Ministry of Water, Sanitation and Irrigation

Athi Integrated Water Resources Management and Development Plan

KENYA WATER SECURITY AND CLIMATE RESILIENCE PROJECT

Implementation Support Consultancy (ISC) to Support Strengthening of Water Resources Management and Planning

August 2020

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FINAL

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Implementation Support Consultancy (ISC) to Support Strengthening of Water Resources Management and Planning

Prepared for:

Ministry of Water, Sanitation and Irrigation

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E

Executive Summary

Water Resources Authority

Executive Summary

E1. Background, context and objectives

The water resources of Kenya, a water-scarce country, are currently threatened on various fronts. Addressing this, demands capacity for comprehensive water resources management and planning, coupled with extensive investment in climate resilient water infrastructure.

In order to align the water sector in Kenya with Kenya's 2010 Constitution, the 2016 Water Act was promulgated in Sep 2016. The Act recognises that water related functions are a shared responsibility between the National Government and the County Governments. To give effect to the constitutional requirement for devolution of functions from National to County level, the Government of Kenya has embarked on a wide-ranging water sector reform programme. The Act prioritises water user categories, outlines an array of institutional shifts and established the new Water Resources Authority to protect, conserve, control and regulate the management and use of water resources through supporting the Cabinet Secretary in the establishment and implementation of a National Water Resource Management Strategy. WRA responsibilities include the formulation and enforcement of procedures and regulations, policy development, water abstraction permitting and collecting of water use fees. The critical importance of proper water resources planning and management is evident in relation to Kenya's Big Four Agenda: Food security, Manufacturing, Affordable universal health care and Affordable housing.

The Government of Kenya received financing from the World Bank toward the cost of implementing the Kenya Water Security and Climate Resilience Project Phase 1 (KWSCRP-1), to be implemented through the Ministry of Water, Sanitation and Irrigation. This Consultancy covers Sub-component 2.2 Strengthening Water Resource Management and Planning of the KWSCRP-1. The overall objective of this Consultancy is to strengthen WRA's capacity in terms of tools, skills and infrastructure to deliver on its mandate for water resource management and regulation in the country. A key set of deliverables under Sub-component 2.2 is the development of six Basin Plans for the six main river basins in Kenya. This document constitutes the Integrated Water Resources Management and Development Basin Plan for the Athi Basin. Integrated Water Resource Management considers the environmental, social and economic aspects of a river basin, and ensures that these aspects are integrated into an overall management strategy. It aims to achieve a sustainable balance between the utilisation, development and protection of water resources.

The main objective of this Plan for the Athi Basin is to provide a clear pathway for the sustainable utilisation and development of the water resources of the Athi Basin. The Plan provides a description of the current state of the basin, establishes a shared vision for the future development of the basin and identifies key strategic areas and actions for effective development and management of the basin's water resources. It draws information from relevant existing plans, sectoral perspectives and strategies, incorporates comprehensive inputs from various stakeholders and presents updated information based on analytical tools developed as part of this Consultancy.

In conjunction with stakeholders in the basin, a Vision for the sustainable development of the Athi Basin was developed, which reads as follows:

A well-managed and protected river basin characterised by good governance, sustainable socio-economic development for all, and a clean, safe and water secure environment, which enhances quality of life from the Aberdares to the Indian Ocean.

E2. Biophysical environment

The Athi Basin has an area of 66 559 km² and borders Tanzania to the south, the Indian Ocean coastline to the east, the Tana Basin to the north and the Rift Valley Basin to the west. Although the Athi Basin only covers about 11% of Kenya's land surface area, it has high economic activity, houses a quarter of the country's population, and hosts the two largest cities in Kenya viz. Nairobi and Mombasa.

The topography of the Athi Basin varies from sea level at the Indian Ocean coastline to approximately 2 600 masl in the highlands of the Aberdare Range. It is divided into 34 sub-basins, 3AA to 3N. The Athi River is the main river in the Athi Basin, draining about 57% (38 170 km^2) of the basin. It is the second longest river in Kenya (after the Tana River) and has a total length of 390 km. The Lumi River originates in the Athi Basin in Kenya along the eastern slopes of Kilimanjaro, and flows across the border into Tanzania, while the Umba River flows from Tanzania into the Athi Basin south of Mombasa. Various smaller rivers drain the eastern coastal parts of the basin and discharge into the Indian Ocean.

The Athi Basin includes major wetland systems including Olngarua swamp, Ol Keju Ado, Ndumato, Mamanga Esokota, Jipe, Mangeri Swamp and the mangrove swamps along the coast. The Athi basin also includes inland freshwater lakes such as Jipe, Chala and Amboseli. These systems are being threatened by overexploitation of surface and groundwater resources, catchment degradation which result in increased sediment loads, land use changes, encroachment and pollution.

The climate of the Athi Basin is primarily forced by the topography of the basin, the proximity to the ocean and to the equator. These factors contribute to the range and variability in precipitation and temperature regimes. The basin is mostly semi-arid land, with a small area of humid land in the upper and middle parts of the basin. Average annual maximum day temperatures vary from 21°C to 39°C across the basin, while the average annual minimum night temperatures vary from 8°C to 22°C. The mean annual precipitation is about 750 mm across the entire basin. The upper and coastal parts of the basin receive higher annual rainfall, up to a MAP of about 1 400 mm, while the annual rainfall reduces to less than 500 mm in the central part of the basin. Two periods of rainfall occur during the year, namely the long rains between March and May, and the short rains from October to November. Under the influence of climate change there has been an increase in extreme climatic events in the Athi Basin.

The climate change analysis which was undertaken as part of this Consultancy showed that projected future precipitation totals are varied across the Athi Basin yet tend to exhibit an increasing gradient in the medium term from the south east to the north west, with mean annual precipitation predicted to increase by 5% by 2050 under RCP4.5. There is also likely going to be increased variability between years and a consistent increase going forward will be unusual. This may result in years that have drought like character adjacent to flood seasons and an increase in the intensity of extreme events. The temperature anomaly also expresses an increase going from the coast to the inland areas for both day and night-time temperatures. These projections are in line with current observed climate trends. The variability of future climate within the basin will necessitate adaptive resilience to significantly different scenarios within a season, inter-annually and by decadal. These challenges include increasing temperature and evaporation rates, increasing intensity of extreme events, unpredictable and irregular weather conditions, increased frequency of droughts, and sea level rise.

Floods and droughts are not uncommon in the Athi Basin; however, the relative extremities of these events in the basin are generally less than floods and droughts experienced in other basins within Kenya.

From the upper reaches of the Athi River to the Tsavo confluence, the vegetation types in the upper and middle Athi Basin transition from forest to woodlands and savannah. The lower part of the Athi Basin is dominated by savannah type vegetation. The Athi Basin is endowed with a wide range of forest ecosystems ranging from the montane forests in the Aberdares, savannah woodlands in the Taita Taveta, Machakos, Makueni areas and the dryland coastal forests. The forests in the basin comprise a critical part of the Athi River hydrological ecosystem and have numerous economic, social, cultural and ecological values, as they provide essential goods and services. Human encroachment is threatening the forest reserves in the basin and there has been a significant loss of vegetation cover.

The Athi Basin hosts various national parks and a national reserve, which provide important wildlife habitats and stimulates tourism in the area.

Land use in the Athi Basin includes urban, industrial and agricultural use. However, many areas are characterised by unsustainable land use.

E3. Socio-economic environment

The total population of the Athi Basin is 13.43 million, which is equivalent to a population density of 202 persons/km^2. The Athi Basin is the basin with the highest ratio of urban to rural population. The rural population is expected to remain relatively unchanged up to 2050, however the urban population is expected to increase by almost 300% by 2050.

Water plays a key role in the Athi Basin and is of critical importance for economic development in the two major urban hubs of Nairobi and Mombasa. Water security is essential for industries, health, tourism and for supporting an improved standard of living.

The Athi Basin is the basin with the largest percentage of formal sector employment, mainly due to the high portion of the population residing in urban areas. There is significant economic activity in the Athi Basin, mainly in the two large economic centres of Nairobi and Mombasa. Despite the above economic activities, the average poverty rate in the Athi Basin is still relatively high. The sources of livelihood vary across the basin, from fishing in the coastal areas to subsistence agriculture and crop and livestock production in the pastoral and farming areas.

There are various levels of food insecurity across the Athi Basin. Although food insecurity prevalence is higher in the rural areas, some of the urbanised counties have many food-insecure households.

The existing water supply in urban areas was designed for a lower population, and water rationing is an issue, with the water demand being far greater than the available supply. At present, about 63% of the urban population in the basin receives piped water provided by Water Service Providers (the highest among the six basins), while 20% are dependent on unimproved water sources. The remaining 17% are supplied from groundwater, which include protected and unimproved sources. Within Nairobi, an unknown number of boreholes are used as sources of local public water supply. The rural population in the basin has a much lower percentage of piped water supply at only 28%.

It has been estimated that approximately 80% of all communicable diseases in Kenya are water-related. Water use conflicts, in which excessive upstream abstraction denies downstream users access to the water resource, are becoming more common in the basin.

E4. Key issues and challenges

The water resources of Kenya are currently threatened by many issues. These include catchment degradation, pollution, inadequate monitoring networks, inadequate integrated basin planning and management, water availability and supply issues, inadequate capacity (number of staff, skills, equipment and finances), uneven spatial and temporal distribution of water resources, anthropogenic encroachment on environmentally sensitive areas, inadequate flood and drought management and various other issues. In addition to the above issues, the Athi Basin has location-specific challenges and issues which, coupled with its unique basin characteristics, are an important consideration for effective water resources management and planning at basin and sub-basin level.

The specific issues for the Athi Basin were identified and prioritised during a two-day workshop with key stakeholders and are presented below under four main categories:

Table E1: Main categories under which key issues in Athi Basin were classified

Biophysical issues	**Climate:** Inadequate flood preparedness; Inadequate drought preparedness; Climate change **Environment**: Poor land use and watershed planning and management; Natural vegetation loss; Biodiversity loss
Socio-economic issues	**Demographics**: Population growth; Education levels; Poverty **Economics:** Economic activity; Employment; Livelihoods **Standard of living**: Water supply and sanitation; Food security; Disaster preparedness
Water resources availability, management and development issues	**Surface water resources**: Spatial and temporal variability; Inadequate protection; Poor water quality **Groundwater resources**: Inadequate protection; Poor water quality **Inadequate water resources infrastructure**: Bulk water supply and transfers; Inadequate Hydropower; Limited formal irrigation schemes; Insufficient water supply schemes; Funding for future projects **Hydromet:** Inadequate monitoring network and monitoring **Water allocation and use**
Institutional issues	**Institutional arrangements**: National policies and legislation; National institutions; Basin and sub-basin institutions; County governments; Partnerships and engagements **Enabling environment** **Transboundary and trans-county issues**

E5. Water availability and water quality

There is significant inter- and intra-annual flow variability in the Athi Basin due to hydrometeorological drivers. The total Athi River natural runoff where it discharges to the Indian Ocean is 1 656 MCM/a. Most of the natural runoff in the Athi River (about 60%) originates from the upper catchment – above the Thwake confluence. A further almost 20% of the total runoff is generated in the incremental catchment between the Thwake and Kiboko confluence. Other rivers in the Athi Basin with meaningful runoff include the coastal rivers e.g. Mwache (126 MCM/a) and Voi (62 MCM/a), the Lumi River (112 MCM/a) draining parts of Mount Kilimanjaro and the rivers (104 MCM/a) draining into Lake Amboseli. The total natural surface water runoff as simulated from all rivers in the Athi Basin equates to 2 555 MCM/a.

The annual groundwater recharge for the Athi Basin was estimated at 2 943 MCM/a, with a sustainable annual groundwater yield of 549 MCM/a. This is significantly higher than the NWMP 2030 sustainable groundwater yield estimate of 305 MCM/a for the Athi Basin. However, whereas the NWMP 2030 assumed sustainable yield as a percentage of recharge (10%), the groundwater assessment which was conducted as part of this Consultancy estimated sustainable yield based on regional and secondary permeability and topography. The eastern part of the basin, next to the coast as well as the most upper part of the basin, have the highest groundwater potential. The lowest groundwater potential occurs in the central part of the basin.

The total current (2018) estimated water demand in the Athi Basin equates to 1 553 MCM/a as shown in Table E2. Most of the water is needed for irrigation and domestic / industrial use in the major urban centres.

Table E2: Current (2018) water requirements in the Athi Basin per main sector

Sector	Total (MCM/a)
Irrigation - Small scale / Private - Large-scale	**1 028** 984 44
Domestic and Industrial - Greater Nairobi - Mombasa, Kwale, Kilifi - Basin-wide	**490** 263 86 141
Livestock	**24**
Other	**11**
Total	**1 553**

The 2018 water balance in the Athi Basin in terms of natural surface water runoff and sustainable groundwater yield, water imports, the ecological reserve and current water demands in the Athi Basin is summarised in Table E3. The current water demand constitutes about 50% of the total water resources available for use. It is important to realise that although the water balance might indicate that the total annual demand is less than the water resources available, supply deficits often occur during dry years and/or the dry season, when the demand exceeds availability of water in the rivers.

Table E3: Athi basin water balance (MCM/a)

	Surface water	Groundwater	Total
Natural / Available water	2 555	549	3 104
Imported water	181		181
Ecological reserve	(156)		(156)
		Total	**3 129**
		Water demand (2018)	1553
		Balance	**1 576**

The scenario evaluations which were undertaken as part of this Study concluded that the planned large-scale irrigation development in the Athi Basin should be significantly reduced, and that only limited large-scale irrigation development can be accommodated, as it is constrained by the availability of water. Furthermore, the scenario analysis highlighted the imperative that water demand management is implemented in all urban areas, while irrigation efficiencies should also be improved. Such a future constitutes the recommended sustainable development future for the Athi Basin. Under this scenario, the total future (2040) water requirement in the Athi Basin is projected as 2 442 MCM/a as detailed in Table E4. This represents an increase of 57% compared to the 2018 water demand in the Athi Basin. The additional water which will be required to meet future demands in the Athi Basin is less than the estimated remaining surface water and groundwater resources potential of 1 576 MCM/a which is still available for development, while it also does not consider the approximately 220 MCM/a which will be transferred into the Athi Basin from the Tana Basin as part of the proposed future inter-basin transfers. However, to utilise the available water in the Athi Basin will require the development of infrastructure for storage, transfer and regulation.

Table E4: projected future (2040) water demands in the Athi Basin per main sector

Sector	MCM/a
Irrigation	**1 416**
- Small scale / Private	835
- Large-scale	581
Domestic and Industrial	**949**
- Greater Nairobi	540
- Mombasa, Kwale, Kilifi	212
- Basin-wide	197
Livestock	**63**
Other	**14**
Total	**2 442**

The climate change analysis which was undertaken as part of this Consultancy projected that the basin mean annual natural runoff will increase slightly to 2 657 MCM/a. This is mainly due to increased annual runoff of up to 15% expected in the western part of the basin due to climate change. Runoff in the south-eastern, coastal sub-basins is expected to decrease by up to 2.5%. Groundwater recharge in the basin will increase by 3.4% to 3 043 MCM/a, while the potential groundwater yield is expected to increase by 2.3% to 562 MCM/a under RCP 4.5.

Water quality management in the Athi Basin is poor and challenging due to a variety of factors which hinder regular water quality sampling and analysis. The Nairobi, Mathare, Mbagathi and the upper Athi rivers are some of the most polluted rivers in the country. Nairobi City at the head waters of Athi River poses the greatest water quality management challenge due to the discharge of untreated or partially treated industrial effluent and domestic sewage. Wetlands and marshlands have been mercilessly encroached on, thereby reducing their use as effluent filters. The water quality across the Athi Basin is heavily impacted by point and non-point sources of pollution, with the latter closely linked to the management and utilisation of land.

At some stage, more than 200 flow gauging stations existed in the Athi Basin. Of these, only 27 stream flow monitoring stations are currently (2018) operational - the majority of which are manually operated as rated sections. One lake monitoring station is operation (2018). Rating curves are updated yearly at the National office and distributed to the regional and subregional offices for use. However, challenges remain because many of the stations are also inaccessible during high flow conditions. Currently, the water quality monitoring programme operated by WRA faces the challenges of inadequately qualified and trained staff and also inadequate operational resources to facilitate regular sampling and laboratory analysis. In addition, because of inadequate equipment currently, the laboratories are only able to carry out limited analyses. There is now a total of 40 groundwater monitoring points across the Basin (4 Strategic, 20 Major, 11 Minor and 3 Special), while there were 34 in the 2014-15 reporting period. An additional 25 dedicated monitoring boreholes are being constructed in the Basin in 2018-19.

E6. Current water resources development and water allocations

Most of the water consumed in Nairobi is transferred from the Tana Basin, with a total transfer capacity of 181 MCM/a. The water is sourced from two dams in the Tana Basin, namely the Thika (or Ndaka'ini) and Sasumua dams. In addition, various intra-basin bulk water transfers occur in the Athi Basin. These include: transfers from the Kikuyu Springs and the Ruiru Dam to the Nairobi City Water Supply System, with a combined transfer of about 10 MCM/a; transfers from the Mzima Springs, Marere Springs, Tiwi Boreholes and Baricho (Sabaki) boreholes to Mombasa and other coastal towns, with a combined transfer capacity of about 50 MCM/a; transfer from Maruba Dam to Machakos town of about 3 MCM/a; and the Nol-Turesh pipeline which draws its water from springs on the slopes of Mt Kilimanjaro and supplies neighbouring counties.

There are currently eight large dams in the Athi Basin, storing in total close to 11 MCM. Individual dam storage capacities vary between 0.5 MCM and 3 MCM. In addition, a large number of small dams and pans occur in the basin, with a total storage capacity of about 11 MCM. The total existing storage in the basin therefore equates to 22 MCM. These dams and pans mainly supply domestic demands.

Construction of Thwake Multipurpose Dam (storage capacity 681 MCM) will commence shortly. The dam, which borders Makueni and Kitui counties, is positioned on the confluence of the Thwake and Athi rivers. The multipurpose dam will supply is meant to supply water for domestic and irrigation water use, as well as to provide hydropower generation.

Invitation for pre-qualification for the construction of Mwache Multipurpose Dam, in Kwale County, has been published. The Mwache Dam, with a planned capacity of 136 MCM, will provide water for domestic, irrigation and livestock use to Kwale County as well as domestic water for Mombasa County and will also generate some hydropower.

The Northern Collector Project (Phase I) in Tana Basin, currently under construction, will take flood flows from the Maragua, Irati and Gikigie Rivers and divert them into a tributary flowing into Thika (Ndaka'ini) Dam. It will add up to 140 000 m^3/day (51.1 MCM/a) to Nairobi water supply.

The Athi Water Service Board has actively pursued the development of deep groundwater resources in the Kiunyu and Ruiru areas, with a proposed abstraction of 64 800 m^3/day (23.7 MCM/a). Exploratory boreholes were constructed in 2013-14 and showed that there were good prospects for deep groundwater at Kiunyu, while shallower aquifers in the Ruiru area were also of reasonable potential. The future status of planned abstraction from these sources is unclear.

There are currently no hydropower installations in the Athi Basin.

The total crop area in the Athi Basin was estimated at about 876 600 ha in 2010, mainly consisting of rain-fed crops. Of this, about 64 500 ha is estimated to be irrigated at present (2018), mainly as small-scale and private irrigation, including Kasokoni and Lake Chala schemes in Taita Taveta, Ngurumani Scheme in Kajiado and the Yatta scheme in Machakos. Apart from 2000 ha at the Galana Kulalu Irrigation scheme along the lower Sabaki River, there is currently no large-scale irrigation in the basin.

The WRA uses the permitting system as a tool to regulate the use of water resources in Kenya. Water permits, as captured in the Permit Database, reflect the current allocation of water to different user categories. In accordance with the daily flow exceedance threshold approach to determine water available for allocation, as per the current (2010) WRA Guidelines for Water Allocation, a high-level analysis was conducted to assess the water allocation status in the Athi Basin - based on sub-basin hydrology developed as part of this Consultancy and current allocation volumes extracted from the Permit Database. The analysis showed that about two thirds of the sub-basins in the Athi Basin are currently over-allocated, i.e. either the Normal Flow component (available for domestic and industrial use) and/or the Flood Flow component (available for irrigation use) has been exceeded by the current allocation volumes in these respective categories as reflected in the Permit Database.

E7. Evaluation of scenarios

Scenario evaluation was undertaken to assess different development and management scenarios and to identify a sustainable development pathway for the Athi Basin which will provide an acceptable trade-off between minimising environmental and social impacts and maximising socio-economic benefits. Scenarios were defined as detailed below. Note that all future scenarios represent a 2040 horizon.

Scenario 0: Baseline

The Baseline Scenario represents the current (2018) conditions in the Athi Basin and provides a baseline against which future scenarios are evaluated. The scenario reflects exiting water resources development and infrastructure, current water demands, no climate change impacts and also assumes non-compliance with the Q95 Reserve due to lack of monitoring and enforcement.

Scenario 1: Lack of funding / Business as usual

This scenario represents the "do nothing" case - a possible worst-case scenario. It assumes that water resources development projects in the basin that are currently being implemented are completed (Thwake and Mwache dams, NCT Phase 1), but that there is no further investment in water resources infrastructure and development. Yet, growth in water demands across all sectors are assumed to be in line with projections, including the future Konza City water demands, as well as Kibwezi and Mwache irrigation demands. A continuation of the deteriorating trend in terms of vegetation loss in the catchment is also assumed (10% reduction by 2040 due to deforestation and overgrazing). Similar to Scenario 0, non-compliance with the Q95 Reserve due to lack of monitoring and enforcement is assumed. Climate change impacts are incorporated in the water resources model.

Scenario 2: Full development

The full development scenario is the same as Scenario 1, except that funds are now available to implement all the major dams and irrigation schemes as well as planned transfer schemes as identified in various studies and plans and by stakeholders, including future phases linked to transfers from the Tana Basin. In essence this scenario evaluates the availability of water and the ability of the identified storage and transfer schemes to reliably supply future demands, specifically the significant large-scale irrigation and the projected urban demands. It evaluates the trade-off between potential socio-economic benefits due to the water resources developments, and negative environmental and social impacts. As funds are now available, compliance with Q95 as the ecological reserve is assumed. However, similar to Scenario 1, vegetation loss at 10% across the catchment is still assumed due to the focus on large scale development in the basin. Two sub-scenarios were defined under Scenario 2:

- Scenario 2A: With climate change impacts
- Scenario 2B: Without climate change impacts

Scenario 3: Sustainable development

This scenario represents a progressive approach towards a sustainable development future, i.e. balanced water resources development which limits environmental and social impacts yet provides meaningful socio-economic benefits linked to the development of water resources with a reliable supply of water. This scenario tries to limit development in environmentally sensitive areas, assumes reforestation, the successful implementation of a reduction in future urban demands through water demand management (-20%), a reduction in large scale irrigation areas which are unproductive, and improved irrigation efficiencies. The criteria which were adopted for the sustainable development of water resources in the Athi Basin include improving the reliability of supply to urban, domestic and industrial users as well to irrigation schemes, compared to the current (baseline) supply reliability, improvement in forested area by 2040, successful implementation of a reduction in future urban demands through water demand management, and improved irrigation efficiencies. Three sub-scenarios were defined under Scenario 3:

- Scenario 3A: With Q95 as environmental flow requirement
- Scenario 3B: With EFlow holding flows as environmental flow requirement
- Scenario 3C: With Munyu Dam instead of Ndarugu 1 Dam to supply Nairobi; and Galana Dam to supply Galana Kulalu Irrigation Scheme and Mombasa. It assumes that smaller dams and pans as well as groundwater abstraction will be implemented at local/sub-basin level to alleviate domestic, livestock and small-scale irrigation water shortages during the dry season

In order to provide a scientific-based, transparent and consistent approach towards the evaluation of water resources development and management alternatives (scenarios) in the Athi Basin, analytical tools were developed. These tools include: (a) tools which assess erosion risk and sediment yield; (b) climate analysis tools which project changes in precipitation and temperature across the basin; (c) tools which classify ecological river condition and estimate variable environmental flow requirements; (d) water resources models, including a rainfall-runoff model, which simulate water availability and demands and the movement of water through river networks and water infrastructure associated with different levels of water resources development, and; (e) a macro-economic tool which, at a coarse level, assesses the impacts of alternative water resources development scenarios in terms of macro-economic sectors.

For the evaluation of scenarios, indicators were defined, categorised as environmental, social or economic indicators, and quantified based on response functions. These functions quantify how interventions affect the direction of change in environmental, social and economic performance, and measure the magnitude of that change through defined relationships or linkages between water resource driven processes (i.e. model outputs) and impacts or benefits. Typically, these response functions are based on empirical relationships derived from observed data, on physically based conceptual models which describe indicator responses in relation to physical parameters or on statistical indices or relevant values extracted from output time series. In order to assess relative impacts and benefits related to the defined water resources development scenarios, criteria, derived from indicators, were used to compare and evaluate different combinations of scenarios using multi-criteria analysis.

The evaluation of development and management scenarios provided useful information towards informing the strategy for the sustainable development of water resources in the Athi Basin. The main outcomes of the scenario evaluation with relevance to water resources development in the basin are summarised below:

- Urban centres are currently experiencing issues with regard to supply reliability. The priority for the development of water resources in the Athi Basin should therefore concern water supply to Nairobi and its surrounding areas as well as to Mombasa and the coastal towns.
- Interventions towards improving water availability and assurance of supply to urban users should include a combination of new storage dams, new and/or upgrades to existing inter- and intra-basin transfers, water demand management measures, conjunctive use and potentially the development of non-conventional water resources e.g. desalination, re-use, rainwater harvesting etc.
- Projected water demands in Nairobi and in the Mombasa areas are expected to increase significantly. Urgent interventions are required to supply the projected water demands.
- The projected future water demands of Nairobi and its satellite towns significantly exceed the water available in the upper Athi Basin and it is imperative that further phases of Tana Transfers are implemented timeously, while there is a need for additional storage in the upper Athi Basin. Munyu Dam on the upper Athi River, as an alternative to Ndarugu 1 Dam, should be considered as a main storage dam for Nairobi to ensure a high supply reliability. The dam would still be able to supply to the Kanzalu Irrigation Scheme – however as a 2nd priority and at a reduced area.
- The projected future water demands of Mombasa and the surrounding coastal towns could be met through significant expansion of existing groundwater supply sources, and through the utilisation of surface water sources which will require the construction of dams. The potential impacts of future major dams in the upper and middle Athi Basin and increased abstractions from Mzima Springs on the future yield of the Baricho Wellfield was found to be significant. To overcome this challenge, it is proposed that the construction of Galana Dam be considered and that the dam is not only used to supply the proposed Galana Kulalu Irrigation Scheme, but that it is utilised as an additional water resource to supply Mombasa.
- To improve current and future reliability of supply to towns and rural settlements outside of major urban centres, for livestock and for supply of small-scale irrigation, new or additional storage (dams and pans), as well as local groundwater development need to be promoted.
- The current extent of planned large-scale irrigation development in the Athi Basin should be significantly reduced taking into consideration the available water in the basin. Only limited large-scale irrigation development within the Athi Basin can be accommodated, as it is constrained by the availability of water. With large-scale irrigation taking preference over small scale irrigation, there is limited water available for expansion of small-scale irrigation.

- Although climate change is expected to result in increased temperatures in the Basin, average net irrigation demand across the basin is not significantly impacted by climate change, due to increased crop water requirements (increased potential evapotranspiration) being offset to some extent by increased rainfall in the basin under future climate change scenarios, especially in the upper, western part of the basin.
- It is imperative that water demand management is implemented in all urban areas, while irrigation efficiencies should also be improved.
- The availability of water for use within the basin will be severely impacted by the introduction of variable minimum environmental flows as opposed to the current Q95 minimum constant flow. Careful consideration should be given to resource classification and how this will impact water resources availability.

E8. Proposed development pathway

The essence of the proposed development route for water resources in the Athi Basin aims to address Nairobi and satellite towns urban demands; Mombasa and Coastal towns urban demands; smaller towns and basin-wide domestic, livestock and small-scale irrigation water demands; and proposed large-scale irrigation development water demands. This will require the following interventions:

- The future water demands of Nairobi and its satellite towns (2040) significantly exceed the water available in the upper Athi Basin and it is imperative that further phases of Tana Transfers are implemented timeously, additional dams be constructed in the Upper Athi Basin as well as Munyu Dam on the Athi River about 400 m downstream of the confluence of the Ndarugu and Athi Rivers - as an alternative to Ndarugu 1 Dam. These schemes combined, would ensure a high reliability of supply to Nairobi. Munyu Dam would still be able to supply to the Kanzalu Irrigation Scheme – however as a 2nd priority and at a reduced area. In addition to the above schemes, it is imperative that water demand management measures to reduce demand in Nairobi (aiming for a 20% reduction) are implemented as soon as possible, while a proper hydro-census in the greater Nairobi area should also be undertaken to evaluate groundwater use and potential as part of conjunctive use.
- The future water demands of Mombasa and the surrounding coastal towns could be met through significant expansion of existing groundwater supply sources, and through the utilisation of surface water sources which will require the construction of Pemba, Rare and/or Galana dams. The potential impacts of future major dams in the upper and middle Athi Basin and increased abstractions from Mzima Springs on the future yield of the Baricho Wellfield was found to be significant, which makes the construction of Galana Dam a key consideration. Galana Dam, which was originally planned along the lower Sabaki River to supply the proposed Galana Kulalu Irrigation Scheme, could be utilised as an additional water resource to supply Mombasa. By integrating this dam into the Coastal Area water supply system, the future (2040) water demand will be met at a high assurance of supply. Galana Dam would still be able to supply to the Galana Kulalu Irrigation Scheme – however as a 2nd priority and with a reduced area. In addition to the above schemes, it is imperative that water demand management measures to reduce demand in Mombasa and the coastal area (aiming for a 20% reduction) are implemented as soon as possible, while a proper hydro-census in the greater Mombasa area should also be undertaken to evaluate groundwater use/potential as part of conjunctive use.
- What is evident from the water resources modelling and scenario analyses undertaken as part of this Study, is that the current extent of planned large-scale irrigation development in the Basin should be significantly reduced taking into consideration the available water in the basin. A sustainable area of about 45 000 ha for large scale irrigation development in the basin is proposed. To ensure reliable supply of water to large-scale irrigation developments, fairly significant regulation of river flows would be required, especially during the dry season. New multipurpose storage dams to meet these large-scale irrigation demands include Munyu Dam, Thwake and Mwache dams (under construction) and Galana Dam. It is proposed to install 20 MW at Thwake Dam, 40 MW at Munyu Dam and 34 MW at Mwache Dam. Preliminary analyses have shown that the generation of hydropower at these dams will be significant but limited as the dams should be operated to meet domestic and irrigation demands as first priorities.

- In order to meet future demands for domestic supply to towns and rural settlements outside of the major urban centres, for livestock as well as for supply to small-scale irrigation, new or additional storage (small dams) as well as local groundwater development should be promoted at sub-basin scale.

E9. Water resources development investment plan

To ensure that the anticipated growth in future water requirements in the Athi Basin can be met, the development of water resources infrastructure for storage and regulation in the basin, as well as additional transfers into the basin from the Tana Basin will be required. The essence of the proposed water resources development plan for the Athi Basin up to 2040 is to address the expected growth in urban water demands in the greater Nairobi area as well as Mombasa and the coastal areas, to ensure water availability for the proposed large-scale irrigation development in the basin, and to improve existing and future water resources availability for smaller towns and basin-wide domestic, livestock and small-scale irrigation water demands. To achieve this, will require the following interventions:

- For the greater Nairobi area, it is proposed to construct four new dams in the upper Athi Basin, to implement the further phases of the Tana Transfer Scheme, and to develop the Ruiru and Kiunyu wellfields.
- For Mombasa and the coastal towns of Kilifi, Kwale and Malindi, it is proposed to construct three new dams, to expand the existing intra-basin transfers from Mzima Springs and the Baricho Wellfield and to expand and/or further develop the wellfields at Msambweni and Tiwi. The possibility of increasing the yield from the Marere Springs should also be considered.
- To meet the future domestic and industrial demands of small towns in and rural areas as well as livestock and small-scale irrigation water demands within the remainder of the Athi Basin, it is proposed that new dams already identified be implemented, that additional storage is provided in small dams and pans, and that additional boreholes are constructed.

A phased project investment plan linked to the development of water resources infrastructure in the Athi Basin is included as Table E5.

Table E5. Athi Basin Water Resources Development Investment Plan

Proposed Infrastructure Development							Expenditure (USD Million)																						
									Phasing (Year)																				
Scheme	Storage / Transfer Volume	1:10 yield (MCM/a)	Purpose: Water Supply	Hydropower	Flood Control	LS Irrigation	Feasibility ESIA / Design	Capital	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Nairobi Water Resources Development	**Capacity**						**197**	**1315**																					
Ruiru and Kiuny Wellfields	24 MCM/a	-	💧				1	5	4	2																			
Maragua 4 Dam and S. Mathioya Transfer	48 MCM/a	-	💧				49	329						25	25	110	110	110											
NCT Phase II	44 MCM/a	-	💧				38	256											19	19	85	85	85						
Kamiti 1 Dam	16 MCM	3.4	💧				9	60																9	30	30			
Ruiru 2 Dam	8 MCM	7.2	💧				7	48														7	24	24					
Stony Athi Dam	23 MCM	6.2	💧				11	76												11	38	38							
Munyu Dam	575 MCM; 40 MW	156	💧	💧		💧	81	541	41	41	180	180	180																
Mombasa, Malindi, Kalifi and Kwale Water Resources Development							**218**	**1455**																					
Mzima Springs Upgrade	38 MCM/a	-	💧				83	556	42	42	185	185	185																
Baricho Wellfield Upgrade	44 MCM/a	-	💧				35	237				18	18	118	118														
Tiwi/Msambweni Wellfield Development	18 MCM/a	-	💧				1	4						1	2	2													
Pemba Dam	19 MCM	12	💧				10	68	5	5	34	34																	
Rare Dam	36 MCM	7.4	💧				17	110																	17	55	55		
Galana Dam	498 MCM	91	💧			💧	72	480										72	240	240									
Other Water Resources Developments			💧				**114**	**757**																					
Kiteta Dam	16 MCM	1.2	💧				9	58					9	29	29														
Thwake Dam	681 MCM; 20 MW	193	💧	💧		💧	88	585	195	195	195																		
Lake Chala Dam	6 MCM	1.3	💧				6	42	3	3	21	21																	
Mbuuni Dam	10 MCM	6.3	💧				7	48							7	24	24												
Miwongoni Dam	1.6 MCM	0.1	💧				4	24	2	2	12	12																	
Small dams / pans % Boreholes							**43**	**287**																					
Small dams throughout basin	115 MCM	-	💧				36	243	18	18	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
Groundwater development in basin	91 MCM	-	💧				7	44	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Large Scale Irrigation Schemes (cost excl. associated dams)							**123**	**821**																					
Kibwezi Irrigation Extension	15 000 ha	-				💧	44	296						44	74	74	74	74											
Galana Kulalu Irrigation	16 300 ha	-				💧	40	268										40	67	67	67	67							
Kanzalu Irrigation	9 000 ha	-				💧	27	177						27	59	59	59												
Mwache Irrigation	2 000 ha	-				💧	3	21	8	16																			
Mt Kilimanjaro Irrigation	700 ha	-				💧	2	14												2	7	7							
Taita Taveta Irrigation	2 300 ha	-				💧	7	45										7	23	23									
								O&M Cost	0	10	26	38	47	51	58	65	72	77	86	95	100	105	108	109	110	113	115	115	115
								Total Annual Cost (USD Million)	**321**	**337**	**669**	**503**	**455**	**310**	**388**	**349**	**354**	**395**	**450**	**472**	**312**	**325**	**233**	**157**	**172**	**213**	**185**	**130**	**131**

E10. Basin Plan for the Athi Basin

In order to comprehensively and systematically address the range of water resources related issues and challenges in the Athi Basin and to unlock the value of water as it relates to socio-economic development, ten key strategic areas were formulated for the Athi Basin as shown below.

Table E6. Basin Plan - Key Strategic Areas and Objectives

Key Strategic Area		Strategic Objective
1	Catchment Management	To ensure integrated and sustainable water, land and natural resources management practices
2	Water Resources Protection	To protect and restore the quality and quantity of water resources of the basin using structural and non-structural measures
3	Groundwater Management	The integrated and rational management and development of groundwater resources.
4	Water Quality Management	Efficient and effective management of water quality to ensure that water user requirements are protected in order to promote sustainable socio-economic development in the basin
5	Climate Change Adaptation	To implement climate change mitigation measures in the water resources sector and to ensure water resource development and management are adapted and resilient to the effects of climate change.
6	Flood and Drought Management	To establish and guide a structured programme of actions aimed at ensuring the prevention of, mitigation of, timeous response to, and recovery from, the harmful impacts of floods and droughts across the Basin or specific catchment area.
7	Hydromet Monitoring	An operational and well-maintained hydromet network supported by effective and functional data management and information management systems
8	Water Resources Development	To develop water resources as a key driver for sustainable economic and social development
9	Strengthened Institutional frameworks	To achieve an appropriate balance between operational functionality and the need for effective oversight and governance.
10	Enabling environment to support effective institutions	Improved regulatory responses to strengthen catchment-based water resources management

Based on the analyses which were undertaken, interactions with stakeholders and the results of the scenario evaluations, strategic themes and strategies were defined under each key strategic area along with a prioritised implementation plan for the development and management of the water resources of the basin. Table E7 summarises the estimated budgets linked to the proposed activities under each Key Strategic Area.

Table E7 Summarised Basin plan budget under the 10 Key Strategic Areas

Key Strategic Areas and Themes		Budget (USD Million)				
		2020-2022	2022-2025	2025-2030	2030-2040	Total
KSA 1	**Catchment management** Promote improved and sustainable catchment management Sustainable water and land use and management practices Natural resources management for protection & sustainable use Rehabilitation of degraded environments	10.4	44.4	40.3	29.1	**124**
KSA 2	**Water resources protection** Classification of water resources Reserve determination Determine Resource Quality Objectives Conserve and protect ecological infrastructure	0.3	0.8	1.8	1.9	**5**
KSA 3	**Groundwater management and development** Groundwater resource assessment, allocation and regulation Groundwater development Groundwater asset management Conservation and protection of groundwater	13.1	35.7	29.1	27.2	**105**
KSA 4	**Water quality management** Effective data collection, information generation, dissemination, knowledge management Promote sound water quality management governance Efficient and effective management of point and nonpoint sources of water pollution	4.1	31.5	91.5	122.0	**249**
KSA 5	**Climate change adaptation and preparedness** Understand impacts of climate change on water resources at appropriate spatial scales Climate change mitigation Climate change adaptation	4.9	13.0	12.4	5.6	**39**
KSA 6	**Flood and drought management** Flood management Drought management	7.7	40.4	4.5	7.8	**60**
KSA 7	**Hydromet monitoring** Improved monitoring network Improved information management	1.0	13.1	8.5	6.0	**29**

Key Strategic Areas and Themes		Budget (USD Million)				
		2020-2022	2022-2025	2025-2030	2030-2040	Total
KSA 8	**Water resources development** Surface water resource assessment, allocation and regulation Water resources planning Water storage and conveyance Groundwater development Hydropower development Water for agriculture Water based tourism and recreation Non-conventional water resources Water resources systems operation	550	2 030	1 630	1 176	**5 387**
KSA 9	**Strengthen Institutional frameworks** Promote improved and sustainable catchment management Guidelines, codes of practice and manuals	5.3	2.6	2.9	2.0	**13**
KSA 10	**Strengthen enabling environment to support institutions** Develop institutional capacities to support improved IWRM&D	5.3	9.0	4.4	6.0	**25**
	Total	**600**	**2 222**	**1 826**	**1 387**	**6 035**

E11. Roadmap for the Basin Plan

In order to ensure the successful implementation of the strategies and actions presented in the Athi Basin Plan as well as effective monitoring and evaluation thereof, institutional role players need to be coordinated, key institutions linked to implementation need to be strengthened, imminent infrastructure feasibility and impact assessments need to be started, the knowledge base presented in the Basin Plan needs to be expanded on, and financial resources need to be mobilised. In parallel, implementation of critical as well as longer-term activities must begin as soon as possible. These four steps provide a roadmap to take the implementation of the Basin Plan forward.

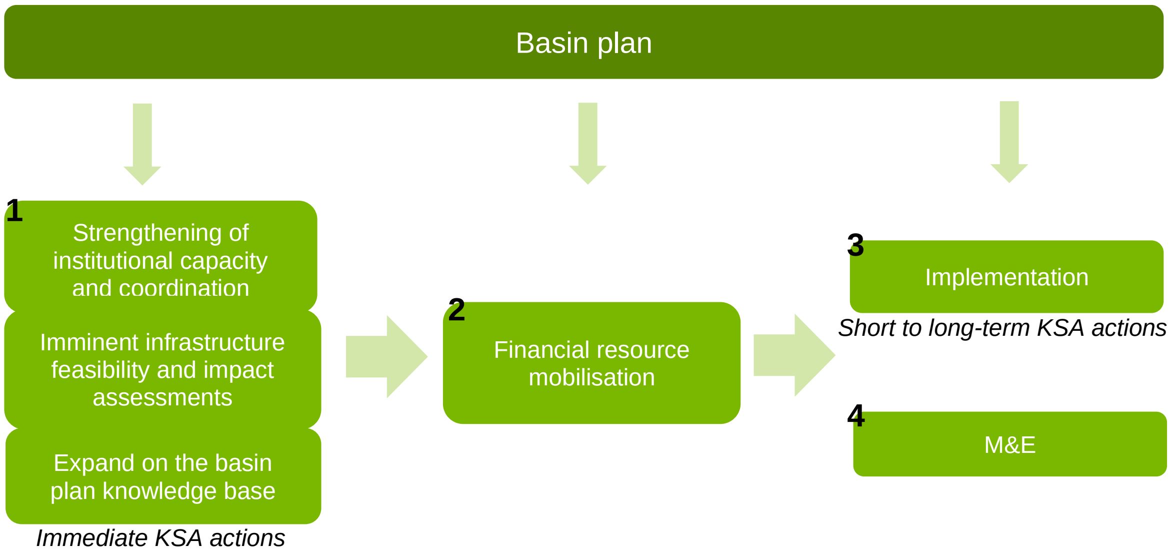

Figure E1: Roadmap for implementation of the Basin Plan

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Abbreviations and Acronyms

AAS	Atomic absorption spectrometry
ADCP	Acoustic Doppler current profiler
AGOA	African Growth and Opportunity Act
AGR	Artificial groundwater recharge
AMP	Aquifer Management Plan
ASAL	Arid or Semi-Arid Land
ASM	Artisanal and small-scale mining
ATAR	Adaptation Technical Analysis Report
AWSB	Athi Water Services Board
AWWDA	Athi Water Works Development Agency
BCEOM	French engineering consultancy, now part of EGIS International
BCR	Borehole Completion Record (old WAB 28; current WRMA 009A or B)
BH	Borehole
BOD	Biochemical Oxygen Demand
BWRC	Basin Water Resource Committee
CA	Conservation agriculture
CAAC	Catchment Area Advisory Committee
CDA	Coast Development Authority
CFA	Community Forest Association
CGs	County Governments
CHTC	Chyulu Hills Conservation Trust
CIDP	County Integrated Development Plan
CMS	Catchment Management Strategy
CMUs	Catchment Management Units
COD	Chemical Oxygen Demand
CRA	Commission on Revenue Allocation
CRBC	China Roads and Bridge Corporation
CWSB	Coastal Water Services Board
CWWDA	Coastal Water Works Development Agency
DEC	District Environmental Committee
DEF	Drought Emergency Fund
DEM	Digital Elevation Model
DHI	Danish Hydraulics Institute
DNAPLs	Dense non-aqueous phase liquids
DO	Dissolved Oxygen
DSS	Decision Support System
DWF	Dry weather flow
EDCs	Endocrine disrupting chemicals
EDE-CPF	Ending Drought Emergencies Common Programme Framework
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment

EMCA	Environmental Management and Coordination Act
ENSO	El Niño–Southern Oscillation
EPC	Export Promotion Council
EPV	Export Production Villages
EPZ	Export Processing Zone
ERC	Energy Regulatory Commission
ERS	Economic Recovery Strategy
FEWS NET	Famine Early Warning Systems Network
FMCF	Forest Management and Conservation Fund
FRF	Flood Response Forum
GCA	Groundwater Conservation Area
GCM	Global Climate Model
GDEs	Groundwater dependent ecosystems
GDP	Gross Domestic Product
GIS	Geographical Information Systems
GMP	Groundwater Management Plan
GW	Groundwater
GW•MATE	Groundwater Management Advisory Team (2002-2011), supported by the World Bank group
HQ	Head-quarters
ICZM	Integrated Coastal Zone Management
IDA	International Development Association
IDP	Integrated Development Plans
IPCC	Intergovernmental Panel on Climate Change
ISGEAG	Improving Sustainable Groundwater Exploration with Amended Geophysics
IUCN	International Union for Conservation of Nature
IWRM	Integrated Water Resource Management
JICA	Japan International Cooperation Agency
KCCAP	Kenya Climate Change Adaptation Programme
KCDP	Kenya Coastal Development Programme
KCSAS	Kenya Climate Smart Agriculture Strategy
KEWI	Kenya Water Institute
KFS	Kenya Forest Service
KMD	Kenya Meteorological Department
KNCPC	Kenya National Cleaner Production Centre
KSA	Key Strategic Area
KWSCRP	Kenya Water Security and Climate Resilience Project
KWT	Kenya Wildlife Trust
KWTA	Kenya Water Towers Agency
LIMS	Laboratory Information Management System
LPG	Liquefied Petroleum Gas
LSRWSS	Large Scale Rural Water Supply Scheme
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation

MAR	Mean Annual Runoff
MCM	Million Cubic Metres
MEMR	Ministry of Environment and Mineral Resources
MFPP	Makueni Fruit Processing Plant
MoLPP	Ministry of Lands and Physical Planning
MoLRRWD	Ministry of Land Reclamation, Regional and Water Development
MoWD	Ministry of Water Development
MTPs	Medium Term Plans
MWS	Ministry of Water and Sanitation
MWSI	Ministry of Water, Sanitation and Irrigation
NAP	National Adaptation Plan
NAS	Nairobi Aquifer Suite
NAWARD	National Water Resources Database
NAWASSCO	Nakuru Water and Sanitation Services Company
NCCAP	National Climate Change Adaptation Plan
NEMA	National Environment Management Authority
NEP	National Environment Policy
NET	National Environmental Tribunal
NGO	Non-Governmental Organisation
NIA	National Irrigation Authority
NLC	National Land Commission
NMK	National Museums of Kenya
NPEP	National Petroleum and Energy Policy
NPS	Nonpoint source
NRW	Non-Revenue Water
NWC&PC	National Water Conservation and Pipeline Corporation (now the National Water Harvesting and Storage Authority)
NWHSA	National Water Harvesting and Storage Authority
NWMP	National Water Master Plan
NWQMS	National Water Quality Management Strategy
PDB	Permit Database
POPs	Persistent organic pollutants
PPP	Public Private Partnership
PV	Photovoltaic
RCP	Representative Concentration Pathways
REA	Rural Electrification Agency
RO	Regional Office
RQOs	Resource Quality Objectives
RUSLE	Revised Universal Soil Loss Equation
SANBI	South African National Biodiversity Institute
SCMP	Sub-Catchment Management Plan
SEA	Strategic Environmental Assessment
SME	Small and Medium Enterprise
SOPs	Standard operating procedures

SRO	Sub-Regional Office
SSWRS	Small Scale Rural Water Supply Scheme
TA	Transboundary aquifer
TAMS	Tibbetts-Abbott-McCarthy-Stratton
TARDA	Tana and Athi River Development Authority
TNC	The Nature Conservancy
USAID	United States Agency for International Development
UWSS	Urban Water Supply System
W/S	Water Supply
WAP	Water Allocation Plan
WASREB	Water Services Regulatory Board
WASSIP	Water Supply and Sanitation Improvement Project
WFP	World Food Programme
Wp	Watt peak
WRA	Water Resources Authority
WRA	Water Resources Authority
WRM	Water resources management (also integrated WRM)
WRMA	Water Resources Management Authority
WRUA	Water Resource User Association
WSB	Water Services Board
WSP	Water Service Provider
WSSP	Water Sector Strategic Plan
WSTF	Water Sector Trust Fund
WT	Water Tribunal
WWDA	Water Works Development Agency
WWF	World Wildlife Fund

01

Image source: Aurecon, 2018, Kwale County

Introduction

1 Introduction

1.1 Background and context

The water resources of Kenya, a water-scarce country, are currently threatened on various fronts. Addressing this, demands capacity for comprehensive water resources management and planning, coupled with extensive investment in climate resilient water infrastructure.

Under the guidance of the Economic Recovery Strategy, the Kenyan economy has recovered and resumed a path of rapid growth. The Strategy expired in 2007 and the updated long-term vision to guide development in Kenya is the **Kenya Vision 2030** (Government of Kenya, 2007a). The aim of this Vision for the water and sanitation sector is *"to ensure water and improved sanitation availability and access to all by 2030"* while aiming to transform Kenya into *"a newly industrialising, middle income country providing a high quality of life to all its citizens in a clean and secure environment*".

The critical importance of proper water resources planning and management is also evident in relation to Kenya's **Big Four Agenda**: Food security, Manufacturing, Affordable universal health care and Affordable housing.

As set out in the **Constitution of Kenya** (2010)**,** the national government is responsible for water resources management through the **Ministry of Water, Sanitation and Irrigation (MWSI)** as the sector leader taking responsibility for policy development. The constitution also introduced a decentralised system of 47 county governments. To align the water sector with the Constitution of Kenya (2010), the **Water Act** (No. 43 of 2016) was promulgated in September 2016. It recognises that water related functions are a shared responsibility between the national government and the county governments and that water resources are vested in and held by the national government in trust for the people of Kenya. To give effect to the constitutional requirement for devolution of functions from national to county level, the Government of Kenya has embarked on a wide-ranging water sector reform programme.

The Act prioritises water user categories, outlines an array of institutional shifts and established the new **Water Resources Authority (WRA)** to protect, conserve, control and regulate the management and use of water resources. WRA also supports the Cabinet Secretary in the establishment of a National Water Resource Management Strategy. WRA responsibilities include the formulation and enforcement of procedures and regulations, policy development, water abstraction permitting and collecting of water use fees.

The Government of Kenya received financing from the World Bank toward the cost of implementing the **Kenya Water Security and Climate Resilience Project Phase 1 (KWSCRP-1)**, to be implemented through the Ministry of Water, Sanitation and Irrigation. KWSCRP-1 is made up of two components, namely:

- **Component 1: Water Resources Development**. This component supports climate resilience and water security for economic growth by financing water investments and by building a longer-term investment pipeline.
- **Component 2: Effective Water Sector Institutions**. This component aims to support the current water sector institutions as well as the preparation, implementation and full function of the new and proposed legal and institutional framework resulting from the alignments with the 2010 Constitution. Ultimately, it aims for improved management and development of Kenya's water resources for its growth and development.

This Consultancy covers Sub-component 2.2 *Strengthening Water Resource Management and Planning* of the KWSCRP-1. The overall objective of this Consultancy is to strengthen WRA's capacity in terms of tools, skills and infrastructure to deliver on its mandate for water resources management and regulation in the country. Kenya's water sector reforms, including WRA's broadened mandate for water resources management, planning and regulation, have introduced new functions that require new capacities within WRA and its de-centralised structures. Existing capacities also need strengthening to address water resources development and management issues in a knowledge-driven manner. The scope of this Consultancy therefore aims to strengthen WRA's capacity to deliver on core functions that are new, have been expanded, or have in the past not been delivered on. A key set of deliverables under Sub-component 2.2 is the development of six Basin Plans for the six main river basins in Kenya as shown in Figure 1-1, namely Lake Victoria North, Lake Victoria South, Rift Valley, Athi, Tana and Ewaso Ng'iro North. This document constitutes the Basin Plan for the Athi Basin.

1.2 Objectives of the Athi Basin Plan

Integrated Water Resources Management (IWRM) considers the environmental, social and economic aspects of a river basin, and ensures that these aspects are integrated into an overall management strategy. It aims to achieve a sustainable balance between the utilisation, development and protection of water resources.

The main objective of this Basin Plan is to provide a clear pathway for the sustainable utilisation and development of the water resources of the Athi Basin. The Basin Plan provides a description of the current state of the basin, establishes a shared vision for the future development of the basin and identifies key strategic areas and actions for effective development and management of the basin's water resources. The Basin Plan draws information from relevant existing plans and strategies, incorporates comprehensive inputs from various stakeholders and presents updated information based on analytical tools developed as part of this Consultancy.

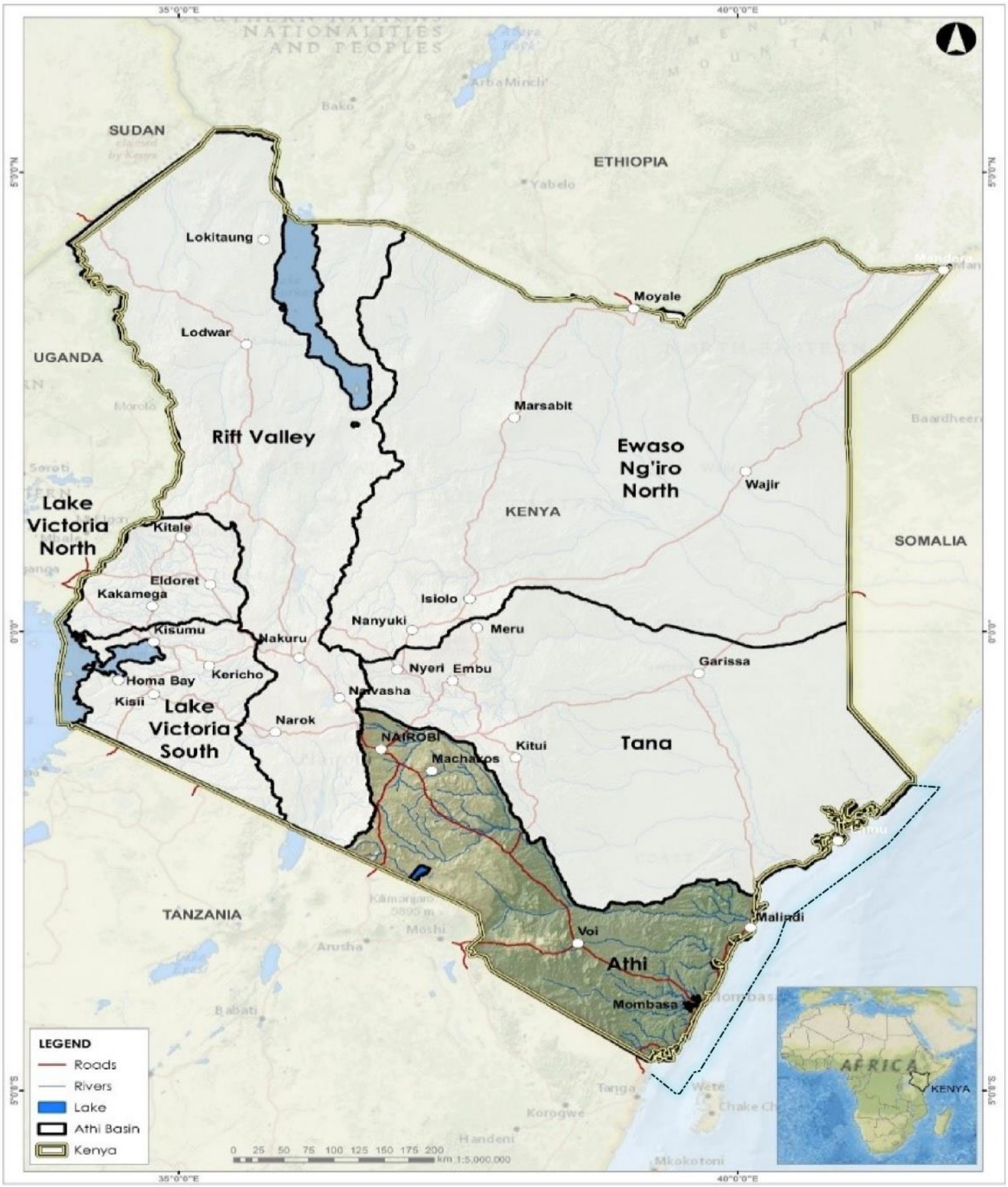


Figure 1-1: Athi Basin location map

1.3 Approach to the development of the Athi Basin Plan

The conceptual approach to the development of a Basin Plan for the Athi Basin is described schematically in Figure 1-2.

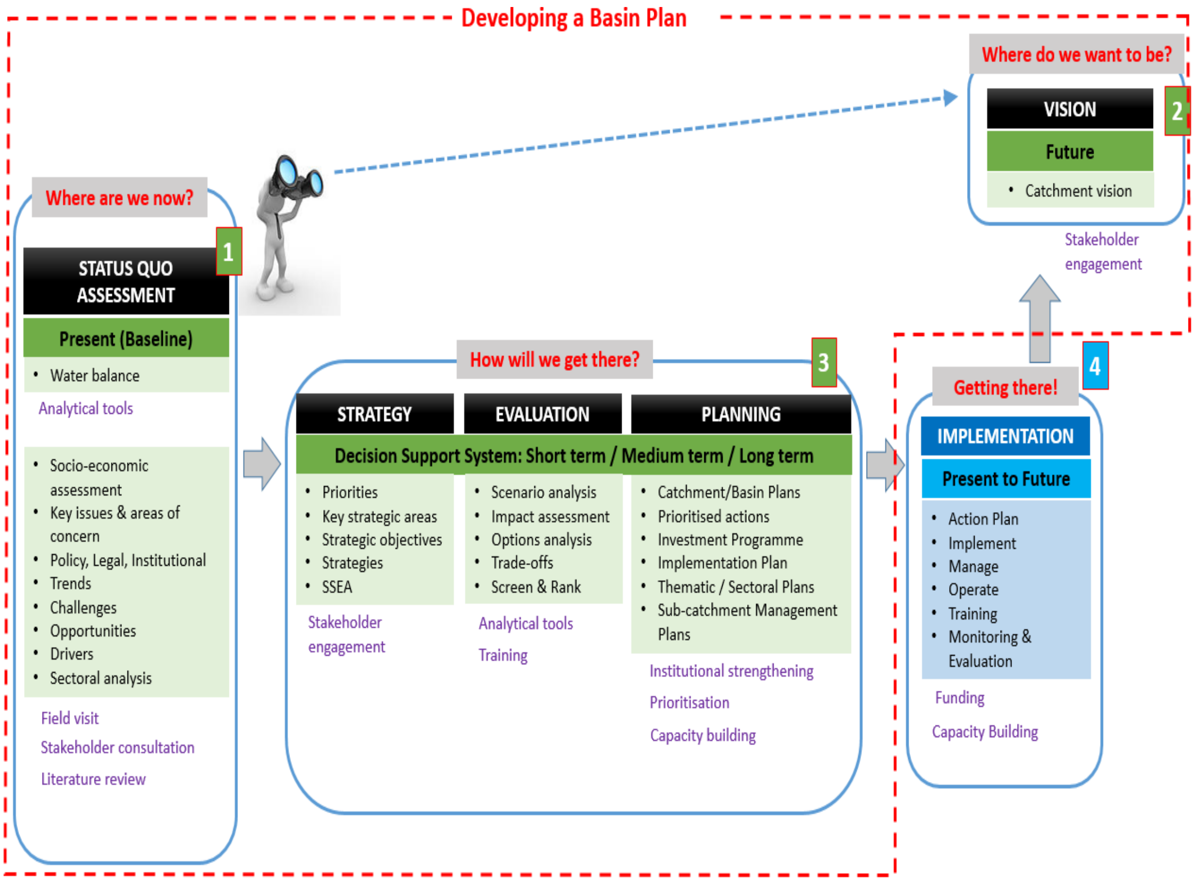


Figure 1-2: Conceptual approach to basin planning

Key elements related to the development of the Plan were to collect and review relevant data and information including the identification of key issues and challenges, to develop analytical tools for decision support, to consult the various stakeholders and organisations involved in the development, management and use of water resources in the basin, to develop a strategic framework for planning and management of water resources and to undertake comprehensive scenario evaluations. Stakeholder involvement at national and basin level was a focus area in the development of the Basin Plan.

Figure 1-3 displays the key stages in the development of a Basin Plan for the Athi Basin.

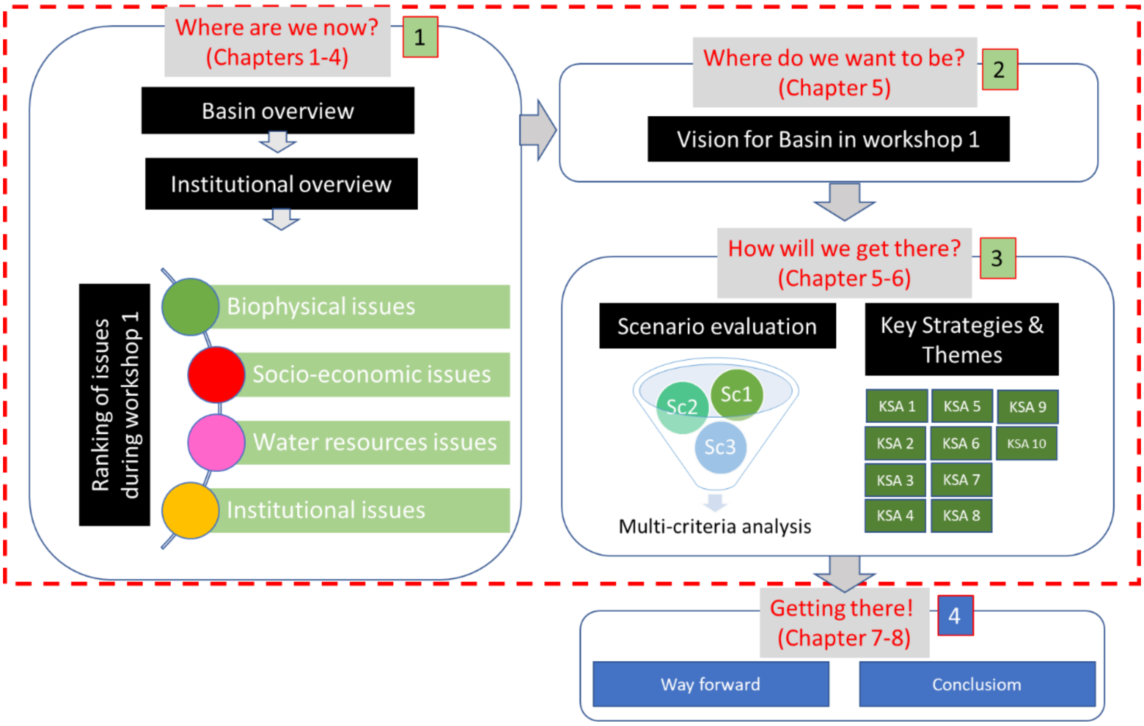


Figure 1-3: Key stages in development of Athi Basin Plan

1.4 Structure of the Athi Basin Plan

This report is structured as follows:

Section 2 provides an overview of the basin including basin characteristics, the bio-physical and socio-economic environments, information on water availability and demands, existing water resources infrastructure, water balances, water quality and the existing hydrometeorological network.

Section 3 presents the current legislative, policy and institutional framework in relation to water resources management as well as summarises the existing development plans and sectoral perspectives which link to water resource planning, management and development in the basin.

Section 4 highlights the key issues, challenges and trends in the basin.

Section 5 covers the vision for the basin and outlines the evaluation strategy and analysis of scenarios, the approach to scenario development and the outcome of the scenario evaluation process.

Section 6 presents the Integrated Water Resources Development and Management Plan for the basin. It provides the strategic framework for sustainable water resources development and management in the basin. Key strategic areas and objectives along with prioritised themes and strategies are provided.

Section 7 provides a way forward for the Basin Plan. This includes key outcomes, context, actions, budgets and a roadmap for implementation of the Basin Plan.

Section 8 provides a conclusion for the Basin Plan.

Section 9 lists the references.

02

Image source: Aurecon, 2018. Tea plantations in the Upper Athi Basin

Basin Overview

2 Basin overview

2.1 Introduction

The Athi Basin has an area of 66 559 km^2 [1] and borders Tanzania to the south, the Indian Ocean coastline to the east, the Tana Basin to the north and the Rift Valley Basin to the west. Although the Athi Basin only covers about 11% of Kenya's land surface area, it has high economic activity, houses a quarter of the country's population, and hosts the two largest cities in Kenya viz. Nairobi and Mombasa. Nairobi as the capital of Kenya, is the largest and most densely populated city in the country. It has a high-water demand and receives a large portion of its water from the Tana Basin via an inter-basin transfer. The city of Mombasa is the second largest city in the country and a popular tourist destination. The Standard Gauge Railway that connects the city of Mombasa with Nairobi is estimated to carry up to 1 million passengers by its second year of running. Mombasa receives water from Mzima Springs and the Athi River via intra-basin transfers. Other major cities and towns in the basin include Kiambu, Kibwezi, Voi, Kajiado, Malindi and Kilifi, and upcoming cities such as Machakos, Konza, Tatu and Diani.

The Athi Basin has the highest urban water demand of all six basins in Kenya, and the demand is expected to increase significantly in future due to growing population and urbanisation. This heightens the need to address the current water-related issues experienced within the basin – not only the growing water demand, which is currently not met, but also issues related to catchment degradation and water resources protection. An overview map of the Athi Basin is shown in Figure 2-1.

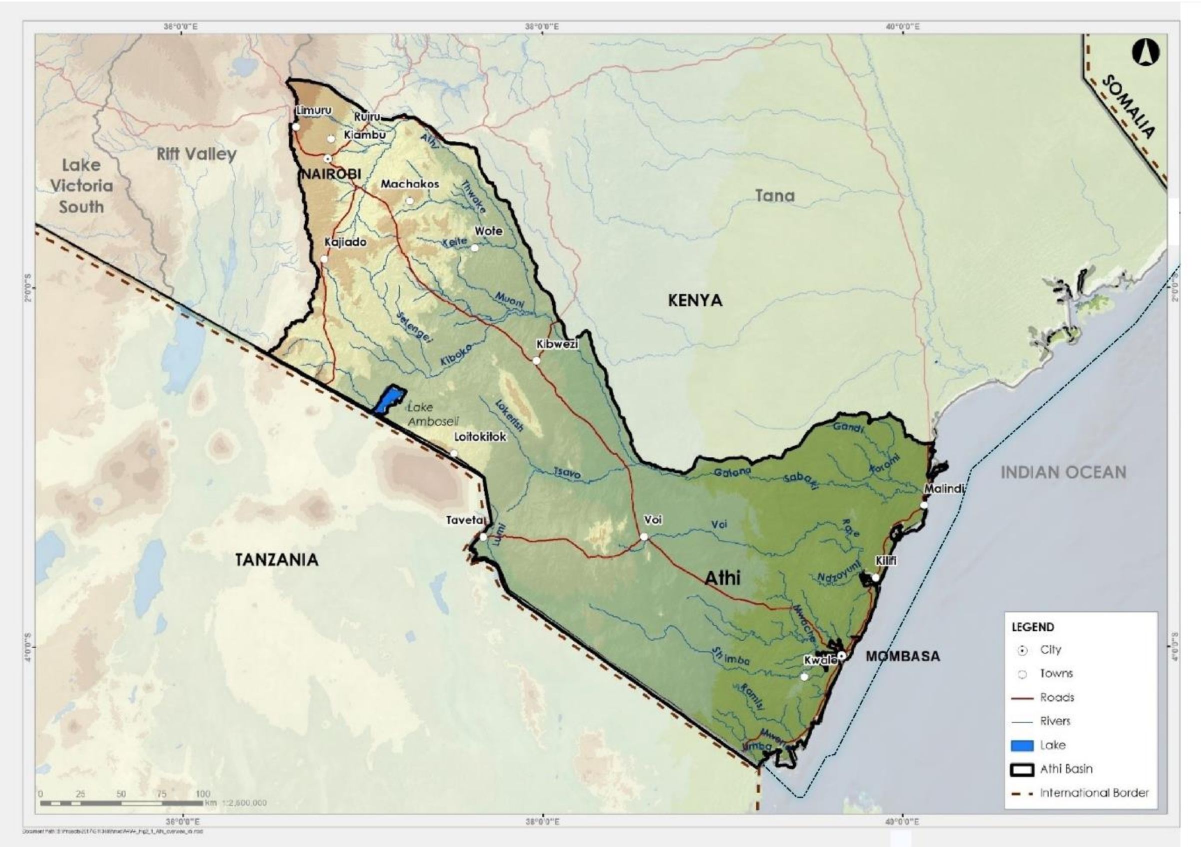


Figure 2-1: Overview map of Athi Basin

[1] Data from JICA. 2013. *NWMP 2030*. Datum: WGS 1984 Projection: UTM zone 37N

There are nine counties within the Athi Basin, which are covered in their entirety or majority by the drainage basin (Figure 2-2). Some counties cross hydrological boundaries and as such have to engage with multiple BWRCs and WRA offices. The counties within the Athi Basin include Kajiado, Kiambu, Kilifi, Kwale, Machakos, Makueni, Mombasa, Nairobi and Taita Taveta. The geographical areas of Kitui, Tana River and Nyandarua counties that lie within the Athi Basin are minor; thus, these counties are not considered in this report.

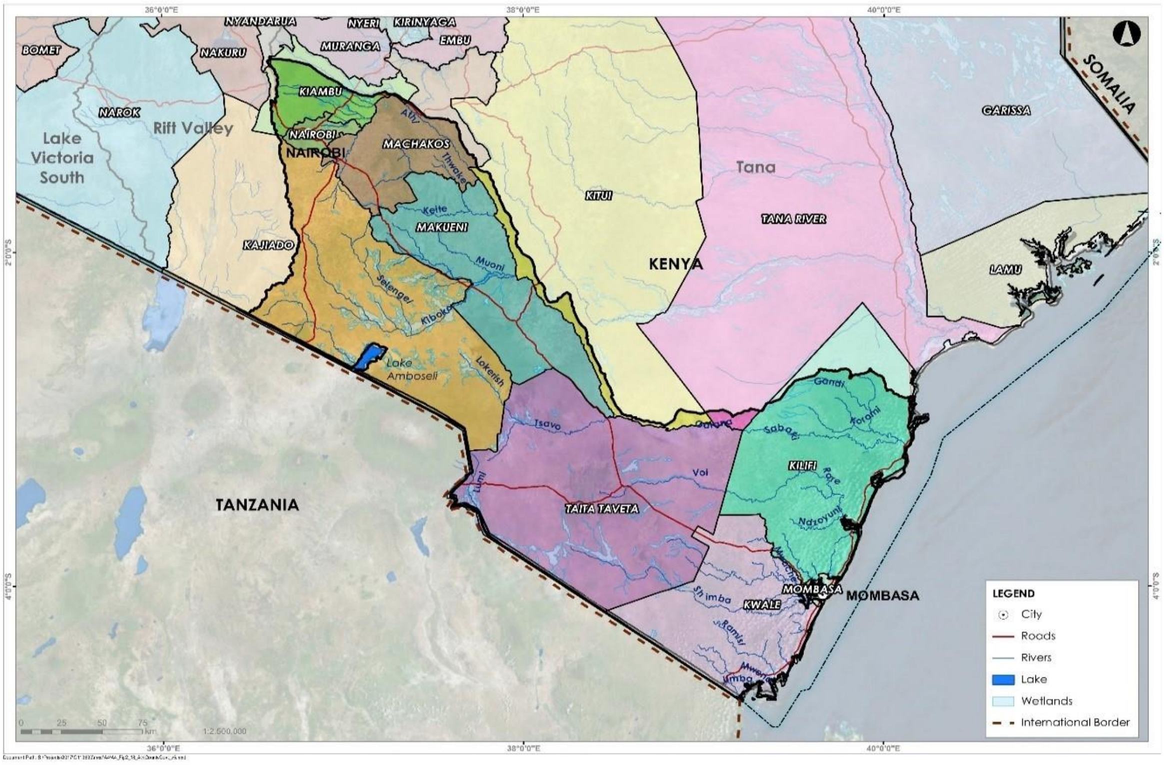


Figure 2-2: Counties within the Athi Basin

2.2 Biophysical

2.2.1 Physiography

2.2.1.1 Topography and landforms

As evident from Figure 2-3, the topography of the Athi Basin varies from sea level at the Indian Ocean coastline to approximately 2 600 masl in the highlands of the Aberdare Range. The basin is divided into three topographic zones: the upper zone (2 600 to 1 500 masl), middle zone (1 500 to 500 masl) and coastal zone (500 to 0 masl).

The terrain slope categories within the Athi Basin are shown in Figure 2-4. Generally, most of the basin is gentle sloping. However, steeper slopes are found in the upper Aberdare Range, in the vicinity of Nairobi and Machakos, at Chyulu Hills and Taita Hills close to Voi and in a narrow band along the coast.

The headwaters of the Athi River originate at an elevation of about 2 600 masl along the Aberdare range plateau. These rivers flow along steep mountain foot slopes towards Nairobi. The southern extent of the upper basin drains a gentler plain landform starting at an elevation of about 1 900 masl in the

Ngong Hills. The main Athi River in the middle Athi Basin is confined to the east by a plateau. Machakos, is surrounded by hills and mountain footridge landforms which extend onto plains. There is an internally draining transboundary sub-basin which is shared with Tanzania and which drains into Lake Amboseli. There are also two international lakes in the Middle Athi Basin which straddle the Kenya-Tanzania border, namely Lake Jipe (in the Lumi River system) and Lake Chala (a crater lake). The Lower part of the Athi Basin includes the lower reach of the Athi River which discharges into the Indian Ocean north of Malindi and other smaller coastal rivers which flow into the Indian Ocean. Figure 2-5 displays the dominant landforms in the upper (top), middle (centre) and lower (bottom) Athi Basin.

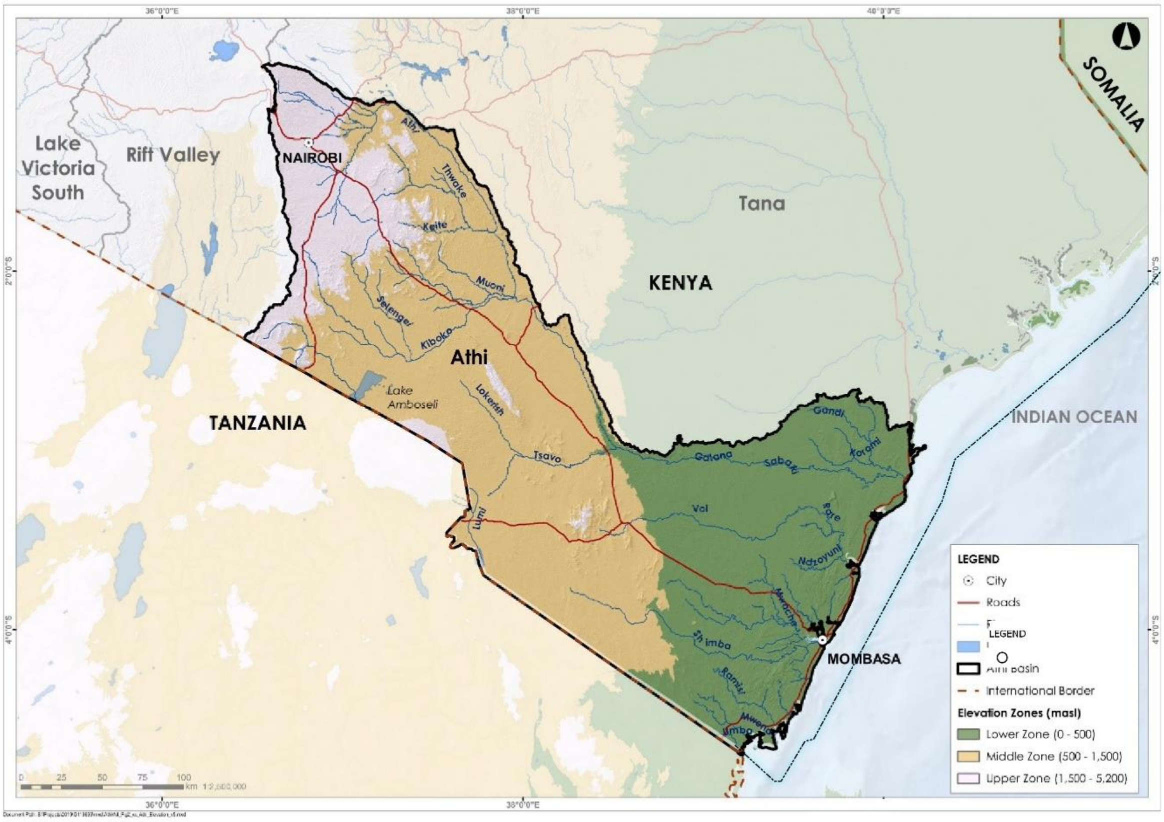


Figure 2-3: Elevation zones in the Athi Basin

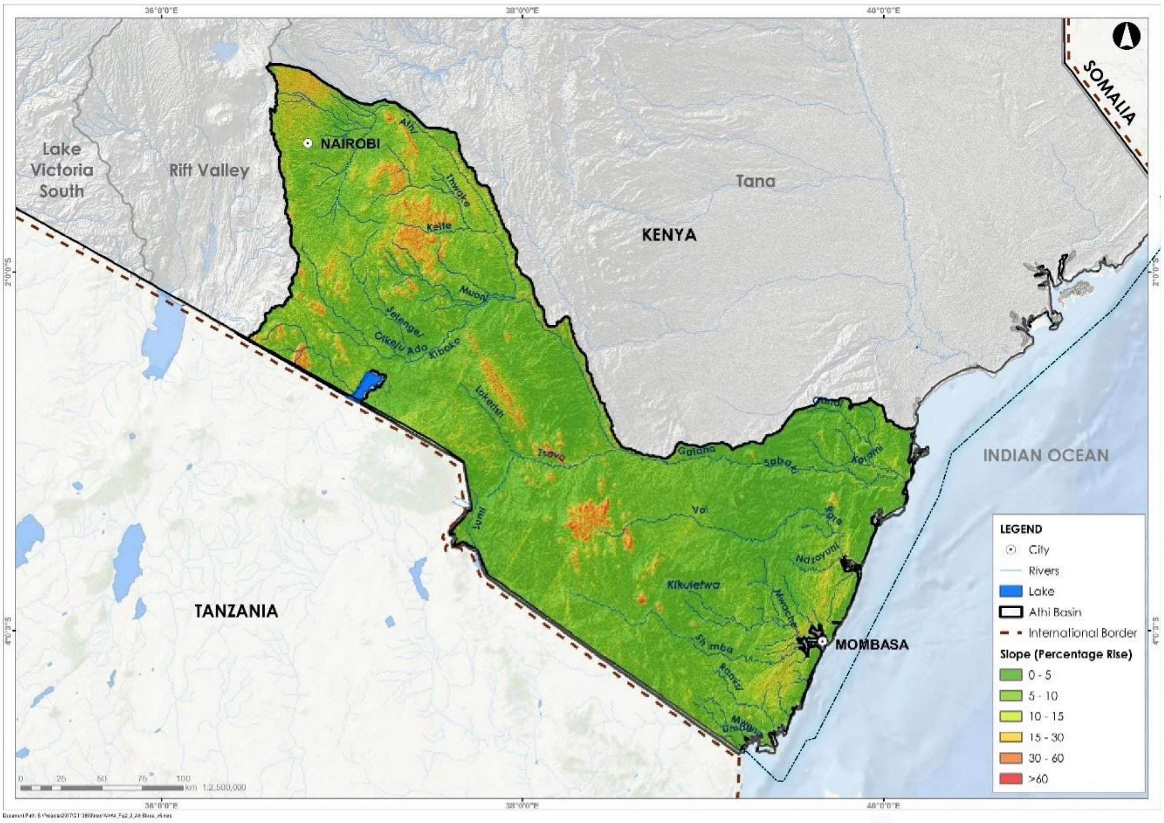


Figure 2-4: Slope categories in the Athi Basin

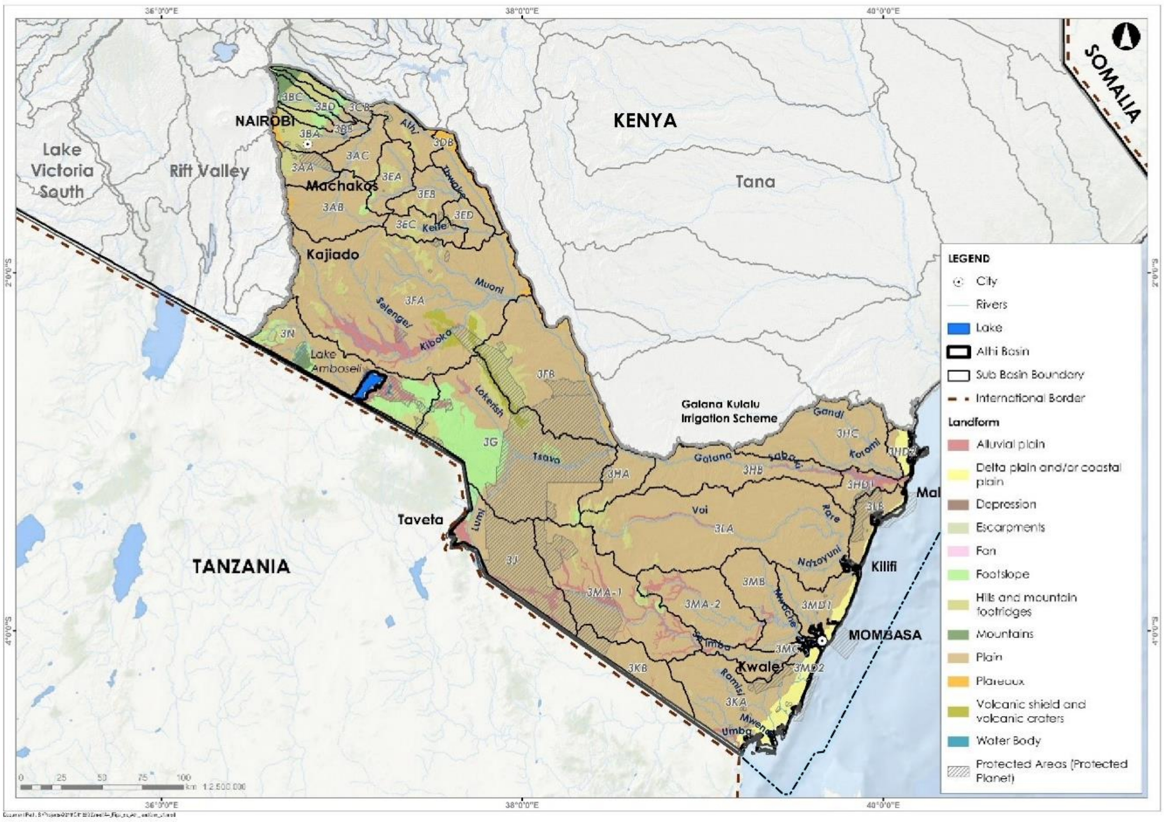


Figure 2-5: Landforms of the Athi Basin

2.2.1.2 Soils

The Soil Atlas of Africa (Jones et al., 2013) was used as a reference for the soil types found across the Athi Basin due to its detailed soil mapping base. The main soil types found in the Athi Basin are listed in Table 2-1. The primary soil type in Nairobi City is red Nitisols, while the upper Athi River basin mainly consists of Vertisols, low-nutrient Ferralsols and Cambisols. The middle Athi River basin is dominated by Lixisols, low-nutrient Ferralsols and Vertisols. The main soil types in the lower Athi River basin are reddish Luvisols, Solonetz, Vertisols and Fluvisols.

