the arid and semi-arid lands (ASALs). Therefore, weather-related hazards present a serious threat to the socioeconomic development of the region and the country.

10.2.2 Previous Studies and Documentations

Until recently, the future impact of climate changes on development in the coastal areas of Kenya and the country's water sector has not been researched in earnest.

In the past few years, however, interest in the subject has been expressed by GoK agencies, as well as international organizations and NGOs. Several studies have been conducted and papers published, among the more noteworthy being:

- State of Environment Report 2006/7, Kenya, Chapter 2: Causes and Manifestation of Climate Change

- National Climate Change Response Strategy of April 2010
- Kenya's Climate Change Technology Needs and Needs Assessment Report Under the United Nations
- Climate Change Vulnerability and Adaptation Preparedness in Kenya, Heinrich Böll Stift ung 2010
- Human Development Report 2007-2008 Climate Change and Human Development UNDP
- Climate: Observations, Projections, Impacts Met Office Hadley Center
- FEWS Net (Famine Early Warning Systems Network publications, USGS & USAID

10.2.3 Temperature Variations

While long-term temperature records in Kenya and the coastal areas show diverse tendencies, they also indicate a regular and unmistakable trend. Since the 1960s, temperature variations have become more pronounced and irregular:

- At the national level, between 1960 and 2007, mean annual temperatures have increased in Kenya by 1 °C per decade. Initial analysis indicates similar trends in the coastal Mombasa-Lamu strip.
- Daily temperature observations show significantly increasing trends in the frequency of hot days and a much larger increase in the frequency of hot nights. Initial analysis indicates similar trends in the coastal Mombasa-Lamu strip.
- Between 1960 and 2007, the average number of hot days has increased by 57, and the average number of hot nights has increased by 113.
- The average number of cold days has decreased by 16, and the number of cold nights has decreased by 42 over the same duration.

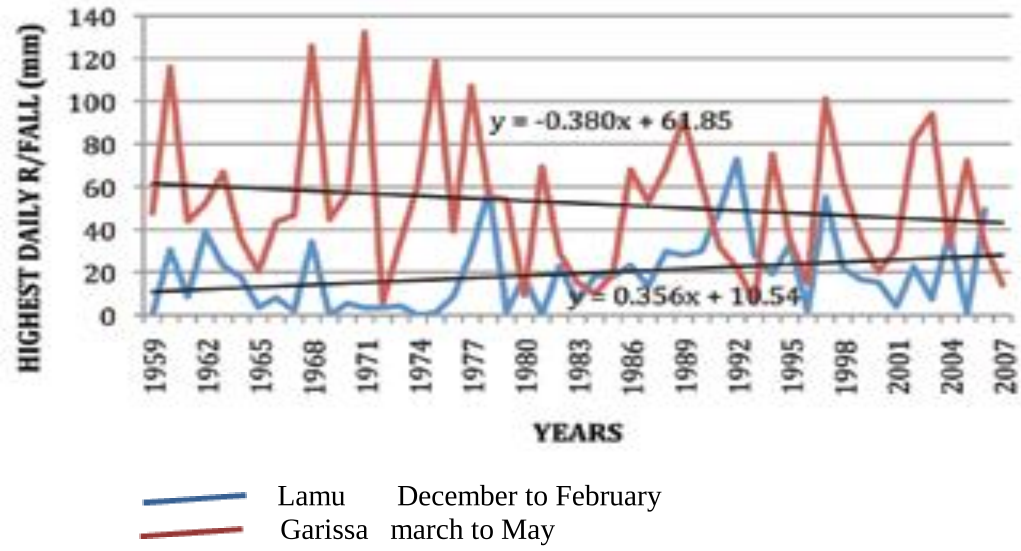
Future predictions are very difficult to make and are inherently imprecise. Moreover, human activities far removed from the country and area will have direct influence on the rate of climate change. Nevertheless, there are projections that indicate that the mean annual temperature may increase by 2.8 °C by 2060, and the frequency of cold days and nights will continue to decrease.

10.2.4 Variations in Seasonal Rainfall

Kenya experiences two rainfall seasons – a long season during the March–May period and a short season during the October–December period. This latter period is characterized by the movement of the inter-tropical convergence zone (ITCZ) from south to north through the equator, and vice versa.

The changing climatic patterns are probably the main cause of the increased variability in precipitation from year to year, and during the year:

- There is a general decline of rainfall during the main March–May rainfall season (the "Long Rains"). Drought is generally more frequent and prolonged. On the other hand, there is a general positive trend (more rains) during the September–February period.
- This suggests that the October–December rainfall season (the "Short Rains") is extending into what is normally the hot and dry period of January and February.
- Measured by the volume of rainfalls in a 24-hour period, more intense rainfalls occur, and more frequently, over the coastal region during the September–February period.
- The periodicity of seasonal rainfall exhibits a generally decreasing trend, in particular for arid and semi-arid areas. However, some areas, such as Lamu (see, for example, Fig. 10-1) indicate an increasing trend of rainfall during the short rainy season.
- Mean rainfall is projected to increase by up to 48% by the 2090s, and, within this, the proportion of rainfall that falls within heavy events is projected to increase by 13% over the same duration.



Source: National Climate Change Response Strategy GoK

Fig. 10-1: Annual precipitation and trends in Lamu and Garissa, 1959–2007

10.2.5 Droughts

Prolonged droughts have become common in recent years, affecting large numbers of people and animals. Climate change has led to an increase in the number of arid and semi-arid districts in Kenya to a total of 36, covering over 80% of the total territorial surface area of the country. The effect of the 2003–2006 droughts in the ASALs led to a loss of livestock and wildlife. In Laikipia

District, the number of cattle declined from 177,780 to 130,020 at the peak of the 1999–2001 droughts, while elephants declined from 1,431 to 828 during the same period (UNEP/GoK, 2006). At the same time, child malnutrition rose to 50% and 11 million people received relief food. Major rivers in the area (including the Tana and Athi) have experienced severe reduced volumes during droughts.

The alarming situation is that drought has been experienced in areas not normally affected. The droughts in Central, Eastern, Rift Valley, Coast and North-Eastern Provinces between 1971 and 2000 had impacted from 20,000 to 200,000 people by 1983, and increased the number of affected people to 4.4 million by 1999.

Drought can be monitored using remote sensing technology. The historical images of the National Oceanic Atmospheric Administration (NOAA) were used to monitor cyclic occurrence of drought in Narok District applying the normalized difference vegetation index (NDVI) parameter as a measure of greenness of vegetation as recorded by satellite. Such analysis over several years reflects troughs below normal, which was the zero axis of the NDVI anomalies. The results show that the critical years experiencing persistent drought in the district were 1984-1985, 1994-1995 and 2000-2001.

10.2.6 Floods

Flooding is another manifestation of climate change that is a frequent occurrence in the country. According to the World Food Programme (WFP) estimate in 2006, approximately 700,000 people were affected by flooding across the country as a result of unexpected and prolonged rains in some areas, namely, North-Eastern, Western, Nyanza, and Coast Province. The floods caused damage to properties worth millions of shillings and loss of life in extreme situations, being among the worst since 1998. Floods are also affected by the El Niño phenomenon.

10.3 Statistical Analysis of Climate Change in the Coastal Region

10.3.1 Methodology

Long-term periods of data were available at three rainfall stations in the coastal region – Msabaha, Malindi and Mtwapa (see Annex 4 in Volume III of the WSMP).

The following statistical analyses were performed separately for each time series:

- Test for absence of trend: Spearman's Rank – Correlation Method
- Test for stability of the variance: F-Test
- Test for stability of the mean: T-Test
- Test for absence of persistence: Serial-Correlation Coefficient

10.3.2 Results

The results of the above analyses are presented in Tables 10-1–10-3 and Annex 4, and demonstrate that climate change in the Mombasa region cannot be discerned, at least for the analyzed periods.

Table 10-1: Results of F-Test and T-Test for Data of Msabaha Station

No.	Test Performed	Objective	Test Result	Test Statistic		Finding
				LCL*	UCL*	
1	Spearman's Rank Correlation Test	Absence of trend	t_t = -0.200	-2.008	2.008	No trend
2	F-Test	Stationarity of variance	F_t = 1.477	0.453	2.219	Variance stable
3	T-Test	Stability of mean	t_t = 0.384	-2.008	2.008	Mean stable
4	Lag 1 Serial Correlation Coefficient	Absence of persistence	R1 = -0.074	-0.288	0.250	No persistence

* LCL = Lower Confidence Limit, UCL = Upper Confidence Limit.

Table 10-2: Results of F-Test and T-Test for Data of Malindi Station

No.	Test Performed	Objective	Test Result	Test Statistic		Finding
				LCL	UCL	
1	Spearman's Rank Correlation Test	Absence of trend	t_t = -0.684	-2.012	2.012	No trend
2	F-Test	Stationarity of variance	F_t = 1.629	0.438	2.299	Variance stable
3	T-Test	Stability of mean	t_t = 0.955	-2.012	2.012	Mean stable
4	Lag 1 Serial Correlation Coefficient	Absence of persistence	R1 = 0.007	-0.301	0.259	No persistence

Note: LCL - Lower Confidence Limit; UCL - Upper Confidence Limit.

Table 10-3: Results of F-Test and T-Test for Data of Mtwapa Station

No.	Test Performed	Objective	Test Result	Test Statistic		Finding
				LCL	UCL	
1	Spearman's Rank Correlation Test	Absence of trend	$t_t = 0.536$	-2.010	2.010	No trend
2	F-Test	Stationarity of variance	$F_t = 0.842$	0.446	2.257	Variance stable
3	T-Test	Stability of mean	$t_t = -0.840$	-2.010	2.010	Mean stable
4	Lag 1 Serial Correlation Coefficient	Absence of persistence	R1 = 0.102	-0.294	0.254	No persistence

Note: LCL - Lower Confidence limit; UCL - Upper Confidence Limit.

10.4 Conclusions

Analysis of available research on future impacts of climate change is generally inconsistent. That said, emerging trends for the long-term climatic projections point to the following:

- Regular and gradual temperature increases are expect in Kenya and in the coastal regions
- Variations and less predictability in the amount and duration of rainfall. The long rainy season seems to exhibit less rains, whereas the short rainy season appears to increase in volume and duration.
- An increase is expected in the frequency and intensity of extreme events, primarily draughts and floods.

In the shorter term, over the planning horizon of the WSMP (2035), hydrological and water resources impacts will probably be marginal and minimal. The climate change analysis does not point to any distinct trend occurring in the Coast Province during this period. Thus, no modifications are recommended to be introduced in the water balance calculation, which are the consequence of possible changes in climate.

11. Financial and Economic Analysis

11.1 Introduction

The main objective of the financial and economic analysis is to provide the CWSB and other policymakers and stakeholders with all necessary information needed for informed decision-making regarding the potential water development scenarios in the region, as well as other promising programs and projects. Initially, the economic analysis for each of the seven water supply scenarios four scenarios for the bulk water supply system and three for the Lamu area) were generated, analyzed and presented in the pre-feasibility and full feasibility MP reports. In this chapter, the analysis applies to the final selected scenario. The engineering attributes were described in the Preliminary Design Report and summarized again in Chapter 8 above.

The final outcome of this chapter is to present the financial and economic indicators of each of the projects and programs set out in the WSMP.

11.2 Methodology

The financial and economic analysis is based on a comparison between the net benefit flows from water delivery and income to the cost of developing and operating the systems that will supply the water. A detailed evaluation and assessment has been applied for the following indicators:

- Discounted investments
- O&M costs
- Energy costs

The analysis also considered basic indicators per supplied m^3 of water, including:

- Total investment per m^3
- Energy and O&M costs per m^3
- Total water cost per m^3 delivered to the utility firm

After setting and verifying the basic indicators (above), more stringent discounted cash flow techniques were applied to further refine the analysis. These include:

- Net present value (NPV)
- Internal rate of return (IRR)
- Economic net present value (ENPV)
- Economic internal rate of return (EIRR)
- Sensitivity and risk analysis

The distinction made between the financial and economic analysis in the master plan computations are based on the traditional differences between the two economic indicators as well as the project-specific variables identified by the Consultant during preparations of the cost estimates, cash flows and economic evaluations.

The financial analysis evaluates the revenues and expenses (investment, maintenance and operation costs, energy) of the concerned agent (in this case, the CWSB) and then computing the corresponding financial returns and indicators. The economic analysis aims at identifying and comparing economic and social benefits accruing to the national, regional and community economies as a whole.

Several key factors are instrumental in explaining the distinctive and significant differences between financial and economic analysis results in the master plan computations. First and foremost are the subsidized terms and conditions of the long term loans for investments. These are the donor funds supporting the CWSB and the other investment agencies – WRMA, CDA, etc.

The subsidized terms of these attractive loans consist of a 10 year grace period, 1% interest per annum and an additional 30 years maturity with 3% per annum. In the financial cash flow analysis, only the annual share of invested funds and the corresponding (very low) interest payments is included as expenses in the cash flow calculations. The major share of the capital investments is deferred to latter years. Concurrently, the cash flow is discounted at 10 percent per annum. These factors produce an attractive investment environment with high IRRs and NPVs. Due to the discounting effects, postponed expenses (especially 20 years into the future), entail low present outlays. These considerations also explain the relatively substantial influence of the O&M components (operations, maintenance, energy) on the ranking of the different scenarios. The low capital expenditures in the present (due to the soft loans and high annual discounts) are dwarfed by the annual O&M costs. In contrast, in the economic analysis computations, the total capital investments are recorded in the same year as implemented. Hence annual expenses are much higher and their relative significance in the total annual expenditure ratio is increased.

11.3 Analysis Indicators – NPV and IRR

In economic and financial analysis there are a number of different approaches that can be used to evaluate any given project. The internal rate of return (IRR) and the net present value (NPV) are among the most widely accepted, accurate and relevant. The net present value approach is considered the most accurate valuation approach to capital budgeting issues. Discounting the cash flows by the weighted average cost of capital allows economists and decision makers to determine whether a project will be profitable or not and, more importantly, it will reveal exactly how profitable a project will be in comparison to alternatives. Generally, all projects which have a positive net present value should be accepted while those that are negative should be rejected. When funds are limited the projects/alternatives with the highest NPV should be selected. The main advantage of the NPV method is that it provides a direct measure/amount of the contribution or income of the project to the investor/initiator. The discount rate selected in the financial analysis of the projects in the master plan is 12% (as stipulated by the World Bank for WB-funded ventures). This means that any alternative with a positive NPV generates a profit above and beyond the 12% discount rate. The internal rate of return (IRR) is the rate of growth a project is expected to generate. It is the interest rate (or discount rate) that makes the net present value of all cash flows of the project equal to zero. Generally, the higher a project's IRR the more desirable it is to the investors or decision makers. Assuming all other factors are equal among various projects, the IRR can be used to rank prospective projects and to select the most feasible. The main advantage of the IRR method is that it clearly displays the return (in percentage) on the original investment. This can be then compared to alternate investment opportunities.

Although, as a rule, projects with higher NPVs and IRRs should be selected for implementation and ones with negative indicators rejected, at times more detailed analysis is required. For example, both NPV and IRR of the immediate emergency investment are negative; this project is not a stand-alone project and cannot be evaluated as such. Rather, it is an initial (and emergency) investment in the overall Baricho project, which exhibits robust and positive cash flows and rates of return at plan horizon.

11.4 General Assumptions for the Evaluation

General assumptions for the evaluation are as follows:

- Costs are expressed at **September 2012 costs**, and are constant.
- **Project lifespan** is set at **50 years**.
- **Investments relate only to the additional infrastructure needed to be developed, regardless of any existing facilities.**
- An **annual discount factor of 10%** has been tentatively set for the analysis.
- Investments relate to development from the water source and up to the final connection point at the water utility company.
- Average **capital** costs and average **O&M** and **energy** costs are calculated for each scenario's additional costs only (without existing facilities), and are determined as a constant rate set at **1% per annum** of the total accumulated investments.

- **O&M** expenditures reflect an annual investment of **0.5%** of accumulated investments for rehabilitation purposes.

- In the event of an **incompatibility between** the total water **capacity** and the total water **demand** (in certain years), the lower between the two is set as a constraint in the calculations.

- **Government policies** regarding water prices will remain unchanged. Policy shifts may cause corresponding changes in the analysis results.

- **Different water prices** have been set for the **Mombasa** area and the **Lamu** area, reflecting the differing costs of water production and supply between the two areas.

- **Investments for each phase** are divided equally by the anticipated number of years of the component implementation (relevant for economic analysis).

- **Total investments do not include** and do not cover the investments that will be required for **water distribution** for the various areas of the WSPs.

- A **standard conversion factor (SCF) of 0.9** was determined in order to reflect additional (or decreased) benefits (or costs) to the economy (relevant for economic analysis).

- **Funding costs** are computed according to the terms of loans of the water utilities – 10-year grace period with annual interest rate of 1%, and additional 30 years of loans' refund with an annual interest rate of 3% (relevant for financial analysis).

11.5 Investments and Capital Outlays

Table 11-1 below presents the main cost outlays (by implementation phases) for the development of each of the projects and subprojects included in the master plan proposals.

Total investment for all projects, for all phases and up to horizon year 2035, amounts to approximately **US$ 894 million. (excluding Mwache Dam)**. The dam is estimated at an additional US$ 168 million. The total required capital cost for the fully implementation of the WSMP for the CWSB is US$ 1,062 million.

For additional details, see Annex 5 in Volume III of the WSMP.

The scope of work and total water supplied are dependent on the total amount available by the donor sources – approximately US$ 36 million.

Table 11-1: Cost Estimate for Implementation of all Proposed Master Plan Projects

Phase	BOQ Sec.	Project Description	Total Cost (US$)
Immediate Phase	1	Baricho Waterworks extension	2,160,274
	2	Baricho-Nguu Tatu Pipeline (segment rehabilitation)	9,591,949
	3	Kakuyuni-Kilifi and Malindi-Gongoni pipelines	22,382,174
	4	Deep Neogenic aquifer investigation in the Lamu region	2,500,000
Total for Immediate Phase – emergency works to improve supply to Mombasa			**36,634,396**
Phase I	1	Mwache Waterworks	50,538,222
	2	Mwache Transmission Pipelines	87,742,124
	3	Taveta Springs* rehabilitation + Taveta local water supply scheme	5,129,419
Total for Phase I (excluding Mwache Dam + WTP)			**143,409,768**
Phase II Baricho 2 expansion + supply schemes	1	Baricho Waterworks – Baricho 2 expansion + supply schemes	14,087,923
	2	Baricho-Nguu Tatu Pipeline	67,239,631
	3	Baricho-Kakuyuni Pipeline	28,470,078
	4	Kakuyuni-Marafa Pipeline	7,024,704
	Total for Baricho 2 expansion + supply schemes		**116,822,334**
Phase II Lamu and Tana River Counties	1	Garsen-Lamu water supply scheme	181,027,526
	2	Hola local water supply scheme	1,285,070
	3	Bura local water supply scheme	1,290,940
	Total for water supply to Lamu and Tana River counties		**182,223,445**
Total for Phase II			**299,045,700**
Phase III	1	Mzima Waterworks + Mzima 2 Pipeline	374,931,688
	2	Voi-Wundanyi-Mwatate branch	13,544,938
	3	Msambweni Waterworks + connection to bulk water supply system	24,790,177
Total for Phase III			**413,266,803**
Grand total for bulk water supply development plan (excluding Mwache Dam + WTP)			**893,750,333**
Investment estimation for Mwache Dam + WTP			**168,291,000**
Grand total for bulk water supply development plan (including Mwache Dam + WTP)			**1,062,041,333**

* known locally as the **Njoro Kubwa Springs**

11.6 Financial Analysis – Mombasa Bulk Water System

Financial analysis was conducted from the perspective of the water utilities firm, namely the CWSB.

Table 11-2 presents the main financial indicators of the WSMP development program (see Annex 6 in Volume III of the WSMP for detailed analysis).

Table 11-2: Financial Indicators

Average Capital Cost (US$/m³)	Average Energy Cost (US$/m³)	Average O&M Cost (US$/m³)	NPV (US$ millions)	IRR (%)	Water Cost (US$/m³)
0.146	0.09	0.06	17.73	32.72%	0.2938

The financial internal rate of return (**IRR**) is computed at over **32.7%**. This is high and indicates that precise and efficient implementation of the projects will generate impressive returns.

The computed net present value (**NPV**) is **US$ 17.73 million**.

The resulting **cost of one m^3 of supplied water** will amount to approximately **0.3 US$/$m^3$** (price to the utilities firms). See Fig. 11-1 below.

This amount is composed of 0.146 US$/$m^3$ attributed to the average capital outlays, 0.09 US$/$m^3$ attributed to the energy expenses and 0.06 US$/$m^3$ due to O&M expenses.

This factor is an aggregation of all expenses attributed to the development of the water resources, conveyance, treatment and desalination per m^3 supplied.

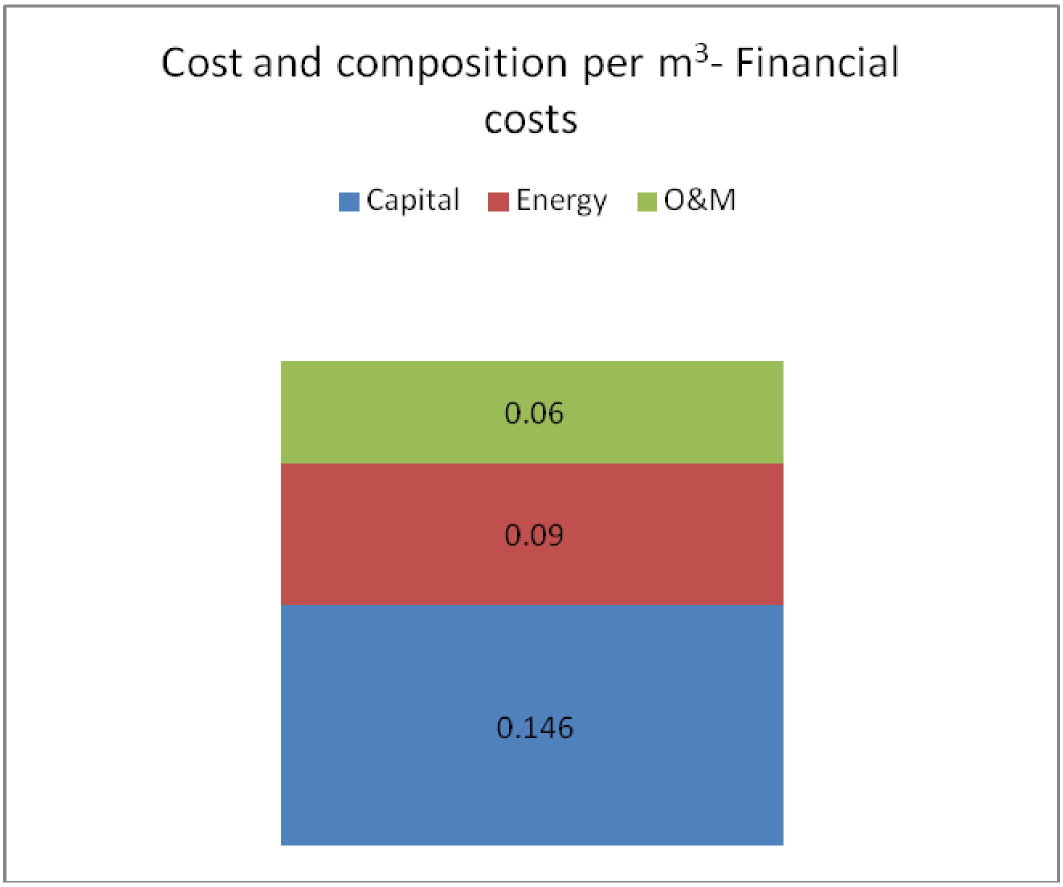


Fig. 11-1: Composition of financial cost of one m³ of water

11.7 Economic Analysis – Mombasa Bulk Water System

Economic analysis examines the feasibility and viability of bulk water supply design from the perspective of the entire regional and national economy.

Table 11-3 presents the main economic indicators.

Table 11-3: Economic Indicators

Average Capital Cost (US$/m³)	Average Energy Cost (US$/m³)	Average O&M Cost (US$/m³)	ENPV (US$ millions)	EIRR (%)	Economic Water Cost (US$/m³)
0.45	0.08	0.06	-139.55	1.54%	0.58

The economic rate of return (**EIRR**) was calculated at **1.54%**

The computed Net Present Value (**NPV**) was calculated at **- US$ 139.55 million**.

The resulting **cost (to the national economy) of one m^3 of supplied water** amounts to approximately **0.58 US$/m^3**, as shown in Fig. 11-2.

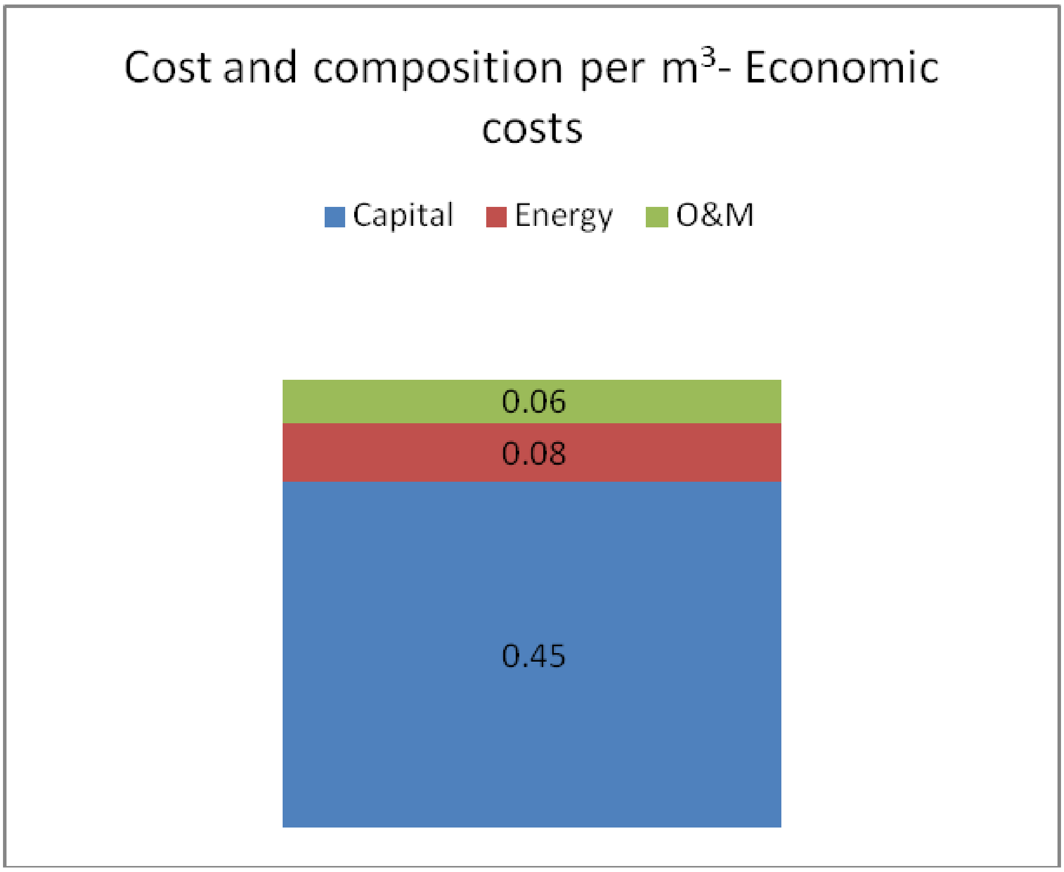


Fig. 11-2: Composition of the economic cost of one m^3 of water

11.8 Lamu Water Supply – Financial and Economic Analysis

The financial and economic analysis and main indicators of the water supply system for the Lamu region (Garsen Barrage) is set out in Table 11-4 and Table 11-5.

Table 11-4: Financial Indicators – Lamu Water System

Average Capital Cost (US$/m³)	Average Energy Cost (US$/m³)	Average O&M Cost (US$/m³)	NPV (US$ millions)	IRR (%)	Water Cost (US$/m³)
0.14	0.21	0.12	24.26	20.80%	0.473

The financial internal rate of return (**IRR**) is computed at **20.8%**.

The computed net present value (**NPV**) is **US$ 24.26 million**.

The resulting **cost of one m^3 of supplied water** will amount to over **0.47 US$/m^3** (price to the utilities firms). See Fig. 11-3 below.

This amount is composed of 0.14 US$/m^3 attributed to the average capital outlays, 0.21 US$/m^3 attributed to the energy expenses and 0.12 US$/m^3 due to O&M expenses.

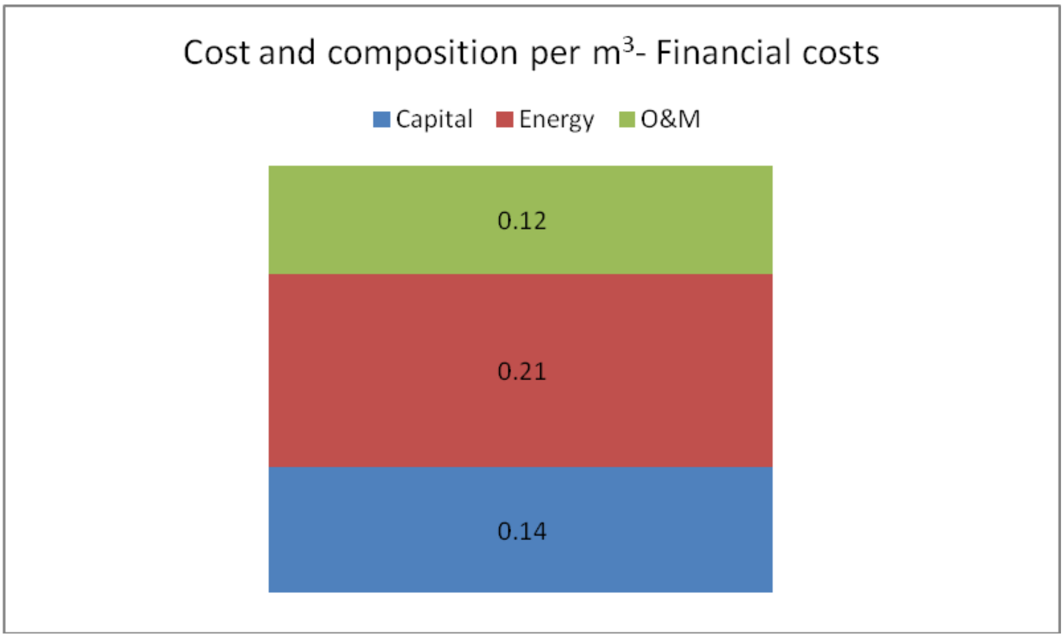


Fig. 11-3: Composition of financial cost of one m³ of water – Lamu water system

Table 11-5: Economic Indicators – Lamu Water System

Average Capital Cost (US$/m³)	Energy (US$/m³)	O&M (US$/m³)	ENPV (US$ millions)	EIRR (%)	Economic Water Cost (US$/m³)
0.45	0.57	0.13	-45.36	4.89%	1.14

The economic rate of return (**EIRR**) is calculated at **4.89%**.