Table 2-1: Description of main soil types found in the Athi Basin

Soil Type	Description
Cambisols	Young soils. Various characteristics depending on factors. One of the better agricultural soils due to good nutrient-holding capacity.
Ferralsols	Low nutrient levels and nutrient retention. Sandy/silty texture. Commonly found under tropical rainforests. Sustains natural vegetation.
Fluvisols	Found in flood plains, lakes, deltas or marine deposits. High agricultural potential, but risk of flooding or waterlogging.
Lixisols	Common in dry savannah region. Slightly acidic with high clay content and low nutrient retention. Fairly productive; irrigation most likely required.
Luvisols	Slightly acidic with high clay content and high mineral nutrient content. Good water retention capacity. Productive soils if managed properly.
Nitisols	High clay content and iron rich. Support a wide range of crops, particularly coffee in East Africa. Fertiliser required for annual cropping.
Solonetz	Alkaline soils. Clay-rich subsoil. High sodium content. Supports natural habitats. Utilised for grazing. Flat lands in hot, dry climate or former coastal deposits.
Vertisols	Clay-rich soils. Productive if managed properly. Large cracks form upon drying. Difficulty to work when wet.

Figure 2-6 displays a detailed soil map of the Athi Basin. The soil unit codes of the Food and Agriculture Organization of the United Nations (FAO) indicated in Figure 2-6 are summarized in Table 2-1 and Table 2-2.

Table 2-2: Soil index list and description

Soil Index	Description	Soil Index	Description	Soil Index	Description
ACf	Ferric Acrisols	**FLe**	Eutric Fluvisols	**LXh**	Haplic Lixisols
ACh	Haplic Acrisols	**FLt**	Thionic Fluvisols	**NTr**	Rhodic Nitisols
ALh	Haplic Alisols	**FRh**	Haplic Ferralsols	**NTu**	Humic Nitisols
ANm	Mollic Andosols	**FRr**	Rhodic Ferralsols	**PHg**	Gleyic Phaeozems
ARa	Albic Arenosols	**FRx**	Xanthic Ferralsols	**PHh**	Haplic Phaeozems
ARb	Cambic Arenosols	**GLe**	Eutic Gleysols	**PHl**	Luvic Phaeozems
ARl	Luvic Arenosols	**LPk**	Rendzic Leptosols	**PLe**	Eutric Planosols
ARo	Ferralic Arenosols	**LPq**	Lithic Leptosols	**RGd**	Dystric Regosols
CLp	Petric Calcisols	**LVf**	Ferric Luvisols	**SCg**	Gleyic Solonchaks
CMc	Calcaric Cambisols	**LVg**	Gleyic Luvisols	**SCh**	Haplic Solonchaks
CMd	Dystric Cambisols	**LVh**	Haplic Luvisols	**SCk**	Calcic Solonchaks
CMe	Eutric Cambisols	**LVk**	Calcic Luvisols	**SNg**	Gleyic Solonetz
CMu	Humic Cambisols	**LVv**	Vertic Luvisols	**SNh**	Haplic Solonetz
CMx	Chromic Cambisols	**LVx**	Chromic Luvisols	**SNk**	Calcic Solonetz
FLc	Calcaric Fluvisols	**LXf**	Ferric Lixisols	**VRe**	Eutric Vertisol

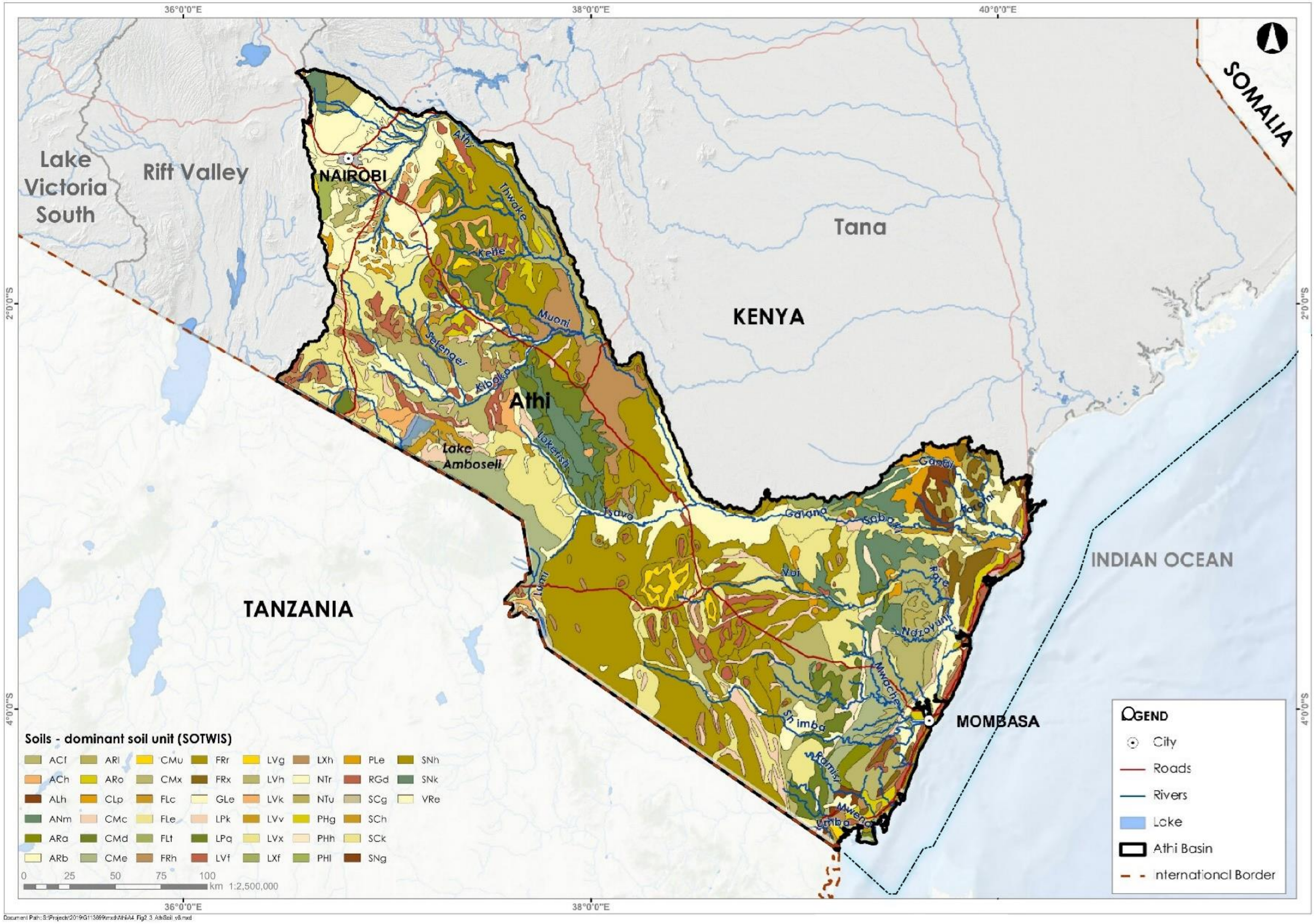


Figure 2-6: Soils in the Athi Basin

To assist with the assessment of erosion risk in the Basin, a GIS-based erosion risk tool was developed based on the Revised Universal Soil Loss Equation (RUSLE) model (refer to **Annexure A1**). the outputs of the model presented both potential soil loss (i.e. inherent erosion risk) and estimated soil loss (i.e. erosion risk with vegetation cover management). When comparing the inherent soil erosion risk (Figure 2-7) to the potential soil erosion risk (Figure 2-8) it is apparent that vegetation cover in protected areas and gazetted forests provides significant protection from soil erosion. Protected areas and gazetted forests have very low rates of erosion, although at the foot slopes of Kitui County Mountain ranges the erosion rates are high due to limited vegetation cover.

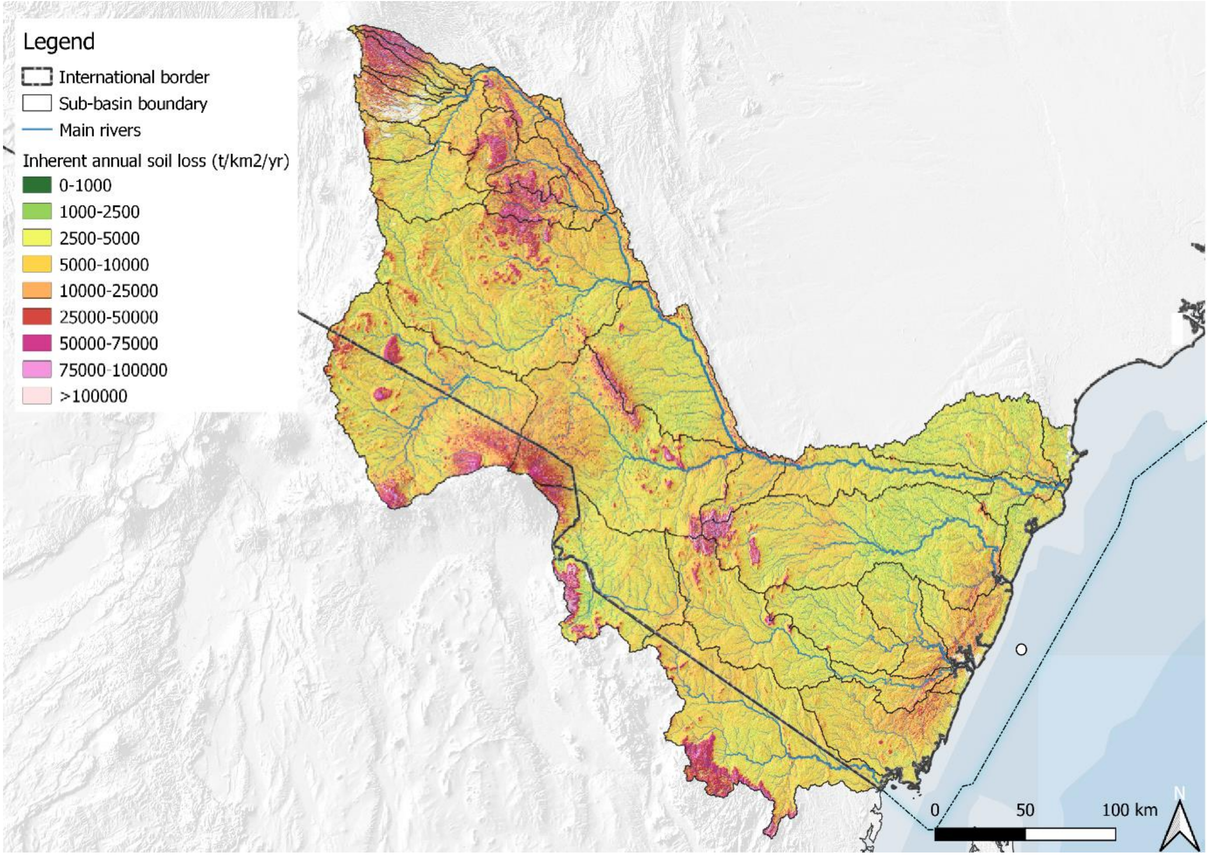


Figure 2-7: Athi Basin Inherent Soil Erosion Risk (C and P factor not included)

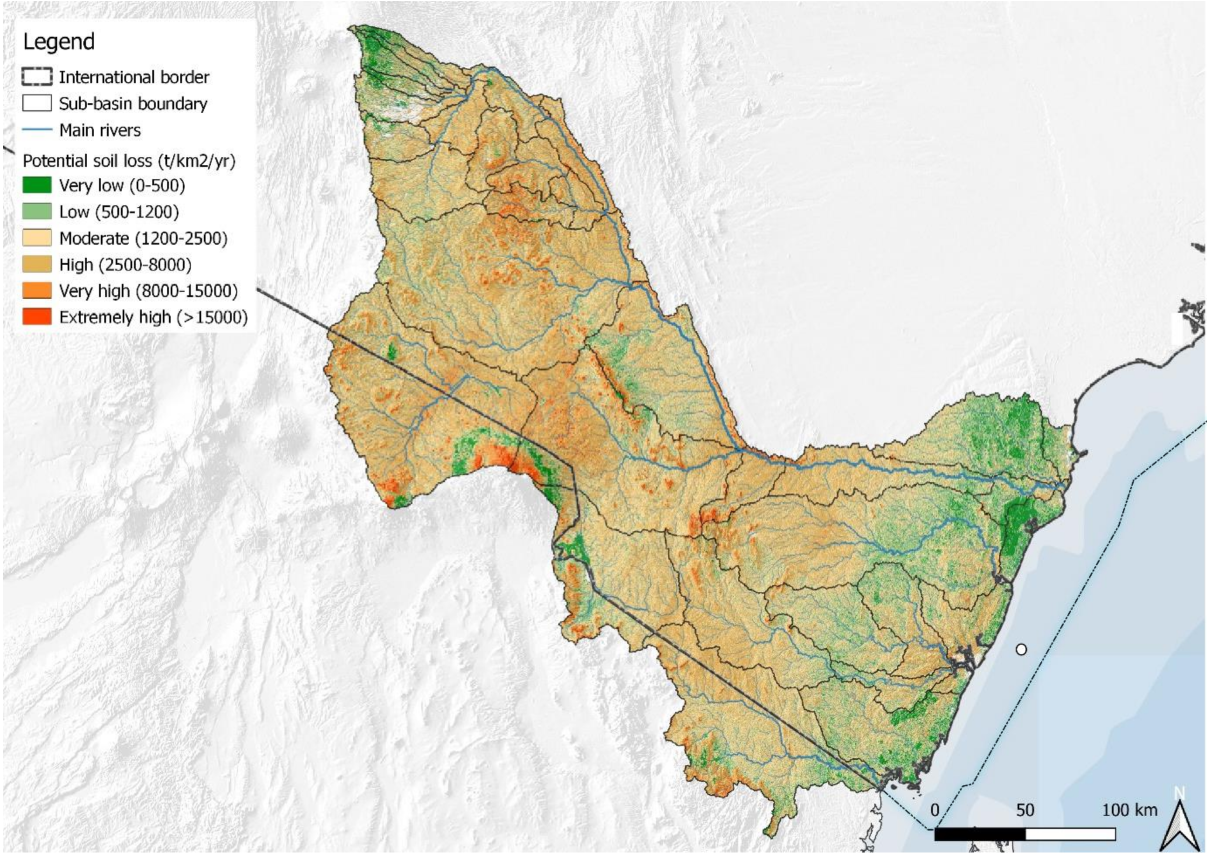


Figure 2-8: Athi Basin Potential Soil Erosion Risk

2.2.1.3 Geology and hydrogeology

Along the coast of the Athi Basin, the geology is made up of quaternary and tertiary sediments. These are coastal sediments consisting of soils and alluvial beach sands. Following the shape of the basin from the coast to the north-east, Triassic and Jurassic geology from the Mesozoic era occur. Appearance of geology from the Carboniferous period is found, followed by a large area of Basement geology in the central and upper parts of the basin. There is an area of quaternary volcanic rocks and sediments bordering Tanzania near Mount Kilimanjaro, which were deposited during the active period of the volcano. In the upper reaches of the catchment, the peneplains of the Rift Valley include tertiary volcanic rocks and sediments. Figure 2-9 display the geology of the Athi Basin.

Geology and groundwater characteristics

The Athi Basin is characterised by the Nairobi Suite aquifer system composed of Pleistocene to Miocene volcanic, Chyulu volcanic, Mt Kilimanjaro volcanic, coastal sediments and Precambrian basement systems. The basin also has several major springs e.g. Mzima, Kikuyu, Njoro Kubwa, Nolturesh and Marere.

The upper zone of the basin is predominately volcanic and has relatively good aquifers, which are a valuable water supply for the domestic and commercial sectors. Kikuyu Springs is a significant water source for Nairobi and Kikuyu. The springs are recharged by the Manguo and Ondiri Swamp, which lie on a fault line leading to the springs. As with surface water, ground water is over-abstracted in the upper Athi area. High concentrations of iron, fluoride and manganese have been found in groundwater in certain areas in the upper basin.

Alluvial aquifers are of local importance in the middle zone, and Chyulu Hills is home to the source aquifer supplying Mzima Springs. The towns of Nolturesh, Kimana and Entonet benefit in terms of water supply, irrigation and tourism value respectively, from several springs, hosted by the volcanic aquifers on the northern side of Mount Kilimanjaro.

The coastal zone is threatened by salt water intrusion, which worsens with proximity to the coastline. Abstraction is limited in certain areas, and the coastal coral limestone and sand aquifers are of commercial importance. The Tiwi and Baricho aquifers provide an essential water supply to the coastal zone. A discovery of an emerging under-the-sea aquifer was recently made in the south-eastern part of the catchment (Water Resources Management Authority, 2015b).

WRMA Aquifer classification

The present aquifer classification system in Kenya is partly demand-oriented and partly geo-political (Water Resources Management Authority, 2007c) and entails five classes:

- STRATEGIC aquifers: aquifers used to supply significant amounts/proportions of water to an area where there are no alternatives, or where alternatives would take time and money to develop
- MAJOR aquifers: high-yielding aquifers with good quality water
- MINOR aquifers: moderate-yielding aquifers with variable water quality
- POOR aquifers: low-yielding aquifers with poor to reasonable quality water
- SPECIAL aquifers: aquifers or parts of aquifers designated 'special aquifers' by the WRA

Each is further defined in terms of its status, i.e.:

- **Satisfactory**: no immediate stress, pressure or threat
- **Alert**: stress, pressure or threat identified or anticipated
- **Alarm**: water levels declining, water quality declining (stress, pressure or threat identified)

The Athi Basin's aquifers under the current classification are summarised in Table 2-3.

Table 2-3: Current classification of aquifers in the Athi Basin

Name	Dominant lithology	Status
Strategic		
Baricho	Alluvium (palaeochannel)	Satisfactory
Voi River	Alluvium	Alert
Amboseli	Alluvium & lavas	Alert
Nairobi Suite	Lavas & volcanoclastic sediments	Alarm
Major		
Mombasa	Coral limestones & sands	Alarm
Kwale, Kilifi, Malindi	Coral limestones & sands	Alert
	Magarini and Kilindini sands	Alert
Minor		
Kwale, Kilifi, Malindi, Mombasa	Kambe shales & limestones	Satisfactory
	Mazeras sandstone [1]	Satisfactory
	Mariakani sandstones & shales	Satisfactory
	Maji ya Chumvi shales & siltstones	Satisfactory
	Taru grits, tillites & shales	Satisfactory
Kilimanjaro volcanic	Basalts and volcanic material	Satisfactory
Poor		
Chyulu Hills volcanic	Basalts & volcanoclasts	Satisfactory
Basement	Weathered metamorphic Basement	Satisfactory
Special		
Ngomeni/Timboni (Malindi)	Alluvial	Alarm

[1] Described as 'coarse limestone' in (Water Resources Management Authority, 2007c), which is incorrect (Caswell, 1953).

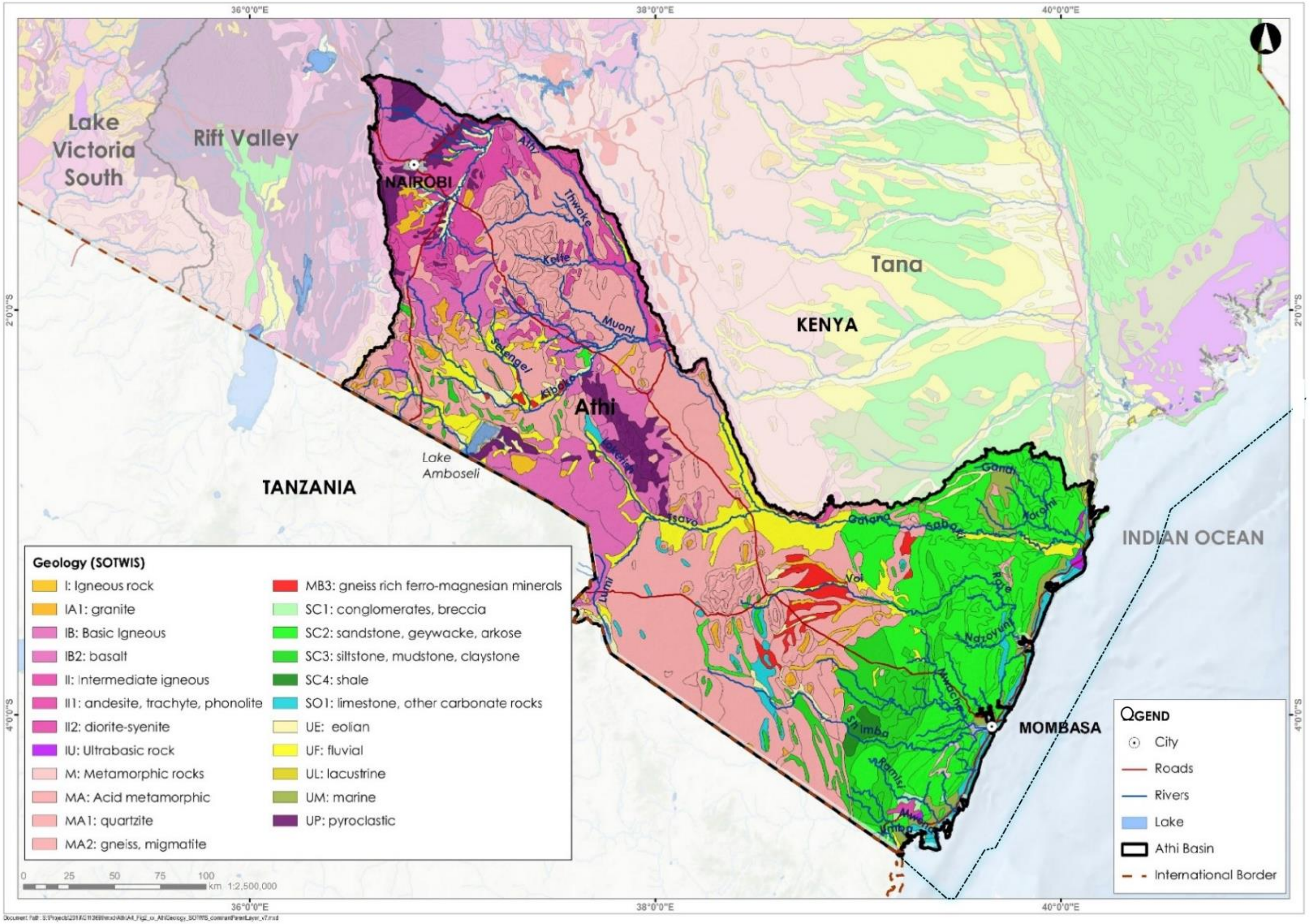


Figure 2-9: Geology in the Athi Basin

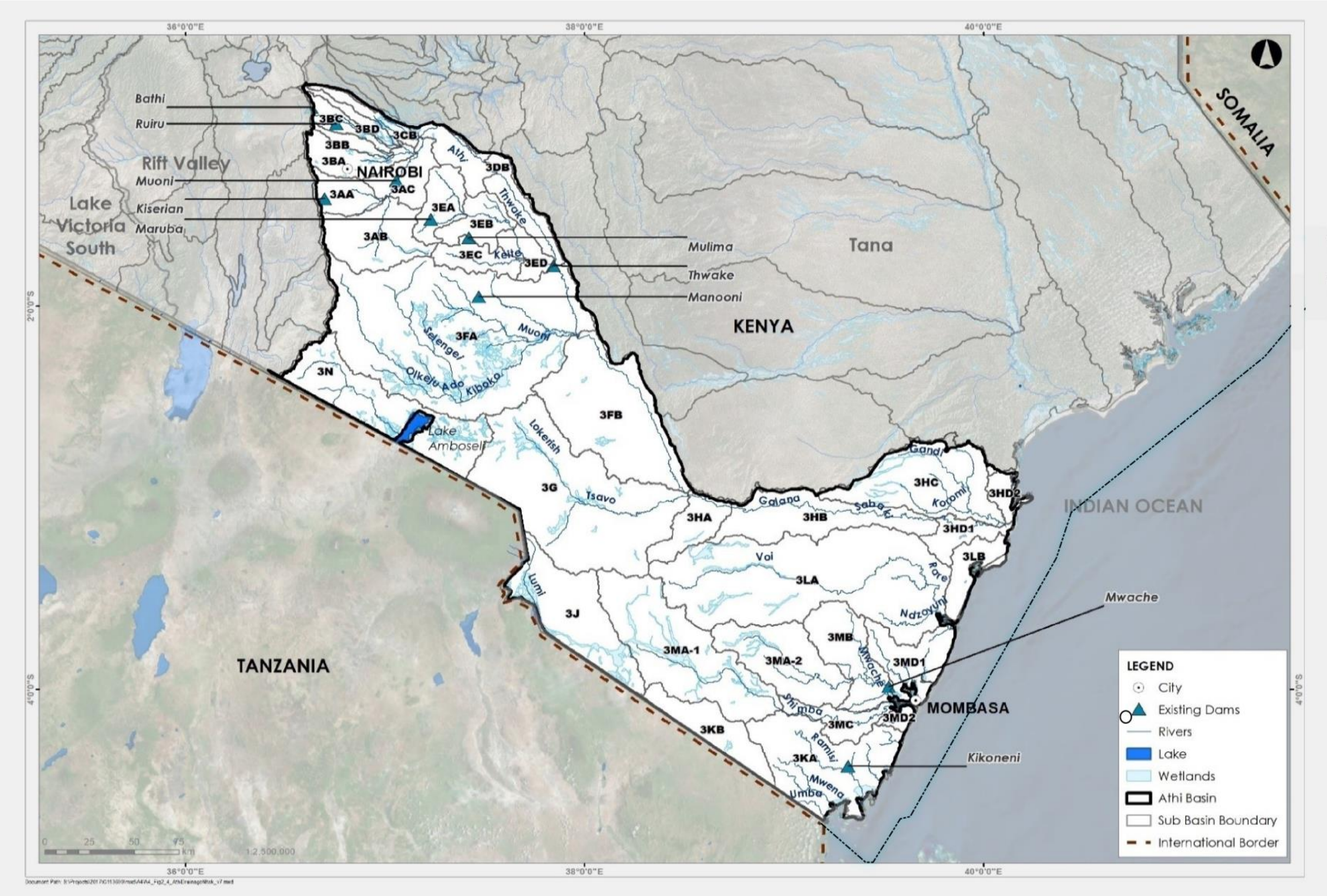
2.2.1.4 Drainage

The Athi Basin is divided into 34 sub-basins, 3AA to 3N. The drainage networks and sub-basins are displayed in Figure 2-10. The Athi River is the main river in the Athi Basin, draining about 57% (38 170 km^2) of the basin. It is the second longest river in Kenya (after the Tana River) and has a total length of 390 km. The Athi River originates on the eastern slopes of the Rift Valley, Aberdare Ranges and Ngong Hills. Downstream of Nairobi, the Athi River is joined by the Nairobi River. The Ngong and Mathare Rivers are tributaries of the Nairobi sub-system, which along with numerous other small feeder streams form the headwaters of the Athi River. Near Thika, downstream of Fourteen Falls, the Athi River turns SSE, running along the boundary with the Tana Basin. Along this reach the river is joined by the Thwake and Kiboko tributaries from the west, before its confluence with its main tributary the Tsavo River, which drains from the eastern side of Kilimanjaro. Downstream of this confluence, a series of rapids known as the Lugard's Falls occur. This lower reach of the Athi River is also referred to as the Galana or Sabaki River. Eventually, the Athi River discharges into the Indian Ocean just north of Malindi Town. Several flood plain lakes maintained by rainfall and runoff exist towards the mouth of the river e.g. Chem Chem, Jilore, Merikano, Mbirikano and Mekimba. Other smaller rivers within the Athi Basin, draining into the Indian Ocean south of Malindi, include the Rare, Mwache, Pemba and Ramisi rivers. The Lumi River originates in the Athi Basin in Kenya along the eastern slopes of Kilimanjaro, and flows across the border into Tanzania, while the Umba River flows from Tanzania into the Athi Basin south of Mombasa.

The upper part of the Athi Basin constitutes the headwaters of the Athi River and includes sub-basins 3AA, 3AB, 3AC; 3BA, 3BB, 3BC, 3BD and 3CB, all draining into 3DA. The northern rivers originate at an elevation of about 2 600 masl along the Aberdare range plateau. The catchments above Nairobi drain into the steep mountain footslopes around Nairobi. The southern extent of the Upper Athi catchment (3AB), drains a gentler plain landform starting at an elevation of about 1 900 masl in the Ngong Hills.

The middle part of the Athi Basin includes three of the main tributaries of the Athi River, i.e. Thwake (3EA, 3EB, 3EC, 3ED), Kiboko (3FA) and Tsavo (3G). Tsavo is a transboundary river with its headwaters on the eastern flank of Mt Kilimanjaro, in Tanzania. There is also an internally draining transboundary sub-basin to the north-west (3N) which is shared with Tanzania and which drains into Lake Amboseli. The main Athi River sub-basins include 3DB and 3FB and are confined to the east by the Yatt Plateau. Machakos, within sub-basin 3EA, is surrounded by hills and mountain footridge landforms which extend onto plains. The Olkeju Ado River drains a depositional zone of alluvial plains and ephemeral wetlands before reaching the volcanic rocks at the north end of the Chyulu Hills, where it forms the Kiboko River.

The lower Athi Basin includes the Athi River sub-basins (3HA, 3HB, 3HD1), which discharge into the Indian Ocean north of Malindi. Other smaller rivers such as Gandi and Koromi (sub-basin 3HC) also flow into the Indian Ocean north of Malindi. The Voi, Rare and Ndzoyuni Rivers (3LA) discharge into the Indian Ocean at Kilifi. The Mwamandi River (3MA1, 3MC) and other smaller rivers in sub-basins 3MA2, 3MB, 3MD1 flow into the Indian Ocean at Mombasa. Further down the coast, the Ramisi and Mwena Rivers also drain into the Indian Ocean (3K).



Note: Mwache and Thwake dams under construction

Figure 2-10: Drainage network and sub-basins of the Athi Basin

2.2.1.5 Lakes and wetlands

The Athi Basin includes major wetland systems associated with the Nairobi, Mbagathi, Kiboko, Tsavo, Athi, Namanga, Lumi and Ramisi rivers as well as inland freshwater lakes namely Jipe, Chala and Amboseli. These systems are being threatened by overexploitation of surface and groundwater resources, and catchment degradation. This is resulting in increased sediment loads in the water bodies, changing use of land, encroachment on riparian areas, and water pollution. Major lakes and wetlands are indicated in Figure 2-12.

The upper part of the Athi Basin hosts numerous wetlands associated with the Nairobi River which originates from the Ondiri Swamp, and the Mbagathi River which originates from the Ngong Hills. These rivers supply water to the Athi River and wetlands provide important flood attenuation and water quality amelioration services to these rivers. Many of the wetlands in this part of the basin occur in or are surrounded by urban developments. There are various wetlands between Nairobi and Thika associated with groundwater/surface water interactions and a change in slope. These wetlands are associated with the unique topography of the Rift Valley Fault System. Wetlands in the upper Athi basin include Ondiri Swamp, Manguo, Riu, Gikambura Swamp, Nachu Swamp (Karai), Lari, Theta and Roromo. The headwaters of the Nairobi River are shown in Figure 2-11.

Figure 2-11: Ondiri Swamp - in the headwaters of the Nairobi River (2018)

Lake Amboseli and its associated wetland areas (Enkongo Narok and Loginye swamps) are located in the Athi Basin near the base of Mt Kilimanjaro. These wetlands are seasonal and are an important source of water for the Amboseli National Park. There are also two international lakes in the Athi Basin which straddle the Kenya-Tanzania border, namely Lake Jipe (in the Lumi River system) and Lake Chala (a crater lake). Wetlands in the middle Athi basin include Namanga, Kibwezi, Makindu, Umeni Swamp, Amboseli, Kimana, Lake Amboseli, Kilui springs, Kitobo and Kimorigho.

Coral reefs, occurring as coral flats, lagoons, reef platforms and fringing reefs occur in the coastal region of the lower Athi River as do important mangroves and grass sea beds. Wetlands in the lower Athi basin include Jilore, Ramisi, Mwatate, Bura, Ronge Juu, Kishenyi, Ngerenyi, Ngelenyi, Lushangoni, Kirindinyi, Nguru Swamp and Aruba.

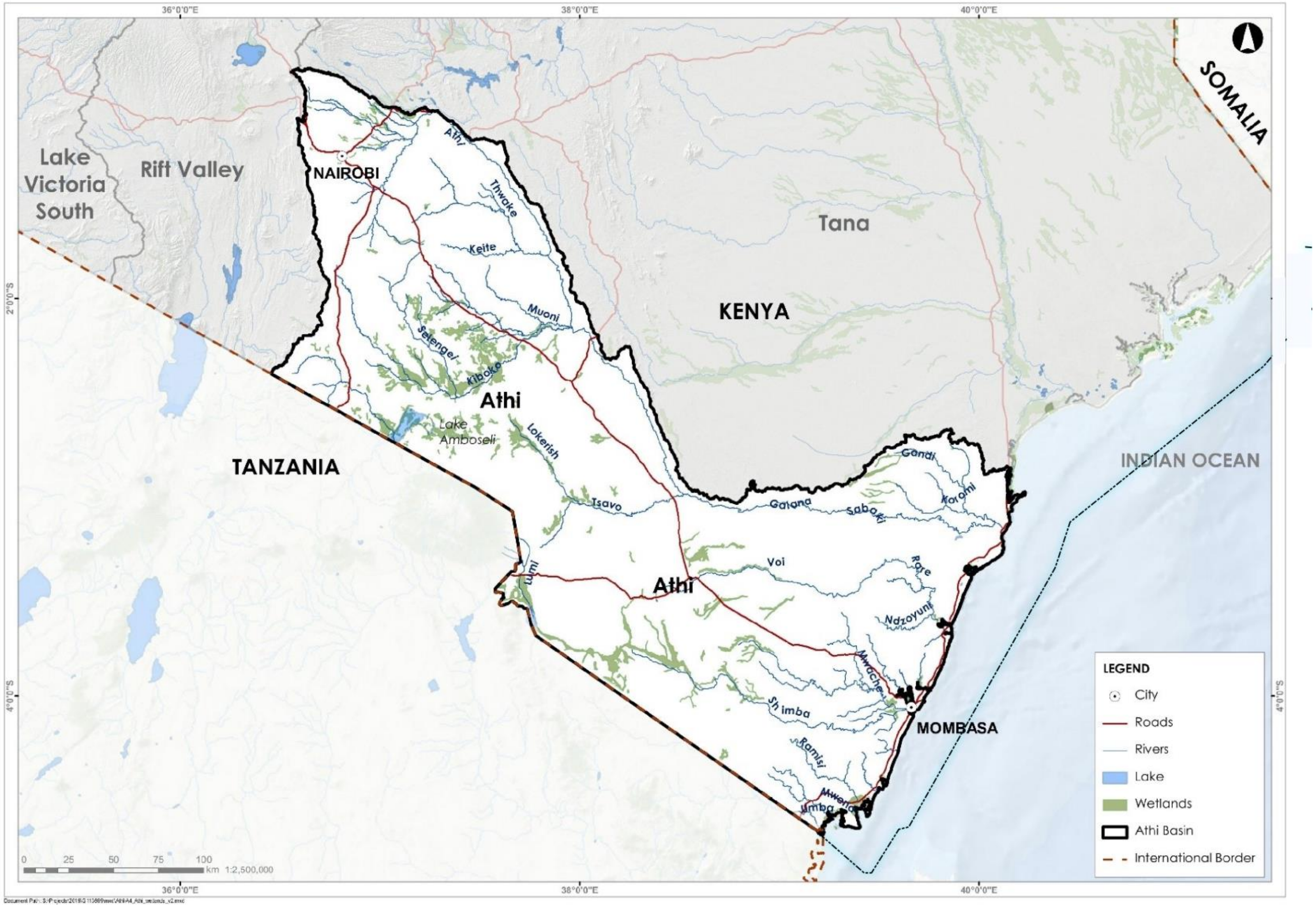


Figure 2-12: Major lakes and wetlands in the Athi Basin

2.2.2 Climate

2.2.2.1 Current climate

The climate of the Athi Basin is primarily forced by the topography of the basin and its proximity to the ocean and to the equator. These factors contribute to the range and variability in precipitation and temperature regimes. The basin is mostly semi-arid land, with a small area of humid land in the upper and middle parts of the basin. Average annual maximum day temperatures vary from 21°C to 39°C across the basin, while the average annual minimum night temperatures vary from 8°C to 22°C. The mean annual precipitation (MAP) is 749 mm across the basin. The upper and coastal parts of the basin receive higher rainfall, up to a MAP of about 1 400 mm, while the MAP reduces to less than 500 mm in the central part of the basin. Figure 2-13 indicates the distribution of mean annual precipitation across the Athi Basin.

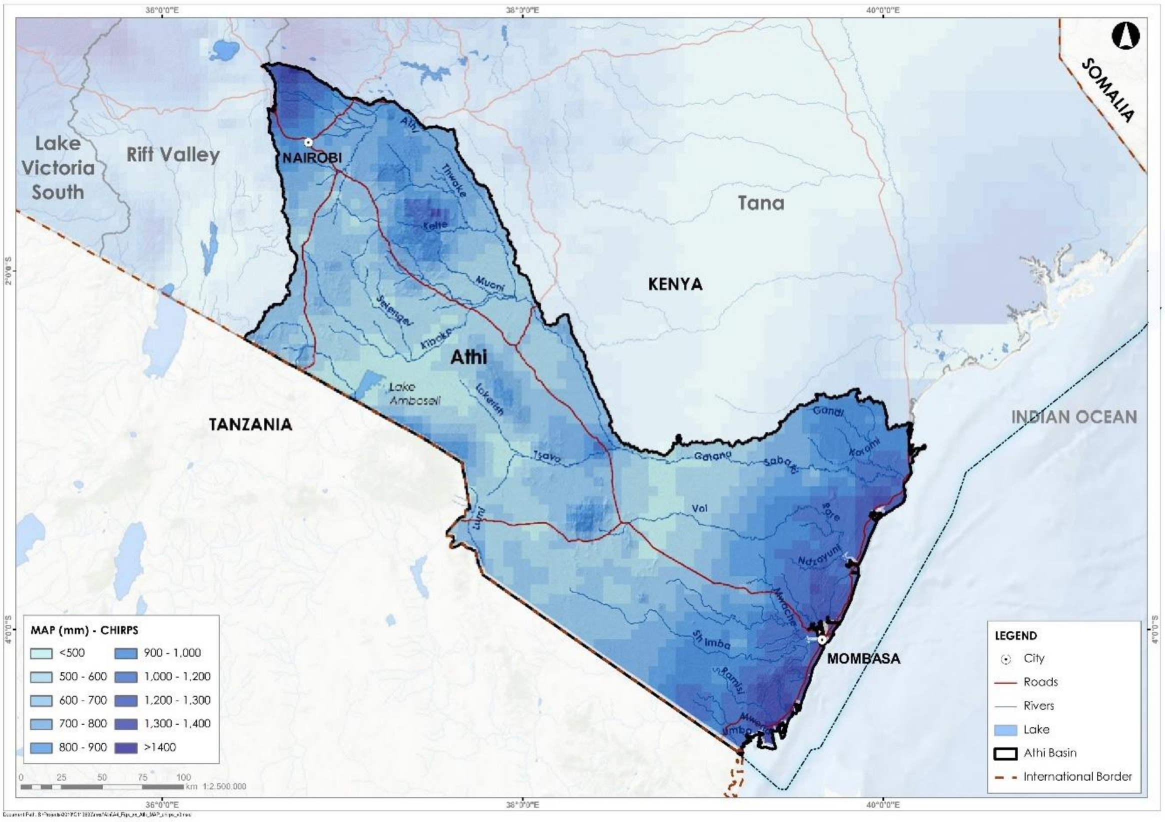


Figure 2-13: Mean annual precipitation across the Athi Basin

Two periods of rainfall occur during the year, namely the long rains between March and May, and the short rains from October to November. Potential evapotranspiration in the catchment ranges from 1 200 mm to 1 650 mm per year, while monthly potential evapotranspiration generally exceeds monthly precipitation, except during the rainy seasons.

The variation of monthly temperature and precipitation in the upper basin (Nairobi) and along the coast is shown in Figure 2-14.

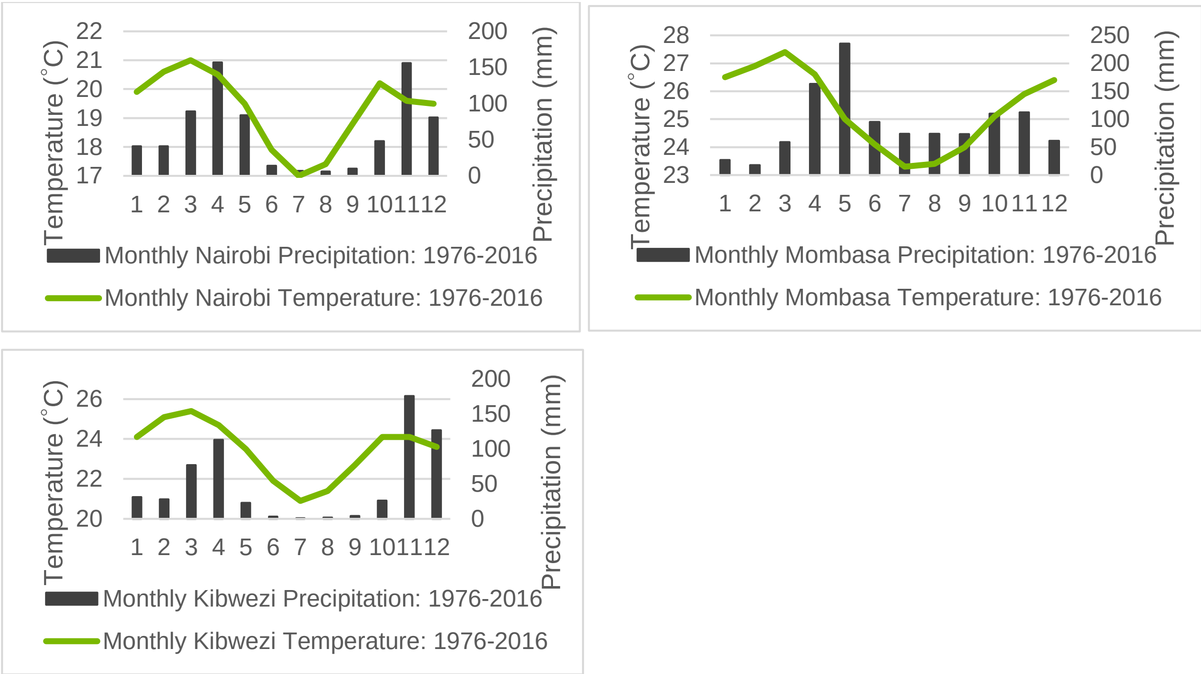


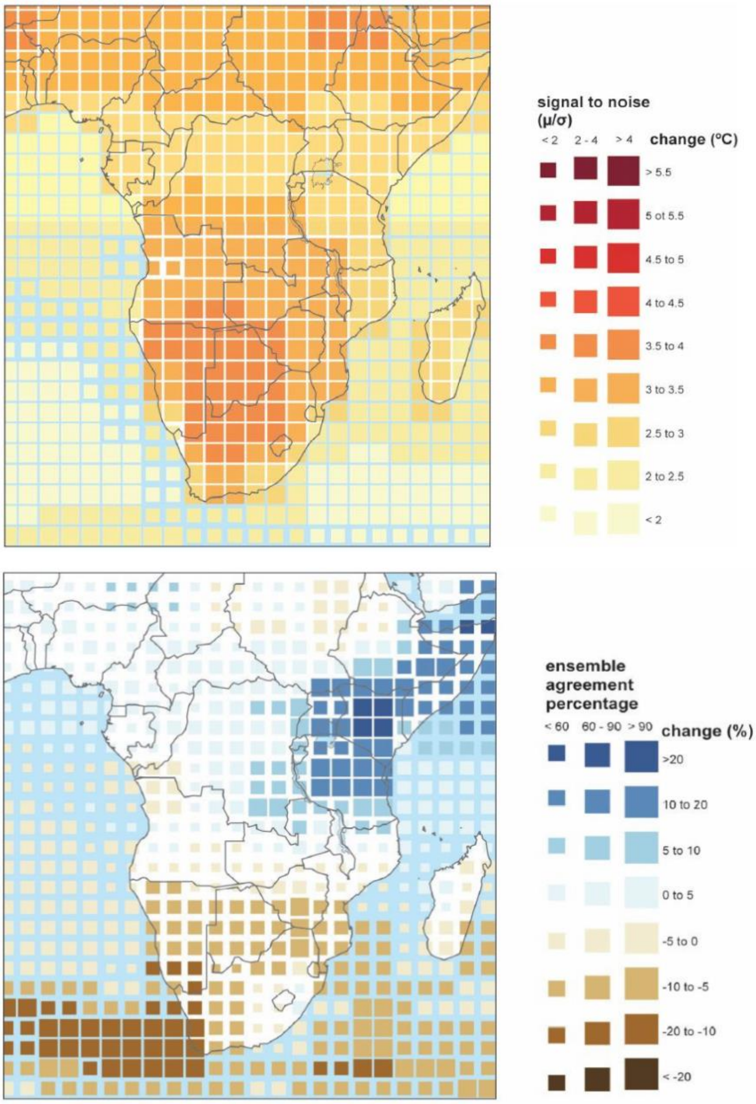
Figure 2-14: Seasonal variation of precipitation and temperature at Nairobi, Mombasa and Kibwezi

2.2.2.2 Future climate

To assist with the assessment of climate change impacts in the basin, an analysis was undertaken as part of this Consultancy (refer to **Annexure A2**). It is recognised that climate change is a serious global challenge and that climate-related impacts may impede economic and social well-being, development efforts, and ultimately catchment sustainability. It is therefore essential to assess the relevant risks associated with a changing climate and the adaptation opportunities at the catchment scale in order to ensure long term water security in Kenya. An effective response to climate change, combining both mitigation and adaptation strategies, will be imperative in achieving sustainable development and enhancing resilience. Figure 2-15 shows the expected changes in precipitation and temperature across parts of Africa by 2100 and indicates that rainfall and temperature over Kenya are expected to increase. This is likely to change the risk and vulnerability profiles of Kenya and its basins.

Factors such as the topography, proximity to the equator, and air masses contribute to the range and variability in precipitation and temperature regimes. The climate analysis which was undertaken as part of the development of the Athi Basin Plan, focused on projected climate trends and analysed multiple spatial and temporal source datasets with the intention of better convey the interactions between and impact on communities, water security and the environment as a result of projected climate change. Temporal analysis, of varying resolutions, informed likely anomalous climatic characteristics such as shifts in seasonality, extreme events occurrence, precipitation intensity and volumes.

With most of the Athi Basin being semi-arid land, the basin will feel the brunt of intensified and prolonged droughts. The areas which are susceptible to flooding may also experience more frequent and more intense floods. Under the influence of climate change there has already been an increase in extreme climatic events in the Athi Basin. Rainfall events have become more erratic and intense, droughts are more likely, and temperatures are swinging to extremes on either end of the spectrum. Changing rainfall seasonality will have a particular impact on farm crop selection and planting regimes. With more rain falling as heavy storm events, it will be less effective, and there will be increased erosion, an increased risk of flooding, and greater environmental degradation. Higher evaporative demand could also offset any benefits should rainfall possibly increase. These changes also have societal impacts through crop yields, as well as on the forestry industry which make proper sustained catchment management implementation ever more essential.



Source: Met Office, 2011

Figure 2-15: Visualisation of GCM predictions of temp (top) and rainfall (bottom) for Africa by 2100

The climate change analysis which was undertaken as part of this Consultancy (refer to **Annexure A2**), showed that projected future precipitation totals are varied across the Athi Basin, yet tend to exhibit an increasing gradient in the medium term from the south east to the north west: +2% to +9% for RCP4.5 and +3% to +12% for RCP8.5. There is likely going to be increased variability between years and a consistent increase going forward will be unusual. This may result in years that have drought like character adjacent to flood seasons and an increase in the intensity of extreme events. On average, the RCP 4.5 analysis predicted that the Mean Annual Precipitation across the Athi Basin would increase from 749 mm to 786 mm by 2050. The temperature anomaly also expresses an increase going from the coast to the inland areas for both day (+1.04°C to 1.18°C for RCP4.5 and +1.42°C to 1.62°C for RCP8.5) and night-time (+1.1°C to 1.3°C for RCP4.5 and +1.52°C to 1.78°C for RCP8.5) temperatures. These projections are in line with current observed climate trends. To assess the expected impacts on more localised precipitation and stream flow in the Athi Basin as result of climate change, four sub-basins are selected for detailed analyses (Annexure A2), namely: 3DA and 3FA (North West Athi), as well as 3HA and 3MB (South East Athi). Nodes and catchments are illustrated in Figure 2-22.

The climate analysis on precipitation, indicates a significant increase in precipitation during September and significant decrease in precipitation during November and December, resulting in the short rainy season shifting to start in September rather than October. Furthermore, the precipitation during August to October is intensified. A similar trend is observed for the long rainy season historically from April to May which is shifted to start in February, reaching its peak in May. It appears that the rainy seasons shift earlier and are accompanied with intensifying rainfall events. The precipitation during the dry season decreases considerably. The north-western sub-basins seem to become wetter while the south-eastern sub-basins are expected to become drier.

The climate analysis on flow indicates an increase in flow over all the months. The total surface water runoff from the Athi Basin is projected to increase with 4% by 2050. However, corresponding to rainfall patterns, the flow in the north-western sub-basins is expected to increase significantly, while the flow in the south-eastern sub-basins is expected to decrease slightly. Furthermore, it is expected that the lower flows in the river will increase in magnitude, while the higher flows will only increase slightly in comparison.

The variability of future climate will result in an area that will need to have adaptive resilience to significantly different scenarios within a season, inter-annually and by decadal. These challenges include increasing temperature and evaporation rates, increasing intensity of extreme events, unpredictable and irregular weather conditions, increased frequency of droughts, and sea level rise.

Figure 2-16 and Figure 2-17 show the expected changes in precipitation and temperature across the Athi Basin.

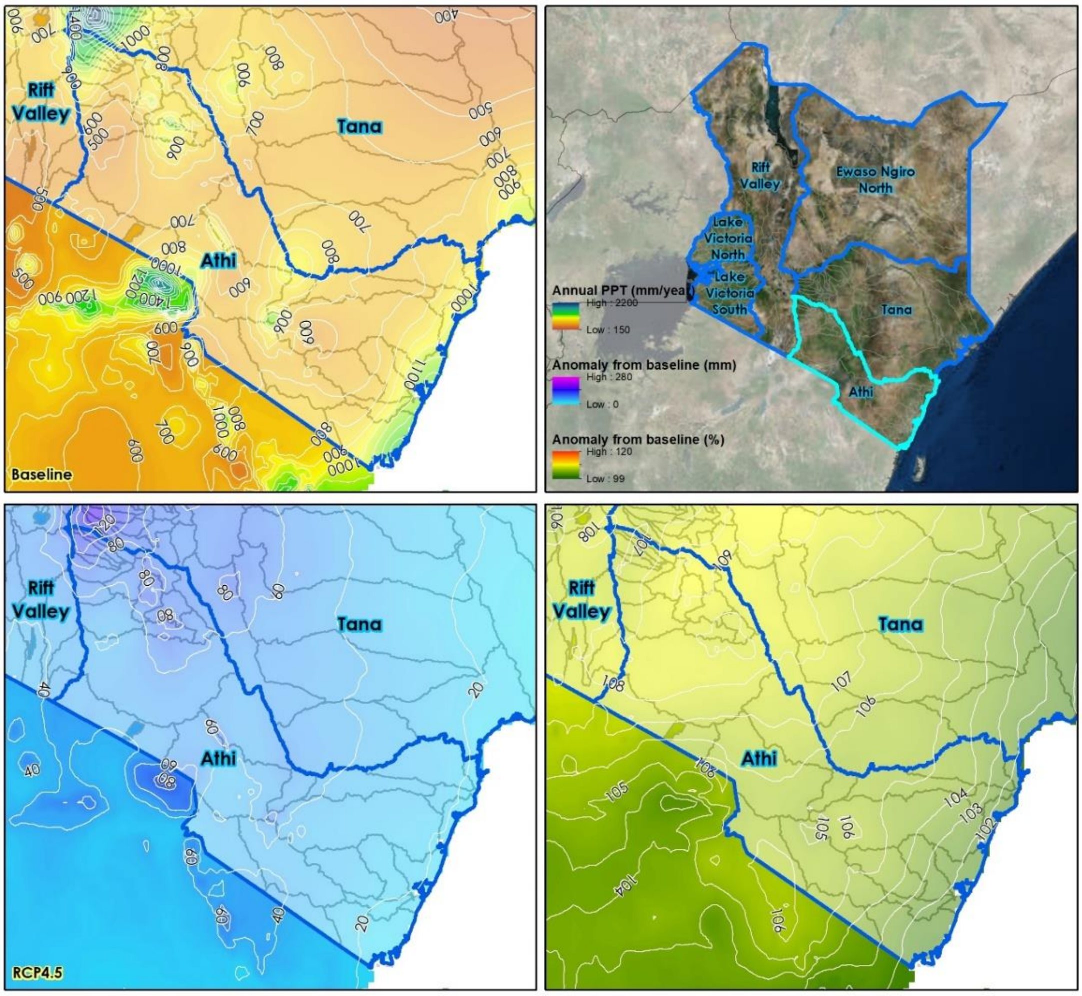


Figure 2-16: Projected Mean Annual Precipitation in the Athi Basin by 2050 (RCP 4.5)

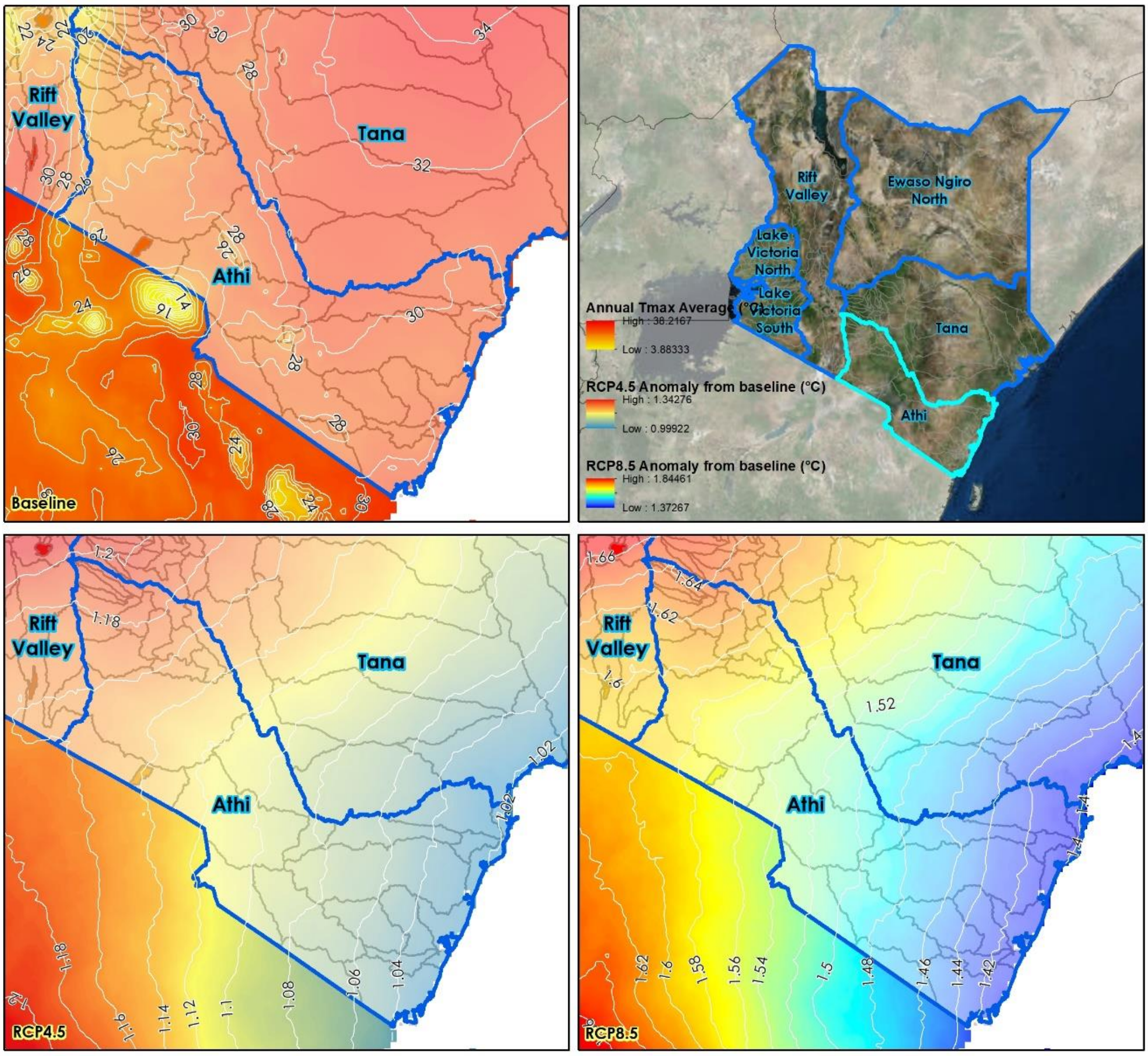


Figure 2-17: Project Tmax anomalies in the Athi Basin by 2050 (RCP 4.5 and RCP 8.5)

2.2.3 Environment

2.2.3.1 Vegetation cover

Vegetation cover is important, as dense vegetation cover will act to protect the land from erosion and increase the infiltration rates, whilst overgrazed and cleared land is more exposed. The density of vegetation cover reflects the influence of cropping practices, vegetation canopy and general ground cover. Maintaining a dense and diverse vegetation cover is important for catchment management as it reduces erosion.

The humid, high lying part of the upper Athi basin generally has good vegetation cover due to natural forests. The main forests within the Athi Basin occur in areas which receive above 800 mm of rainfall per year. They are regarded as the major water towers and groundwater recharge areas of the Athi basin, protect the watershed and influence the quality, quantity and seasonal flow of rivers. In the upper Athi basin the main, gazetted water tower is the Aberdare Range.

The semi-arid plains in the middle Athi basin have limited cover provided by the vegetation. The plains also host cropland and rangeland, with rangeland moving more towards agro-pastoralism and urbanisation. The foot slopes of Mt Kilimanjaro, Chuyulu Hills and Machakos/Wote regions host important forest ecosystems that form a critical part of the hydrological system and provide important natural resources to surrounding wildlife and communities. Chuyulu Hills is the gazetted water tower in the middle Athi.

Along the coastal zone, areas of rainforest, swamp forest and mangroves occur. Shimba Hills is the water tower in the Lower Athi basin. The mangrove forest is an important ecosystem in this region. The coastal forests in the basin are relics of an ancient forest mass stretching across Central Africa from the Atlantic to the Indian ocean. Today, only 10% of the original forest remains, and it is distributed in fragmented patches.

Figure 2-18 shows the spatial variation of vegetation cover in the Athi basin. (A high cover management factor indicates poor vegetation cover and vice versa).

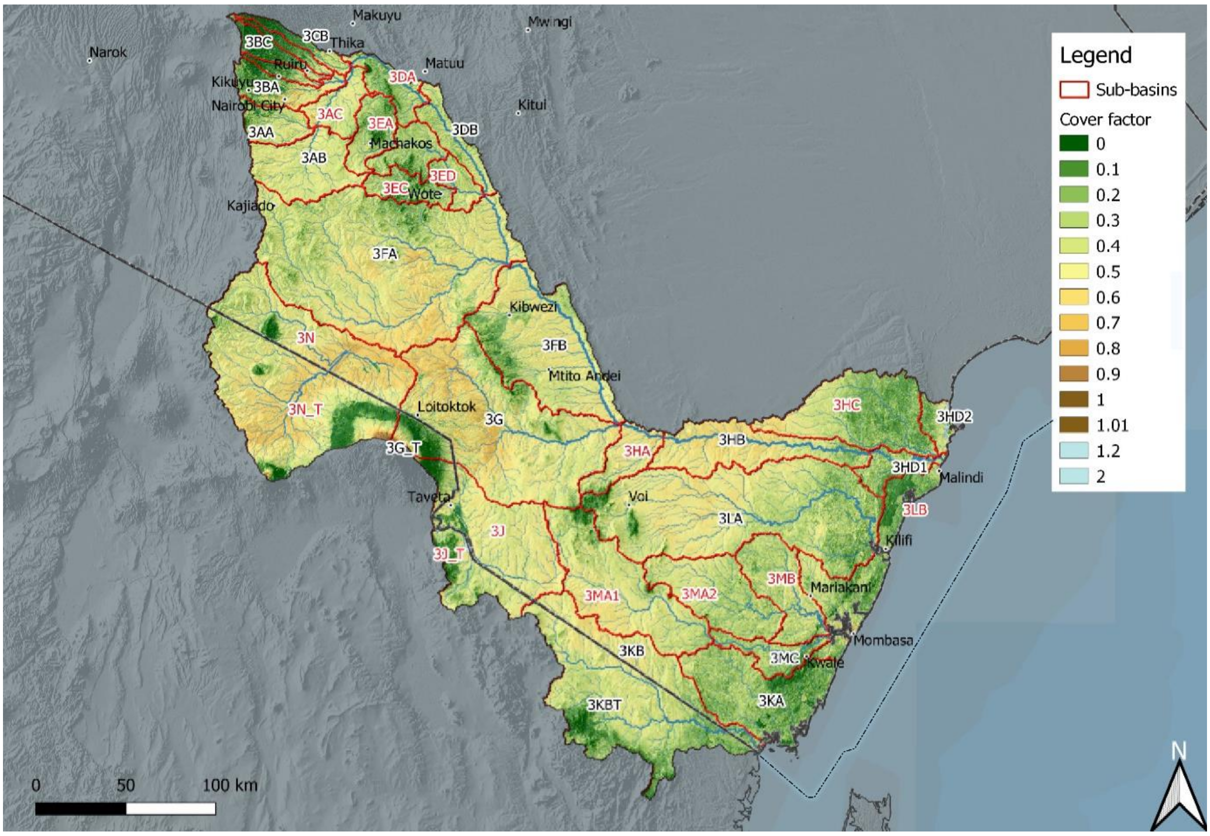


Figure 2-18: Vegetation cover in the Athi Basin

The Athi basin is endowed with a wide range of forest ecosystems ranging from the montane forests in the Aberdares, savannah woodlands in the Taita Taveta, Machakos, and Makueni areas and the dryland coastal forests. Table 2-4 lists some of the main forested hills in the Athi basin.

Table 2-4: Major forested hills in the Athi Basin

Forest Mountain /Hill	Catchment	County	Comments
Kinale	Kinale	Kiambu/ Nyandarua	The Kinale sub catchment has a forest which covers about 30% of the total catchment area and is under great threat from urbanisation. In 1976-2009 the main Kinale sub catchment had a 3% decrease in forest cover arising from clearing of indigenous forest for large scale plantations resulting in a decrease of base flow of 1926-2000 with a mean of 14% (Government of Kenya, 2012)
Ngong Hills	Ngong/Athi	Nairobi/ Kajiado	Under very great pressure from urbanisation and heavy infrastructure development
Namanga/ Oldonyo orok	Local-Border TZ	Kajiado	11 863 Ha of gazetted forest. A Cross border water tower that has benefitted from conservation efforts by the local community (Kenya Water Towers Agency, 2015)
Emali Hills	Local	Kajiado	A newly gazetted water tower under pressure from human encroachment
Chyulu hills	Mzima, Tsavo, Galana	Machakos, Makueni	The ecosystem is under great pressure from both pastoral and agricultural activities from the Maasai and Kamba communities, human wildlife conflicts and is under dual management of KWS and KFS (Chyulu Hills Conservation Trust, 2017)
Ol Donyo Sabuk	Athi	Machakos	This is a small mountain park of 20.7km2 under major threat from human encroachment arising from agricultural activities. It borders Fourteen Falls in Kiambu county and serves as a catchment to the Athi River
Machakos Hills/Iveti Forest	Athi	Machakos, Makueni	Under major threat from urbanisation
Kasigau Mt	Local	Taita Taveta	Taita hills, a local catchment area for Voi River, there was a 78% decrease in tree cover over the same period arising from increased subsistence farming and high population pressure
Maungu Hills	Local	Taita-Taveta	This is within the catchment area of Kasigau river a major tourist circuit area

2.2.3.2 Biodiversity

At least 58 species of fish are known to occur in the Athi River system, four of which were introduced: *Ctenopharyngodon idella* (grass carp), *Cyprinus carpio* (common carp) for cultural reasons and *Oncorhynchus mykiss* (rainbow trout) and *Salmo trutta* (sea trout) for sport fishing (Seegers et al., 2009). There is a greater diversity of fish along the lower reaches of the river than along the upper reaches (Wanja, 2013). Lake Jipe is of global importance as it is the habitat of the only remaining *Oreochromis jipe*, a fish species which is on the verge of extinction.

Along the coastal zone areas of rainforest, swamp forest and mangroves occur. The mangrove forest is an important ecosystem in this region. The Catchment Management Strategy (CMS) for Athi Basin (Water Resources Management Authority, 2015b) states that there was a high probability of significant deterioration of the mangrove forest. It is necessary for strategies of restoration of the affected areas as well as monitoring and management of the unaffected areas to be implemented.

2.2.3.3 Protected areas

The Athi Basin hosts 6 National Parks and 1 National Reserve, which provide important wildlife habitats and stimulates tourism in the area. Figure 2-19 shows the protected areas in the Athi Basin. The Tsavo National Park is the largest protected area in the country, with a total area of about 20,800 km^2. The protected marine areas in the basin have a total combined area of 690 km^2, and include the Diani-Chale, Malindi and Mombasa Marine National Reserves.

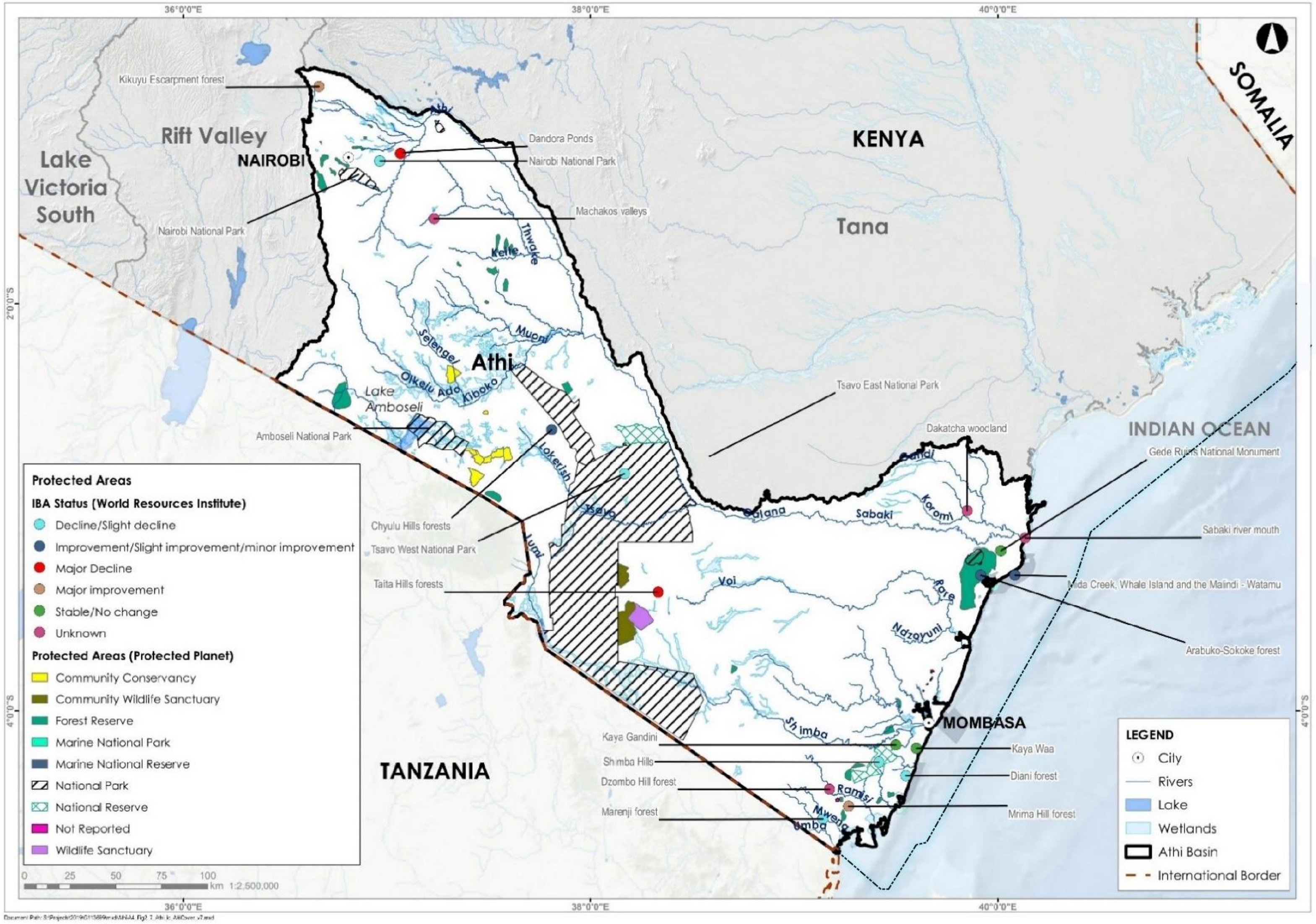


Figure 2-19: Protected areas across the Athi Basin

2.2.4 Land use

Land use in the Athi Basin includes urban, industrial and agricultural use. The basin includes the country's two largest cities, Nairobi and Mombasa, and therefore has a significant portion of urban and built-up areas. Approximately 0.5% of the basin area constitutes urban areas and infrastructure such as roads and airports. Typical impacts associated with built-up environments include erosion of river banks, encroachment of wetlands and riparian zones, poor solid waste disposal and pollution.

The dominant land use in the Athi Basin are croplands and rangelands. The total crop area in the Athi Basin in 2011 was estimated as 876 544 ha, mainly consisting of rain-fed crops (Water Resources Management Authority, 2013b). In the upper basin, coffee and tea farming is predominant, and horticulture is also practised. Cereals, fruits and vegetables are grown in the upper and middle catchment areas. Cotton is grown in the Machakos region. Cashew nuts, coconuts, maize, vegetables, sugarcane and mangoes are grown in the coastal region.

Figure 2-20 shows the major land use and land cover types in the Athi Basin.

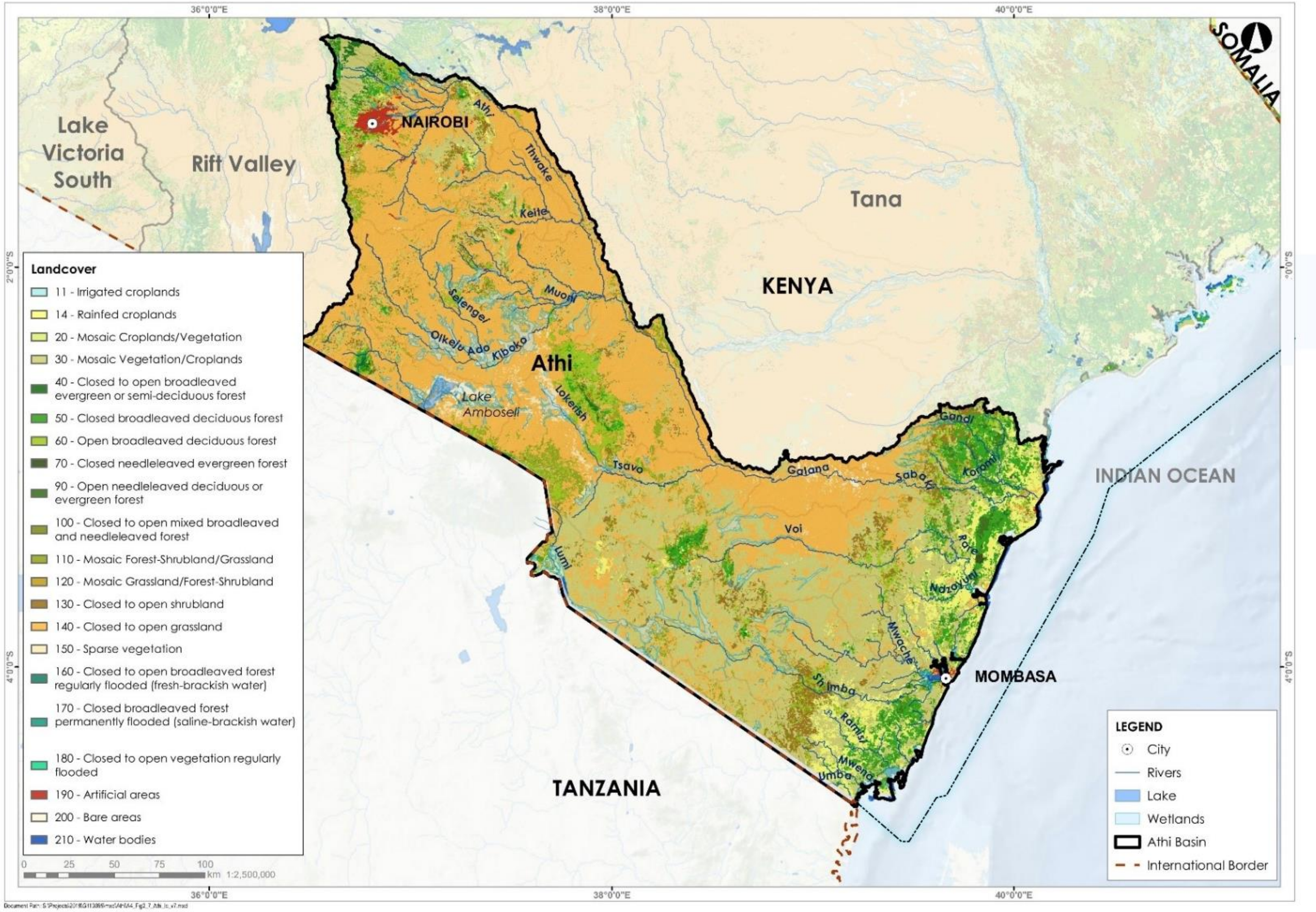


Figure 2-20: Athi Basin land cover

To assist with the assessment of land capability and sustainable land use in the Basin, a GIS-based land capability tool was developed based on the USDA Land Capability Classification (refer to **Annexure A1**). Placing soils into these classes allows for an understanding of the crop and management constraints. It is apparent from the assessment that most of the Basin has a soil capability of 1-3 (i.e. arable land) and that the tops of hills and mountains and steep slopes have a soil capability of 5-8 (i.e. non-arable land).

Overlaying the Land Capability map with the current land use in the Basin, provides an indication of the level of sustainable land use in the basin under current conditions (Figure 2-21). Sustainable land use occurs where crops occur on arable land, and unsustainable land use occurs where crops occur on non-arable land. The mountainous regions in Sub-basin 3DA have unsustainable land uses as does Ngong Hills in Sub-basin 3AA. Other non-woody vegetation in the southern part of the upper basin also occurs on non-arable land. Other forest, grassland, shrubs and herbaceous vegetation occurs on suitable land. The northern part of middle Athi has non-woody vegetation and crops on non-arable land, while there are small areas along the coast with unsustainable land uses.