The computed economic net present value (**ENPV**) is estimated at **-45.36 US$ million**.

The resulting **cost (to the national economy) of one m^3 of supplied water** will amount to approximately **1.14 US$/m^3**. See Fig. 11-4 below

This is mainly due to the high energy costs required for the generation of each m^3, at over 0.57 US$/m^3.

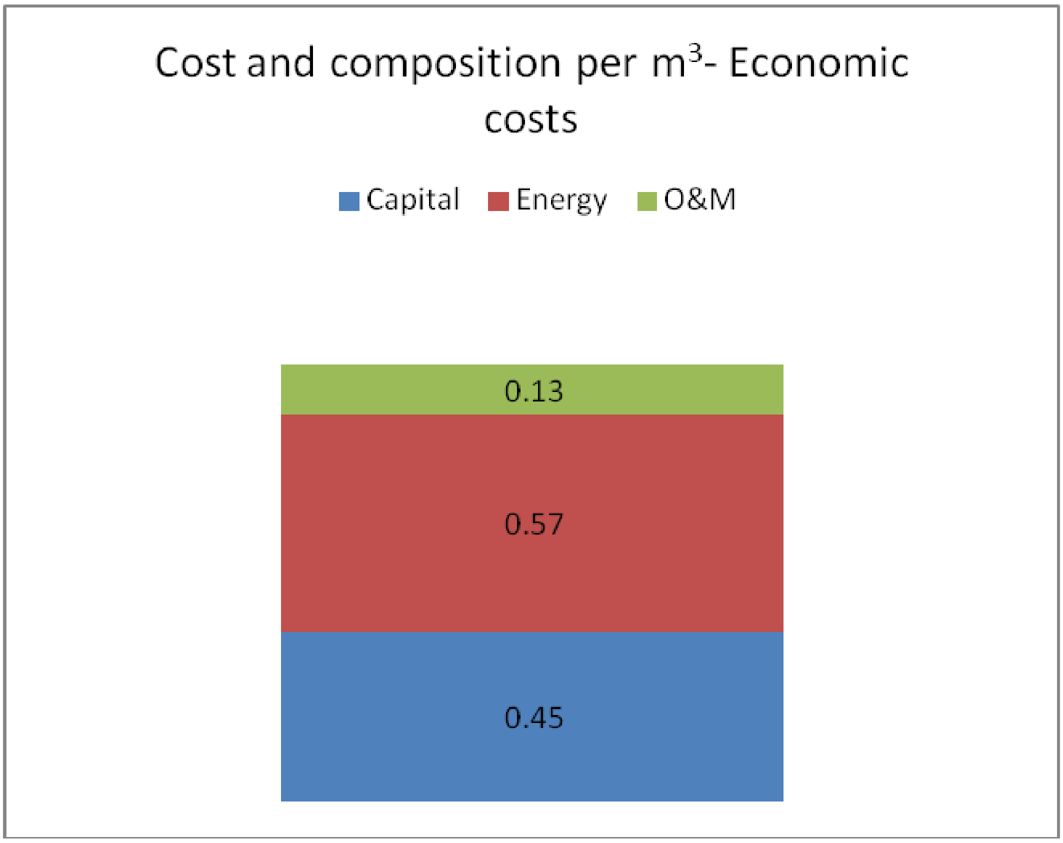


Fig. 11-4: Composition of economic cost of one m³ of water – Lamu water system

11.9 Sensitivity Analysis and Results

Sensitivity analysis is an analytical technique that systematically tests the effects on the financial and economic indicators of the water supply system after applying changes to its basic assumptions. Sensitivity analysis is carried out by varying one element or a combination of elements and determining the effect of that change on the NPV of the relevant scenario. The results of the analysis are presented in Table 11-6.

The base case has been calculated with a discount factor of 10% and O&M at 1% of capital. The variables include percent changes in investments and percent changes in water production amounts. The net present value has been tested against these variables.

Table 11-6: Net Present Value Sensitivity to Increases and Decreases in Investments and Water Production Amounts (US$ millions)

Changes in Water Production Amounts (%)		Changes in Investments (%)						
		-30%	-20%	-10%	0	10%	20%	30%
	-15%	20.6	7.8	0.63	-6.5	-13.6	-20.8	-27.9
	-10%	23.0	15.8	8.7	1.5	-5.6	-12.7	-19.8
	-5%	31.0	23.9	16.8	9.6	2.5	-4.6	-11.7
	0	39.1	32.0	24.9	17.7	10.6	3.47	-3.7
	5%	47.2	40.1	32.9	25.8	18.7	11.5	4.4
	10%	55.3	48.14	41.0	33.9	26.7	19.6	12.5
	15%	63.3	56.2	49.1	42.0	34.8	27.7	20.6

The NPV of the bulk water supply system will exhibit negative figures if the water production falls by more than **15%** of the amount planned for, or if total investment exceeds the planned amounts by more than **30%**.

12. Resettlement Action Plan (RAP)

12.1 The Objective of the RAP

The primary objective of the RAP is to prepare and submit a rational program for the resettlement planning of all persons and communities affected by the water supply infrastructure schemes proposed in the WSMP.

12.2 Methodology

The methodology used to achieve the objective of the RAP was described in Section 4.8 above.

It should be emphasized that at the master plan level, the assessments regarding usage of acquired land, loss of agricultural land or trees, and the resulting costs and compensation comprise only preliminary estimations. A more detailed RAP will have to be prepared during the detailed design for each individual water supply scheme (e.g., Mzima, Baricho, Mwache, etc.).

12.3 Policy, Legislation and Administrative Framework

The overall framework and context of the present study is strongly anchored in the World Bank OP 4.12 (Operational Policy Statement) and BP 4.12 (Bank Procedures), both revised in April 2013, and in the comprehensive body of legislation and statutes of the Government of Kenya and its agencies.

The main objectives of the WB policy, on involuntary resettlement, as expressed in **OP 4.12**, and adhered to in the present study, are:

- Involuntary resettlement should be avoided where feasible, or minimized, exploring all viable alternative project design.
- Where it is not feasible to avoid resettlement, resettlement activities should be conceived and executed as sustainable development programs, providing sufficient investment resources to enable the persons displaced by the project to share in project benefits. should have opportunities to participate in planning and implementing resettlement programs
- Displaced persons should be assisted in their efforts to improve their livelihoods and standards of living or at least to restore them in real terms, to pre-displacement levels.
- All direct economic and social impacts that may result from involuntary resettlement should be assessed. These include: relocation or loss of shelter, loss of assets and loss of income sources or means of livelihood.

The broad WB guidelines are shared by the main body of GoK Legislation that pertains to voluntary and involuntary resettlement issues, as set out in the following documents:

- Evictions and Resettlement Procedures Bill, 2012
- Land Act No. 6 of 2012
- Land Adjudication Act, Cap 283
- The Trust Land Act, Cap 288
- Land Registration Act No. 3 of 2012
- Land Control Act, Cap 302
- The Survey Act, Cap 246
- Building Code 1968
- Constitution of Kenya 2010
- Kenya Vision 2030

12.4 Similarities and Gaps in WB and GoK policies and Mitigation

The legal directives as stipulated in the relevant acts (specifically Land Act No. 6; Land Adjudication Act, Cap 283; Land Control Act, Cap 302; and the Constitution of Kenya) are generally aligned with the policies set out in the WB's OP 4.12.

Table 12-1 points out the similarities and the gaps that exist between the WB Policy requirements and the GoK Legislation.

Table 12-1: WB Policy Requirements and GoK Legislation

#	Category/ Assets	Kenya Law	WB Policy	Apparent Gap
1	General	Kenya law stipulates a drafting of RAP document prior to resettlement	Bank differentiates between RAP, policy framework or process framework	WB provides more flexibility concurrent with magnitude of resettlement
2	Land Owners	Cash compensation at market rate for land and development 15% of sum total award as disturbance Loss of business on premises Land for land option	Compensation at replacement cost Compensation on land-for-land basis recommended	GoK stipulates specific compensations for disturbance and loss of business during relocations
3	Tenants/ Lease Holders	Compensation for loss of opportunity on balance of lease	Compensation on whatever legal claims to the affected property	Apparently similar

4	Land users/ easements	Assistance in relocation of infrastructure Compensation for crops and other investments	Compensation for crops Replacement for land and Income opportunity to be restored	Where GoK refers to assistance only and compensation for crops only OP 4.12 stipulates full replacement also for land
5	Squatters/ Licensees	Cash compensation for assets Alternative sites with title security	Cash compensation or in-kind at full replacement cost Assistance for relocation expenses prior to displacement.	Where GoK requires provision of alternative sites with title OP 4.12 requires assistance for relocation
6	Communit y Assets	Cash compensation or restitution of the assets where land not compensated	Complete provision of all community assets expected to be lost. Land, compensation and other assets.	Bank more detailed

As stated above, the WB guidelines and safeguards and the Legislation of the GoK are generally aligned in principle and objectives. In the event of disparities (detailed above in Table 12-1) it was recommended to utilize the more demanding stipulations. Meaning that when in doubt the GoK should choose the more considerate, benevolent and generous solution towards the PAPs. This procedure will also enable to cut red tape and shorten bureaucratic processes.

12.5 General Relocation Guidelines

The following guidelines, based on WB and GoK regulations, along with the Consultant's findings, directed the RAP procedures throughout the process:

- Involuntary resettlement should be avoided or minimized where feasible.
- Where displacement is inevitable, comprehensive and holistic resettlement development programs shall be prepared.
- The comprehensive resettlement programs shall be initiated and developed in conjunction to the water supply projects themselves. Prior to resettlement decisions, all viable alternative project designs will be explored.
- Resettled persons/households/groups shall be provided with sufficient investment resources and opportunities to share in project benefits.
- Displaced persons should be compensated for their losses at full replacement cost prior to the actual displacement.
- PAPs and any other person/household/entity entitled to compensations will not be required to incur any costs towards processing their claims or to pay for costs attendant to the relocation expenses.

- Moreover, following the transfer, assistance and support will continue to be provided to all PAPs in their efforts to maintain/improve their former living standards, income earning capacity, and production levels.
- Specific consideration should be paid to the needs of the most vulnerable and poorest of the resettled people
- Community participation in planning and implementing resettlement should be encouraged
- Existing social and cultural institutions of the resettled groups and their hosts should be maintained and reinforced to the greatest extent possible. Moreover, resettled persons should be integrated socially and economically into host communities so that adverse impacts on host communities are minimized.
- Land, housing, infrastructure and other compensation should be provided to the adversely affected population, indigenous groups, ethnic minorities and pastoralists who may have customary rights to the land or other resources taken for the project.
- Absence of legal ownership deeds to land by vulnerable groups (such as indigenous, minorities, pastoralists, etc.) should not be an obstacle to compensation.
- A site/project specific detailed EIA and RAP will need to be prepared during detailed design of each program proposed for development within the MP study.

12.6 Public Consultations

World Bank policies on involuntary resettlement and the GoK legislation both indicate the need for a comprehensive and practical process of public consultations and stakeholder engagement. The process is viewed as an integral part of any planning and design activity, especially where involuntary resettlement undertakings are concerned.

Effective public consultation and community engagement is central to the successful management of risks and impacts on the PAPs and communities affected by the upcoming projects, as well as central to achieving enhanced community benefits.

The RAP consultation process for the WSMP included the following general steps:

- Identification of project stakeholder groups and PAPs that may be affected by the projects
- Stakeholder engagement process and information disclosure
- Meaningful consultations – The consultation process was based on the disclosure of information relevant to the development of Mwache Dam, Baricho Wellfield, Mzima 2 Pipeline and all ancillary facilities; conveyance systems, treatment, storage and distribution systems.

The stakeholders and PAPs were generally classified into three main groupings according to their geographical and spatial location distribution:

- Those affected by the Mwache Dam and conveyance
- Those affected by the Baricho Wellfield and conveyance (with specific reference to the Immediate Phase investment component)
- Those affected by the Mzima 2 Pipeline

The Mwache RAP is covered extensively by the CES (consultancy firm) RAP document prepared and submitted to MoRDA and CDA.

For Baricho and Mzima resettlement will be minimal. The affected persons and communities were identified through the office of the provincial administration and by the Consultant teams involved in the Socioeconomic Survey. Since final siting of the pipes and other facilities will be done in the detailed design, the participating PAPs were provided general indications on the project and a broad description of the possible siting of structures and areas designated for resettlement. Most of the PAPs that took part in the consultation process will probably not be physically relocated. And the impact on them will be minimal. That said, the Consultant believes that their observations and inputs were candid, invaluable and contributed to the final design of the projects and the recommendations put forward in the WSMP document and the RAP.

12.7 Project Components and Potential Impacts

12.7.1 Mzima Facilities and Conveyance

12.7.1.1 Project Components

Very general land requirements and compensation figures have been assessed based on previous studies and preliminary designs. These may change when more detailed designs are embarked upon. The main land requirements and project components are as follows:

- The **source works**, including the Chalk Beach pool intake, pipeline and headworks. All land required for the source work falls within areas already allocated to existing infrastructure.
- The **pipelines**, including the gravity mains from Mzima Springs to Mazeras, and the extension pipelines to Chamgamwe and Kaya Bombo. Additional compulsory acquisition is not required. Mostly wayleave arrangements will have to be made along the entire length. Pipelines and conveyance systems run along existing roads and the wayleaves fall within existing reserves (see Table 12-2).
- The **service reservoirs**, including Chamgamwe, Nguu Tatu, Upper Kaya Bombo and Mariakani, the Nguntini, Mazeras and Mokobeni break-pressure

tanks, the building works and office conversions, and the Mzima, Nguntini, Taru and Mazeras water sterilization works. For the aforementioned structures, compulsory acquisition of land will be unavoidable.

12.7.1.2 Project Implementation and Resettlement Impacts

Wayleave Compensation

Pipeline routes are obtained by wayleaves for which no land acquisition costs are involved.

Within private lands, wayleaves compensation shall be limited to the loss of income during the pipeline construction period and will therefore be minimal.

Exact compensation amounts can only be determined after final pipeline routes have been established and on a case by case study.

Table 12-2 presents details regarding required wayleaves.

Table 12-2: Wayleave Lengths

Pipeline Section	Length (km)				
	Along existing service roads	Along existing road reserves		Rangelands and Agricultural Lands	Total
		Road No.	Length		
Mzima 2 Pipeline (Mzima to Mazeras)	176.0	A 109	40.4	3.0	219.4
Mazeras to Chamgamwe pipeline extension	–	A 109	7.1	5.6	12.7
Kaliangombe to Lower Ribe pipeline	–	Tracks E 932 C 111	2.0 1.8 9.3	3.2	16.3
Mazeras to Kaya Bombo pipeline extension	12.5	E 942	6.0	3.2	21.7
Total	188.5	–	66.6	15.0	270.1

Source: Second Mombasa & Coastal Water Supply Engineering and Rehabilitation Project – Study 2, The Second Mzima Pipeline, September 1996, National Water Conservation and Pipeline Corporation (NWCPC) and joint venture Sincat-Atkins.

Land Acquisition

Land acquisition will be required for those segments of the project that involve aboveground structures, for which land has not yet been settled. These include the break-pressure tanks and reservoirs.

Tentative land acquisition areas and costs are presented in Table 12-3.

Table 12-3: Mzima Project – Tentative Land Acquisition Areas and Costs (exclusive of staff salaries, office expenses, planning and training)

#	Site	Area (ha)	Unit Price Costs (US$/ha)	Amount (US$)
1	Land acquisition			
1.1	Nguntuni break-pressure tank site	1.5	3,000	4,500
1.2	Taru break-pressure tank site	1.5	3,000	4,500
1.3	Makobeni break-pressure tank site	1.5	3,000	4,500
1.4	Mariakani Service Reservoir site	8.0	3,000	24,000
1.5	Kaya Bombo Service Reservoir site	5.0	3,000	15,000
1.6	Kaya Bombo Reservoir access road	8.0	3,000	24,000
	Total land acquisition	**14.1**	–	**76,500**
	Particulars	**Unit Quantity**	**Unit Price (US$)**	**Amount (US$)**
2	Acquisition of trees	80	16	1,280
3	Compensation for productive assets/crops (ha)	60	250	15,000
4	Economic rehabilitation grant to PAFs	20	300	6,000
5	Contingency	5.0%	–	2,176
6	**Total compensation budget for Mzima:**			**100,076**

Source: Second Mombasa & Coastal Water Supply Engineering and Rehabilitation Project; Study 2; the second Mzima Pipeline September 1996, The National Water Conservation and Pipeline Corporation and joint venture Sincat-Atkins.

12.7.2 Mwache Multipurpose Dam, Reservoir and Conveyance

12.7.2.1 Project Components

At the present time the Mwache Dam Development Project, conducted for the CWSB by CES, is in its final planning stages.

The planning process includes a formulation of a comprehensive RAP study for both the dam and reservoir. Most of the CES RAP products and outcomes have been examined, reviewed and sanctioned. Additional infrastructure development (southbound route) was computed and included.

The project entails the construction of a dam across the Mwache River in Kinango District of the Coast Province of Kenya. The dam will provide water for irrigation and domestic usage in the dam project area and the city of Mombasa. The project is undertaken by the Ministry of Regional Development Authorities (MoRDA) through the Coast Development Authority (CDA). Project components include the dam, reservoir, pumping stations, tanks and conveyance. Daily water supply will be approximately 186,000 m^3. The period and duration allocated for the implementation and construction of this segment is 2013–2017.

12.7.2.2 Project Implementation and Resettlement Impacts

A summary of the total number of affected households, land and property loss due to project implementation is presented in Table 12-4.

Table 12-4: PAF Losses of Land, Houses and Trees, by Village

Village	Number of PAFs	Loss of Land		Loss of Houses		Perennial Tree Loss	
		# of households	Submerged area (acres)	# of households	# of displaced houses	# of households	# of submerged trees
Bokole	13	6	19	13	28	13	1,743
Chigomeni	6	1	4	6	18	5	183
Chenguluni	34	18	94.25	34	86	34	2,319
Fulughani	13	0	0	13	30	12	468
Miyani	2	0	0	2	6	0	0
Mnyanzeni	4	3	19	4	20	3	121
Mwache	38	32	273	38	93	38	4,497
Mwachipa	11	4	27	11	40	10	978
Mwashanga	4	3	24	4	15	4	138
Nunguni	8	7	116	8	17	8	443
Rombo	16	12	82	16	40	15	1.684
Vikinduni	12	3	18.5	12	27	11	366
Scattered houses	6			6	18		
Other + buffer area		22	2,063.25				
Total	**167**	**89**	**2,740**	**167**	**438**	**153**	**12.940**

Source: CWSB CES Mwache Multipurpose Dam Development Project, Resettlement Action Plan (draft), November 2012

A total of 12 villages will be directly affected by the reservoir, as well as a few other scattered households. A total of 2,740 acres belonging to 89 households will be submerged, and 12,940 perennial trees owned by 167 households/persons will be lost.

Total land and assets to be acquired and their valuation are presented in Table 12-5.

Table 12-5: Mwache Dam Project – Tentative Land Acquisition Areas and Costs

#	Particulars	Unit Quantity	Unit Price (US$)	Amount (US$)	Remarks
1	Acquisition of land (ha)	1,109	3,000	3,327,000	
2	Acquisition of houses (no.)	438	1,500	657,000	
3	Acquisition of trees (no.)	12,940	16	201,375	
4	Acquisition of other properties				
4a	Latrines (no.)	35	100	3,500	
4b	Water pipes (no.)	2	100	200	
5	Compensation for productive assets/crops (ha)	677	250	169,250	Crop loss at $250/ha
6	Compensation for productive assets-businesses (no.)	5	450	2,250	
7	Transitional allowance (PAFs)	167	1,800	300,600	3-year existing income loss
8	Shifting allowance (PAFs)	167	100	16,700	Transport of shifting assets
9	Economic rehabilitation grant (PAFs)	167	2,000	334,000	At US$ 2,000 per PAF
10	Livelihood support allowance (PAFs)	167	2,847	475,449	One year of support per PAF at $1.00/day/person
11	**Relocation of common property resources (CPRs) (no.)**				
11a	Kayas	2	20,000	20,000	
11b	Graves	35	2,000	7,000	
12	Training and capacity building of MoRDA/CDA staff (no. of training days per person)	50	40	2,000	
13	Training and capacity-building of PAPs (no. of training days per person)	2,500	25	62,500	10 staff for a week
14	Workshops and seminars (no)	5	250	1,250	500 adult PAPs for one-week training
15	Fees paid to NGOs for implementation of RAP	5% of cost items 1–14		279,004	
16	Fees paid to M&E consultants				
17	Contingency		2.5%	139,502	
18	**Total RAP budget for Mwache:**			**5,998,580**	

Source: Mwache Multipurpose Dam Development Project, Resettlement Action Plan (draft), November 2012

12.7.3 Baricho Wellfield

12.7.3.1 Project Components

The preliminary design development plan calls for the development of the Baricho Wellfield within two sequential phases:

- Immediate Phase, which will consist of an emergency additional production of 22,000 m^3/d, to be available in the year 2015
- Phase II (Baricho 2), with additional production reaching a total abstraction of 175,000 m^3/d, to be available in the year 2025. This abstraction could be sustained even at the minimum flow of 2.6 m^3/s in the Sabaki River (99.9% exceedence).

The additional boreholes required will have to be drilled, equipped and connected to the intake works.

12.7.3.2 Project Implementation and Resettlement Impacts

It is recommended to try first to rehabilitate the two existing boreholes near the old Sabaki River Intake, which were apparently used to dilute the Sabaki River water extracted from the old intake. If this rehabilitation is successful, these wells should be outfitted with appropriate pumping equipment, and pumping tests should be conducted in order to establish the well capacities.

These actions will enable appropriation of a smaller private land area for the proposed facilities and less compensation.

The new RHC-type boreholes, for the Immediate Phase and Phase II, should be located to the north and east of the area of the existing borehole group 4–8 near the bend of the Sabaki River.

Hence, the additional number of RHC-type boreholes designed for the Immediate Phase is between 0 and 2; and 4 RHC-type boreholes during Phase II.

The total area that must be acquired for construction of additional facilities during the Immediate Phase and Phase II is estimated at 185,000 m^2 (18.5 ha) – 150,000 m^2 (15 ha) for the system of wells, 30,000 m^2 (3 ha) for the conveyance system and 5,000 m^2 (0.5 ha) for pump and tank structures.

A tentative compensation calculation is set out in Table 12-6.

Table 12-6: Baricho Project – Tentative Land Acquisition Areas and Costs

#	Particulars	Unit Quantity	Unit Price (US$)	Amount (US$)	Remarks
1	Acquisition of land (ha)	45	3,000	135,000	
2	Acquisition of trees	560	16	5,760	
3	Compensation for productive assets/crops (ha)	40	250	10,000	Crop loss at 250 US$/ha
4	Economic rehabilitation grant (PAFs)	10	2,000	20,000	At US$ 2,000 per PAF
5	Fees paid to M&E consultants	5% of cost items 1–4		3,700	
6	Contingency	2.5%		1,942	
7	**Total RAP budget for Baricho:**			**79,650**	

12.8 Resettlement/Compensation due to the Immediate (Emergency) Phase Works

12.8.1 Components of the Works

The development plan calls for an Immediate Phase investment component (donor provided) for the purpose of emergency works for the expansion of Baricho Wellfield. The objective is to supply an additional 22,000 m^3 to Mombasa by 2015.

This will necessitate the development of additional infrastructure consisting of:

- Two new boreholes
- Improvements of the Sabaki-Mombasa Pipeline
- A new pipeline – the Kakuyuni-Kilifi Pipeline

12.8.2 Resettlement/Compensation for the Works

Resettlement and/or compensation will not be required for the first two items listed above:

- The two boreholes will be developed within the current fenced Baricho facility complex.
- Work on the Sabaki-Mombasa Pipeline is not expected to encroach beyond the current infrastructure overlay.

However, the route of the Kakuyuni–Kilifi Pipeline has not yet been determined. After precise designation of its route and the subsequent detailed design and mapping, an accurate survey of PAPs, assets, crops and community facilities can be conducted. Preliminary inspections of the pipeline route indicate that it will be approximately 47 km in length, with about 37 km along a sparsely populated footpath sporadically lined with rainfed field crops. While damage and uprooting of crops is expected during construction activities, the pipe excavation and overlaying work is expected to conclude within a few days for each agricultural tract. Compensation will have to be paid only for crop damage along the construction route (and perhaps the odd informal kiosk along the way).

12.9 Relative Impacts of Displacement on PAPs

Wherever possible, displacement of people will be minimized or avoided altogether. This guideline is also validated by the policies and procedures of the GoK, CWSB, CDA and the Ministry of Environment, Water and Natural Resources. It is also endorsed by World Bank Directive OD 4.3 and the IFC Handbook on Resettlement Action Plans.

Resettlement resolutions regarding the Mwache area PAPs can commence shortly. The feasibility and preliminary design of the dam (by CES) are complete. The dam location, reservoir volume and dimensions and siting of the facilities and hydraulic structures have all been established.

With regards to the Mzima 2 Pipeline and Baricho Wellfield, itemized RAP can commence only after the detailed design has been completed.

The Consultant recommends that a contractual linkage be created between the implementation of the resettlement activities to the schedule of disbursements for project financing. This may help ensure that displacement does not occur before the implementing agent/contractor has carried out the necessary measures for the resettlement of the affected people.

Project impacts in Mzima and Baricho are expected to be minimal. Mzima infrastructures will probably be established along the current route, by either replacing the current pipeline and structures or establishing a new pipeline and structures parallel to the current ones. Baricho expansion will require only a marginal amount of additional land, as detailed above.

The Mwache project is expected to have the most significant impact on the communities due to loss of land that will be acquired for the dam, the reservoir and the tree buffer. Moreover, isolated parcels will also be acquired for water tanks. The total land required for appropriations is detailed in the CES report. The WSMP indicates that rising water mains will be constructed along the road shoulders and it will be necessary to acquire right of way from the landowners where the road shoulders are not wide enough to accommodate the water pipes. Existing housing within the area of displacement will be demolished. A total of 438 houses of different types will be affected in the project.

The properties to be affected in the displacement include:

- Farmland that will be required for dam construction activities and to be submerged under dam water, area for water storage tanks and for tree buffer to protect the dam water
- Houses and other farm structures
- Cultural sites used by the community for traditional rituals
- Roads of access and river crossings that will be impounded
- Graveyards that will be acquired together with the land for dam purposes
- Cash crops, commercial trees and any food crops within the dam impounding area
- Loss of livelihood from farming activities, as all of the PAPs are farmers and landowners. It is anticipated that all buildings, infrastructure and trees below the 100 m contour lines will be either submerged or lost to the tree buffer, where farming activities will not be permitted, as the land will belong to the executing agency and used for dam-related activities. The most common types of trees that will be affected are mainly fruit trees, as well as several species of timber trees. Their valuation will vary based on type and age of the tree, as well as what they produce.

12.10 Conflict Resolution, Redress and Compensation Procedures

A mechanism for conflict resolution is essential for both the Client and the PAPs. The respective project RAP implementing teams will develop and prepare appropriate grievance policies and compensation procedures. Although the respective projects and RAP interventions are site specific and set apart, it is the Consultant's opinion (based on previous experience and studies) that the relevant committees should draft policies with similar internal logic and rationale, in order to prevent PAP contrasting comparisons and the resultant protests. The main objectives of the conflict resolution committees will be as follows:

- To identify and settle disputes in a fair, unbiased and equitable manner
- To reduce the risk of escalation of conflicts and avoid unnecessary delays
- To ensure documentation of grievances, complaints and the necessary corrective actions
- To enhance accountability and reduce liability

In any case, conflicts that cannot be resolved by the system proposed here will seek legal redress through the courts of law.

12.11 Grievance Settlement Process

With the aim of reducing bureaucracy, swift resolutions of conflicts and transparency, the RSC will be the sole agent to address and resolve PAP grievances (prior to legal redress).

A flowchart depicting the proposed grievance settlement process is presented in Fig. 12-1.