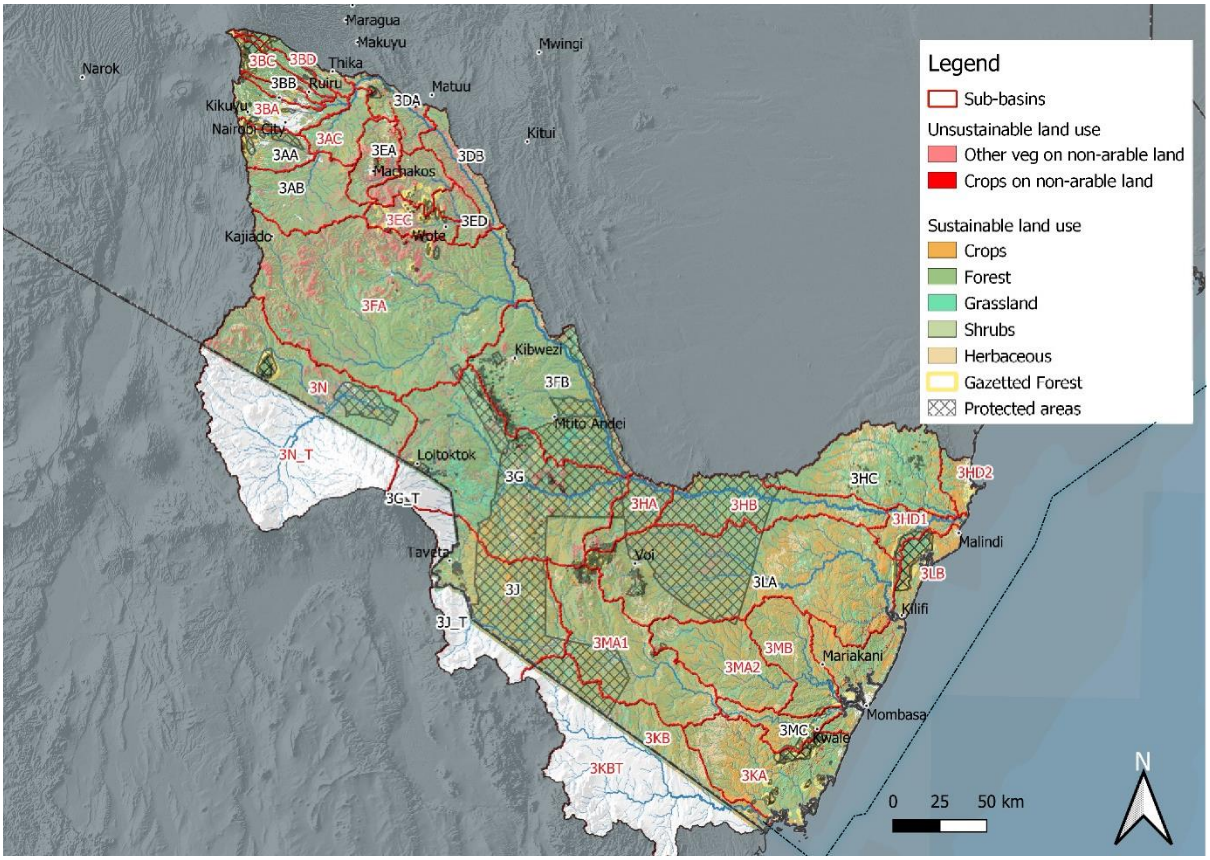


Figure 2-21: Sustainable land use in the Athi Basin

2.3 Socioeconomic

Water plays a key role in the socio-economic environment in the Athi Basin. It is of critical importance for the agricultural sector, which is the mainstay of Kenya's economy, for industries, health, tourism and for improving the standard of living. The Economic Recovery Strategy for Wealth and Employment Creation (Government of Kenya, 2003) emphasised economic growth and creation of wealth and employment as a means of eradicating poverty and achieving food security and water is central to this growth strategy.

2.3.1 Demographics

The main demographics was sourced from the 2019 Census (Kenya National Bureau of Statistics, 2019), the Socio-economic Atlas of Kenya (Wiesmann et al., 2016) as well as County Fact Sheets (Commission on Revenue Allocation, 2013). The total population of the Athi Basin is 13.43 million, which is equivalent to a population density of 202 persons/km^2. The Athi Basin is the basin with the highest ratio of urban to rural population.

Projections based on the Census 2019 (Kenya National Bureau of Statistics, 2019) population data and United Nations population growth rates as estimated in the Kenya Vision 2030. The rural population is expected to remain relatively unchanged up to 2050, however the urban population is expected to increase by almost 300% by 2050. The projected population density is 350 persons/km^2 and 500 persons/km^2 for 2030 and 2050 respectively.

The education level index measures the average level of formal education reached by adults in a given area. It is calculated by averaging together the highest education level reached by each individual in a specific area. When calculating the index ranges from 0 (no formal education), 1.0 (completed primary school), 2.0 (completed secondary school) and 3.0 (completed university degree). The education level index in the Athi Basin is 1.3, which is the highest in the country. This is an average value, individuals in a given area will differ. Although the Athi Basin has the highest education level index in the country, there is still a large proportion of the population without secondary school education (about 65%). School attendance is relatively high in Kiambu and Nairobi counties. However, Kwale and Kilifi counties have low levels of school attendance.

2.3.2 Economy

2.3.2.1 Economic activity

There is significant economic activity in the Athi Basin, mainly in the two large economic centres of Nairobi and Mombasa. Industrial activities occur in the capital city of Nairobi include agricultural equipment, brewing and beverages, cement, chemicals and pharmaceuticals, coffee processing, construction material, electricity appliances, food processing, shoes, glass, leather, light industries, meat processing, painting material, paper industry, plastic products, printing, soap, steel, textile, timber and timber products, tobacco and automobile accessories. Other well-known industrial activities in the basin include the textile industry at Voi town and the food processing industries at Malindi and Kilifi towns. The coastal zone hosts significant economic activities due to the marine industry, tourism and the Port of Mombasa, while industrial activities in Mombasa city include brewing and beverages, cement, construction material, food processing, glass, light industry, meat processing, oil refinery, paper, plastic products, ship repair, soap, steel, textile, automobiles and shoes. The basin is also a busy transport corridor for products within the country and with neighbouring countries. Figure 2-2 displays a map of the counties which fall within the Athi Basin.

Table 2-5: Economic activity of each county

County	Economic Activities	Reference
Kiambu	Kiambu County relies mostly on agriculture and industries to sustain its economy. Although most residents are small scale farmers growing tea and coffee, there are several large-scale coffee and tea farms which are serviced by local industries mostly located in Thika and Ruiru Constituencies. It is estimated that 21 447 ha is under food crop and 35 367 ha is under cash crops in the County. Commercial horticulture is also practiced under greenhouses and there exists plantations of pineapples within the county. The county in its CIDP proposes to establish at least 600 greenhouses, fish ponds and construction of cooling plants in an effort to improve productivity of the sector and to increase food security in the County. The Komo and Kamuka irrigation schemes have about 57 ha and 64 ha respectively under production. The county plans to construct two dams in Kinale and Gatundu south to support irrigation activities	County Government of Kiambu, 2018
Nairobi	Nairobi business contributes enormously to the economy of Kenya. In fact, Nairobi is considered a business hub for East and Central Africa. Many multinationals companies have established their headquarters in Nairobi owing to its strategic location in the region. Manufacturing in Nairobi consists of many small and medium-sized industries. These include industries manufacturing steel products, plastic goods, soaps, flour, vegetable oil, canned fruit and fruit juice, horticulture, and dairy and poultry farming. Bulk trading of Kenyan coffee (the Kenyan coffee auction) also takes place weekly at the Nairobi Coffee Exchange. Although Nairobi trade is based on an agricultural economy, the most vibrant industry is the service-based industry. The service industry contributes 59.2 percent of Nairobi's GDP as compared to 24 percent from agriculture, followed next by the manufacturing industry. The informal sector is an integral part of Nairobi business. The "Jua Kali" sector is comprised of artisans who craft, fabricate and re-model all kinds of items. They also deal in the trading of second-hand goods such as clothes, fabric, shoes, electronics and vehicle spare parts. Although Nairobi City County is majorly an urban centre, urban agriculture is being practiced mainly under greenhouse technology. The National Irrigation Authority (NIA) in the National Green House Project, supported the setting up of 15 greenhouses within Nairobi County. It is estimated that 96.8km2 is under urban agriculture. The crops grown are primarily vegetables for subsistence and market but on a small scale there is also cut flowers grown in Langata area as an export cash crop. The limited space limits the extent of agricultural activities and thus increases demand for innovative ways and modern technologies in urban agriculture.	County Government of Nairobi, 2017
Machakos	Machakos County has an estimated 161 700 ha under food crops and 86,600 ha under cash crops. The food crops include maize, beans, pigeon peas and cassava while cash crops include coffee, French beans, pineapples and sorghum. There are several small-scale irrigation projects within Machakos county with the largest being Kayatta/Kathama/Mbiuni (Kambi) Irrigation project covering a total area of about 800 ha. Some irrigation projects are still under implementation while others are operational. They include Kamuthambya, Kauti, Kangeta-Kitoi, Wakulima/Kyangii, Ngulini, Kabaa, Muthwani, Kananie, Syokisinga, Katangi, Ndasuco, Kombu, Kyumba, Kambi, Ekalakala and Kyangosi. The agricultural sector in Machakos County has continually improved over the years since the rehabilitation of the Yatta canal. In addition, development of water resources by the County Government has resulted in increased agricultural activities, especially greenhouse farming. Machakos County has more than 150 manufacturing companies though as per county records, only about 65 of them are operational including steel, various agricultural, meat and cement factories. The county will also be the future home of the Konza City which has been dubbed the silicon savannah.	County Government of Machakos, 2018

County	Economic Activities	Reference
Kaijiado	Kaijiado county mainly consists of ASAL where livestock production is the main activity. The county however has a total estimated area of 1 068 ha and 50.6 ha under food crop and cash crop respectively. The main food crops grown in the county include maize, beans, potatoes and vegetables. Commercial farming of onions and tomatoes is largely practiced in Loitokitok, Isinya and Nguruman (Rift Valley Basin). The NIA established Isinet irrigation project with 700 acres under production and Entarara irrigation scheme with 80.9 ha under production. Opportunities in the sector are limited by the semi-arid nature of the county, though greenhouse technologies are increasingly being used for high value crops. Kajiado county has a very conducive environment for companies to set up manufacturing and processing plants. This is due to availability of expansive land, underground water resources, raw materials and affordable labour force. Existing manufacturing industries in Kajiado County include a steel melting plant in Isinya, Isinya Feeds production plant located near Isinya, Allied East Africa Ltd Liquefied Petroleum Gas Cylinder Manufacturer and Revalidator located near Kitengela and Kitengela Glass located opposite the Nairobi National Park. Industries currently under construction include a steel Mill, a cooking oil factory and a gas production plant.	County Government of Kajiado, 2018
Makueni	Makueni County has limited industries mainly due to limited natural resources, distance from major urban centres and low level of investment. It has an estimated area of 65 500 ha under food crops and 23 400 ha under cash crops. The food crops include maize, green grams, pigeon peas and sorghum. Fruit trees like mangoes, pawpaws and oranges have gained popularity in the county as commercial crops. The county has about 1 800 ha under irrigation. The irrigation projects include Iviani, Kwa Majee, Kiboko, Kambi ya Mawe, Kwa Miui, Kibwezi, Kako/Kathonzweni, Yatikaa and Mukuku irrigation schemes. The County Government plans to expand Kibwezi irrigation scheme by about 162 ha. Flagship manufacturing industries include the Makueni Fruit Processing Plant and the Kikima Dairy Plant. Other industries include a cotton ginnery and a bakery as well as several light industries.	County Government of Makueni, 2018
Taita Taveta	Taita Taveta County has agriculture as its predominant economic activity. An estimated 18 100 ha is under food crops and 3 300 ha under cash crops. The food crops are mainly maize and beans but there are also green grams, sorghum, cow peas, pigeon peace, cassava and sweet potatoes. There exists also large-scale sisal farming. Agriculture is mainly rain fed but there exist irrigation activities like Kimorigho, Gimba, Bura, Kimala, Lake Chala Tuhire, Njukini and Kishau irrigation schemes. The county plans to increase the area under irrigation to 4 800 ha. Crop production in the county has been limited by the total available arable land and limited water resources across the county. However, opportunity exists for greenhouse farming in the county. Agriculture is mostly practiced in the highlands with horticultural production becoming an important economic pursuit in the Taita Hills. Other activities include cattle, dairy, sisal and wildlife tourism. Mining is carried out in the drier parts of the county, where large deposits of precious stones can be found. Significant iron ore deposits have recently been discovered and mining has commenced in the Kishushe area of Wundanyi. Asbestos, chalk, limestone, gemstones, construction stones and sand are also among the region’s minerals portfolio. The County Government has a strategic investment plan dubbed Transform Taita Taveta 2020 which has identified flagship projects which are set to benefit residents. Most of the projects will be implemented through either Public Private Partnership (PPP) or Private Initiated Investment.	County Government of Taita Taveta, 2018

County	Economic Activities	Reference
Kwale	Kwale County is rich in coconuts, cashew nuts, sisal, mangoes, bird eye chillies and commercial crafts. Processed sisal and bird eye chillies are currently being exported while raw cashew nut and mature coconuts are bought by processors for value addition before export. Mangoes are being processed into pulp by a company which is currently selling locally as it prepares for export. The County has about 28 000 ha under food crops and 45,400 ha under cash crops. The food crops include maize, cassava, beans green grams and peas while cash crops include cashew nuts, sugarcane, cotton, simsim, bixa and tobacco. Several irrigation projects have been proposed. They include Mwache irrigation development project with already 151 800 ha of land prepared for production, Waga/Machame irrigation project for rice production, Vichigini/Matovoni project for rice irrigation on 135 ha of private land, Pemba irrigation and Koromojo dam for sugar irrigation. There is opportunity to increased crop production under irrigation especially with the implementation of Mwache Multipurpose Dam. The existence of Kwale International Sugar Company presents an opportunity for sugarcane farmers to increase production. Kwale County is also home to Coast Calcium Limited, Base Titanium, Bixa Limited and Kwale International Sugar Company. These industries are engaged in mining and agricultural activities. Industrial developments planned in Kwale County include agroforestry manufacturing operations and a bitumen manufacturing plant. Top Steel Kenya Limited also recently constructed a steel manufacturing facility at Mwavumbo area in Kwale County (very near to Mariakani in Mombasa).	County Government of Kwale, 2013
Kilifi	Kilifi County has numerous opportunities in agriculture, particularly dairy and crop farming thanks to fertile soils and a good weather pattern. The county has about 52 500 ha under food crops and 47 700 ha under cash crops. The food crops include maize, green grams, cow peas and cassava while cash crops are coconut, cashew nuts, pineapples, mangoes and sisal. There exist several irrigation schemes in Kilifi. The Galana-Kulalu irrigation scheme is expected to irrigate at least 364 217 ha with a target of up to 485 623 ha subject to availability of land and adequate water resources. The proposed Thwake Multipurpose Dam in Makueni County is one of two proposed dams expected to support the Galana-Kulalu irrigation project, which depends on the Athi/Galana river and Tana river for its water sources. The county is also rich in coconuts, cashew nuts, sisal, mangoes, bird eye chillies, neem trees, water melons and commercial crafts and various processing plants are in operation. The County also has potential for growing and tapping rubber at 'Mpirani'. It has a strong industrial sector with the Mabati Rolling Mill and the Athi River Cement Factory contributing to the region's economy both in employment provision and income generation. There are existing Export Processing Zones (EPZs) in the county which export textiles to the US under the AGOA while other EPZs are being planned. The Department of Finance and Economic Planning, Kilifi County, is spearheading the preparation of the Second CIDP 2018-2022.	County Government of Kilifi, 2018
Mombasa	Mombasa County is an industrial hub with several manufacturing enterprises which include export processing, oil refineries, fisheries, glassware, flour mills and car assembly plants. Most of these industries are in Mvita, and Changamwe sub-counties. The County has about 400 ha under food crops and 500 ha under cash crops. The area under crop production is not adequate to meet local food demand. There are plans by the Mombasa County Government to irrigate about 4 000 ha in Mwakirunge and Dongo areas in Mombasa County. However, a feasibility study still should be done. Mining activities in the County are minimal. The only notable mining activity that is ongoing is limestone mining by Bamburi Cement factory in Kisauni Sub-county. There is small-scale extraction of coral blocks in some parts of the county. Apart from offering prospects for sea bed mining, several companies are now undertaking seismic surveys off shore prospecting for oil, gas and coal deposits. The county has the only port which is the main entry point for almost all imported materials and exit for exports from the hinterland which has a combined population of over 150 million people. A significant proportion of the service industry is thus related to serving the import and export business through Mombasa port. Mombasa CIDP objectives are to attract new investment into the tertiary sector and the creation of an enabling environment and maximising of opportunities within the manufacturing sector.	County Government of Mombasa, 2018

Despite various economic activities, the average poverty rate in the Athi Basin is at 38%. Although this is the basin with the lowest average poverty rate in the country, this is still significantly high. The poorest areas in the basin namely Kwale and Makueni counties have poverty rates of about 70% and 60% respectively. Kinango (Kwale County) has an infant mortality rate which is among the highest in the country due to its poverty and inadequate healthcare. Kilifi County is also a highly impoverished area.

2.3.2.2 Employment and livelihoods

Most formal employment is in the urban centres although there is also formal employment in rural areas. The formal sector employs 39% of the labour force in the Athi Basin.

Livelihoods refers to a person's means of securing the basic necessities of life (i.e. food, water, shelter and clothing). Engaging in livelihood activities involves acquiring knowledge, skills, social network, raw materials, and other resources to meet individual or collective needs on a sustainable basis. Investing in livelihood activities reduces the costs associated with the provision of aid and protection; and builds self-reliance. The sources of livelihood vary across the basin, from fishing in the coastal areas to subsistence agriculture and crop and livestock production in the pastoral and farming areas. The livelihoods of the various counties are described below.

Table 2-6: Economic activity of each county

County	Economic Activities	Reference
Kiambu	Most of the wage earners in Kiambu county are employed in the coffee/tea estates and horticulture. Self-employed persons are mainly construction companies, super markets, jua kali, manufacturing, hotels and bars. The level of unemployment is 60%, most of the unemployed having no skills. Small land holdings are mostly found in the upper parts of the county, with most farmers converting farms into residential plots to supplement the meagre income from farms. Larger land holdings are usually found in the lower parts of the county.	County Government of Kiambu, 2018
Nairobi	Nairobi has the largest share of the formal sector wage employment in Kenya and about 3.5 times the wage employment is those employed in the informal sector. The informal sector covers small activities that are semi-organized, unregulated and uses low and simple technologies while employing fewer people per establishment. Earnings in the labour market are the main source of income for urban dwellers, although this does not necessarily keep them above the poverty line. Crop production and value addition addresses food insecurity and supplements household incomes.	County Government of Nairobi, 2017
Machakos	There are few formal employment opportunities in the county, with most of jobs being casual labour for the farms, construction, manufacturing and textile industries. There is a surplus of skilled and unskilled labour, not matched by job opportunities. Land use change from agriculture to real estate has shrunk employment opportunities in the agricultural sector. The youth are also shying away from agricultural jobs and financial insecurity, in preference for white collar jobs with more financial security.	County Government of Machakos, 2018
Kaijiado	The working population in the county mainly work in the formal and informal sectors. Most self-employed people are engaged in livestock trade, retail and wholesale trade, horticulture and floriculture, industrial activities, Jua kali and tourism. Micro small and medium enterprises employ about 40% of the county population. There is a rapidly expanding labour force. The change in land tenure system, reducing the number of ranches from 56 to 10 under private ownership. Privatisation of land tenure, subdivision and commercialisation of communal rangelands have resulted in further degradation of human settlement in the county. The rural community who were formally nomadic pastoralists settle and have to manage cattle on their parcels thus leading to land degradation and further compounding human-wildlife conflict.	County Government of Kajiado, 2018

County	Economic Activities	Reference
Makueni	Agriculture is the main source of income in the county, accounting for up to 78% of household income, followed by wage employment at 10%. Although the Mombasa-Nairobi highway has provided income from trade, trade among other sources of income are limited which have led to an overreliance on the agriculture sector.	County Government of Makueni, 2018
Taita Taveta	Half of the population is employed in the labour force, whilst the rest are urban self-employed operating small-medium business enterprises and the rural self-employed engage in small scale agriculture including farming, agroforestry, livestock keeping, chicken rearing and fish farming. There are 28 ranches in the county and two National Parks cover about 62% of the county.	County Government of Taita Taveta, 2018
Kwale	Land issues have led to squatter settlement problems. Wage earners are below 10% and self-employment contributes up to 6 percent to household income. The agricultural sector contributes up to 80% to the household income and employs a large proportion of the population.	County Government of Kwale, 2013
Kilifi	The level of employment in the county has remained high since independence but has worsened due to the tourism industry recession. A large proportion of the population still engage in subsistence family farming and low-productivity self-employment. Historical land injustices have delayed the state's implementation of land sector reforms. This legacy has resulted in more than half of the population not having formal titles to the land, which impacts their use of the land. Food crops are grown for subsistence and horticultural crops such as cashew, coconut and mangoes play a critical role in increasing the household level income.	County Government of Kilifi, 2018
Mombasa	There are limited people involved in agricultural activities, however up to 60% are engaged in other wage earning. Major employers include the hotel industry, the Kenya Ports Authority, the Government of Kenya, Container Freight Terminals and various private institutions. A large number of people in the peri-urban areas of the county practice subsistence small-scale farming and keep different types of livestock, although land ownership is an issue.	County Government of Mombasa, 2018

2.3.3 Standard of living

2.3.3.1 Water supply and sanitation

There are currently seven large dams in the Athi Basin, as well as a large number of small dams and pans as well as springs, with a total storage volume of about 22 MCM, supplying urban and domestic demands. The Athi Basin contains the two largest urban areas in Kenya: Nairobi is the capital of Kenya and also the largest city. Three main sources supply Nairobi with its water resources: Kikuyu Springs (used since 1906), Ruiru Dam (since 1938); and an inter-basin transfer from the Tana River Basin. Groundwater supplies make up approximately 20% of the supply in Nairobi. Kenya's second largest city, Mombasa, mainly obtains its water supply through the Marere Water Works (Marere Springs) in the south-west, the Baricho Intake at the lower Athi River, from Mzima Springs through a 220km pipeline to the city and from the Tiwi boreholes.

Based on 2009 Census data, the total population in the Athi Basin in 2009 was 9.79 million, of which 6.51 million live in urban areas (concentrated in the Nairobi and Mombasa areas) and 3.28 million live in rural areas. Water Service Providers (WSPs) mainly cover the urban population, while the rural population is served by small community-based water supply schemes.

At present, about 63% of the urban population in the basin receive piped water provided by WSPs (the highest among the six basins), while 20% are dependent on unimproved water sources (17% from water vendors and 3% as direct use from rivers, ponds and lakes). The remaining 17% are supplied from groundwater, which include protected and unimproved sources. Within Nairobi, an unknown number of boreholes are used as sources of local public water supply. In rural areas, 35% of the population abstract water directly from rivers, ponds and lakes, 34% use groundwater and only 3% are supplied by water vendors. The rural population in the basin also has a much lower percentage of piped water supply at only 28% compared to the urban population at 63% (Water Resources Management Authority, 2013b).

The Water Act 2016 devolves water and sanitation services to the county governments, who provides these services through WSPs. Within the Athi Basin, the Athi Water Works Development Agency, Coastal Water Works Development Agency and Tanathi Water Works Development Agency contract these WSPs to provide potable water to the population.

The Athi Basin can be delineated into three distinct water supply areas, namely Nairobi and Satellite Towns, Mombasa and Coastal Surrounding Areas and the remaining areas of the basin. These areas are served by 21 urban WSPs and 7 rural WSPs, which in total supply almost 675 Mℓ/day. These utilities vary in size with the largest being Nairobi City Water and Sewerage Company that serves more than 3 million people followed by Mombasa Water and Sewerage Company that supplies water to almost 600 hundred thousand people. The total population served by the WSPs are estimated to be close to 5 million, which is about 61% of the population living within the supply areas of these water utilities(Water Services Regulatory Board, 2016). The non-revenue water (NRW) of these WSPs ranges from 24% to 89%

The Athi Basin has the largest proportion of households connected to a formal sewerage system, with 22% of the population having access. On-site sanitation facilities like pit latrines and septic tanks are used by 71% of the population, while 7% of the population have no form of sanitation system and resort to unsanitary waste disposal. There are eight waste water treatment plants located in six UCs around Nairobi and Mombasa, with a total treatment capacity of about 222 000 m^3/day. Around 71% of the population use alternative methods of wastewater disposal, such as septic tanks.

2.3.3.2 Land tenure

Four different entities can own land in Kenya, namely, the government, individuals and groups. Any Kenyan individual can own land if they have been granted citizenship, which includes natural citizens as well. Companies which are fully owned by Kenyan citizens or any trust whose beneficiaries are Kenyan citizens can own land.

The land tenure systems within Kenya can be characterised as private/modern and communal/customary. There are five types of land tenures**:**

- **Freehold:** allows the owner to hold the land for an indefinite term.
- **Leasehold:** a leasehold agreement confers upon the owner a limited term on the property, which can be extended upon expiry. The Kenyan constitution limited the tenure for non-citizens to no more than 99 years.
- **Customary:** rights are based on communal ownership, where the land is assigned to a defined group of users or individuals. Users may belong to a clan or ethnic community.
- **Public/State land:** this is when the government is a private land owner. This system dates from the Crown lands Ordinance of 1902 which declared that all waste and unoccupied land in the protectorate was crown land.
- **Foreign access to land in Kenya:** a person who is not a citizen of Kenya may hold the land as part of a leasehold tenure and this lease should not extend before 99 years.

The land tenure trends for the counties is as follows:

Table 2-7: Economic activity of each county

County	Economic Activities	Reference
Kiambu	Officially 85% of land owners have received title deeds. Within the registered there is a large quantity of land that has been subdivided and titles have not been registered.	County Government of Kiambu, 2018
Nairobi	A large proportion of households do not have title deeds, with a lower proportion of the poor having title deeds. Issues of landlessness has affected those living in informal settlements the most. The situation is fuelled by historical land injustices, land grabbing and an influx of unskilled and semi-skilled job seekers from rural areas.	County Government of Nairobi, 2017
Machakos	The county has 28.5% of proportion of parcels with title deeds. The most affected areas are Athi River, Machakos and Kathiani which has led to land ownership conflict.	County Government of Machakos, 2018
Kaijiado	Land in the county is categorized as community land, private land or public land and registered as leasehold or freehold interest. Land with title deeds is estimated at 95% in rural areas and 5% in townships.	County Government of Kajiado, 2018
Makueni	Only 19.8% of land owners have title deeds. Kibwezi West and East Constituencies have issues with squatters.	County Government of Makueni, 2018
Taita Taveta	The land in the county is communally owned with approximately 35% having title deeds.	County Government of Taita Taveta, 2018
Kwale	Only 22.5% of land has title deeds. There is a high incidence of landlessness and squatters in the county. Most households are landless, making them vulnerable.	County Government of Kwale, 2013
Kilifi	About 66% of land does not have formal titles to the land, with 34% having title deeds. Delay is redressing crown land legacy along the coast has led to a squatter problem and what is considered “land grabbing”.	County Government of Kilifi, 2018
Mombasa	Only 30% of land has title deeds. There is a high incidence of landlessness, thus leading to squatters.	County Government of Mombasa, 2018

2.4 Water resources management

2.4.1 Surface water resources

2.4.1.1 Conceptual approach to surface water resources assessment

A surface water resources analysis for the Athi Basin was undertaken to quantify the available surface water within the basin under natural conditions in both space and time (See **Annexure A3**). This involved the development of a water resources systems model of the basin, including a rainfall-runoff model. Based on the availability of historical rainfall data, a simulation period from 1960 to 2017 was used for the model simulations, conducted at a daily time-step. MIKE HYDRO Basin, which incorporates the NAM rainfall-runoff model, was used as the water resources systems model. The water resources modelling task involved a number of sequential steps including the collection, review and quality control of hydrometeorological data, model sub-catchment delineation, model calibration and validation, the configuration of a system model, and hydrological assessment through water resources simulation.

Note: More details regarding the surface water resources assessment for the Athi Basin are provided in “ISC Report C1-1: Athi Surface Water Resources Assessment”.

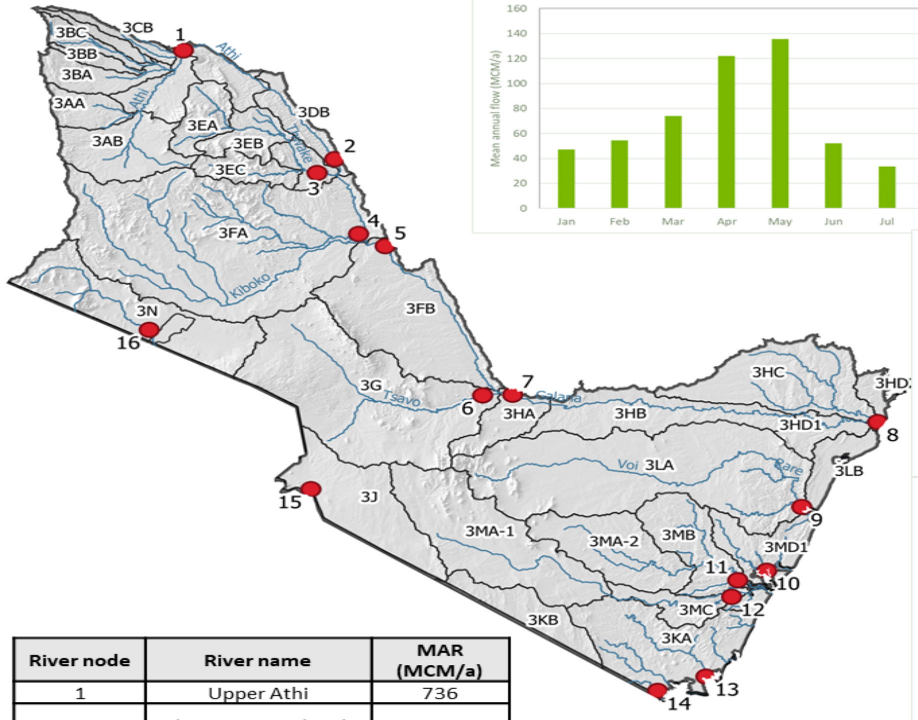
the Report: "Athi Water Balance: Surface water, Nov 2018, WRA. Report No. IR2 Volume 3A".

2.4.1.2 Surface water resources potential

Figure 2-22 displays the simulated natural Mean Annual Runoff (MAR) at key locations across the Athi Basin. From the Figure 2-22, the following observations can be made:

- The total Athi River natural runoff where it discharges to the Indian Ocean is 1 656 MCM/a. Most of the natural runoff in the Athi River (about 60%) originates from the upper catchment – above the Thwake confluence. A further (about 20%) of the total runoff is generated in the incremental catchment between the Thwake and Kiboko confluence.
- Other rivers in the Athi Basin with meaningful runoff include the coastal rivers e.g. Mwache (126 MCM/a) and Voi (62 MCM/a), the Lumi River (112 MCM/a) draining parts of Mount Kilimanjaro, and the rivers (104 MCM/a) draining into Lake Amboseli.
- The total natural surface water runoff as simulated from all rivers in the Athi Basin equates to 2 555 MCM/a.

Annexure B1 lists the natural surface water runoff per sub-basin.



River node	River name	MAR (MCM/a)
1	Upper Athi	736
2	Athi upstream Thwake	813
3	Thwake	198
4	Kiboko	305
5	Athi downstream Kiboko	1315
6	Tsavo	134
7	Athi downstream Tsavo	1531
8	Athi outlet	1656
9	Voi	62
10	Subbasin MD1	146
11	Mwache	126
12	Shimba	75
13	Ramisi	101
14	Umba	44
15	Lumi	112
16	Namanga	104

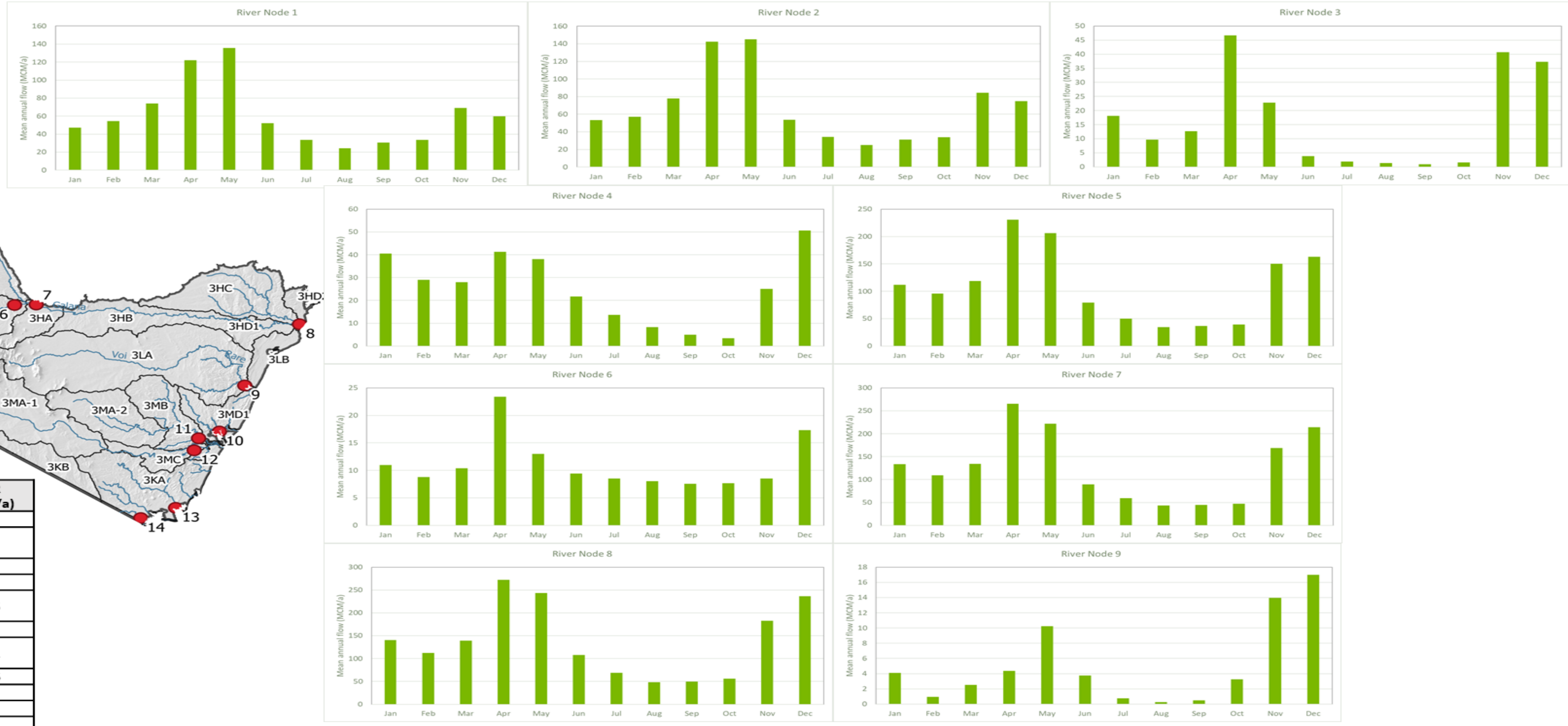


Figure 2-22: Natural mean annual runoff and seasonal flow patterns at key nodes in the Athi Basin

2.4.1.3 Seasonal flow variability

Also shown in Figure 2-22 is the seasonal variability of flow at key locations in the Athi Basin. All of the rivers in the basin display two pronounced runoff seasons during a year viz. Apr to May (wettest) and Oct to Dec (wet), with distinct low flow seasons from July to Oct and Jan to Mar.

To assess the extent to which the seasonal flows in the rivers vary, a Seasonal Index Map was developed (Figure 2-23), which expresses the cumulative natural flow volume during the three driest consecutive months, as a proportion of the total annual natural flow volume per sub-basin.

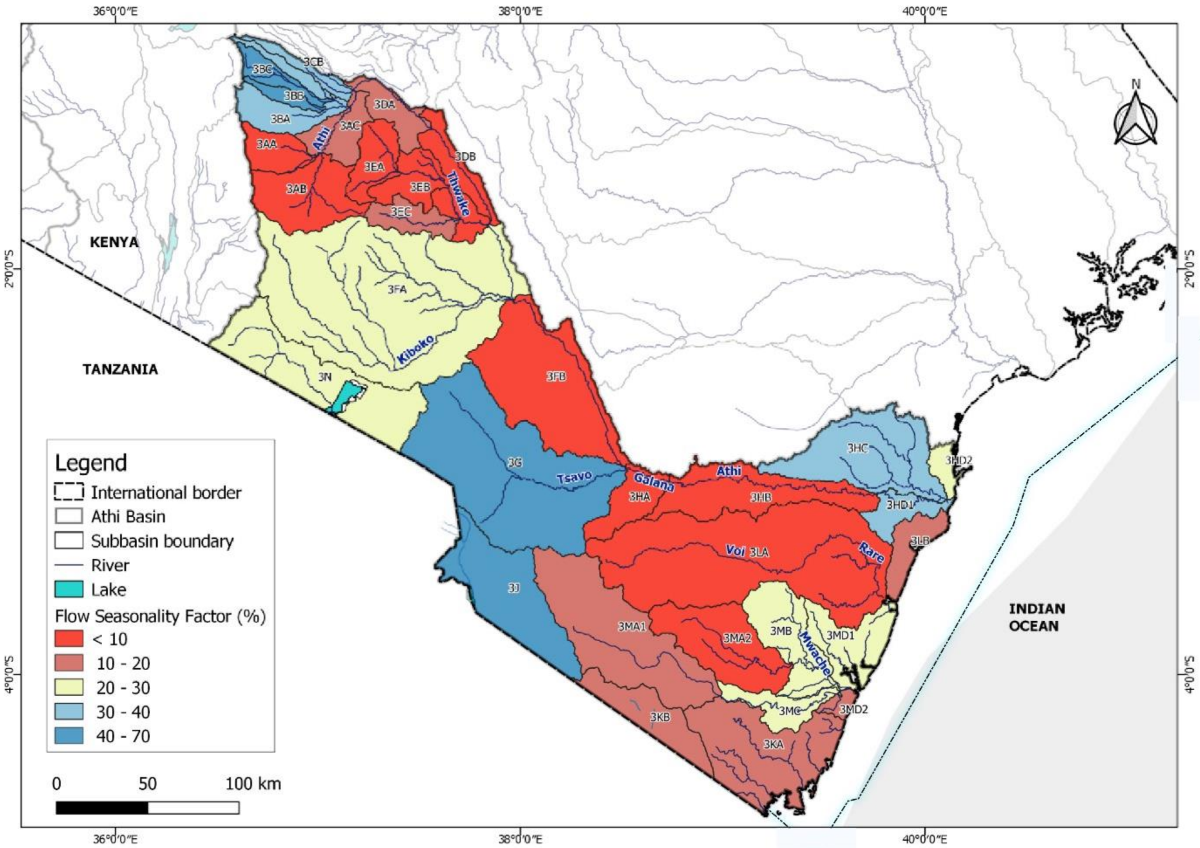


Figure 2-23: Flow seasonality Index per sub-basin

2.4.1.4 Annual flow variability

A key objective of water resources development concerns mitigation of inter-annual flow variability through the provision of carry-over storage. Figure 2-24 displays the annual variability of natural flow at the outlet of the Athi River from which it is evident that there is significant flow variability in the basin due to hydrometeorological drivers. This highlights the need for the provision of more storage within the basin to improve resilience.

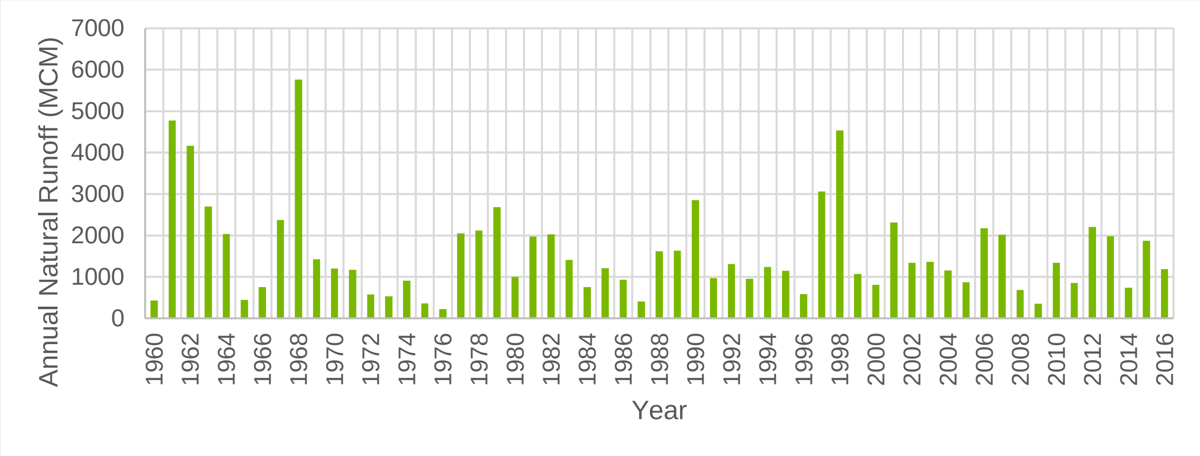


Figure 2-24: Annual flow variability in the Athi River

2.4.1.5 Unit runoff

Unit runoff is defined as the depth of runoff (mm) from a catchment area and as such allows for direct comparison between geographically distinct areas. Figure 2-25 shows calculated natural unit runoff values at sub-basin scale in the Athi Basin and highlights the relatively high unit runoff in the most upper part of the Athi Basin as well as the progressively lower unit runoff values towards the lower, south eastern inland part of the basin. The coastal catchments, from Mombasa southwards, again display higher unit runoff values.

2.4.1.6 Runoff coefficient

The runoff coefficient is a dimensionless coefficient relating the amount of runoff from a catchment to the amount of precipitation received. It is typically a function of soils, topography, vegetation and rainfall intensity. A high runoff coefficient indicates lower interception, lower infiltration and higher runoff associated with steeper areas, while a lower runoff coefficient is associated with higher permeability, denser vegetation and more gentle topography. As shown in Figure 2-26, it is only the sub-basins in the most upper part of the Basin which have runoff coefficients above 15%. Some of the sub-basins upstream of the Kiboko confluence and along the coast are characterised by runoff coefficients between 5% and 15%, while the middle and inland lower parts of the basin have very low runoff coefficients.

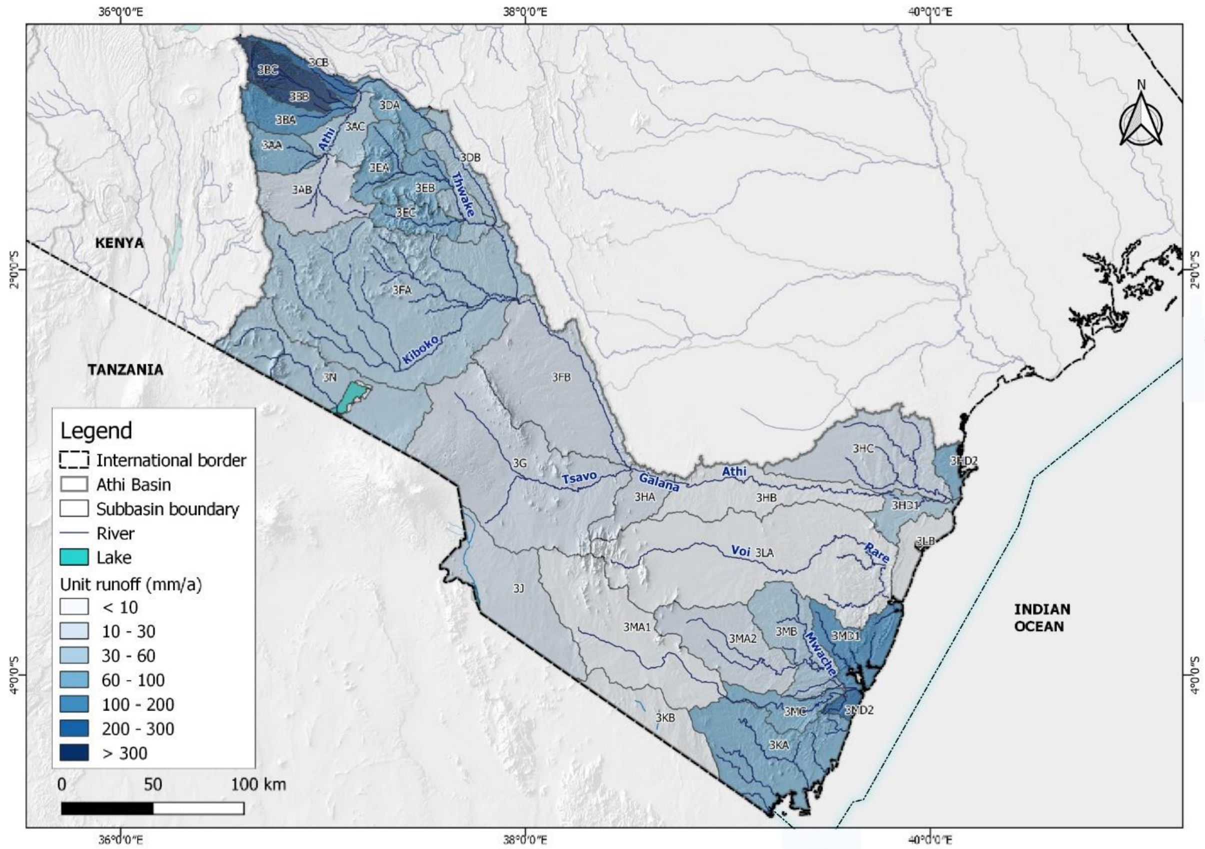


Figure 2-25: Unit runoff per sub-basin

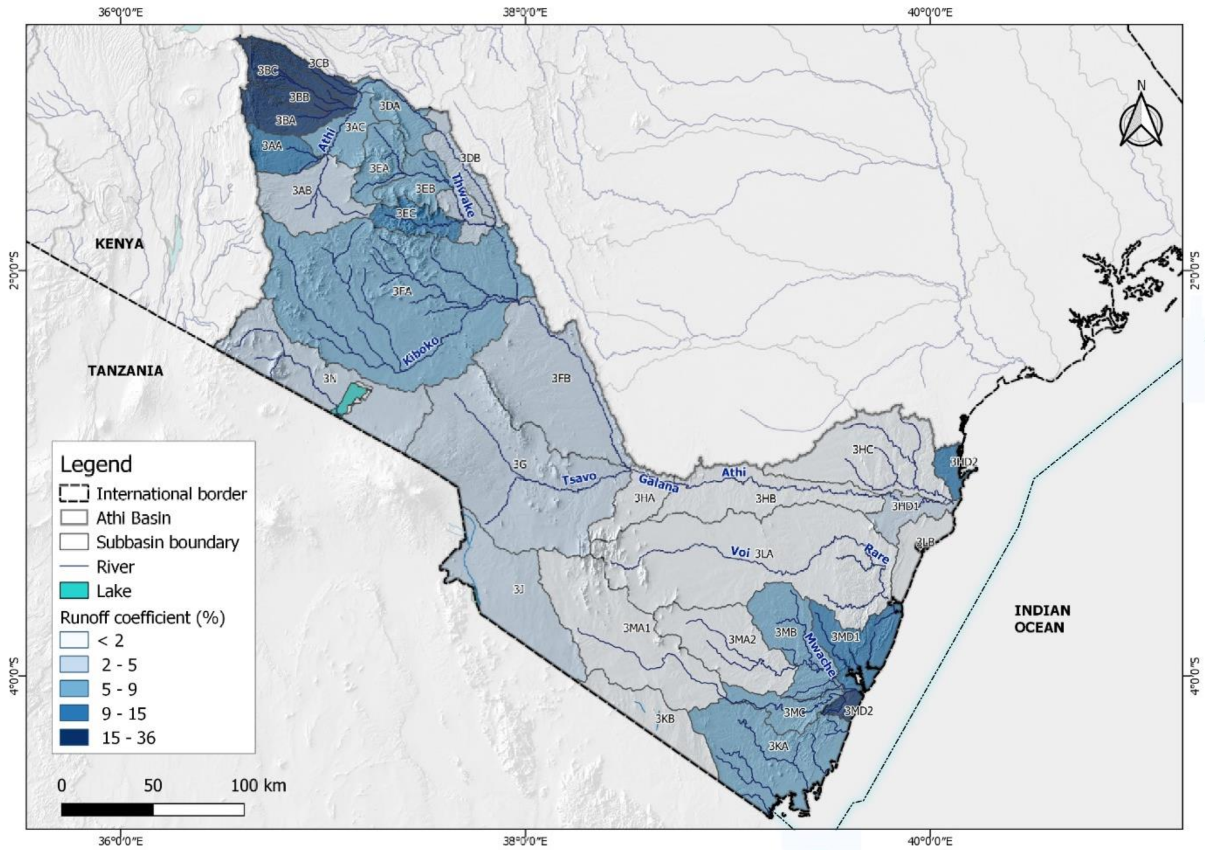


Figure 2-26: Runoff coefficient per sub-basin

2.4.1.7 Impacts of climate change on surface water resources

The climate change analysis which was undertaken as part of this Consultancy (refer to **Annexure A2**), showed that projected future precipitation totals are varied across the Athi Basin yet tend to exhibit an increasing gradient in the medium term (2050) from the south east to the north west. On average, the RCP 4.5 analysis predicted that the Mean Annual Precipitation across the Athi Basin would increase by 4.9% to 786mm, while day and night temperatures in the basin are expected to increase by up to 1.18°C and 1.3°C respectively by 2050.

Projected sub-basin precipitation and temperature changes under climate change scenario RCP 4.5 were superimposed on the hydrological model of the Athi Basin to assess the potential impacts on runoff. Figure 2-27 shows that the mean annual natural runoff is expected to increase by up to 15% in the western part of the basin. Runoff in the south-eastern, coastal sub-basins is expected to decrease by up to 2.5%. The total surface water runoff from the Athi Basin is projected to increase with 4.0% from 2 555 MCM/a to 2 657 MCM/a under RCP 4.5. **Annexure B1** provides natural surface water runoff volumes per sub-basin.

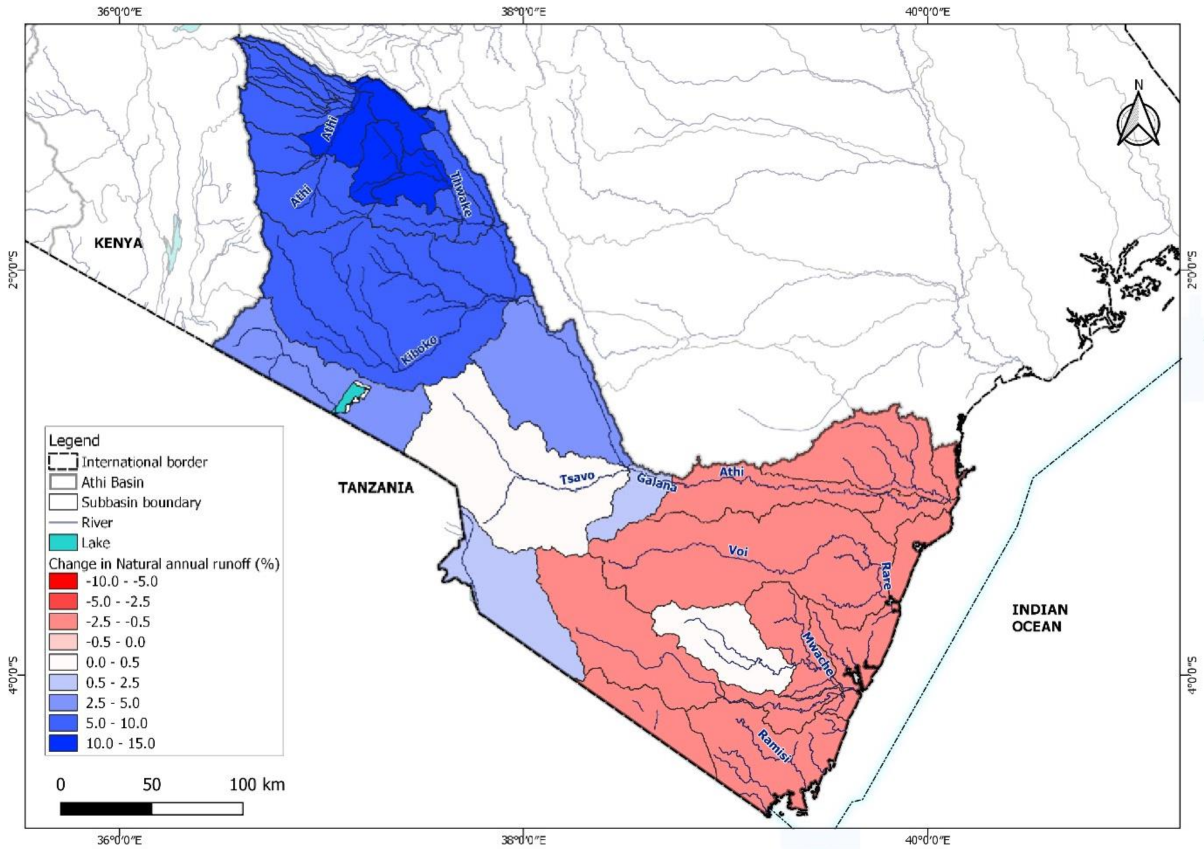


Figure 2-27: Climate change impacts on mean annual natural runoff in the Athi Basin 2050 (RCP 4.5)

2.4.2 Groundwater resources

2.4.2.1 Conceptual approach to groundwater resources assessment

A high-level groundwater assessment to quantify the groundwater resources of the Athi Basin was undertaken as part of this Consultancy (**Annexure A4**). This entailed a GIS-based approach that used existing data at a national scale. Datasets were derived from macro and secondary geology, topography, rainfall and estimates of recharge, which were categorised and weighted to quantify groundwater availability / potential. While this approach allows for assessments at any scale, it provides generic data sets best suited for rapid and regional-scale groundwater resource assessments and does not replace the need for detailed resource assessments for areas with high groundwater competition or water quality concerns like saline aquifer intrusion, for example. The adopted approach takes local rainfall-groundwater recharge relationships and local lithological and structural permeabilities into account, and therefore is not applicable for deep-seated aquifers located far from their recharge source. It aims to capture the vast majority of the country where the availability of groundwater is a function of local recharge and permeability.

For the approach to be practical, the following principles were incorporated in the methodology:

- The data sets are spatially (GIS) based
- The data sets can easily be replaced once new data becomes available
- The approach is applicable at various scales (e.g. for aquifer, minor and major catchment studies)
- The approach is easy to use

The approach is considered scientifically sound and the assumptions, data sources and mathematics used to determine the answers are documented so that the calculations can be re-evaluated, checked and improved as new data becomes available. The main deliverables are data sets and maps on groundwater potential in a format that is accessible and useable for development planning and for providing guidance on how much water can be allocated for use.

Note: A detailed description of the groundwater assessment approach and methodology is provided in "ISC Report C2-1: National Groundwater Potential Assessment".

2.4.2.2 Groundwater resources potential

The annual groundwater recharge for the Athi Basin was estimated at 2 943 MCM/a, with a sustainable annual groundwater yield of 549 MCM/a. This is significantly higher than the NWMP 2030 sustainable groundwater yield estimate of 305 MCM/a for the Athi Basin. However, whereas the NWMP 2030 assumed sustainable yield as a percentage of recharge (10%), the groundwater assessment which was conducted as part of this Consultancy estimated sustainable yield based on regional and secondary permeability and topography.

Figure 2-28 displays the recharge and potential groundwater availability in the Athi Basin. It shows that the eastern part of the basin, next to the coast as well as the most upper part of the basin, have the highest groundwater potential. The lowest groundwater potential occurs in the central part of the basin. **Annexure B1** lists the groundwater potential per sub-basin.

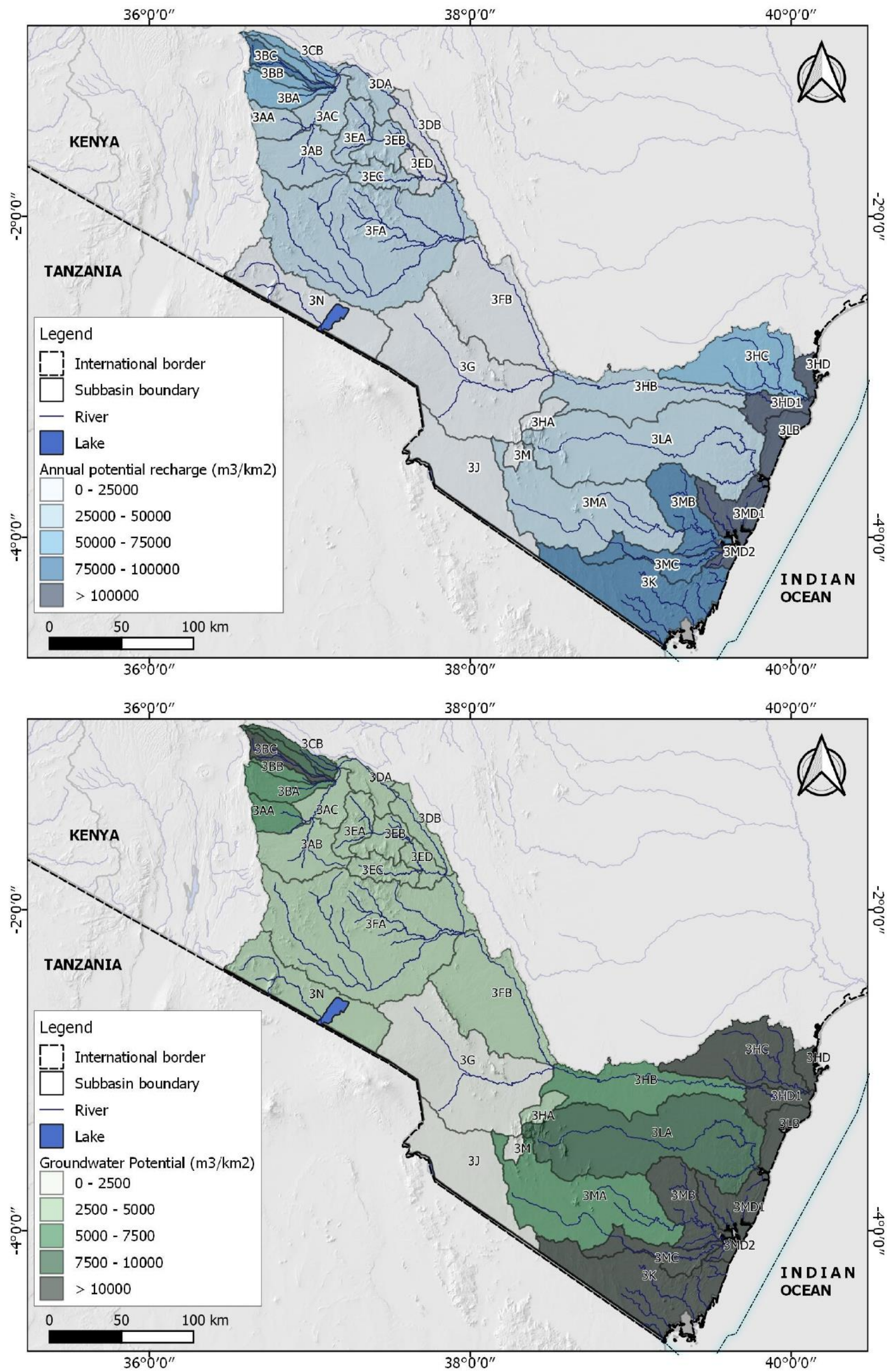


Figure 2-28: Estimated groundwater recharge and groundwater potential in the Athi Basin

2.4.2.3 Impacts of climate change on groundwater resources

Projected sub-basin precipitation and temperature changes under climate change scenario RCP 4.5 (refer to **Annexure A2**) were superimposed on the groundwater model of the Athi Basin to assess the potential impacts on recharge and groundwater potential. It was found that the recharge in the basin will increase by 3.4% to 3 043 MCM/a, while the potential groundwater yield is expected to increase by 2.3% to 562 MCM/a under RCP 4.5.

2.4.3 Current water requirements

At present, the main demand for water in the Athi Basin is constituted by the urban domestic and industrial water requirements of Nairobi and Mombasa and their surrounding areas, as well as water required for irrigation.

2.4.3.1 Irrigation water requirements

Irrigation area

Food crops constitute the majority of cultivated crops in the Athi Basin, followed by horticultural crops. The NWMP 2030 estimated the total crop area in the Athi Basin in 2010 as 876 544 ha, mainly consisting of rain-fed crops. To estimate current (2018) irrigation water requirements in the Athi Basin as part of this Consultancy, information on the location and spatial extent of irrigated areas as well as information on crop types, cropping patterns and cropping intensities were sourced from several sources. Information was obtained from the NWMP 2030, the 2015 UNECA Regional Centre for Mapping of Resources for Development crop mask for Kenya (Regional Centre for Mapping of Resources for Development, 2018), the 2015 Global Food Security-Support Analysis dataset (Xiong et al., 2017), and the IWMI Irrigated Area Map of Africa (2010).

- **NWMP 2030**

  The NWMP 2030 differentiated between large-scale, small-scale and private schemes for the estimation of irrigation areas in Kenya. Information on large-scale irrigated areas were based on data as reported by the National Irrigation Authority (NIA), as well as on data extracted from the Water Permit Database. Information related to small-scale irrigation were sourced from Provincial and District Irrigation Field Offices, while areas under private irrigation were estimated with the assistance of regional WRA offices and based on data available in the Water Permit Database.

- **Regional Centre for Mapping of Resources for Development (RCMRD)**

  http://opendata.rcmrd.org/datasets/kenya-crop-mask-2015)

  The RCMRD Kenya Crop Land layer provides information on the extent of cropland, area specific major crops and other crops being grown in the same location. The layer was generated from Landsat 8, 30 meters resolution imagery data for Sep/Oct 2015 and validated using location points collected from subsequent field visits.

- **Global Food Security Analysis-Support Data at 30 Meters (GFSAD30) Project**

  https://lpdaac.usgs.gov/products/gfsad30afcev001/

  The GFSAD30 is a NASA funded project to provide high resolution global cropland and water use data that contribute towards global food security in the twenty-first century. The GFSAD30 products are derived through multi-sensor remote sensing data (e.g., Landsat, MODIS, AVHRR), secondary data, and field-plot data and aims to produce consistent and unbiased estimates of global agricultural cropland products such as cropland extent\area, crop types, irrigated versus rainfed, and cropping intensities. It is produced at a resolution of 30 m for the entire continent of Africa for the nominal year 2015 using Sentinel-2 and Landsat-8 time-series data. (Xiong et al., 2017).

- **IWMI Irrigated Area Map of Africa (2010)**

  http://waterdata.iwmi.org/applications/irri_area/

  The IWMI Irrigated Area Map of Africa aimed to map the irrigated and rainfed areas of Africa using freely available, remotely sensed, MODIS satellite data. High resolution images and the seasonal variations captured in multi-seasonal satellite images were used to classify the landscape and identify irrigated croplands using classification methods based on the seasonal profile of vegetation. The mapping was done using 16-day MODIS 250m NDVI composites images (MOD13Q1). A hierarchical classification procedure involving classification techniques and time-series analysis of the NDVI data was followed. The agricultural areas were categorised into irrigated and rainfed by analysing the seasonal vegetation trends.

The above data sources were supplemented with information provided by the NIA, and information provided by the Department of Irrigation at the Ministry of Agriculture, Livestock and Fisheries on dominant crop types, cropping intensities, irrigation efficiencies and an FAO Irrigation inventory.

An analysis and synthesis of the data and trends allowed present-day (2018) large-scale, small-scale and private irrigated areas to be determined per sub-basin as summarised in Table 2-8. The total current (2018) irrigated area in the Athi Basin was determined as 64 544 ha, compared to the NWMP 2030 irrigation area in 2010 of 44 898 ha. It is important to note, however, that the 2018 irrigation area which was used in this Study is 40% more than the NWMP 2030 area, that more conservative assumptions were made with regard to irrigation efficiencies and cropping intensities, and that different approaches were used to estimate crop water requirements.

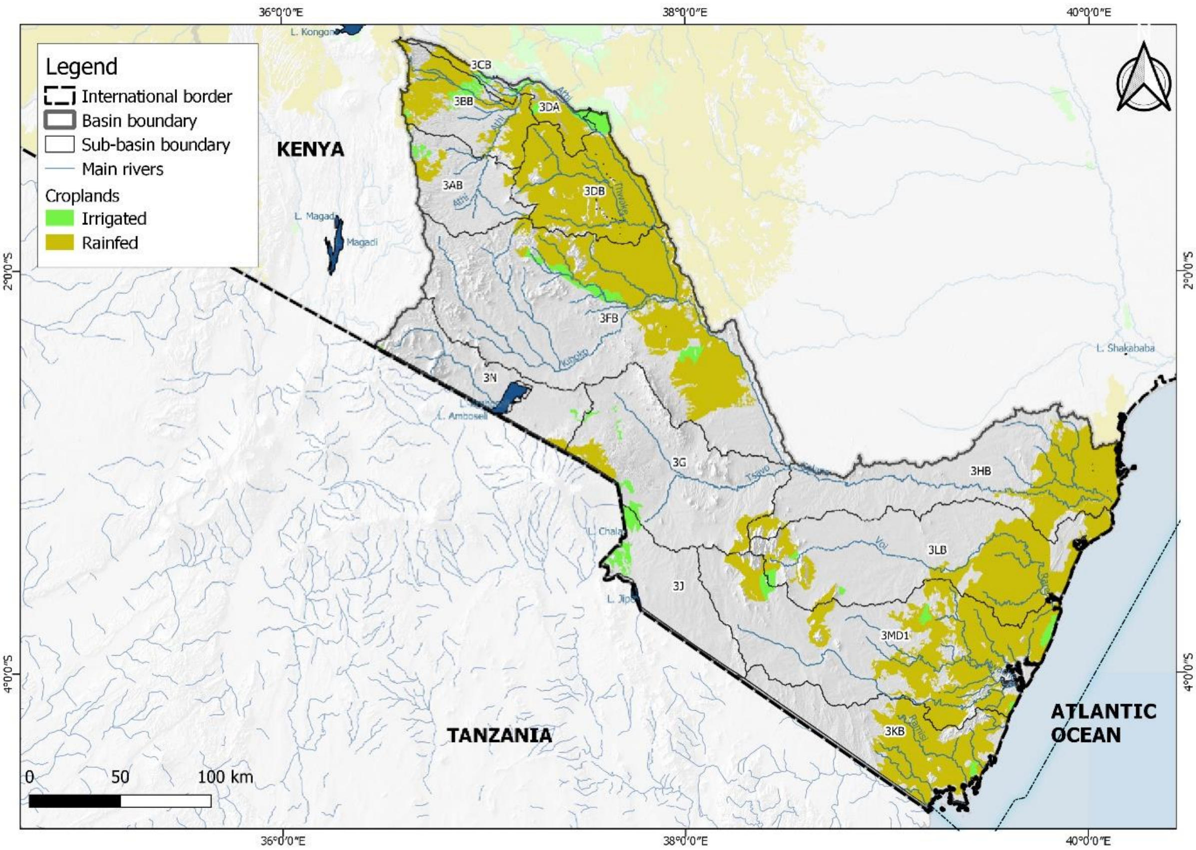


Figure 2-29: Irrigated crops in the Athi Basin (RCMRD Kenya Crop Mask, 2015)

Table 2-8: Irrigated areas per sub-basin (2018)

Sub-basin	Area (ha)	Sub-basin	Area (ha)
3AA	1,772	3HA	1,560
3AB	2,122	3HB	4,317
3AC	532	3HC	1,978
3BA	2,535	3HD1	729
3BB	1,016	3HD2	855
3BC	2,003	3J	5,152
3BD	1,346	3KA	607
3CB	3,056	3KB	0
3DA	616	3LA	6,556
3DB	302	3LB	736
3EA	383	3MA-1	3,052
3EB	405	3MA-2	4,360
3EC	383	3MB	160
3ED	330	3MC	110
3FA	4,476	3MD1	60
3FB	2,708	3MD2	13
3G	7,675	3N	2,637

Irrigation water demand

The standard crop coefficient (Kc) approach was used to estimate irrigation water requirements per sub-basin. Kc values were obtained from the FAO Irrigation and Drainage Paper 56 (Allen et al., 1998), using regional data where available. An effective rainfall factor of 0.6 was assumed, and average irrigation efficiencies of 50% for small scale and 60% for large-scale irrigation. 200% cropping intensities were assumed for large scale irrigation schemes as well as for small-scale horticulture, maize, rice and sorghum, while a 60% cropping intensity was used for vegetables, beans, green grams and cow peas (Ministry of Agriculture, Livestock and Fisheries, personal communication, February 2019).

The total current irrigation demand in the Athi Basin was calculated as 1 028 MCM/a. The estimated irrigation demand equates to an average of 15 900 m^3/ha per annum.

2.4.3.2 Domestic and Industrial water requirements

For the major urban centres in the Athi Basin i.e. Nairobi City and surrounding towns and Mombasa and the main coastal towns, current water demands for domestic and industrial use were sourced from recent master plans viz. Feasibility study and Master Plan for Developing New Water Sources for Nairobi and Satellite towns (Ministry of Water and Irrigation & Athi Water Services Board, 2012) and Consultancy Services for Water Supply Master Plan for Mombasa and Other Towns Within Coast Province (Tahal Group, 2013). The water demand estimates in these studies were based on detailed investigations based on published population numbers (Census 2009), design water consumption rates as per the Practice Manual for Water Supply Services in Kenya (Ministry of Water and Irrigation, 2005), allowances for non-revenue water, and categories of consumers to derive estimates of domestic and industrial water demands.

For estimates of domestic and industrial water demands in the smaller towns and rural areas in the Athi Basin, information per sub-basin was sourced from the NWMP 2030 and from the WRA Permit Database and compared. Where the Permit Database values were higher than the NWMP 2030 estimates extrapolated to 2018, the permit Database values were used as representative of the current demand and vice versa.

The total domestic and industrial water demand for urban and rural users in the Athi Basin was estimated at 490 MCM/a. This is less than the 2010 domestic and industrial water demand of 612 MCM/a for the Athi Basin as estimated in the NWMP 2030. However, the NWMP 2030 made a very conservative allowance of 45% for non-revenue water, whereas the 490 MCM/a estimate is based on a 20% allowance for non-revenue water.

2.4.3.3 Livestock water requirements

The livestock water demands in the Athi Basin as per the WRA Permit Database, were compared to livestock water demands as per the NWMP 2030 and found to be significantly less. Due to the livestock water requirements in the Athi Basin being almost negligible when compared to the urban-rural and irrigation demands, a conservative approach was adopted for this study by using the NWMP 2030 estimate of 24 MCM/a.

2.4.3.4 Wildlife and fisheries

Water demands for fisheries and wildlife constitute less than 1% of water demand in the Athi Basin. Consequently, the wildlife and fisheries water demand figures as stated in the NWMP 2030 were accepted as correct at 11 MCM/a.

Current water requirements per main user category in the Athi Basin are summarised per sub-basin in **Annexure B1.**

2.4.3.5 Total water requirements

The total current estimated water demand (2018) in the Athi Basin equates to 1 553 MCM/a as presented in Table 2-9. Most of the water is needed for irrigation and domestic / industrial use in the major urban centres.

Table 2-9: Current (2018) water requirements in the Athi Basin per main sector

Sector	MCM/a
Irrigation	**1 028**
Small scale / Private	984
Large-scale	44
Domestic and Industrial	**490**
Greater Nairobi	263
Mombasa, Kwale, Kilifi	86
Basin-wide	141
Livestock	**24**
Other (Wildlife and Fisheries)	**11**
Total	**1 553**

Figure 2-30 shows the distribution of current water demands across the Athi Basin.

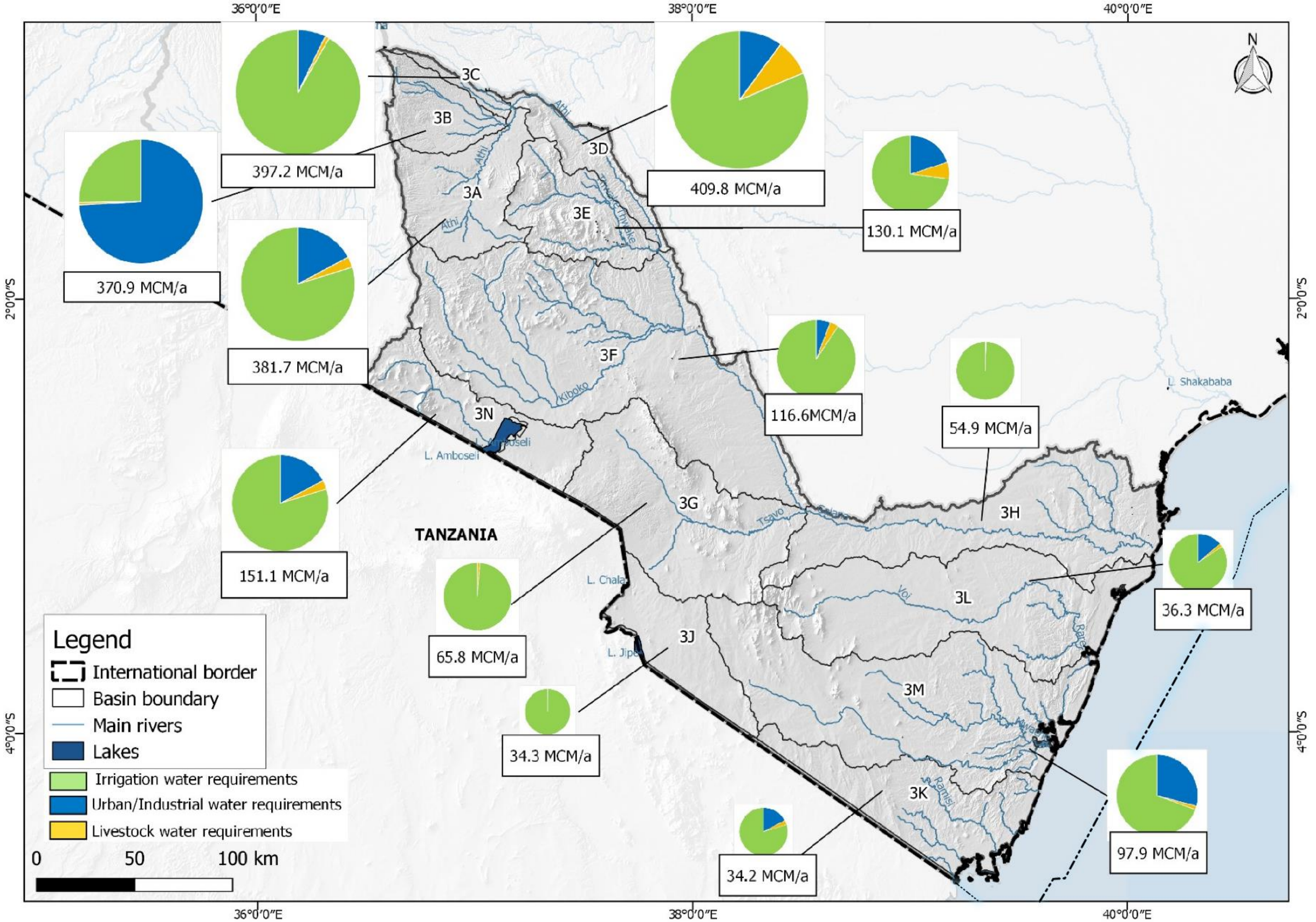


Figure 2-30: Present-day (2018) water requirements across the Athi Basin

2.4.4 Current large-scale water resources developments

The existing water resources developments in the Athi Basin include a number of dams and transfers, which mainly supply domestic demands. In addition, there are a number of schemes which involve large-scale groundwater abstractions.

2.4.4.1 Storage

The total storage volume of the existing dams in the Athi Basin is approximately 22 MCM, of which about half is stored in small dams and pans across the basin (Water Resources Management Authority, 2013b). The existing dams in the Athi Basin, as well as their approximate storage capacities and uses are listed in Table 2-10. Only dams with a storage capacity equal to or greater than 1 MCM were explicitly modelled in this Consultancy.

Table 2-10: Existing large dams in the Athi Basin

Dam Name	Storage Capacity (MCM)	Purpose
Ruiru	3	Domestic supply (Nairobi area)
Bathi	< 1	Domestic supply (Nairobi area)
Mulima	< 1	Domestic supply (Machakos and Makueni Counties)
Manooni	< 1	Domestic supply (Makueni County)
Muoni	< 1	Domestic supply (Machakos County)
Kikoneni	<1	Domestic supply (South coast)
Maruba	2	Domestic supply (Machakos Town)
Kiserian	1.3	Domestic supply (Kiserian & Ongata Rongai Towns)
Small dams & pans	11.6	Domestic and livestock supply; limited irrigation

2.4.4.2 Hydropower

There are currently no hydropower installations in the Athi Basin.

2.4.4.3 Water transfers

Most of the water consumed in Nairobi is transferred from the Tana Basin, with a total transfer capacity of 181 MCM/a. The water is sourced from two dams in the Tana Basin, namely the Thika (or Ndaka'ini) and Sasumua dams. The Thika Dam has a storage capacity of 77 MCM. Water is transferred from the Thika Dam into the Chania River. Raw water is abstracted from a weir on the Chania River and piped to the Ngethu Water Treatment Plant, after which the treated water is conveyed to the Kiambu and Gigiri Reservoirs from which the City of Nairobi is supplied (379,200 m^3/day or 138.4 MCM/a). The Sasumua Dam has a storage capacity of 16 MCM. Raw water is abstracted from the Sasumua Dam and piped to the Sasumua Water Treatment Plant. The treated water is piped to the Kabete Reservoir from which the City of Nairobi is supplied (58,600 m^3/day or 21.4 MCM/a.). Several offtakes supply small distribution areas en route, directly from the pipeline.

Intra-basin bulk water transfers within the Athi Basin include:

- Transfers from the Kikuyu Springs (4 500 m^3/day or 1.64 MCM/a) and the Ruiru Dam (22 800 m^3/day or 8.3 MCM/a) to the Nairobi City Water Supply System, with a combined transfer of about 10 MCM/a.

- Transfers from the Mzima Springs (35 000 m^3/day), Marere Springs (8 000 m^3/day), Tiwi Boreholes (13 000 m^3/day) and Baricho (Sabaki) boreholes (67 000 m^3/day) to Mombasa and other coastal towns, with a combined transfer capacity of about 46 MCM/a.
- Transfer from Maruba Dam to Machakos town of 8 700 m^3/day or about 3 MCM/a.
- The Nol Turesh pipeline which draws its water from springs on the slopes of Mt Kilimanjaro to supply neighbouring counties including Machakos Town.

2.4.4.4 Large scale irrigation schemes

Only schemes equal to or larger than 2 000 ha were classified as large-scale for this Consultancy. Other irrigation was lumped together in each sub-basin and modelled as small-scale irrigation. The first phase of the Galana Kulalu Scheme along the lower Athi River, which has an area of 2 000 ha within the Athi Basin, is the only existing irrigation scheme in the Athi Basin which has an area equal to or larger than 2 000 ha.

Note: Other irrigation areas such as the irrigation schemes next to the Lumi River in Taita Taveta County, the schemes close to Chyulu Hills, and the irrigation in the upper Athi Basin have been classified under small-scale and private irrigation.

2.4.4.5 Groundwater development and use

Groundwater has provided and will continue to provide much of the water needed for livelihoods and development for many communities and industries in Kenya. Numerous rural communities and small towns across the Republic depend on groundwater from boreholes and shallow wells for their domestic and livestock needs, and to support other economic activities.

Nairobi

Kenya's capital city Nairobi relies extensively on both publicly and privately developed groundwater resources to augment its domestic, commercial and industrial water supply. The Nairobi aquifer system (NAS) covers an area of 6 759 km^2 and underlies the Nairobi Metropolitan area. The NAS underlies areas including a number of satellite towns surrounding Nairobi, including Ongata Rongai, Ngong, Isinya, Kitengela, Mavoko, Mlolongo, Ruiru, Juja and Kikuyu.