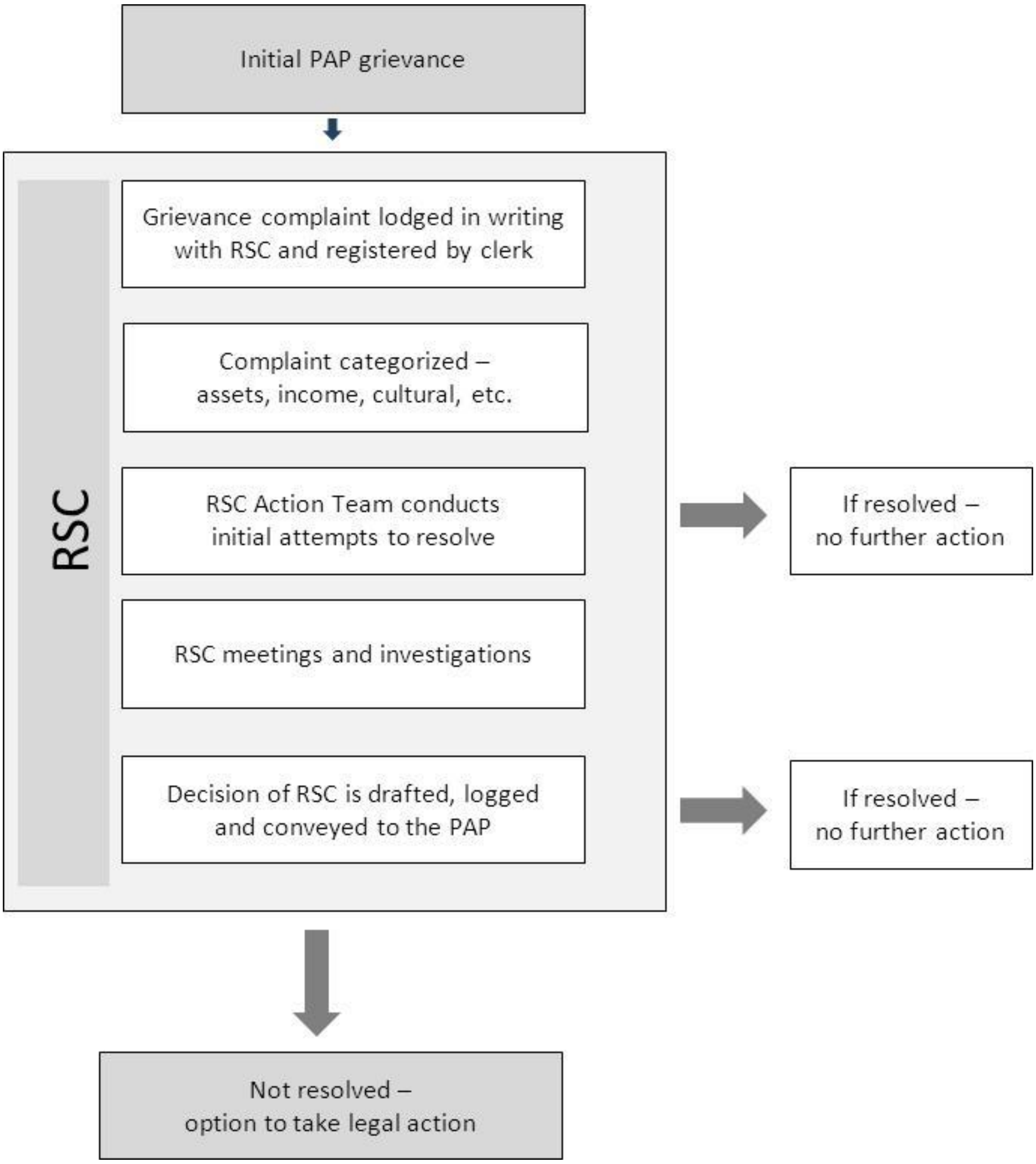


Fig. 12-1: Grievance settlement process flowchart

The process will commence when a grievance is filed, in writing, by the affected person or his/her representative. The grievance will be documented and logged by the RSC clerk, and a grievance report forwarded to all members of the RSC within seven days.

Efforts will be made to resolve the complaint amicably before a formal hearing by the RSC. An RSC session will assemble not more than 21 days after lodging the grievance. If an understanding is not reached or the affected person is not satisfied with the RSC decision, he/she may seek legal redress at a court of law or any other statutory body. The period between initial lodging of grievance to final RSC decision and notification (minutes of the meeting) should not in any case exceed five weeks.

12.12 Rehabilitation and Resettlement (R&R) Budget

This section presents the computation of the R&R budget that will be required for compensation within the three main projects of the WSMP. It should be stated, again, that since conveyance routes have yet to be settled in the Baricho and Mzima projects, as well as final specifications and sitings of facilities, the final budget will have to be modified only after detailed design is conducted.

Total R&R budget for the three projects is US$ 6.45 million. The major share, amounting to over US$ 5.99 million will be utilized for resettlement around the Mwache Dam, reservoir and conveyance projects. Mzima and Baricho require more modest resettlement costs, estimated at about US$ 195,600 and US$ 260,300, respectively.

12.13 Valuation Procedures – Land, Assets and Compensation

Findings of the socioeconomic survey indicated that the price of land in the area is determined by its location, proximity to water, electricity, transportation infrastructure, community infrastructure and other traditionally-based justifications.

Valuation of land prices for the purposes of compensation were set after an appraisal exercise based on data collected from three independent information sources:

- **Findings of the socioeconomic study** – Respondents of the study, not specifically PAPs, but rather persons living in close proximity to the projects generally indicated that land prices range between 100,000 to 400,000 KSh/ha (1,250 and 5,625 US$/ha respectively, averaging 3,400).

- **Private property valuators** (two private valuation firms in Mombasa) – Two firms were consulted with regards to their assessments based on professional know-how and experience, and also by reviewing actual contract costs of recent property purchase transactions. Prices ranged between 150,000 to 300,000 KSh/ha (1,875 and 3,750 US$/ha, respectively, averaging 2,800).

- **County administrations**, specifically the Department of Finance and Economic Planning, Department of Agriculture and Department of Water, Energy and Natural Resources of the relevant counties – Officials and administrators in the counties of Kwale, Kilifi and Taita Taveta were interviewed. Moreover, actual costs of recent transactions were reviewed. Prices ranged between 85,000,000 to 350,000 KSh/ha (1,063 and 4,375 US$/ha, averaging 2,700 US$/ha). A frequent statement by the officials (supported by the valuator firms) referred to the low level of development and efficiency of the land market in the area, leading to the wide range of price estimations and the inherent inaccuracies.

12.14 Other Assets

Other valuated assets include houses, shops, infrastructure (pipes, latrines) crops, trees, etc.

The valuation process conducted was similar to the land price assessment. Data was collected from the local inhabitants through the socioeconomic survey, from county administration officials (specifically the departments of finance and economic planning and the department of agriculture) and from local contractor firms and businesses.

12.15 Determining the Prices for Land and Assets Compensation

The scope and level of detail of the master plan does not allow for precise siting of structures or exact routes of conveyance systems. Hence, accurate land and property prices according to location or house size cannot be conducted at this stage. General price averages were set for each asset, regardless of its location. A 10–15% add-on was included on top in order to safeguard in the event of under-evaluation.

Table 12-7 and Table 12-8 summarize the selected average costs and R&R budget, respectively.

Table 12-7: Selected Average Costs for Land and Assets

No.	Item	Unit	Average Price (US$)
1	Land	hectare	3,000
2	House residential	unit	1,500
3	Trees	tree	16
4	Businesses/kiosks/shops	unit	450

Table 12-8: R&R Budget (rounded)

	Cost US$			Comments
Operations	**Mwache**	**Mzima**	**Baricho**	
Salaries	85,000	35,000	35,000	
Office Admin	25,000	15,000	15,000	
Consulting services	30,000	12,500	12,500	
Miscellaneous (office and general admin)	10,000	5,000	5,000	
Compensation				
Compensation to land owners for agricultural land	169,250	15,000	10,000	
Compensation for house plots	657,000	–	–	
compensation for trees	201,375	1,280	8,960	
compensation for enterprises	2,250	–	–	
compensation for moving/disturbance	40,000	–	–	
Transitional allowance (PAFs)	141,000	–	–	
Economic rehabilitation grant (PAFs)	335,000	–	5,000	
Livelihood support allowance (PAFs)	475,000	6,000	3,000	
wayleave compensation	18,000	5,000	3,500	
Land acquisition and Resettlement Site Planning				
Land acquisition	3,327,000	76,500	135,000	
Site planning	20,000	10,000	10,000	
Other infrastructure	35,000	–	–	
Monitoring and Evaluation				
RAP monitoring and evaluation	25,000	5,000	5,000	
Agricultural Extension services	45,000	–	–	
Training and capacity building, workshops and seminars	72,000	–	–	
TOTALS				
Subtotal all items	5,712,875	186,280	247,960	
contingency 5%	285,644	9,314	12,398	
TOTAL	**5,998,519**	**195,594**	**260,358**	
GRAND TOTAL (3 projects)	**6,454,471**			

13. Environmental Impact Analysis (EIA)

13.1 The Objective of the EIA

The objective of this assessment is to inform project design, and help reduce possible adverse impacts. In doing so, the EIA assessment has identified possible impacts from various project components and activities, and possible management needs to reduce or avoid impacts of identified adverse impacts. For each of the management activities, appropriate implementation actions and capacity needs have also been developed. This is to ensure the possible implementation of identified management actions to safeguard the environment.

This Environmental Impact Assessment is for the selected WSMP scenarios. Considering that this is a master plan – and not a detailed design for the identified resources and projects – this EIA only deals broadly with identified impacts. The assessment will need to be further detailed once the final alignment and other technical aspects for the development of sources and systems are identified. This EIA should be used as a guiding tool for individual projects which are a part of the planned Coast Province bulk water supply system. However, this must not be taken as the final assessment for the individual projects and a detailed EIA will need to be conducted for each project separately. The EIA for the separate projects should be conducted by an entity independent of the project design agency, at must be developed the time of the detailed design for the project. Findings of the suggested EIA will need to be incorporated in the detailed design, along with a budget and an institutional structure to implement the EMP.

13.2 Methodology

The methodology used to achieve the objective of the EIA was described in Section 4.7 above.

13.3 Policy, Legislation and Administrative Framework

13.3.1 Kenyan Environmental Legislation

Major environment-related Kenyan legislation applicable are summarized in Table 13-1.

Table 13-1: Major Implications of Relevant Environment-Related Kenyan Legislation

Category	Most Relevant Legislation	Summary of Major Implications
Environment	- Act No. 8 of 1999: The Environmental Management and Co-ordination Act, 1999. - Legal Notice No. 101: The Environment (Impact Assessment and Audit) Regulations 2003	- Dam construction needs an EIA. - Desalination plants and barrages may require an EIA, as they could be included under Notice 101's general category description – "activities out of character or scale of their surroundings and major land use changes". - Catchment management needs to be considered for the Mwache Reservoir design. - Biodiversity conservation and protection to be considered when working in sensitive or protected areas - Local population's access and rights to areas, such as Kaya forests and Arabuko-Sokoke, to be considered. - Need for adherence to effluent discharge standards and obtaining required permission, as mandated by law.
Forest	- Forest Act, 2005 - The Forest (Charcoal) Rules, 2009	- Work in forest or protected areas – such as Mzima Springs, Gongoni Forests and the Baricho Pipeline alignment – would need to consider applicability of the Forest Act, depending upon the nature of the planned activities. - Permissions, etc., for working in protected areas must be obtained. Design should minimize disturbances to sensitive and protected areas. - Design, construction and post-construction management work must follow protected area rules. - Charcoal and firewood needs during construction must not damage forests and protected areas.

Category	Most Relevant Legislation	Summary of Major Implications
Wildlife and Biodiversity	- Legal Notice No. 160: The Environmental Management and Co-ordination Act (No. 8 of 1999). The Environmental Management and Co-ordination (Conservation of Biological Diversity and Resources, Access to Genetic Resources and Benefit Sharing) Regulations, 2006 - Wildlife Conservation and Management Act, 1976 (Revised 2009) - Wildlife Conservation and Management Act, 2009 - Wildlife Act, 2010	- Detailed design must consider the implications of working in protected areas – such as Tsavo West, Arabuko-Sokoke and marine parks – to minimize disturbance. - Activities resulting in reduced downstream flows, any activity on the coastal belt, waste discharge into the marine environment, plantation activities, and activities in migratory routes, dispersion routes, corridors and fly paths, would need to consider these legislations. - Labour camps in Tsavo West would need to ensure hunting and consumption of bushmeat does not take place. - Need to ensure that only appropriate flora species for an area are used in plantation activities under the project.
Water management	- The Water Act 2002 - The Water Resources Management Rules, 2007 - Draft (Revised), Sessional Paper on National Wetlands Conservation and Management April 2008 - Legal Notice No. 19: The Environmental Management and Co-Ordination (Wetlands, River Banks, Lake Shores and Sea Shore Management) Regulations, 2009	- Public consultation needs and procedures for EIAs in Kenya are identified in these laws. - They also identify permissions that need to be obtained for project activities, as well as waste and effluent discharge standards. - For reservoirs and barrages, storage, release, environmental flows and cumulative impacts need to be considered. - For groundwater, all wellfields would need to follow abstraction and usage rules.

Category	Most Relevant Legislation	Summary of Major Implications
Pollution and waste management	- Legal Notice No. 120: Environmental Management and Coordination (Water Quality) Regulations, 2006 - Legal Notice No. 61: The Environmental Management and Coordination (Noise and Excessive Vibration Pollution) (Control) Regulations, 2009 - Legal Notice No. 73: The Environmental Management and Coordination (Controlled Substances) Regulation, 2007 - Legal Notice No. 121: Environmental Management and Co-Ordination (Waste Management) Regulations 2006	- Permissions will be required for digging wellfields, or any other activity near water bodies. - Effluent and discharge standards must be adhered to, and required permission for waste and effluent discharge must be obtained. - Noise levels must be within identified levels, as noted under Legal Notice No. 61.
Occupation health and safety	- Occupational Safety and Health Act, 2007	- The provisions of this Act need to be applied for all work during the construction and O&M stage of the project to protect workers and keep them safe.
Archaeology and heritage	- The Antiquities and Monuments Act, 1983	- No antiquities or monuments have been identified so far. However, the Act would become relevant in case of chance findings.
Land resources	- National Sand Harvesting Guidelines, 2007 - The Mining Act, 1986 - Land Act, 2012 - Physical Planning Act, 1996	- Procurement of sand and other minerals must follow these Guidelines and Acts. - Compensation for permanent and temporary land acquisition will be based upon the Land Act. - All development activities must adhere to existing development plans, and only after required permissions have been obtained. - Post-construction restoration of an area must be completed within 90 days of completion of work.

13.3.2 World Bank Environmental Legislation

Since the project will be financed in part by the World Bank, WB safeguards will also need to be considered. The most relevant ones are as follows:

- **OP 4.01: Environmental Assessment** will be relevant, as project activities include the construction of dams and reservoirs, work in sensitive/protected areas and parks, as well as the possible construction of desalination plants. Therefore, this project is a Category A project, requiring an EIA.
- **OP 4.04: Natural Habitats** will be triggered, as there are a number of natural habitats, such as the Mzima Springs.
- **OP 4.09: Pest Management** is only applicable for the agricultural component of the Mwache Reservoir. However, this project is a water supply master plan and some of the sources, such as the Mwache Reservoir, may be used for more than one purpose. This policy would not be triggered for the water supply component alone.
- **OP 4.11: Cultural Property** will be triggered because of several possible cultural property issues, such as the Kaya forests, which are located throughout the Coast Province.
- **OP 4.36: Forests** is applicable, as there will be some activities within forest areas, such as the wellfields located in the Gongoni Forest.
- **OP 4.37 Safety of Dams** will be triggered, as there is a plan to construct the Mwache Reservoir as part of the water supply system.