In addition to the development of the Kikuyu Springs water supply system (4 500 m^3/d or 1.64 MCM/a), thousands of boreholes have been constructed since the first was drilled in 1927. Over time groundwater development in the Nairobi area has evolved as follows:

- 1906: the Kikuyu Springs were developed for Nairobi W/S (1.8 MCM/a) (Ministry of Water and Irrigation & Athi Water Services Board, 2012)
- 1964: there were at least 481 boreholes (in the city area, 684 km2) (Gevaert EAL, 1964)
- 1977: there were at least 518 boreholes (684km^2), abstraction ≈11.8 MCM/a (Tippett Abbett McCarthy and Stratton Engineers, 1977)
- 1992: abstraction was estimated to be 13.8 MCM/a (Water Resources Management Authority, 1992)
- 1998: abstraction was estimated to be 32.9 MCM/a from the central part of the aquifer, covering some 2 000 km^2 (Ministry of Land Reclamation Regional and Water Development, 1998)
- 2000: there were 1 150 registered boreholes and an unknown number of unregistered BHs in what is now Nairobi County alone (684 km^2) (Chesang, 2000)
- 2005: there were approximately 2 000 boreholes across the entire aquifer, estimated abstraction 31 MCM/a (S. Foster & Tuinhof, 2005)

- 2007: 1 639 boreholes across what is now Nairobi County (684 km^2), and 4 319 boreholes in the Athi Basin part of the NAS (i.e. excluding the NAS in the Tana Basin) (Water Resources Management Authority, 2007b)
- 2010: Preliminary Water Allocation Plan (Water Resources Management Authority, 2010): abstraction was estimated to be 57.6 MCM/a across an area of 5 460 km^2.
- 2011: at least 4 136 boreholes in the central part of the NAS (covering an area of 2 727km^2). The census figure was considered an under-count, with a more likely estimate of 4 400 boreholes; approximate annual abstraction was 32.3 MCM. (Water Resources Management Authority, 2011). Groundwater Governance Study (Mumma et al., 2011); a separate study of the NAS estimated that there were 4 856 boreholes across the aquifer;
- 2012: abstraction was estimated at 44.4 MCM/a (entire aquifer) from an estimated 5 500 boreholes in 2010 in the Nairobi Water Master Plan (Ministry of Water and Irrigation & Athi Water Services Board, 2012)
- 2017: abstraction estimate of ≈50 MCM/a across entire aquifer (Oiro et al., 2017)
- 2018: The current number of boreholes in the NAS very likely approaches 7 000

Mombasa

Mombasa relies entirely on groundwater sources, comprising the Marere Springs, Mzima Springs, Tiwi aquifer and the Baricho intake. Mombasa demand far exceeds current supply. The significance of privately-developed groundwater resources as a major water source for Mombasa is becoming increasingly clear; multiple stakeholders have suggested that up to 70% of demand is met from boreholes and shallow wells across the County in mid-2018 (The Nature Conservancy, 2018).

Malindi and Kalifi

Malindi and Kilifi are major settlements in the Athi Basin that rely wholly on the Baricho aquifer. This source currently has a supply capacity of about 90,100 m^3/d (33.2 MCM/a) (The Nature Conservancy, 2018). The Baricho intake, which is more correctly a surface water resource which recharges a near-surface palaeochannel aquifer, has been modelled and is potentially capable of supplying up to 74.5 MCM/a (National Water Conservation & Pipeline Corporation, 1995).

Other towns and sources of supply

- Voi, Maungu, other small towns and a broad range of consumers located along the Nairobi-Mombasa highway rely on the Mzima Springs. The Mzima Springs discharge 2.95m3/s (Q95) (93.0 MCM/a) from the volcanic Chyulu aquifer (WS Atkins International Ltd & Rural Focus Ltd, 2018).
- Groundwater from springs in the Chyulu Hills aquifer is the principal source of water for towns to the east of the Chyulu Hills (Kiboko, Makindu and Kibwezi).
- West and south west of the Chyulu Hills, the regionally extensive North Kilimanjaro aquifer is an important groundwater resource:
  - The Nolturesh Spring supplies water to communities from Loitokitok to the Nairobi-Mombasa Road, and northwards into Makueni County. This project, constructed in the late 1980s, was originally conceived and constructed in the 1950s to meet steam locomotive water supply at railway stations along the Mombasa-Nairobi railway (Emali, Sultan Hamud and Simba); the schemes between them abstract approximately 16 000m^3/d (7.3 MCM/a) (Scheumann & Herrfahrdt-Pähle, 2008). The newer pipeline supplemented flow with water from a high-capacity borehole and piped water north to serve communities along the pipeline, and a pumped component partly supplies Machakos, Athi River and Kajiado Towns;
  - This aquifer also supplies some users in Loitokitok town, and livestock, wildlife, hotels and community groups in the Amboseli ecosystem. Springflow from the Kilimanjaro aquifer supplies water used for extensive irrigation in the Kimana area (north of Loitokitok);

- Taveta Town water demand is met from the North Kilimanjaro aquifer. Groundwater from the Njoro Kubwa and associated springs also serves irrigation projects in the area between Taveta Town and Lake Jipe. Excess flows leave Lake Jipe and form the upper tributary of the Pangani, a major water resource in north eastern Tanzania.

- Namanga Town, on the Kenya-Tanzania border, is largely supplied by groundwater from boreholes drilled in alluvium over metamorphic Basement.
- Kajiado Town is largely supplied from aquifers in weathered Basement associated with fracturing and faulting; as many as 50 boreholes, both public and private, are in commission (ISGEAG, 2018).

Elsewhere, localised and often poor aquifers serve rural communities and small centres across the Basin; often occurring in metamorphic Basement rock, these are small-scale but nevertheless important in terms of local water supply. In the South Coast, groundwater from boreholes and shallow wells are a critical component in rural and urban water supply, supplying over 100 000 people with water (T. Foster & Hope, 2016). This illustrates the importance of groundwater to human livelihoods and development in the Athi Basin.

Current groundwater use in the Athi Basin is estimated at 64 MCM/a. The percentage of the total water demand in each sector that is met by groundwater is shown in Table 2-11. Groundwater supply for each sector was determined from information in the Permit Database and the NWMP 2030.

Table 2-11: Groundwater contribution to total water demand in the Athi Basin per user sector (%)

Use	Domestic (basin-wide)	Domestic (urban centres)	Livestock	Large-scale Irrigation	Small-scale Irrigation	Industrial	Other
% supplied by groundwater	25%	5%	19%	0%	1%	5%	0%

2.4.4.6 Ongoing major water projects

Construction of Thwake Multipurpose Dam (storage capacity 681 MCM) commenced in early 2018. The dam, which borders Makueni and Kitui counties, is positioned on the confluence of the Thwake and Athi rivers. The multipurpose dam is meant to supply water for domestic and irrigation water use, as well as to provide hydropower generation.

Invitation for pre-qualification for the construction of Mwache Multipurpose Dam, in Kwale County, has been published. The Mwache Dam, with a planned capacity of 136 MCM, will provide water for domestic, irrigation and livestock use to Kwale County as well as domestic water for Mombasa County. It will also have hydropower installed.

The Northern Collector Project (Phase I) in Tana Basin, currently under construction, will take flood flows from the Maragua, Irati and Gikigie Rivers and divert them into a tributary flowing into Thika (Ndaka'ini) Dam. It will add up to 140 000 m^3/day (51.1 MCM/a) to Nairobi water supply.

The Athi Water Service Board has actively pursued the development of deep groundwater resources in the Kiunyu and Ruiru areas, with a proposed abstraction of 64 800 m^3/day (23.7 MCM/a). Exploratory boreholes were constructed in 2013/14 and showed that there were good prospects for deep groundwater at Kiunyu, while shallower aquifers in the Ruiru area were also of reasonable potential. The future status of planned abstraction from these sources is unclear.

Figure 2-31 indicates the locations of existing dams and intra- and inter basin transfers in the Athi Basin.

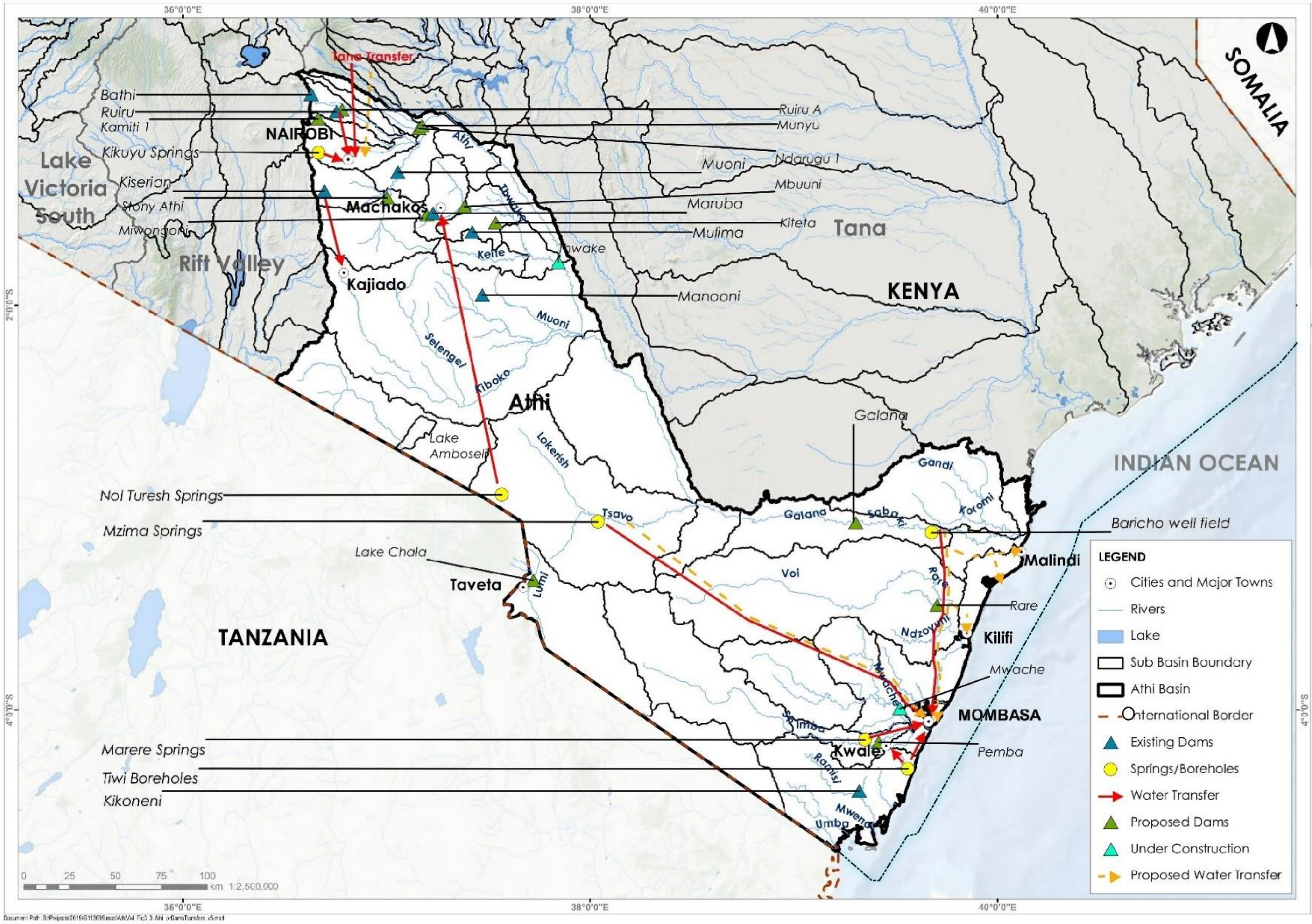


Figure 2-31: Existing dams and transfers in the Athi Basin

2.4.5 Water balance

2.4.5.1 Athi Basin water balance

The 2018 water balance in the Athi Basin in terms of natural surface water runoff and sustainable groundwater yield, water imports, the ecological reserve and current (2018) water demands in the Athi Basin is summarised in

Table 2-12. The current water demand constitutes about 50% of the total water resources available for use.

Table 2-12: Athi basin water balance (MCM/a)

	Surface water	Groundwater	Total
Natural / Available water	2 555	549	3 104
Imported water	181	-	181
Ecological reserve	(156)	-	(156)
		Total	**3 129**
		Water demand (2018)	**1553**
		Balance	**1 576**

Due to climate change impacts, the natural surface water runoff is expected to increase to 2 657 MCM/a, while the groundwater yield is projected to increase to 562 MCM/a by 2050. This will increase the total water available to 3 219 MCM/a.

Note: Future water balance scenarios which assess climate change impacts on future water availability and requirements are addressed in Section 5 of this Plan.

The water resources model which was developed under this Consultancy, was used to assess surface water availability under current (2018) development and water requirement conditions at sub-basin level. To determine current water balances at sub-basin scale, the total annual water demand per sub-basin was expressed as a proportion of the surface water (less the ecological reserve) and sustainable groundwater available in that sub-basin. Water balances were then calculated as a surplus or shortfall, i.e. where the sub-basin demands constitute 60% of the sub-basin MAR, the water balance is calculated as 40%. Conversely, if the total demand in a sub-basin exceeds annual runoff in the sub-basin by 20%, the water balance is expressed as -20%. Figure 2-32 displays the current surface, sub-basin water balances, while Figure 2-33 schematically displays the current surface water runoff at key locations in the Athi Basin. It shows that the current mean annual runoff of the Athi River where it discharges into the Indian Ocean is 1 321 MCM/a. It is important to realise that although the sub-basin water balances might indicate that the total annual demand in a sub-basin is less than the water resources available in the sub-basin, supply deficits often occur during dry years and/or the dry season, when the demand exceeds availability of water in the rivers. Supply reliability and water deficits are evaluated as part of the scenario analysis (refer to Section 5).

The current estimated groundwater use in the Athi Basin was estimated as 383 MCM/a, which is about 70% of the estimated sustainable groundwater yield of 549 MCM/a.

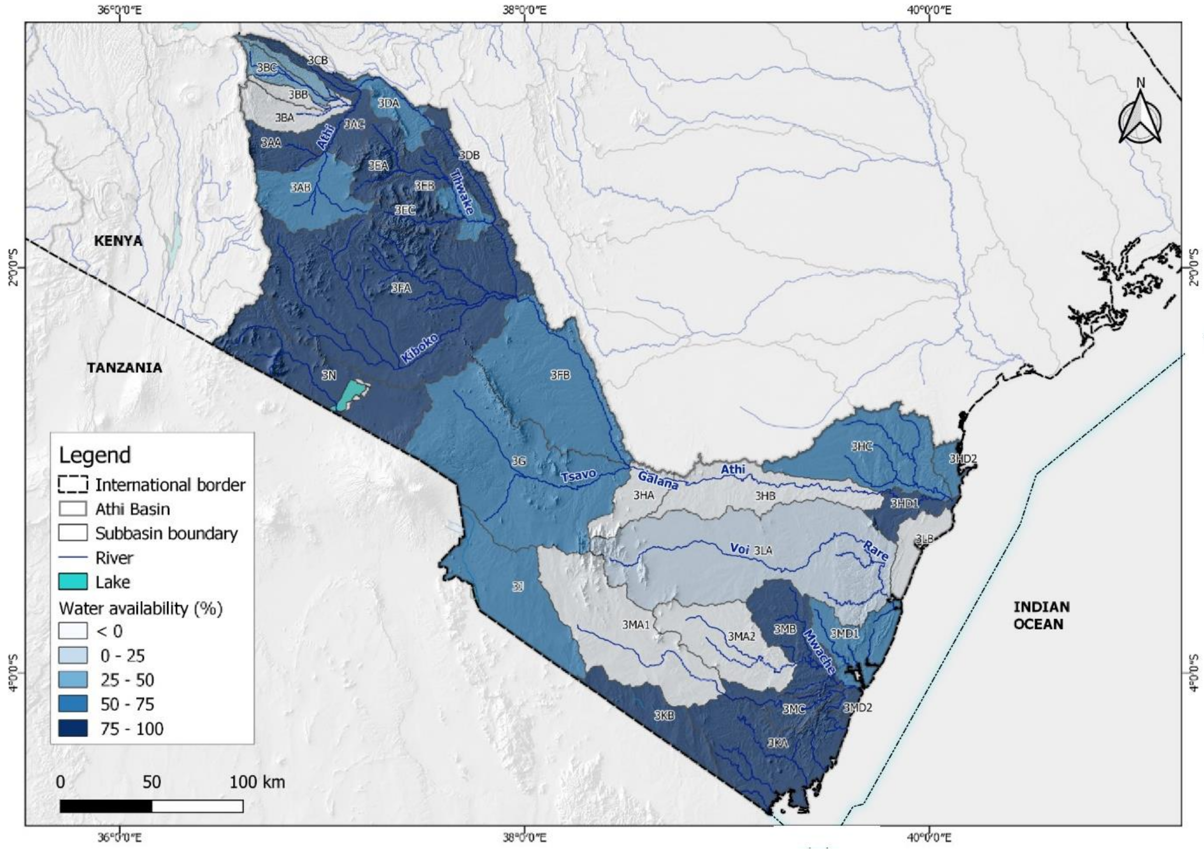


Figure 2-32: Surface water balance per sub-basin

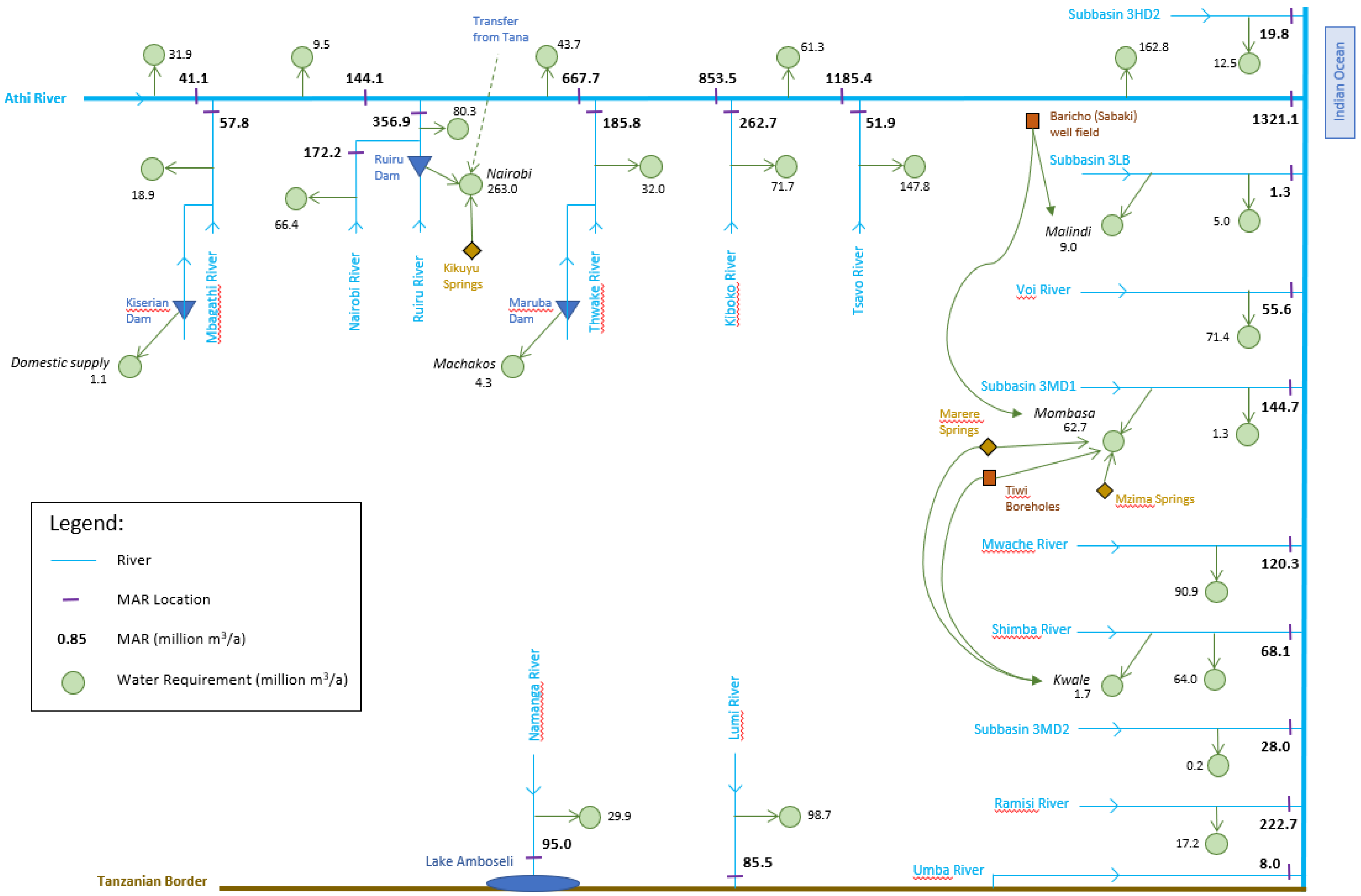


Figure 2-33: Current-day water availability and use in the Athi Basin

2.4.6 Surface water allocations

The WRA uses the permitting system as a tool to regulate the use of water resources in Kenya, and enhance equitable use of water resources. This water allocation is based on order of priority; reserve, domestic, agricultural, and finally industrial. Water permits have a five-year validity period, with renewal subject to the conditions attached for compliance. These permits, as captured in the Permit Database, reflect the current allocation of water to different user categories. The volume of water which is available for allocation in any catchment, is determined in accordance with the Guidelines for Water Allocation (Water Resources Management Authority, 2010), superseded by Draft 2018 Water Allocation Guideline (Water Resources Authority, 2019a). Essentially, the Guideline prescribes a flow/reliability approach based on natural flow exceedance values, to estimate the volumes of water which are available for allocation to domestic and irrigation users. It also specifies how the Reserve should be quantified:

$Q < Q95$: Ecological reserve

$Q95 < Q < Q80$: Normal flow (available for domestic and industrial use)

$Q80 < Q$: Flood flow (available for irrigation use)

This water allocation framework which is reflected in the water regulations aims to:

- safeguard at least a minimum ecological reserve (Q95) throughout the year
- safeguard dry season resource availability for domestic use by restricting allocation to the dry season resource availability. The dry season flows (called normal flow) are typically less than the Q80 flow
- allocate water for irrigation from flood flows (i.e. when flow exceeds Q80) which implies the need for storage as irrigation demand occurs during the dry season when abstraction for irrigation is restricted

In accordance with the guidelines, a high-level analysis was conducted, using the above daily flow exceedance thresholds (m^3/day), to assess the water allocation status in the Athi Basin - based on sub-basin hydrology developed as part of this Consultancy and current allocation volumes extracted from the Permit Database. It is important to note that this calculation approach did not consider the availability of storage.

Figure 2-34 provides a comparison, per sub-basin, of the current permit allocations per user category vs the water available for allocation in the Athi Basin. Sub-basins shown as “under-allocated”, mean that either the Normal Flow component (available for domestic and industrial use) and/or the Flood Flow component (available for irrigation use) has not been exceeded by the current allocation volumes in these respective categories as reflected in the Permit Database and vice versa. Sub-basins indicated with “no data” represent sub-basins with no permit-based allocation records in the Permit Database.

Note: It is important to note that the above water allocation balance calculations only consider the incremental surface water runoff generated in each sub-basin and do not accommodate excess water (river flow) from upstream sub-basins.

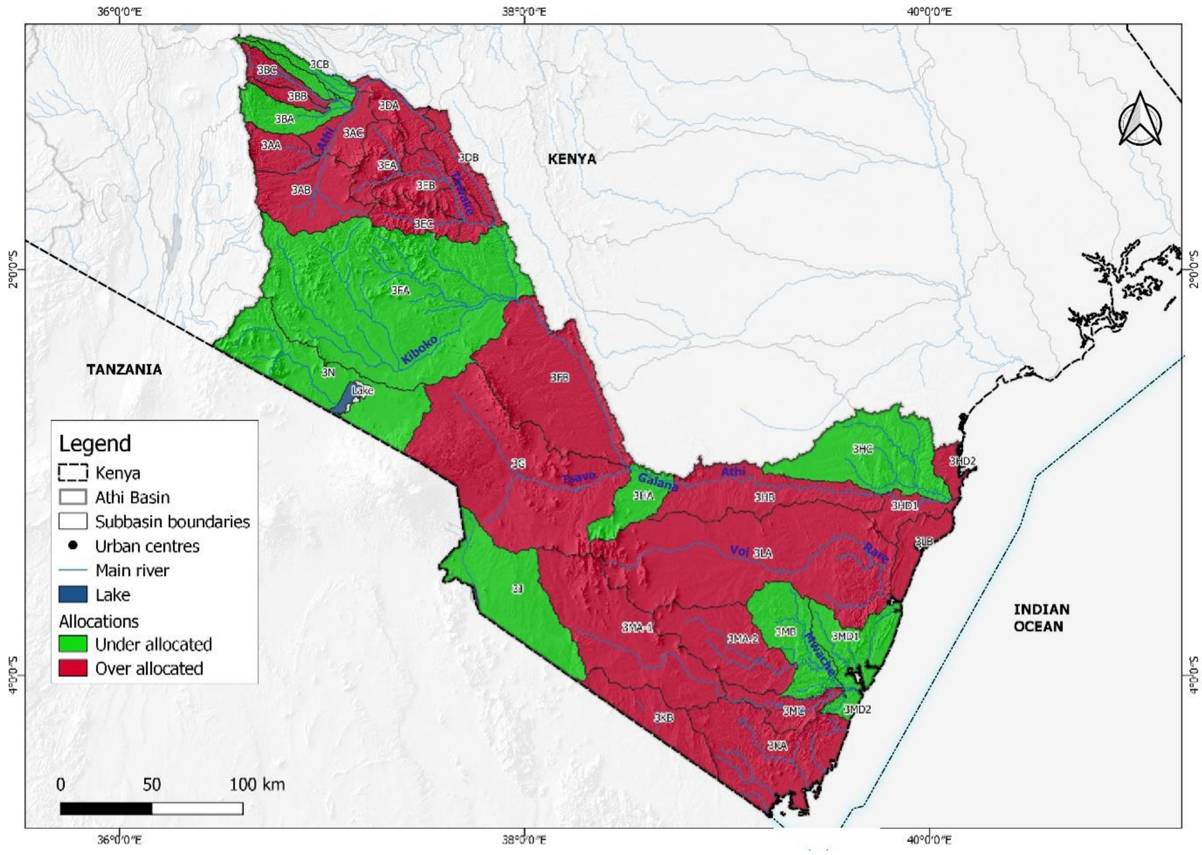


Figure 2-34: Water allocation status per sub-basin (2018)

2.4.7 Water quality

Water quality in the Athi Basin is challenging due to a variety of factors. The water quality across the basin is heavily impacted by point and non-point sources of pollution, with the latter closely linked to the management and utilisation of land. Catchment degradation as a result of tree-felling in forest reserve areas, sand harvesting, unsustainable agricultural practices and encroachment of wetlands have led to serious water quality issues across the basin, while pollution from urban areas, municipal wastewater, domestic sewage and industrial effluents is also a serious problem.

Nairobi City at the head waters of the Athi River poses the greatest water quality management challenge due to the discharge of untreated or partially treated industrial effluent and domestic sewage. Furthermore, wetlands and marshlands have been mercilessly encroached on, thereby reducing their use as effluent filters. Further away from Nairobi City, the rivers comprise fewer chemical pollutants due to the natural filtration and assimilative capacity of the river system as well as dilution effects. However, sediment deposits are greater along the lower reaches of the river.

Pollutant levels of the rivers in the basin tend to vary seasonally. During the wet season, the concentration of chemical pollutants decreases due to dilution, while the sediment loads increase due to erosion processes. During the dry season, evidence of chemical deterioration of the rivers is observed.

The Nairobi, Mathare, Mbagathi and the upper Athi rivers are some of the most polluted rivers in the country. Water samples from these rivers show high concentrations of Biochemical Oxygen Demand and Chemical Oxygen Demand and low concentrations of Dissolved Oxygen.

In general, the point sources of water pollution hotspots that impact on water quality in the Athi Basin are categorised as follows:

Upper Athi: The Export Processing Zone in the upper Athi River basin discharges directly into Athi River; Dandora and Kariobangi Sewage works, which handle the liquid wastes of Nairobi city, discharges into Nairobi River; Kiambu Sewage effluent discharges into Riara River; Kahawa West Effluent treatment facility discharges into Kiu river; Thika Sewage treatment works discharges into Komo River; Limuru town sewerage discharges into Ithanji stream; Agro-chemical leachates from farms in Kiambu and Thika.

Middle Athi: Domestic sewerage and effluents generated by activities in Makueni, Machakos, Kitui, Tsavo Lodges, Voi and Taita Taveta Towns, as well as the leaking of septic tanks in areas not served by water utilities (e.g. Rongai, Utwala, Athi River, Ruiru, Kasarani and Muthurwa) affect the water quality in the middle Athi basin; Sediment from soil erosion caused by degraded sub basins, overgrazing and runoff from rural roads also reach the river system.

Lower Athi: Main point sources of pollution in the lower Athi basin include effluents generated by activities in Galana Kulalu Irrigation Scheme and Vipingo Sisal estates; Domestic wastes from Malindi, Mombasa, Kilifi and Kwale Towns discharge into the Indian Ocean

Groundwater in the Athi Basin is often hard and saline in some areas, but varies considerably, depending on location. Sewage pollution and seawater intrusion affect water quality along the coastal area. Groundwater with high fluoride levels, hardness and high iron and manganese contents occur in parts of the basin.

2.4.8 Existing hydrometeorological monitoring network

As part of this consultancy, the current hydrometeorological network was reviewed, and a proposed hydrometeorological monitoring design network is discussed in section 6.8.3. The chapters below present the existing situation of hydrometeorological stations in the basin, as it was in 2018. It is important to note that the number of operational hydrometeorological stations may have changed since the study was completed in 2018. For stream, lake and dam monitoring, only WRA stations were reviewed.

2.4.8.1 Stream flow monitoring

At some stage, more than 200 flow gauging stations existed in the Athi Basin. Of these, only 27 are known to be currently operational.

Table **2-13** provides details on the operational stream flow monitoring network in the Athi Basin. From

Table **2-13** it is evident that the majority of currently operational stations are manually operated.

Table 2-13: Current stream flow monitoring stations in Athi Basin

Sub-Regional Office	Operational			
	Telemetric	Automatic	Manual	Total
Kiambu	0	0	6	**6**
Kibwezi	1	0	7	**8**
Loitokitok	0	0	3	**3**
Mombasa	0	2	5	**7**
Nairobi	0	0	3	**3**
Total	**1**	**2**	**24**	**27**

Figure 2-35 displays the currently operational river gauging stations in the Athi Basin. The majority of the operational river gauging stations are rated sections. Most are read manually by gauge readers, with 3 automatic stations (1 of which is fitted with telemetry). Rating curves are updated yearly at the National office and distributed to the regional and subregional offices for use. However, challenges remain because many of the stations are also inaccessible during high flow conditions.

2.4.8.2 Monitoring of dam and lake levels

There is currently one operational lake monitoring stations in the Athi Basin at Lake Jipe (3JA02). Levels in Lake Jilore (3HC01) and Lake Chala (3JA01) used to be manually monitored by means of staff gauges and a reader that took daily water level measurements. According to WRA sub-regional staff, Station 3HC01 in the Mombasa sub-region was closed in 2015 due to damaged equipment and has not been repaired since. Station 3JA01 in the Loitokitok subregion is set to be updated to an automatic station under the Capital Improvement Projects according to WRA staff.

2.4.8.3 Meteorological monitoring

Many different organisations including the WRA, Kenya Meteorological Department (KMD), regional police stations, primary and secondary schools, National Parks, private enterprises, research institutions and agricultural offices operate meteorological stations throughout the Athi basin. Figure 2-36 displays the spatial distribution of the operational meteorological stations in the Athi Basin for which information is available.

2.4.8.4 Water quality monitoring

Kenya's existing surface water quality monitoring network was designed to collect water quality data in key river systems to support assessment and management of water quality in the country. The current practice in WRA is to monitor certain water quality parameters at most operational river gauging stations. This is done by sub-regional WRA staff at unknown intervals. In addition, effluent samples are supposed to be taken at potential point source pollution locations across the basin. In 2018, as part of this project, the number of existing water quality monitoring stations (for surface water, effluent and groundwater) were assessed across the basin (Table 2-14).

Table 2-14: Number of water quality monitoring stations in the Athi Basin (2018)

Athi Basin water quality stations	No. of current stations (2018)
Surface water	31
Effluent stations	21
Groundwater	37
Total	**89**

Currently, the water quality monitoring programme operated by WRA faces the challenges of inadequately qualified and trained staff and inadequate operational resources to facilitate regular sampling and laboratory analysis. In addition, because of inadequate equipment currently, the laboratories are only able to carry out analysis on a handful of parameters as listed in Table 2-15.

Table 2-15: Surface water quality parameters currently analysed

Type of Water quality monitoring station	Parameters tested
Effluent discharge points	Flow, pH, DO, Temperature, BOD, COD, Conductivity, TDS, Nutrients- NO^{2-}, NO^{3-}, PO_4^{3-}, TSS
Surface water quality monitoring stations	Flow, pH, DO, Temperature, TSS Conductivity, TDS, Nutrients- NO^{2-}, NO^{3-}, PO_4^{3-}.
Ground water quality monitoring stations	pH, DO, Temperature, TSS Conductivity, TDS, Nutients- NO^{2-}, NO^{3-}, PO_4^{3-}.

2.4.8.5 Groundwater monitoring

The current groundwater monitoring network in the Athi Basin was initiated in January 2006, hence the longest records span more than 10 years. These were mainly production boreholes for which WRA made arrangements with the borehole owners to have them monitored. The monitoring is for static water level and periodic water quality testing on some wells. Water levels for these sites are measured manually by dip-meter inserted in a dipper tube. Further to these, WRA installed a few automatic level-loggers on dedicated solitary monitoring wells in 2013.

The choice of monitoring sites was based on aquifer category with sites distributed across all categories. Thus, there are monitoring wells in strategic, major, minor and special aquifers. Nonetheless, the current monitoring network is limited and not all aquifers in each category are monitored. In fact, the vast majority of aquifers are not monitored.

There is now a total of 40 groundwater monitoring points across the Basin (4 Strategic, 20 Major, 11 Minor and 3 Special) (Water Resources Authority, 2018f), while there were 34 in the 2014-15 reporting period (Water Resources Management Authority, 2015a). Data quality is patchy; most groundwater level data are collected from boreholes that are used as production boreholes, so all too often the data show dynamic as well as static water levels. This restricts the utility of water level data to determine long-term trends.

This is changing, however; an additional 25 dedicated monitoring boreholes are being constructed in the Basin in 2018-19. These monitoring sites are to be fitted with water level loggers and telemetry.

- 8 shallow and 8 deep monitoring boreholes are to be installed in the NAS;
- 3 shallow and 6 deep monitoring boreholes are to be installed in the Tiwi aquifer;

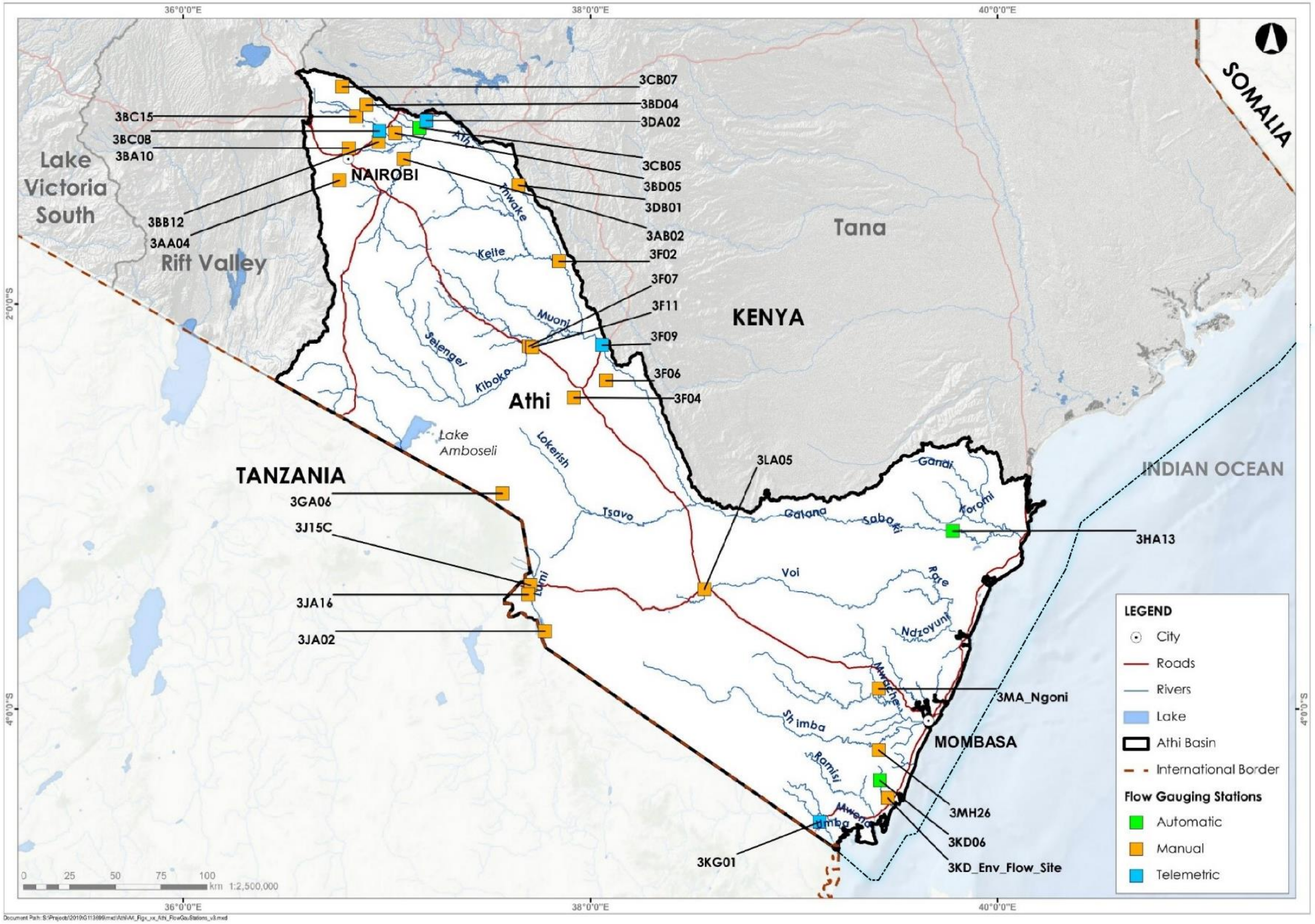


Figure 2-35: Locations of operational stream flow gauging stations in the Athi Basin

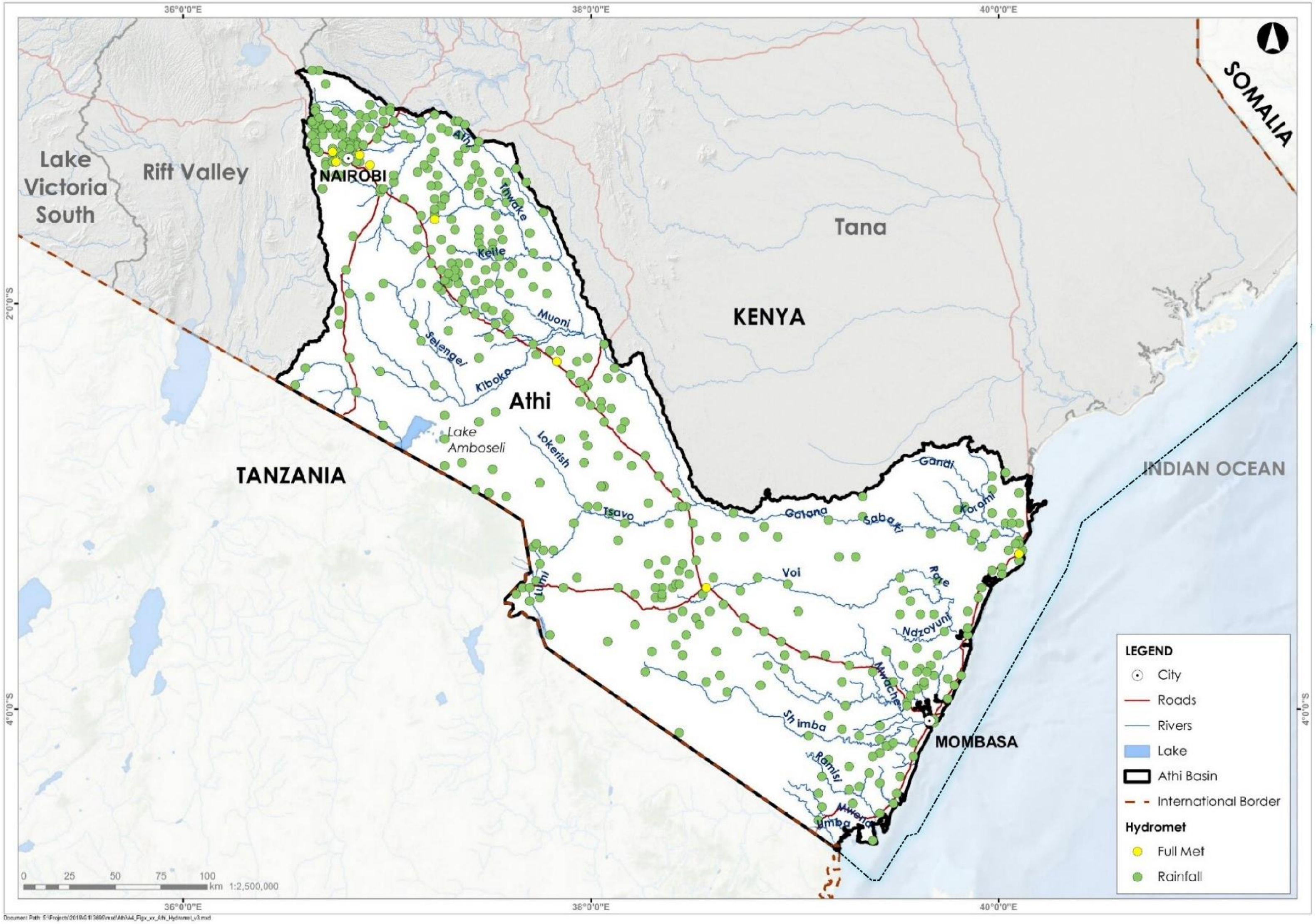


Figure 2-36: Locations of operational meteorological stations in the Athi Basin

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Image source: Nina R, 2016. Nairobi, Kenya. Available Online at https://flic.kr/p/NSkqQi

Institutional Overview

3 Institutional overview

3.1 Legislative, Policy and Institutional Framework

3.1.1 Introduction

The Constitution of Kenya (2010) provides the basis for water resources management in the country and recognises this through the right to a clean and healthy environment, through the management and sustainable development of natural resources (which includes both surface and ground water), as well as through the economic and social right "*to clean and safe water of adequate quantities*". Importantly, the State has the obligation to ensure that water is conserved, that development is managed to be sustainable and to ensure that the benefits accrued are shared equitably. Whilst it is noted that the utilisation of natural resources should be for the benefit of the people of Kenya, there is important emphasis placed upon the needs of marginalised communities. Also of importance is the recognition of the link between water and land. As such, this recognition provides the basis for improved integration in the planning, management and sustainable development of natural resources. In this regard, institutional arrangements from national to county level are imperative for leading efforts in socio-economic development at national scale and for implementing national government policies on natural resource and environmental conservation at a local scale.

Annexure C provides an overview of the legal, institutional and policy framework relating to environmental and integrated water resources management.

3.1.2 National policies

3.1.2.1 Water

Worldwide, there is increased recognition of the importance of water in terms of socio-economic development. This is increasingly emerging through the nexus discussions which acknowledge the interfaces between water, food, energy, and more recently, climatic risks. The findings of the World Economic Forum through their Global Risks Reports which repeatedly reflect water and climate related risks as being the most significant to economic growth.

At national level in Kenya, this sentiment has been mirrored in the development of various forms of national development plans. The Kenya Vision 2030, published in 2007, provides the national development blueprint. It is structured around economic, social and political dimensions and notes the important role of water in catalysing growth. National targets outlined in the Vision 2030 that have implications for the water sector include:

- Water and sanitation - to ensure that improved water and sanitation are available and accessible to all by 2030
- Agriculture - to increase the area under irrigation to 1.2 million ha by 2030 for increase of agricultural production
- Environment - to be a nation that has a clean, secure and sustainable environment by 2030
- Energy - to generate more energy and increase efficiency in the energy sector

In addition to these more strategic targets outlined above, many flagship projects were identified for unlocking development related to water resources. These projects include rehabilitation and protection of Kenya's five major water towers (the Aberdares, Cherengany, Mau, Mt. Kenya and Mt. Elgon), and waste management and pollution control.

The Kenya National Water Resources Management Strategy provides the overarching policy framework for water resource management and development in Kenya, despite a number of successive adjustments in the core water legislation. This consistency in policy intent has been critical in guiding the water sector, with legislative amendments being progressively utilised to improve and strengthen the way that policy is affected. At the time of its introduction, the 'Sessional paper no. 1 of 1999 on national policy on water resources management policy and development' (Government of Kenya, 1999) introduced key shifts in policy such as the separation of functions (including water resource management, water service delivery, policy, regulation, financing), the devolution of decision making to regional and local levels, the commercialisation of water (i.e. water to be treated as an economic and social good) and stakeholder participation through community and private sector participation.

The 'Sessional paper no. 1 of 1999 on national policy on water resources management policy and development' provides specific policy objectives covering the core focus of water resources management, water supply and sewerage development, institutional arrangement and financing of the water sector, which include:

- Preserve, conserve and protect all available water resources and allocate it in a sustainable, rational and economical way;
- Supply of water of good quality and in sufficient quantities to meet the various water needs including poverty alleviation, while ensuring safe disposal of wastewater and environmental protection;
- Establish an efficient and effective institutional framework to achieve systematic development and management of the water sector;
- Develop a sound and sustainable financing system for effective water resources management, water supply and sanitation development.

3.1.2.2 Environment and natural resources

In conjunction with the 'Sessional paper no. 1 of 1999 on national policy on water resources management policy and development', the National Environment Policy (NEP) (Government of Kenya, 2013a) provides an important framework in terms of improved river basin management in that the NEP has the goal of ensuring a "b*etter quality of life for present and future generations through sustainable management and use of the environment and natural resources*". As such, this framework policy has relevance to a number of differing sectors that are engaged in the management of natural resources, including water resources. The objectives of this policy that have relevance to the management of the Athi River Basin include, amongst others:

- Provide a framework for an integrated approach to planning and sustainable management of Kenya's environment and natural resources;
- Strengthen the legal and institutional framework for good governance, effective coordination and management of the environment and natural resources;
- Ensure sustainable management of the environment and natural resources, such as unique terrestrial and aquatic ecosystems, for national economic growth and improved livelihoods;
- Promote and support research and capacity development as well as use of innovative environmental management tools such as incentives, disincentives, total economic valuation, indicators of sustainable development;
- Promote and enhance cooperation, collaboration, synergy, partnerships and participation in the protection, conservation, sustainable management of the environment and natural resources;
- Ensure inclusion of cross-cutting and emerging issues such as poverty reduction, gender, disability, HIV&AIDS and other diseases in the management of the environment and natural resources.

Incorporated in the NEP are a number of important principles to take into consideration in undertaking planning in the Athi Basin and these are presented in Table 3-1.

Table 3-1: Guiding NEP principles for basin planning

Environmental Right	Every person in Kenya has a right to a clean and healthy environment and a duty to safeguard and enhance the environment
Right to Development	The right to development will be exercised taking into consideration sustainability, resource efficiency and economic, social and environmental needs.
Ecosystem Approach	An integrated ecosystem approach to conserving environmental resources will be adopted and enhanced to ensure that all ecosystems are managed in an integrated manner while also providing a range of benefits to the citizenry.
Sustainable Resource Use	Environmental resources will be utilised in a manner that does not compromise the quality and value of the resource or decrease the carrying capacity of supporting ecosystems.
Equity	The management of the environment and natural resources will ensure equitable access to resources for present and future generations.
Public Participation	A coordinated and participatory approach to environmental protection and management will be enhanced to ensure that the relevant government agencies, County Governments, private sector, civil society and communities are involved in planning, implementation and decision-making processes.
Subsidiarity	The management of the environment and natural resources will be through decentralisation and devolution of authority and responsibilities to the lowest level possible.
Precautionary Principle	Where there are credible threats of serious or irreversible damage to key environmental resources, lack of full scientific certainty will not be used as a reason for postponing cost-effective measures to prevent environmental degradation.
Polluter Pays Principle	The polluter and users of environmental and natural resources shall bear the full environmental and social costs of their activities
Good Governance	Rule of law, effective institutions, transparency and accountability, respect for human rights and the meaningful participation of citizens will be integrated in environmental management.
Benefit sharing	Where benefits will accrue from utilisation of biodiversity, these will be shared in order to promote conservation and sustainable use of biodiversity.
Community Empowerment	Communities will be involved in decision making and empowered in the implementation of such decisions.

There is significant alignment in the objectives and principles laid down in NEP with the current approaches utilised within the Kenyan water sector, and this is aligned with best practice.

A key issue to distil from the 'Sessional paper no. 1 of 1999 on national policy on water resources management policy and development' and NEP concerns the recognition of the value and benefits that are accrued from ecological infrastructure. This refers to the naturally functioning ecosystems that deliver valuable services to people, such as water and climate regulation, soil formation and disaster risk reduction (SANBI , 2013). Our ability to ensure that ecological infrastructure is managed and maintained will be an essential dimension of our resilience against climate variability and climate change.

3.1.2.3 Agriculture

The Kenya Vision 2030 identified agriculture as one of the key sectors to deliver the desired economic growth rate of 10% per annum and resulted in the development of various policies and strategies for the agricultural and irrigation sectors to guide the development, transformation and strengthening of these sectors. The transformation of smallholder agriculture from that of subsistence to an innovative, commercially oriented and modern agricultural sector has been identified as a fundamental component for achieving agricultural growth. It is realised that this transformation will be achieved through transforming key institutions in agriculture, livestock, forestry and wildlife to promote agricultural growth;

increasing productivity of crops, livestock and tree cover; introducing land-use policies for better use of high- and medium-potential lands; developing more irrigable areas in ASALs for both crops and livestock; improving market access for smallholders through better supply chain management; and adding value to farm, livestock and forestry products before they reach local, regional and international markets.

Increasing the productivity of agricultural water use in Kenya is a national priority given the country's low water endowment, growing population, and changing climate. Increasing productivity will also help contribute to achieving one of the primary targets of the Big Four Agenda; food security. Expanding the use of modern irrigation technology, such as drip and sprinkler systems, will be fundamental to achieving water productivity because of the potential for such systems to increase yields relative to water withdrawals. One of the key outputs of the NWMP 2030 was the identification of potential areas for future irrigation expansion. All the proposed schemes will be supplied from surface water - either by means of irrigation dams, multi-purpose dams or weirs. An Irrigation and Drainage Master Plan for Kenya was prepared in 2009 (Government of Kenya, 2009), which identified the following interventions to increase agricultural production: finalising and implementing the national irrigation policy and legal framework; intensifying and expanding irrigation; improving rainwater harvesting and storage for agriculture; rehabilitation and protecting water catchments; and implementing the irrigation flagship projects.

3.1.2.4 Energy

The enactment of the 2010 Constitution generated transformative processes in the energy sector. National government is tasked with the formulation of energy policy under the auspices of the Ministry of Energy and Petroleum. The draft National Energy and Petroleum Policy, (Government of Kenya, 2015b) indicates that government will transform the Rural Electrification Agency (REA) into the National Electrification and Renewable Energy Authority (NERA) to be the lead agency for development of energy resources that includes both geothermal energy and hydropower. Hydropower provides a significant portion of the energy mix, with the intention to further improve current systems whist developing new opportunities.

3.1.3 Legislation

The water and environmental legislation in Kenya has developed over time and this has enabled successive adjustments in order to improve the manner in which water (and other natural resources) are managed and sustainably developed.

The 2002 Water Act, came into effect in March 2003. This Water Act (Act No. 8 of 2002) provided the legal framework to support the 'Sessional paper no. 1 of 1999 on national policy on water resources management policy and development'. Importantly, the Act provided for the establishment of new institutions with clearly determined functions, with decentralised decision-making reflected in a number of autonomous regional water management institutions and Water Resource User Associations (WRUAs). This provided a key step forward to enable more effective implementation of national policy.

The promulgation of the Water Act (Act No 12 of 2016) was required to align with the 2010 Constitution as well as enabling amendments that were required to support the improved management of water resources. The Water Act 2016 revises the institutional mandates of key water sector institutions and sets out the role of counties in the water sector. It also defines a clear role for the WRA in the regulation of water resources, which provides a potential strengthening in the way that water resource development is regulated. However, there are some ambiguities in the Water Act 2016 that require resolution in order to clarify institutional matters. The MWSI is leading a water sector transition process which will address such challenges and assist institutions to give effect to policy and law.

The Environmental Management and Co-ordination Act (EMCA) was promulgated in 1999 and provided Kenya's first framework for environmental legislation. The EMCA recognises the importance of improving the legal alignment and administration across the various sectors that are engaged in the management and development of environmental resources. As it stands there is a range of legislative instruments, across these various sectors, that face challenges in alignment towards the aim of sustainable development as outlined in Vision 2030. The EMCA has undergone a number of revisions over time to strengthen various elements of the law and in a sense, these have also been largely focused upon improving the regulatory environment.

There are a range of legislative instruments that underpin the development of agriculture in Kenya. Amongst these is the Agriculture, Fisheries and Food Authority Act (Act No 13 of 2013) which provides for the regulation and promotion of agriculture. This is supported through the establishment of the Agriculture, Fisheries and Food Authority that is charged with, in consultation with County Governments, administering the Crops Act (Act No 16 of 2013) and the Fisheries Act (Chapter 378 of 1989). The drive to increase agricultural development will require ongoing development in irrigation capacity. As such, a draft Irrigation Bill was developed in 2015 intended to repeal the Irrigation Act (Chapter 347 of 2013). This amendment bill has been enacted to the Irrigation Act (Act No 14 of 2019) for the strengthening of irrigation regulations.

In terms of energy, the current legal framework is still informed by Sessional Paper No 4 on Energy of 2004 (Ministry of Energy, 2004) and the Energy Act (Act No 6 of 2006). Sessional Paper 4 identified the need to integrate energy and petroleum planning with national economic, social and environmental policies, as energy and petroleum are critical inputs in the social economic progress of the economy. The 2006 Energy Act assigns the responsibility for development of indicative national energy plans to the Energy Regulatory Commission (ERC). In 2009, the ERC established a committee with responsibility for preparation of the Least Cost Power Development Plan (LCPDP) in the electricity sub sector. The development of plans for the petroleum, coal and renewable energy subsectors, as well as for integrated energy and petroleum are yet to be developed and are a critical part of supporting the socio-economic development of Kenya.

3.1.4 National institutions

The 2010 Constitution provides for two tiers of Government with national government being broadly responsible for policy development and regulation to ensure that policies are effectively implemented. Some of the key functions, articulated in detail within the fourth schedule of the Constitution, relate to socio-economic development and natural resources management and are critically important from a basin planning perspective. These include, for example: the use of international waters and water resources; national economic policy and planning; national statistics and data on population, the economy and society generally; education; national public works; general principles of land planning and the coordination of planning by the counties; protection of the environment and natural resources with a view to establishing a durable and sustainable system of development, including, in particular - fishing, hunting and gathering; protection of animals and wildlife; water protection, securing sufficient residual water, hydraulic engineering and the safety of dams; and energy policy; disaster management; agricultural policy; energy policy including electricity and gas reticulation and energy regulation; capacity building and technical assistance to the counties; public investment; and tourism policy and development.

In the aftermath of the 2017 national elections, the national government in Kenya has undergone some changes in configuration to support a more effective and efficient Government. Whilst there are a number of Ministries that can be seen as enablers (e.g. Education, Justice etc), the key sector ministries from a basin planning perspective include:

- Ministry of Water, Sanitation and Irrigation
- Ministry of Environment and Forestry

- Ministry of Agriculture, Livestock and Fisheries
- Ministry of Energy and Petroleum
- Ministry of Devolution and ASAL.

Whilst these Ministries have the broad ambit to develop policy, under legislation they have established various national level public entities that have the mandate to perform regulatory and developmental functions. These public entities that function at a national level are tabulated, in Table 3-2.

Table 3-2: National level public entities that have relevance to basin plans

Institution	Roles and responsibilities*
Water Resources Authority (WRA)	- Formulate and enforce standards, procedures and Regulations for the management and use of water resources and flood mitigation. - Regulate the management and use of water resources. - Receive water permit applications for water abstraction, water use and recharge and determine, issue, vary water permits; and enforce the conditions of those permits. - Determine and set permit and water use fees as well as collect water permit fees and water use charges. - Provide information and advice to the Cabinet Secretary for formulation of policy on national water resource management, water storage and flood control strategies.
Water Services Regulatory Board (WASREB)	- Protect the interests and rights of consumers in the provision of water services. - Determine and prescribe national standards for the provision of water services and asset development for water services providers. - Evaluate and recommend water and sewerage tariffs to the county water services providers and approve the imposition of such tariffs in line with consumer protection standards. - Set licence conditions and accredit water services providers. - Monitor and regulate licensees and enforce licence conditions.
National Environmental Management Authority (NEMA)	- Co-ordinate environmental management activities being undertaken by lead agencies and promote the integration of environmental considerations into development policies, plans, programmes and projects to ensure the proper management and rational utilisation of environmental resources. - Take stock of natural resources in Kenya and their utilisation and conservation. - Establish and review in consultation with the relevant lead agencies, land use guidelines. - Monitor and assess activities, including activities being carried out by relevant lead agencies, to ensure that the environment is not degraded by such activities and environmental management objectives are adhered to.
Energy Regulatory Commission (ERC)	- Issue, renew, modify, suspend or revoke licences and permits for all undertakings and activities in the energy sector. - Develop regulations which may be necessary or expedient for the regulation of the energy. - Formulate, enforce and review environmental, health, safety and quality standards for the energy sector, in coordination with other statutory authorities.
Water Sector Trust Fund (WSTF)	- Financing provision of water and sanitation to disadvantaged groups and includes: - Community level initiatives for the sustainable management of water resources. - Development of water services in rural areas considered not to be commercially viable for provision of water services by licensees. - Development of water services in the under-served poor urban areas. - Research activities regarding water resources management and water services, sewerage and sanitation.
Water Tribunal (WT)	- Arbitration of water related disputes and conflicts.
National Water Harvesting and Storage Authority (NWHSA)	- Development of national public water works for water resources storage and flood control. - Maintain and manage national public water works infrastructure for water resources storage. - Develop a water harvesting policy and enforce water harvesting strategies.

Institution	Roles and responsibilities*
Water Works Development Agencies (WWDAs)	- Undertake the development, maintenance and management of the national public water works within its area of jurisdiction. - Operate water works and provide water services as a water service provider, as a transitional arrangement or as instructed by the WASREB. - Provide technical services and capacity building to such County Governments and water service providers within its area as may be requested.
Kenya Water Towers Agency (KWTA)	- Coordinate and oversee the protection, rehabilitation, conservation, and sustainable management of Kenya's water towers. - Co-ordinate and oversee the recovery and restoration of forest lands, wetlands and biodiversity hot spots. - Promote the implementation of sustainable livelihood programmes in the water towers in accordance with natural resource conservation.
Kenya Water Institute (KEWI)	- Provides training, research and consultancy services in the wider water sector. - Provide a forum for effective collaboration between the public and private sectors and other interested parties for the development of the water and sanitation sectors.
National Irrigation Authority (NIA)	- Conduct research and investigation into the establishment of national irrigation schemes. - Formulate and be responsible in conjunction with the WRA for the execution of policy in relation to national irrigation schemes. - Raise funds for the development of national irrigation schemes. - Design, construct, supervise and administer national irrigation schemes.

* The roles and responsibilities provided are not comprehensive but provides some of the key functions.

To achieve effective integrated planning and management, there is a need for integrated approaches between different departments and agencies at the national level. However, there are significant challenges in terms of ensuring the alignment in policy and legislation, which requires capacity in the respective institutions, to be able to work in an integrated manner and have the necessary systems to support this integration.

3.1.5 Basin and sub-basin institutions

Noting the requirements of Integrated Water Resources Management, institutions have been established at basin and sub-basin levels to improve the day-to-day management of water resources as well as to improve the regulation and oversight required to ensure that water is efficiently used in accordance with water use permits. Under the auspices of the Water Act 2016, this is achieved through the Regional and Sub-Regional Offices of the Water Resources Authority (WRA) and the Water Resource Users Associations (WRUAs).

The Athi Basin is managed by five WRA Sub-Regional Offices (SROs) with the WRA Regional Office (RO) located in Machakos. The basin has been delineated into eight Catchment Management Units (CMUs) based on hydrological and water resource considerations. Table 3-3 lists the sub-regions, the locations of the SROs and the CMUs managed by each SRO, while Figure 3-1 displays the locations of the WRA offices and the geographical extent of each sub-region.

Table 3-3: WRA sub-regions, offices and CMUs in the Athi Basin

Sub-Region	WRA SRO	CMUs
Upper Athi	Kiambu	Ruiru, Ndarugu
Mbagathi - Nairobi	Nairobi	Mbagathi/ Nairobi
Middle Athi	Kibwezi	Thwake
Noltresh - Lumi	Loitokitok	Tsavo
Coastal - Athi -Mombasa	Mombasa	Coastal Zone/ Mombasa

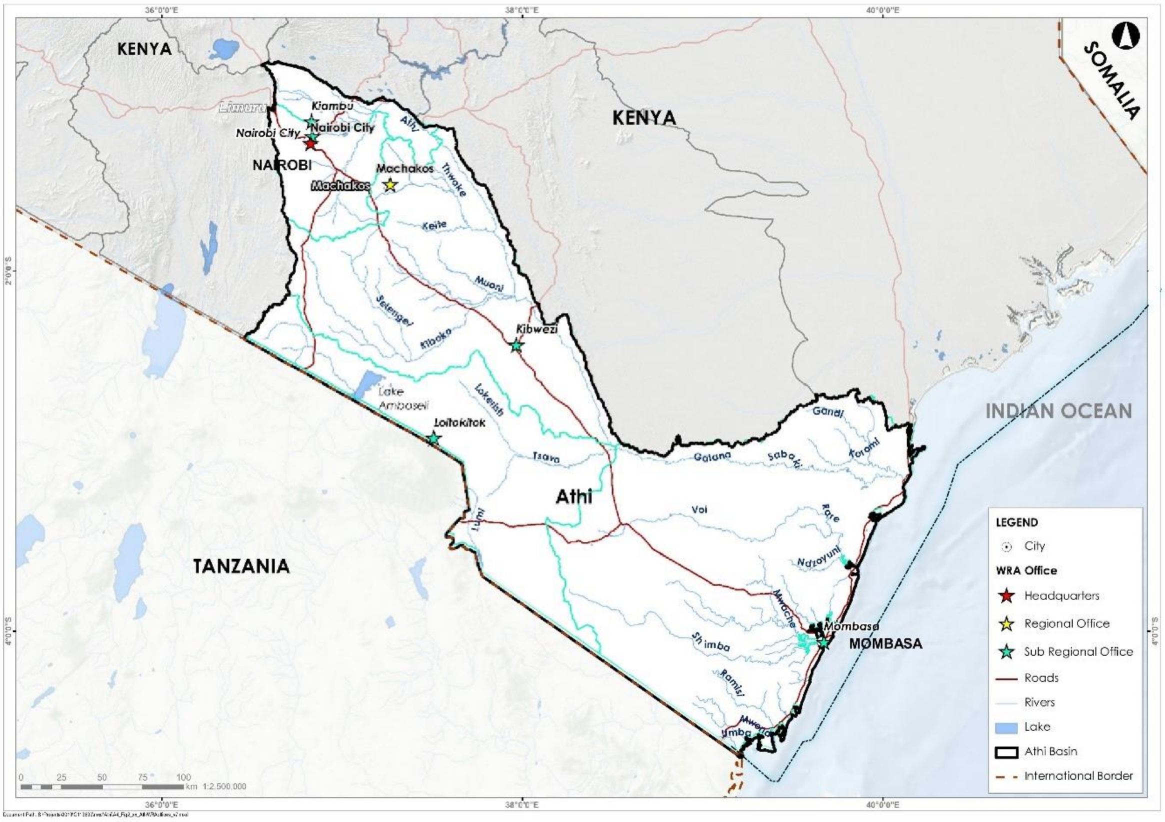


Figure 3-1: WRA Offices in the Athi Basin

Water users apply for water permits through the relevant WRA SRO, and the application is then sent to the RO for processing. Class A to C permits are handled at RO level, while Class D permits are handled at Head Office. A hydrological or hydrogeological assessment report conducted by a qualified professional must be submitted by the water user with the application. The water permits are recorded in the Water Permit Database at the RO.

The 2016 Water Act in effect strives to strengthen the management of water resources at the basin and sub-basin level, whilst strengthening the regulatory role of WRA both at national and basin scales. This not only removes the dichotomy that WRA faced as being manager and regulator, but also attempts to create a stronger management regime within the basins and sub-basins, noting that counties have a key role to play in water service delivery as well as ensuring that water is used efficiently within their jurisdictions. To this end, the Water Act 2016 introduced Basin Water Resource Committees (BWRCs) as a replacement for the previous Catchment Area Advisory Committees (CAACs), with a more managerial intent than the purely advisory role that was played by the CAACs. At this juncture, during what is effectively a period of transition, the BWRCs will initially provide a more advisory function, however, it will be critically important to learn from the challenges that were experienced with the CAACs so that the BWRCs become more effective in supporting water resource management. The regulatory function of the WRA will continue to be strengthened and, in the transition period, ring-fencing of staff within the Regional and Sub-Regional Offices will be essential to separate staff and functions that are managerial in nature, and as such, supportive of the BWRCs. The BWRCs fall under the WRA, and their responsibilities (which must be delegated by WRA) include the formulation of Basin Water Resources Strategies, management of basins, advice to WRA and the facilitation of WRUA establishment.

At a more localised level, the establishment of the Water Resource User Associations (WRUAs) has been essential in ensuring a focus on the operational management functions within a sub-basin. The WRUAs are community-based, voluntary associations made up of water users and riparian owners interested in proper management of their water resources and were established to enable the collaborative management of water resources and to provide essential support in the resolution of conflicts concerning the use of water resources. The BWRCs may contract WRUAs as agents to perform certain duties in water resource management. To date, WRUAs have performed important local functions, but have faced an array of challenges that have served to hinder their effectiveness. Many of these are enabling factors such as capacity in terms of having sufficient skills and training, but also include such issues as inadequate equipment and in sufficient financial resources. These challenges will require redress to support the implementation of this Basin Plan and realise the local level capacitation that can unlock the localised socio-economic development required to support Vision 2030. This is supported by the Water Act 2016 that provides in Section 29 (3) that "*basin area water resources management strategy shall facilitate the establishment and operation of water resources user associations*".

3.1.6 County governments

The 2010 Constitution introduced a decentralised system, with 47 county governments and one national government with specific functions accorded to the two levels. Guided by the overarching objectives and principles of the county governments as set out in the Constitution, specific functions of counties are provided in Schedule Four of the Constitution. County functions which are closely related to basin planning include:

- Agriculture: Crop and animal husbandry; plant and animal disease control; and fisheries
- Health: Refuse removal, refuse dumps and solid waste disposal
- County planning and development: statistics; land survey and mapping; boundaries and fencing; housing; and electricity and gas reticulation and energy regulation
- Natural resources and conservation: Implementation of specific national government policies on natural resources and environmental conservation: soil and water conservation; and forestry
- County public works and services: Storm water management systems in built-up areas; and water and sanitation services
- Firefighting services and disaster management
- Community participation: Ensuring and coordinating the participation of communities in governance at the local level and assisting communities to develop the administrative capacity for the effective exercise of the functions and powers and participation in governance at the local level

The county governments face considerable challenges as a relatively new level of government and these include capacity and financial resources. The latter is being assisted through the Division of Revenue Act which will provide an "equitable share" of national revenue to the counties. In addition, the Equalisation Fund, which targets specific counties and areas, typically in the arid areas, where socio-economic indicators lag significantly behind the national average, will also support in reducing the financial shortfalls. Recognising that the county governments will be required to give effect to policy that is provided by national government across an array of sectors, they will face considerable institutional challenges in working horizontally across these various sectors endeavouring to ensure effective integration whilst trying to ensure that there is effective vertical interaction with the various Ministries and national public entities. The effective alignment in various planning instruments across spatial scales and differing sectors will be critical for county governments to ensure the service delivery mandate that they have been given.

3.1.7 Partnerships and engagement

3.1.7.1 Partnerships

Internationally there has been a growing recognition of the important role that the private sector and civil society must play in the management of water resources. The importance of collective action is being realised in that the available capacity and resources within Government are not sufficient to ensure that common-pool resources such as water are sustainably managed.

In addition, partnerships and civil society engagement becomes more important as water resources become increasingly utilised (through increasing abstractive water use and waste discharges) and exposed to the associated risks. Therefore, whilst there is a need for the private sector and civil society to engage in water resources management to manage their own risks, in so doing they provide critical support to the wider water sector.

The nature of these partnerships will vary depending on their relationship with the water sector and the various interfaces that these actors have. For example, the partnership between WRA and the Kenya Meteorological Department (KMD) at national level is critical in that KMD provide meteorological and climatological services to the water sector. This is not only essential for the hydrological modelling that assists in understanding the status of water resources, but also provides important information in terms of flood and drought warnings. Another example is that with international Non-Governmental Organisations (NGOs) such as World Wildlife Fund (WWF) and International Union for Conservation of Nature (IUCN), amongst others. These provide useful capacity as well as enable (and often fund) studies and research that sometimes serve to unlock challenges.

As the implementation of the Athi Basin Plan progresses, partnerships will be further developed to realise the implementation of the basin plan. It will be important to map and bring together all the partners into one big picture that is centrally monitored for the good of the entire basin. The Nairobi River Rehabilitation Program which includes 17 government ministries and agencies is one such initiative. The multi-stakeholder initiative brings together the Government of Kenya, development partners, the private sector and civil society. The main objective of the Programme is to rehabilitate, restore and sustainably manage the Nairobi River Basin (a sub-basin of Athi) in order to provide improved livelihoods, enhance environmental quality and values through well-regulated economic and recreational ventures.

3.1.7.2 Engagement

Legislation across the sectors emphasises the importance of stakeholder engagement. This provides a means of not only bringing in diverse views and opinions that enrich solution development, but also creates the sense of ownership for processes and products that can help to ensure better implementation.

There is always room for improvement with regard to stakeholder engagement and there is a sense that in Kenya this is the case. The benefits that can be realised through catchment forum processes have not always been maximised and ongoing work is needed to find more appropriate forum structures and functional modalities that ensure that the maximum benefits from stakeholder engagement is ensured. To date the forums have met annually and have not truly enabled the discussion required. The basin planning process has not only in itself been a vehicle to improve engagement, but also provides a cogent and pragmatic stakeholder engagement framework.

It emerged from consultations with the various levels of government at national, county and local levels that one of the major challenges on effective engagement is overlap of mandates of the various national and county government agencies working in water resources management. The proposed BWRCs could fill this gap. The BWRCs will provide a better engagement plan with county governments and will allow for better representation of basin area stakeholders in matters relating to IWRM. This Consultancy has developed tools to better equip the BWRCs to ensure they deliver on their mandate and to provide a systematic way of enhancing their effectiveness (refer to **Annexure A**: Analytical Tools). This process however must involve adequate stakeholder consultations including county governments and various actors in the basin who need to be included in the planning for such engagement to work (refer to **Annexure D**).

3.2 Existing Development Plans and Sectoral Perspectives

3.2.1 Introduction

To ensure that this Basin Plan is representative and aligned with current plans and strategies related to water resources planning and management in the Athi Basin, relevant current plans and strategies were reviewed and are briefly described below. In addition, high-level sectoral perspectives in relation to water resources planning and management in the Athi Basin are also presented in this Section.

3.2.2 National Water Master Plan 2030

The NWMP 2030 was completed in 2013 and covers all six river basins in Kenya. For each basin, the NWMP 2030 provides information related to water resources, water demands, high-level water allocations, economic evaluations of proposed interventions and implementation programmes. In addition, the NWMP 2030 presents development plans related to water supply, sanitation, irrigation, hydropower and water resources as well as management plans for catchment management, hydrometeorological monitoring, floods, droughts and an environmental management plan.

NWMP 2030 information on surface water and groundwater resources availability and use in the Athi Basin were compared with the water resources assessment results undertaken in this Consultancy (refer to Section 2.4). Furthermore, the NWMP 2030 was used extensively to inform the development of the Athi Basin Plan, specifically the sub-plans as outlined in Section 5.

3.2.3 Sub-catchment management plans

WRA has delineated Kenya into 1 237 sub-catchment areas with the intention of forming Water Resources User Associations (WRUAs) for each. At present, only 150 WRUAs out of a potential 309 WRUAs have been formed in the Athi Basin. The sub catchment management plan (SCMP) is a planning tool that is developed by the Water User Associations (WRUA) under regulation by the Water Resources Authority (WRA). Its main objective is to guide the implementation of water resources management and regulation activities within a defined period of time in any given sub catchment. The activities, in most cases, relate to catchment protection, pollution control and water infrastructure development. Being the lowest planning tool developed to implement the National Water Master Plan and the basin area plan, it is directly held in the custody of the WRUAs who are in charge of its implementation. The plan is a resource mobilization tool that the WRUA uses to source for implementation funds and other resources.

The constitution 2010, Fourth Schedule Part 2, section 10, outlines water resource management as a function of the county government. This devolvement of the conservation role to the counties creates a direct linkage between the SCMP and the County Integrated Development Plan (CIDP). The county sets aside funds for the management of catchments that are absorbed through the implementation of SCMP or directly through CIDP identified activities. The regulation of the process to ensure the catchments are well protected and the harmony of the two planning perspectives rests with the Authority.

The Basin Plan is used as a reference document in the preparation of the SCMPs. To date, only 53 SCMPs have been developed in the Athi Basin.

3.2.4 Catchment management strategy

The Athi CMS for the period 2015-2022 (Water Resources Management Authority, 2015b) was completed in 2015. The CMS provides a vision and framework for the management of water resources and related land resources in the Athi Basin and outlines how the concept of integrated water resources management should be implemented at catchment level. It proposed water resources and related strategies for:

- **Protection of the right to water:** Management approaches; Water balance and demand management; Water allocation and use management
- **Water resource protection:** Water resource protection; Catchment protection and conservation
- **Resource augmentation adaptation and development:** Flood and drought management; Climate change adaptation; Water resources infrastructure development; Rights based approach; Livelihoods enhancement
- **Implementation, information management and financing:** Institutional strengthening; Monitoring and management; Financing and implementation

The strategic actions which were identified in the Athi CMS were cross-referenced in the Basin Plan implementation plans developed as part of this Study (refer to Section 6 and **Annexure E**).

3.2.5 County integrated development plans

County Integrated Development Plans (CIDPs) are prepared every five years by counties as a road map for development. The plan touches on all sectors devolved to county governments, providing a plan towards improvement. Catchment protection and water and sanitation services are devolved functions and as such feature in all CIDPs. A review of the CIDPs showed that planned activities related to water resources mainly revolve around rehabilitation of old pipe networks, extension of distribution network, development of new water sources including boreholes and small dams/pans, extension of sewer networks and expansion of sewer treatment plants.

The key development aspects of each CIDP which are relevant to water resources management in the nine counties located in the Athi Basin are briefly described in term of water and sanitation, natural resources and agriculture in Table 3-4

Table 3-4: Key aspects of the CIDP

County	Water and Sanitation	Natural Resources	Agriculture
Kiambu CIDP (2018-2022)	Programmes include enabling policy, water resource conservation, protection and improved sanitation services, water harvesting and flood control, development of water supply infrastructure.	Programmes include promoting a clean environment through county environmental monitoring and management, enabling policy, solid waste management and environmental education. To increase forest cover and for sustainable management of natural resources programmes include forest conservation and management to increase forest cover to 20%, map cover, relocate people, wildlife conservation and security, reclaiming quarry sites.	Programmes include improved extension services; an enabling policy for increased productivity; increased productivity through conservation agriculture, farming resources, soil and water conservation, increased area under irrigation, agricultural mechanization services, upgrading of Waruhiu ATC, agricultural inputs and financing; increased fisheries productivity through enabling policy, aquaculture development and marketing; increased livestock productivity through enabling policy, livestock production and management, disease management, product value addition and marketing.
Nairobi CIDP (2018-2022)	Water demand is increasing whilst catchment areas remain limited, catchment areas are being degraded by wastes and encroachment, there is a lack of space for public infrastructure. The county intends to expand infrastructure in areas where there are lacking and address issues of inequality. On-going projects include slum upgrading and urban renewal. New projects include the Mukuru Special Planning Area and provision of social housing in Mji Wa Huruma.	Proposed strategies include fencing National Parks, a river rehabilitation programme, legal and policy enforcement, tourism promotion and a reforestation and afforestation programme. New projects include riparian, wildlife and migratory management plans.	Agro-based industries are located in the high agricultural potential areas with poor linkages to markets. The county intends to enhance access for these industries. On-going projects include: installation of green houses and water harvesting; construction of poultry units/rabbit hutches/fish tanks for youth groups. New projects include construction of fish ponds and fish markets, establishment of multi-storey gardening units and installation of food processing machines.
Machakos CIDP (2018-2022)	Programmes include water harvesting; improved assess to water through pans, major dams, weirs, boreholes; increased irrigation, improved sanitation and service delivery. Machakos water supply and sewer line expansion is considered a flagship project.	Programmes include enabling policy, catchment rehabilitation, tree planting, alternative energy sources, awareness on rain water harvesting, rehabilitation of degraded rivers, solid waste management.	Programmes include enabling policy, mechanization, farming resources, improved extension services, disease management, soil and water conservation, irrigation schemes and earth dams, greenhouses, diversified agro-enterprises, conservation agriculture, priority value chains, increased indigenous livestock, adoption of appropriate fodder and forage under different climatic zones, increased livestock productivity, improved income from sale of livestock, increased fish production, improved cooperative functioning.

County	Water and Sanitation	Natural Resources	Agriculture
Kajiado CIDP (2018-2022)	Programmes include piped water supplied to households, boreholes drilled, public institutions ensured water supply, dams/pans constructed, improved water supply services, stormwater infrastructure developed, and catchment areas conserved. Irrigation programmes include increasing acreage under irrigation and increasing storage capacity.	Programmes include policy development, climate change training, solid waste and pollution control, forest and riparian area restoration and rehabilitation of quarries.	Programmes include improving extension services, reduced incidence of crop pest and disease attack, supply of agricultural machines, soil and water conservation, supply of farm inputs, post-harvest management, small scale irrigation and value addition, climate smart agriculture promoted and Agricultural Sector Development Support Project (ASDSP II).
Makueni CIDP (2018-2022)	The climatic conditions of the county have led to acute water shortage and access to water supply is on average up to 5 km away. Programmes include increasing access to safe water within 2 km through the construction of dams, boreholes, water kiosks, piped water, sewerage systems and improving water harvesting. Improving catchment management through conservation of water towers and wetlands and improving climate information systems. Improved water governance through institutional support and strengthening of communities' participation in water management.	The county views natural resources as natural assets for economic production or consumption. Sustainable management of these resources involve mineral mapping and development, environmental conservation and enhanced tourism infrastructure development.	Agriculture is considered to be a sector which enhances household income and is a priority for economic empowerment in the county. Increased productivity will be achieved through fruit and other horticultural crops development, production and marketing of drought tolerant cereals and legumes, enhancing agricultural mechanisation, integrated beef and marketing, dairy development, honey development, enhancing feed and fodder production, crop and livestock pest control. Improved food security will be promoted through irrigation and water conservation and enhancing access to farm inputs. Reduced post-harvest losses will also be managed.
Taita Taveta CIDP	The county intends to provide clean, reliable and adequate water through improved management and protection of the environment. Sub-programmes include water resource management, transboundary water resource management, legal framework and policy formulation, rainwater harvesting and storage, water supply management, flood management and enhanced sanitation management. Water supply has been proposed for various wards through boreholes and larger water projects.	Taita Taveta has lakes, rivers, springs, wetlands, forests, wildlife and minerals on which multiple sectors are dependent. Water levels in lakes are fluctuating, water quality of lakes, rivers and wetlands is deteriorating, and riparian areas, wetlands and forests are being encroached on. The county intends to follow best practices for Integrated Watershed Management and eco-tourism and alternative tree farming is being promoted.	Agriculture growth is being promoted through improving food security and incomes of farmers. Agro-processing and value addition is also promoted. The livestock and fisheries industry are also to be improved. On-going projects include procurement of seed, plantlets and seedlings; procurement of fertilizer and manure; desilting and excavating water pans; irrigation and agro-processing materials; rehabilitation of farms; livestock improvement project; fish ponds.