The AFD has a Social and Environment Responsibility Policy which aims at promoting sustainable and equable development though a set of eight guiding principles or goals. These include economic growth and wealth distribution, preservation of climate, renewable natural resources and ecosystems, contribution towards preservation of cultural heritage, and promoting transparency and stakeholder engagement.

Looking at the overall picture of the Coast Province, it is obvious that there will be a number of benefits from this project, as well as a need for safeguards to ensure environmental sustainability. According to Kenya's 2009 Census, only 8% of the urban population has piped water in dwellings, and another 39% use standpipes, with a majority depending upon unsafe sources. About 25% depend on springs, wells and boreholes, 12% on water vendors, 8% on dams and 7% on streams. Urban populations also depend upon aquifers to fulfil domestic water needs. Due to this unregulated boring of wells, in some places there is an increasing risk of seawater intrusion into coastal freshwater aquifers.

Water is chlorinated, either prior to distribution water or at the source, in areas where pipelines supply water to settlements en route to their final destination. However, risks of contamination and possible reduction of water quality are high at points where water is distributed en route. Yet another quality concern is the proximity of pit latrines to private drinking water wells, especially in urban areas.

Considering that 63% of the urban population depend upon pit latrines to dispose human excreta, this is a major risk. Only about 10% of urban households are presently connected to a sewerage system.

While diarrhoeal diseases only account for 4% of the total burden of disease according to the 2008-2009 Demographic and Health Survey, some literature such as the UN-Water/World Water Assessment Programme (WWAP) reports regular cholera epidemics in the Coast Province. Vector-borne diseases, such as malaria, elephantiasis and schistosomiasis, are another concern. While malaria and elephantiasis vectors require stagnant water to breed, the schistosomiasis vector's intermediate host does well where surface water systems levels show little fluctuations, as in reservoirs and their regulated downstream flows.

In the Coast Province, catchment degradation is a major concern for both the Tana and Athi Galana-Sabaki rivers. Some of the chief causes are charcoal production; increasing, yet poorly managed, areas under agriculture; livestock pressure and overgrazing; and the discharge of inadequately treated industrial effluents. Not only does this result in high loads of sediments and water pollution, but it also reduces groundwater recharge while increasing soil erosion. Moreover, with rising population and growing industrial and agriculture systems, pressure on water resources will continue to increase.

Resource degradation and increasing water resources are of greater concern if identified climate change predications are considered. Kenya's coastline is one of the five most vulnerable in Africa to rising sea levels, with freshwater aquifers becoming more vulnerable to salinity ingress. Glaciers at Mt. Kenya and Mt. Kilimanjaro are receding, and would impact water availability in both major river systems of the Coast Province – Tana and Sabaki. Predicted rise in temperatures and increase in floods and droughts will impact ecosystems, agriculture and water availability. Together, these changes are likely to have a major impact on water availability, quality and distribution.

The Coast Province is rich in biodiversity, and has a large number of protected areas and areas of conservational interest. Parts of the Coast Province are included in two conservation hotspots – the Coastal Forests of Eastern Africa and the Eastern Afromontane. Also, according to WWF's ecoregion classification, parts of the Coast Province fall under the Northern Zanzibar-Inhambane Coastal Forest Mosaic and the Northern Acacia-Commiphora bushland and thickets. Due to its exceptional level of plant endemism, the northern area of the mosaic is now reclassified as the Swahilian Regional Centre of Endemism. There are also a number of conservation areas and parks. These include the Tsavo ecosystem, Arabuko-Sokoke, Shimba Hills, Tana River Primate National Reserve and the Kora National Park. In the coastal forests alone, there are an estimated 105 threatened fauna and flora species.

The Kenyan coast is part of the Eastern Africa Marine Ecoregion (EAME). The area has over 200 species of coral, 1,500 species of fish and over 3,000 species of molluscs. The ecosystem is home to 34 marine mammals, including the dugong and all five species of Indian Ocean turtles. Kenyan has nine Marine Protected Areas (MPAs).

13.4 Positive and Adverse Project Impacts

The WSMP is expected to have a number of positive impacts, especially on the health and quality of life of the region's inhabitants who will benefit from the project's activities. These will be very important positive impacts, given the high risk of diarrhoeal diseases in the Coast Province population. Another major positive impact will be the reduced risk of salinization of coastal freshwater aquifers if the project results in reduced pressure on local aquifers along the coast. There could however be a number of adverse impacts from project activities. The major ones, along with possible mitigation actions are presented in Table 13-2. In Section 13.5 below, a complete list of the potential environmental impacts stemming from the planned project activities are presented.

Table 13-2: Adverse Project Impacts and Suggested Mitigation Actions

Major Design Impacts	Suggested Mitigation
Contamination risk to water from en route users	- Development of leak detection and management system - Information, Education and Communication (IEC) for users to ensure proper management of standpipes and household taps - Identify ways with local population to reduce leakages from system
Schistosomiasis due to dam construction	- Management system that regularly fluctuate reservoir water levels and if needed use of molluscicides. - Minimize local population contact with reservoir water and IEC to reduce risk
Reduced or degradation of habitat for terrestrial and aquatic species	- Create appropriate infrastructure for species – like fish ladders and nurseries - Ensure infrastructure sites do not damage or destroy specie habitats - Ensure no alien species are used for any plantation activities or released in water - Minimize work in animal dispersion areas, corridors or bird fly paths with any infrastructure built in the areas designed to create least disturbance to species
Dam Safety	- Develop appropriate dam safety measures in project design and for O&M
Downstream infrastructure for reservoirs and barrages	- Ensure design and O&M provides sufficient flows to flush out sediments - Downstream sediment needs to be considered, e.g., deltas and coastline sediment.

Major Design Impacts	Suggested Mitigation
Sacred site sanctity, for example Kayas	- All sacred sites need to be identified during the detailed design and to be avoided. If not possible consult with local population for identification of appropriate solution
Major Construction Impacts	**Suggested Mitigation**
Disturbance to local population for construction activities	- Consult with local population and identify appropriate access routes for transport, work timing, location and management issues of labour camps, construction sites and material storage sites. - Create required safety plans, and barriers and signage to minimize accidents. - Clean and rehabilitate construction site after construction is over - Ensure appropriate waste, sanitation and drainage is in place for all construction related activities
Worker health and safety	- Ensure protection and safety measures in place at construction sites - Provide appropriate facilities at camp site and at construction site - Ensure proper emergency management system in place at construction site - Ensure waste and chemical storage systems in place and working - In areas with wildlife, consult with Kenya Forest Service (KFS) and Kenya Wildlife Service (KWS) to ensure required safety measures
Degradation due to material procurement and construction	- Rehabilitate all sites after work - Plan all sites, including quarries to ensure least possible damage to them
Chance finding	- Stop all work and inform local Chief and National Museums of Kenya officials
Animal safety and habitat disturbance	- Work not be undertaken during periods of high wildlife movement or other important times, should be carried out only during periods of the day when least disturbance to wildlife and safety precautions to ensure minimum danger to wildlife.
Air and noise pollution	- All work needs to be carried out in day hours, with low noise and vibration creating machinery. - Sprinklers, covering of transport vehicles, etc., should be considered as required.
Major O&M Impacts	**Suggested Mitigation**
Leakages, etc., reducing water quality	- Appropriate O&M system, including leak detection and repair to be in place and IEC for water users to reduce contamination en route should be considered

Major Design Impacts	Suggested Mitigation
Worker safety during O&M activities, like in Baricho due to crocodiles and Tsavo due to park animals	- Safety measures as appropriate and needed for all location should be considered; such as picking up and dropping workers at Baricho by vehicles during floods to avoid chance meeting with crocodiles. The KWS ma be consulted for appropriate safety measures where required.
Degradation of environment from waste disposal	- Appropriate O&M and waste disposal for all sites should be considered and an accident clean up system should be in place
Disruption to wildlife during regular O&M	- Regular O&M cycles timed so as not to disturb animals. For other repair work, the Kenya Forest Service (KFS) and Kenya Wildlife Service (KWS) should be consulted to ensure least possible disturbance.

13.5 Impact Analysis

13.5.1 Screening of Potential Impacts

Tables 13-4, 13-5 and 13-6 present the potential environmental impacts from planned project activities. This matrix identifies all possible impacts on the environment. However, management of these impacts was presented separately in the Environmental Management Plan of the EIA document).

Table 13-3 indicates the meanings of the various impact indicators used in Tables 13.4–13.6.

Table 13-3: Legend for Impact Indicators used in Environmental Impact Matrices

Legend of Impacts			
A	Adverse	**+**	Positive
P	Permanent	**T**	Temporary
W	Widespread	**L**	Localized
C	Cumulative	**S**	Significant
?	Unknown	**I**	Intermittent
N	Negligible		

13.5.2 Design and Location Impacts

Note: See Table 13-3 above for the legend identifying the impact indicators used in the following table.

Table 13-4: Design and Location Impacts

Design and Location Impacts				
Environmental Issue	**Impact Indicator**	**Positive Impact**	**Adverse Impact**	**Other Concerns**
Human Environment				
Local population and settlements	+, P, L, S	- Settlements along the way of the pipeline will benefit from availability of domestic water - Less time spent collecting water therefore more time for other activities, including relaxation	- Displacement of around 200 households and 400 houses is expected in the Mwache Dam and Reservoir areas. Please refer to the project RAP for more information	- Along some water vending points, north of Arabuko-Sokoke cattle also visited the booths. If adequate measures are not used, may contaminate water. - Present Baricho Pipeline to Kakuyuni also used in emergencies (drought situation) to source water for wetlands in Arabuko-Sokoke. ▫ Therefore, need to consider additional animal demands, both cattle and wildlife, or identify alternate plan for their water needs

Design and Location Impacts				
Environmental Issue	**Impact Indicator**	**Positive Impact**	**Adverse Impact**	**Other Concerns**
Livelihoods and household economics	+, P, W, S A, L, ?	- Improved health with better quality, more and reliable water supply would result in improved health, lower risk of waterborne and water wash diseases, resulting in: ▫ reduced person day loss from illness – increasing days for work ▫ reduced illness in children and women would result in healthier adults in the next generation, improving ability to work. ▫ reduced diarrhoeal disease incidences in children result in better mental development, therefore better performance in academics and increased possibility to better quality of life - Less time spent collecting water therefore more time for possible livelihood activities	- If in areas where 100% household connection in all urban is targeted is successful, it could mean a loss of income to water vendors. However, while this may occur this is expected both to be much lower in impact compared to the overall health and other benefits from the project.	
Waterborne diseases	+, P, W, S A, P, W, S	- Improved health with better quality, more and reliable water supply result in lower risk of waterborne	- Risk of contamination of water during distribution to settlements along the transmission pipeline receive water	- Along some water vending points, north of Arabuko-Sokoke cattle also visited the booths. If adequate measures not used, may contaminate water

Design and Location Impacts				
Environmental Issue	**Impact Indicator**	**Positive Impact**	**Adverse Impact**	**Other Concerns**
Vector and other water related diseases	+, P, W, S A, P, W, S	- Improved health with better quality, more and reliable water supply result in lower risk of waterborne and water wash diseases	- Presently all urban areas suffer from inadequate storm water drainage and sewage management. More water will result in a greater generation of sewage, and in squatter settlements it may also result in water being discharged on roads. This will reduce local sanitary conditions and give rise to vector habitats. - Possible increase in certain diseases due to construction of Mwache Reservoir – schistosomiasis /bilharzia. This may also need to be considered if a barrage is built on Tana River.	- While there are tsetse flies in the area – Shimba, Gongoni and Tsavo – there is no reported case of sleeping sickness yet. However, there will be a need to monitor for the disease, especially during the construction and O&M stage when workers live and work in the area.
Nutrition and other health concerns	+, P, W, S A, P, L, S	- Reduced diarrhoeal disease incidences in children and adults result in improved health	- The construction of the Mwache Reservoir may result in reduced habitat for certain fish species which are a part of the local diet, like the mud fish	

Design and Location Impacts				
Environmental Issue	**Impact Indicator**	**Positive Impact**	**Adverse Impact**	**Other Concerns**
Safety	A, L, I/T, S		- Worker safety if adequate precautions not used for management plan, especially for Baricho as there are Nile crocodiles during floods and rainy season when the river flow is high, especially at night - In adequate dam safety measures leading to a disaster, especially downstream - If a barrage is built on Tana River there is a risk of larger number of resident crocodiles on it, and perhaps also hippopotamuses	- There are also some concerns about Mwache Reservoir being infested by crocodiles and hippopotamuses. While the possibility of these species is dependent upon their existence in the area from where they can migrate, and no such natural habitat is known; due to the local population's concerns this needs to be considered. The likely possibility of such an even could be if there are any breeding farms within a distance that the crocodiles can move to the reservoir and escape from their enclosures. If this be the case, since crocodiles and hippopotamuses mainly move at night, it is not necessary that they will be easily seen when relocating themselves. It is however dependent upon the distance they can travel without water and perhaps food.
Archaeological, paleontological sites and aesthetics	?			- So far no archaeological or paleontological sites have been identified along project locations. However, there is always a possibility of chance finds and will have to be managed during construction
Cultural spaces	?, P, A, S		- Given the existence of Kaya forests in the Coast Province, there is a need to carefully develop the alignment of pipelines to ensure that neither are the Kayas or access to them are impacted.	- No Kaya site has been identified at the site of the intakes identified so far.

Design and Location Impacts				
Environmental Issue	**Impact Indicator**	**Positive Impact**	**Adverse Impact**	**Other Concerns**
Conflicts of use	A, C, L, W, P		- Possible concern with animals – watering holes along existing Mzima Pipeline, new pipeline may not have it - People through whose land pipelines pass may expect a share, will need to allocate - Cumulative impacts – the Tana River schemes, for example, could conflict with aquatic and downstream user needs	- Climate change concerns of decreasing availability of water, and riparian cultivators, and concern of agrochemical return flows
Economic systems				
Agriculture	C, A, L, W, S		- Long-term impacts may occur – if and when irrigation projects are considered. If so, amount of water required for drinking and environmental flows restricts the amount available for agriculture.	- Existing agriculture practices in themselves are a constraint on the project as they will impact water quality through return flows.
Industries	A, P, C, W		- Probable in the long term some conflicts, if there is a plan to industrialize the area – as suggested in Kenya Vision 2030. In such a case, the amount of water required for drinking and environmental flows may restrict available for industry.	
Mining				- Mining activities in themselves could damage the aquifer or impact river hydroponics downstream. Discussions with KFS and NEMA officials identified catchment degradation and river sand mining as probable concerns for river flows, and changing river hydraulics. This may have an impact on both water availability and quality.