County	Water and Sanitation	Natural Resources	Agriculture
Kwale CIDP (2013-2017)	Programmes include rehabilitation and expansion of water supply systems including Marere water supply system, Tiwi and Waa boreholes, Mwananyamala-Kikoneni and Msambweni water supply systems. Community small scale schemes will also be promoted.	Programmes include developing a mineral resources map, gazette mineral deposits, land accessions, enabling policy for environmental protection, environmental education, demarcation of protected areas, develop tree growers' initiatives, rehabilitate degraded land.	Programmes include improved extension services, establishing disease-free zones, farmers production and marketing cooperatives, irrigated agriculture along major rivers and introduce rain water harvesting, affordable farm inputs.
Kilifi CIDP (2018-2022)	Programmes include increased access to water supply, diversification of water sources, catchment rehabilitation and improved sanitation services. Flagship projects include Rare, Sabaki and Gwaseni/Mbubi dams.	Programmes include improved governance, forest resource conservation and management, wildlife and sensitive ecosystem conservation and waste management. A flagship project is the water to energy project.	78.5% of the county is agricultural land, over 90% of the population depend on agriculture, dependent of rain-fed agriculture. Programmes include modernizing, promoting capacity building, improving production, livelihoods, dairy and beef cattle farming, fish production and marketing, land regularization and research and development.
Mombasa CIDP (2018-2022)	Mombasa has underdeveloped water supply systems and irrigation systems. Programmes to improve this are sanitation blocks and sludge treatment plants, sewer systems and stormwater systems built, waste water treatment plants rehabilitated, water supply pipelines, water bowsers, water storage, desalination plants, boreholes, water/earth pans and policy review.	Natural resources are overutilized and degraded. Programmes to improve this are development of disposal sites and waste management equipment, rehabilitation of quarries, management of hazardous waste and improved governance.	Programmes to improve agriculture include crop development through support services, farmer inputs, marketing and value addition and post-harvest management; livestock development through support services, livestock productivity management and marketing and value addition; fisheries development through support services, fish production management and marketing and value addition; and co-operatives development.

3.2.6 Regional development plans

District development plans were once a tool for implementing development at the district level in Kenya. Currently, under the new dispensation, local development is done under county governments. However, there are regional bodies within the Athi Basin who are responsible for development activities within their respective areas of jurisdiction. These include the Tana and Athi River Development Authority (TARDA) and the Coast Development Authority (CDA).

TARDA's area of jurisdiction covers approximately 138 000 km^2, comprising 100 000 km^2 of the Tana Basin and 38 000 km^2 of the Athi Basin. The mandate of TARDA is to enhance equitable socio-economic development through sustainable utilisation and management of resources in the Tana and Athi Basins. TARDA therefore has a focus on environmental protection, natural resource management, sustainable development and socio-economic wellbeing of the people. The proposed Munyu multipurpose dam on the Athi River is one of TARDA's identified projects in the Athi Basin.

CDA was established by an Act of Parliament to provide integrated development planning, coordination and implementation of projects and programmes within its area of jurisdiction which includes the seven counties of the Coast Region as well as the Kenya Exclusive Economic Zone. Construction of water pans, rehabilitation of boreholes and the construction of Mwache Dam are ongoing CDA projects. CDA is also mandated to enhance capacity building for environmental and water resources management and currently manages a number of projects under various programmes such as the Kenya Coastal Development Programme and the Kenya Climate Change Adaptation Programme.

3.2.7 Projects planned by Water Works Development Agencies

Three Water Works Development Agencies (WWDAs) are operational in the Athi Basin. The Athi Water Works Development Agency (AWWDA) covers Nairobi and Kiambu counties; the Tanathi Water Works Development Agency (Tanathi WWDA) covers Kajiado, Machakos and Makueni counties; and the Coast Water Works Development Agency (CWWDA) covers Mombasa, Kwale, Kilifi and Taita Taveta counties. The WWDAs have ongoing and proposed projects that vary from rehabilitation of water supply schemes, extension of service lines, construction of storage tanks and drilling and equipping of boreholes in all the counties, to major dam and water resource projects.

The **AWWDA**, which also covers part of the upper Tana Basin, is planning the implementation of further phases of the Northern Collector Tunnel Project, which will transfer water from the upper Tana Basin to Nairobi,

The **Tanathi WWDA** is planning the Ndarugu Dam Project in the Athi Basin as part of enhancing the water supply to Nairobi as well as improving water supply in Kiambu, Machakos and Kajiado counties.

The **CWWDA** recently developed a Water Supply Masterplan for Mombasa and the Towns within Coast Province (Tahal Group, 2013), which sets out a programme of infrastructure development to meet water and sanitation demands.

Note: Following the enactment of the Water Act 2016, Water Services Boards (WSBs) have transformed into Water Works Development Agencies (WWDAs).

3.2.8 Sectoral perspectives

3.2.8.1 Water supply and sanitation

There are currently eight large dams in the Athi Basin, as well as a large number of small dams and pans, with a total storage volume of about 22 MCM, supplying mainly urban and domestic demands as well as irrigation demands. The basin already receives a large volume of water via an inter-basin transfer from the Tana Basin. However, further bulk water resources development is essential in order to satisfy the growing future water demands. This should be supplemented by the development of small dams for scattered water demands as well as groundwater resource development to augment surface water in certain areas.

About 24% of the population in the Athi Basin currently receives drinking water from unimproved sources (unregistered water vendors and water taken from lakes and streams without proper treatment), while 22% receive water directly from boreholes and springs. The Athi Basin has the highest proportion of households receiving piped water (54%). There are 20 urban WSPs and seven rural WSP, and together these WSPs provide a capacity of 674 175 m^3/day. The non-revenue water (NRW) of these WSPs ranges from 24% to 89%. The Athi Basin has the largest proportion of households connected to a formal sewerage system, with 22% of the population having access. Pit latrines and septic tanks are used by 71% of the population, while 7% of the population have no form of sanitation system.

Development in the water supply and sanitation sector in the basin is hampered by insufficient institutional, human resources, financial and technological capacity. Some of the specific aspects relate to poor performance of many utilities, high levels of non-revenue water (NRW) in many utilities (above 40%), poor governance practices, non-viable utilities, inadequate enforcement of water resources regulations, a lack of clear mandates for actors in the storage sub-sector. Challenges under the water supply sector include water scarcity, assurance of supply, population growth, urbanisation and industrialisation, financial constraints, water quality, low reliability of supply, and various institutional challenges. In order to overcome these challenges, innovative solutions such as public private partnerships, water demand management and payment recovery mechanisms should be considered.

3.2.8.2 Energy, hydropower and mining

The energy sector in Kenya relies on three main sources of energy, namely biomass, petroleum and electricity at 68%, 21% and 9% of total energy consumption (Institute of Economic Affairs, 2015). The remaining 1 percent consisting of solar and other forms of energy. Hydroelectric power in Kenya currently accounts for about 49% of installed capacity, which is about 761 MW. However, the Government of Kenya is strongly pushing for a shift to other alternative resources of electricity generation and by 2030 it is expected that hydro power will only account for 5% of total capacity at 1 039 MW.

The National Water Resource Management Strategy (Government of Kenya, 2006) acknowledges the need to identify and prioritise energy-based needs as part of the planning and management aspects of water resources management. Due to the increasing power demand in Kenya, there is a need to expand the existing hydropower system, but also a need to diversify into other alternative but sustainable energy forms based on life cycle least cost criteria in order to minimise stress on the water resources. The lack of access to modern energy services for cooking and lighting is leading to the destruction of trees and resultant catchment degradation in many parts of Kenya. This in turn impacts base flows along rivers that provide the driving force for hydro power.

About 44% of the population in the Athi Basin has access to electricity. Paraffin is commonly used for lighting in households without access to electricity, and about 57% of the population use biomass (burning of fire wood and charcoal) as a source of energy for cooking. There are currently no hydropower schemes in the basin and although there are plans for the development of hydropower, the hydropower potential is not as high as in other parts of the country.

Connection of users to the main electricity grid in the Athi Basin is generally very poor except in the highly connected Nairobi and Mombasa cities as well as in medium level connected smaller towns. The rest of the basin has no access to modern energy service or employs off-grid energy systems like solar, wind and hydro.

A possible reason that informs the low progress in extending the grid to many in this basin is the dispersed nature of the population. Realising that the basin is essentially arid and semi-arid, the rural-dwellers in this basin tend to be mainly semi-nomadic pastoralists and agro-pastoralists.

The Athi Basin will need to develop specific plans based on distributed generation and renewable energy to expand energy access to many users in this region. The Athi Basin is richly endowed with three main renewable energy resources: wind, solar, and hydro. Part of the coal deposits in the Mui belt is also found in the basin. Considering that a major section of the Athi Basin is not connected to the national grid, the opportunity for exploiting renewable energy is very attractive. This would involve using mini-grid hydro, mini-grid wind, stand-alone diesel, stand-alone PV or a hybrid combination of these technologies. The use of the tributaries feeding into the main Athi River using run of the river micro-hydro systems is also a potential possibility.

Advanced atmospheric models have shown that the wind speeds in the Athi Basin are sufficient to run wind turbines. An example of a current wind farm in the basin is the Ngong Hills Wind Power station, which was the first wind farm to be connected to the national grid. The wind farm, owned by Kengen had an original capacity of 5.1 MW, but is currently being upgraded to produce 25.5 MW. In addition, Kipeto Wind Power Project in Kajiado County is currently under implementation and is expected to generate 100 MW. The Athi Basin also has a high potential for electricity generation through solar PV systems.

The Athi Basin holds a variety of mineral deposits. Gemstones are found in Kwale, Kilifi, Taita Taveta and Makueni counties. Other mineral deposits include Titanium minerals, Manganese, Barytes, Gypsum, Granite, Niobium, Vermiculite, Pozzolana and Diatomite. Taita Taveta County has a large mining sector, including Iron ore, Chalk, Limestone, Gemstones, construction stone and sand. The Base Titanium Ltd mine in Kwale County is estimated to have reserves of 140 million tonnes of titanium.

The geology of an area is of critical relevance to the occurrence of different minerals. The Athi Basin comprises six broad groups of geological formation relating to likely mineral occurrence including Precambrian Basement (metamorphic rocks of the Mozambique Belt); Karoo-Jurassic sediments of the coast; Igneous rocks (volcanic) underlying Nairobi, Kiambu, Nyandarua and Muranga counties; younger rocks (Pliocene to Pleistocene) underlying the eastern side of Kwale and Kilifi; very young erosive material across most of the basin; and intrusive rocks which are sparsely distributed across the basin but dominant in the south-western part of Kwale County where they give rise to rare earth elements and geothermal potential.

The Mining Handbook (Government of Kenya, 2015a), lists “registered mineral occurrences” in the counties of the Athi Basin as follows.

Table 3-5: Registered Mineral Occurrences in counties in the Athi Basin (Government of Kenya, 2015a)

County	Minerals	Remarks
Kajiado	Soda Ash, Feldspar, Limestone Gypsum, Gemstones, Marble & Granite (dimension stone), Carbon Dioxide Gas	Soda ash occurs in the Rift Valley Basin
Kiambu	Carbon Dioxide Gas, Diatomite	Diatomite occurs in the Rift Valley Basin
Machakos	Gypsum, Pozzolana	
Makueni	Vermiculite, Gemstones	
Taita-Taveta	Iron Ore, Gemstones, Manganese, Graphite	
Kwale	Gemstones, Heavy Mineral Sands (titanium minerals), Silica Sand, Rare Earth Elements, Niobium	
Kilifi	Titanium Minerals, Manganese, Barytes, Gypsum, Gemstones	

Prospecting activities in the Athi Basin are on-going and include:

- Mineral sands (ilmenite, rutile and zircon). It is known that mineral sands occur in the Mambrui area of Kilifi County and a recent application for a prospecting license has been made by the Valencia Mining Company (Government of Kenya, 2018).
- An application for a prospecting license has been made by Pacific Industrial Energy Limited in the extreme south-western corner of Kwale County for base metals and gemstones (Government of Kenya, 2018).
- The Chivara Community Based Organisation applied for a special licence to prospect for manganese in the western part of Kilifi County (Government of Kenya, 2015a).

Potential future mining activities in the basin include:

- Base Titanium Ltd is expected to continue to prospect for heavy mineral sands in Kwale.
- Cortec Mining Kenya Ltd held a special prospecting license in the Mrima area (Kwale), which was revoked in August 2013 (Yager, 2014). Having the fifth largest known niobium source in the world, it appears likely that this area will eventually be mined, once ownership, land, community and metallurgy issues have been resolved.
- The Coastal strip is underlain by sedimentary rocks of Triassic and Jurassic age, rocks that are potential hydrocarbon reservoirs. Prospecting is on-going, concentrating on offshore resources.
- Horkel et al. (1979) describe a graphite prospect that was considered worth further investigation, at Chawia (Taita Hills). The estimated reserve was 1.2 million tons of ore with a maximum graphite concentration of 13%. This might be developed in the future.
- It is certain that the artisanal to small-scale gemstone sector will grow in those counties where gemstones are found (Taita-Taveta, Kwale and Makueni). The recent rate of national growth of the gemstone sector strongly supports this.

It is thus very important that future water demands for the mining sector are accommodated in water resources planning.

3.2.8.3 Agriculture

The Kenya Vision 2030 identified agriculture as one of the key sectors to deliver the annual economic growth rate of 10% envisaged under the economic pillar. However, there are many issues and challenges related to agriculture in Kenya linked to crop production, climate, water security, markets, finance, trade, institutional setups, land management, soil management and environmental sustainability. To achieve agricultural sector growth, transforming smallholder agriculture from subsistence to an innovative, commercially oriented and modern agricultural sector is critical. This will be supported by appropriate institutional reform in the agricultural sector. Agriculture is the most important sector of the Kenyan economy and agricultural sector growth and development is therefore crucial to Kenya's overall economic and social development.

Only 17% of Kenya's land area is suitable for rain-fed agriculture, with 83% of Kenya being Arid or Semi-Arid Land (ASAL). While most of Kenya's arable land is cultivated for crop production, a very small proportion is irrigated. However, as the cropping and livestock production systems follow the annual rainfall patterns which are highly variable and unreliable, it is well recognised that the country must embrace irrigation development to remain competitive in the global and regional arena. Kenya has not fully developed her irrigation potential. In 2010, about 142 000 ha was under irrigation, with a corresponding total irrigation water demand of 1.6 BCM/a. Most of this is used for private and smallholder irrigation and mostly in the Athi and Tana catchments. Most of the growth in irrigation in recent years is contributed by smallholder and private sector schemes, while no substantial development was achieved in public schemes over the last number of years. Although Kenya has ample land resources available, water resources for irrigation are limited in most basins. Based on high-level water balance calculations undertaken for the NWMP 2030, it was anticipated that water for future irrigation will have to be supplied mainly from surface water, supplemented from groundwater and water harvesting sources and it is evident that significant investments in large dams would be required for storage purposes. Increasing the productivity of agricultural water use in Kenya is a national priority, given the country's low water endowment, growing population, and changing climate. Expanding the use of modern irrigation technology, such as drip and sprinkler systems, will be fundamental to achieving water productivity because of the potential for such systems to increase yields relative to water withdrawals.

The total livestock water requirement in Kenya in 2010 was estimated at 255 MCM/a in the NWMP 2030 and is mainly supplied from surface water. However, this is expected to almost double by 2030. Water harvesting measures such as small dams and/or pans have been identified as the most feasible for supplying this growth in demand, a large portion of which is expected to occur in the ASAL parts of Kenya. In high-rainfall areas there is potential to develop the dairy, poultry and pig industries, whilst in ASALs the availability of natural resources is linked to emerging industries although rangelands are chronically short of pasture and water (Government of Kenya, 2010a).

Aquaculture is an important contributor to Kenya's fisheries sector. Freshwater aquaculture development has grown remarkably, making Kenya one of the fastest-growing major producers in Sub-Saharan Africa (Saunders et al., 2017). Aquaculture production has risen since the late 1990s, with a focus on private, large-scale aquaculture development. However, the aquaculture sector suffers basic challenges such as inadequate knowledge and skills and inadequate supplies of quality feed and seed fish. Small-scale rural enterprises produce mainly Tilapia at a subsistence level. The main large-scale fish farms in the Basin are listed below:

Table 3-6: Large-scale aquaculture in the Athi Basin

Name (Location)	Established	Species	Potential Production	System
Ngomeni Project (Malindi)	1978	Tilapia	25 t/y	Tidal ponds
Kilifi Sisal Estate (Kilifi)	1979	Tilapia	5 t/y	Tank
Baobab Farm (Mombasa)	1971	Tilapia, Prawns	50 t/y	Tanks & Ponds
Ukunda Estate (Ukunda)	1979	Tilapia, Shrimps	5 t/y	Tank
Mbingi Farm (Mombasa)	1982	Tilapia	5 t/y	Pond
Lake Jipe Sisal Estate (Taita)	1948	Tilapia	100 t/y	Pond

The Athi Basin is classified as semi-arid land, except in the upstream area of the Athi River which is classified as humid land (Water Resources Management Authority, 2013b). The mean annual rainfall is thus higher in the upper Athi Basin than the lower plains. Water demands for agriculture in the Basin include irrigation, livestock and fisheries. These demands are projected to increase due to population and economic activities. The total crop area in the Basin in 2011 was 876,544 ha, with the existing irrigation area consisting of 13 524 ha (30%) small-scale schemes and 31 374 (70%) private schemes (Water Resources Management Authority, 2013b). The development schemes proposed by the NWMP 2030 for Athi Basin are discussed in Section 3.1. above.

Various Directorates under the Agriculture, Fisheries and Food Authority (AFFA) provide technical input and advice to County Governments. The Authority also conducts farmers' training programs aimed at increasing their knowledge on production technologies and prospects for various types of crops, through farmer training institutions. Conservation agriculture has been promoted as a sustainable alternative for farmers to address the problem of declining soil fertility and provide the dual benefit of enhanced food production and adaptation/resilience to changing climatic conditions (Agriculture and Food Authority, 2017). Aquaculture has been promoted as a food security intervention at the household level. Counties are being encouraged to increase aquaculture in both marine and inland systems. Improved livestock productivity has been promoted through improving animal breeds, improving feeds regulation, developing pastures and forage and enhancing extension services. Cooperatives have not performed adequately since State withdrawal from their day-to-day operations (Agriculture and Food Authority, 2017), therefore counties are encouraged to revitalise cooperatives and strengthen their capacities to make them competitive. The schemes being promoted by different Counties are discussed in Section 2.4.4 above.

3.2.8.4 Forestry, Land use and Catchment management

Poor land use planning and management have detrimental effects on the water resources of a basin. Human encroachment of riparian land and forest areas, as well as unsustainable agricultural, pastoral and livelihood activities that are incompatible with the capacity of the land are some of the major land use issues in the Athi Basin. The valuation of the forests in the basin and its contribution to the national economy is largely undocumented. From the Aberdares to the Arabuko Sokoke in the Coast, human encroachment, illegal logging, overgrazing, fires, pests and diseases among others are threatening the forest reserves leading to a significant loss of vegetation cover. In 2010, the total forest area in the Athi Basin was about 120 000 ha. However, according to satellite imagery, the forested area had decreased by about 53% since 1990 (Water Resources Management Authority, 2013b). In recognition of the importance of forests for sustainable development, the 2010 Constitution in Article 69 provides for the state to work towards increasing the country's forest cover to 10% of the land area of Kenya (The Constitution of Kenya, 2010). A total area of 870 000 ha of forestation is proposed in the NWMP 2030 for Athi Basin up to 2030.

The National Environmental Management Authority (NEMA) has Environmental Committees who provide technical support for environmental management and provide input to county integrated development plans. The Kenya Water Towers Agency (KWTA) looks after Kenya's water towers. The Forest Management and Conservation division under the Kenya Forest Service (KFS) is charged with the management and conservation of the natural forests in Kenya, of which most form water towers. Strategic outputs involve increasing percentage cover through tree planting and gazetting new forests; as well as improving livelihoods. The KFS Forest Farm and Dryland Forestry program provides technical support to the Counties, advisory services for forest management, promoting biomass energy development and utilization, promote dryland forest conservation and promote participatory forest extension methodologies including farmer field schools.

In the Athi Basin, forest reserves largely cover the areas surrounding the major water towers of the catchment as well as groundwater recharge areas. These reserves include: Aberdares, Kikuyu Escarpment, Muguga, Dagoretti, Ngong Hills, Ololua, Karura, Kinare, Kiambu, Nyamweru, Kieni, Kitondo, Kilungu, Katunga, Machakos Hills, Kitui Hills, Namanga Hill, Chyulu Hills, Taita Hills, Ol Donyo Sabuk, Shimba Hills and Arabuko Sokoke forest reserves. The Kikuyu Escarpment, Chyulu Hills and Ngong Hills forest reserves are important groundwater recharge areas in the catchment.

The upper part of the basin has seen significant vegetation loss between 2001 and 2013 in areas such as the Aberdares, Dagoretti, Ngong Hills, and Namanga Hill forest reserves. Other areas of significant vegetation loss include Ol Donyo Sabuk in Machakos County; and Gonja, Mrima, Jombo, Marenji in Kwale County. A significant decline in the mangrove coastal forest has also been noted. These forests play an important role in the coastal ecosystem and will require unique strategies for restoring forest cover. The forest and land use management schemes being promoted by different Counties are discussed in Section 3.2.5. above.

3.2.8.5 Biodiversity, protected areas and tourism

The Athi Basin is of crucial importance to Kenya's economy as a wildlife habitat, and a tourism/recreation asset. It includes six national parks namely, Tsavo West and East NP, Amboseli NP, Shimba Hills NP, Chyulu hills NP, and Nairobi NP. Between them, these protected areas account for approximately 60% of KWS park entry fees. Furthermore, Mombasa is a well-known international tourist destination, mainly for its beautiful beaches. The Nairobi National Park is also a major tourist attraction, especially due to its close proximity to the city. The Athi Basin has the most developed infrastructure for tourism, including holiday resorts, shopping malls, camping areas and transport infrastructure.

The tourism industry in the Athi Basin is well developed and forms the interface between the Safari circuit and the coastal (beach) tourism sector in Kenya. Due to the increased constraints on the water resources, there will be increased pressure from pastoralists seeking to use grazing and water in areas perceived to be preserves of wildlife and tourism. This can be a recipe for violent resource conflict, as was witnessed in northern Kenya in early 2017. Tourism is a sensitive industry, which is adversely affected by insecurity and even the actions taken to restore security. To preserve this important industry, it is imperative that all stakeholders come together to develop a new approach that ensures its resilience and sustainability vis a vis current reality. To remain competitive, tourism can no longer revolve exclusively around wildlife populations, unless they are endemic species. The current tourist is a sophisticated individual who will be attracted by human factors, such as resilient and functioning ecosystems, rather than exclusion zones, which are anachronisms from the past. An unexploited townsman attraction in Kenya is the interface between wildlife habitats and livestock production. This calls for government policy action to manage rather than eliminate that interface with fences and barriers, which also fragment wildlife habitat. This policy action would be geared towards practicing conservation that is based on an equilibrium between human and wildlife, rather than mutual exclusion.

Aside from the Water Towers and gazetted forests, which are managed by KWTA and KFS respectively, the Parks and Reserves division of the Kenya Wildlife Service (KWS) manages the National Parks, National Reserves, National Sanctuaries, Marine National Parks and Marine National Reserves in the country. KWS is also involved in forest conservation and water towers conservation as well as ratifying the RAMSAR convention. KWS exercises mandates over the Athi River, not just in areas within parks and reserves, but also as the custodians of Kenya's biodiversity, a role they are committed to through the Nagoya Protocol of the Convention of Biological Diversity. Kenya ratified the Protocol in May 2014, which obliges states to develop appropriate domestic measures for effective management of biodiversity in relation to access to genetic resources, benefit-sharing and compliance. Biodiversity in wetlands and sections of the river flowing through protected areas also receive protection by KWS.

The main threats to protected areas in the Athi Basin are increased deforestation and loss of biodiversity. This has been caused by both direct and indirect drivers. The main direct drivers to increased forest degradation and deforestation leading to high biodiversity losses are illegal and legal excision arising mainly from pressure for expansion of agricultural land, urban development and settlements, unsustainable utilisation of forest resources, increasing dependence on wood energy for lighting and domestic consumption especially firewood and charcoal, forest fires, overgrazing and institutional failures. The weak institutions arise from weak governance structures and inadequate capacity for law enforcement, and weak stakeholder participation in forest management and governance. This is exacerbated by inadequate funding of the forestry sector from the exchequer, civil and public sectors.

The Athi Basin ecosystems, as with most river basins in Kenya, do not have specific plans or strategies that target biodiversity and ecosystem conservation. However, efforts made for natural resource management, basin rehabilitation, and integrated water resource management in the basin result in biodiversity conservation. The wetland ecosystems of the Athi Basin are environmentally sensitive areas under threat from human encroachment. Lake Amboseli and its associated wetland areas (Enkongo Narok and Loginye swamps) are located in the Athi Basin near the base of Mt Kilimanjaro. These wetlands are seasonal and are an important source of water for the Amboseli National Park. There are also two international lakes in the Athi Basin which straddle the Kenya-Tanzania border, namely Lake Jipe (in the Lumi River system) and Lake Chala (a crater lake). The National Environment Management Authority (NEMA) raised great concern for the degradation of wetlands in Kenya, and in 2011 NEMA enforced regulations to improve and conserve these ecologically sensitive areas.

The protection of biodiversity schemes being promoted by different Counties are discussed in Section 3.2.5. above.

04

Image source: Aurecon, 2018. Ruiru Dam

Key Issues, Challenges and Trends

4 Key Issues, Challenges and Trends

4.1 Introduction

The water resources of Kenya are currently threatened by many issues. These include catchment degradation, pollution, inadequate monitoring networks, inadequate integrated basin planning and management, water availability and supply issues, inadequate capacity (number of staff, skills, equipment and finances), uneven spatial and temporal distribution of water resources, anthropogenic encroachment on environmentally sensitive areas, inadequate flood and drought management and various other issues. In addition to the above issues, the Athi Basin has location-specific challenges and issues which, coupled with its unique basin characteristics, are an important consideration for effective water resources management and planning at basin and sub-basin level.

Main concerns are detailed in this Section and substantiated with further research. The information presented in this Section also informed the evaluation of scenarios (Section 5) and the development of plans for key strategic areas (Section 6).

4.2 Stakeholder engagement

The specific issues for the Athi Basin were identified and prioritised during a two-day workshop with key stakeholders. Figure 4-1 illustrates the key issues and associated frequency of occurrence within the Basin as identified during the workshop sessions. The colours on the map relate to types of issues, while the numbers relate to sub-issues raised during the workshops and recorded in feedback tables.

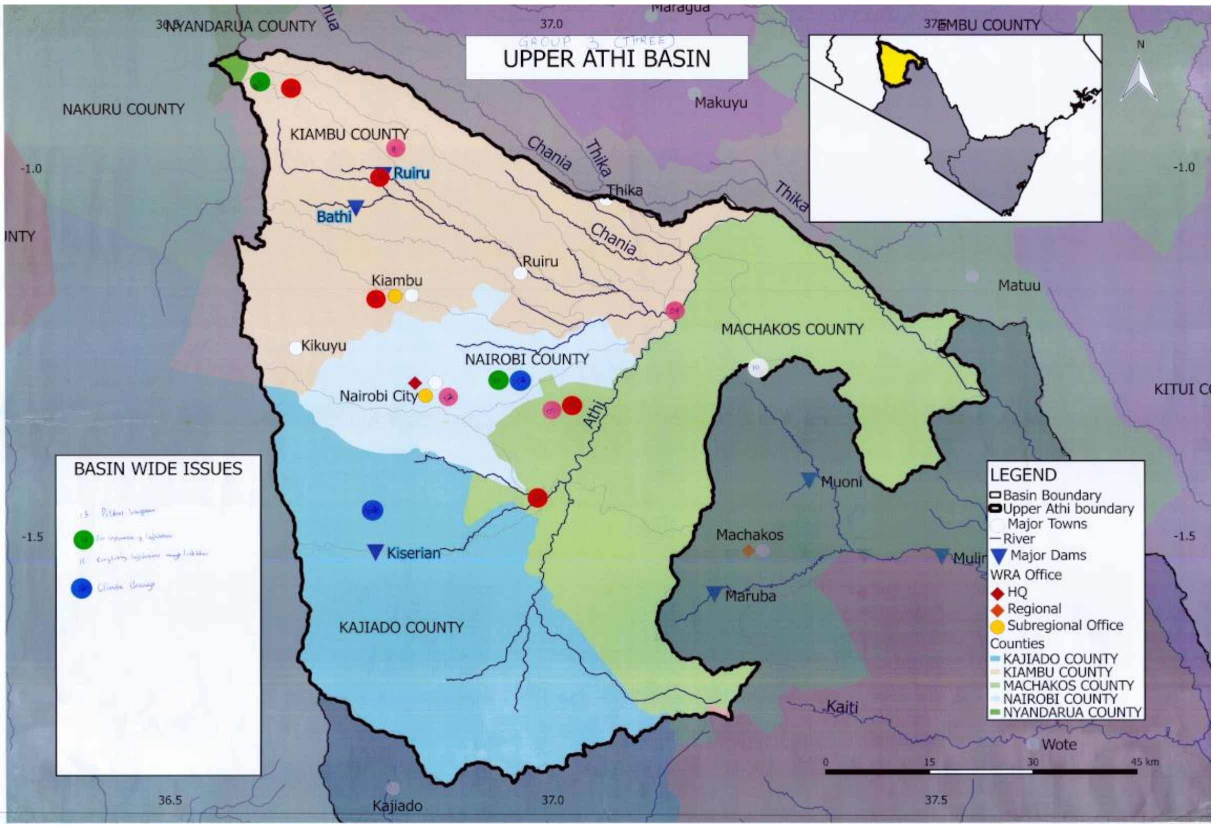


Figure 4-1: Example of an outputs map for the upper Athi from the workshop

Issues were identified under the following main categories:

- Biophysical issues
- Socio-economic issues
- Water resources issues
- Institutional issues

Figure 4-2 illustrates the relative frequency of occurrence within the Athi Basin under the above categories

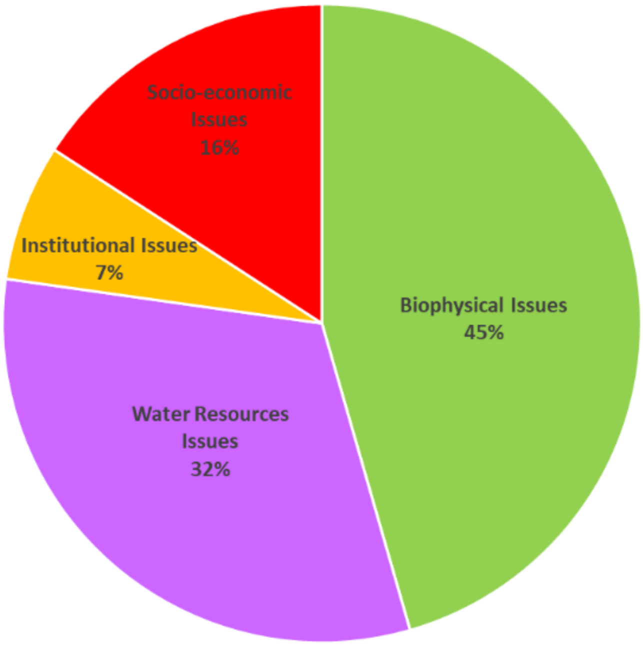


Figure 4-2: Frequency of identified key issues in the Athi Basin

The remainder of this Section presents and addresses the issues identified during the workshop based on the categories and sub-categories framework as depicted in Figure 4-3.

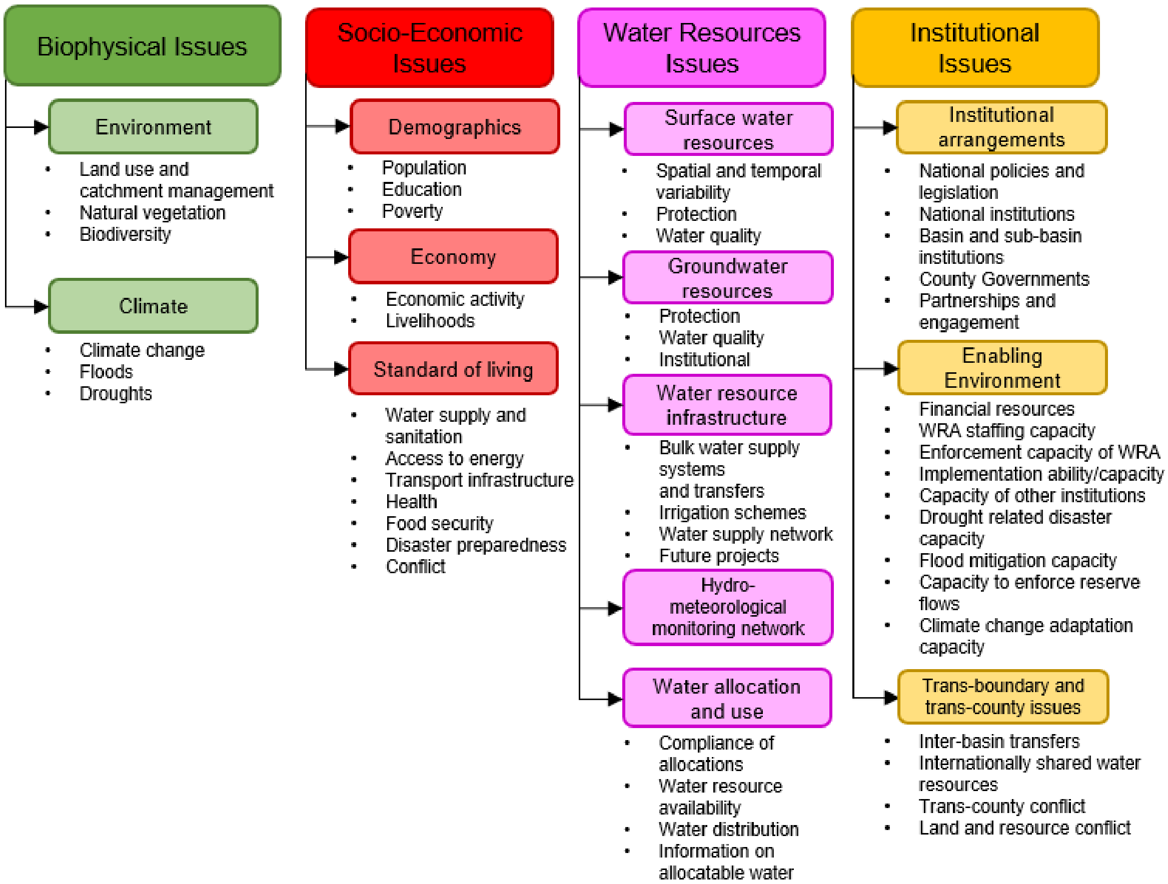


Figure 4-3: Key issues framework

4.3 Biophysical issues

According to the Worksop 1 results, the main biophysical issues in the Athi Basin are poor land use and catchment management. Floods and droughts are more significant in the Middle Athi.

4.3.1 Environment

4.3.1.1 Land use and catchment management

Land is the most important resource in agricultural production, but limited availability of productive land is a major constraint to the Vision 2030 strategy of a 10% annual economic growth rate. The current strategy is to expand agriculture through increasing productivity, changing land-use, improving access to markets and value addition (Government of Kenya, 2007a). About 16% of Kenya's land is potentially arable. This is dominated by commercial agriculture (cropland 31%, grazing land 30% and forests 22%), urban centres, game parks, markets, homesteads and infrastructure (Government of Kenya, 2010a). The remaining 84% of Kenya's land that is non-arable is arid or semi-arid land (ASAL), which are mainly used as rangelands by ranchers, agropastoralists and pastoralists.

Land management is critical to the social and economic pillars of national development, but land degradation can erode these pillars and lead to chronic poverty for those that are closely linked to natural resource use. Poor land use planning and management can also have detrimental effects on the water resources of a basin. Human encroachment of riparian areas, springs, wetlands and forest areas, as well as unsustainable agricultural, pastoral and livelihood activities that are incompatible with the capacity of the land are some of the major land use issues in the Athi Basin.

Agricultural systems can either be rainfed or irrigated agriculture. Most of Kenya is dependent on rainfed agriculture, with the performance being dependent on the agro-climatic zones. In the humid, high-altitude areas such as the Upper Athi predictability of a good crop is high (Government of Kenya, 2010a). However, the population density has increases and land has been subdivided to a degree that it has become uneconomical for farm enterprises. In the medium altitude and moderate-rainfall areas, arable rainfed farming is moderately suitable however, there is a high risk of crop failure due to droughts. The ASAL areas have frequent droughts and the land is most suitable to pastoralism and ranching. While there is ample land, farmers tend to grow crops that are unsuitable for the rainfall regime or soils (Government of Kenya, 2010a).

According to the Athi Catchment Management Strategy (Water Resources Management Authority, 2015b) if good and sustainable farming practices are carried out in the cropland areas, there could be a huge potential to reduce on-farm soil erosion and sources of fertilizer pollution. Rangelands, especially in the Middle Athi and Nolturesh Lumi sub-regions, are also increasingly being converted to agro-pastoralism and urbanisation with a consequent loss in vegetation cover. Unsustainable farming practices have been widely reported, implying that most cropland areas are not properly managed.

Unsustainable agricultural practices and expansion

The predominant agriculture in Athi Basin is small-scale rain-fed farming in high potential areas. With an increased population in these areas there has been an expansion of agriculture into sensitive ecosystems such as riparian areas, estuaries and wetlands. Unsustainable agricultural practises have resulted in land degradation including soil erosion, soil infertility, increased water losses and thus poor crop yields.

Examples of unsustainable agricultural/pastoral practices and expansion:

- Poor farming management leading to pollution in Kiambu county (County Government of Kiambu, 2018). There is also overgrazing and farming on steep slopes leading to soil erosion. This is also an issue in Kwale and Makueni counties (Workshop output)
- Poor farming management contributing to degradation of Athi River in Kajiado county (County Government of Kiambu, 2018)
- Cultivation of hill slopes in Taita Taveta county has increased risks of landslides (County Government of Taita Taveta, 2018). This is also an issue in Machakos and Kiambu county (Workshop output).
- The Sabaki River, which is the estuarine part of the Athi River, is an Important Bird Area and harbours rich fish diversity. It is however under great environmental pressure from upstream pollution and increased siltation due to catchment degradation. The National Environment Management Authority (NEMA) has initiated plans to promote sustainable development of the Sabaki Estuary. Recently, the Coastal Development Authority and NEMA have launched an Integrated Coastal Zone Management Action Plan and Shoreline Management Strategy, which have identified the need to address the environmental issues facing the Sabaki Estuary.

Unsustainable sand harvesting

Sand is harvested mainly for commercial purposes and is a major source of income and livelihood. Sand harvesting is considered detrimental when operated without environmental considerations. Sand harvesting sites require an environmental management plan (EMP) to guide the rehabilitation of the site (National Sand Harvesting Guidelines, 2007). Sand harvesting can take the form of on-farm harvesting, seashore/lakeshore harvesting and river bed harvesting. Sand harvesting may not be conducted on river banks due to the significant soil erosion risks, and catchment degradation risks associated.

The greater Nairobi area is currently undergoing a construction boom and 100% of the sand is being harvested from the Athi Basin. In savannah areas and non-protected wildlife habitats, riparian zones are crucial wildlife habitats due to the cover they provide. Environmental regulations should therefore stipulate the locations where sand can be sustainably harvested as part of the environmental impact assessment for any construction project.

Example of unsustainable sand harvesting:

- Rivers with sand mining:
  - Olkeriai River and tributaries have degradation due to sand harvesting (County Government of Kiambu, 2018)
  - Voi, Lumi, Galana, Tsavo Rivers have sand harvesting (County Government of Taita Taveta, 2018)
  - Mwache River basin, where rampant sand harvesting occurs along the riverbed, especially in the dry season (Workshop output)
  - Banks of rivers which are mined for sand include Voi, Kajiado, Muoni, Kaiti and Thwake (Workshop output)
- Counties with sand mining issues:
  - Makueni county has issues with sand harvesting (County Government of Makueni, 2018). Communities have been pushed to look for alternative livelihood activities such as sand harvesting during periods of drought. This has led to erosion of river banks.
  - Machakos County is the main supplier of sand and the area is also mined for minerals used to make cement. Banks of rivers which are mined for sand include Voi, Kajiado, Muoni, Kaiti and Thwake (County Government of Machakos, 2018).
  - Other areas where sand mining occurs include Mazeras, Mkurumudzi, Guranze and Timboni (Workshop output).
  - The harvesting of sea sand in Kwale County by China Roads and Bridge Corporation (CRBC) for the construction of the Standard Gauge Railway was stopped by the National Environmental Tribunal (NET) in January/February 2016. Environmental experts raised the concern of destruction of the reefs as well as the beaches as a result of the sand harvesting. In October 2014, the CRBC was seen dredging near Tiwi River in Diani. Locals raised the initial appeal for concern of past experiences reoccurring – reefs destroyed from sand deposit, fish dying, and as a result, fishermen left jobless and an impacted tourism industry (Environmental Justice Atlas, 2017).

Unsustainable mining

Mining and collection of stones and other minerals is carried out and sold for commercial value and as building materials. Quarry sites require an environmental management plan (EMP) to guide the rehabilitation of the site, although small scale mines have not been adhering to this legislation. Small scale mining has adverse environmental impacts due to the limited rehabilitation and planning conducted. Quarrying involves the destruction of vegetation and fauna habitats, soil erosion, dust and noise impacts. Many quarry sites are uncontrolled and have been located haphazardly without proper planning. When quarry sites are located near a river they may lead to water pollution through oil or petroleum spills, sedimentation and other waste products.

Example of unsustainable mining:

- Uncontrolled quarrying activities in Juja have led to land degradation and impacts to Ndarugu River (County Government of Kiambu, 2018)
- Machakos County is mined for minerals used to make cement (Workshop output) with impacts to Thwake River.
- There is rampant stone harvesting without rehabilitation in Taita Taveta which has resulted in landslides and erosion (i.e. Mwakingali in Voi there have been rocks falling into houses) (County Government of Taita Taveta, 2018).
- Quarrying in Kilifi South/North, Ganze, Rabai and Magarii (County Government of Kiambu, 2018)

Land use change

Land in the ASALs are considered to be under-exploited for agricultural production and is being promoted as an area for land-use change from rangeland to cultivation through irrigation (Government of Kenya, 2010a). This may be a long-term strategy, but small-scale farmers are already implementing similar strategies, although cultivation may not be appropriate in most ASAL areas with limited rainfall and poor soil conditions. The change in land use can have several effects, depending on the type of change that occurs. Farmers turning rangeland to farmland may result in increased soil erosion once the land is cultivated as well as the introduction of fertilisers and pesticides into the soil, which may seep into nearby water sources. Rangeland may also be turned to settlements, which may increase surface runoff due to the change in land cover. Agricultural areas, specifically tea and coffee, are also being cleared for commercial development and residential areas. Urban areas will produce waste, which may increase pollution if not handled properly.

Examples of land use change:

- In Rombo and Loitokitok, farmers are turning the rangeland to farmland.
- Kitengela is transforming from rangeland to settlements.
- Tatu and Konza City are converting farming land into urban areas.

Fragmentation and urban sprawl

In the high productive land of Athi Basin the population density has increased, and land has been subdivided into such small sizes that it has become uneconomical to farm in some cases (ASDS, 2010). The subdivision of large landholdings into quarter and eighth of an acre pieces is increasing local water demand, (for domestic purposes) without the benefit of increased production.

Urban sprawl is defined as the fast spread of a city or its suburbs and often involves construction of residential and commercial buildings on undeveloped land on the outskirts. Urban sprawl is driven by urbanisation, which increases the demand for housing in the urban and peri-urban areas of Nairobi, Mombasa, Machakos and Kilifi.

4.3.1.2 Natural vegetation

The major contributors to the loss of natural vegetation in the Athi Basin are encroachment and deforestation. The livelihoods of the people are becoming reliant on these acts of encroachment and deforestation, which raises a big concern for the lifespan of the Athi Basin's natural vegetation.

The density of vegetation cover on the land is important, as dense vegetation cover will protect the land from erosion and less dense cover will expose the land to erosion. The occurrence of flooding is also more likely when the natural vegetation is removed. The density of vegetation cover reflects the influence of cropping practices, vegetation canopy and general ground cover. The key drivers of vegetation loss are deforestation for agriculture, charcoal fuel and construction.

Deforestation

In the Athi Basin forest reserves serve as the major water towers for the Basin and groundwater recharge areas (Water Resources Management Authority, 2015b). These forests have been threatened by human encroachment and there is a need to protect them. The total forest area in the Athi Basin in 2010 was about 120 000 ha, and according to satellite imagery, the forested area had decreased by about 53% since 1990 (Water Resources Management Authority, 2013b).

Increasing demand from urban markets drives deforestation for commercial purposes. New and expanding settlements have also led to encroachment as communities use wood for firewood and charcoal. Some communities fell the trees and use the logs and sticks to build their houses. Charcoal burning has become a major economic activity and source of income and livelihood for the local communities.

Examples of deforestation

- The Kinale forest is under great threat from urbanisation and has shown a 3% decrease in forest cover arising from clearing of indigenous forest for large scale plantations since the 1970s. This has resulted in a decrease of base flow.
    - Ngong Hills are under increasing pressure from urbanisation and heavy infrastructure development, leading to reduced cover on the hillslopes. The Kikuyu Escarpment and Ngong Hills are important groundwater recharge areas. These areas have seen significant vegetation loss between 2001 and 2013.
    - Significant vegetation cover has also been lost due to encroachment in the southern part of the Aberdare Range, Dagoretti and Namanga Hill forests.
    - There has been illegal harvesting of forest products and deforestation in Taita Taveta county (County Government of Taita Taveta, 2018). Vast areas of the indigenous forests in Taita Hills were destroyed through deforestation. These forests are important water towers, and not only support the communities downstream, but are also home to historical caves as well as many rare plant and animal species, including the over hundred-year-old ‘mother tree’. The remaining indigenous forests in Taita Hills include Ngangao, Chawiya, Mbololo and Vuria hills.
    - There is deforestation along the Nairobi River banks (County Government of Nairobi, 2017).
    - There is deforestation for fuel and firewood in Machakos county. This has led to soil erosion. The most affected areas are Kibauni forest, Yathui and Muumandu hills (County Government of Machakos, 2018). OlDonyo Sabuk in Machakos County has had significant vegetation cover decline.
    - Oldepe, Oltepesi, Toresei, Mailua, Meto, Illmarba, Ilpatimaro, Lomgosua have been degraded through illegal logging and charcoal burning (Kajiado CIDP, 2018). Flash floods are an issue in the county during long rains mainly due to soil erosion and a lack of vegetation cover (County Government of Kiambu, 2018).
- In Makueni county drought pushes communities to look for alternative livelihood activities such as charcoal burning (County Government of Makueni, 2018).
- In Kwale county there has been deforestation and cutting down of mangrove trees (County Government of Kwale, 2013).
- In Kilifi county there has been deforestation in Dakatcha, Galana Ranch, Mwangea Hills, Jorore, Fungo, Rabai, Tsolokero kayas (County Government of Kiambu, 2018).

As an industry the forestry sector provides timber, poles and fuel wood. The demand for these products has grown faster than supply, resulting in an increase in net imports (Kenya Forest Service, 2015). Farmers are increasingly practicing agroforestry through the introduction of trees to meet their wood requirements, increase productivity and livelihoods. The KFS plays a role in training farmers on tree management, harvesting and management and county governments encourage agroforestry for development.

Examples of forest conservation efforts:

- The upper catchments of the Athi River, found within the forested zones, have benefited from diverse forest and water catchment efforts through KFS. A good example is the Ngong and Dagoreti forests that are managed by KFS and provide habitats for diverse fauna and flora. In these areas the Forests Act (No. 7 of 2005), provides KFS with the mandate to conserve, develop and sustainably manage forest resources, which include the river catchment and drainage areas. The Act also allows for sector coordination and guidance including monitoring and evaluation.
- In the Kinale forest the KFS is implementing reforestation initiatives whereby cypress trees are planted to replace natural trees that have been removed. This is not considered to be replacing the natural vegetation and may result in an issue of erosion, vegetation loss and water availability limitations.
- The 'shamba' system is a CFA initiative where the community can do subsistence farming between the trees, while they are still saplings. Some members of the community take advantage of the system and uproot the trees so that they are unable to grow, allowing the people to continue farming.
- Some conservation efforts are on-going through collaborative partnership in fencing off the hot spots in the Chyulu, Shimba and the Aberdares. More however needs to be done through enhanced partnership and engagement of key stakeholders. In addition, there is need to undertake a comprehensive mapping and evaluation of the forests/hills in the basin and promote them as natural capital assets critical for the sustainable economic development of the area and overall.
- In Kiambu county tree planting is being promoted by the county as a soil erosion mitigation strategy. Industry woodlots are also promoted as an alternative to natural forests.
- In Taita Taveta county the introduction of eucalyptus trees for catchment restoration has been counterproductive as they require a lot of water for growth (County Government of Taita Taveta, 2018).

Encroachment of aquatic land

Wetlands in Athi Basin are being encroached for farming, residential or commercial development. This causes an issue for downstream water resources as upstream wetlands are an important part of the hydrological system. NEMA raised great concern for the degradation of wetlands in Kenya and in 2011 enforced regulations to improve and conserve these ecologically sensitive areas.

Examples of encroachment of aquatic land (wetlands):

- In Nairobi, wetlands and riparian zones are rapidly being reclaimed for residential and commercial development (Water Resources Management Authority, 2015b).
- There is also encroachment on Manguo Swamp and Ondiri Swamp which provide important services for downstream river/groundwater systems (Water Resources Management Authority, 2015b).
- Cultivation activities are occurring in the wetland area upstream of Ruiru Dam. The remaining riparian buffer around Ruiru Dam has reduced to less than ten metres in some areas. One of the reasons for encroachment into riparian areas is that these areas are not demarcated, which makes it difficult to protect and manage.
- The Mangeri Swamp as well as other seasonal wetlands are under threat of encroachment into the riparian area.
- Amboseli National Park, and associated seasonal wetlands, form an important habitat for a variety of large mammals, which also stimulates the tourism industry in the region. The vegetation in the Park has changed from dense woodlands covering 30% of the Park in the 1950s to more scrub and grassland in the 2000s. The Kimana Swamp, east of the Park, is also under threat of land use change to agriculture

- Other riparian areas which have been encroached include those of Nairobi, Ngong, Mathare, Kiu and Athi rivers as well as Bathi Dam and Kiserian Dam.
- The lower reaches of the Athi and Ramisi rivers are under threat of encroachment into the riparian area.

Invasive alien species

As a result of increased forest degradation, there has been increased incidences of invasive species in the various forest ecosystems in the basin the most common being *Prosopis juliflora, Psidium quajava, Opuntia ficus indica* and *Lantana camara*. The invasive species affect the integrity of the forest ecosystem and greatly undermine the realisation of sustainable management of the forests and other natural resources in the basin including water.

4.3.1.3 Biodiversity

Along with the loss of natural vegetation, human encroachment is resulting in the loss of biodiversity due to habitat loss. Pollution is also contributing to water quality issues. The management of environmental flows in also inadequate. The issues of biodiversity loss are addressed below.

Threatened ecosystems

The Athi Basin has many important ecosystems which are being threatened by human encroachment and pollution. The KFS and KWS are responsible for the protected areas in the Basin, but there are various sensitive ecosystems outside of protected areas.

Examples of threatened ecosystems:

- The upper Athi Basin is influenced by the untreated effluent from industries, particularly in Nairobi City, and informal settlements which lack proper sanitation facilities (Water Resources Management Authority, 2015b) . Nairobi River receives huge volumes of raw sewer effluents, solid waste and industrial discharge (County Government of Nairobi, 2017). In addition, use of excess fertilizers and herbicides lead to nutrients polluting rivers and promoting he growth of invasive aquatic weeds (i.e. water hyacinth in Nairobi Dam) (Water Resources Management Authority, 2015b).
- Lake Jipe, Lake Chala and the Amboseli National Parks are threatened by human encroachment.
- In Lake Jipe, salinity has been increasing, while its depth and biodiversity have been decreasing, and hippopotamus and crocodiles have migrated upstream due to salinity. The lake also houses *Oreochromis jipe*, a fish species on the verge of extinction.
- The Karura and Ngong Road forests and the Nairobi Arboretum in Nairobi County are inadequately conserved due to human encroachment from the fast-growing population. There is urgent need to preserve and conserve these threatened ecosystems, as they play important aquatic ecological functions as well as act as natural water purification media.
- Fourteen Falls, a waterfall located on the Athi River in Thika, was once a major tourist attraction, but due to pollution from upstream towns, the water quality has degraded drastically. As a result, the biodiversity of the ecosystem has been impacted. Fourteen Falls is an example of a threatened ecosystem due to a water quality issue caused by pollution, resulting in a socio-economic issue of loss of revenue within the tourism industry.

Inadequate reserve flow requirements

Reserve flows are currently determined using the 95th percentile of the naturalised present daily flow duration curve. This method, which is known as a hydrological index method, has many shortcomings and should ideally be replaced with more comprehensive reserve determination methods which promote variable environmental flow regimes. Although WRA are putting in efforts to monitor and enforce the reserve, there are serious challenges in this regard.

Wildlife impacts

Infrastructure and irrigation schemes which impact wildlife migration routes or water supply will increase human-wildlife conflict.

Examples of wildlife impacts:

- The Galana Kulalu irrigation scheme, which plans to turn hundreds of thousands of acres of wildlife and livestock grazing areas into maize farms while also straining available water resources. This is likely to increase human-wildlife conflict while compromising livelihood security of pastoralist communities.
- The standard gauge railway project through the Tsavo and Nairobi national parks has cut across wildlife migration routes and marred the landscape with its large structures thus reducing the quality of the tourism product. The scale of the construction has been devastating to the Nairobi national park and added pressure to wildlife populations already threatened by the city's urban sprawl.
- The planned Konza Technopolis is located in a prime wildlife dispersal area, which does not have any available surface water. In addition to a supply from Thwake Multipurpose Dam, the city is likely to use boreholes, applying further pressure on the groundwater resources in the Athi-Kapiti plains.

4.3.2 Climate

4.3.2.1 Climate change

Key issues related to climate change are as follows:

Increasing intensity of extreme events

An increase in the intensity of extreme events may result in the event of a combination, or all, of the following scenarios:

- Increased intensity of rainfall
- Increased frequency of floods
- Prolonged droughts
- Increased frequency of droughts

As a result, the issues associated with each of these scenarios may be heightened.

Increasing temperature and evaporation rates

An increasing temperature predicted for Kenya may result in an increase in evaporation rates and general harsher weather conditions. Water quantity will be affected as a result, as well as water quality due to higher temperatures, land use changes, impacts on rivers and lakes, changes to physicochemical parameters, micro-pollutants and biological parameters. Rising temperatures provides environments conducive for malaria vectors to thrive, therefore creating health issues. Average annual temperature in the Athi Basin is expected to rise between 1°C and 5°C, typically 1°C by 2020s and 4°C by 2100 (Water Resources Management Authority, 2015b).

Unpredictable and irregular weather conditions

Kenya's weather patterns have started changing and are becoming more unpredictable. As the majority of farmlands in the Athi Basin are rain-fed, the inconsistent rainfall makes farming difficult. The unpredictability also makes long-term planning difficult and creates uncertainty in prioritisation of short-term adaptation strategies. According to the CMS (Water Resources Management Authority, 2015b) the climate in the Athi Basin is likely to become wetter in both rainy seasons, but particularly in the Short Rains (October to December). Rainfall seasonality is likely to remain the same although there will be more intense rainfall in the short rains, with likely acceleration in soil erosion following a dry spell.

Increased frequency of droughts

An increased severity of droughts that is expected in the Athi Basin (Water Resources Management Authority, 2015b) will increase the issue of water scarcity, food insecurity and inflation. It will also lead to increased malnutrition and loss of lives and an increase in the number of children dropping out of school due to families migrating to better lands.

Sea level rise

According to the National Adaptation Plan (NAP) (Government of Kenya, 2016) there will be a 0.3 m rise in sea level. The coast lines of Kwale, Kilifi and Mombasa counties are susceptible to the impacts of sea level rise, and 4-6 km^2 in Mombasa is likely to be submerged. Areas that become submerged or permanently inundated will become uninhabitable, thus leading to migration, which may cause land conflict. Salinization of fresh water aquifers may occur, affecting the water quality.

Examples of climate change impacts:

- Low agricultural production in Machakos county (County Government of Machakos, 2018).
- Crop failures reported at 90% during the 2009 drought in Kajiado County, whilst livestock loss was at 70% (County Government of Kiambu, 2018). Local pastoral communities adjust to climate change through maintaining mobility.
- Taita Taveta county has had reduced rainy seasons and delayed onset of the rains. This has impacted farmers who have experienced reduced yields, leading to food insecurity in the county. Shifting seasons have affected crop performance and increased incidence of drought has reduced pasture. Health facilities are also burdened with increasing cases of malaria.
- Kilifi county has had considerable changes in rainfall patterns, particularly on the onset. This has impacted crop yields, livestock production, water sources and forest resources (County Government of Kiambu, 2018).
- Mombasa county has experienced frequent flooding, high incidence of crop failure and on average temperature rising above normal (County Government of Mombasa, 2018).

4.3.2.2 Floods

Floods and droughts are not uncommon in the Athi Basin; however, the relative extremes of these events in the basin are generally less than floods and droughts experienced in other basins within Kenya. Floods occur almost annually in the coastal region of the Athi Basin, affecting areas within Kilifi, Kwale and Mombasa. Flooding in the Lumi River frequently affects villages in Taita Taveta County. The cities of Nairobi and Mombasa also experience regular urban flooding during the rainy seasons, exacerbated by inadequate stormwater drainage systems. Major flood-prone areas in the Athi Basin include the lower Athi River, lower Lumi River, Kwale County (especially the lower Umba River), Nairobi City and Mombasa City. Outside of these flood-prone areas, the extent of flooding is relatively small. However, it is expected that flooding risks will increase in the catchment due to urbanisation and the effects of climate change. The main types of flood damage are the destruction of houses, agricultural product and livestock loss, contamination of water resources, worsening sanitary conditions and muddy road conditions. Flooding also negatively impacts development within the basin as issues of flood management are often the priority issue identified during sub-catchment management planning.

Figure 4-4: Urban flooding in Nairobi (The Associated Press, 2018)

An Integrated Flood Management Plan (IFMP) was developed for the Lumi River Basin in 2013 (Water Resources Management Authority, 2013a). More information regarding the Lumi IFMP is provided in Section 6.7 of this Plan.

Floods have various impacts ranging from direct impacts to people, to indirect impacts to the economy. Floods can also cause transboundary conflict and damage to infrastructure. The following sections provide examples of the issues caused by the inadequate preparedness for floods in the Athi basin.

People affected by floods

People near rivers are vulnerable to the impacts of floods. Communities living within floodplains is a major issue as they have been established in areas which are not safe to inhabit and relocating them has many issues and is often not regarded as an option. Pit latrines are easily destroyed or washed away, resulting in sanitation issues as well as waterborne diseases. Floods also cause erosion and sedimentation.

Examples of people affected by floods:

- Frequent flooding occurs along the Lumi River, especially in the small villages downstream of the Taveta urban area.
- The downstream areas of the Athi River (Lower Sabaki) also experience frequent flooding, causing inundation of small-scale migratory settlements.
- The coastal areas of the Athi Basin suffer flood damages nearly every year during heavy rains. The floods of September 1997 caused 86 recorded deaths and displaced 900 000 people in Kilifi, Mombasa and Kwale.
- Populated flood risk areas include Kibwezi East, Kikandu village, Kilome, Sultan Hamud (Makueni); Lumi River floods in Kimorigo, Rekeke, Kitobo, Lambo, Ngutini, Marodo/Maseketeni, Shauri Moyo villages, Kimungu (Taita Taveta); River Galana/Sabaki in Malindi and Magarini sub-counties (Kilifi); flooding from Mount Kilimanjaro affecting people in Kimana and Rombo (Kajiado); Nairobi City (Nairobi) and Mombasa (Mombasa)

Economic impacts of floods

The agricultural sector and individual farmers can experience major setbacks due to floods. Crops can be destroyed, or the growth stunted through inundation or leaching. Irrigation equipment can also be damaged in a flood. As a result, the farmers and agricultural sector experiences a loss of income with reduced crop yields, additional expenses to repair equipment and possible re-cultivation of the land. Floods can cause livestock diseases and deaths, which result in livestock farmers incurring profit losses. In the urban centres, flooding not only causes physical damage to businesses, but losses may be incurred due to loss of manpower and reduced efficiency when employees are unable to commute to work as well as the inability to perform certain activities resulting from shutdowns.

Examples of economic impacts of floods:

- Floods, which have impacted farmlands occur in Kibwezi East and Kilome (Makueni County); Taveta (Taita Taveta) and along the Galana\Sabaki River in Malindi and Magarini sub-counties (Kilifi).
- Floods impacting livestock farmers often occur in Taveta sub-county.
- The large cities of Nairobi and Mombasa suffer from urban flooding due to inadequate and ineffective urban storm drainage systems.

Transboundary conflict

Certain floods in the Athi Basin have resulted in transboundary conflict due to rivers originating from a certain basin floods in a neighbouring basin – in this case, the basins are located in two different countries.

Examples of transboundary conflict:

The issue of flooding of the Umba River in Kwale County has challenges due to the river originating from Tanzania.

Damage to infrastructure

Floods can cause major damage to infrastructure depending on the severity of the flood. In the Athi Basin, bridges have been washed away, roads became inaccessible due to mudslides/soil erosion and buildings have collapsed. Various small dams have also been washed away. Various areas have experienced damage to infrastructure as a result of floods and bridges and roads as well as buildings are often damaged during flooding.

4.3.2.3 Droughts

The middle and lower regions of the Athi Basin are susceptible to droughts during periods of low rainfall. Droughts in the Athi Basin are not as severe as in other parts of the country. However, parts of Kilifi, Makueni, Machakos, Kwale, Kajiado, Kitui and Taita Taveta do experience droughts during periods of low rainfall, which are sometimes only 10% to 20% of normal rains.

Droughts have various impacts ranging from direct impacts to people, to indirect impacts to the economy. The following sections provide examples of the issues caused by the inadequate preparedness for droughts in the Athi Basin.

People affected by droughts

People are affected by droughts directly through reduced water availability, and indirectly through reduced crop yields and water quality issues. Droughts reduce surface water availability but may also reduce recharge rates for groundwater. This is an issue in Athi Basin as a large portion of the population are reliant on groundwater.

Droughts increase food insecurity due to poor crop growth or lower crop yields and a decrease in milk production. As a result of lower crop yields, crop prices increase, which reduces the household purchasing power. Water scarcity increases, which decreases water supply and the communities who collect water from a water source may need to travel further.

Water quality issues increase during droughts, which increases the number of health issues of the population. The environment and living standards during a drought increase people's susceptibility to diseases.

> **Example of people affected by droughts**:
>
> Cholera outbreak in Kilifi in August 2017.

Economic impacts of droughts

The agricultural and livestock sectors experience major losses due to droughts. Due to a large amount of the farmlands in the Athi Basin being rain-fed agriculture, droughts result in low crop yields. Although crop prices increase to counter the lower crop yields, the agricultural sector usually experiences a reduction in sales. The livestock sector experiences several issues as a result of droughts. The lack of water for cattle results in decreased milk production. Water scarcity also contributes to livestock diseases and deaths. There is concern that pastoralists and crop farmers may desert the agricultural sector in the hope of finding new work opportunities in the urban centres.

> **Example of economic impacts of droughts:**
>
> - The NWMP 2030 states that the drought which occurred in January 2011 occurred due to the areas of Taita Taveta and Malindi only receiving 10% to 20% of normal rains. This drought not only resulted in decreased agricultural production, but also caused an outbreak of livestock disease as a result of deterioration in water quality.
> - Pastoralists are often forced to migrate in search of water for their livestock. Droughts impacting livestock farmers frequently occur in Magadi, Mbirikani, Emukutano, Poka, Mosiro, Ewuaso, Meto and Dalalekutuk (Kajiado).

Conflict due to droughts

Droughts result in scarcity of water for both wildlife and people. This gives rise to conflicts between various groups. Conflict arises between locals and pastoralists when the migration of the pastoralists' livestock increases competition for available resources. The probability of humans coming into contact with wildlife also increases during droughts as both humans and animals are in search of food and water. Drought is the cause of many trans-county conflicts as it worsens water scarcity and thus results in County Government's fighting for water supply for their residents.

> **Examples of conflict due to droughts:**
>
> - Resource-based conflict has occurred in the following areas: Kilifi County: immigration from Tana River County to Ganze and Magarini sub-counties – conflict between local crop farmers and livestock keepers from Tana River County. Makueni County: Mukaa and Makindu (from Kajiado County). Taita Taveta County: Taveta subcounty herders moved to park. Kajiado County: livestock in Rombo migrating to Tsavo West and Tanzania, Kajiado central to Chyulu and Maparasha, Kajiado east to Mashuru, Chyulu and Makueni, Kajiado South to Chyulu, Rombo to Tsavo West and Tanzania.
> - There have been instances in Makueni County where people came into contact with elephants, which came from Chyulu and Tsavo. This occurred in Muuani, Wandei, Yikivuthi, Athi Salama, Utini and Muangeni.
> - This predation of livestock often occurs in Taita Taveta County: Ngolia, Buguta, Kasigau, Maungu, Sagalla, Mbololo, Bura, Chawia, Sasenyi, Makwasinyi, Rukanga, Jora, Kajire, Kishambe, Ndara, Talio, Mazola, Marapu and Zongwani. This also occurs in Kajiado, Machakos and Kilii counties.

4.4 Socio-economic issues

According to Workshop 1 the main socio-economic issues in Athi Basin were transboundary and trans-county conflict and other socio-economic challenges.

Agriculture, as the mainstay of Kenya's economy, is critical to the growth of the national economy. Following independence, the agricultural sector recorded a high growth rate and during this time small-scale agriculture grew rapidly as land and technology was made available (Government of Kenya, 2010a). Agricultural extension and research was also well supported by the government. Since then there has been a gradual decline, followed by growth when the Government identified the agriculture sector as a priority. The Economic Recovery Strategy for Wealth and Employment Creation (Government of Kenya, 2003) emphasised economic growth and creation of wealth and employment as a means of eradicating poverty and achieving food security. The development of the agricultural sector was considered a top priority in reducing poverty because it is the most important economic activity for the poor in rural areas. In 2008, Kenya Vision 2030 was launched as the new long-term development blueprint for the country. This plan intends to convert smallholder agriculture from subsistence to an innovative, commercially oriented and modern sector. This has promoted livelihoods through agriculture as an important priority for Kenya.

The Athi Basin is expected to exhibit the highest population growth as well as urbanisation in the country. On average, the basin has the highest levels of education and the least amount of poverty; however, large portions of the population still face a range of socio-economic challenges. The main socio-economic challenges in the basin are described below.

4.4.1 Demographics

The demographic challenges in the Athi Basin include an increasing population in certain areas, the inadequate education and the level of poverty.

4.4.1.1 Population

Increased population growth

The Athi Basin is expected to experience the highest population growth in the country. Although there are high natural growth rates in the basin, the population growth in the basin is dominated by migration. This poses a challenge in terms of managing and servicing the growing population, especially in the growing urban centres.

Urbanisation

With the two largest cities of Kenya occurring in the Athi Basin, urbanisation is rapidly taking place. This means that there will be an increased need for water supply and sanitation systems in urban areas. With an increase in paved areas, the amount of stormwater runoff will increase. Industrial areas increase along with the growth of an urban area, which will result in increased industrial effluent.

Example of population growth and urbanisation issues:

- According to the Socio-Economic Atlas of Kenya (Wiesmann et al., 2016), the highest natural growth (driven by fertility and mortality, excluding migration) will be experienced in the Kajiado, Kwale and Kilifi counties.
- In-migration is high for the cities of Nairobi and Mombasa, with in-migration rates (proportion of in-migrants) of 69% and 58% respectively.
- In Mombasa, there is an influx of people into areas where land and housing is cheap. These are mainly unplanned areas which have deteriorated, or which are without adequate sanitation infrastructure.

- The sewerage infrastructure in Nairobi does not correlate to the current population, which is a major issue as the population growth in Nairobi City is expected to increase.

4.4.1.2 Education

Information sharing

Education and literacy levels impact the ability to share information with the community. This creates challenges when the authorities are required to share information with the public, such as any changes in regulations, water restrictions that are being implemented or even alternative methods of water harvesting.

Inadequate understanding and awareness

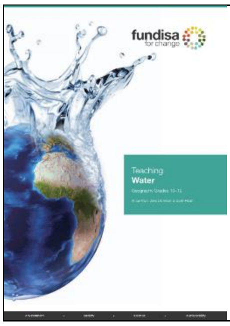
There is inadequate understanding of catchment management and the protection of land and water resources as people think it is normal to live or farm within riparian areas or floodplains. This has resulted in catchment degradation. Improved education will give the opportunity for better understanding of laws and regulations, and implementation and enforcement will also improve. There is inadequate awareness and knowledge within communities on the impacts of climate change as well as adaptation strategies, which can be implemented at household and community level, such as reforestation and rainwater harvesting.

Limited education of water resources from a young age

Understanding brings awareness, which raises the concern of the lack of exposure of school children to water resources and its protection. It will be very beneficial to incorporate water resources management information into the school curriculum.

Examples of education issues:

- Adoption of sustainable agricultural activities, such as conservation agriculture and agroforestry, by small-holder farmers is reliant on extension services supplied by the AFFA and KFS. These extension services need to be strengthened.
- There is a high dropout rate in primary schools during the drought seasons (County Government of Kiambu, 2018).
- Technical and Vocational Training Centres (TVETs) are aimed at equipping trainees with practical skills and entrepreneurial skills to enable opportunities and improve livelihoods. These facilities need to have sustainable water and land management strategies integrated into them.

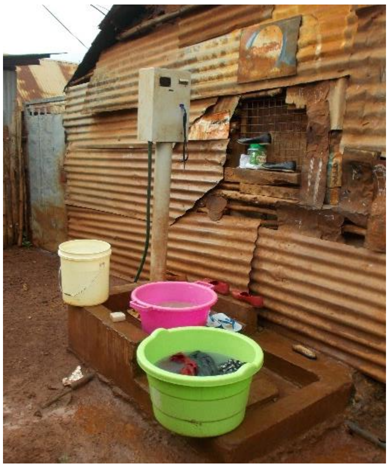


In South Africa a non-profit organisation called Fundisa for change provides teacher training which strengthens the teaching of environmental concepts in schools. The programme involves state, parastatal, NGO and private companies, which have an interest in teacher education. Recently the “Teaching Water” supplementary curriculum has been updated to include practical catchment management concepts and more local references.

4.4.1.3 Poverty

The Constitution of Kenya (2010) is based on the identification of sustainable access to safe water and basic sanitation as a human right and an economic good. Although there are multiple poverty eradication strategies being implemented in the Basin there are still challenges with reaching a large and increasing population, particularly in the urban centres. Athi Basin has a poverty rate of 38%, with

Kwale and Makueni counties having rates above 60% (Wiesmann et al., 2016). The rural population is expected to remain stable, but the urban population is expected to increase by almost 300% by 2050. The challenges with poverty are that it creates a financial handicap, which restricts an individual's financial capacity. This affects the individual's ability to pay for services, making them reliant on incentivised programmes. The challenges faced in the Athi Basin due to poverty are described below.



Subsistence farming

Subsistence farming and natural resource use are the livelihoods of the rural poor. It is often subsistence farmers who encroach on riparian and wetland areas as these areas receive a good amount of water for crops. Encroachment is usually driven by droughts.

Lack of finances

Poverty affects the financial capacity of individuals to pay for services. This means that certain areas of the Athi Basin require free basic water supply and sanitation. This is costly, due to the increasing population in urban areas. The Water Sector Trust Fund provides financial assistance towards capital investment costs in areas lacking adequate services, which are usually inhabited by the poor. The Fund works with WASREB in partnership to encourage utilities to improve services for low-income customers.

Access to water supply

The poor, particularly women and children, spend a significant amount of time fetching water in both urban and rural areas.

4.4.2 Economy

4.4.2.1 Economic activity

As discussed above, agriculture is the mainstay of Kenya's economy but with two major urban centres the Athi Basin is also involved in various other important economic activities. Economic development has a major influence on the development of water resources. Water scarcity has a direct impact on rain-fed and irrigated agriculture as well as livestock and an indirect impact on food processing industries. The economic activity occurring in the Athi Basin, discussed below, will influence the planning for water resources.

Plans for new city development

With the projected increase in urbanisation in Athi Basin it is important to provide for a growing population in certain areas. Kenya has proposed various new city developments which require adequate water supply and sanitation.

Examples of new city developments:

- One of the large potential developments is the Konza Technopolis, which falls within three counties, namely Machakos and Makueni counties in the Athi Basin and Kajiado County in the Rift Valley Basin. The vision for Konza is to be a mixed-use, high density walkable city which encourages high-value development. The first phase plans include office, university, hospital, school, hotel, retail and residential developments. The city is expected to accommodate 260 000 people in the long-term. The development will include transport, water, energy and communication infrastructure. The currently planned water sources are an allocation from the Thwake Dam (currently under development), on-site groundwater and on-site water reuse facilities.

- Other projects:
  - Expansion of the industrial area of Nairobi City.
  - Tatu City development in Kiambu County.
  - Resort City in Diani, Kwale County.
  - Taveta and Mwatate stadiums in Taita Taveta County.
  - 35 urban centres in Makueni County.
  - Self-sustainable stadium in Shanzu, Mombasa County.

Plans for new transport infrastructure

The Standard Gauge Railway project in Makueni County (County Government of Makueni, 2016) aims to make transport to major markets in Nairobi and Mombasa more efficient, thus positively contributing to the city's economic development. Along with Nairobi City's plan to expand further south, the County plans to introduce a new railway freight station in Embakasi. New transport infrastructure in Mombasa includes a commuter railway, which will provide transport from the mainland to the island and will ease congestion along these routes. There are several proposed projects across the basin which aim to improve the transport infrastructure by upgrading roads and building new bridges and roads (according to various CIDPs). It is important to account for these developments to ensure that the catchment is protected during construction and operation of the new routes.

Agriculture

Access to water for livestock

Livestock plays an important economic and socio-cultural role in Kenya. Both crop farmers and pastoralists keep livestock for food and income generation. Livestock production is constrained by access to water and limitations thereof has influenced conflict amongst pastoralists.

Aquaculture impacts

Aquaculture has been promoted in Kenya as a subsector which can significantly contribute to the national economy by creating employment, earning foreign exchange, reducing poverty and supporting food security (Government of Kenya, 2010a). Through this promotion areas that are unsuitable for crop production such as rivers, wetlands, lakes and swamps are being promoted as areas for aquaculture, which may have a detrimental effect on water resources.

Dwindling coffee sector

Kenya's coffee is mainly sold in the international markets and with the decrease in price, coffee farmers in Kenya have been drastically affected as profits have plummeted. This has resulted in many of the coffee plantations being eradicated and replaced with housing and industrial developments (described above) as well as flower farms. This economic change affects the employment of the coffee industry and may result in people relocating to find work. It may be affecting the migration from the agricultural sector to urban areas.

Flower farming

The flower farming industry in Kenya is increasing. Although historically flower farming has been dominated by large-scale bulk flowers for export to Europe, recently small-scale farmers are changing over to flower farming. The bulk flowers are usually grown in green houses and are run with sophisticated technology to produce optimal yields. Small-scale farmers grow summer flowers for a relatively low initial investment and a high, industry related gain. Machakos, Nairobi, Kiambu and Kajiado counties are registered flower growing areas under the Kenya Flower Council. This change in land use may impact water requirements for Athi Basin.

4.4.2.2 Livelihoods

Crop and livestock disease

Pests and disease cause heavy loss through deaths, reduced productivity and loss of markets for products (Government of Kenya, 2010a). Managing livestock disease requires heavy investment in preparedness, surveillance and controls at entry ports. Lack of appropriate storage and poor handling have resulted in high post-harvest losses. Pesticides and pest control equipment is also expensive for small-scale farmers. County governments have proposed strategies for improved post-harvest storage and handling and improved livestock disease control.

4.4.3 Standard of living

4.4.3.1 Water supply and sanitation

The greatest water security needs in Kenya are for household and agricultural use. A first step in increasing access to potable water is recognising equal rights to water, regardless of ability to pay (UNDP, 2011). The Water Act 2016 devolves water and sanitation services to county governments, who provide services through WSPs. About 63% of the urban population receive piper water provided by the WSPs, whilst 20% are dependent on unimproved sources (i.e. vendors and direct access) and the rest from groundwater sources (Water Resources Management Authority, 2013b). Achieving the goal of increasing access to potable water across the Basin has the following challenges:

Although the Athi Basin is the basin with the highest percentage of piped water connections, only about half of the population has access to piped water from a Water Service Provider (WSP). Water is also supplied directly from groundwater sources, with 22% of the population receiving water directly from springs and boreholes. About a quarter of the population receives water from unimproved water sources (without proper treatment). Formal sewerage systems have been developed in limited parts of the rural areas in the Athi Basin, and the majority of the population (77%) still makes use of septic tanks and pit latrines for sanitation purposes. There is an uneven distribution of water in terms of urban and rural areas, with the former generally having better access to water and sanitation facilities. However, water systems in the urban areas are often degraded and/or inadequate. Water and sanitation issues in informal settlements are prevalent due to inadequate access to safe water, improper drainage systems, and inadequate access roads and social amenities.

4.4.3.2 Access to energy

Access to electricity is an important factor in raising living standards. Electrification can reduce poverty by increasing productivity, employment and time spent in school and reducing environmental degradation (UNDP, 2011). Areas without access to electricity use inefficient fossil fuels as a substitute. Over-exploitation of biomass can cause catchment degradation and requires a large amount of time for fuel gathering. Green technologies are being promoted by Counties and the government has also implemented tariff changes for green energy, but at the local scale communities are still engaging in charcoal and wood burning.

Example of access to energy issues:

- In Nairobi and Mombasa, most households have access to electricity.
- Most households in Kwale, Kilifi, Taita Taveta, Makueni and Machakos counties rely on paraffin for lighting and biofuels (wood, shrubs/grass, dung or charcoal) for cooking.

4.4.3.3 Inadequate transport infrastructure

Inadequate transport infrastructure contributes to food insecurity and limits future opportunities for development. Several roads in the Athi Basin become unusable during the rainy seasons as they become muddy or submerged. Sectors or industries which rely on transport, are therefore limited in their ability to travel to various parts of the basin during the year.

4.4.3.4 Health

It has been estimated, by the Socio-economic Atlas of Kenya (Wiesmann et al., 2016), that approximately 80% of all communicable diseases are water-related and include water-borne diarrhoea, trachoma, cholera, typhoid and bilharzia. As set out previously, it is anticipated that flooding risks would increase in the basin due to urbanisation and the effects of climate change. It is anticipated that the increase in temperatures due to climate change would provide an environment conducive for malaria vectors to thrive. Many of the counties within the Athi Basin have experienced high rates of malaria.

- Kiambu county (County Government of Kiambu, 2018)

  The top cases of morbidity are respiratory disease, skin disease, diarrhoea, urinary tract infection and hypertension.

- Nairobi county (County Government of Nairobi, 2017)

  The top cases for morbidity are respiratory diseases, urinary tract infections, diarrhoea, dental disorders and typhoid fever. Bouts of cholera do occur and occasionally reach epidemic levels.

- Machakos county (County Government of Machakos, 2018)

  The top cases for morbidity are malaria, flu, stomach aches, respiratory infections and diarrhoea.