Design and Location Impacts				
Environmental Issue	**Impact Indicator**	**Positive Impact**	**Adverse Impact**	**Other Concerns**
Tourism	+, W, L, S, P	- A constraint identified for tourism is the lack of sufficient potable water, which will hinder growth of the sector. Given the large contribution of coastal tourism for the provincial and national economy, this will be work well to support the sector		
Fisheries	A, L/W, C, P, S/N		- In the case of Mwache, there could be some concern, if certain local species habitat – especially as now the river has become a seasonal river. Discussions in the field also identified mudfish habitats. These may be affected due to the reservoir - As there are likely to be more reservoir projects, especially on Tana River	
Forestry				- Impacts from the project are likely to be negligible, if any on the forestry sector - However, increasing degradation of the catchment including for charcoal cultivation will impact source sustainability in the long run

Design and Location Impacts				
Environmental Issue	**Impact Indicator**	**Positive Impact**	**Adverse Impact**	**Other Concerns**
Natural resource use	A, L, P,		- The project is unlikely to have any major impact on existing natural resource use. Nonetheless, some areas like Mwache given that there will be impounding of water users of the local water resources, such as for fishing and washing are likely to be impacted. - Another concern due to impounding is likely to be the land which in some areas is being used for grazing will no longer be available. These issues would need to be identified clearly and compensated in the final RAP for the dam.	
Infrastructure				
Water and sanitation	+, L, P, S	- Overall there will be an improvement in the availability of water. However, this project is for bulk water supply and therefore limited to only increasing the overall availability of water		
Waste	A, C, W, S		- Likely increase in sewage and perhaps also an increase in drainage which will be a secondary and indirect impact and will need to be addressed separately.	

Design and Location Impacts				
Environmental Issue	**Impact Indicator**	**Positive Impact**	**Adverse Impact**	**Other Concerns**
Physical Environment				
Water Resources				
River system and environmental flows	A, L, W, S, C		- There would be a decrease in the flow of the Tsavo, due to increased abstraction from Mzima Springs. Given that other springs in the area are already drying up, this could become an issue in the future. This would be a part of a large and cumulative impact of various activities. Therefore a catchment approach for the management of the area would be required to address the issue. This would need a greater understanding of the area, and only further studies in the area can identify an appropriate approach for the issue.	- In itself the project is likely to have very little impact on the river system or flows, except perhaps for Mwache Reservoir, which according to discussions is already facing increasing degradation. However, cumulative outcome of other projects and water abstraction with this project could be a concern in the long run - Another concern that could become an increasingly important issue is that of catchment degradation. The combination of catchment degradation and climate change predictions of rainfall variability, changes in temperature and glacier melt may result in a decrease in overall availability of water. This added to a degraded catchment, where there is insufficient groundwater recharge, increased runoff and also a larger sediment load in existing surface water systems would in the long run have an impact on the total water available for consumption. This is likely to be further exacerbated due to the large livestock population in the area, and an increasing demand for agricultural lands.
Wetlands & local water bodies	?			- At present, given that the possible water supply plan for Tana River and Lamu counties is still not completely identified, impacts on wetlands and local water bodies is difficult to estimate

Design and Location Impacts				
Environmental Issue	**Impact Indicator**	**Positive Impact**	**Adverse Impact**	**Other Concerns**
Delta and estuaries	A, C, L, S,		- Cumulative impacts of projects on Rive Tana may have an impact in the long run on the delta, which is a Ramsar-designated wetland. Therefore, if Tana River is identified for supplying water to Tana River County and Lamu County, the environmental flows for the downstream must be considered within the framework of the overall water use plans. This is however beyond the present scope of activities of a water supply master plan. Therefore, it is recommended to undertake required environmental flow studies and incorporate required design modifications for all activities to be undertaken on the Tana River.	
Groundwater				- Need to consider the small aquifers near Lamu carefully, especially as there is increasing encroachment upon the sand dunes which are considered to be an integral part of the aquifer's catchment
Water quality	+, W, P, C A, W, P, C	- With increased availability of reliable and adequate domestic water there is a likelihood that pumping the groundwater may decrease. This would reduce the risk of salinity ingress in the coastal areas	- Depending upon the proposed waste management plan for desalination plants, if used water quality of both fresh and marine areas may be adversely impacted - Insufficient wastewater and drainage management in settlements, once domestic water is available regularly there is likely to be greater discharge of sewage and drainage water which may find its way into local water bodies, seep into aquifers or contaminate the sea and coasts	

Design and Location Impacts				
Environmental Issue	**Impact Indicator**	**Positive Impact**	**Adverse Impact**	**Other Concerns**
Land Resources				
Soil quality	A, L, P		- Degradation of soil due to insufficient wastewater and drainage management in settlements, once domestic water is available regularly	
Natural Environment and Ecosystems				
Terrestrial				
Fauna	A, L, W, C, S		- With the emphasis in Kenya Vision 2030 to increase land under agriculture, number of industries and mining activities, climate change projections and issues in the long run there could be some conflict in use for water that may impact Baricho and Mzima/Tsavo. - Infrastructure location in IBAs disturbing the habitat, either by their location or due to waste discharge - Some localized disturbances may also take place if adequate precautions are not taken. This could include habitat of resident bird species at the site of infrastructure development. For example, at Baricho there were a large number of nesting weaver birds, especially in a few trees. Similarly, a number of swallows including mosque swallows were also noted at the site. - Disturbance to birds, both migratory and residents due to light pollution.	- There could be some issues about elephants breaking the pipeline if it is not dug sufficiently deep, especially during drought seasons. This is of greatest concern for Mzima. However, may also be applicable for the Baricho Pipeline if the system is to pass through elephant habitats. It is understood that there are some elephant corridors upstream of the area, and prior to fencing Arabuko-Sokoke, the forest elephants used to regularly visit the river. Therefore, it would be prudent to consider measures for Tsavo pipeline laying also for Baricho.
Flora	A, P, W, C, S		- Degradation of the environment if pipeline goes through important ecosystems, such as the Arabuko-Sokoke	

Design and Location Impacts				
Environmental Issue	**Impact Indicator**	**Positive Impact**	**Adverse Impact**	**Other Concerns**
Aquatic Environment				
Freshwater ecosystem	A, P, W, C, S		- There could be concerns of contamination from drainage and sewage water with more water available and insufficient wastewater management - Conflict with outer users, so reduced water availability	Presently there is insufficient information on environmental flow needs of identified river systems, yet there are a number of development activities planned for these rivers. Therefore, in the future, given these plans and possible climate change impacts, freshwater ecosystems may degrade, both adversely impacting the project, and becoming a constraint for further resource development and ecosystem needs.
Marine ecosystems	A, W, C, S, P		- Concern of drainage and sewage water contamination with more water available and insufficient wastewater management exist. This could degrade the marine ecosystem as sewage and drainage water is washed into marine systems. Some studies on mangroves identify the change in species in mangroves near Mombasa due to the discharge of untreated sewage in them. - Mwache Reservoir may result in downstream changes for mangroves if nutrition or freshwater availability decreases - Damage to habitats of turtles due to drainage and wastewater on nesting grounds or location of desalination plant alongside	

Design and Location Impacts				
Environmental Issue	**Impact Indicator**	**Positive Impact**	**Adverse Impact**	**Other Concerns**
Sensitive areas	A, P, W, C, S		- Desalination plant site location will need to be considered very carefully, as large sections of the coast have important biodiversity sites. There is a need to consider the waste brine disposal from it - Another concern will be the currents and where the brine from the desalination plant may flow into. This may also violate international conventions that discuss contamination and disposal of waste into marine environments or that may flow into marine environments - The cumulative impacts on the Tana Delta with too much water withdrawn from it, if the barrage is an identified source for water to Tana River County and Lamu County considering other planned projects - Impact of barrage on certain aquatic species that travel upstream, and are know to be there in the river could be a concern - Drainage and sewage release into the sea and contaminating important biodiversity sites	
Fly path, corridors, etc.	A, P, W, I/P, S		- Blocking or disruption of free animal movement in the area where the reservoir and barrage is built, or in areas where pipelines pass overland.	- Danger to infrastructure from animals – especially in dry season or droughts.

Design and Location Impacts				
Environmental Issue	**Impact Indicator**	**Positive Impact**	**Adverse Impact**	**Other Concerns**
Other environmental issue	A, P, W, C, S		- The construction of the Mwache Reservoir will cover a large expanse of area where there is natural vegetation of trees and bushes, although not very dense. This if not cleared before hand will result in slow decomposition once the dam is filled up. In turn this will result in release of greenhouse gasses, contributing to increased carbon in the atmosphere and climate change	
Coastal zone	A, P, C, S, W		- Mwache Reservoir is likely to have an impact on the nutrition that is received downstream. This may impact the mangrove forests in the area, which are dependent on the upstream nutrition that comes with sediments - If a desalination plant is constructed, depending upon the location of the disposal of the desalination plant's brine mangroves may on the coast may be impacted - Increase contamination of coastal area due to drainage and sewage releases, making them unfit for any other use - Due to any damage to mangrove on the coast that protect the area coastal erosion may occur	

13.5.3 Construction Impacts

Note: See Table 13-3 above for the legend identifying the impact indicators used in the following table.

Table 13-5: Construction Impacts

Construction Impacts				
Environmental Issue	**Impact Indicator**	**Positive Impact**	**Adverse Impact**	**Other Concerns**
Human Environment				
Local population and settlements	A, T, L		- Disturbance to local population due to construction activities, movement of vehicles, noise or from labour. While laying the pipeline, depending upon the final location of the pipeline settlements along the route of the pipeline will be affected. - Settlements near the planned dam during the construction of the Mwache Reservoir are likely to be affected from construction activities. - Conflict with local population due to restriction in construction sites and access to some sites for them - Accidents from vehicles and poor construction site management - Increase water stagnation and drainage problems due to construction activities, poorly managed labour or construction sites and vehicles being cleaned and serviced in the area - Increased traffic at sites for material procurement and transport routes to the construction site, disturbing population	

Construction Impacts				
Environmental Issue	**Impact Indicator**	**Positive Impact**	**Adverse Impact**	**Other Concerns**
Livelihoods and household economics	P, L, T A, T, L	- Except for skills not available locally all labour will be local, it is expected that there will be a overall temporary positive impact to the local economy	- There could be reduced access to grazing lands, or agricultural lands along the route of the pipeline due to construction labour camps – if any, digging and other construction related activities.	
Waterborne diseases	A, P, L		- Increase water stagnation and drainage problems due to construction activities, poorly managed labour or construction sites and vehicles being cleaned and serviced in the area - Where there are labour camps, without adequate drainage and sanitation, they could create disease both for labour and local population	
Vector and other water related diseases	A, P/T, L,		- Increase water stagnation and drainage problems due to construction activities, poorly managed labour or construction sites and vehicles being cleaned and serviced in the area - Health problems due to water stagnation at sites, resulting in breeding sites for disease vectors - Poor rehabilitation of sites – construction, labour, borrow sites, leading to habitats for disease vectors - Poor design and waste management systems may also create habitats for certain disease vectors	

Construction Impacts				
Environmental Issue	**Impact Indicator**	**Positive Impact**	**Adverse Impact**	**Other Concerns**
Nutrition and other health concerns	A, L, T		- Increase in disease due to influx of migrant labour - There are tsetse flies in Tsavo. While there are no records of sleeping sickness in the area, these flies can still bite and create irritation to the workers in the area	
Safety	A, P/T, L		- Occupational Health and Safety. Construction hazards due to inadequate management of site, access to site for all people including local population not working at site, and inadequate protection gear and training to labour. - In areas where work is in/next to forests and in Tsavo animal attacks could be a concern. The major animals to be careful of are elephants, rhinoceros, buffaloes, and perhaps lions and leopards. In Baricho specifically, there could be a concern of crocodiles; Mzima crocodiles and hippopotamuses - Although there is the tsetse fly in the area, there is no known sleeping sickness. However, while working in tsetse fly areas there will be some likely annoyance from bites.	
Archaeological, paleontological sites and aesthetics	A, L, P,?		- Chance findings – archaeological sites. - Scaring of landscape due to borrow sites, such as in hills or from firewood collection	

Construction Impacts				
Environmental Issue	**Impact Indicator**	**Positive Impact**	**Adverse Impact**	**Other Concerns**
Cultural spaces	A, L, P, ?		- The Coast Province has a number of sacred sites – the Kayas and other cultural sites scattered all over the province and some of them may be in the probable alignment of these sites.	
Conflicts of use	A, L, T		- Conflict with local population on resources with labour camps – if any - Conflict with local wildlife in camps in Tsavo on use of local resources, water and firewood/charcoal - Material storage at construction sites may conflict with other land uses	
Economic Systems				
Agriculture	A, L, T		- Access to farms due to construction sites or material storage	
Mining	+, L, T	- Some material will be required for the various construction activities. Therefore there is likely to be a positive impact from the construction related activities.		
Tourism	A, L, T		- In Tsavo, during the laying of the pipeline there could be some areas which may become inaccessible to tourists.	
Natural resource use	A, L, T/P		- In some area there could be increased pressure on forests/scrub land due to labour needs for energy	

Construction Impacts				
Environmental Issue	**Impact Indicator**	**Positive Impact**	**Adverse Impact**	**Other Concerns**
Infrastructure				
Transport	A, L, T/P		- Congestion of routes due to movement of transport vehicles to construction sites from material procurement sites could be an issue. This may be of greater concern as many roads are in poor condition and therefore may also degrade further	
Water and sanitation	A, L, T/P		- Since new pipelines in some areas may run parallel to the earlier ones, construction work and transportation lines could damage existing networks	
Waste	A, L, T/P		- There will be waste from construction sites, labour camps and at borrow and quarry areas	
Physical Environment				
Water Resources				
River system and environmental flows				- None of the work identified so far will work in any river at present. However, depending upon what is planned for Lamu there could be some impacts. This will have to be considered once the possible water supply sources are finalized for Lamu
Wetlands & local water bodies				- None of the work identified so far is expected to have an impact on any wetland. However, depending upon what is planned for Lamu there could be some impacts. This will have to be considered one the possible water supply sources are identified for Lamu

Construction Impacts				
Environmental Issue	**Impact Indicator**	**Positive Impact**	**Adverse Impact**	**Other Concerns**
Delta and estuaries				- None of the work identified so far is expected to have an impact on the deltas or estuaries at present during construction. However, depending upon what is planned for Lamu there could be some impacts. This will have to be considered one the possible water supply sources are identified for Lamu
Groundwater				
Water quality				- None of the work identified so far is expected to have an impact on water quality. However, depending upon what is planned for Lamu there could be some impacts. This will have to be considered one the possible water supply sources are identified for Lamu
Atmospheric Parameters				
Air	A, T, L, I		- Air pollution from vehicles and machinery, construction activities and at quarry sites - Dust and sand flying from trucks during transportation, and quarry and borrow sites	

Construction Impacts				
Environmental Issue	**Impact Indicator**	**Positive Impact**	**Adverse Impact**	**Other Concerns**
Noise	A, T, L, I		- Poorly maintained vehicles or heavy drilling activities resulting in high level of noise or vibration - Noise from generators and other construction activities like trucks, etc., passing the area	
Land Resources				
Soil quality	A, P/T, L, C		- Waste, labour camps and material storage could all lead to the contamination of soil at the construction sites and camp sites. - In adequate management of drainage and sanitation will reduce soil quality - Accumulation of water and increased soil toxicity at borrow sites - Accidents and spillage resulting in toxicity and damage to the soil	
Erosion/ compaction	A, T/P, L		- Erosion from borrow sites - Compaction of soil/soil erosion for access to various sites and to quarries by trucks	

Construction Impacts				
Environmental Issue	**Impact Indicator**	**Positive Impact**	**Adverse Impact**	**Other Concerns**
Natural Environment and Ecosystems				
Terrestrial				
Fauna	A, T/P, W/L, C		- Plantation activities resulting in alien species introduction, degrading the local environment resulting in changes in habitat of local species - Destruction of vegetation by vehicular movement and clearance for paths, storage of construction material and for sourcing material resulting in changes in habitat of local species - Risk of species falling into trenches built for laying pipes and may either be injured or killed	
Flora	A, T/P, W/L, C		- Destruction and removal of vegetation for fuel for labour camps - Plantation activities resulting in alien species introduction, degrading the local environment resulting in changes in habitat of local species - Destruction of vegetation by vehicular movement and clearance for paths, storage of construction material and for sourcing material resulting in changes in habitat of local species	

Construction Impacts				
Environmental Issue	**Impact Indicator**	**Positive Impact**	**Adverse Impact**	**Other Concerns**
Aquatic Environment				
Freshwater ecosystem	A, T/P, W/L, C		- Sand is often mined from riverbeds. Usually from seasonal rivers when it is dry. However, these could be habitats of species habituated to the environment, which may be damaged or destroyed. - Rivers beds, even in seasonal rivers are important sources of various food and other products for aquatic species when flooded. These may be reduced or destroyed due to sand mining in rivers	
Marine ecosystems	A, P, W/L, C		- If raw material used includes the use of coral blocks for building material, damage to local ecosystem may occur	- No work at present is expected to impact marine ecosystems adversely. However, depending on what is planned for Lamu, there may be an impact during the construction phase
Sensitive areas	A, T, L		- For Mzima, there will be work in Tsavo, with labour camps in the park itself. This will disturb animals within whose territories the labour camps or the pipeline laying is	
Fly path, corridors, etc.	A, T, L		- Construction at the time of animal migration that disturbs the migratory routes and patterns	
Coastal zone	A, T, P, C		- If raw material used includes the use of coral blocks for building material, long-term degradation of coastal zone could be expected as the corals are largely safeguards against coastal erosion	- No work at present is expected to impact coastal zone adversely. However, depending on what is planned for Lamu, there may be an impact during the construction phase

13.5.4 Operation and Maintenance Impacts

Note: See Table 13-3 above for the legend identifying the impact indicators used in the following table.

Table 13-6: Operation and Maintenance Impacts

Operation and Maintenance Impacts				
Environmental Issue	**Impact Indicator**	**Positive Impact**	**Adverse Impact**	**Other Concerns**
Human Environment				
Local population and settlements				- Along some water vending points, north of Arabuko-Sokoke cattle also visited the booths. If adequate measures are not used, may contaminate water. - Present Baricho Pipeline to Kakuyuni also used in emergencies (drought situation) to source water for wetlands in Arabuko-Sokoke. Therefore, need to consider additional animal demands, both cattle and wildlife, or identify alternate plan for their water needs
Waterborne and vector diseases	A, W, P, S		- Leaks in the system at the time of distribution may lead to contamination of drinking water - Outlets at settlements along the pipelines are possible points of entry for contamination, as they are often at ground level, without adequate drainage or protection from animals and are also in many places leaking.	- Rainwater Harvesting (RWH) may be a feasible option in some areas, especially for remote, isolated and rural areas. However, some health concerns may arise from mosquito vectors, poor maintenance of system resulting in contamination of water tank or aquifer or from the growth of blue green algae – cyanobacteria.

Operation and Maintenance Impacts				
Environmental Issue	**Impact Indicator**	**Positive Impact**	**Adverse Impact**	**Other Concerns**
Safety	A, I, L		- Worker safety at Mwache Reservoir may be a concern, especially if any crocodiles accidentally reach the area - In Tsavo while inspecting the pipeline or carrying out any repair work there could be accidents with wild animals	
Physical Environment				
Water Resources				
Delta and estuaries	A, W, L, C		- Improper disposal of waste disposal for the desalination plant, if finally built depending upon its location - Accidents without adequate or timely clean up may result in contamination of the area for the desalination plant, if finally built depending upon its location	
Groundwater	A, L, P, C		- Improper disposal of waste disposal at intakes or at the reservoir - Accidents without adequate or timely clean up may result in groundwater contamination	
Water quality	A, P/T, L		- Improper disposal of waste disposal at intakes or at the reservoir - Accidents without adequate or timely clean up may result in contamination of water in and around the area. This is most likely a concern for Mwache and Baricho	- Waste – either agriculture or sewage and sanitary waste from the catchment finds its way into the Mwache Reservoir it will impact the area adversely

Operation and Maintenance Impacts				
Environmental Issue	**Impact Indicator**	**Positive Impact**	**Adverse Impact**	**Other Concerns**
Land Resources				
Soil Quality	A, L, P/T		- Improper disposal of waste disposal at intakes or at the reservoir is likely to have an adverse impact on the soil of the area - Accidents without adequate or timely clean up may result in contamination of soil in the area	
Natural Environment and Ecosystems				
Terrestrial				
Fauna	A, I, L		- Disturbance to local species during regular operation and maintenance. This may be most likely in Tsavo and where there is a need to enter forests for any activity	
Aquatic Environment				
Freshwater fauna	A, L/W, P/T		- Improper disposal of waste disposal at intakes or at the reservoir. This may have an impact on the local biodiversity - Accidents without adequate or timely clean up may result in contamination of water in and around the area.	
Freshwater flora				- Depending on the plan for Lamu and Tana River counties, freshwater ecosystems may be impacted. This could be due to disposal of waste – desalination plant or a barrage, specifically

Operation and Maintenance Impacts				
Environmental Issue	**Impact Indicator**	**Positive Impact**	**Adverse Impact**	**Other Concerns**
Marine ecosystems				- Depending on the plan for Lamu and Tana River County marine ecosystems may be impacted. Disposal of waste, etc., into the sea for desalination plants could be one area of concern.
Sensitive areas	A, I, L		- Any maintenance in forest or Tsavo areas will disturb animals, this is especially a concern at the time of high animal activity, such as during animal/bird migration or breeding time is likely to impact the local ecosystem and species.	
Coastal zone				- Depending upon what is planned for Tana River County and Lamu County, the coastal zone may be impacted. For example, a desalination plant along the coast may impact species or with poor disposal of waste also impact the coast

13.6 Recommendations

The Coast Province has a large number of ecologically important areas and eco sensitive areas, including internationally identified conservation zones. Part of the Coast Province fall under the Coastal Forests of Eastern Africa or the Eastern Afromontane conservation hotspots. Also, the Kenyan coast is part of the Eastern Africa Marine Ecoregion (EAME), which starts in Somalia and ends in South Africa. Many sections of this project themselves either passes through or near two important conservation areas – Tsavo West and Arabuko-Sokoke.

The Coast Province also has a number of sacred forests – the Kayas. Equally important, there are a number of UNESCO World Heritage Sites, and some sites on UNESCO's tentative list of potential World Heritage Sites. Tana Delta is a Ramsar site. Given this, and the fact that some project components like the Mwache Reservoir and some possible options for Lamu and Tana River counties are likely to have more extensive impacts, this project has been categorized as a World Bank Category A project. Therefore, an EIA will be required as a part of the detailed design of the project and the alignment of identified infrastructure.

While there are design and location impacts from individual project components and activities, most of the impacts are expected during the construction period. Most of these impacts are manageable with good housekeeping and appropriate safety measures implemented. On the other hand, there are some design related issues that could have permanent impacts either due to design and location issues, or due to cumulative impacts from other projects. These have been discussed in detail in the impact and management sections of the report. However, there are some other issues that may not be directly linked to the impact of the projects but need to be considered either for the sustainability of the source in the long term or due to cumulative impacts from various activities. These possible linkages are discussed here.

Perhaps the most important issue is of possible long-term sustainability of resources. Kenya Vision 2030 and other development plans are likely to result in increased abstraction from the river system – such as the planned dams on Tana River. This will have a downstream impact, and is likely to affect all activities below the dam. In case water supply is considered from barrages on the river, the viability may need to considered, especially as a Ramsar site, the Tana Delta lies downstream.

Another very important issue is that of catchment management. Discussions with officials from KFS and NEMA highlighted that, the now seasonal Mwache River, was once a perennial river. This has largely been attributed to the degradation of the catchment. Similarly, a number of springs in Tsavo have either dried up or are starting to dry up, creating greater pressure on the Mzima Springs. The catchment of the Mzima Springs in areas is considered to be showing signs of degradation. Information on both the Athi-Sabaki and Tana River systems show increasing degradation of the catchment, which in turn will impact all water resource projects dependent upon these systems. Considering that some of the planned sources for this project and a number of other planned Kenyan projects will be dependent upon the waters of these two systems, catchment degradation will pose a risk to the long term sustainability of the projects. Furthermore, poor agricultural practices, industrial pollution, deforestation and mine management are resulting in increased sedimentation and toxicity of surface water and groundwater sources. This is likely to create an even greater pressure in the existing resources and increase the costs of providing adequate and clean water in the future.

Most of these issues are also likely to be further exacerbated by impacts of climate change. Predictions of increased temperatures, more severe droughts and floods, and the melting of glaciers that feed the rivers and most of their tributaries in the Coast Province are some of the identified concerns. These predictions suggest that in the long run there may be reduced flows in many rivers. This is likely to further add to the existing stress in the province, especially as large tracts of it fall under arid and semi arid lands; with agriculture is an important source of livelihood in many areas. This would obviously result in the need for more water for irrigation, even if the present areas under agriculture is to be maintained; increased need to provide for water for wildlife while continuing to provide for planned expanding industrial base and human and cattle needs.

Considering all these impacts perhaps there is a need to work towards identification of comprehensive catchment management for river systems that look at land management and use plans, water distribution and tradeoffs, while considering climate change impacts. What perhaps will also need to be considered is the management of demand on water from all sectors, and increased efficiency of use.

The CDA has been working on catchment management and has programmes for increasing the vegetation cover through plantation activities. Such programmes are likely to be important to help reduce the degradation of the catchment. Also, they can consider the plantation of firewood lots and tree species that can be used for carving and other handicraft purposes while ensuring planted species are appropriate for different ecosystems. This may ease some of the pressure on existing forests, tree plantations and isolated trees in the catchment.

Coastal and marine ecosystems are another major concern for the area. Not only are these concerns important from the perspective of siting of infrastructure, but also for the disposal of waste from the system, created due to increased availability of water, harvesting of raw materials from the sea, and from increased damming upstream. They are also important from the perspective of preservation of ecosystems and conservation of coastal aquifers. There are many important and high conservation value or protected sites along the coast, or in the ocean adjoining the Kenyan coast, including Important Bird Areas (IBAs). Therefore, disposal of waste – directly from infrastructure like desalination plants or indirectly due to inadequate sewage and drainage management – will degrade these ecosystems. Damming upstream may also result in reduced nutrition and water to mangroves by reducing sediments, and reduced sediments would also result in an increase in coastal erosion. This is a major concern both for the settlements along the coast and for tourism, much of which is coastal tourism in the province. Equally, harvesting of corals or degradation of mangroves may result in increased vulnerability of coastal aquifers to salinity ingress. This will be further compounded by any sea level rise that may occur due to climate change. Therefore, both for the local and national economy and for preservation of the quality of aquifers, it is important to consider the conservation of coastal and marine ecosystems.

There are also likely to be some increased demand for water for other not domestic purposes, from the piped system. These include water for livestock and, in case of Arabuko-Sokoko, for elephants and other species. While it would be difficult to actually design such systems as part of the master plan, which focuses on domestic water needs, species needs must also be considered, as the same sources are already being used for both. Therefore, alternate water supply systems, or water points for livestock and emergency water needs of wild species in Arabuko-Sokoko needs to be worked at along with the KFS, KWS and local populations in each area.

Domestic water handling for ensuring that there is no contamination of treated water in the pipeline needs to be considered for all settlements that will receive water from the main pipeline. There are many leakages and other possible sources of contamination at many of these points or water vending booths. Therefore, appropriate handling and management must be considered through IEC for ensuring safety of water quality.

Considering the various sustainability issues and possible impacts of other activities or resource degradation on the project a few studies are also suggested. These are:

Assessment of climate change and variability on natural resources in the Coast Province. This should address the impacts of climate change on water resource, its availability and changes in needs and with seasonal changes. The study should also look at possible competition and conflicts that may arise due to the impact of changing and variably climate change.

Given the various development activities planned in the area, many of which will result in an increased demand and pressure on natural resources; especially water resources, there is a need to examine the cumulative impact of these activities in the Coast Province. Therefore it is suggested that:

- A study on the overall impact of various development activities in the Coast Province be undertaken. The study should look at existing natural resources, future needs and demands on natural resources due to development activities, identify resource constraints to development and suggest appropriate/sustainable development pathways that would address economic growth and the management of existing resources, including their improved health. This should also include existing traditional economic systems, such as livestock rearing and expected demands on natural resources on them, to provide a comprehensive understanding of resource constraints and sustainable management options.

- A study on the water resources and impact of planned development activities for the province. As there are a number of other development activities that are planned for the existing water resources, which are also sources for the WSMP, it is important to understand the total water available for use and existing environmental flow needs. Presently, there are no such studies available for the two main rivers that are being considered as sources – the Tana and Sabaki-Athi rivers – yet there are a number of development activities planned for both river systems. Given the existing pressures on the resources and the climate change predictions it would be important to understand the total sustainable and wise use of these resources, to work within the constraints. Therefore, there is a need to understand the limits to which these river systems can be utilized for development activities and as sources of domestic water.

Study to understand the causes and impacts of coastal erosion. This study should try and assess what are the major causes of coastal erosion in the area along with identifying management actions and needs. The study should assess the impact of coastal erosion on infrastructure, specifically water supply and sanitation infrastructure and coastal aquifers due to the coastal erosion. Along with its assessment of impact on coastal water supply and sanitation infrastructure, the study should also try and identify required management actions to protect the infrastructure.

Concerns of catchment degradation seem to be a major issue that can constraint the overall availability of water resources, both as they could lead to the degradation of quality and also impact the overall availability of the resource, due to increased runoff, etc. In the long run, therefore, catchment can result in constraining the availability of the resource. Therefore, a study that examines the current situation vis-à-vis catchment health, major sources of degradation and the impact of current and future development plans on the health of the catchments of the Coast Province, needs to be carried out. It is suggested that the study especially considers the concerns with reference to the impact of water resources and drinking water needs in the province; specifically those that are likely to have an impact on the WSMP. The study must also consider possible future impact on identified catchments due to climate change predictions and existing traditional livelihood that also result in increased pressure on the identified catchments.

Coastal ecosystem health is an important issue when it comes to protecting the coastline from erosion, coastal aquifers and is also important for sighting of infrastructure such as desalination plants and disposal of waste. These ecosystems are also important sources of livelihood – both as tourism and fishing, which if degraded would result in increased pressure on land resources. While there is information on coastal ecosystems and details of some of the ecologically significant ones; it would also be important to understand measures required to ensure the health of these ecosystems, both from coastal and inland activities. Therefore, it is suggested that a study that understands coastal ecosystems from these perspective also be considered.