- Kajiado county (County Government of Kiambu, 2018)

  The top cases for morbidity are respiratory, diarrhoea, skin disease, pneumonia and urinary tract infections.

- Makueni county (County Government of Makueni, 2018)

  The top cases for morbidity are malaria, flu, stomach ache, respiratory and diarrhoea.

- Taita Taveta county (County Government of Taita Taveta, 2018)

  The top cases for morbidity are malaria, respiratory tract infections, skin infections, diarrhoea and pneumonia. Sporadic cases of cholera are reported.

- Kwale county (County Government of Kwale, 2013)

  The top cases for morbidity are malaria, diarrhoea, flu, respiratory and stomach ache.

– Kilifi county (County Government of Kiambu, 2018)

  The top cases for morbidity are respiratory, diarrhoea, skin disease, malaria and pneumonia.

– Mombasa county (County Government of Laikipia, 2018)

  The top cases for morbidity are malaria, flu, stomach aches, respiratory diseases, diarrhoea and cholera.

4.4.3.5 Food security

High population growth and low agricultural productivity in Kenya have led to agricultural production not meeting consumption. Low production is linked to the reliance on rain-fed agriculture, limited access to farming inputs, low uptake of new technology and influence of climate change. Populations in semi-arid counties are already facing food crises due to chronic drought. There are various levels of food insecurity across the Athi Basin. Kwale County has the highest level of food insecurity in the basin, with up to 20% of households having poor or borderline food consumption. This is mainly due to high levels of poverty and very high unemployment rates. Kajiado, Taita Taveta and Machakos counties have up to 15% of households with poor or borderline food consumption, while Nairobi and Makueni counties have less than 10%. Although food insecurity prevalence is higher in the rural areas, the highly-urbanised Nairobi County has many food-insecure households. Some 96 000 households in Nairobi County have unacceptable food consumption. Food insecurity in the urban areas may arise due to the high cost of city living, unhygienic and crowded living conditions, as well as limited coping strategies (limited access to land and inter-generational support networks) (World Food Programme, 2016).

Food security in the counties is summarised according to basic nutrition levels of children. The National stunting level is 26%, wasting at 4%, underweight 11%.

– Kiambu county (County Government of Kiambu, 2018)

  Children under five have stunting levels at 15.7%, wasting at 2.3% and underweight at 5.1%.

– Nairobi county (County Government of Nairobi, 2017)

  Children under five have stunting levels at 17%, wasting at 3% and underweight at 4%.

– Machakos county (County Government of Machakos, 2018)

  Children under five have stunting levels at 27%, wasting at 7% and underweight at 8%.

– Kajiado county (County Government of Kiambu, 2018)

  Children under five have stunting levels at 23.5%, wasting at 10%

– Makueni county (County Government of Makueni, 2018)

  No information

– Taita Taveta county (County Government of Taita Taveta, 2018)

  Children under five have stunting levels at 34%, wasting at 11.2% and underweight at 28.5%.

– Kwale county (County Government of Kwale, 2013)

  Children under five have stunting levels at 35%, wasting at 6% and underweight at 21%.

– Kilifi county (County Government of Kiambu, 2018)

  Children under five have stunting levels at 39%, wasting at 4.7% and underweight at 18.2%.

– Mombasa county (County Government of Laikipia, 2018)

  Children under five have stunting levels at 34%, wasting at 11.2% and underweight at 28.5%.

Food insecurity is most prominent in Kwale County, mainly due to high levels of poverty and very high unemployment rates, followed by Kajiado, Taita Taveta and Machakos counties. The lack of irrigation systems and reliance on rain for crop production is another reason resulting in low crop yields and thus leading to food insecurity. Farmers in Machakos County are abandoning the agricultural industry for a more prosperous career in the commercial sector. These are factors contributing to food insecurity, which are discussed further below:

Rain-fed agriculture

There are no major irrigation schemes in the Athi Basin. While there are small-scale irrigation schemes, a large portion of the agricultural land in the basin is rain-fed agriculture. Most crops are rain fed in Machakos, Kwale and Makueni counties. This means that many of the crops are rain-dependent, leaving the season’s productivity up to chance. This contributes to the basin’s food insecurity. Droughts have a devastating impact on the crop production.

Food price fluctuations

With the crops being vulnerable to the weather conditions, price fluctuations occur depending on the crop yield for the season. When the crop production is low the price rises, while the price falls when the crop yield is high.

High cost of living

Although food insecurity prevalence is higher in the rural areas, the highly-urbanised Nairobi County has many food-insecure households, mainly due to the high cost of city living, unhygienic and crowded living conditions, as well as limited coping strategies (limited access to land and inter-generational support networks). City by-laws in Nairobi County prohibit farming and livestock keeping, giving preference to development of residential and commercial areas.

4.4.3.6 Disaster preparedness

In areas where natural resources are degraded or where no disaster planning has taken place, communities are more vulnerable to the effects of the disasters. Fires can damage and destroy houses, forests, crops and grazing land. Floods can cause personal danger to communities and can also wash away good farming soil if there is no village-level emergency planning in place. Floods can cut off access to clean water supply and contribute to the spread of illnesses such as cholera. In the Athi Basin there is inadequate disaster response and disaster management protocols in place for communities. With the effects of a disaster often being devastating, the inadequate preparedness for these disasters increases and prolongs these effects as the relief work may be delayed in response to the disaster. As a result, the people and the economy are affected more when there is inadequate preparedness to a disaster event. The issues and challenges involved are discussed further below.

Susceptibility to impacts of disasters

There is currently inadequate capacity for community-based disaster management in the scarcely-populated areas. This is a major concern as certain communities are affected by seasonal floods and droughts. The susceptibility of communities to a disaster affects the residents’ standard of living as their houses could get destroyed and the community’s economy will dip. There is also an element of fear involved when a community is aware that it is susceptible to the effects of a disaster, but there is no plan in place for them to protect themselves or their community.

Dependence on charities/NGO's

The Government does not have the funds for disaster relief and rehabilitation to the damages occurred. The Government, and therefore the affected communities, are dependent on funds and aid from charities and organisations.

4.4.3.7 Conflict

Most of conflicts within the Athi Basin fall into one of the following categories:

- Human-wildlife conflicts, principally among communities that live in proximity to wildlife areas such as the national parks.
- Conflicts related to sand harvesting in which commercial extraction of sand, sometimes from sand dams, affects water availability for local residents.
- Water use conflicts in which excessive upstream abstraction denies downstream users access to the water resource.
- Resource use conflicts from pastoralist communities.

4.5 Water resources availability, management and development issues

According to Workshop 1 results there is mainly inadequate infrastructure in the Middle Athi and the largest water quality issues are in the Lower Athi.

4.5.1 Surface water resources

The Athi Basin has the highest water demand in the country, and it is therefore essential to properly manage water quantity and quality in the basin. The quantity of surface water in the Athi Basin is an issue as the resource is not efficiently protected resulting in water shortages and inefficient water use. The quality of surface water is threatened by various types of pollution. The main issues regarding surface water quantity and quality are described below.

4.5.1.1 Spatial and temporal variability

The spatial variability of water resources in Athi Basin influences the availability of water supply. The level of population pressure and water demand is also varied across the Basin.

Water security

The upper region of the Athi Basin has a high demand for water, which surpasses its water supply. The middle region of Athi Basin, including parts of Kajiado, Makueni and Machakos counties, experiences water shortages. This issue is due to the area being arid or semi-arid; and during a drought, the water deficiency worsens. The water demand in the middle Athi region is increasing due to people moving from livestock to agriculture. Many of the rivers in the lower Athi region are seasonal, which results in an inconsistent supply of water. Overall, the coastal region is water deficient and suffers from perennial water shortages.

Water supply access

Access to clean and safe water is the foundation of a community and due to the spatial variability of water resources in the Basin, this varies greatly.

Example of water access issues:

- Kiambu county is endowed with both direct surface and groundwater resources and water supply schemes. The distance covered to gain access to water ranges from less than 1 km to about 2.5 km (County Government of Kiambu, 2018).
- Nairobi county has no main water tower, with most of its supply coming from the Tana Basin. This supply is impacted by droughts and siltation of the reservoirs. There are also boreholes operated by private consumers.

4.5.1.2 Protection

Poor management of Kenya's limited water resources breaches the constitution and urgent measures are required to reverse the trend. Water resource protection issues in Athi Basin are discussed below:

Inefficient water use

The non-revenue water (NRW) is high for several of the WSPs in the basin. The average NRW is about 40% for Nairobi and surrounding satellite towns and about 35% for the Mombasa coastal area (Water Resources Management Authority, 2013b). The use of inefficient irrigation systems is also an issue, and it is estimated that the current irrigation efficiency is about 60% on average in Kenya (Water Resources Management Authority, 2013b).

Inadequate water for development

There is a concern associated with inadequate water resources for proposed projects to be developed. An example is the Galana Kulalu irrigation project, which requires more water than is available.

Inadequate resource quality objectives

The resource quality objectives for the water resources in the Athi Basin are currently inadequate. The resource quality objectives represent the desired status of the water resource, covering all aspects of quantity, quality, timing and aquatic biota. Management decisions should be made such that the condition of the resource is targeting the resource quality objectives. The degradation of the water resources in the Athi Basin due to pollution emanates, among many other things, from inadequate resource quality objectives. However, there are urgent plans to develop guidelines for the establishment of resource quality objectives and River Classification for all the Catchment areas.

4.5.1.3 Water quality

Water quality in the Athi Basin is very poor due to various cases of pollution, including solid waste, sewerage, industrial effluent and non-point sources such as chemicals from the agricultural sector. Sedimentation and stormwater runoff also decrease the quality of water. Socio-economic development coupled with human settlements has led to deposition of garbage, industrial waste, agrochemicals, heavy metal and other pollutants, to the detriment of ecosystems and extinction of aquatic species. The contributors to the decrease in water quality in the Athi Basin are described below.

Dumping of solid waste

The dumping of solid waste contributes to surface water pollution. In the Athi Basin, rubbish can be seen in and around rivers, specifically near informal settlements and in urban areas. There is inadequate rubbish removal companies and citizens are required to pay private companies to remove their waste. As a result, rubbish is often seen on the sides of the roads in the urban areas. This solid waste lands up in the stormwater, which ends up in rivers and dams.

Many residents in Kwale are known to dump their solid waste in the ocean. Dumping of solid waste also occurs in Kabarini and Nguu Tatu.

Sanitation

Many urban centres usually have unplanned slum areas, often with high population densities. Slums lack sewer systems and on-site sanitation is used to dispose of faecal matter. These wastes often find their way into nearby water courses and can contaminate shallow groundwater. This occasionally occurs in Mombasa.

Example of sanitation issues:

- Huruma Village in Nairobi County is an example of an unplanned village, which has a designated area for the pit latrines, located close to Ruaka River. The sewerage contaminates the groundwater which seeps to the watercourse.
- The Kibera slum is located upstream from Nairobi Dam and releases sewerage, solid waste and polluted stormwater into the dam. The effects can be seen in the form of water hyacinth and other weeds on the surface of the dam. During the workshop it was stated that public defecation occurs in Sabaki River near Mwache Dam. Other rivers receiving the effluent from sewerage facilities include Mitheu, Iliyini, Riara, Kiu and Komo rivers. Point sources polluting the Nairobi River include the Dandora and Kariobangi sewerage treatment facilities.

Inadequate sewerage treatment

Similar to the limited connections to proper sewerage systems, there are inadequate wastewater treatment facilities, which makes efforts to alleviate water quality deterioration difficult to implement. The Athi and the Nairobi Rivers are affected by inadequate wastewater treatment and illegal dumping of waste from Nairobi City.

Industrial Effluent

The pollution in the upper Athi River, mainly from Nairobi City, gets transported downstream, impacting the water quality downstream as well.

Example of industrial effluent:

- The main contributors to catchment pollution in the Athi Basin are the major cities of Nairobi, Mombasa, Thika, Kiambu, Makueni and Machakos.

Non-point sources

Non-point sources of pollution include agricultural chemicals (fertilisers and pesticides), unmanaged storm water, soil erosion, overgrazing and infrastructural developments.

Examples of point and non-point source pollution:

- A study by Kithiia 2006 found heavy metals in the water of the upper Athi River catchment, but most of these metals were adsorbed by river sediments and riverine vegetation.
- Ruiru, Ndarugu, Nairobi River and Athi river, in the upper region of the Athi Basin, have indicated high fluoride levels. In May 2015, there was an oil spill in Thange River in Kibwezi East, Makueni County, which caused major health issues.
- Further downstream of the Athi River, the water quality is also poor due to sediment load, domestic waste, industrial waste, pesticides and fertilisers.
- Oil spills are also a source of pollution in the coastal areas.
- The Athi basin is an extremely busy transport corridor for inland products that go across the country and beyond (by road, railway and pipeline systems). Accidental incidents of product spillage are common (such as in in Thange and Kiboko that are situated on the national road between Mombasa and Nairobi), and can lead to water pollution and contamination.

Soils

The river water quality in the southern area of Kwale County is saline due to the underlying rocks.

Sedimentation

Sedimentation negatively affects the water quality of the rivers. Agricultural activities are a major contributor to sediment loads in rivers. Also, stormwater from urban areas gets washed into rivers, carrying the sediments from the roads and pavements. Deforestation is another major contributor to increased sediment loads. It must be noted that the planting of cypress trees as an act of reforestation, an activity occurring in several areas of Kinale Forest, reduces the amount of sediment run-off; however, the land cover is reduced from natural forest to plantation, thereby contributing to sediment transport. Sediment loads are generally higher in the rainy seasons and lower in the dry seasons. The Sabaki River transports a significant amount of sediment, which discharges into the Indian Ocean in the coastal areas of Malindi and Mambrui. As a result of the sediment load, the water quality is reduced, which has impacted the fisheries and tourism sector. The Mwache and Rare Rivers also transport sediment to the coast.

To monitor reservoir performance, some monitoring stations have been proposed immediately upstream to monitor both stream flow and sediment loading.

4.5.2 Groundwater resources

A large portion of the population in the Athi Basin obtain its water supply from groundwater sources, often resulting in over-abstraction of groundwater in the basin. The quality of groundwater is a major concern as the quality is often affected by inadequate sanitation systems or salinization. The main issues regarding groundwater quantity and quality are described below.

4.5.2.1 Protection

Discussions about a policy for groundwater protection were initiated within the WRMA in 2006 (Water Resources Management Authority, 2006); these were considered during the development of the National Groundwater Policy(Ministry of Water and Irrigation, 2013).

The unsustainable use of groundwater is a major concern for the Athi Basin. Groundwater issues have resulted from inadequate groundwater protection, which is discussed further below.

Groundwater protection programs

The National Water Quality Management Strategy (Ministry of Water and Irrigation, 2012): in S. 2.7 (Ground Water Protection), the NWQMS lays out the following “strategic responses”:

- Extraction of groundwater at sustainable rates to avoid seawater intrusion.
- Intensifying groundwater quality monitoring by sinking observation boreholes.
- Establishing a monitoring program for selected production wells to capture any changing trends.
- Requiring all borehole owners to have their water tested periodically as part of the water quality monitoring programme.
- Maintain updated database of borehole data.

It recommended the “Development of Ground Water Protection programs” without defining or describing them. This needs to be refined.

Groundwater recharge areas

Groundwater recharge areas, particularly the Nairobi Aquifer System (NAS), have had encroachment and changing land use. New estimates for groundwater recharge and groundwater potential are available (Water Resources Authority, 2019b). A few models or partial models are available (NAS, Msambweni aquifer; Chyulu Hills aquifer, Baricho palaeochannel aquifer). Elsewhere there are no models. There is a need to select Priority Aquifers for modelling, then prioritise these and develop models; this inevitably requires the establishment of a water resources monitoring network in advance of generating a model, which would involve any or all of the following:

- Climate
- Surface water flows
- GW levels
- GW abstraction
- Water quality (both surface and GW).

A time series of several years is ideally required for the baseline dataset which the model will use for calibration; given the natural climate variability of much of the Basin, it is desirable that both drier and wetter than ‘normal’ years are captured.

Example of groundwater recharge areas issues:

- During a field visit in Nairobi and Kiambu counties, there was evidence of encroachment into groundwater recharge areas, such as Manguo swamp, which lies on the fault line recharging the groundwater source of Kikuyu Springs. Manguo Swamp also receives the effluent from an abattoir, thus polluting the groundwater source of the springs.
- The riparian area of Ondiri Swamp is subject to commercial and small-scale flower farming, which affects the groundwater recharge from the swamp, which also supplies Kikuyu Springs.
- Elsewhere in the basin there are recharge areas that may be under threat, such as the recharge zone to aquifer in the Kilimanjaro aquifer which lies largely in Tanzania.
- The western side of the Chyulu Hills which overlies the Chyulu aquifer (the source of the strategic Mzima Springs) is not protected (The Nature Conservancy, 2018).
- Other vulnerable systems include the Baricho paleochannel aquifer, which is at risk from upstream development (dams and consumptive water use; and irrigation water demand from the Sabaki River for the Galana-Kulalu Project).

Unsustainable groundwater use

Due to inadequate enforcement, groundwater is under major stress as over abstraction of groundwater has been occurring for an extended period. Over-abstraction across the Athi Basin is patchy and restricted to ‘hotspots’:

- In the NAS (not everywhere); the extent of depletion could be mapped reasonably easily. There is some limited scope for Managed Aquifer Recharge (MAR) (National Water Conservation & Pipeline Corporation, 2006; Water Resources Management Authority, 2009) or for substitution of alternative water sources (surface water sources from out of catchment or new dams in-catchment).
- Across much of Mombasa County (where over-abstraction is probably worse than currently understood); there is limited scope for mitigation other than by boosting public water supply, which is acknowledged as falling far short of current demand. Current supply is about 17.0 MCM/yr.; 2015 demand was 56.9 MCM/yr. Local stakeholders estimate that up to 70% of water demand is met from local groundwater sources, with both saltwater intrusion and declining water levels in boreholes and shallow wells reported (The Nature Conservancy, 2018). Wastewater treatment capacity is poor, and coverage is incomplete, so the use of treated wastewater as a MAR water source is not at present a viable option.
- Tiwi aquifer (the central and northern parts are salinizing (Oiro et al., 2018). Infiltration basins between the sea and the wellfield is probably the easiest technical option, but the source of recharge water is uncertain. Recharge water quality will be relatively poor (road runoff; poor solid waste management) and may require treatment prior to recharge.
- Other aquifers are not known. Possibly some Basement aquifers have suffered localised depletion

Coastal aquifers

In the lower catchment, the marine environment is characterised by fragile ecosystems which are sensitive to water resources fluctuations. Thin perched fresh water aquifers are underlain by sea water at shallow depths. Abstraction of these aquifers is limited by salinization occasioned by sea water intrusion consequent from the pumping, and natural discharge from the coast. The coastal aquifers are faced with a myriad of challenges including inadequate information, inadequate monitoring, poor understanding of the dynamics and lack of water supply alternatives. Furthermore, shallow aquifers beneath leaking sewers and from pit latrines in informal settlements are at risk of direct pollution. Finally, open shallow wells exploited by bucket lift are exposed to the atmosphere and the introduction of foreign materials into the wellbore (including dropped and none too clean buckets and jerry cans).

Example of coastal aquifers issues:
A notable example of shallow aquifers beneath leaking sewers are Kisauni; in 2005, most of the pit latrines in Mombasa County were located in low-income residential areas, and a full 55% of the 34,000 pit latrines in the County were located in Kisauni (Munga et al., 2005).

Pollution risks elsewhere

The NAS may be under threat from polluted surface waters; there is no doubt that Nairobi's surface waters are polluted, and there is evidence that recharge may occur via impoundments and floodplains (Oiro et al., 2018). Consequently, uncontrolled release of wastewaters from wastewater treatment plants, significant oil spills, industrial plants and pollution from informal settlements all pose a risk to the NAS. Uncontrolled release of organic wastes from abattoirs into surface waters is a further threat.

Transboundary aquifers

The East African Community Protocol on Environment and Natural Resource Management (East African Community, 2018). Article 13 (Management of Water Resources): "The Partner States shall develop, harmonise and adopt common national policies, laws and programmes relating to the management and sustainable use of water resources" is not yet ratified by Tanzania. The Draft National Policy on Trans-Boundary Waters (Ministry of Water and Irrigation, 2009), provides limited guidance or intent on transboundary GW resources. There are two transboundary aquifers in the Athi Basin and part of a third out of eight across the country (Nijsten et al., 2018):

- AF31 – Coastal Sedimentary Basin/Karoo Sedimentary aquifer system (ILEC et al., 2015); total area 15 000km², shared with Tanzania. Combines the Karoo Suite, Shimba Hills, Kambe Limestone and Shale, and Coastal Sediment aquifers;
- AF32 – Kilimanjaro Aquifer (ILEC et al., 2015); total area 13 000km², shared with Tanzania. The Northern Kilimanjaro aquifer is part of this aquifer system; ILEC includes the Chyulu Hills aquifer within this unit, which is incorrect; it is lithologically and structurally different to the Kilimanjaro aquifer;
- AF72 – Rift Aquifer (ILEC et al., 2015; Nijsten et al., 2018); a total of 19 000km², shared with Tanzania. The extreme eastern edge of this aquifer lies in the Athi Basin; the boundaries of this aquifer system are ill-defined;
- A transboundary aquifer policy needs to be developed; the National GW Policy (Ministry of Water and Irrigation, 2013), lists the following activities required to improve transboundary GW management ("Issue 9"):

Table 4-1: **Proposed transboundary aquifer (TA) policy measures**

Issue	Objective	Policy direction	Activity	Timeframe
Transboundary aquifers not well known, characterised nor managed	TAs well known, characterised and managed by countries sharing TAs	Implement appropriate new policies and institutions to ensure seamless management of TAs	a) Identify and demarcate TAs; b) Collect information; c) Promote information sharing and adopt international good practices; d) Expand transboundary water unit to Department	Short- to long-term

There is also the National Land Use Policy (Ministry of Lands and Physical Planning, 2017), which specifically describes measures to be adopted in relation to the definition and management of transboundary groundwater resources.

4.5.2.2 Water quality

Sewerage and salinization are major contributors to poor groundwater quality in the Athi Basin. There are currently no Groundwater Quality Management Plans for areas with a high level of risk to groundwater quality issues.

Sanitation

Pit latrines are a major contributor to poor groundwater quality as the sewerage from them contaminates shallow groundwater. Pollutants from human wastewater occur in Mombasa, Coastal Strip; and possibly in informal settlements in Nairobi where shallow groundwater is available (uncertain). Pollution by pharmaceuticals is likely but not certain. No evidence of agriculture-sourced diffuse pollution in the humid upper parts of the Basin exists, but this has apparently not been studied. Generally, the extent and significance of GW pollution in the Athi Basin is unknown.

Salinization

Kajiado has high salinity levels in its groundwater. Salt water harvesting in Gongoni affects the groundwater in that area. Saltwater intrusion is widespread along the Athi Basin coastal strip: see Oteri

(1991), Tole (1997), Opiyo-Akech et al. (2000), Munga et al. (2006), Mwaguni et al. (2013), Idowu et al. (2017), Oiro et al. (2018) and Nowicki et al. (2019).

High levels of fluoride

Nitrate levels were found to be high in the groundwater in Kajiado town, especially in the central area, with several samples exceeding the national limit (Oord, 2017).

Kiambu County has a high fluoride content in its groundwater. According to a groundwater quality study in the Upper Athi Basin (Ashun & Bansah, 2017), the groundwater quality of three representative sub-catchments is over the acceptable limit for potable water use mainly due to high concentrations of turbidity, chloride, iron, manganese and nitrate.

High fluoride levels were found in the groundwater in Kilimambogo in Kiambu County, east of Nairobi County. Poor agricultural practices are often the cause of these constituents affecting the groundwater quality.

- Nationwide: Natural contaminants are widespread, e.g. elevated natural nitrate in GWs beneath Wajir; elevated natural sulphate beneath El Wak; elevated iron and manganese in GWs from the Greenstone Belt (Western Kenya). Elevated fluoride concentrations across the country in metamorphic Basement and igneous rocks.
- Athi Basin: Natural contaminants (fluoride, iron, manganese among others). Widespread natural fluoride in the NAS and some other volcanic aquifers (not the Chyulu aquifer); natural Fe and Mn in much of the Basement and in the Mazeras Sandstone. Naturally elevated TDS in some of the Karoo aquifer system (Taru Grits, Maji ya Chumvi and Mariakani). Basement GWs often contain GW with elevated TDS

Turbidity

Sand harvesting contributes to the turbidity of water, which decreases the water quality. The groundwater quality in Timboni is affected by the sand dune harvesting.

Agricultural pollution

Pollution of surface and groundwaters in the Central Rift by agricultural fertilisers has been reported (Olago et al., 2009).

4.5.2.3 Institutional

Regulations

There is poor planning and water allocation when it comes to considering surface water and groundwater allocation. The two remain divided, and effectively treated as different water resources. The recent Water Allocation Plan Guideline (Water Resources Authority, 2019a) should help to resolve this, as it treats both resources in a given area in its approach to WAPs. There is confused NEMA and WRA mandates with regards to wastewater management and licensing (both bodies seek ‘polluter payments’ from water users/polluters). NEMA legislation (Act in 1999 and effluent regulations in the Environmental Management and Coordination (Water Quality) Regulations, 2006) pre-date water legislation (Water Act in 2002, and effluent regulations in the WRM Amendment Rules, 2012). Communication of mandates between counties and the WRA are also uncertain, with counties in particular drilling boreholes without the benefit of WRA Authorisations and sometimes of poor technical quality (installing mild steel casing/screen in low pH GW environments, for example). Further potential conflict between national and county governments is likely, regarding the sharing of natural resources benefits (*The Natural Resources (Benefit Sharing) Bill*, 2014; *The Natural Resources (Benefit Sharing) Bill*, 2018), the 2014 Bill was shelved, and the 2018 Bill has yet to be debated. Both Bills specifically include water resources mandates between different state actors are trans-sectoral.

Inadequate monitoring

Monitoring status has improved significantly in the past decade, with a total of 40 groundwater monitoring points across the Basin (4 Strategic, 20 Major, 11 Minor and 3 Special) (Water Resources Authority, 2018c); there were 34 in the 2014-15 reporting period (Water Resources Management Authority, 2015a). Data quality is patchy; most groundwater level data are collected from boreholes that are used as production boreholes, so all too often the data show dynamic as well as static water levels. This restricts the utility of water level data to determine long-term trends. This is changing, however; an additional 25 dedicated monitoring boreholes are being constructed in the Basin in 2018-19, of which:

- 8 shallow and 8 deep monitoring boreholes are to be installed in the NAS;
- 3 shallow and 6 deep monitoring boreholes are to be installed in the Tiwi aquifer;
- These monitoring sites are to be fitted with water level loggers and telemetry.

Private sector or NGO players may operate their own monitoring networks, such as that operated by Base Titanium Ltd in the South Coast (covering both water levels and water chemistry). The water level monitoring network operated by UNICEF/CARE Kenya in the Dadaab part of the Merti aquifer has been terminated. Field water quality data collection is also improving, with a broader range of measurements planned in order that resource-quality objectivescan be determined. Parameters planned cover the following: electrical conductivity, turbidity, temperature, pH, total suspended solids, dissolved oxygen, total nitrogen and total phosphorus (this list given in the 2015 Athi CMS for surface water, it is assumed that the same instruments are available for groundwater quality monitoring: (Water Resources Management Authority, 2015b)). Abstraction monitoring is done on an ad hoc basis at best. Groundwater users are required to submit abstraction data monthly or quarterly as evidence to support their water charge payments, but these are rarely checked in the field by the WRA. The capacity to improve abstraction monitoring will be boosted by the adoption of formal guidelines for groundwater abstraction surveys, using electromagnetic flow meters (Water Resources Authority, 2018e).

Borehole inventory

Borehole data have been and are stored in a number of separate systems. The 1992 NWMP initiated the National Water Resources Database (NAWARD), which remains a source of data though it has not been updated since 2005; in the period 2005-10 the data collection role was taken up by the WRA, and during the handover period, there was a measure of confusion as to which agency drilling contractors should submit drilling data to (Ministry of Water and Irrigation, 2012); NAWARD included, inter alia, the paper-based borehole data set in Nairobi. The WRA currently collects and stores borehole data in a combination of paper and digital formats, with the long-term intention of digitising all records. The first attempt at digitising borehole data was made in 2010-11 as part of the Nairobi Borehole Census. All borehole records that could be found across a wide range of sources were digitised and established in a Microsoft Access database system, protected by password access. Completion of the digitisation exercise is essential. This should be digitally linked to/interfaced with the PDB.

Unclassified groundwater applications in the PDB

The PDB of the WRA has had challenges, including numerous duplicate or out-of-date entries. As an example, one large-scale water user on the South Kenya Coast has six production boreholes, six small-scale domestic groundwater sources, numerous monitoring piezometers and two surface water offtakes. However, the database shows it to have 53 files, as follows:

- 18 files: 15 groundwater and three surface water Authorisations (which include some dedicated piezometer and exploratory boreholes);
- Two files: two old boreholes described as ‘Deferred’, for which “Notification Approval for Construction of Works and Use of Water” (Form WRMA OA3) have been issued;
- Five files: four GW sites and one surface water site described as ‘Pending HQ Verification’.

- Thirteen files: Permits issued (this conforms with paperwork held by this water user, except for two GW sites which are uncertain);
- Two files: Inspection reports received, permits yet to be issued;
- One file for a site that was drilled but for which no Water Permit was sought, described as 'Received Completion Certificate';
- Twelve files that were rejected.

This water user is understandably confused and has sought clarification from the WRA. A good deal of the confusion in this case appears to be because the name of the Company making the applications changed half-way through the process, which necessitated striking out and re-issuing paperwork with new file numbers; in addition, a number of Authorisations were issued for piezometer and exploratory boreholes, for which permits were not ultimately sought.

For water permit classification it is necessary to determine whether dedicated monitoring boreholes (or piezometers) require a Water Permit. In cases where a monitoring borehole may be periodically used to obtain small quantities of water for analysis (<<1m3), a Category A Permit should potentially be issued. Prior to 2014, applications to construct monitoring boreholes were issued with Authorisations but not Water Permits; since 2014 there has apparently been no requirement for either Authorisations or Permits for monitoring boreholes (diameters <4"/102mm). It is necessary to determine whether true exploratory boreholes require a Water Permit after completion if they are not to be commissioned as production boreholes. There is a need to clarify the role and application of the Form WRMA 0A3 (Notification Approval for Construction of Work and Use of Water).

For Class A, the applicant will get an Approval. For Class B, C and D, the applicant is issued with a Permit. For all Classes, the applicant is mandatorily required to obtain an Authorization.

4.5.3 Water resources infrastructure

The Athi Basin has the highest water demands in the country; however, about 80% of the water used in Athi is transferred from the Tana Basin due to limited water availability and storage infrastructure in Athi. The key issues regarding water resources infrastructure are described below.

4.5.3.1 Bulk water supply systems and transfers

The main issue of bulk water supply systems in the Athi Basin is inadequate storage for various uses. There is also a concern that the current infrastructure will not meet the growing demands. The design of dams and other infrastructure is important to maintain the capacity designed for. There has been evidence that some dams as well other infrastructure are undersized for floods, which raises the question of whether floods were considered during the design of the infrastructure.

The NWMP 2030 gives the water supply deficit as 65% of the total water demand for the Athi Basin and confirms that the existing water resource infrastructure will not be sufficient to satisfy the growing water demands up to 2030.

4.5.3.2 Hydropower schemes

There are currently no hydropower schemes in the Athi Basin. There are a few proposed hydropower projects as part of proposed dam projects.

4.5.3.3 Irrigation schemes

There are no major irrigation schemes in Athi Basin and a large portion of the agriculture is rain-fed. The lack of major irrigation schemes is a concern for the basin. There are proposed irrigation schemes, which should help relieve the problem of food insecurity.

4.5.3.4 Water supply network

The water supply and sanitation systems suffer from various issues including losses due to leakages, bursts and blockages, illegal connections, inefficient and wasteful water use and overflow of sewers. There are several unplanned developments in the Athi Basin, which have been constructed without proper planning resulting in inadequate sanitation systems.

4.5.3.5 Future projects

Inadequate capacity for infrastructure development

The WRA and the Water Works Department do not have sufficient capabilities and financial resources for the regulatory, monitoring and technical aspects of water resource infrastructure development. The high cost of assessment of potential dam sites inhibits the Water Works Department's ability to support the development of new reservoirs. There is also inadequate capacity at WRUA level to initiate the development of storage infrastructure.

Lack of investments into infrastructure development

An article by Business Daily (Wafula, 2010), highlights the issue that potential investors in the water sector are put off by Kenya's regulatory framework. Investors are hesitant to invest in the high-risk water sector of Kenya where there are no guaranteed payments from consumers. The CIDP for Taita Taveta County listed several projects which have been halted due to inadequate funds. Some of these projects include Bomeni water pan, Chala water pan and Gimba irrigation scheme.

Priority areas for groundwater resource development

There is currently inadequate information regarding the groundwater potential across the Athi Basin, and priority areas have not been identified for groundwater resource development.

4.5.4 Hydro-meteorological monitoring network

The current monitoring network in the Athi Basin is inadequate, and the network is not being effectively operated. Data management and sharing platforms are not well established, and there is inadequate technical capacity coupled with an oversupply of work that requires data processing, analysis and reporting, beyond the available time of the staff. There is also inadequate maintenance of the gauging stations. Although the WRA continuously rehabilitates and expands the hydromet monitoring network, issues such as ageing, vandalism and flood damage limit progress. There is difficulty in monitoring meandering rivers, which occur in the lower Athi region.

4.5.5 Water allocation and use

One of the key challenges across most of the Athi Basin is limited water resource availability. There is intense competition for water resources and pressure on prioritisation of water use. This basin therefore has the biggest challenge to ensure the equitable and sustainable allocation of water to domestic, industrial and agricultural users, and has the opportunity to take the lead in water allocation planning. Managing and enforcing water allocations and use is one of the major challenges in the basin, as described below.

4.5.5.1 Compliance of allocations

Managing and enforcing water allocations and use is one of the major challenges in the basin, and there is currently inadequate capacity and time in WRA to enforce compliance and to collect, record and analyse water resource monitoring data. There is also inadequate monitoring of actual water use for large water users and illegal abstractions taking place which are not monitored and removed. Over-abstraction and illegal abstraction of groundwater occurs throughout the Athi Basin, with known cases in Nairobi, Taveta area, Rombo, Loitokitok and Kimana.

4.5.5.2 Water resource availability

One of the key challenges across most of the Athi Basin is limited water resource availability. The basin includes the two largest Kenyan cities of Nairobi and Mombasa. The discrepancy in water availability verses water demand creates challenges in allocation of water.

Groundwater is used as a supplementary resource to surface water and is currently exploited without adequate knowledge of groundwater potential. There is over-abstraction of water in Nairobi City with several unauthorised boreholes existing in the area.

4.5.5.3 Water distribution

Uneven water distribution

The water supplied in the Athi Basin is distributed unevenly in terms of both spatial and temporal contexts. The areas beyond the jurisdiction of the nine WSPs either have no water infrastructure or receive water through community water projects. In Kwale County, the existing water systems are based around the urban and commercial centres, resulting in uneven distribution and low access to water in the sparsely populated rural areas. Mombasa is reliant on other counties due to the unavailability of water sources within the county. The eastern part of Kiambu County has a high amount of surface water, while the western part has limited surface water (except for Lari). In Nairobi, the bulk water supply is unreliable during droughts, with only 40% of household connections receiving water continuously (County Government of Nairobi, 2017). Another issue is the drying of springs, streams and rivers at certain times of the year attributed to unpredictable and unreliable rainfall and increased human activity.

Growing water demands within competing sectors

The basin includes the two largest Kenyan cities of Nairobi and Mombasa, and most economic production in Kenya occurs in the Athi Basin, including economic production in the industrial sector, tourism industry and irrigated agriculture. As a result, there is intense competition for water resources and pressure on prioritisation of water use. This basin therefore has the biggest challenge to ensure the equitable and sustainable allocation of water to domestic, industrial and agricultural users.

While the upper part of Kiambu County has a high density of agricultural activity, the water in this upper catchment area is stored and used to supply Nairobi.

4.5.5.4 Information on allocatable water

There is currently inadequate information on surface and groundwater availability for the purpose of water allocation management. Only limited estimates of allocatable water are available.

4.5.5.5 Water allocation

The fair allocation of water resources is affected by the social standing in society. For example, in Kwale County, corruption, chauvinism and bias results in the uneven allocation and development of resources (County Government of Kwale, 2013).

Water is a necessity for all sectors, which, when the availability is low or restricted, can result in tension. When one sector is favoured in terms of water supply above another, conflict arises. An example is the domestic water supply to Nairobi is a higher priority than water supply to the farmers in Kiambu, the upper catchment area.

4.6 Institutional issues

4.6.1 Institutional arrangements

Key institutional issues in the basin include inadequate capacity of the WRUAs, inadequate capacity and knowledge of integrated water resource management in the County Governments, and inadequate reporting framework to the public. During the workshop institutional issues were only identified in the upper Athi.

4.6.1.1 National policies and legislation

Promulgation of the Constitution (2010)

Kenya's new Constitution (2010) introduced the County Governments structure that was aimed at decentralising some of the national functions to the 47 counties. The Water Act 2016 provides policy direction and relegates catchment management and water supply services to County Governments.

Conflicting policies, regulations and mandates

Conflict exists in certain counties where either the County Government or Water Service Provider acts in contention with the WRA mandates in order to increase income or to gain favour with the public. This results in animosity towards the WRA.

The County Government of Kajiado County has a financial policy whereby the County Government collects taxes from water users and abstractors and issues licenses to increase revenue within the county, which is against WRA's mandate. Mombasa Water and Sewerage Company (MOWASCO) was shutting down wells and confiscating equipment (e.g. standpipes supplying water) from people who were complying with WRA's mandate. WRA had to intervene.

Organisations such as NEMA and Kenya Wildlife Trust (KWT) have acts in place, which conflict with WRA regulations. An example is NEMA's physical planning act, which is not in alignment with WRA regulations. A major issue is the mandates on wetlands and riparian lands. The Physical Planning Act, and Agricultural/Land Acts, hold different definitions to the Water Act regulations as to what constitutes riparian land. This has created mandate conflict on a national level and has also made it easy for people to encroach on riparian land or for developers to bypass the law.

There is need to carry out a mapping and analysis of key institutions in the national and County Governments, civil and private sectors and their overlapping mandates while identifying opportunities of synergy. A detailed stakeholder analysis is to be undertaken at the beginning of the Strategic Environmental Assessment (SEA) process. This will include a governance and institutional assessment of the various institutions and how these are envisaged to change in the proposed basin plan. A range of institutions and organisations are directly involved in forest management and conservation of forests in the basin. Most of the forests in the basin forests are found on protected areas whose management is vested in the KFS. There are also closed canopy forests gazetted as national parks and national reserves managed by KWS. Moreover, a significant forest area is found in trust land and vested in the respective County Governments. There are also indigenous forest areas under private ownership, either as units held individually or within group ranches especially in Makueni, Kajiado and Machakos. Many of these are usually small holdings and are important for water catchment and streamline conservation purposes as well as for providing subsistence and small-scale commercial produce.

Revenue collection and resource mobilisation challenges

Currently, the billing system is not integrated with the Permitting Data Base (PDB) thus lowering revenue billed. Initial consultations by ISC indicate that there is need to explore innovative additional revenue streams to increase revenue base such as: (a) Further developing a policy directive/caveat on all future development projects to include a 10-15 % budget to be set aside for conservation of water resources management activities. Such a policy caveat has been developed, and the percentages are the only remaining bit under discussion with the MWSI; (b) Commercialise water testing labs through accreditation; and (c) Establish a Water Payment for Ecosystem Services Scheme anchored on ‘beneficiary pays principle’. Revenue collection rates for WRA are low due to inadequate resources to facilitate this process. However, since 2009 the Authority has recently incorporated electronic payment services through Mpesa, a mobile money transfer platform that will significantly increase the revenue collected because of the convenience it offers the water users. Also, there are on-going discussions on acquiring an integrated system that will increase efficiency in the permitting and commercial processes at WRA. Furthermore, there is on-going installation of automated telemetric consumer meters to enhance revenue collection, while also minimising time for WRA staff to travel for meter readings.

Non-compliance to effluent discharge regulations

According to Athi River Restoration Programme (Water Resources Management Authority, 2015c), the following dischargers had not complied to WRA’s effluent discharge regulations: Limuru Water and Sewerage Company, Export Processing Zone Authority, Machakos Water and Sewerage Company, Kariobangi Sewerage Treatment Works and Kahawa West Sewage Treatment ponds. Dandora Sewerage Treatment Works partially complied to WRA’s effluent discharge regulations.

4.6.1.2 National institutions

Uncoordinated institutional roles

The uncoordinated roles of the various organisations cause not only poor efficiency, but also conflict between the organisations. WRA, KFS and KWT all have a catchment protection mandate, which creates conflict when all three organisations have their set roles to fulfil. Similarly, there is conflict between CFAs and WRUAs in terms of forest management, where the river sources are in the forest which falls under the jurisdiction of the CFAs, while the WRA usually manages the sub catchment outside the jurisdiction of CFAs.

There is inadequate coordination between CGs and WRA. This makes it difficult for the WRUAs, whose responsibility lies between that of the CGs and WRA, to implement sub-catchment based water resources management interventions. Also, water resources management is a function that has devolved to the CGs, while WRA performs regulation of the CG’s management of water resources.

4.6.1.3 Basin and sub-basin institutions

Dormant or potential WRUAs

Athi Basin has 150 existing WRUAs out of a potential 309 WRUAs needed to cover the whole basin. The gap of 159 dormant or potential WRUAs needs to be addressed to ensure basin coverage of WRUAs is increased. Even among the existing WRUAs, there are capacity concerns and disparities in levels of development and maturity of the WRUAs. This denotes the need for continued capacity building for the existing WRUAs in addition to continued technical and financial support.

The unclear role of the BWRCs

There are conflicting mandates for the BWRCs in the Water Act 2016 where they have both advisory and management functions. ISC has an understanding that the BWRCs will remain advisory for the foreseeable future with a long-term plan of making the BWRCs have an executive role. There is a need to develop tools to support the operationalisation of the BWRCs, when they are finally established.

Expansive area of jurisdiction

Some of the WRA offices in the Athi Basin have jurisdiction over expansive areas. This, combined with the issue of understaffing, makes it difficult to manage the entire area. An example in the middle Athi region is the Loitokitok office, which covers the area from Namanga to Taveta.

Inadequate institutions in forestry sector

The inadequate institutions arise from weak governance structures and inadequate capacity for law enforcement and weak stakeholder participation in forest management and governance. This is exacerbated by inadequate funding of the forestry sector from the exchequer, civil and public sectors. Since the enactment of the new Constitution in 2010, nationally and within the basin, the level of public support to the conservation of forests has increased significantly but has not been matched by an equal measure of resource allocation in all sectors. For example, the Forest Management and Conservation Fund (FMCF) established in the Forests Act 2005 and the Forest Conservation and Management Act, 2016 to promote the development of forests, maintenance and conservation of indigenous forests, the promotion of commercial forest plantation, provision of forest extension services, the establishment of arboreta and botanical gardens, and a variety of other purposes outlined in Forest Act is yet to be fully operationalised. Furthermore, there are conflicting institutional mandates as is evident from the overlapping mandates, programmes, projects, and conflicting policies and legislation. Overall, forest conservation has witnessed increased cases of political interference in the management of forests, poor governance as well as inadequate and/or weak structural/institutional capacity for forest law enforcement and governance.

4.6.1.4 County Governments

Governance issues

Water resources management decisions in Kenya are often influenced by political agendas, which are not always aligned with scientific, engineering and resource realities. This creates unrealistic expectations and often leads to frustration. Furthermore, there is sometimes a misconception that WRA acts as a barrier to people’s desire to get access to water resources. This in return occasionally creates animosity amongst community members towards WRA, which can negatively impact WRA’s activities on the ground. Another instance of political opportunism involves politicians announcing unrestricted access to water, which for example results in people drilling illegal boreholes.

Limited coordination

Apart from the limited land use planning in the Athi Basin, isolated planning is another major challenge to conservation**.** Since 2013, Kenya has had a devolved system of government and one of the components of this is the counties planning their own land independently of each other. In the case of ‘moving resources’ like wildlife and water, this has led to the loss of coordination and poor resource use. There is need for policy action to ensure integration of planning and decision making at all levels.

4.6.1.5 Partnerships and engagement

Limited partnerships

Partnerships are very important for different categories of users within the basin. Initial discussions with WRA indicate that there are a few partnerships in place, majority being nationwide partnerships with key strategic partners whose focus is nationwide. Given the strategic need to have more localised partnerships e.g. with industries in the basin etc., more effort needs to be vested in ensuring this becomes a reality. This is particularly needed as some of the potential partners have already entered into agreements with other players on the ground such as KFS, NEMA, Kenya Water Towers Agency (KWTA), NGOs etc.

Limited coordination between stakeholders

There is currently weak coordination between the WRA, WRUAs and the County Governments, which leads to poor urban planning and uncontrolled development.

Low public awareness of WRA's mandate

Generally, there is low public awareness of WRA in the Athi Basin. Some of the stakeholders in this basin are unaware of WRA's role in regulating the use and management of water resources. There is urgent need to create awareness and understanding of WRA mandate as a Regulator through activism and engagement with other partners, articulate WRA's functions well, demonstrate ways of measuring results achieved, package those results in ways attractive to different stakeholders in this basin.

4.6.2 Enabling environment

Key enabling environment issues in the basin include inadequate resources (financial, equipment, materials, office space, monitoring stations and laboratories). These issues and challenges are cross-cutting across all regional offices of WRA. However, key issues and challenges specific to the Athi Basin are described below.

4.6.2.1 Financial resources

WRA has insufficient funding, which results in a clear gap in financing, that in turn affects operational activities which have a bearing on quality and quantity of outputs by the Authority. This has negatively affected procurement of modern equipment, upgrading existing stations, improving monitoring networks, increasing staffing capacity, training etc. However, although approved recurrent budgets over the years has increased steadily, though with a small percentage and actual funds released for operations have also improved over recent years in line with the available funding, the financing gap has been significant with FY2016/17 having a financing gap of KES 819 million. Opportunities that exist within the sector with regards to financing water and sewerage infrastructure include:

- Donor finance – there exist several international organisations that supports this sector. Projects like KIWASH, WSUP are opportunities that can be explored in bridging the financing gap.
- Market finance – Commercial banks are currently supporting water utilities in expansion activities. This initially happened under Output Based Aid and has supported several water utilities. The water utility must demonstrate that it is commercially viable to benefit from the loan facility.
- Water Sector Trust Fund – The Water Sector Trust Fund targets to improve service in pro-poor areas. The water utilities can take advantage of this facility to increase access to services in low income areas where the population is limited by the ability to pay for connection to services.
- Public Private Partnership – The sector in recognition of the financing gap and the need to achieve vision 2030 has embraced PPP arrangement.

Current funding includes WSTF financing for WRUAs as well as African Development Bank funding for the Kenya towns sustainable water supply and sanitation programme through which WRA is being facilitated in institutional strengthening and funding of WRUAs.

In addition, there are programmes by international banks that target the sector under special conditions such as the Kenya Towns Sustainable Water and Sanitation Program being implemented by the African Development Bank Group.

Some of the issues arising from inadequate financial resources are inadequate office space and equipment, inadequate vehicles and/or fuel and inadequate laboratory facilities.

Inadequate office space and equipment

The Machakos RO and Mombasa and Loitokitok SROs have adequate office space, while the Kiambu, Kibwezi and Nairobi SROs and satellite offices indicated that they have inadequate office space and equipment including computers, monitoring equipment amongst others during a recent institutional assessment exercise carried out by ISC in November 2017. Data collection tools/equipment and infrastructure at gauging stations are often in need of maintenance, repair or upgrade, e.g. survey equipment, meter readers, water quality monitoring equipment and manual data collection tools. This is a major concern considering that there are internationally and locally shared rivers and aquifers which require regular monitoring to ensure that water use activities do not negatively impact on users downstream.

Inadequate vehicles and/or fuel

Athi Basin has a cumulative total of 12 vehicles distributed as follows; Machakos (2), Mombasa (3), Kiambu (1), Loitokitok (1), Kibwezi (2), and Nairobi (3). This is a huge challenge that affects all functions of the Athi Basin offices. Inadequate funds assigned for vehicle maintenance and operational costs has had a negative effect on day to day activities. This has for example affected data collection, monitoring and compliance activities in the basin.

Inadequate laboratory facilities

The central water testing laboratory located at the Nairobi SRO has recently had some rehabilitation work done and is in a better condition than the RO laboratory. However, it still requires additional rehabilitation. The cupboards, reagent shelves and the work tops tables are worn out and need refurbishment. The floor needs re-tiling. The cold room needs a compressor and a chemical store is needed. The building needs repainting. Basic equipment is available and is in good working condition. The AAS used for determination of heavy metals, is not functional and a new one is needed. A GLC needs to be procured as well as a Flame Photometer. This facility has seven staff but could benefit from additional recruitment to enable more and efficient laboratory services to WRA's customers. The Machakos laboratory occupies one small room, where all the analysis is done. More laboratory space and a chemicals store is needed. Basic equipment is available and is in good working condition. There is need to procure a multi-parameter meter.

4.6.2.2 WRA staffing capacity

A recent institutional assessment exercise carried out by the ISC in November 2017 revealed that the basin is understaffed. This varies greatly between the different departments. The basin hosts Machakos, Loitokitok, Kibwezi, Mombasa, Malindi Satellite, Taita Taveta, Kiambu and Nairobi RO, SROs and satellite offices. These offices had a cumulative total of 143 staff with Malindi (2) and Taita Taveta (2) having the least number of staff as indicated in parenthesis. The total number of WRA staff countrywide was estimated at 763[2] across all 6 regional offices. This situation is exacerbated by many staff who are retiring soon which may result in institutional memory loss if no comprehensive knowledge transfer mechanism is put in place. This will also create a huge gap in technical expertise that may be difficult to replace.

4.6.2.3 Enforcement capacity of WRA

The legal department that is taking the lead on enforcement issues is currently a centralised function operating from HQ and serves all the six regional offices based on demand and occurrence of legal enforcement matters. WRA has approximately 17 trained legal prosecutors drawn from various departments such as water rights. The number of trained legal prosecutors keeps reducing as some of the members have retired and others are going to retire soon. There has been inadequate capacity building to continue growing this number to ensure that WRA has the capacity to handle all issues arising periodically. There is also an inadequate number of enforcement teams on the ground for cases of polluters resulting in WRA having to involve policemen.

[2] The total number of current WRMA staff varies between 763 or 799 based on numbers provided during expert review workshops. WRMA has no digitised HRIS hence staff data and information is manually kept.

4.6.2.4 Implementation ability/capacity

There is a concern for the ability within the WRA in implementing the strategic plan, which is an issue that needs to be addressed in the enabling environment strategic action plan as well as the institutional strengthening plan.

4.6.2.5 Capacity of other institutions

There are capacity challenges in some of the offices of the other institutions, including KFS, NEMA, and in some of the County Governments.

A part of Kinale Forest in Kiambu County is used for a community initiative whereby community members may farm around the trees while they are still saplings. Some people take advantage of this by uprooting the trees, which kills the trees, thus enabling them to continue farming on the land. This is a result of inadequate enforcement capacity of the CFA's and/or KFS.

4.6.2.6 Capacity in WRA to deal with drought related disasters

Although the WRA implements water use restrictions during times of drought, reference water levels for the restrictions are not clearly determined for the Athi Basin, leading to operational issues.

4.6.2.7 Capacity in WRA with regards to flood mitigation

There is currently no systematic flood management taking place in the Athi Basin (although IFMPs have been developed for Lumi and Lower Sabaki), and flood warning levels have not been confirmed at major river gauging stations. There is also inadequate timely data collection and subsequent analysis necessary for setting up of early warning systems.

4.6.2.8 Inadequate capacity to enforce reserve flows

There is currently inadequate capacity (number of staff and technical capacity) in the WRA to carry out environmental monitoring and to enforce the implementation of reserve flows. The absence of sufficient environmental policies and regulations at county level also constrains efforts to enforce environmental conservation.

4.6.2.9 Capacity of WRA with regards to climate change adaptation strategies

The Government of Kenya has developed the NAP. The issue arises with inadequate knowledge and ability to implement these adaptation strategies as well as insufficient staff capacity. Available funding and investments for continuous implementation, assessment and maintenance of the strategies poses an issue

4.6.3 Transboundary and trans-county issues

The Athi Basin shares water resources with its neighbouring country, Tanzania, as well as via an inter-basin transfer from the Tana Basin, as described below. These shared water resources can potentially cause major conflicts if they are not managed and developed cooperatively. Conflict between counties also arises when water availability is low or when they are required to share resources.

4.6.3.1 Inter-basin transfers

The Athi Basin receives about 80% of its water from the Tana Basin via an inter-basin transfer from the Thika and Sasumua dams to Nairobi. Any future developments within the Tana Basin could therefore potentially impact on the quantity, quality and seasonality of flows transferred to Nairobi.

4.6.3.2 Internationally shared water resources

There are several international rivers in the Athi Basin. The Lumi River flows across the border to Tanzania, while the Umba River has its source in Tanzania and flows into Kenya. Any future developments on the Lumi River or activities within the Lumi River catchment could negatively impact on the quantity, quality and seasonality of flows entering Tanzania, which may lead to conflict. Similarly, any future developments on the Umba River or activities within the Umba River catchment could negatively impact on the quantity, quality and seasonality of flows entering Kenya from Tanzania. It is essential to ensure cooperative management and development of the water resources shared with Tanzania.

Both Lake Jipe and Lake Chala are located on the border of Kenya and Tanzania. Before the Memorandum of Understanding (MoU) was signed, there was conflict between the two countries, which was aggravated due to inadequate cooperation framework, the lack of an integrated management plan for the ecosystems and the difference in national policies and legislation. In February 2013, the Governments of Kenya and Tanzania signed a MoU, which establishes a Joint Cooperative Framework for Lake Chala, Lake Jipe and Umba River.

4.6.3.3 Trans-county conflict

There is conflict between the counties within the Athi Basin often due to counties not wanting to share water supply. A false idea has developed whereby counties believe that the water belongs to them if the source is within their county. Conflict is heightened during a drought when water availability is at a minimum.

There has been a lot of tension between Muranga and Nairobi counties during the construction of the Northern Water Collector Tunnel. Recent tension arose when AWWDA neglected to uphold the agreement, which involved ensuring water supply to the locals in Muranga County (the start of the tunnel) before commencing construction of the tunnel to Nairobi.

In the middle region, conflict exists between Kajiado, Machakos and Makueni counties. In 2017, the Governor of Kajiado instructed Nolturesh-Loitokitok Water and Sanitation Company to disconnect the water supply to Machakos and Makueni counties to ensure supply to Loitokitok and satellite towns and thereafter to Kajiado town, Isinya and Kitengela. Machakos and Makueni counties had been receiving water from Nolturesh Water, making it a conflicting situation.

Similarly, there has been upset in Kwale County due to their water scarcity, while Mombasa is supplied with water from Kwale. There is conflict between Mombasa, Kwale, Kilifi and Taita Taveta counties over shared water resources.

Mombasa Water Supply and Sanitation Company Limited manages the Baricho-Sabaki Well field, Mzima Pipeline, Marere Pipeline and Tiwi Boreholes, which all mainly supply Mombasa with water. Other areas these water sources supply include Malindi, Kilifi, Voi, Mariakani, Mazeras, Kaloleni, Kwale and Kinango, among others. Mombasa is the top priority for receiving water, so when water is scarce the other areas suffer from water shortages.

The Yatta Furrow supplies Kithimani (Tana Basin), Ndalani (Athi Basin) & Matuu towns (Tana Basin). Conflict arises when water levels are low.

It was mentioned during the workshop that counties have the idea that if the water source is located in their county, it belongs to them, and when water is scarce, they do not want to share this water with neighbouring counties.

4.6.3.4 Land and resource conflict

An analysis conducted by OCHA Kenya stated that there were over 112 deaths due to conflict of resources in pastoralist areas between January and May of 2011. Compared to the 68 deaths during the same period in 2010, this indicated an increase in deaths due to conflict. Transboundary conflict hot-spot areas include the Uganda-Kenya and Kenya-Ethiopia borders.

Image source: Aurecon, 2017. Tsavo West National Park

05

Vision and Scenario Evaluation

5 Vision and Scenario Evaluation

5.1 Introduction

In light of an improved understanding of the current situation in the Athi Basin as described in Sections 2 to 4, this Section presents the Vision for the Athi Basin along with scenarios and evaluations towards identifying a sustainable development pathway for the basin which is aligned with the Vision.

5.2 Vision for Athi Basin

A Vision for the Athi Basin was developed in conjunction with stakeholders and reads as follows:

A well-managed and protected river basin characterised by good governance, sustainable socio-economic development for all, and a clean, safe and water secure environment, which enhances quality of life from the Aberdares to the Indian Ocean.

5.3 Conceptual approach towards the evaluation of water management interventions

Scenario analysis provides a structured method of thinking about possible future options, opportunities and risks, and how these might interact. The results are useful for consensus building and decision making. Furthermore, it augments the understanding about the future by highlighting issues and exposing underlying forces in a sector or geographic region that would otherwise not be considered.
Within a basin planning context, a scenario is defined as a contemplated future state of the basin, induced either through targeted human intervention (e.g. combinations of development and management interventions) or through externalities (e.g. climate change, economic policies etc.). Development interventions and/or management options form the basis of alternatives, which are expressed in the form of different scenarios.

Figure 5-1 presents a typical six step conceptual approach towards the evaluation of water management interventions.

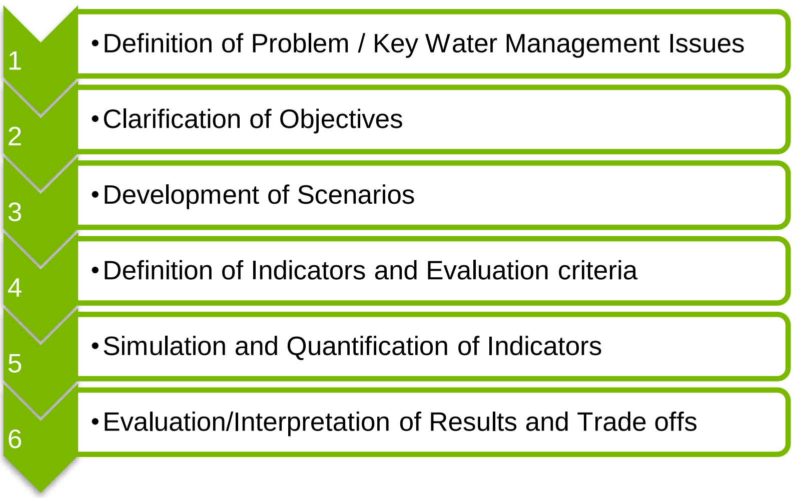


Figure 5-1: Scenario Evaluation (adapted from Kusek & Rist, 2004; World Bank, 2008)

The key aim of the Athi Basin Plan is to provide a pathway towards a future which achieves a sustainable balance between utilisation and development of water resources and the protection of the natural environment, i.e. minimising negative environmental and social impacts and maximising socio-economic benefits, taking into consideration the availability of water.

The approach adapted by this Study is illustrated in Figure 5-2 below. The interventions and drivers are the variables that depict the scenarios. Each scenario produces a set of indicators and scenarios are then compared through their indicators using multi-criteria analysis. Through evaluation of the results, a sustainable development pathway was identified

Evident from Figure 5-2 is the use of analytical tools at various key stages throughout the scenario development and evaluation process. These tools included erosion models, climate change analysis tools, surface water resources models, groundwater assessment tools, environmental flow assessment tools and multi-criteria analysis tools. Detailed descriptions of the analytical tools are provided in **Annexure A.**

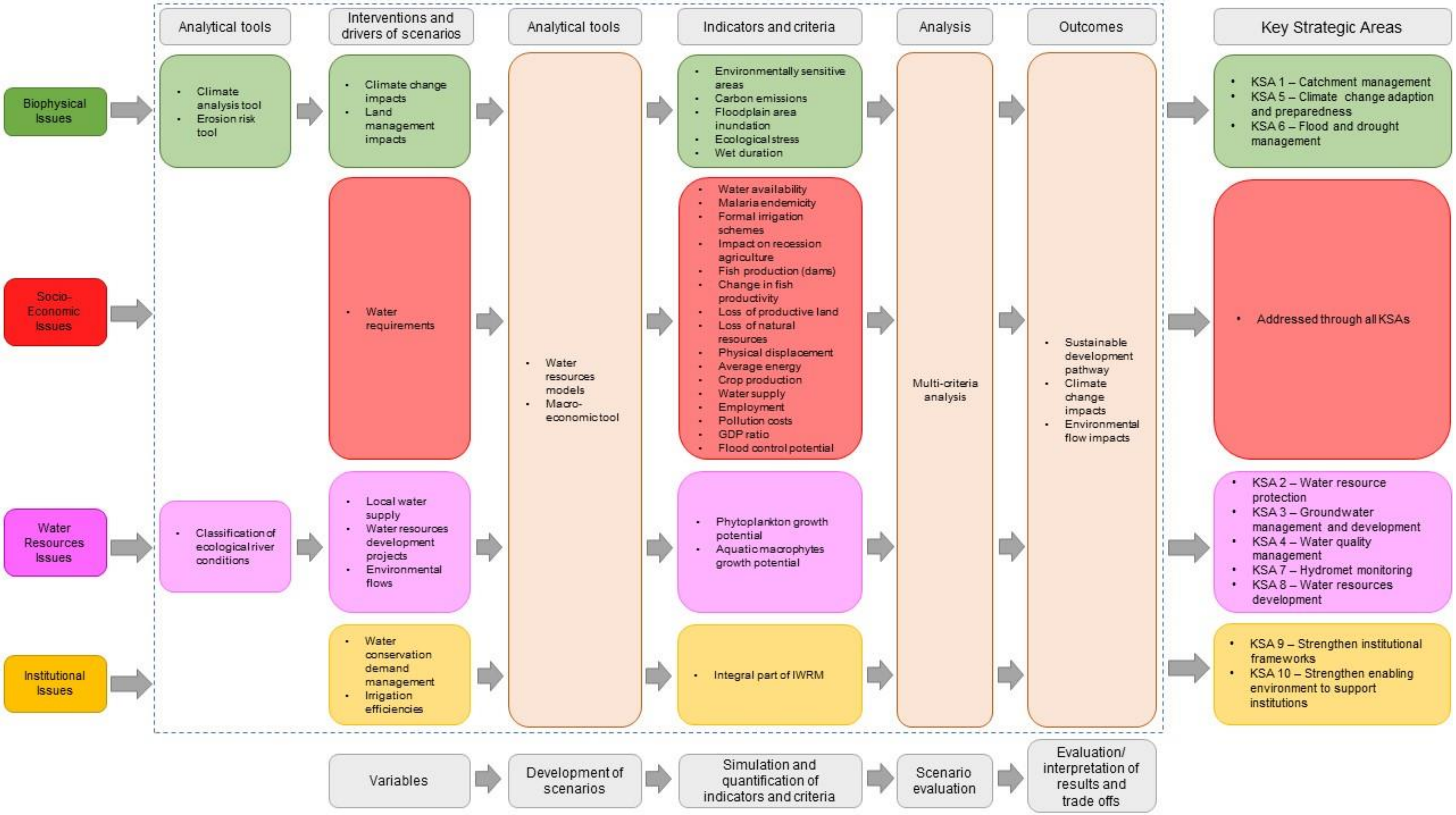


Figure 5-2: Approach to scenario development and evaluation

5.4 Interventions and drivers

To build scenarios, several key interventions and drivers were identified and incorporated into the scenario analysis in different combinations, constituting the key "building blocks" or variables of the defined scenarios. These include climate change impacts on water availability and water use, land use management, the anticipated growth in future water requirements, potential local water supply and large-scale water resources developments, the degree of compliance with environmental flows and possible institutional interventions. To align with the issues discussed in Section 4, the "building blocks" for the scenarios were categorised into biophysical, socio-economic, water resources and institutional interventions and drivers.

5.4.1 Biophysical

5.4.1.1 Land management

The erosion risk tool which was developed as part of this Study was used to quantify erosion risk and potential sediment yields and loads in relation to changes in vegetation (forestry) under different scenarios.

5.4.1.2 Climate change impacts

The impacts of climate change on future precipitation and temperature within the Athi Basin were superimposed on the hydrological models of the basin representing different scenarios, to assess how the change in climate translates into changes in surface water runoff, groundwater availability and crop water requirements.

5.4.2 Socio-economic

5.4.2.1 Future water requirements

A key driver in the development of future scenarios in the Athi Basin relates to the expected growth in future water requirements. To estimate future (2040) water requirements in the Athi Basin, the following approach was used:

Irrigation water requirements

To estimate future (2040) small-scale irrigation areas in the Athi Basin, the baseline (2018) small-scale irrigation area in each sub-basin was extrapolated linearly to 2040 based on the projected growth factor in small-scale irrigation areas between 2010 and 2030 as presented in the NWMP.

The growth in large-scale irrigation area up to 2040 in the Athi Basin was based on the expected growth in large-scale irrigation as per Table 5-3 - validated with the Department of Irrigation at the Ministry of Agriculture, Livestock and Fisheries. Only schemes with proposed areas larger than 2000 ha were considered as large-scale. Planned schemes with areas below 2000 ha were included in the small-scale irrigation areas as determined per sub-basin.

To estimate future (2040) small-scale irrigation water requirements, crop types, crop patterns and cropping intensities were assumed to be similar to current conditions. For planned large-scale schemes, information on crop types was sourced from the NIA. Using the FAO 56 approach, future irrigation water requirements could be estimated per sub-basin for different growth and irrigation efficiency scenarios.

Domestic and Industrial water requirements

For estimates of future domestic and industrial water demands in the major urban centres as well as the smaller towns and rural areas in the Athi Basin, information per sub-basin was sourced from the NWMP and CIDPs as relevant.

The NWMP estimated 2030 water demands based on expected population growth in urban and rural areas, assumptions with regard to design water consumption rates, and future target levels of coverage in terms of different water supply systems. Baseline (2018) demands were therefore extrapolated to 2040 demands, based on projected growth factors between 2010 and 2030 as presented in the NWMP.

Livestock and wildlife water requirements

Current estimated livestock and wildlife water demands in the Athi Basin were extrapolated to 2040 based on observed trends. Growth factors were calculated per sub-basin using data from the NWMP.

5.4.3 Water resources

5.4.3.1 Local water supply

As evident from Section 2.4, there are still surface water resources available in some sub-basins which can be used to address current and future local supply deficits. However, utilising this water optimally will require storage in dams and pans. Similarly, based on the groundwater analysis conducted as part of this study, groundwater resources are still available for allocation in some sub-basins.

The provision of additional surface water storage in dams and pans in conjunction with local groundwater development to improve water availability to local domestic, industrial, small-scale irrigation and livestock demands at sub-basin scale, was considered as part of the scenario development. Required surface water storage and sustainable groundwater abstraction volumes were estimated with the use of the water resources system model and groundwater assessment tool.

5.4.3.2 Potential water resources development projects in the Athi Basin

Strategic and master plans at national, regional and local level by the Water Resources Authority, Regional Development Authorities, Water Works Development Agencies, Counties, the NIA, the National Water Harvesting and Storage Authority, relevant ministries and other national agencies and stakeholders identified several potential water resources projects in the Athi Basin. These include surface water storage for water supply and flood control, irrigation development, hydropower development, inter and intra-basin transfers, and groundwater development schemes. For the purpose of this Basin Plan, information on water resources development schemes in the Athi Basin, which represent potential projects for implementation within the next 20 years (i.e. by 2040), were extracted and used as input for the definition of scenarios. These projects include dams and hydropower, inter- and intra-basin transfers, large-scale irrigation schemes and groundwater development as listed in

Table 5-1, Table 5-2, Table 5-3 and Table 5-4 respectively. Only dams greater than or equal to 1 MCM are considered large-scale, while irrigation schemes greater than or equal to 2 000 ha are considered large-scale.

Table 5-1: Potential water resources development projects - dams and hydropower

Dams and Hydropower				
Name	Sub-basin	County	Proposed Storage (MCM)	Purpose
Thwake	3FA	Makueni, Kitui	681	Water Supply: (Makueni / Kitui County, Konza City); Large-scale irrigation (Kibwezi extension / New); Hydropower
Mwache	3MA	Kwale	136	Water supply (Mombasa; Kwale / Mombasa County); Large scale irrigation (New); Hydropower
Kamiti 1	3BB	Kiambu	16	Water supply (Nairobi)
Kiteta	3EB	Makueni	16	Water supply (Makueni / Machakos County)
Lake Chala	3J	Taita Taveta	6	Water supply (Taveta; Taita Taveta County); Small-scale irrigation (Existing and New)
Mbuuni	3EA	Machakos	10	Water supply (Machakos County)
Miwongoni	3EA	Machakos	1.6	Water supply (Machakos)
Ndarugu 1	3CB	Kiambu	300	Water supply (Nairobi)
Pemba	3HC	Kwale	19	Water supply (Kwale County)
Rare	3LA	Kilifi	36	Water supply (Mombasa)
Ruiru 2/A	3BC	Kiambu	8	Water supply (Nairobi)
Stony Athi	3AB	Machakos	23	Water supply (Nairobi)
Munyu	3DA	Machakos	575	Water supply (Nairobi); Irrigation (Kanzalu)
Galana	3HB	Kilifi	498	Water supply (Mombasa/Kilifi County and Galana Kulalu Irrigation Scheme)

Table 5-2: Potential water resources development projects – transfers

Transfers			
Scheme	Counties	Proposed capacity (MCM/a)	Purpose
Maragua 4 Dam (Tana Basin)	Muranga, Kiambu, Nairobi	48	Water supply (Nairobi)
Northern Collector Tunnel Phase II (Tana Basin)	Muranga, Kiambu, Nairobi	44	Water supply (Nairobi)
Upgrade: Pipeline from Mzima Springs to Mombasa	Taita Taveta, Kwale	38	Water supply (Mombasa; Taita Taveta / Kwale Counties
Baricho wellfield abstraction and transfer upgrade	Kilifi	44	Water supply (Mombasa; Kilifi County)

Table 5-3: Potential water resources development projects - large-scale irrigation

Large-scale irrigation				
Scheme	County	Proposed Area (ha)	Crop type	Source
Mt Kilimanjaro	Kajiado	1 500	Horticulture	Springs
Kibwezi	Makueni	17 000	Maize, sugarcane, horticulture	Thwake Dam
Kanzalu	Machakos	15 000	Horticulture	Munyu Dam
Galana Kulalu	Kilifi	400 000*	Maize	Lower Athi River/ Galana Dam
Taita Taveta	Taita Taveta	3 780	Horticulture	Lumi River
Mwache	Kwale	2 000	High value crops	Mwache Dam

*Total proposed area of scheme – partly located in Athi Basin

Table 5-4: Potential water resources development projects - groundwater

Groundwater development			
Scheme	County	Abstraction volume (MCM/a)	Purpose
Ruiru and Kiunyu Wellfields	Kiambu	24	Water supply (Nairobi)
Mzima Springs (Upgrade)	Tait Taveta	38	Water supply (Mombasa; Taita Taveta / Kwale Counties
Baricho wellfield (Upgrade	Kilifi	44	Water supply (Mombasa; Kilifi County)
Tiwi/Msambweni Wellfield development	Kwale	18	Water supply (Mombasa; Kwale County)

5.4.3.3 Environmental flows

Three alternatives regarding environmental flows were considered and incorporated into scenario development viz. no environmental flows, using Q95 as a constant minimum environmental flow and implementing variable "holding e-flows" as opposed to Q95 (refer to **Annexure A5**).

5.4.4 Institutional

5.4.4.1 Water conservation and demand management

Water conservation and demand management interventions were considered which reduced future water requirements.

5.4.4.2 Irrigation efficiencies

The inefficient water use by irrigation schemes was addressed in the scenario development by improving the irrigation efficiencies of both large scale and small-scale irrigation schemes.

5.5 Scenario Definition

To evaluate the potential impacts and benefits of different development and management alternatives in the Athi Basin towards identifying a sustainable development pathway, various scenarios representing a possible 2040 future were defined and analysed using analytical tools. For each scenario, a separate MIKE HYDRO Basin model was configured reflecting the specific rainfall-runoff characteristics in relation to climate change, various degrees of infrastructure development, water demands under different development levels and climate impacts, and predefined environmental flow requirements.

Table 5-5 summarises the main development and management interventions incorporated in each scenario.

5.5.1 Scenario 0: Baseline

The Baseline Scenario represents the current (2018) conditions in the Athi Basin and provides a baseline against which future scenarios are evaluated. The scenario reflects existing water resources development and infrastructure, current water demands, no climate change impacts and assumes non-compliance with the Q95 Reserve due to lack of monitoring and enforcement.

5.5.2 Scenario 1: Lack of funding / Business as usual

This scenario represents the "do nothing" case - a possible worst-case scenario. It assumes that there is no further investment in water resources infrastructure and development including large-scale irrigation. Schemes which are currently being implemented are, however, completed. Growth in water demands up to 2040 across all sectors are assumed to be in line with projections (urban, domestic, industrial, livestock, small-scale irrigation). A continuation of the deteriorating trend in terms of vegetation loss in the catchment is also assumed (10% reduction by 2040 due to deforestation and overgrazing). Like Scenario 0, non-compliance with the Q95 Reserve due to lack of monitoring and enforcement is assumed. Climate change impacts are incorporated in the water resources model.

5.5.3 Scenario 2: Full development

The full development scenario is the same as Scenario 1, except that funds are now available to implement all the major dams with a storage volume greater than 1 MCM and large-scale irrigation schemes greater than 2000 ha as identified in various studies and plans and by stakeholders. This scenario evaluates the availability of water and the ability of the identified storage and transfer schemes to reliably supply future demands, specifically the significant growth in large-scale irrigation and the projected increase in urban and rural demands. It evaluates the trade-off between potential socio-economic benefits due to the water resources developments, and negative environmental and social impacts. As funds are now available, compliance with Q95 as the ecological reserve is assumed. However, like Scenario 1, vegetation loss at 10% across the catchment is still assumed due to the focus on large scale development in the basin.

Two sub-scenarios were defined under Scenario 2:

- Scenario 2A: With climate change impacts
- Scenario 2B: Without climate change impacts

5.5.4 Scenario 3: Sustainable development

This scenario represents a scaled-back version of Scenario 2 towards a sustainable development future, i.e. balanced water resources development which limits environmental and social impacts yet provides meaningful socio-economic benefits linked to the development of water resources with a reliable supply of water. This scenario aims for reduced sediment through reforestation, the successful implementation of a 20% reduction in future urban demands through water demand management, a reduction in large scale irrigation areas which are unproductive, and improved irrigation efficiencies.

The criteria which were adopted for the sustainable development of water resources in the Athi Basin include:

- Improving the assurance of supply to above 90% for urban, domestic and industrial users, taking into consideration the projected increase in water demand by 2040
- Improving and/or maintaining a high supply reliability for irrigation and livestock users, compared to the current (baseline) supply reliability, taking into consideration the projected increase in irrigation areas and livestock numbers by 2040
- A 10% improvement in forested area by 2040
- Successful implementation of a reduction in future urban demands through water demand management (-20%)
- Improved irrigation efficiencies: 60% for small scale and 80% for large-scale schemes

Three sub-scenarios were defined under Scenario 3:

- Scenario 3A: With Q95 as environmental flow requirement
- Scenario 3B: With EFlow holding flows as environmental flow requirement
- Scenario 3C: Same as 3A, except:
  - Munyu Dam supplies Nairobi instead of Ndarugu 1 Dam
  - Galana Dam supplies Galana Kulalu Irrigation Scheme and Mombasa
  - In addition, it assumes that smaller dams and pans as well as groundwater abstraction will be implemented at local/sub-basin level to alleviate domestic, livestock and small-scale irrigation water shortages during the dry season.

Table 5-5: Scenario definition

Category	Type	Scenario						
		0	1	2A	2B	3A	3B	3C
Water resources development	Large dams	Ruiru (3 MCM)	Ruiru (3 MCM)	Ruiru (3 MCM)	Ruiru (3 MCM)	Ruiru (3 MCM)	Ruiru (3 MCM)	Ruiru (3 MCM)
		Maruba (2 MCM)	Maruba (2 MCM)	Maruba (2 MCM)	Maruba (2 MCM)	Maruba (2 MCM)	Maruba (2 MCM)	Maruba (2 MCM)
		Kiserian (1.3 MCM)	Kiserian (1.3 MCM)	Kiserian (1.3 MCM)	Kiserian (1.3 MCM)	Kiserian (1.3 MCM)	Kiserian (1.3 MCM)	Kiserian (1.3 MCM)
			Thwake (681 MCM)	Thwake (681 MCM)	Thwake (681 MCM)	Thwake (681 MCM)	Thwake (681 MCM)	Thwake (681 MCM)
			Mwache (136 MCM)	Mwache (136 MCM)	Mwache (136 MCM)	Mwache (136 MCM)	Mwache (136 MCM)	Mwache (136 MCM)
				Kamiti1 (16 MCM)	Kamiti1 (16 MCM)	Kamiti1 (16 MCM)	Kamiti1 (16 MCM)	Kamiti1 (16 MCM)
				Kiteta (16 MCM)	Kiteta (16 MCM)	Kiteta (16 MCM)	Kiteta (16 MCM)	Kiteta (16 MCM)
				Lake Chala (6 MCM)	Lake Chala (6 MCM)	Lake Chala (6 MCM)	Lake Chala (6 MCM)	Lake Chala (6 MCM)
				Mbuuni (10 MCM)	Mbuuni (10 MCM)	Mbuuni (10 MCM)	Mbuuni (10 MCM)	Mbuuni (10 MCM)
				Miwongoni (1.6 MCM)	Miwongoni (1.6 MCM)	Miwongoni (1.6 MCM)	Miwongoni (1.6 MCM)	Miwongoni (1.6 MCM)
				Ndarugu1 (300 MCM)	Ndarugu1 (300 MCM)	Ndarugu1 (300 MCM)	Ndarugu1 (300 MCM)	
				Pemba (19 MCM)	Pemba (19 MCM)	Pemba (19 MCM)	Pemba (19 MCM)	Pemba (19 MCM)
				Rare (36 MCM)	Rare (36 MCM)	Rare (36 MCM)	Rare (36 MCM)	Rare (36 MCM)
				Ruiru2 (8 MCM)	Ruiru2 (8 MCM)	Ruiru2 (8 MCM)	Ruiru2 (8 MCM)	Ruiru2 (8 MCM)
				Stony Athi (23 MCM)	Stony Athi (23 MCM)	Stony Athi (23 MCM)	Stony Athi (23 MCM)	Stony Athi (23 MCM)
								Munyu (575 MCM)
								Galana (498 MCM)
	Hydropower		Thwake (40 MW)	Thwake (40 MW)	Thwake (40 MW)	Thwake (40 MW)	Thwake (40 MW)	Thwake (40 MW)
			Mwache (34 MW)	Mwache (34 MW)	Mwache (34 MW)	Mwache (34 MW)	Mwache (34 MW)	Mwache (34 MW)
								Munyu (40 MW)
	Intra-basin transfers	Kikuyu Springs (1.5 MCM/a)	Kikuyu Springs (1.5 MCM/a)	Kikuyu Springs (1.5 MCM/a)	Kikuyu Springs (1.5 MCM/a)	Kikuyu Springs (1.5 MCM/a)	Kikuyu Springs (1.5 MCM/a)	Kikuyu Springs (1.5 MCM/a)
		Ruiru Dam (8.3 MCM/a)	Ruiru Dam (8.3 MCM/a)	Ruiru Dam (8.3 MCM/a)	Ruiru Dam (8.3 MCM/a)	Ruiru Dam (8.3 MCM/a)	Ruiru Dam (8.3 MCM/a)	Ruiru Dam (8.3 MCM/a)
		Bathi Dam	Bathi Dam	Bathi Dam	Bathi Dam	Bathi Dam	Bathi Dam	Bathi Dam
		Mzima Springs (12.8 MCM/a)	Mzima Springs (12.8 MCM/a)	Mzima Springs (38 MCM/a)	Mzima Springs (38 MCM/a)	Mzima Springs (38 MCM/a)	Mzima Springs (38 MCM/a)	Mzima Springs (38 MCM/a)
		Tiwi aquifer (4.7 MCM)	Tiwi aquifer (4.7 MCM)	Tiwi aquifer (7.3 MCM)	Tiwi aquifer (7.3 MCM)	Tiwi aquifer (7.3 MCM)	Tiwi aquifer (7.3 MCM)	Tiwi aquifer (7.3 MCM)
		Marere Boreholes (2.9 MCM/a)	Marere Boreholes (2.9 MCM/a)	Marere Boreholes (4.4 MCM/a)	Marere Boreholes (4.4 MCM/a)	Marere Boreholes (4.4 MCM/a)	Marere Boreholes (4.4 MCM/a)	Marere Boreholes (4.4 MCM/a)
		Baricho Wellfield (30.3 MCM/a)	Baricho Wellfield (30.3 MCM/a)	Baricho Wellfield (44 MCM/a)	Baricho Wellfield (44 MCM/a)	Baricho Wellfield (44 MCM/a)	Baricho Wellfield (44 MCM/a)	Baricho Wellfield (44 MCM/a)
								Galana dam

Category	Type	Scenario						
		0	1	2A	2B	3A	3B	3C
Water resources development	Inter-basin transfers to Athi Basin	Tana - Thika (160 MCM/a)	Tana - Thika (160 MCM/a)	Tana - Thika (160 MCM/a)	Tana - Thika (160 MCM/a)	Tana - Thika (160 MCM/a)	Tana - Thika (160 MCM/a)	Tana - Thika (160 MCM/a)
		Tana - Sasamua (21 MCM/a)	Tana - Sasamua (21 MCM/a)	Tana - Sasamua (21 MCM/a)	Tana - Sasamua (21 MCM/a)	Tana - Sasamua (21 MCM/a)	Tana - Sasamua (21 MCM/a)	Tana - Sasamua (21 MCM/a)
			Tana - NCT Phase 1 (57 MCM/a)	Tana - NCT Phase 1 (57 MCM/a)	Tana - NCT Phase 1 (57 MCM/a)	Tana - NCT Phase 1 (57 MCM/a)	Tana - NCT Phase 1 (57 MCM/a)	Tana - NCT Phase 1 (57 MCM/a)
				Tana - AWSB phase 4 (105 MCM/a)	Tana - AWSB phase 4 (105 MCM/a)	Tana - AWSB phase 4 (105 MCM/a)	Tana - AWSB phase 4 (105 MCM/a)	Tana - AWSB phase 4 (105 MCM/a)
	Small scale irrigation (ha)	62 544	62 649	62 649	62 649	62 649	62 649	62 649
	Large scale irrigation (ha)	Galana Kulala (2 000 ha)	Galana Kulala (2 000 ha)	Galana Kulala (163 100 ha)	Galana Kulala (163 100 ha)	Galana Kulala (40 800 ha)	Galana Kulala (40 800 ha)	Galana Kulala (16 300 ha)
			Mwache (2 000 ha)	Taita Taveta (3 800 ha)	Taita Taveta (3 800 ha)	Taita Taveta (2 300 ha)	Taita Taveta (2 300 ha)	Taita Taveta (2 300 ha)
			Kibwezi (40 000 ha)	Kilimanjaro (1 500 ha)	Kilimanjaro (1 500 ha)	Kilimanjaro (700 ha)	Kilimanjaro (700 ha)	Kilimanjaro (700 ha)
				Kibwezi (40 000 ha)	Kibwezi (40 000 ha)	Kibwezi (20 000 ha)	Kibwezi (20 000 ha)	Kibwezi (15 000 ha)
				Kanzalu (15 000 ha)	Kanzalu (15 000 ha)	Kanzalu (9 000 ha)	Kanzalu (9 000 ha)	Kanzalu (9 000 ha)
				Mwache (2 000 ha)	Mwache (2 000 ha)	Mwache (2 000 ha)	Mwache (2 000 ha)	Mwache (2 000 ha)
	Small dams/pans (MCM)	12	12	12	12	127	127	127
	Groundwater use (MCM/a)	383	383	458	458	549	549	549
Environment	Ecological reserve	No	No	Q95	Q95	Q95	Eflows	Q95
Catchment	Forests	Current	10% reduction	10% reduction	10% reduction	10% improvement	10% improvement	10% improvement
	Erosion risk - sediment (million t/a)	15 320	16 844	16 844	16 844	13 755	13 755	13 755
Climate	Climate change	No	Yes	Yes	No	Yes	Yes	Yes
Water demand (MCM/a)	- Irrigation	1 028	1 780	5 496	5 396	1 869	1869	1 416
	- Domestic/Industrial	490	1 137	1 137	1 137	949	949	949
	- Other	35	77	77	77	77	77	77
	Total	1 553	2 994	6 710	6 610	2 895	2 895	2 442

5.6 Scenario analysis

5.6.1 Definition and quantification of indicators

Within the context of water resources management scenario evaluation, indicators are required to quantify and simplify information in a manner that facilitates an understanding of impacts related to water resource interventions. Typically, their aim is to assess how interventions affect the direction of change in environmental, social and economic performance, and to measure the magnitude of that change. Evaluation criteria are then defined through a single or combined set of indicators, which have been identified and quantified during scenario planning and appraisal and which forms the basis of scenario evaluation. The selection and specification of indicators is a core activity during the evaluation of water management interventions as it drives all subsequent data collection, analysis and reporting tasks.

Table 5-6 provides a categorisation of indicators based on the typical structure of the results-based approach to project design and management, where indicators are used to quantify or measure results of project interventions or actions. Impact and Outcome indicators, which are used for 'results' monitoring and evaluation, are typically most relevant for water resources planning. The indicators which were defined for the multi-criteria analysis, which was done as part of the development of the basin plans, can be classified as Impact, Outcome and Output indicators.

Table 5-6: Structured indicators for evaluation of water management interventions

<table>
<tr><th>Category</th><th colspan="3">Type of Measurement</th></tr>
<tr><td>Impact indicators:
measures of medium or long-term physical, financial, institutional, social, environmental or other developmental change that the project is expected to contribute to.</td><td rowspan="2">Leading indicators:
advance measures of whether an expected change will occur for outcomes and impacts.</td><td rowspan="5">Cross-cutting indicators:
measures of crosscutting concerns at all levels.</td><td rowspan="5">Exogenous or external indicators:
measures of necessary external conditions that support achievement at each level.</td></tr>
<tr><td>Outcome indicators:
measures of short-term change in performance, behaviour or status of resources for target beneficiaries and other affected groups.</td></tr>
<tr><td>Output indicators:
measures of the goods and services produced and delivered by the project.</td><td rowspan="3"></td></tr>
<tr><td>Process indicators:
measures of the progress and completion of project activities within planned work schedules.</td></tr>
<tr><td>Input indicators:
measures of the resources used by the project.</td></tr>
</table>

Table 5-7 lists the indicators used for the evaluation of scenarios in this analysis. The indicators are categorised as environmental, social or economic indicators and are quantified based on response functions. These functions quantify how interventions affect the direction of change in environmental, social and economic performance, and measure the magnitude of that change through defined relationships or linkages between water resource driven processes (i.e. model outputs) and impacts or benefits. Typically, these response functions are based on empirical relationships derived from observed data, physically based conceptual models which describe indicator responses in relation to physical parameters or statistical indices or relevant values extracted from output time series.

Table 5-7: Indicators used for scenario evaluation

Type	Category		Indicator	
Environment (EN)	1	Footprint	1	Environmentally sensitive area
			2	Carbon emissions
	2	Downstream	1	Floodplain inundation
			2	Ecological stress
			3	Wet season duration
	3	Water quality	1	Phytoplankton growth potential
			2	Aquatic macrophytes growth potential
Social (SL)	1	Water availability	1	Riparian users
	2	Community health and safety	1	Malaria susceptibility
	3	Food security / livelihoods	1	Commercial irrigation
			2	Recession agriculture
			3	Fish production – dams
			4	Fish production – river
			5	Productive land use
			6	Access to natural resources
	4	Displacement	1	Physical displacement
Economic (EC)	1	Energy	1	Energy generated (hydropower)
	2	Food production	1	Crop production
			2	Fish production – dams
	3	Water supply ratio	1	Urban supply
			2	Rural supply
			3	Large-scale irrigation supply
			4	Small-scale irrigation supply
	4	Flood damage	1	Flood reduction benefit
	5	Macro-economic	1	Employment: Commercial irrigation
			2	Employment: Hydropower
			3	Health costs: Water quality
			4	Contribution to GDP
	6	Sediment	1	Sediment load

More detail regarding the categorisation and quantification of individual indicators are provided in **Annexure A6** and **Annexure A7**.

5.6.2 Multi-criteria analysis

To assess relative impacts and benefits related to the defined water resources development scenarios, the indicator values at pre-determined locations within the basin for each scenario, were combined into three criteria groups representing the three dimensions of sustainability viz. Environmental, Social and Economic.

Table 5-8 describes how the criteria were determined from the indicators, which were then used to compare and evaluate different combinations of scenarios using multi-criteria analysis.

Table 5-9 indicates the evaluation criteria as calculated for each scenario of the Athi Basin, with each criterion ranked with a green (best) to orange (worst) colour scale.

By assigning weights to criteria categorised under the three dimensions of sustainability, it was possible to assess the relative impacts and benefits of scenarios in relation to these three dimensions. Table 5-10 indicates the weightings used per sustainability dimension. The multi-criteria analysis was based on the unit vector normalisation method, while ordinal ranking was used for weighting. In ordinal ranking, the order of ranking assigned to criteria is important, while the absolute differences between criteria values is not, due to it being disproportionate and/or difficult to quantify. The indicator analysis provides a wide array of indicators, which cannot be assessed against each other; thus, ordinal ranking was the suitable option.

Table 5-8: Criteria used for scenario evaluation

Type	Criteria				
	Category	Name	Units	Description	Indicator ID
ENVIRONMENT	Footprint Areas	Environmentally Sensitive Area	km^2	Summed Environmentally Sensitive Area for all schemes in scenario	1.1
		Carbon emissions (dams / large scale irrigation schemes)	Million tons	Summed Carbon emissions for all schemes (dams / large scale irrigation) in scenario	1.2
	Downstream Areas	Floodplain Area Inundated	% change from Baseline	Average Floodplain Area Inundated downstream all schemes in scenario	2.1
		Ecological Stress	Index (-5 to 0)	Average Ecological Stress downstream all schemes in scenario	2.2
		Wet Duration	% change from Baseline	Average Wet Duration downstream all schemes in scenario	2.3
	Water Quality	Phytoplankton growth potential	%	Average Phytoplankton growth potential of all dams in scenario	3.1
		Aquatic macrophytes growth potential	Index (-5 to 5)	Average Aquatic macrophytes growth potential of all large scale irrigation schemes in scenario	3.2
SOCIAL	Water Availability	Change in availability of water for riparian users: domestic consumption, subsistence agriculture and livestock	% change from Baseline	Average Change in water availability for riparian users downstream all schemes in scenario	1.1
	Community Health and Safety	Susceptibility of development scheme areas in basin to malaria	km^2	Summed Susceptible malaria area of all schemes in scenario	2.1
	Food security and Livelihoods	Establishment of formal, commercial irrigation schemes in basin	km^2	Summed Irrigation scheme footprint areas in scenario	3.1
		Impact on recession agriculture due to changes in flow regime - floodplain inundation	% change from Baseline	Average Impact on recession agriculture downstream all schemes in scenario	3.2
		Fish production in all dams	ton/annum	Summed Fish production in all dams in scenario	3.3
		Change in fish productivity along river reaches in basin	% change from Baseline	Average Change in fish productivity along river reach downstream all schemes in scenario	3.4
		Productive land use for crops, grazing inundated by dam or lost due to development of schemes in basin	km^2	Summed Productive land use lost due to establishment of all dams and irrigation schemes in scenario	3.5
		Loss of access to natural resources due to development of schemes in basin	km^2	Summed Loss of natural resources due to establishment of all dams and irrigation schemes in scenario	3.6
	Displacement	Physical displacement of population due to development schemes in basin	Population	Summed Physical displacement due to estabishment of all dams and irrigation schemes in scenario	4.1
ECONOMIC	Energy	Average Energy generated by hydropower in basin	GWh/annum	Summed Average energy for scenario	1.1
	Food production	Crop production in basin	million ton/annum	Summed Crop production for scenario	2.1
		Fish production - dams	ton/annum	Summed Fish production in all dams in scenario	2.2
	Water supply	Percentage of urban demand supplied	%	Average Percentage urban demand supplied in scenario	3.1
		Percentage of rural demand supplied	%	Average Percentage domestic demand supplied in scenario	3.2
		Percentage of large scale irrigation demand supplied	%	Average Percentage large scale irrigation demand supplied in scenario	3.3
		Percentage of small scale irrigation demand supplied	%	Average Percentage small scale irrigation demand supplied in scenario	3.4
	Flood control	Flood control potential	Ratio	Basin wide flood reduction benefit	4.1
	Employment	Jobs created through establishment of formal, commercial irrigation schemes	No. jobs	Summed Jobs created through establishment of formal, commercial irrigation schemes in scenario	5.1
		Jobs created through energy generation of hydropower plants	No. jobs	Summed Jobs created through energy generation of hydropower plants in scenario	5.2
	Pollution cost	Health related costs of phytoplankton growth, aquatic macrophyte growth and urban pollution	Ratio of baseline	Equal to Pollution cost indicator	5.3
	Macro-economic	Impact on GDP	Ratio of baseline	Equal to Macro-economic indicator	5.4
	Sediment	Sediment potential index	Ratio of baseline	Equal to Sediment indicator	6.1

Table 5-9: Scenario evaluation criteria

Dimension	Category	Criteria	Unit	SC0	SC1	SC2A	SC2B	SC3A	SC3B	SC3C
ENVIRONMENT	Footprint areas	Environmentally sensitive areas	Area (km^2)	n/a	153	928	928	269	269	160
		Carbon emissions dams	tons	n/a	30525	56029	56029	56029	56029	169071
		Carbon emissions LIR	tons	n/a	839543	3834902	3834902	1215358	1215358	719200
	Downstream areas	Floodplain area inundated	% change from baseline	n/a	0.2	-53.0	-58.9	-42.2	26.2	11.0
		Ecological stress	Index (-5 to 0)	n/a	-2.6	-3.5	-3.8	-3.3	-3.4	-4.8
		Wet duration	% change from baseline	n/a	-1.1	-21.9	-28.4	-14.0	-17.3	152.8
	Water quality	Phytoplankton growth potential	Average growth potential %	58.6	93.4	71.1	70.7	72.5	85.9	77.5
		Aquatic macrophytes growth potential	Index (-5 to 0)	-0.8	-0.8	-2.7	-2.7	-1.8	-1.3	-1.5
SOCIAL	Water availability	Change in availability of water for riparian users	% change from baseline	n/a	-2.1	-1.1	-2.8	5.6	25.9	30.0
	Community health and safety	Malaria endemicity	Malaria endemicity (km^2)	3	53	319	319	106	106	72
	Food security and livelihoods	Formal irrigation schemes	Area (km^2)	20	440	2254	2254	747	747	452
		Impact on recession agriculture	% change from baseline	n/a	0.2	-53.0	-58.9	-42.2	26.2	11.0
		Fish production (dams/lakes)	tons/annum	19	211	426	385	470	401	766
		Change in fish productivity	% change from baseline	n/a	-1.1	-21.9	-28.4	-14.0	-17.3	152.8
		Loss of productive land	Area (km^2)	n/a	1754	15449	15449	6363	6363	58
		Loss of natural resources	Area (km^2)	n/a	153.5	928	928	269	269	160
	Displacement	Physical displacement	Number people	n/a	12927	42469	42469	27661	27661	28595
ECONOMIC	Energy	Avg energy	GWh/annum	0	93	83	81	81	99	79
	Food production	Crop production (formal irrigation)	Million ton/annum	0.0	0.2	1.7	1.8	1.1	0.9	0.9
		Fish production (dams/lakes)	tons/annum	19	211	426	385	470	401	766
	Water supply	Urban water supply	Ratio	0.67	0.52	0.68	0.70	0.78	0.71	0.86
		Domestic water supply	Ratio	0.77	0.75	0.76	0.75	0.76	0.60	0.80
		Formal irrigation water supply	Ratio	0.59	0.54	0.42	0.45	0.56	0.42	0.64
		Small-scale irrigation water supply	Ratio	0.56	0.53	0.51	0.51	0.54	0.43	0.80
	Employment	Employment formal irrigation	Jobs/annum	4000	88000	450700	450700	186765	186765	113108
		Employment hydropower	Jobs/annum	0	186	166	162	202	246	197
	Pollution costs	Pollution cost index related to dams and formal irri	Ratio of baseline	1.0	1.2	1.5	1.5	1.4	1.4	1.3
	Sediment	Sediment potential index	Ratio of baseline	1.00	1.10	1.10	1.10	0.90	0.90	0.90
	Primary GDP	GDP index	Ratio of baseline	1.0	43.4	43.9	43.9	44.4	44.1	70.2
	Flood control	Flood control potential	Ratio	0.00	0.49	0.49	0.49	0.49	0.49	0.80

Table 5-10: Criteria weightings

Dimension	Category	Criteria	ECON	ENV	SOC
ENVIRONMENT	Footprint areas	Environmentally sensitive areas	28	1	30
		Carbon emissions dams	29	2	29
		Carbon emissions LIR	30	3	28
	Downstream areas	Floodplain area inundated	24	4	27
		Ecological stress	26	5	25
		Wet duration	25	7	26
	Water quality	Phytoplankton growth potential	27	6	24
		Aquatic macrophytes growth potential	23	8	23
SOCIAL	Water availability	Change in availability of water for riparian users	22	11	18
	Community health and safety	Malaria endemicity	21	17	11
	Food security and livelihoods	Formal irrigation schemes	18	13	1
		Impact on recession agriculture	20	12	10
		Fish production (dams/lakes)	14	15	2
		Change in fish productivity	19	14	4
		Loss of productive land	16	10	14
		Loss of natural resources	17	9	15
	Displacement	Physical displacement	15	16	16
ECONOMIC	Energy	Avg energy	10	28	12
	Food production	Crop production (formal irrigation)	8	26	13
		Fish production (dams/lakes)	9	23	9
	Water supply	Urban water supply	2	19	6
		Domestic water supply	3	20	8
		Formal irrigation water supply	4	21	20
		Small-scale irrigation water supply	12	22	19
	Employment	Employment formal irrigation	5	24	5
		Employment hydropower	6	25	3
	Pollution costs	Pollution cost index related to dams and formal irrigation schemes	7	18	21
	Sediment	Sediment potential index	13	30	22
	Primary GDP	GDP index	1	27	7
	Flood control	Flood control potential	11	29	17

5.7 Scenario evaluation

5.7.1 Sustainable development pathway

The objective of this evaluation was to compare the benefits and impacts under four development scenarios: Scenario 1, where there is significant growth in water demand without investment in water resources infrastructure vs. Scenario 2A, which involves full development in water resources infrastructure and irrigation as per existing plans vs Scenarios 3A and 3C, which aim for more sustainable development.

The results of the analysis are summarised in Table 5-11.

- Scenarios 3A and 3C in general rank above Scenarios 1 and 2A from an Economic and Social perspective, which confirms Scenario 3 as the sustainable development pathway, i.e. maximum economic benefit, without unsustainable social footprints. Both Scenarios 3A and 3C include reduced water demands, which highlights the importance of improved water demand management in the Athi Basin
- Scenario 3C scores the highest from an Economic, Environmental and Social perspective. It is similar to Scenario 3A, except that water supply reliability to Nairobi, Mombasa and the coastal towns is improved. This Scenario includes Munyu dam, which increases the supply reliability to Nairobi and Kanzalu Irrigation Scheme, as well as Galana Dam as a solution to improve the supply reliability of Galana Kulalu Irrigation Scheme and Mombasa. The supply reliability of Mombasa is improved due to the storage along the lower Sabaki River as well as an increased transfer capacity from the Baricho well field. The improved regulation of flows in the rivers, especially during the dry season, ensures that minimum environmental flows are met.
- There is a low Environmental score under Scenario 2A, which confirms the significant environmental impacts of the very large areas of commercial irrigation and flow regulation proposed under this scenario.

- The business as usual (Scenario 1) as well as full development (Scenario 2A) scenarios score lowest under Economic, mainly due to the impacts of increased water demands without investment in infrastructure (Scenario 1) and the overdevelopment of irrigation (Scenario 2A).

Table 5-11: Scenario scores and ranking for the business as usual, full development and sustainable development scenarios

	ECON	ENV	SOC
SC1	0.451	0.573	0.459
SC2A	0.418	0.317	0.412
SC3A	0.458	0.496	0.459
SC3C	0.588	0.678	0.638
SC1	4	2	2
SC2A	3	4	4
SC3A	2	3	3
SC3C	1	1	1

The evaluation of development and management scenarios provided useful information towards informing the strategy for the sustainable development of water resources in the Athi Basin. The main outcomes of the scenario evaluation with relevance to water resources development in the basin are summarised below:

- Urban centres are currently experiencing issues with regard to supply reliability. The priority for the development of water resources in the Athi Basin should therefore concern water supply to Nairobi and its surrounding areas as well as to Mombasa and the coastal towns.
- Interventions towards improving water availability and assurance of supply to urban users should include a combination of new storage dams, new and/or upgrades to existing inter- and intra-basin transfers, water demand management measures, conjunctive use and potentially the development of non-conventional water resources e.g. desalination, re-use, rainwater harvesting etc.
- Projected water demands in Nairobi and in the Mombasa areas are expected to increase significantly. Urgent interventions are required to supply the projected water demands.
- The projected future water demands of Nairobi and its satellite towns significantly exceed the water available in the upper Athi Basin and it is imperative that further phases of Tana Transfers are implemented timeously, while there is a need for additional storage in the upper Athi Basin. Munyu Dam on the upper Athi River, as an alternative to Ndarugu 1 Dam, should be considered as a main storage dam for Nairobi to ensure a high reliability of supply. The dam would still be able to supply to the Kanzalu Irrigation Scheme – however as a 2nd priority and at a reduced area.
- The projected future water demands of Mombasa and the surrounding coastal towns could be met through significant expansion of existing groundwater supply sources, and through the utilisation of surface water sources which will require the construction of dams. The potential impacts of future major dams in the upper and middle Athi Basin and increased abstractions from Mzima Springs on the future yield of the Baricho Wellfield was found to be significant. To overcome this challenge, it is proposed that the construction of Galana Dam goes ahead and that the dam is not only used to supply the proposed Galana Kulalu Irrigation Scheme, but that it is utilised as an additional water resource to supply Mombasa.
- To improve current and future reliability of supply to towns and rural settlements outside of the major urban centres, for livestock as well as for supply of small-scale irrigation, new or additional storage (dams and pans), as well as local groundwater development need to be promoted.
- The current extent of planned large-scale irrigation development in the Athi Basin should be significantly reduced taking into consideration the available water in the basin. Only limited large-scale irrigation development within the Athi Basin can be accommodated, as it is constrained by the availability of water. With large-scale irrigation taking preference over small scale irrigation, there is limited water available for expansion of small-scale irrigation.

- Although climate change is expected to result in increased temperatures in the Basin, average net irrigation demand across the basin is not significantly impacted by climate change, due to increased crop water requirements (increased potential evapotranspiration) being offset to some extent by increased rainfall in the basin under future climate change scenarios, especially in the upper, western part of the basin.
- It is imperative that water demand management is implemented in all urban areas, while irrigation efficiencies should also be improved.
- The availability of water for use within the basin will be severely impacted by the introduction of variable minimum environmental flows as opposed to the current Q95 minimum constant flow. Careful consideration should be given to resource classification and how this will impact water resources availability.

5.7.2 Climate change impact analysis

The objective of this evaluation was to assess the impacts of climate change under the two full development scenarios: Scenario 2A, which includes climate change vs Scenario 2B, which excludes climate change.

The results of the analysis are summarised in Table 5-12.

- Scenario 2A (with climate change), ranks above Scenario 2B (without climate change) from a Social, Economic and Environmental perspective. This is expected due to the anticipated increased rainfall in the basin under Scenario 2A, which will increase runoff in the Basin. Although climate change is expected to result in increased temperatures in the Basin, the water resources modelling showed that average irrigation demand across the basin is not significantly impacted by climate change impacts due to the increased crop water requirements (increased potential evapotranspiration) being offset by increased rainfall to some extent.

Table 5-12: Scenario scores and ranking for the climate change comparison

	ECON	ENV	SOC
SC2A	0.621	0.572	0.669
SC2B	0.548	0.393	0.549
SC2A	1	1	1
SC2B	2	2	2

Climate change is expected to result in increased rainfall and temperatures, however, the net impact will be more water availability even with increased irrigation demands. Climate change is thus anticipated to have a positive impact on the Athi Basin from a water resources perspective, although it is still important to mitigate climate risks and improve resilience at relevant scales within the basin.

5.7.3 Environmental flow impact analysis

The objective of this evaluation was to compare the benefits and impacts on water availability of imposing the first order EFlows as determined during this Consultancy as opposed to the Q95 environmental flows under the sustainable development scenario: Scenario 3A with Q95 as minimum environmental flow vs. Scenario 3B with EFlow holding flows.

The results of the analysis are summarised in Table 5-13.

- The impact of the EFlows from an Economic perspective is evident and Scenario 3B scores lower than Scenario 3A for this category. Under Scenario 3B, the minimum flows in the rivers are significantly greater; however, this results in lower storage volumes in the dams, reducing the supply reliability of the urban and irrigation demands. As a result, crop production and assurance of supply to urban users are impacted negatively.

- Scenario 3A scores lower than Scenario 3B from an Environmental perspective. This is expected as the Q95 constant environmental flow is not sufficient to mimic the natural flow in the rivers, which leads to a deterioration of river health with associated environmental impacts.
- Scenario 3A scores lower than Scenario 3B from a Social perspective. Even though the water supply to urban and domestic water users is somewhat less in Scenario 3B, the water availability in rivers will be higher due to the larger EFlow releases; thus, providing more water to riparian users downstream of dams.

Table 5-13: Scenario scores and ranking for the environmental flow comparison

	ECON	ENV	SOC
SC3A	0.589	0.456	0.604
SC3B	0.585	0.529	0.627
SC3A	1	2	2
SC3B	2	1	1

Although the EFlow scenario ranked higher than the Q95 scenario in all dimensions, careful consideration should be taken for the implementation of environmental flows. The current Water Act (No. 43 of 2016) stipulates the implementation of Q95 as the minimum flow. The availability of water for use within the basin will be severely impacted by the introduction of variable minimum environmental flows as opposed to the current Q95 minimum constant flow. Careful consideration should be given to resource classification and how this will impact the availability of water resources.

Image source: H. Fiebig 'Mwea National reserve'. Available online at https://thetreasureblog.wordpress.com/mwea-national-reserve-35/

06

Key Strategies and Themes

6 Key Strategies and Themes

6.1 Introduction

The key aim of the Athi Basin Plan is to provide a clear way forward for the integrated management and development of the water resources of the Athi Basin as a pathway towards a future which achieves a sustainable balance between utilisation and development of water resources and the protection of the natural environment, i.e. minimising environmental and social impacts and maximising socio-economic benefits, taking into consideration the availability of water.

To comprehensively and systematically address the range of water resources related issues and challenges in the Athi Basin and to unlock the value of water as it relates to socio-economic development, ten Key Strategic Areas (KSAs) were formulated for the Athi Basin as presented in Table 6-1.

Table 6-1: Key Strategic Areas and Objectives

Key Strategic Area		Strategic Objective
1	Catchment Management	To ensure integrated and sustainable water, land and natural resources management practices
2	Water Resources Protection	To protect and restore the quality and quantity of water resources of the basin using structural and non-structural measures
3	Groundwater Management	The integrated and rational management and development of groundwater resources.
4	Water Quality Management	Efficient and effective management of water quality to ensure that water user requirements are protected in order to promote sustainable socio-economic development in the basin
5	Climate Change Adaptation	To implement climate change mitigation measures in the water resources sector and to ensure water resource development and management are adapted and resilient to the effects of climate change.
6	Flood and Drought Management	To establish and guide a structured programme of actions aimed at ensuring the prevention of, mitigation of, timeous response to, and recovery from, the harmful impacts of floods and droughts across the Basin or specific catchment area.
7	Hydromet Monitoring	An operational and well-maintained hydromet network supported by effective and functional data management and information management systems
8	Water Resources Development	To develop water resources as a key driver for sustainable economic and social development
9	Strengthened Institutional frameworks	To achieve an appropriate balance between operational functionality and the need for effective oversight and governance.
10	Enabling environment	To enhance human and institutional capacities for sustainable management of the water, land, ecosystems and related resources

The KSAs are discussed in detail in the following sections in terms of the current status, context, challenges and constraints, and current best practice as applicable, with themes and strategies specific to each KSA being presented.

Implementation Plans for the KSAs (refer to **Annexure E**) constitute the next step towards implementation of the strategies and themes under each KSA and are discussed in Section 7.

6.2 Catchment Management

6.2.1 Introduction

Water resources degradation is intimately linked to land degradation and influenced by various catchment management and land use factors. Implementing effective catchment management therefore requires a bigger picture perspective and an understanding of the role of natural resource use within a water resources context. People, animals and plants constitute those components of a catchment that make use of the physical resources of land and water. Misuse of these resource elements will therefore lead to unstable natural and social systems, often resulting in further land and water degradation. Integrated catchment management acknowledges the relationships between households, villages, communities and the broader catchment and envisages that individuals take ownership of their role in catchment management - as opposed to a top-down approach lead by legislation and regulations. This is the cornerstone of Integrated Water Resources Management. A key issue in many catchments in Kenya relates to the influence of population pressures on the existing landscape-biodiversity dynamics. With an increasing demand for natural resources and under the influence of historic-political and socio-economic drivers, the human footprint has pushed many natural systems beyond a stable threshold. Any disruption to the natural system impacts the human population, more so in rural areas where communities still live and work very closely to the natural environment.

The objective of catchment management is to enable communities, county governments and other relevant governing bodies and institutions to implement integrated catchment management interventions through increased knowledge. As water is the common link among resource users in a catchment, it is appropriate that the catchment is used as a planning unit for resource management. Integrated catchment management is aimed at deriving the greatest possible mix of sustainable benefits for future generations and the communities in a catchment, whilst protecting the natural resources upon which these communities rely. This approach seeks to maintain a balance between the competing pressures exerted by the need to maintain natural resources in the long-term, against the need for continuous economic growth and use of these resources.

6.2.2 The key principles of Catchment Management

Land and water degradation, together with the subsequent impacts on users, cannot easily be separated or managed independently of one another. The utilisation and management of land and water resources should thus be done in an integrated manner in order to ensure the sustainability of both.

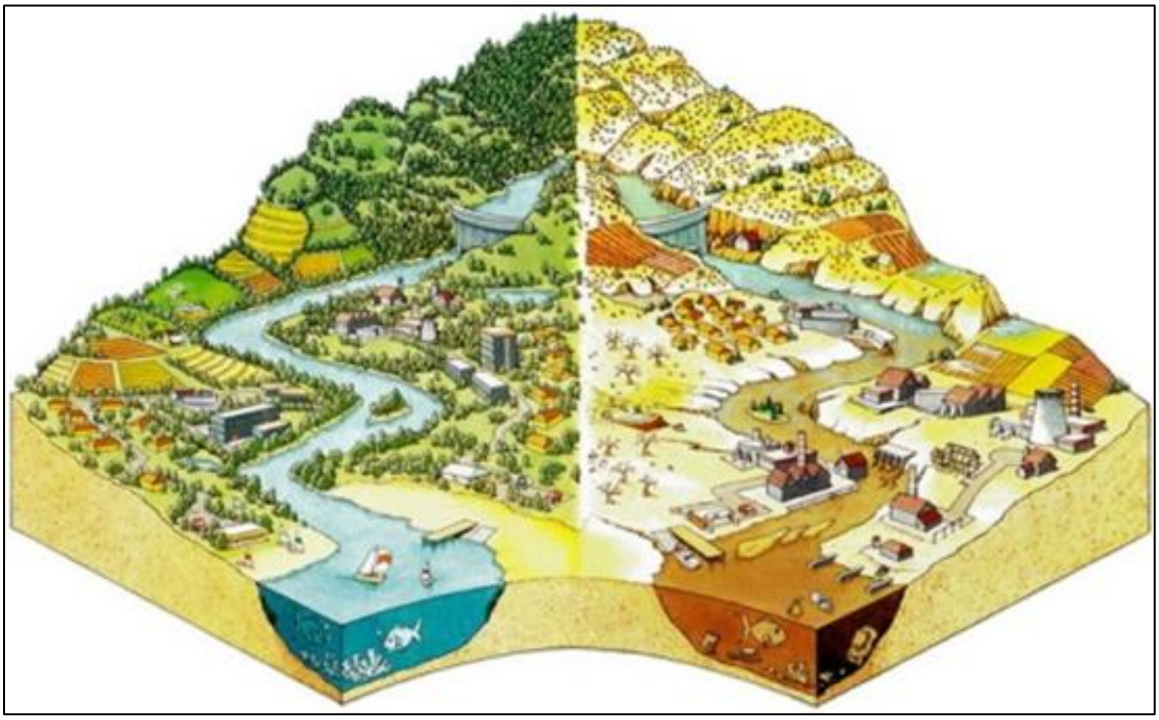


Figure 6-1: Illustration of good (left) and poor (right) state of land and water resources in a catchment

Land degradation is not just the physical degradation of the soil, but the disturbance of the biophysical environment through human activity. This occurs through activities such as overgrazing, deforestation, alien invasive infestation, poor solid waste management and other similar disruptive actions, and leads to a disturbance of the natural system, which in some cases pushes a system beyond a critical threshold. The impacts of land degradation are long-term and damaging to not only the biophysical environment, but also the socio-economic environment of communities. A loss of soil fertility will lead to low crop yields, which in turn lead to food shortages and reduced income generation, whilst increased runoff due to exposed soil and soil erosion leads to gully erosion and sedimentation of water bodies, leading to biodiversity threats and water resources depletion and degradation, and a reduced capacity to use the water resource e.g. for irrigation or hydropower. In general, the impact that is readily felt in rural communities is a reduced standard of living, which leads to chronic poverty.

Soil degradation (the long-term decline on soil productivity) is exacerbated through the physical decline in soil structure or through accelerated erosion via water and wind. Soil, termed sediment once eroded, also becomes a significant non-point pollution source for water resources. Soil erosion and sedimentation is one of the biggest problems facing mankind globally due to the serious environmental, economic and social consequences, including loss of productive land, siltation of reservoirs, reduction of water quality for human use and impacts on aquatic ecosystems.

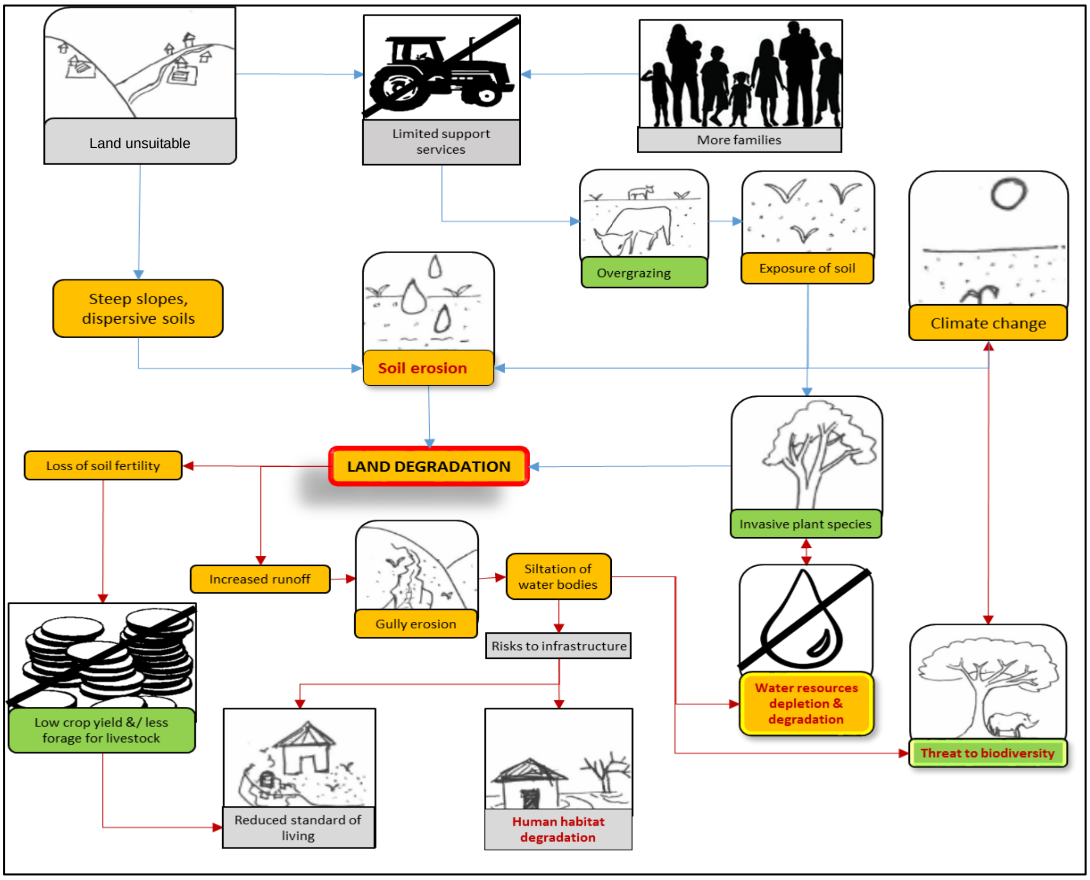


Figure 6-2: An example of the interconnected links of land degradation

The above implies that a co-ordinated and integrated approach and actions are required across all scales of a catchment and through all levels of catchment management - from individual land users, through local and regional structures to national level. Integrated Catchment Management addresses soil, water, biodiversity and people issues at a catchment scale as shown in Figure 6-3.

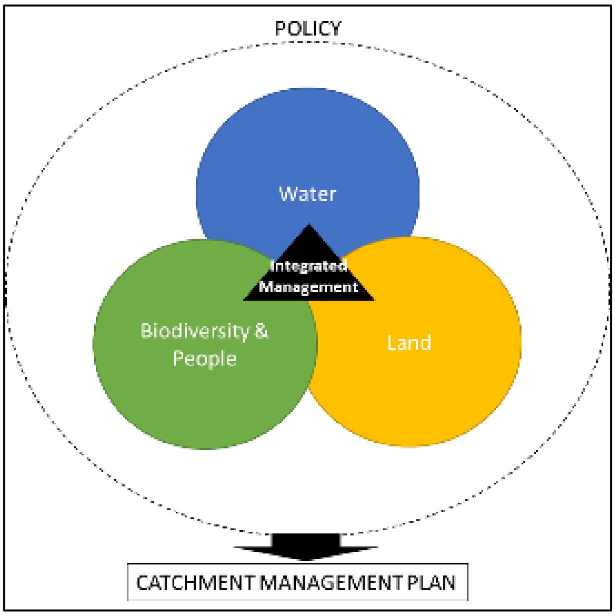


Figure 6-3: The interaction of different management strategies for Catchment Management

In its widest possible sense, Integrated Catchment Management recognises the need to integrate all environmental, economic and social issues within a catchment (at any scale) into an overall management philosophy, process and strategy or plan. It is thus aimed at deriving the greatest possible outcome of sustainable benefits for future generations and the communities in the area of concern whilst protecting the natural resources upon which these communities rely. Often, water resource management paradigms have assumed that sustainability of water resources can be achieved merely through focused efforts to control water use and protect the integrity of water resources within a catchment context. However, in more recent times it has been acknowledged that this approach ignores the complex issues of land use patterns and the varied roles played by stakeholders, which impact on the water use and water resources. In order to achieve integrated catchment management and derive the best outcome of benefits while protecting resources, requires careful planning, the physical implementation of activities in day to day practices and livelihoods, and a strong legislative, regulatory and institutional framework to support the planning process and implementation.

There are several concepts and principles that are important to integrated catchment management. These are discussed below:

6.2.2.1 Catchment and River Basin Scale

A water resource at a particular location is the product of runoff or groundwater recharge that originates in, and reflects conditions and events throughout, a geographically defined drainage area known as a catchment (“local scale”) or basin (large scale, multiple catchments). The way humans use and abuse land inside the catchment has a decisive impact on the quantity and quality of the water resource and on the health of the aquatic ecosystems reliant on that resource. In this way the hydrological cycle, land-use and aquatic ecosystem functioning form a continuum bounded by the extremities of the catchment. This calls for recognition that naturally occurring water can usually be effectively and efficiently management only within river basin (regional scale management) or catchment (local scale management) boundaries, because of the need to technically account for all aspects of the hydrological cycle, including the way humans change aspects of the cycle by land use.

Figure 6-4 illustrates how water and land use activities overlap in an example catchment.

6.2.2.2 Integrated management

Catchment management is a philosophy, a process and an implementation strategy, to achieve a sustainable balance between utilisation and protection of water resources in a catchment. Catchment management recognises the interdependence of land-use, water and the environment, and aims to manage these components in an integrated manner in order ensure the sustainable utilisation of environmental resources and the protection of such resources.

6.2.2.3 Sustainability

Sustainability in the use and development of natural resources systems means that the system can cope with and recover from stresses and shocks and maintain or enhance its capability and assets both now and in the future, while not undermining the natural resource base. Sustainable use of resources therefore must deliver basic environmental, social and economic services to all residents of a community without threatening the viability of the natural built and social systems upon which the delivery of these systems depends. The key to achieving sustainability is adopting a long-term and forward-looking approach to improving quality of life. This ensures that future and cumulative impacts of current development activities are anticipated and managed for continued productivity. It is generally accepted that sustainable development requires a process and ultimately consensus-building among all stakeholders. This must be inclusive of all role-players, government institutions, stakeholders, clients, non-governmental organisations and community-based organisations as partners who together define the problems, design possible solutions, collaborate to implement them, obtain specific products, and monitor and evaluate the outcome. In some cases, this has been incorporated into “water stewardship” whereby water use is evaluated across the entire value chain and water users are willing to be accountable to a larger group that is operating in a service and working to achieve a fundamental change.

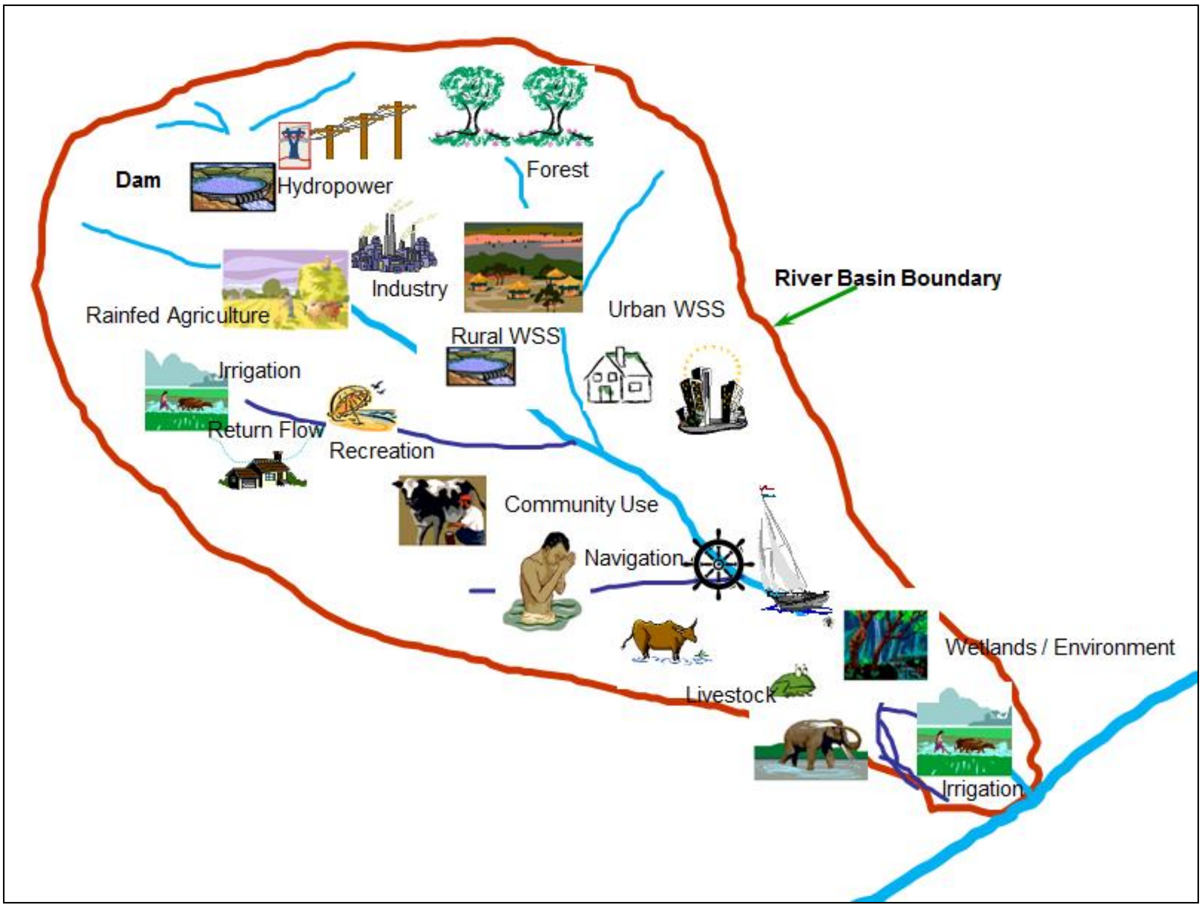


Figure 6-4: Illustration of water and land use activities within a catchment

6.2.2.4 Reasonable utilisation

In order to ensure that natural resources are not depleted or ruined, development must be balanced between economic and social benefits whilst also protecting the resource base that supports these. People want access to more reliable domestic water supply, better sanitation, water for livestock and irrigation, timber and fuel from forests and good soils for productive agriculture. Many of these activities, singly and in combination, can result in adverse impacts on the catchment itself and on the natural resource base of the catchment such as impacts on groundwater recharge, streamflow, flood flows and soil erosion. Water for environmental services especially in wetlands and securing the biodiversity in the plants and wildlife, are all very important to protect and improve the present access to water and land resources. Reasonable utilisation of natural resources must be encouraged so that that development and resource use do not waste or diminish the resource, as for example, discharge of wastewater and pollutants into the catchment.

6.2.3 Key catchment management issues in the Athi Basin

There are always rules, formal/informal, which determine how people access resources and opportunities (Levine & Pavanello, 2012). These rules, and the ways in which they are enforced, constitute 'institutions'. Institutions could relate to the institutions of the state or organised committees following written constitutions, to informal rules of culture and locally accepted figures of authority.

Local-level catchment management strategies address issues that are locally relevant, but depending on the mandate, also legislatively relevant.

Who is responsible for catchment management?

Integrated catchment management requires management of both land and water resources, inclusive of different role players and institutions. Some of the institutions involved are as follows:

- Water resource-based: WRA/BWRC/WRUA
- Land/Agricultural based: AFFA/Extension officers/Pastoralists
- Environmental/Biodiversity based: NEMA/KWTA/KFS/KWS
- Governance based: County government

It is critical that these institutions are aware of each other to achieve sustainable management of the Athi Basin.

6.2.3.1 Water resources-based issues

The Athi Basin is managed by five WRA Sub-regional offices, which manage Catchment Management Units (CMUs) based on hydrological, water resources and land use considerations. Some of the WRA offices in the Athi Basin have jurisdiction over expansive areas. This, combined with the issue of understaffing, makes it difficult to manage the entire area.

Basin Water Resource Committees (BWRCs) are responsible for management of the six main basins in Kenya. However, conflicting mandates for the BWRCs have been identified in the Water Act (2016), where BWRCs are assigned both advisory and management functions. Both scenarios cannot be implemented at the same time without conflicts and thus only one scenario can work. This implies that there is urgent need to remove this ambiguity. WRA's transition committee is currently addressing this issue and the outcome of this process will inform what function will be adopted by the BWRCs.

A CMS was developed for the Athi Basin for the period 2015-2022 (Water Resources Management Authority, 2015b). Section 6 of the strategy focused on catchment protection and conservation for sustainable availability of good quality water. Reducing catchment degradation through soil and water conservation activities and appropriate land use practices was considered an important step. Key issues were identified as soil erosion and sedimentation, unsustainable sand harvesting, loss of vegetation cover, loss of wetlands and pollution from solid waste disposal. It was noted that identification of hotspot areas is an important initial step and that there needs to be periodic monitoring and livelihood support in order to ensure sustainability.

Water Resource User Associations (WRUAs) have been established at a more local level to focus on the operational management within a catchment. These are community based, voluntary associations made up of water users and riparian owners. The WRUAs are formed around Sub-Catchment Areas. These areas require Sub-Catchment Management Plans (SCMPs), developed through access to a grant from the Water Sector Trust Fund or other sources of financing. The SCMP is an IWRM tool for water resource management to support sub-catchment management. The Athi Basin has 150 existing WRUAs out of a potential 309 WRUAs needed to cover the whole basin. The gap of 159 dormant or potential WRUAs needs to be addressed to ensure basin coverage of WRUAs is increased. Even among the existing WRUAs, there are capacity concerns and disparities in levels of development and maturity of the WRUAs. This denotes the need for continued capacity building for the existing WRUAs in addition to continued technical support. SCMPs mainly focus on the management of water and land resources.

Table 6-2: Catchment management institutions local level in the Athi Basin

Upper Athi		
	WRA SR / SRO / CMUs	Upper Athi / Kiambu / Ruiru, Ndarungu Mbatgathi-Nairobi / Nairobi / Mbatgathi-Nairobi
	Issues	Catchment Management Strategy: • Soil Erosion • Sand harvesting • Loss of vegetation cover • Loss of wetlands • Sedimentation • Solid waste pollution
Middle Athi		
	WRA SR / SRO / CMUs	Middle Athi / Kibwezi / Thwake Noltresh-Lumi / Loitokoitok /Tsavo
	Issues	• Loitokoitok office covers the expansive area from Namanga to Taveta. Catchment Management Strategy: • Sand harvesting • Soil Erosion • Loss of vegetation cover • Loss of wetlands • Sedimentation • Solid waste pollution
Lower Athi		
	WRA SR / SRO / CMUs	Coastal-Athi-Mombasa / Mombasa / Coastal zone, Mombasa
	Issues	Catchment Management Strategy: • Soil Erosion • Sand harvesting • Loss of vegetation cover • Loss of wetlands • Sedimentation • Solid waste pollution • Salt water intrusion

6.2.3.2 Land/Agricultural-based issues

Various Directorates under the Agriculture, Fisheries and Food Authority (AFFA) provide technical input and advice to County Governments. The Authority also conducts farmers' training programs aimed at increasing their knowledge on production technologies and prospects for various types of crops, through farmer training institutions. Extension officers are involved in on the ground catchment management activities, particularly for smallholder farmers. These smallholder farmers are most at risk to the impacts of climate change and infertile soils. Conservation agriculture has been promoted as a sustainable alternative for farmers to address the problem of declining soil fertility and provide the dual benefit of enhanced food production and adaptation/resilience to changing climatic conditions (Agriculture and Food Authority, 2017).

Agricultural extension services in Kenya date back to the early 1900s. Agricultural extension services refer to a systematic process of working with producers or communities to help them acquire relevant and useful agriculture or related knowledge and skills to increase farm productivity, competitiveness and sustainability (Agriculture and Food Authority, 2017). Catchment management approaches are promoted through various methods, with a focus on soil and water conservation and conservation agriculture.

Land and water is also important to pastoralists, although the importance of the resource is linked to treating it as common property freely available for all with livestock (Levine & Pavanello, 2012). The management of natural resources is thus inseparable from the management of relationships between the pastoralist clans and ethnic groups. Pastoralists move their herds in seasonal patterns, according to the conditions of each year. This movement is managed to maintain the right balance of species in the best possible condition over the long term through careful control of grazing (Levine & Pavanello, 2012). Management requires a set of rules and requires the right institutional framework. This is mainly set by groups of elders, who constitute customary authorities.

The Agricultural Sector Development Strategy (ASDS) intends to provide a guide for overcoming challenges facing the agricultural sector in Kenya. The ASDS 2010-2020 (Government of Kenya, 2010a) proposes integrated development and management of rangeland due to the climatic changes, coupled with overstocking and degraded environment, having devastating effect on pasture regeneration and pastoralists livelihoods. Rangelands are chronically short of pasture and water (Government of Kenya, 2010a), restoring this will require reseeding and range pitting, bush control, soil conservation and water rehabilitation and development. The ASDS 2010-2020 (Government of Kenya, 2010a) also emphasises the need to rehabilitate and protect water catchments due to issues such as increased runoff, flash floods, reduced infiltration, erosion and siltation, and limited water resource base.

Table 6-3: Land/agricultural institutions at local level in the Athi Basin

Upper Athi		
	AFFA/extension services	Kiambu, Nairobi, Machakos, Kajiado
	Pastoralists	Kiambu, Machakos, Kajiado
	Issues	• High rainfall erosivity, high soil erodibility and decreasing natural forest cover linked to moderate level of erosion • High to moderate sediment yield • Forests and wetlands under threat of encroachment from subsistence agriculture • Poor farming methods, pesticides and chemicals used in agricultural activities led to pollution of rivers and the environment. • Farming of hillslopes and marginal areas • Machakos county used to have contour farming and terracing on farm lands by the Ministry of Agriculture, Livestock and Fisheries, this will now need to be conducted by the county • Farming activities encroaching on wetlands and causing pollution • Real estate development and land use changes without appropriate water resource protection

Middle Athi		
	AFFA/extension services	Kajiado, Makueni, Taita Taveta
	Pastoralists	Kajiado, Makueni, Taita Taveta
	Issues	• Low rainfall erosivity, high soil erodibility and limited vegetation cover linked to high level of erosion • High sediment yield from the loss of vegetation due to farming activities • Amboseli rangelands degraded and land area decreasing • Forests and wetlands under threat of encroachment from subsistence agriculture • Loss of wetlands due to encroachment
Lower Athi		
	AFFA/extension services	Taita Taveta, Kwale, Kilifi, Mombasa
	Pastoralists	Taita Taveta, Kwale, Kilifi,
	Issues	• Low rainfall erosivity, moderately-high soil erodibility and vegetation cover linked to moderate level of erosion • High sediment yield • Forests and wetlands under threat of encroachment from subsistence agriculture

6.2.3.3 Environmental/biodiversity-based issues

The National Environmental Management Authority (NEMA) has Environmental Committees who provide technical support for environmental management and provide input to county integrated development plans. The Kenya Water Towers Agency (KWTA) looks after Kenya's water towers – defined as "montane forests", i.e. mountainous regions that are the sources of water. A water tower collects and filters natural water including rain, dew and snow. It is the zone through which the rainwater and snow seeps to eventually provide base flow to rivers, lakes and spring water and also provides for groundwater recharge. There are 18 gazetted, 24 non-gazetted, water towers in Kenya. In the Athi Basin the gazetted water towers include the Aberdare Range (including the Kikuyu escarpment) which forms the upper catchment of Athi River; Chyulu Hills in the middle part of the basin and Shimba Hills towards the coast, south of Mombasa.

The Forest Management and Conservation division under the Kenya Forest Service (KFS) is charged with the management and conservation of the natural forests in Kenya, of which most form water towers. Strategic outputs involve increasing percentage cover through tree planting and gazetting new forests; as well as improving livelihoods. The Division includes forest biodiversity conservation, participatory forest management and fire management, natural forest management, licencing and eco-tourism.

The KFS Forest Farm and Dryland Forestry program provides technical support to the Counties, advisory services for forest management, promoting biomass energy development and utilization, promote dryland forest conservation and promote participatory forest extension methodologies including farmer field schools. Issues in the Forestry sector are weak institutions arising from weak governance structures and inadequate capacity for law enforcement and weak stakeholder participation in forest management and governance. This is exacerbated by inadequate funding of the forestry sector from the exchequer, civil and public sectors. Since the enactment of the new Constitution in 2010, nationally and within the basin, the level of public support to the conservation of forests has increased significantly but has not been matched by an equal measure of resource allocation in all sectors. For example, the Forest Management and Conservation Fund (FMCF) established in the Forests Act 2005 and the Forest Management and Conservation Act No.34 2016 (The Forest Conservation and Management Act, 2016) to promote the development of forests, maintenance and conservation of indigenous forests, the promotion of commercial forest plantation, provision of forest extension services, the establishment of arboreta and botanical gardens, and a variety of other purposes outlined in Forest Act is yet to be fully operationalised. Furthermore, there are conflicting institutional mandates as is evident from the overlapping mandates, programmes, projects, and conflicting policies and legislation. Overall, forest conservation has witnessed increased cases of political interference in the management of forests, poor governance as well as inadequate and/or weak structural/institutional capacity for forest law enforcement and governance.

The Parks and Reserves division of the Kenya Wildlife Service (KWS) manages the National Parks, National Reserves, National Sanctuaries, Marine National Parks and Marine National Reserves in the country. KWS is also involved in forest conservation and water towers conservation as well as ratifying the RAMSAR convention. KWS exercises mandates over the Athi River, not just in areas within parks and reserves, but also as the custodians of Kenya's biodiversity, a role they are committed to through the Nagoya Protocol of the Convention of Biological Diversity. Kenya ratified the Protocol in May 2014, which obliges states to develop appropriate domestic measures for effective management of biodiversity in relation to access to genetic resources, benefit-sharing and compliance. Biodiversity in wetlands and sections of the river flowing through protected areas also receive protection by KWS.

Table 6-4: Biodiversity institutions at local level in the Athi Basin

Upper Athi		
	Water Towers (KWTA)	Aberdare Range
	Gazetted forests (KFS)	Dagoretti, Escarpment, Kamiti, Kiambu, Kikuyu Escarpment, Muguga and Nyamweru gazetted forests occur in Kiambu County; Karura, Arboretum and Ngong Road gazetted forests occur in Nairobi County; Kilisa, Iveti, Nduluni-Kalani and Uuni gazetted forests occur in Machakos County; Embakasi, Loitokitok, Namanga Hill, Ngong Hills and Ololua gazetted forests occur in Kaijado County.
	National Parks (KWS)	Nairobi, Ol Donyo Sabuk
	Issues	• Abederare Range faced with illegal logging, land clearing, unsustainable energy consumption. • Kinale and Ngong forest under threat of urbanisation • Massive felling of trees in Kinale forest • Ol Donyo Sabuk has had significant vegetation cover decline

Middle Athi		
	Water Towers (KWTA)	Chyulu Hills
	Gazetted forests (KFS)	Loitokitok and Namangahill, gazetted forests occur in Kaijado County; Kalimani, Katende, Kemeto, Kenze, Kibwezi, Kilala, Kilungu, Kiongwani, Kioo, Kiteta Hill, Kithendu, Kitondu Makueni, Kitoo, Kitumbuuni Makueni, Kiu(Ngungu), Kyai Makueni, Momandu, Mutuia, Nzaui Makueni, South Mbooni, Kyemundu, Tulimani, Utangwa, Utunene, Nthangu, Nthoani, Mataa, Ndatai, North Mbooni, Waiya and Makongo gazetted forests occur in Makueni County; Mdengu, Ngangao, Choke(Mnjonyi), Figi, Fururu, Goye, Kasigau, Kilulunyi, Kinyesha Mvua, Kulundu, Macha, Ngomenyi, Mbili, Mchungunyi, Modagache (Weni-Tole), Mtege, Mwachora, Mwakamu Weni, Mbogho, Yale, Susu, Weni, Mwandongo and Ndiwenyi gazetted forests occur in Taita Taveta County
	National Parks (KWS)	Amboseli, Chyulu Hills, Tsavo East and West
	Issues	• Vegetation in Amboseli Park has changed from dense forest to more scrub and grasslands. • Human wildlife conflicts on Chyulu Hills
Lower Athi		
	Water Towers (KWTA)	Shimba Hills
	Gazetted forests (KFS)	Loitokitok and Namangahill, gazetted forests occur in Kaijado County; Kalimani, Katende, Kemeto, Kenze, Kibwezi, Kilala, Kilungu, Kiongwani, Kioo, Kiteta Hill, Kithendu, Kitondu Makueni, Kitoo, Kitumbuuni Makueni, Kiu(Ngungu), Kyai Makueni, Momandu, Mutuia, Nzaui Makueni, South Mbooni, Kyemundu, Tulimani, Utangwa, Utunene, Nthangu, Nthoani, Mataa, Ndatai, North Mbooni, Waiya and Makongo gazetted forests occur in Makueni County; Mdengu, Ngangao, Choke(Mnjonyi), Figi, Fururu, Goye, Kasigau, Kilulunyi, Kinyesha Mvua, Kulundu, Macha, Ngomenyi, Mbili, Mchungunyi, Modagache(Weni-Tole), Mtege, Mwachora, Mwakamu Weni, Mbogho, Yale, Susu, Weni, Mwandongo and Ndiwenyi gazetted forests occur in Taita Taveta County
	National Parks (KWS)	Shimba Hills National Reserve; and Kisite Mpunguti, Mombasa, Watamu, Malindi Marine National Park and Reserve
	Issues	Mangrove forests deteriorating

6.2.3.4 Governance-based issues

County Governments' Integrated Development Plans (IDPs) are meant to provide an overall framework for development in each county. The plans aim to coordinate the work of both levels of government in a coherent plan to improve the quality of life for all the people and contribute towards devolution. The first plans cover the period 2013 to 2017. The County governments rely on technical input and advice from the different agencies with a mandate to govern natural resources. A major issue is the mandates related to wetlands and riparian lands. There are about nine laws with contradicting recommendation on riparian distance. There is need for all the relevant laws to be harmonized in order to give directions on the riparian distance. This will enable people and developers be aware and be compliant. There is also an issue of limited coordination and poor resource use due to the independent nature of County planning.

According to the Kiambu IDP 2017/2018 (2016) the main income in the county is commercial forestry. Farmers also sell seedlings and dairy farmers plant fodder trees, there is also beekeeping and fruit tree planting. Obilizati trees are planted around identified water catchment sites to protect these areas. Industries have woodlots with fast growing eucalyptus trees. Soil fertility in the county is improved with agroforestry trees being planted in alley cropping and growing *Grevviea robusta*. Nairobi county hosts a large urban centre, acting as a node for import and export of products. The large and growing population drives environmental degradation (Nairobi IDP, 2016) and there are no water towers in the county. Machakos county has sizeable arable land, with agriculture being the main source of job creation (Machakos IDP, 2016). Agroforestry trees are planted for commercial purposes and seedlings are established in tree nurseries. Fruit trees are also grown for income and consumption. The main water catchment areas are Iveti hills, Muumandu, Kalimanzalu and Kiima Kimwe. Indigenous trees have been planted in these sites. Woodlots have been planted for use as fuel, but there is an interest to look for alternative sources.

Kajiado county has also experienced increased urbanisation, which has put pressure on natural resources (County Government of Kiambu, 2018). Pastoralism is a major economic activity in the county. There is also an increase in manufacturing industries and large-scale farming. Makueni county occurs in the arid and semi-arid zone of the country. The high demand for fuel and charcoal has led to depletion of forests.

The Taita Teveta county has conducted a natural resources assessment of the status and level of utilization, opportunities and constraints for sustainable management. Resources that were assessed are lakes, rivers, springs/wetlands, forests, wildlife and minerals (County Government of Taita Taveta, 2018). The Kwale county extends from hills and a semi-arid plateau to white sand beaches and productive coral reefs. The county has abundant fisheries reserves along the coastline, and fish ponds inland. Although there are no commercial forests, forestry is a major source of income, food and medicine to local communities. Most farmers have adopted to agroforestry (County Government of Kwale, 2013). The main contributor to environmental degradation is waste products, overgrazing, mining and sand harvesting. Most of Kilifi county is natural pastures and has a similar topography to Kwale county. The forests have also been experiencing encroachment and fast coastal urbanization. The county has identified environmental degradation hotspots in the county (County Government of Kiambu, 2018). Mombasa county has both marine and terrestrial ecologies under threat from development. Agroforestry is being promoted for income generation, protection of water catchment areas, prevention of soil erosion and improvement of soil fertility. Poor waste disposal is a leading cause of environmental degradation. Mombasa county has also assessed natural resources (County Government of Laikipia, 2018).

Table 6-5: Governance at local level in the Athi Basin

Upper Athi		
	**Counties**	**Kiambu, Nairobi, Machakos, Kajiado**
	Issues	• Kiambu: ○ tree planting is being promoted as an erosion mitigation, but this is not the only technique available ○ industry woodlots need to be managed and natural forests should not be replaced with eucalyptus or pine trees ○ poor farming management leading to pollution ○ uncontrolled quarry activities in Juja led to land degradation ○ approach to domestic waste management by communities is poor ○ Inadequate sewerage systems a great threat to the environment • Nairobi ○ Environmental degradation for instance Nairobi River receives huge volumes of raw sewer effluents, solid waste and industrial discharge ○ Deforestation along river banks ○ Solid waste management • Machakos ○ Main supplier of sand and cement, with associated water quality impacts i.e. Thwake river ○ Firewood and charcoal used for fuel leading to deforestation and soil erosion. Most affected areas are Kibauni forest, Yathui and Muumandu hills
Middle Athi		
	Counties	Kajiado, Makueni, Taita Taveta
	Issues	• Kajiado ○ Olkeriai River and tributaries have major degradation mainly due to sand harvesting ○ Oldepe, Oltepesi, Torosei, Mailua, Meto, Ilmarba, Ilpatimaro, Lorngosua degraded through illegal logging and charcoal burning ○ Flash floods are an issue during long rains mainly due to erosion and lack of vegetation cover • Makueni ○ Drought pushes communities to look for alternative livelihood activities such as charcoal burning or sand mining ○ Poor farming methods and industrial effluent contributes to degradation of Athi River ○ Sand harvesting results in erosion of river banks

<table>
<tr><th colspan="3">Lower Athi</th></tr>
<tr><td rowspan="2"></td><td>Counties</td><td>Taita Taveta, Kwale, Kilifi, Mombasa</td></tr>
<tr><td>Issues</td><td>• Taita Taveta
o Hilly parts of the county at risk of landslides as cultivation has exposed the slopes to soil erosion
o Introduction of eucalyptus trees for catchment restoration has been counterproductive as they require a lot of water for growth
o Illegal harvesting of forest products
o Rampant stone harvesting without rehabilitation has resulted in erosion and landslides (i.e. Mwakingali in Voi rocks have fallen onto homes)
o Deforestation for charcoal
o Lake Jipe and Chala have fluctuation of water levels due to floods and droughts. Water quality expected to decline due to increased farming activities.
o Voi River increased drying. Lumi, Galana and Tsavo Rivers have declining levels. High sediment loads. Sand harvesting and over abstraction of rivers.
o Springs drying up. Wetlands overutilized.
• Kwale
o Pollution and waste management
o Deforestation and cutting down mangrove trees
o Land degradation
• Kilifi
o Deforestation in Dakatcha, Galana Ranch, Mwangea Hills, Jorore, Fungo, Rabai, Tsolokero kayas
o Charcoal production in Ganze and Magarini
o Quarrying in Kilifi South/North, Ganze, Rabai and Magarini
o Mining in Ganze
o Salt mining in Magarini
o Solid waste in urban centres
• Mombasa
o Kashani, Dongo Kundu and Majaoni catchment areas require protection
o Untreated sewage disposed into the ocean
o Wetlands and springs encroached and degrading. Competing water uses and pollution also an issue.</td></tr>
</table>

6.2.4 Strategy

In previous Section of this Report, many critical issues related to catchment management have been identified including the need for sustainable land use, improved management and protection of natural resources, and land restoration and rehabilitation. In addition, erosion risk scenarios have demonstrated the impacts and potential benefits of improved land management (Figure 6-5).

In order to comprehensively and systematically address the catchment management issues and challenges in the Athi Basin, Table 6-6 sets out 4 Strategic Themes with specific Strategies under each Theme. The Themes address Improved and Sustainable Catchment Management, Sustainable Water and Land Use Practices, Natural Resources Management, and Rehabilitation of Degraded Environments.

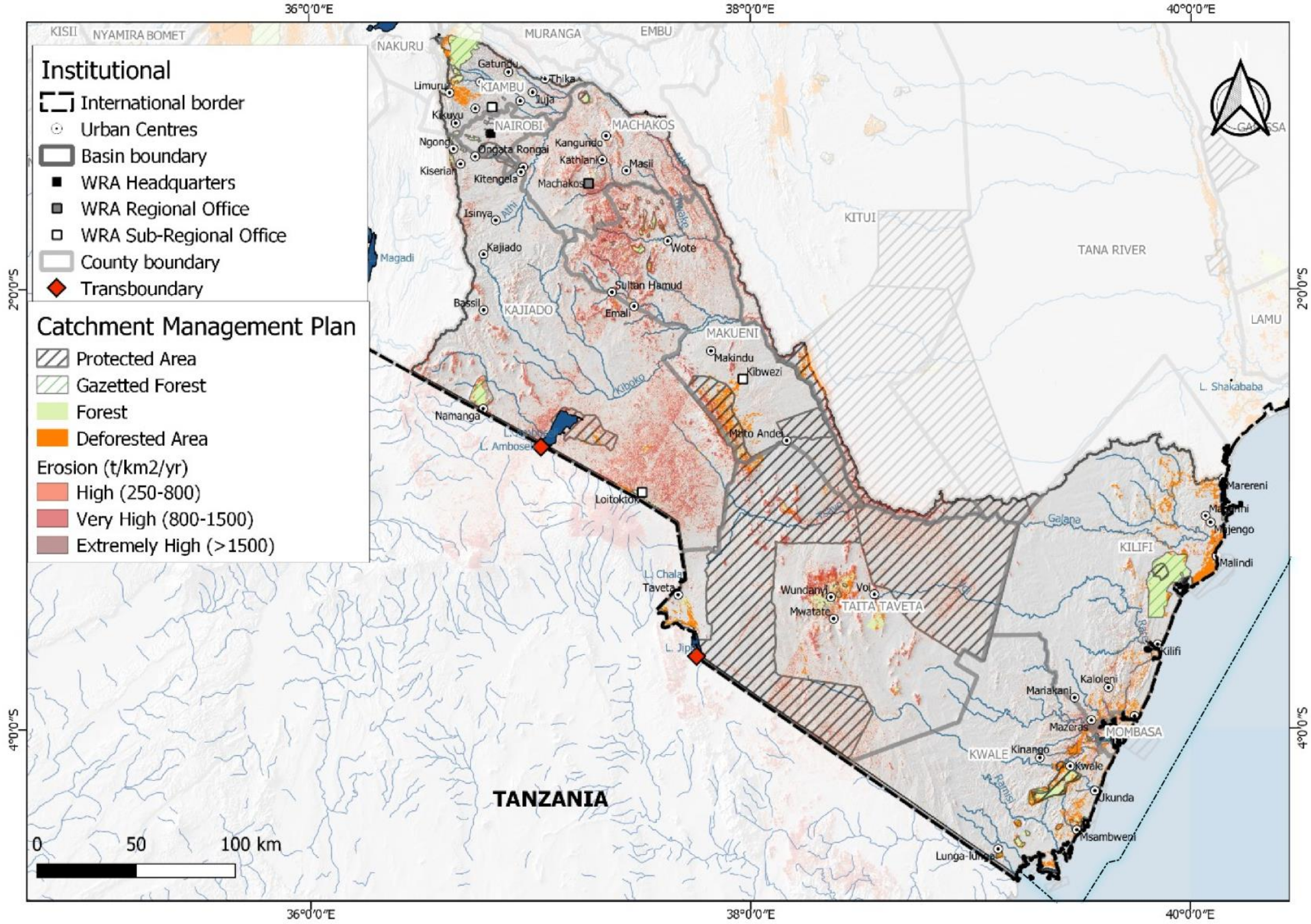


Figure 6-5: Catchment management considerations in Athi Basin

Table 6-6: Strategic Framework - Catchment Management

1	**Key Strategic Area:**	**Catchment Management**
1.1	**Theme:**	**Promote improved and sustainable catchment management**
1.1.1	Promote sustainable land development and planning	

NEMA Environmental Sustainability Guidelines for Ministries, Departments and Agencies (MDAs) defines sustainability as meaning "meeting the needs of the present without compromising the ability of future generations to meet their own needs". Sustainability is defined as not being an end goal, but rather a journey that MDAs should take to improve the social equity, environmental, and economic conditions in their jurisdiction.

In order to reduce the degradation of land and water resources, a sustainable management approach must be implemented in the Athi Basin. It is important that resource management activities not only apply to new activities, but rehabilitation of degraded resources is critical in order to ensure sustainable management of ecosystem functions and availability of resources for future generations. Degradation of resources will continue if no action is implemented and resources will be further depleted.

MDAs should explore the environmental issues within their operations, develop appropriate interventions and document the same in the form of an environmental sustainability policy.

1.1.2	Strengthen participatory approaches	

The National Environment Policy (Government of Kenya, 2013a) guiding principles emphasises the inclusion of communities in decision making. These participatory approaches need to be strengthened for sustainable catchment management as communities are closely connected with resources in a catchment. Communities need to take ownership of catchment management activities, and this can be achieved through participatory processes through SCMPs, agricultural extension services and CIDPs.

The aim of SCMPs is to plan the activities of the sub-catchment in an efficient and sustainable manner to achieve optimum benefits for all in the sub-catchment, through making use of available resources in a sustainable and efficient manner. The process and purpose of a SCMP is to empower the people of the sub-catchment to make decisions and take responsibility for and promote the collective action for the rehabilitation, sustainable management and utilisation of their natural resources. The Plan is developed by the community of the sub-catchment, for the community of the sub-catchment. The plan accommodates the resources available to the village community and their needs.

Agricultural extension officers and Farmers Field Schools from the AFFA need to be aware of the SCMPs and ensure that catchment management activities fit in with this plan.

County governments are also required to consider the SCMPs in the CIDPs.

Appropriate catchment management activities should be considered from theme 1.2. to 1.4.

1.2	**Theme:**	**Sustainable water and land use and management practices**
1.2.1	Promote water conservation and management at catchment level	

Water conservation and management is considered a priority in the Athi Basin due to high water use and limited supply. Water is important in the Basin both for urban use as well as for agricultural use therefore water management and access to water are important. Access can be improved through community or household storage of water and through resource protection. Access to water is also improved through water efficiency and through recycling water. The timeframe of access to water is also important as the seasonality of water resources in the Middle Athi has meant that pastoralists need to move further into National Parks to find water, which increases human/wildlife conflict.

Water resource management has been identified as a strategic objective in most CIDPs, with strategies involving water harvesting, storage and treatment. Catchment management activities that can be also be implemented to promote water conservation and management are as follows (Braid & Lodenkemper, 2019):

1. **Water use efficiency and recycling**

   By improving water efficiency through suitable crop selection, proper irrigation scheduling, effective irrigation techniques, and using alternative sources of water for irrigation, it will be possible to increase

1	Key Strategic Area:	Catchment Management

water availability and make the water last longer. These also address point source protection of water collection points. These activities should be implemented by smallholder farmers.

- **Water use efficiency,** i.e. through installation of drip irrigation systems.
- **Wastewater recycling**, i.e. treating wastewater to remove solids and impurities, greywater can be separated from blackwater.
- **Excess water reuse**, i.e. channel water spills at hand pumps to a 'fertility pit'.

2. Water harvesting and storage

By providing access to additional water by harvesting water (collecting runoff) and storing water. By harvesting water, farmers can increase the area they irrigate, grow crops in the dry season, and support livestock. Water storage at the household or village level improves access to water, and reduces the labour burden, by reducing the number of trips to boreholes. These activities should be implemented in the semi-arid regions of the Athi Basin. Ridging and swales should be implemented on steep hillslopes where small scale farming is being practiced.

- **Roof runoff and storage**, installation of rainwater harvesting tanks for households.
- **Below ground storage**, installation of large below ground storage of potable water for larger populations.
- **Road runoff**, diversion of runoff from roads into channels/canals and then distributed into ditches/basins or farmland.
- **Ridging**, erosion and runoff control located in drainage lines or near culvert outlets, which are put in place to prevent or reduce sedimentation and erosion of the landscape.
- **Swales**, erosion from rainfall on steep slopes can be reduced by creating swales. A swale is a long, shallow depression in the ground designed to collect or redirect water.

3. Groundwater protection and Infiltration

By providing information to improve groundwater resources, particularly the infiltration of rainwater into the soil, thereby increasing availability of water stored in the rooting zone and groundwater. Increased water availability in the rooting zone reduces dependence on surface water irrigation and provides increased potential for cultivation during dry seasons. Increased groundwater feeds the spring and improves surface water flow lower down the catchment as well as the level of water in wells close-by. These activities should be implemented as a priority in groundwater recharge zones in the Athi Basin.

- **Contour bunds**, construct stone or earth bunds to harvest water on crop lands, or degraded rangeland. Stone bunds act as semi-permeable barrier along contour to retain runoff for water harvesting. Earth bunds retain all runoff from slope for water harvesting.
- **Zai planting pits**, act as micro-catchments within fields to retain runoff from the slope for water harvesting. Suitable for range and degraded land.
- **Infiltration trenches**, shallow excavations with rubble or stone that create temporary subsurface storage of stormwater runoff, thereby enhancing the natural capacity of the ground to store and drain water. Infiltration trenches allow water to exfiltrate into the surrounding soils from the bottom and sides of the trench.
- **Spring protection and management,** designate set-back distances for springs and monitor for contamination.

1.2.2	Promote soil conservation and management at catchment level

Soil erosion, deforestation, poor agricultural practices, loss of soil fertility, inadequate runoff management and gully formation each contribute to the degradation of land resources with resultant impacts on the Basin both up and downstream. To reduce land degradation, mitigate degradation and implement sustainable land use practices, various aspects of sustainable land management are required. Implementing these techniques and practices will minimise the loss of topsoil (through erosion) and reduce the erodibility of a catchment.

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The steeper regions of Athi Basin which do not have a dense vegetation cover are more prone to high levels of erosion than the lower plains. Land use in these areas is becoming increasingly more urban and stormwater management is becoming an issue during frequent floods. Improved erosion and runoff control measures and sediment trapping will improve resilience to floods and erosion. In the lower plains of Athi Basin rangeland management should be implemented to prevent overgrazing. The movement of livestock up slopes and over rivers also needs to be managed as this can lead to eroded paths.

Although there are many different parties involved in providing soil conservation and management advice, it is recommended that consensus is built, and a consistent message is given by the SCMPs, CIDPs and Extension Officers.

Most of the CIDPs promote soil and water conservation as a key programme, with the objective to promote sustainable land use and environmental conservation. Activities that are promoted are on farm water harvesting structures (i.e. terraces), tree planting during rainy season, use of organic manure, river bank protection, rehabilitation of degraded land and gully control, excavation of water pans, construction of check dams/sand dams and desilting of water pans. Catchment management activities that can be implemented to promote soil conservation and management are as follows (Braid & Lodenkemper, 2019):

1. **Rangeland management**

   In Kenya rangelands are managed by pastoralist communities, and much of the knowledge related to its management is based on an inherited knowledge of the landscape. Climate changes, coupled with overgrazing and degraded environments, have a devastating effect on pasture regeneration and pastoralists livelihoods. The ASDS (Government of Kenya, 2010a) emphasizes the need to restore rangelands through reseeding and range pitting, bush control, soil conservation and water resource development and management. The CIDPs also promote the development of range and ranch resource management through training of herders, developing ranch plans, constructing water pans and developing firebreaks. Access roads. Rangeland management is the practice of deciding where to graze animals, how many animals to graze at one time, when to burn, how to harvest firewood and thatch-grass, and other issues relevant to managing natural resources.

   - **Rotational resting of rangeland**, overgrazed land leads to increased soil erosion and loss of soil nutrients. Grazing lands should be rested to allow vegetation to recover and protect the soils while other areas are being grazed in rotation. Pastoralism practices which allow for grazing areas to be rested should be promoted.
   - **Prevention and rehabilitating overgrazing**, where land has been overgrazed, it needs to be rehabilitated to improve ecosystem function and goods and services provision.
   - **Grazing movement**, moving animals around allows livestock owners to control where and when animals graze. This allows much greater control over the feeding of the animals and the resting of different areas. This is applicable to livestock owners who do not move over large areas, and who can practice block grazing.
   - **Cattle paths up a slope**, cattle paths on slopes can be a major source of erosion and can quickly become large gullies. Reducing cattle paths up slopes requires a combination of rehabilitating existing paths and using strategies to prevent future paths from forming.

2. **Erosion and runoff control measures**

   Erosion and runoff control tools are structures or measures, located in drainage lines or near culvert outlets, which are put in place to prevent or reduce sedimentation and erosion of the landscape caused by intensive rainfall and direct runoff.

   - **Contour ridging**, construct during dry season to allow time for re-aligning ridges. Height is usually 30-40cm and interval between ridges varies according to slope gradient.
   - **Contour vegetation rows**, vegetation barrier slows down and retains runoff and reduces erosion. Roots increase resistance to rills and gullies.

1	Key Strategic Area:	Catchment Management

3. **Gully management and sediment trapping**

Gullies may not be actively eroding in some cases but provide a channel for increased runoff and sediment delivery. Prevention is better than rehabilitation.

- **Gully prevention**, prevent gully development through sound land use, runoff control and reduction in flow concentration. Raised footbaths and field boundaries should also be implemented.
- **Gully reclamation (small),** gullies can be reclaimed either to cultivate, or simply to prevent further loss of soil and land.
- **Stone check dams**, large gully rehabilitation requires more complex interventions to prevent continued erosion. Check dams can be implemented in a stepped-approach for larger gullies to gradually trap sediment and be reclaimed.
- **Brushwood check dams**, where stones are not available brushwood check dams may be used in some cases.
- **Vegetation barriers**, silt traps reduce the loss of soil and the resulting sedimentation of rivers.
- **Erosion management along roadsides,** one of the areas most prone to erosion and gully formation is along the side of roads, especially dirt roads. This affects the usability of these roads during the wet season. Improved runoff management, such as mitre drains, along the roads will help mitigate this problem.

4. **Stream/River bank management**

A more manageable riverbank habitat is beneficial to wildlife and at the same time manages the riverine zone, ensuring adequate river function through sediment control and water quality improvement.

- **Riparian buffer zones**, some of the most productive farming areas are on stream/river banks because of the fertile silt and ease of access to water. However, this practice results in the loss of important riparian vegetation which amongst other things helps to clean the water, reduce flood flows, trap sediments, provide food and is also an important habitat for biodiversity.
- **River crossing for cattle**, cattle can cause a lot of damage to river banks where they cross rivers. They cause soil erosion, can drop dung and urine in rivers, which pollutes the water for people living downstream of the cattle crossing. Well-designed cattle crossings can substantially improve the water quality, as well as making it safer for animals and people to cross rivers.
- **Earth berm**, flooding is a natural phenomenon of rivers. For ease of access to water and highly fertile soils, many villages are established near rivers. However, these are affected by floods. A berm/dyke is a wall that runs parallel with the watercourse. Berms or dykes help reduce flood waters affecting villages –they do not stop floods or prevent damage. They require prioritised maintenance.
- **Gabion baskets**, bank collapse along rivers and gullies contribute to catchment degradation. Gabion baskets are rock filled structures to protect banks, reduce erosion and prevent bank collapse.

1.2.3	Promote conservation agriculture and improved farm management

One of the most important natural resources is the soil. Healthy and fertile soils produce good yields of crops; whereas poor or degraded soils produce low and unreliable yields. Soil health is a function of rooting depth, nutrient fertility, structure, organic matter content, below-ground biodiversity and water holding capacity – all of which are related. Ensuring soils remain healthy and fertile requires a variety of management techniques including climate-smart farming practices and nutrient management.

Most of the CIDPs promote soil fertility improvement and agroforestry but a more holistic approach would to consider conservation agriculture and improved farm management as follows (Braid & Lodenkemper, 2019):

1. **Climate-smart agriculture**

Climate-smart agriculture practices contribute to improving the health of the soil by enhancing its physical, chemical and biological properties. Good soil health will produce higher and more stable yields. These techniques contribute to avoiding erosion and controlling rainfall runoff, by increasing infiltration of rainwater and water holding properties and thereby improving soil moisture. Climate-smart agriculture covers the principles and practices of conservation agriculture and Permaculture (natural farming). Nutrient management focuses on soil fertility, which is of fundamental importance for agricultural production. These include compost techniques and natural fertilizers.

- **Conservation agriculture**

  Conservation agriculture combines profitable agricultural production with environmental concerns and sustainability by conserving, improving, and using natural resources more efficiently through integrated management of soil, water and biological resources. Conservation agriculture contributes to food security and increases tolerance to changes in temperature and rainfall including incidences of drought and flooding. Conservation agriculture combines three basic principles or 'pillars': (i) minimum tillage, (ii) crop rotation and (iii) maintaining soil cover by crops or crop residues.

  - Conservation tillage

    Minimum tillage is superficial loosening of the soil (5 cm), ripping of planting rows with a ripper tine (chisel plough), or making permanent planting basins by hand, without disturbing the soil between. Zero or no-tell is direct planting through a mulch layer using a special planter or hand tool. Conservation tillage is any form of reduced tillage technique.

  - Crop rotation and intercropping

    Mixing crops by either planting a different crop in each field every season, or by planting a mixture of crops which complement each other can be beneficial. Rotating crops regularly reduces the ability of each crop's pests to become established in the soil through minimising the available food and habitat for each pest. The variety of crops also increases opportunities for a mixture of pest predators to survive.

  - Soil cover (mulching)

    Soil cover and mulches protect the soil from the heating and drying effects of direct sunlight and the physical damage caused by heavy rain. They also reduce evaporation, and moderate soil surface temperatures. Soil covers also slow surface runoff during rainstorms, reducing erosion and increasing infiltration.

- **Natural farming (small scale)**

  Energy can be saved by laying out the farm and household cultivation/ farming beds and plots more efficiently.

2. **Nutrient management**

Soil fertility is of fundamental importance for agricultural production. Certain techniques maximize the efficiency of nutrients and water use for better agricultural productivity. This improves and sustains soil quality for the future. These include compost techniques and natural fertilizers.

- **Compost**

  Compost helps return nutrients to the soil, reduces reliance on chemical fertilizers, increases soil organic matter, maintains moisture and provides soil cover. Compost can be made household level for cost-effective soil fertility improvement.

- **Natural fertilizer**

  A balance of all essential soil nutrients is necessary for healthy plant growth. The application of any one nutrient in a soil with multiple nutrient deficiencies will have limited impact on crop growth.

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- **Micro dosing**

  Low-technology precision agriculture technique initially developed by ICRISAT. Small doses of fertilizer applied in the right place has been found to lead to large benefits in yields for the smallholder farmer.

- **Weeding**

  A move from conventional farming (i.e. tilling the soil) to conservation farming can result in increased number of weeds. An appropriate weeding strategy is required for successful conservation farming. Weeds lower crops yields due to competition for water, nutrients, light and space.

- **Agroforestry**

  Agroforestry is the intentional integration of trees within a cropping system for multiple benefits. It is increasingly recognised as one way of dealing with the lack of space and infertile soils.

1.2.4	Promote erosion control measures

Refer to Strategy 1.2.2.

1.2.5	Promote soil fertility management

Refer to Strategy 1.2.2.

1.3	Theme:	Natural resources management for the protection and sustainable use of natural resources

1.3.1	Improved wetlands and lake management

According to the Athi Basin CMS (2015) wetlands are under pressure from human encroachment for settlement, expansion of crop production, urbanization, property development and livestock grazing. In Nairobi, Upper Athi and Coastal Athi sub-regions, most wetlands are rapidly being reclaimed and converted into residential estates or commercial/industrial centres. These wetlands need protection from degradation and restoration of their functional capacities.

Although significant wetlands are protected from use (refer to KSA 2), in certain cases seasonal wetlands are utilized by surrounding communities. It is important to not only conserve what is existing, but also improve the farming practices and grazing in wetlands for more sustainable utilisation and reduced impacts (Braid & Lodenkemper, 2019).

1. **Wetland conservation**

Wetlands should be delineated and classified at basin scale and conduct status quo assessment for significant wetlands considered as part of Resource Directed Measures. an effective and efficient institutional and legal framework for integrated management and wise use of wetlands which will enhance and maintain functions and values derived from wetlands in order to protect biological diversity and improve livelihood of Kenyans.

2. **Wetland rehabilitation**

   Refer to 1.4.4.

3. **Sustainable utilization of wetlands**

   WRUAs should facilitate the integrated sustainable management of wetlands that require communities to not only manage the wetlands through land use planning but also the surrounding catchments that sustain and impact the wetlands.

   Wetlands must be clearly zoned with a 50m buffer of protected natural vegetation to act as an infiltration zone and blocker of sediments/runoff reaching the wetland. Cultivation in the wetland should be limited to small plots or beds surrounded by natural vegetation closer to the edge of the wetland, with no development at the centre of the wetland. This will limit erosion and gully formation. Erosion and increased sedimentation can be further limited through managed grazing practices.

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Correctly utilised drainage ditches will give crops space to grow, move water away to prevent waterlogging (wet season), be well placed to limit erosion, not be dug too deep/have excessive drainage which would lower the water table (dry season) and lead to gully development (flash flood event).

Organic compost improves water infiltration close to the roots of the crops. Water hungry plants such as sugar cane and Eucalyptus that reduce the water supply should not be planted in wetlands. In the catchment, agroforestry trees reduce sedimentation, improve infiltration, and stabilise and improve soil fertility. It also reduces the removal of natural vegetation for fuel wood and building materials which is a problem.

Wetlands must be clearly zoned to ensure communities manage it sustainably.

The wetland centre must be clearly demarcated, and natural vegetation must be protected to prevent erosion

Community wells should not be located in the centre of the wetland because they can become focal point for gully formation. They should be placed closer to the edge of the wetlands.

1.3.2 Promote alternative and sustainable livelihoods

Communities rely on natural resources to live and earn an income. Over utilisation leads to the depletion of natural resources. Natural resources need to be managed and utilised in a sustainable manner, to maximise the goods and services received from them, while still maintaining their function and production capacity. Natural forests, grasslands and wetlands are finite resources that must be managed sustainably; similarly, alien vegetation can provide useful resources but needs to be managed to prevent uncontrollable spread. Programmes that require management are as follows:

- Alien vegetation woodlots for personal and commercial use
- Promotion of alien vegetation for agroforestry use
- Agroforestry tree nurseries
- Beekeeping
- Inland aquaculture

1.3.3 Improved solid waste management

To ensure that catchment management activities and resource protection activities can be implemented, it is important that activities around the household, farm and village are also sustainable and of a high standard. These include activities such as waste management. Waste management involves the generation, collection, transportation, and disposal of garbage, sewage and other waste products. Responsible waste management is the process of treating solid wastes and offers a variety of solutions for waste with the ultimate aim of changing mind-sets to regard waste as a valuable resource rather than something that must be thrown away. The government is constitutionally bound to provide sanitation services to all of its citizens, this includes the removal and proper treatment of solid waste. In reality this is not being done in many parts of the country, particularly in remote rural areas. Water resources nearby urban areas are particularly at risk, as evident in the CIDPs. It is important to ensure that the mind-set of waste management extend to individuals and communities as it is important for a clean and safe environment.

1. **Household waste management**

   Household waste management reduces the potential for underground contamination of water by preventing the infiltration of pollutants into the surrounding soil of illegal dump sites. Households should be encouraged to reduce the production of unnecessary waste and dispose of what cannot be reused, recycles or composted in a responsible way at a legal disposal site.

2. **Village waste management**

   In communal rural areas, solid waste is left on open land or dumped on the roadside. Food scraps and plastic present in dumped waste creates unpleasant odours and can contribute to the spread of diseases. Waste often spreads from these sites into drains causing blockages leading to local flooding and results

1	Key Strategic Area:	Catchment Management

in various undesirable health and environmental impacts. A village waste management program involves the community in waste management.

3. Buy back centres

Many unemployed people earn some income collecting and selling recyclable goods on an informal basis. Waste picking is therefore an important alternative for those who cannot find employment in the formal labour market due to inadequate skills. Buy back centres play a crucial role in facilitating the recycling potential of these informal sector participants. Buy back centres are depots where waste collectors can sell their recyclable waste. The Buyback centres, in turn, sell these waste products to other larger Buy back centres or directly to recycling companies. Formal recycling companies process the recyclable waste into a form that is readily usable by a manufacturer or end-use market, where the recyclable waste is converted into materials or other consumption products. Buy back centres are the link between formal and informal sector activities.

1.3.4 Improved forestry management

Forests are important to return moisture to the air through evapotranspiration, which then generates rain, as well as to stabilise soils with their root systems; they can also be rich in terms of biodiversity as well as stores of carbon. Sustainable management of forests both natural and plantation, for reforesting of areas where forests have been removed including the selection of beneficial tree species.

The Vision 2030 requires the country to work towards achieving a forest cover of at least 10% of the land area to ensure sustainable resource use, growth and employment creation. The National Forest Policy (Ministry of Environment and Natural Resources, 2014) indicates that the sustainable management of forests includes:

- Indigenous forests
- Plantation forests
- Dryland forests
- Urban forests and roadside tree planting
- Farm forestry

To achieve the national forest cover target of 10% of land area, the major afforestation effort will have to be in community and private lands. Dryland forests offer great potential for intensified afforestation but woody vegetation in the arid and semi-arid areas are unique and require special attention. Most CIDPs promote reforestation through agroforestry, and in some cases water catchment areas are being protected through the use of alien trees (i.e. eucalyptus). Consideration needs to be made to the objective of these programmes as there could be significant long-term challenges associated with planting trees with high water requirements in counties with limited water supply.

1.3.5 Removal of alien invasive species

Communities need to be educated on the general approaches to sustainably manage invasive and alien plant species. The KFS and KWTA need to consider alien invasive vegetation management as invasive alien plant species are a threat to water resources and water availability. By managing them and preventing their further spread, these plants can also provide useful resources and alternatives to rapidly depleting indigenous vegetation.

1. Controlling alien invasive vegetation

Invading alien plants use much more water than indigenous trees and plants – and through doing so they grow faster. They prevent rainwater from reaching rivers and deprive people and ecosystems of much needed water. Invasive alien plants can displace indigenous species and thereby reduce biodiversity. Invading alien plants also increase fuel loads making the area vulnerable to devastating fires that destroy infrastructure and damage soils. By damaging the soils, important indigenous seed banks are destroyed and may be eliminated from the area.

Invasive alien plant control relies on four main methods - manual, mechanical, chemical and biological control. Long-term success of any programme is best achieved through a combination of these. This is called an integrated control approach.

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Removal of larger hardwood invading alien vegetation:

- Ring barking
- Strip barking
- Hand pull

2. **Utilising and controlling blue gum (eucalyptus) trees**

Blue Gum trees, if left unmanaged, will invade and replace indigenous vegetation by monopolising the water resources. Application of invasive species management should be done throughout the catchment, but a particular focus should be given to areas closer to settlements, areas near smaller non-perennial rivers and areas known to have an elevated fire risk

3. **Utilising and controlling pine trees**

Invasive plants such as pine trees use much more water than indigenous species. As such they prevent rainwater from reaching rivers and deprive people and ecosystems of much needed water. Invasive alien plants can displace indigenous species and thereby reduce biodiversity. Invading alien plants also increase fuel loads enhancing the potential intensity of fires that destroy infrastructure and damage soils. However, as they are fast growing trees they are useful for afforestation projects, they must however be carefully managed in order to prevent uncontrollable spread through the catchment.

4. **Utilising and controlling Bamboo**

There are many types of bamboo but in general they can be divided into either clumpers or runners. The clumping species are non-invasive and can be used for building materials or stabilising soil erosion. Running bamboo species can be become very invasive and must be controlled.

5. **Utilising and controlling Prosopis species**

Prosopis spp. also known as mesquite, is a dominant groundwater dependent invasive alien species found in the arid and semi-arid areas. Hybridization between the dominant species, *Prosopis velutina* and *Prosopis glandulosa* var. *torreyana* are very invasive.

6. **Utilising and controlling water weed/hyacinth**

Water hyacinth, *Eichhornia crassipes* (Mart.) *Solms-Laubach* (Pontederiaceae) is a perennial, herbaceous, free-floating aquatic plant that is widely recognized as one of the world’s worst invasive weeds. Anyone undertaking biological or chemical control methods should have proper training in the use of the chemical/biological agents. Additionally, they must have a strategic plan in place over several years to ensure that the process in successful and the system doesn’t relapse into an infestation state.

1.3.6	Improved fisheries management

Promote the sustainable development and management of fisheries in lakes, dams, wetlands and rivers.

1.3.7	Improved energy management

To ensure that catchment management activities and resource protection activities can be implemented, it is important that activities around the household, farm and village are also sustainable and of a high standard. These include activities such as energy management. Renewable sources of energy should be promoted to generate electric power for use in the household, or community, as a replacement for the burning of wood or charcoal.

Most CIDPs promote “green energy” as an alternative fuel to wood and charcoal.

The following renewable sources could also be promoted for energy supply instead of burning wood or charcoal:

- Solar cooker, Solar electrification, Solar borehole pump
- Wind pump
- Micro hydropower
- Biogas digester

1	**Key Strategic Area:**	**Catchment Management**

- Energy efficient stoves and ovens
- Heat retention cooker
- Solar turtle

1.3.8	Improved sand mine management

Develop policies for sand harvesting. Consider alternative sources of sand.

1.4	**Theme:**	**Rehabilitation of degraded environments**

1.4.1	Rehabilitation and Restoration Plan

Develop a restoration and rehabilitation programme. Also refer to Strategy 1.2.2.

1.4.2	Land restoration and rehabilitation of specific priority areas

Implement restoration and rehabilitation programme.

1.4.3	Site specific rehabilitation of degraded riparian areas

Rehabilitation planning, implementation and associated management is a long-term commitment to a natural resource. The successful rehabilitation of freshwater ecosystems, and thus the overall resilience and sustainability of the system, can only be achieved through engagement of all the stakeholders reliant on the natural capital.

Through the Reserve process studies should be conducted to delineate riparian areas of significant water resources. These studies are required to understand the riparian functioning so that an effective rehabilitation strategy can be developed. The level and type of rehabilitation adopted is case/site specific, as rehabilitation planning is largely dependent on the extent and duration of historical and current disturbances, the cultural landscape in which the ecosystem is located and the opportunities available for rehabilitation. Understanding the overall functioning of the system, particularly in a landscape where the community is dependent on the natural resource, is key for the success of any rehabilitation project. This is further supported by ensuring that an adaptive management approach is incorporated into the planning and aftercare of the system, thus ensuring the ecosystem is maintained at a desirable level and offering it resilience to stressors.

1.4.4	Site specific rehabilitation of degraded wetlands

Prioritize wetlands in need of rehabilitation. Once these have been prioritised, rehabilitation and restoration plans should be developed, that will result in increased natural vegetation cover. Local CBOs and NGOs should be involved in this process.

1.4.5	Site specific rehabilitation of Gazetted forests or protected forests that have been degraded

Gazetted forests or protected forests that have been degraded need to have new trees planted in order to meet the Kenya Vision 2030. When KFS engage in re-planting trees, it should be done considering appropriate soil and water conservation techniques and beneficial/natural trees as a part of an integrated catchment management approach.

According to the Athi Basin CMS (2015) the Aberdares, Dagoretti, Ngong Hills and Namanga Hill forest reserves have had significant vegetation cover loss between 2001 and 2013. Other forest areas which have had significant cover decline are OlDonyo Sabuk, Gonja, Mrima, Jombo and Marenjo. There was also a high probability of significant decline of the mangrove along the Indian Ocean Coast between 2001 and 2013. The CIDPs have promoted tree planting for agroforestry, woodlots for alternative energy and provided education about the detrimental effects of deforestation for communities and the environment.

1.4.6	Mining area rehabilitation

Mining removes the protective covering from the land and exposes soils to soil erosion as well as pollution impacts. During mining activities exposed soils must be revegetated and soil conservation techniques implemented.

6.3 Water Resources Protection

6.3.1 Introduction

Water is critical to social and economic development but also supports key ecological systems which underpin human wellbeing and provides essential ecosystem goods and services. According to the Water Act (2016), a water resource is defined as *"any lake, pond, swamp, marsh, stream, watercourse, estuary, aquifer, artesian basin or other body of flowing or standing water, whether above or below the ground, and includes sea water and transboundary waters within the territorial jurisdiction of Kenya*". It is important to differentiate between surface and groundwater resources as these are treated differently within the context of water resources protection: surface water resources include rivers (i.e. stream, watercourse), wetlands (i.e. lakes, ponds, swamp, marsh, spring) and estuaries, while groundwater resources refer to aquifers and artesian basins.

> In Kenya, wetlands are defined as areas of land that are permanently or occasionally water logged with fresh, saline, brackish, or marine waters, including both natural and man-made areas that support characteristic plants and animals. These include swamps, marshes, bogs, shallow lakes, ox-bow lakes, dams, riverbanks, floodplains, fishponds, lakeshores and seashores. They also include coastal and marine wetlands such as deltas, estuaries, mud flats, mangroves, salt marshes, seagrass beds and shallow reefs all of which at low tide should not exceed 6 meters.
> - Ministry of Environment Water and Natural Resources, 2013

The 2016 Water Act also outlines the designation of basin areas, with functions of BWRCs within each basin clearly stated. Furthermore, the Act defines the establishment and functions of WRUAs i.e. associations of water resource users at the sub-basin level in accordance with Regulations prescribed by the Authority. These associations are community based for collaborative management of water resources and resolution of conflicts concerning the use of water resources.

Protection of water resources in Kenya therefore starts at the National level with the WRA developing policies and legislation for protection of water resources. BWRCs then enact these measures to fulfil the water resource quality objectives for each class of water resource in a basin and need to put in place measures for sustainable management of the water resources; whilst at the sub-basin level more local level community-based management occurs through WRUAs (see Figure 6-6).

Figure 6-6: The different levels of water resources protection in Kenya

6.3.2 Classification of water resources and resource quality objectives

To date, Kenya has not classified its water resources. Protection of water resources requires defining the Class, the Resource Quality Objectives and the Reserve of the resource. The Water Act (2016) states that the WRA shall classify each water resource, specify the resource quality objectives, and specify the requirements for achieving the objectives. The Act also prescribes criteria for classifying water resources for the purpose of determining water resources quality objectives for each class of water resource. These criteria include trans-boundary considerations, strategic functions, ecological functions and vulnerability and may be considered as resource directed measures, which provide the descriptive and quantitative goals for the state of the resource. This is different to the local scale management of resources, which is directed through source directed controls (i.e. specifying the criteria for controlling impacts such as waste discharge or abstraction).

Classifying water resources is a step-wise process. The classification and resource quality objectives approach forms part of the water resource management cycle which is an adaptive management approach focused on goal-setting (Figure 6-7). The first step in the cycle is to determine a vision for the desired future state of water resources. Water resources are then categorised according to specific Water Resource Classes which represent a management vision of a particular catchment, take into account the current state of the water resource and defines the ecological, social and economic aspects that are dependent on the resource (Department of Water Affairs, 2007). The vision for the desired future state of water resources are typically expressed as a range of Ecological Categories e.g. from A to F, in order of decreasing levels of protection for, or increasing levels of risk to aquatic species and habitats (Department of Water Affairs, 2011). The resulting Ecological Categories and ultimately the determined Class of a resource will then dictate the resource quality objectives and the associated Reserve that is set to achieve it. The resource quality objectives are numerical and/or narrative descriptive statements of conditions which should be met in the receiving water resources in order to ensure that the water resource is protected. The purpose of determining the resource quality objectives is to establish clear goals relating to the relevant water resources that can be monitored and thereby give effect to the desired water resource classes in the catchment.

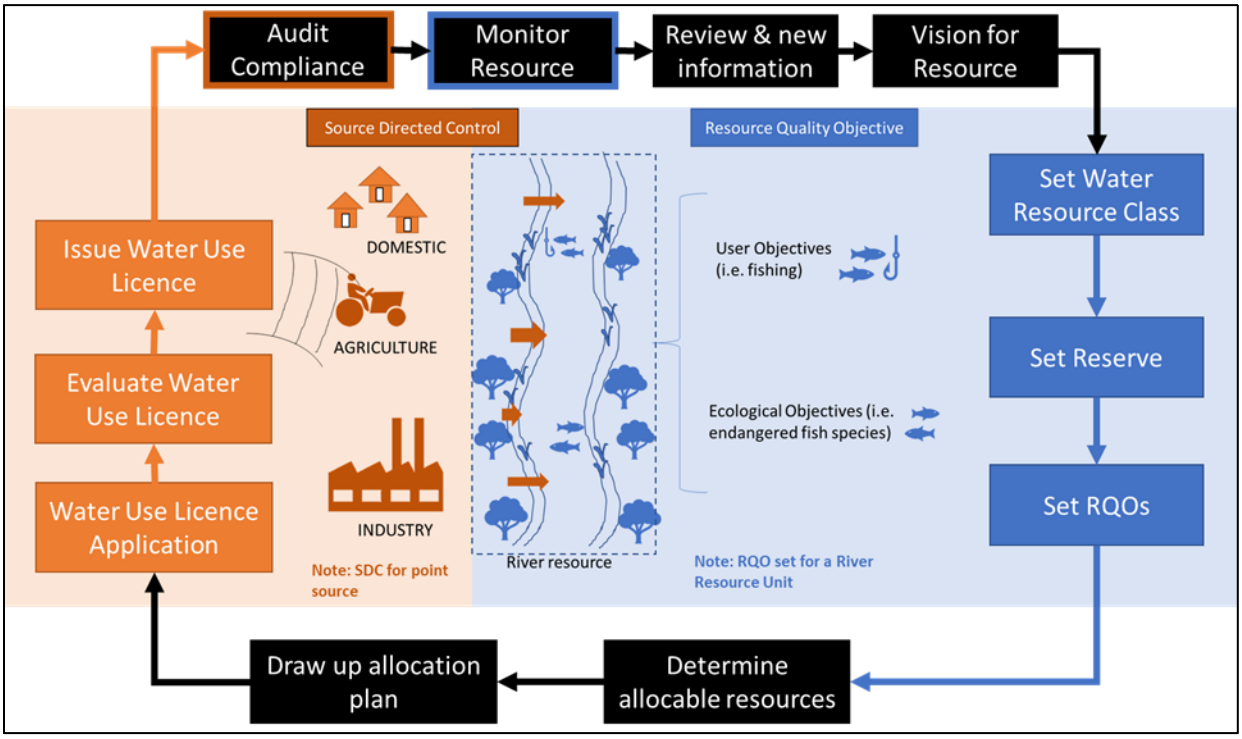

Figure 6-7: Water resources management cycle

Classifying water resources and determining resource quality objectives follow aligned steps as shown in Figure 6-8. These involve delineating the water resources, establishing a vision for the basin, linking the value and condition of water resources, quantifying the environmental water requirements (i.e. the EFlows), determining future scenarios and associated water resource classes, then prioritising and selecting resource units to take forward for development of resource quality objectives.

The Reserve (in terms of quantity and quality) refers to the volume of water needed to satisfy the basic human needs of people who are or may be supplied from the water resource (i.e. Basic Human Needs) and the volume of water needed to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the water resource (i.e. ecological Reserve). The Reserve must therefore be met before any allocation may be made.

The Kenya Guidelines for Water Allocation (Water Resources Management Authority, 2010) defines the Reserve quantity for streams and rivers as "*the flow value that is exceeded 95% of the time as measured by a naturalised flow duration curve*". Although this minimum flow value, which classifies as a rapid hydrological index method, allows the Reserve to be quantified, no consideration is given to the specific nature of rivers or its biota, the timing and duration of flows or the broader aquatic ecosystem.

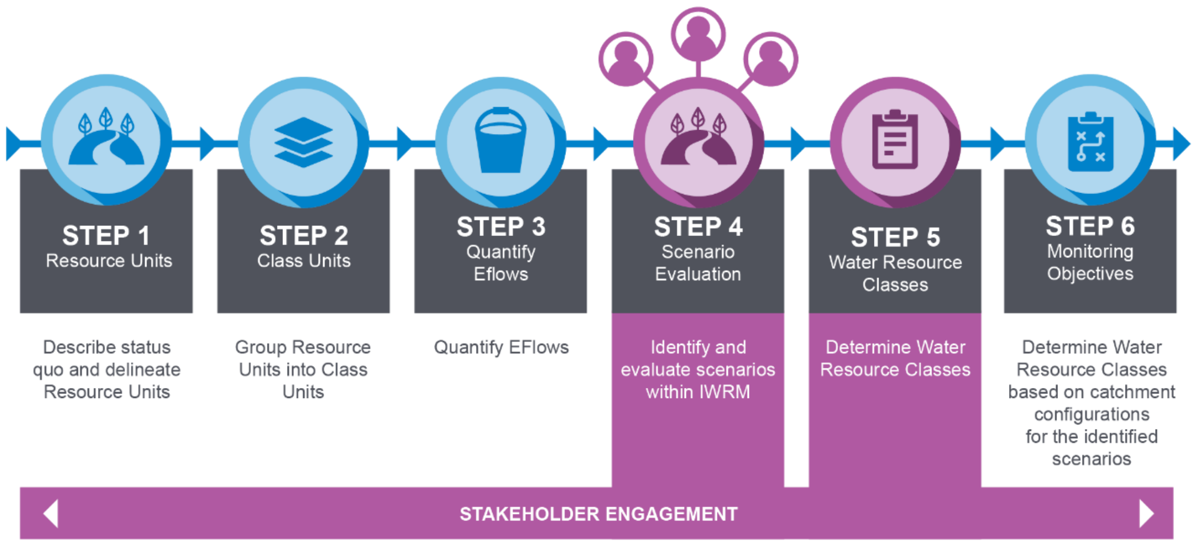

Figure 6-8 The six steps to determine water resource classes and resource quality objectives (based on Department of Water Affairs, 2007, 2011)

The Reserve constitutes one of the four demand categories when allocating water resources in Kenya as shown in Figure 6-9. The total water resource is made up of what is available for allocation or use and the Reserve.

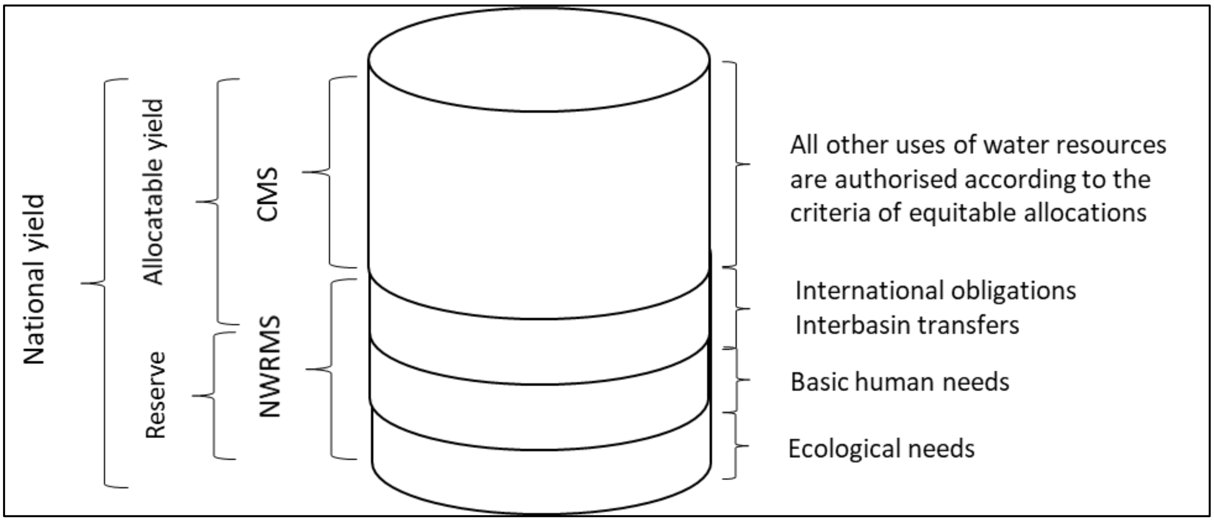

Figure 6-9: The total water resource, comprised of the Reserve and allocable resource (Water Resources Management Authority, 2010)

6.3.3 Water resources protection in the Athi Basin

In accordance with the Water Act 2016, at the basin-level, BWRCs have to enact water resources protection and advise the WRA and county governments concerning conservation and protection of water resources. The BWRCs, in consultation with the WRA and the county governments whose jurisdiction lie within the basin area, are tasked with:

- putting in place measures to fulfil the water resource quality objectives for each class of water resource in the basin area
- describe the measures to be put in place for the sustainable management of water resources of the basin area
- contain a water allocation plan for the water resources of the basin area
- provide systems and guidelines to enable the users of water resources within the basin area to participate in managing the water resources of the basin area

As the water resource classes and water resource quality objectives in Kenya have not been defined yet, this puts strain on the BWRCs as in order to manage and protect the water resources, they need a Water Management Strategy which defines the Class, Reserve and resource quality objectives. Management decisions should be made based on strategic targets for water resources. Without these targets there is no reference to manage towards.

Community based management of water resources is enacted through WRUAs. WRUAs are tasked with the development of SCMPs, which are local level action plans. The Athi Basin has 150 existing WRUAs out of a potential 309 WRUAs needed to cover the whole basin. The gap of 159 dormant or potential WRUAs needs to be addressed to ensure basin coverage of WRUAs is increased. Even among the existing WRUAs, there are capacity concerns and disparities in levels of development and maturity of the WRUAs. This denotes the need for continued capacity building for the existing WRUAs in addition to continued technical support.

The county governments and WRA sub-regional offices responsible for the upper, middle and lower Athi basins as well as water towers are summarised in Table 6-7. The table also lists water towers, gazetted and non-gazetted, in these respective parts of the basin, which are the responsibility of the KWTA.

Table 6-7: Counties, WRA offices and Water Towers in the Athi Basin

Basin	Counties	WRA Sub-Region	WRA SRO	CMU	Water Towers (KWTA)
Upper Athi	Kiambu Nairobi Machakos Kajiado	Upper Athi	Kiambu	Ruiru Ndarungu	*Aberdare Range Kikuyu Machakos Hills Kabauni Hills Kanzalu Hills Matetani Hills Iveti Hills Oldonyo Sabuk Ngong Hills Emali Hills Maparasha Hills
		Mbagathi-Nairobi	Nairobi	Mbagathi-Nairobi	
Middle Athi	Kajiado Makueni Taita Taveta	Middle Athi	Kibwezi	Thwake	*Chyulu Hills Namanga Hills Taita Hills Kasigau Hills Maungu Hills Makuli Hills Mbooni Hills Nthanga Hills Kilungu Hills Mbui Nzay Hills Yekanga Hills Nzueni Hills Makongo Hills
		Noltresh-Lumi	Loitokoitok	Tsavo	
Lower Athi	Taita Taveta Kwale Kilifi Mombasa	Coastal-Athi-Mombasa	Mombasa	Coastal zone/Mombasa	*Shimba Hills Mwang'ea Hills

**Gazetted*

6.3.4 Strategy

In previous Sections of this Report, water resource protection issues have been identified. Environmental nodes have also been identified for environmental flow monitoring (Figure 6-10).

In order to comprehensively and systematically address the hydrometeorological monitoring issues and challenges in the Athi Basin, Table 7-8 sets out 4 Strategic Themes with specific Strategies under each Theme. The Themes address Classification of water resources, Reserve determination, Resource quality objectives and the Conservation and Protection of ecological infrastructure.

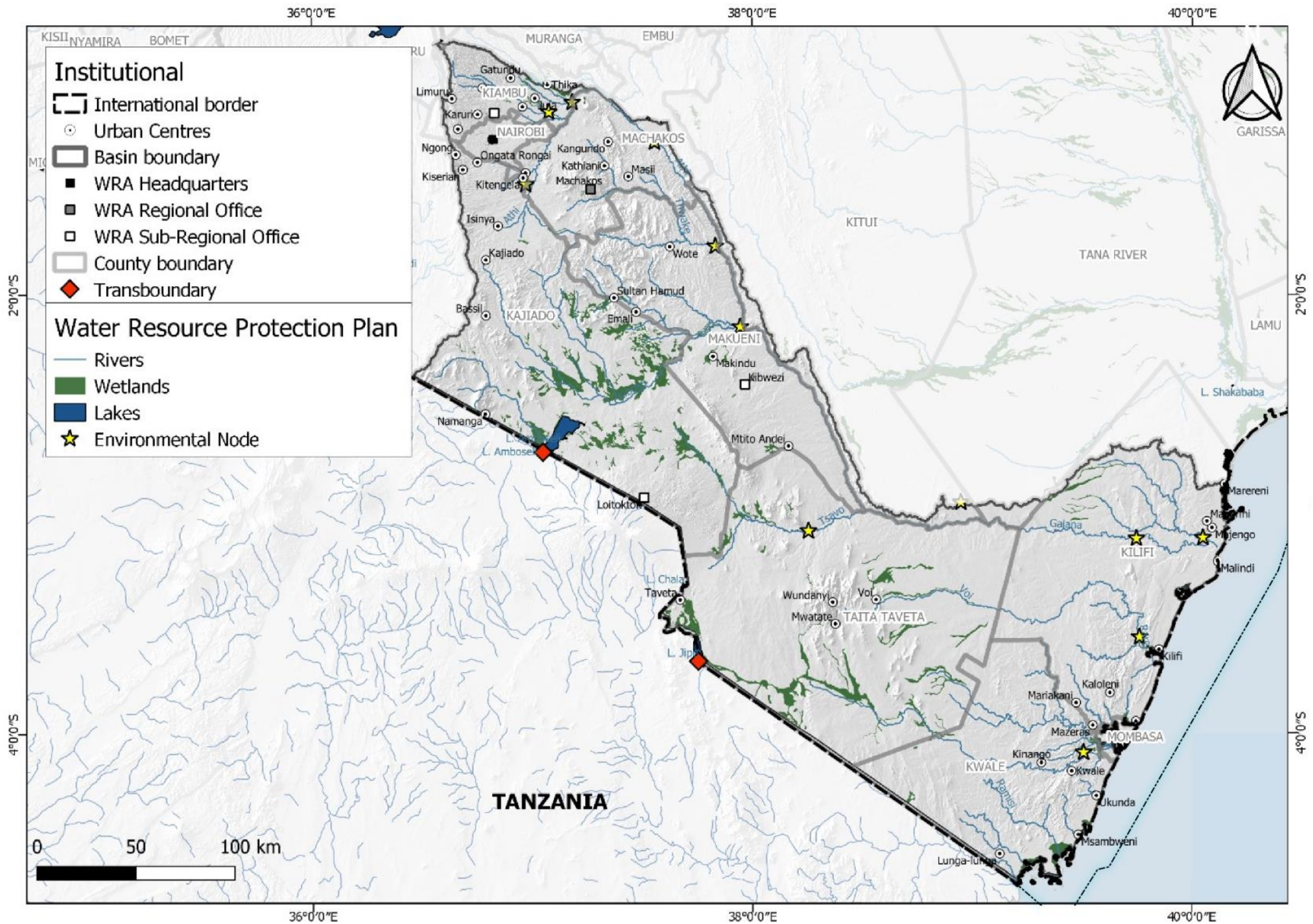

Figure 6-10: Water resource protection considerations for Athi Basin

Table 6-8: Strategic Framework - Water Resources Protection

2	**Key Strategic Area:**	**Water Resources Protection**
2.1	**Theme:**	**Classification of water resources**
2.1.1	Determine the baseline for Resource Directed Measures: Surface and groundwater assessments at appropriate scales to inform the classification of water resources in the basin.	
Water quality and quantity assessments are required in order to set a baseline for resource directed measures. This baseline will inform the classification and resource quality objectives for the significant water resources in the Athi Basin.		
2.1.2	Determine Class of water resources	
Determining the Class of a water resource is the first step in the water resource management cycle. A vision for the desired future state of water resources results in Ecological Categories for water resources based on the level of protection or increasing levels of risk. Ultimately the determined Class of a resource will determine the Reserve and associated resource quality objectives that are set to achieve it.		
2.2	**Theme:**	**Ecological Reserve**
2.2.1	Reserve determination	
In order to protect the water resources of the Athi Basin the ecological Reserve needs to be determined. The total water resource (surface and groundwater) is made up of what is available for allocation or use and the Reserve. The Reserve (in terms of quantity and quality) is made up of what is needed to satisfy the basic human needs of people who are or may be supplied from the water resource (i.e. Basic Human Needs) and what is needed to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the water resource (i.e. ecological Reserve). The water requirements of the ecosystem must therefore be met before any allocation may be made. This forms part of the water resource management cycle which is an adaptive management approach focused on goal-setting. Once the environmental reserve is defined then the resource quality objectives can be determined for priority water resources.		
2.2.2	Reserve compliance	
Water quantity is a key driver of water resources therefore its management is critical in the maintenance of ecosystems and for the provision of water for socio-economic purposes. Once the environmental reserve has been set then the flows required to maintain the reserve need to be managed. Implementing the operating rules to ensure that the releases from infrastructure required by users and the ecology are met in time and at Eflow site. This may consist of the operation of dams, abstractions and other infrastructure as well as management through licensing and implementation of restrictions. Compliance hydrological monitoring is required, based largely on the continuous monitoring at a network of flow and water level gauges. Compliance monitoring is also required, based on monitoring low flows and water levels at gauging weirs and boreholes.		
2.3	**Theme:**	**Determine resource quality objectives**
2.3.1	Set resource quality objectives	
Determine the resource quality objectives for prioritised water resources in the Athi Basin.		
2.4	**Theme:**	**Conservation and protection of ecological infrastructure**
2.4.1	Integrate environmental considerations into basin development and planning	
Water is critical to social and economic development but is also a critical component in supporting key ecological systems which underpin human wellbeing as well as providing essential ecosystem goods and services. A strategic social and environmental assessment is therefore an important component of the Classification of Athi Basins water resources. The Classification of water resources strikes a balance between social and environmental considerations.		
2.4.2	Groundwater protection	
Rehabilitate polluted aquifers, springs and wells as part of Catchment Management Plan. Groundwater source protection zones defined by WRA and gazetted under Water Act 2016.		

2.4.3	Riparian areas protection
Riparian areas, as defined by WRA, gazetted under Water Act 2002 and WRM Regulations 2007, currently under amendment by Attorney General in accordance with revised definition agreed on at sixteenth meeting held on 2 June 2020 by the National Development Implementation and Communication Cabinet Committee.	
2.4.4	Ecosystem services protection
Water is critical to social and economic development but is also a critical component in supporting key ecological systems which underpin human wellbeing as well as providing essential ecosystem goods and services. In particular, certain environmentally sensitive areas are reliant on the protection of water resources. Although environmentally sensitive areas are defined by NEMA, this information should be provided to WRA during the Classification of water resources in order for WRA to classify and protect according to the Water Act 2016.	

6.4 Groundwater Management

6.4.1 Introduction

Groundwater has provided and will continue to provide much of the water needed for livelihoods and development for many communities and industries in Kenya. Numerous rural communities and small towns across the Republic depend on groundwater from boreholes and shallow wells for their domestic and livestock needs, and to support other economic activities. Spring flow and baseflow contribute significantly to maintaining streamflow, particularly during dry seasons. Groundwater management is known to be one of the most important, least recognised and highly complex of natural resource challenges facing society (S. S. D. Foster, 2000).

Groundwater in Kenya is currently not managed in a coherent fashion (Mumma et al., 2011). A final draft National Policy on Groundwater Resources Development and Management was published in 2013 (Ministry of Water and Irrigation, 2013), but despite the best of intentions, groundwater remains poorly understood and poorly managed. The policy document highlights a number of specific issues:

- Availability and vulnerability of groundwater resources in Kenya are poorly understood
- Institutional arrangements for groundwater management in Kenya, including management capacity and financing are weak
- Very limited integrated water resources management in Kenya, with groundwater and surface water typically being treated as separate water resources
- Very limited groundwater quality management in Kenya

In addition to the National Policy on Groundwater Resources Development and Management, the National Water Quality Management Strategy (NWQMS) (Ministry of Water and Irrigation, 2012) addresses groundwater protection in Section 2.7. It recommended the “Development of Ground Water Protection programs” without defining or describing them. The NWQMS lays out the following “strategic responses”:

- Extraction of groundwater at sustainable rates to avoid seawater intrusion.
- Intensifying groundwater quality monitoring by sinking observation boreholes.
- Establishing a monitoring program for selected production wells to capture any changing trends.
- Requiring all borehole owners to have their water tested periodically as part of the water quality monitoring programme.
- Maintain updated database of borehole data.

A groundwater management strategy is influenced by hydrogeological, socio-economic and political factors and is informed by both policy and strategy. This Groundwater Management Plan is necessary for the integrated and rational management and development of groundwater resources in the Athi Basin. It aims to capture and integrate a basic groundwater understanding, describes sustainable management measures and presents an action plan with clear objectives and desired outcomes. It also estimates the financial requirements needed for implementation and the timeframe for its implementation. It is not a static instrument. As resources monitoring and data analysis takes place across the planning period, improvements and even whole new aspects may need to be incorporated.

The key objectives of the Plan include:

- Conserve the overall groundwater resource base and protect its quality
- Recognise and resolve local conflicts over resource allocation (abstraction or pollution)

Note: A Groundwater Management Plan needs to be differentiated from an Aquifer Management Plan: the former considers groundwater management from a Basin perspective, while an Aquifer Management Plan is applied to a single aquifer unit.

6.4.2 Groundwater use

Groundwater has provided and will continue to provide much of the water needed for livelihoods and development for many communities and industries in Kenya. Numerous rural communities and small towns across the Republic depend on groundwater from boreholes and shallow wells for their domestic and livestock needs, and to support other economic activities.

Within the Athi Basin, Kenya's capital city Nairobi relies extensively on both publicly and privately developed groundwater resources to augment its domestic, commercial and industrial water supply. The Nairobi aquifer system (NAS) underlies the Nairobi Metropolitan area and a number of satellite towns surrounding Nairobi. In addition to the development of the Kikuyu Springs water supply system many boreholes have been constructed for water supply in Nairobi since the first was drilled in 1927.

Mombasa relies almost entirely on groundwater sources, comprising the Marere Springs, Mzima Springs, Tiwi aquifer and the Baricho intake. Malindi and Kilifi are major settlements in the Athi Basin that also rely wholly on the Baricho aquifer. Voi, Maungu, other small towns and a broad range of consumers located along the Nairobi-Mombasa highway also rely on the Mzima source.

Groundwater from springs in the Chyulu Hills aquifer is the principal source of water for towns to the east of the Chyulu Hills (Kiboko, Makindu and Kibwezi).

West and south west of the Chyulu Hills, the regionally extensive North Kilimanjaro aquifer is an important groundwater resource e.g. the Nolturesh Spring supplies water to communities from Loitokitok to the Nairobi-Mombasa Road, and northwards into Makueni County. This aquifer also supplies some users in Loitokitok town, and livestock, wildlife, hotels and community groups in the Amboseli ecosystem. Springflow from the Kilimanjaro aquifer supplies water used for extensive irrigation in the Kimana area (north of Loitokitok), while Taveta Town water demand is also met from the North Kilimanjaro aquifer. Groundwater from the Njoro Kubwa and associated springs serves irrigation projects in the area between Taveta Town and Lake Jipe. Excess flows leave Lake Jipe and form the upper tributary of the Pangani, a major water resource in north eastern Tanzania.

Namanga Town, on the Kenya-Tanzania border, is largely supplied by groundwater from boreholes drilled in alluvium over metamorphic Basement.

Kajiado Town is largely supplied from aquifers in weathered Basement associated with fracturing and faulting; as many as 50 boreholes, both public and private, are in commission (ISGEAG, 2018).

Elsewhere, localised and often poor aquifers serve rural communities and small centres across the basin; often occurring in metamorphic Basement rock, these are small-scale but nevertheless important in terms of local water supply. In the South Coast, groundwater from boreholes and shallow wells are a critical component in rural and urban water supply, supplying over 100 000 people with water (T. Foster & Hope, 2016). This illustrates the importance of groundwater to human livelihoods and development in the Athi Basin.

The Mzima Springs aquifer currently supplies about 12.8 MCM/a to Mombasa via a 220 km pipeline as well as communities along the pipeline. There are plans to expand the existing offtake and a pipeline wayleave, some infrastructure and a preliminary design in fact already exist for the Mzima II project which will abstract 38.3 MCM/a.

The Baricho aquifer abstraction along the lower Sabaki River equals about 32.9 MCM/a and supplies Mombasa, Kilifi and Malindi, and communities along the pipeline. The resource could potentially provide up to 74.5 MCM/a (National Water Conservation & Pipeline Corporation, 1995). Chlorination works, pipeline wayleaves and some storage already exist. Pre-feasibility and conceptual designs for additional abstraction exist.

The Marere Springs currently supply about 4.6 MCM/a to Kwale, Kinango Towns and Mombasa. Possibly as much as an additional 1 MCM/a could be abstracted. This would require improved intake works and water treatment facilities.

Use from the Tiwi aquifer is already at its limit at an abstraction rate of 4.8 MCM/a. However, additional abstraction could be marginally feasible if borehole efficiencies improve and abstraction management recognises seawater intrusion. This would improve water supply to Ukunda/Diani and the proposed South Coast Resort City.

The South Coast ‘Msambweni aquifer’ has a current abstraction rate of about 6.9 MCM/a (commercial/irrigation uses). The mean modelled annual recharge is 122 MCM/a (Ferrer et al., 2019). The aquifer could potentially be used to improve water supply to Ukunda/Diani, Kinondo, Gazi, and Msambweni and southwards towards Shimoni. This would require high-capacity boreholes, and water to be pumped into the supply network.

The Nairobo Aquifer System (NAS) has limited scope for further public water supply development, but the proposed Ruiru and Kiunyu deep boreholes could potentially supply 22 MCM/a (via 2 x 11MCM/a wellfields) to Nairobi. There are, however, fluoride problems and high temperatures at Kiunyu, and high manganese at Ruiru. The current status of this option is uncertain

Springs from the Northern Kilimanjaro volcanic currently supply irrigation (5 160 ha) in the area between Taveta and Lake Jipe (County Government of Taita Taveta, 2018) and domestic demands in Taveta Town (current supply approx. 1.1 MCM/a). It also provides transboundary flows which are vital for Tanzania for water supply, irrigation and hydropower in the Ruvu/Pangani Basin). It has potential for further development.

Within the Athi Basin there is currently limited conjunctive use for public water supply:

- Within Nairobi, some public boreholes are used in conjunction with the extensive surface water supply system
- For water supply to Ongata Rongai and Kiserian: Kiserian Dam on the Mbagathi River is used in conjunction with springs and boreholes
- Machakos is supplied from the Maruba Dam and with water from the Nolturesh Pipeline (recently not fully operational).
- Mavoko (Athi River) receives bilk water from the Nairobi supply system as well as from the Nolturesh Pipeline and boreholes
- Mombasa, Malindi and Kilifi received water from the Baricho intake (groundwater recharged from stream flow), Mzima Springs, Marere Springs and Tiwi aquifer boreholes.

Private sector conjunctive use in the basin include numerous irrigated floricultural and commercial vegetable farms in the upper basin who use the whole range of water sources – groundwater, surface water, rainwater harvested from greenhouse roofs and in many cases, re-cycling of hydroponic water or treated water.

On the South Coast, at least two commercial activities rely on a combination of surface and groundwater resources:

- Base Titanium Ltd relies on a storage dam (Mkurumudzi Dam) and six production boreholes in the 'Msambweni aquifer' (up to 3.5 MCM/a) to supply process water to their mineral sands mine. This user also recycles a significant proportion of the water it uses. The dam and boreholes will be handed over to CWWDA for public water supply ate some future date.
- Kwale International Sugar Co Ltd relies on four storage dams and about 12 boreholes to meet irrigation and plant water demand. It has a surface water abstraction permit for up to 11 MCM/a, and a groundwater abstraction permit up to 3.8 MCM/a.

6.4.3 Groundwater resource potential

The annual groundwater recharge for the Athi Basin was estimated at 2 943 MCM/a, with a sustainable annual groundwater yield of 549 MCM/a. This is significantly higher than the NWMP 2030 sustainable groundwater yield estimate of 305 MCM/a for the Athi Basin. However, whereas the NWMP 2030 assumed sustainable yield as a percentage of recharge (10%), the groundwater assessment which was conducted as part of this Consultancy estimated sustainable yield based on regional and secondary permeability and topography.

Projected sub-basin precipitation and temperature changes under climate change scenario RCP 4.5 (refer to **Annexure A2**) were superimposed on the groundwater model of the Athi Basin to assess the potential impacts on recharge and groundwater potential. It was found that the recharge in the basin will increase by 3.4% to 3 043 MCM/a, while the potential groundwater yield is expected to increase by 2.3% to 562 MCM/a under RCP 4.5.

Annexure B lists the groundwater potential per sub-basin.

6.4.4 Proposed aquifer classification

The current classification system of aquifers in the Athi Basin (refer to Section 2.2.1) has the advantage of simplicity. It relies primarily on aquifer use and use intensity to determine aquifer description and status, followed by the county or locality, and finally the geology/hydrogeology.

However, this classification system is not entirely appropriate as it may lead to the understanding that certain aquifers or aquifer types 'belong' to specific counties or locales. They do not; geology and hence groundwater does not respect geopolitical boundaries. A revised system is therefore proposed, which ignores geopolitical boundaries and relies wholly on the geology of the Basin's aquifers, as shown in Table 6-9 and Figure 6-11.

It is acknowledged that this approach does not specifically capture those aquifer units or parts of aquifer units that are of key importance as water supply sources. However, these should ultimately be captured by Aquifer Management Plans and numerical models developed for them. They would be designated Priority Aquifers.

Note: Proposed classification, aquifer use management and aquifer health management are addressed in "ISC Report D2-2: Groundwater Monitoring and Management Guideline".

Table 6-9: Proposed classification of aquifers in the Athi Basin

Name	Geology/lithology	Area (km²)	Depth range (m)	Yield potential (m³/day)	Dominant flow type(s)	Typical water quality	Status
Strategic							
Nairobi Aquifer Suite	Nairobi Aquifer Suite (NAS) is a multilayer volcanic aquifer that comprises aquifer units composed of volcanic flows from different ages. The principal lavas are trachytic and are divided into 3 units: The Upper Trachyte Division, the Middle Trachyte Division and the Lower Trachyte Division. The Middle Trachyte Division comprises Tigoni, Karura, Kabete and Ruiru Dam Trachytes and the Kerichwa Valley Tuffs, with the tuffs being the main aquifer. Rocks of the Lower Trachyte Division include the Nairobi Trachyte, Nairobi Phonolite, Mbagathi Phonolitic Trachyte, Athi Tuffs and Lake Beds sediments and Kapiti Phonolite.	6 648	UAS-200; LAS-400	UAS->860 LAS-<240	Intergranular and fracture	$NAHCO_3$ type EC<1500 mg/l Variable fluoride UAS-<5 mg/l Fl^- LAS -> 1.5 mg/l Fl^-	Alarm
Chyulu Hills	Overlain by a succession of young (<26 000yrs) basaltic and pahoehoe lavas, agglomerates, volcanic cones and ash deposits, to a maximum thickness of 1,150m at the crest. Includes the Mzima Springs sediments (calcareous fossiliferous silts; lacustrine/depositional). The exact make-up of the material hosting the aquifer is uncertain.	2 140	<100	<860	Intergranular and fracture	EC<1000 µS/cm	Alert
Minor							
Sala Basement	Consists of gneiss, schists and granulites; metamorphosed psammitic and pelitic sediments; granitoid gneisses, with minor marble. Migmatites occur at a few locations presenting as biotite-hornblende banded and contorted gneiss.	474	<100	<86	Intergranular and fracture	EC>3000 µS/cm	Alert
Karoo Sediments	The suite comprises the Taru, Maji ya Chumvi and Mariakani formations. They comprise arkoses, sandstones, shales, and siltstones with minor conglomerates and limestones.	14 215	<100	<86	Intergranular & fracture	EC>3000 µS/cm	Satisfactory
Southern Basement	Banded gneisses; Granitoid gneisses; Granulites, these being part of the Kurase-Kasigau group of metasediments. Mainly biotite-hornblende gneisses in the Kurase Group and quartz-felspar-biotite-hornblende gneiss in the Kasigau Group.	32 010	Generally <100	<240	Intergranular and fracture	EC>3000 µS/cm	Alert
Yatta Phonolite	The phonolite is a dense microcrystalline type with dark green to grey colours and porphyritic texture.	645	<15	<86	Fracture	EC<1500 µS/cm	Alert

Coastal Sediments Suite	Members include the Pliocene Magarini Formation, pale cream to red-brown fine to coarse sands, though clays, silts and occasionally weakly-cemented sandstones are present. The Pleistocene Kilindini Formation comprises a heterogeneous mix of clays, silts, sands, coral blocks and breccia, with occasional calcareous sandstones laid down under lagoonal conditions behind a fringing reef. Also included is the Pleistocene fossil coral reef formed contemporaneously with the Kilindini sands, and the two formations are inter-fingered. Usually present as a massive and compact fossil limestone with well-preserved coral fossils with sandy bands. It is the highest yielding of the Coastal Sediments Suite. Recent material (alluvium) is not extensive; typically quite thin (<15m), fine to coarse sands occasionally form a useful but low-yielding aquifer.	3 487	Two types; Sands <25; coral breccia <70;	>860	Intergranular	EC<1500 µS/cm in the South Coast; EC>1500 µS/cm in the North Coast	Alert
Poor							
Kambe Limestone & Shale	Kambe Formation comprises dark grey, dense, oolitic, coralliferous/reefal and dark bluish limestones with interbedded shales. The formation has three distinct limestone facies, including the Rare Limestone, the Pangani Limestone and the Mwachi Limestone Members, named after their type localities. The aquifer also includes the Mtomkuu Formation, mainly shales with subordinate sandstones, limestones, marls and siltstones.	1 374	<100	<86	Intergranular	EC<3000 µS/cm	Alert
Special							
Kilimanjaro	The aquifer is comprised of olivine basalt, phonolites, rhomb porphyries lavas and pyroclastics from the Kibo Stage of Mt Kilimanjaro volcanicity.	3 348	100-200	<860	Intergranular and fracture	EC<2000 µS/cm	Alert
Shimba Hills	The aquifer is made up of the Shimba Grits which is the upper member of the Mazeras Formation and the youngest in the Karoo System. Due to its higher groundwater potential, this unit of the Karoo is designated a separate aquifer unit. The rocks are coarse sandstones with pebbly horizons; the pebbly facies being much coarser, thicker and better developed in the Shimba Hills.	674	<100	<860	Intergranular and fracture	EC<1500 µS/cm	Satisfactory

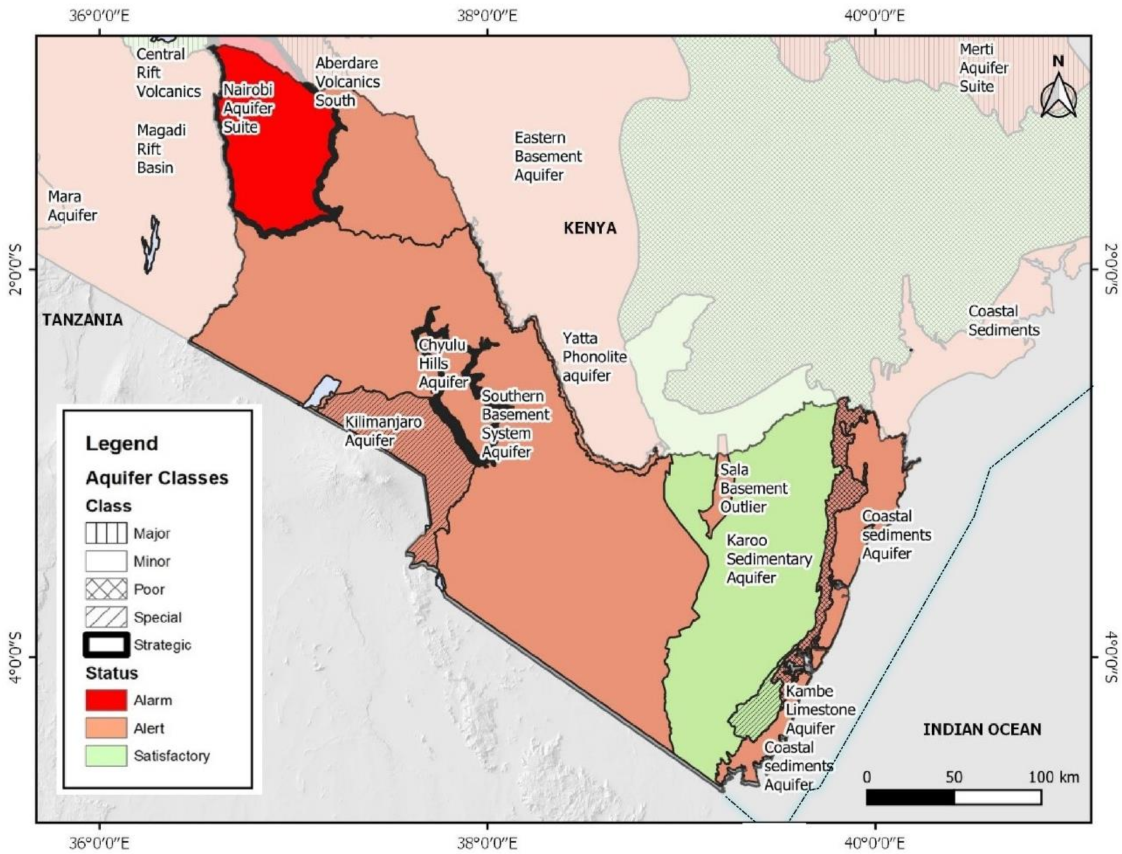

Figure 6-11: Proposed aquifer classification of the Athi Basin

6.4.5 Key groundwater issues and challenges in the Athi Basin

6.4.5.1 Vulnerability

A review of groundwater vulnerability assessment in Kenya as a whole is given by Rendilicha et al. (2018) and highlights how few vulnerability assessments have been carried out in Kenya. Groundwater pollution by human waste leaching from pit latrines has been demonstrated beneath Kisumu (Kimani-Murage & Ngindu, 2007) and Eldoret (Kiptum & Nbambuki, 2012). Seawater intrusion risk has been identified in the Lamu Shela dunes aquifer (Kuria et al., 2010).

The vulnerability of Athi Basin aquifers is largely unknown as few aquifers have been studied at the appropriate level of detail. Published studies have concentrated on coastal areas including Ukunda/Diani and Kwale (Tole, 1997); Kisauni and Mombasa County (Munga et al., 2006); Dongo Kundu and Kwale County (Mwaguni et al., 2013); and southern Kwale County (Nowicki et al., 2019). All of these studies confirmed that groundwater pollution by human wastewaters had occurred.

Oteri (1991) found saline intrusion in the Diani, but not the Msambweni area. However, Tole (1997) confirmed that saltwater intrusion was taking place along the seafront in the Diani to Msambweni area. A 2015 study found that shallow well and borehole waters in the Ruiru area contained elevated concentrations of both total coliform and *E coli* bacteria (Olonga et al., 2014).

A 2011 GW Governance Study (Mumma et al., 2011) considered the vulnerability of four Kenyan aquifers to pollution and seawater intrusion; three of these are in the Athi Basin as listed below:

Table 6-10: Vulnerability of three Athi Basin aquifers to pollution and seawater intrusion

Name	Pollution vulnerability (GOD [1])	Seawater vulnerability (SEA-GIndex [2])
Nairobi aquifer system	0.1 (negligible to low)	None
Baricho aquifer	0.6 (high)	0.1 (negligible)
Tiwi aquifer	0.3 (low to moderate)	0.5 (moderate)

[1] GOD is a vulnerability assessment method based on **G**roundwater confinement, **O**verlying strata and **D**epth to groundwater.

[2] SEA-GIndex is a modification of DRASTIC which allows a qualitative assessment of seawater intrusion risk (Bocanegra & Massone, 2004).

Seasonal saltwater intrusion into parts of the North Mombasa Mainland aquifer system (shales, back-reef deposits and coral limestones) has also been described (Idowu et al., 2017).

Saltwater intrusion into the northern part of the Tiwi aquifer has recently been confirmed (Oiro et al., 2018). Seawater intrusion in the Ngomeni/Timboni aquifer, north east of Malindi, is due at least partly to the impact of industrial salt works (cf. Table 6-10 above, where it is designated a SPECIAL aquifer for this reason).

Concerns have previously been expressed about the vulnerability of the NAS: GW•MATE (S. Foster & Tuinhof, 2005) expressed concern about the potential for groundwater pollution from land uses to the 'upper aquifer', and observed that while there was no hard evidence of pollution, there had been little investigation of it. GW•MATE listed the following as potential sources of pollution:

- Solid waste landfills and dumpsites
- Seepage from latrines, septic tanks, sewers and drains
- Leakage from underground storage of petroleum and chemicals
- Seepage of industrial effluents
- Infiltration from polluted streams.

There is no doubt whatsoever that streams draining the Nairobi area are polluted (Njuguna et al., 2017). Recent studies show that recharge to the NAS occurs in part from surface water impoundments and flood events (Oiro et al., 2018), suggesting that where these are polluted, recharging water may be polluted too.

Groundwater users downstream are also potentially at risk; at Baricho, Sabaki river waters have been tested and found to contain organochlorine pesticide metabolites at measurable concentrations (Lalah et al., 2003). This is of concern, as the palaeochannel aquifer at Baricho is recharged from streamflow in the Sabaki River.

K'oreje et al. (2016) found pharmaceutical compounds in wastewaters, surface waters and groundwaters in Kisumu; and in wastewaters and surface waters in Nairobi, albeit at low concentrations. Similar groundwater pollution in the Athi Basin is almost certain, particularly in aquifers beneath high density informal settlements.

The foregoing illustrates that while relatively few studies have been carried out, there is broad evidence showing that pollution has already occurred in shallow groundwater systems in both Kenya and the Athi Basin, as has seawater intrusion in the South Coast and Mombasa areas. Measures aimed at addressing vulnerability should include:

- Define vulnerable aquifers (through abstraction and groundwater quality surveys; and the review of data)
- Delineate vulnerable aquifers (through GIS and mapping on the ground)
- Develop methods to protect vulnerable aquifers

6.4.5.2 Water quality

Natural contaminants in the Athi Basin include fluoride, iron and manganese. Widespread natural fluoride occurs in the NAS and in some of the other volcanic aquifers (not the Chyulu aquifer), while natural iron and manganese are found in much of the Basement and in the Mazeras Sandstone. Naturally elevated salinity characterises some of the Karoo aquifer system (Taru Grits, Maji ya Chumvi and Mariakani), while Basement groundwater also often contain elevated TDS.

Saltwater intrusion is widespread along the Athi Basin coastal strip (Idowu et al., 2017; Munga et al., 2006; Nowicki et al., 2019; Oiro et al., 2018; Opiyo-Akech et al., 2000; Oteri, 1991; Tole, 1997).

Pollutants from human wastewater are a threat to shallow groundwater in Mombasa, along the Coastal Strip and possibly in informal settlements in Nairobi. Pollution by pharmaceuticals is likely but not certain. No evidence of agriculture-sourced diffuse pollution in the humid upper parts of the basin exists, but this has not apparently been studied. Generally, the extent and significance of groundwater pollution in the Athi Basin is unknown.

6.4.5.3 Other issues and challenges

Regulatory

Poor planning and lack of integration when it comes to surface water and groundwater allocation are evident, with surface and groundwater effectively treated as different water resources. The recent Water Allocation Plan Guideline (Water Resources Authority, 2019a) should help resolve this, as it defines both surface water and groundwater as resources.

Unclear NEMA and WRA mandates re wastewater management and licensing (both bodies seek ‘polluter payments’ from water users/polluters) is an issue. NEMA legislation (Act of 1999 and effluent regulations in the Environmental Management and Coordination (Water Quality) Regulations, 2006), pre-dates water legislation (Water Act in 2002, and effluent regulations in the WRM Amendment Rules, 2012).

Mandates between Counties and the WRA are also uncertain, with Counties in particular drilling boreholes without the benefit of WRA Authorisations and sometimes of poor technical quality (installing mild steel casing/screen in low pH GW environments, for example). Furthermore, potential conflict between national and county governments is likely, regarding the sharing of natural resources benefits (*The Natural Resources (Benefit Sharing) Bill*, 2014; *The Natural Resources (Benefit Sharing) Bill*, 2018), the 2014 Bill was shelved, and the 2018 Bill has yet to be debated. Both Bills specifically include water resources.

Inadequate monitoring

Groundwater monitoring has improved significantly in the past decade, with a total of 40 groundwater monitoring points across the Athi Basin (4 Strategic, 20 Major, 11 Minor and 3 Special) (Water Resources Authority, 2018f). Data quality is, however, patchy - most groundwater level data are collected from boreholes that are used as production boreholes. All too often, the data show dynamic as well as static water levels. This restricts the utility of water level data to determine long-term trends. This is changing, however: an additional 25 dedicated monitoring boreholes were being constructed in the Basin in 2018-19, to be fitted with water level loggers and telemetry. These include:

- 8 shallow and 8 deep monitoring boreholes are to be installed in the Nairobi Aquifer System (NAS)
- 3 shallow and 6 deep monitoring boreholes are to be installed in the Tiwi aquifer

Private sector or NGO players do operate their own monitoring networks, such as that operated by Base Titanium Ltd in the South Coast (covering both water levels and water chemistry). The water level monitoring network operated by UNICEF/CARE Kenya in the Dadaab part of the Merti aquifer has been terminated.

Field water quality data collection is also improving, with a broader range of measurements planned in order that resource quality objectives can be determined. Parameters planned cover the following: electrical conductivity, turbidity, temperature, pH, total suspended solids, dissolved oxygen, total nitrogen and total phosphorus (this list given in the 2015 Athi CMS for surface water, it is assumed that the same instruments are available for GW quality monitoring: (Water Resources Management Authority, 2015b)).

Abstraction monitoring is done on an ad hoc basis at best - groundwater users are required to submit abstraction data monthly or quarterly as evidence to support their water charge payments, but these are rarely checked in the field by the WRA. The capacity to improve abstraction monitoring will be boosted by the adoption of formal guidelines for groundwater abstraction surveys, using electromagnetic flow meters (Water Resources Authority, 2018d).

Groundwater permit classifications

For water permit classification it is necessary to determine whether dedicated monitoring boreholes (or piezometers) require a Water Permit. In cases where a monitoring borehole may be periodically used to obtain small quantities of water for analysis (<<1m^3), a Category A Permit should potentially be issued. Prior to 2014, applications to construct monitoring boreholes were issued with Authorisations but not Water Permits. Since 2014 there has apparently been no requirement for either Authorisations or Permits for monitoring boreholes (diameters <4"/102mm). It is necessary to determine whether true exploratory boreholes require a Water Permit after completion if they are not to be commissioned as production boreholes. There is a need to clarify the role and application of the Form WRMA 0A3 (Notification Approval for Construction of Work and Use of Water).

For Class A, the applicant will get an Approval. For Class B, C and D, the applicant is issued with a Permit. For all Classes, the applicant is mandatorily required to obtain an Authorization.

Outdated borehole inventory

Borehole data have been and are stored in several separate systems:

- The 1992 NWMP (Water Resources Management Authority, 1992) initiated the National Water Resources Database (NAWARD), which remains a source of data - although it has not been updated since 2005. In the period 2005-2010, the data collection role was taken up by the WRA, and during the handover period, there was a measure of confusion as to which agency drilling contractors should submit drilling data to (Ministry of Water and Irrigation, 2012).
- The WRA currently collects and stores borehole data in a combination of paper and digital formats, with the long-term intention of digitising all records. The first attempt at digitising borehole data was made in 2010 as part of the Nairobi Borehole Census. All borehole records that could be found across a wide range of sources were digitised and established in a Microsoft Access database system, protected by password access.

Completion of the digitisation exercise is essential. This should be digitally linked to/interfaced with the PDB.

Inadequate protection

Discussions about a policy for groundwater protection were initiated within the WRMA in 2006 (Water Resources Management Authority, 2006); these were considered during the development of the National Groundwater Policy (Ministry of Water and Irrigation, 2013).

The National Water Quality Management Strategy (Ministry of Water and Irrigation, 2012): in S. 2.7 (Ground Water Protection), lays out the following "strategic responses":

- Extraction of groundwater at sustainable rates to avoid seawater intrusion.
- Intensifying groundwater quality monitoring by sinking observation boreholes.
- Establishing a monitoring program for selected production wells to capture any changing trends.

- Requiring all borehole owners to have their water tested periodically as part of the water quality monitoring programme.
- Maintain updated database of borehole data.

It also recommended the "Development of Ground Water Protection programs" without defining or describing them.

Over-abstraction in the Athi Basin

Over-abstraction across the Athi Basin is patchy and restricted to 'hotspots':

- In the NAS (not everywhere), the extent of depletion could be mapped reasonably easily, while there is some limited scope for Managed Aquifer Recharge (MAR) (National Water Conservation & Pipeline Corporation, 2006; Water Resources Management Authority, 2009).
- Across much of Mombasa County (where over-abstraction is probably worse than currently understood), there is limited scope for mitigation other than by boosting public water supply, which is acknowledged as falling far short of current demand. Local stakeholders estimate that up to 70% of water demand is met from local GW sources, with both saltwater intrusion and declining water levels in boreholes and shallow wells reported (The Nature Conservancy, 2018). Wastewater treatment capacity is poor, and coverage is incomplete, which means that the use of treated wastewater for recharge is not at present a viable option.
- The central and northern parts of the Tiwi Aquifer are salinizing due to over-abstraction (Oiro et al., 2018). This could be mitigated through managed artificial recharge - infiltration basins between the sea and the wellfield is probably the easiest technical option, but the source of recharge water is uncertain.
- Other aquifers are not known. Possibly some Basement aquifers have suffered localised depletion.

Insufficient information on groundwater recharge and potential

Updated high level estimates of groundwater recharge and potential have been completed as part of this Consultancy (see Section 2.4.2). A few numerical models or partial models on groundwater in the Athi Basin are available e.g. NAS, Msambweni aquifer; Chyulu Hills aquifer and Baricho palaeochannel aquifer. Elsewhere there are no models and often a poor level of understanding. There is therefore a need to select Priority Aquifers for modelling. This will inevitably require the establishment of a water resources monitoring network in advance of generating a model, which would involve any or all of the following: climate; surface water flows; groundwater levels, abstraction rates and water quality. A time series of several years is ideally required for the baseline dataset which the model will use for calibration. Given the natural climate variability of much of the Basin, it is desirable that both drier and wetter than 'normal' years are captured.

Transboundary aquifers

There are two transboundary aquifers in the Athi Basin and part of a third out of eight across the country (Nijsten et al., 2018):

- AF31 – Coastal Sedimentary Basin/Karoo Sedimentary aquifer system (ILEC et al., 2015); total area 15 000km^2, shared with Tanzania. Combines the Karoo Suite, Shimba Hills, Kambe Limestone and Shale, and Coastal Sediment aquifers.
- AF32 – Kilimanjaro Aquifer (ILEC et al., 2015); total area 13 000km^2, shared with Tanzania. The Northern Kilimanjaro aquifer is part of this aquifer system; ILEC includes the Chyulu Hills aquifer within this unit, which is incorrect; it is lithologically and structurally different to the Kilimanjaro aquifer.
- AF72 – Rift Aquifer (ILEC et al., 2015; Nijsten et al., 2018); a total of 19 000km2, shared with Tanzania. The extreme eastern edge of this aquifer lies in the Athi Basin; the boundaries of this aquifer system are ill-defined.

The East African Community Protocol on Environment and Natural Resource Management (East African Community, 2018), Article 13 (Management of Water Resources) addresses transboundary water resources: "The Partner States shall develop, harmonise and adopt common national policies, laws and programmes relating to the management and sustainable use of water resources". The EAC has not yet been ratified by Tanzania.

Nationally, the Draft National Policy on Trans-Boundary Waters (Ministry of Water and Irrigation, 2009), provides limited guidance or intent on transboundary GW resources. The statement is brief, and cited in full below (S. 5.1, para. 38):

> "Consideration will also be given by the Government to the feasibility of declaring vulnerable trans-boundary catchment areas as "protected areas" under the provisions of the Water Act, 2002. This allows the Minister to declare an area to be a protected area if special measures are necessary for the protection of the area. A similar mechanism exists with respect to groundwater, in which case the protected area is designated a "groundwater conservation area." This mechanism may be useful with respect to shared water resources such as Lake Jipe or, in the case of groundwater, the Merti Aquifer, which are vulnerable to unsustainable exploitation and, because of their trans-boundary character, lack effective frameworks for sustainable management."

A transboundary aquifer policy needs to be developed for Kenya.

The National Groundwater Policy (Ministry of Water and Irrigation, 2013), lists the following activities required to improve transboundary groundwater management ("Issue 9").

Table 6-11: Proposed transboundary aquifer (TA) policy measures

Issue	Objective	Policy direction	Activity	Timeframe
Transboundary aquifers not well known, characterised nor managed	TAs well known, characterised and managed by countries sharing TAs	Implement appropriate new policies and institutions to ensure seamless management of TAs	a) Identify and demarcate TAs; b) Collect information; c) Promote information sharing and adopt international good practices; d) Expand transboundary water unit to Department	Short- to long-term

Finally, the National Land Use Policy (Ministry of Lands and Physical Planning, 2017) specifically describes measures to be adopted in relation to the definition and management of transboundary groundwater resources.

Climate change

That climate change will affect Kenya is largely unquestioned. Numerous global climate models forecast increasing temperatures, deeper dry seasons and more intense rainfall. The effects of both floods and drought have been significant, adversely affecting gross domestic product (GDP). Adverse effects on the water sector are well documented (Mogaka et al., 2005; Mwangi & Mutua, 2015).

Kenya has developed a climate change adaptation plan (Ministry of Environment and Natural Resources, 2016), which "recognizes that climate change is a cross-cutting sustainable development issue with economic, social and environmental impacts". The Plan is underpinned by the Climate Change Act (2016).

Groundwater is less affected by climate change than surface water, and as such it can contribute hugely to ameliorating the short-term effects of climate change (also see conjunctive use). In the longer term, the effects of climate change on Athi Basin aquifers are uncertain, though as adduced above, a slight increase in mean annual recharge is likely. Sea level rise will affect coastal aquifers in hydraulic continuity with the sea (Coastal Sediments). Other potential impacts related to climate change may include declining recharge from the forest belt of Mt Kilimanjaro to the Northern Kilimanjaro aquifer system, exacerbated by deforestation or substitution of natural forest with plantation forest.

Poor technical quality of drilling

The National Groundwater Policy (Ministry of Water and Irrigation, 2013) acknowledges that the quality of drilling in Kenya is poor - which is widely understood in the groundwater sector (S. 3.10 National and local level Capacity Needs, p. 36 – 37). Despite a drilling contractor registration and regulation process, the technical quality of borehole drilling in Kenya is poor and has declined perceptibly in the past two decades; This needs to be reversed by appropriate application of the existing Codes of Practice (for siting boreholes; for construction of boreholes; for supervision of borehole drilling and construction; and for the conduct of pumping tests – see (Water Resources Authority, 2018a, 2018b, 2018d). Regulation and registration is currently carried out by the parent Ministry, which does not monitor the quality of drilling works. This creates confusion between the WRA and the Ministry, as it is the WRA who observe the consequences of poor-quality drilling and are best positioned to report on and regulate it.

The technical capacity of the WRA in the supervision of borehole drilling needs to be improved, and the number of groundwater staff available to monitor or supervise drilling activities need to be increased. This is important not only to vet the private sector hydrogeologists who currently supervise drilling operations (if they are supervised at all), but also to support the development of this capacity.

Boreholes drilled by County water ministries often do not comply with the WRM Rules (Water Resources Management Authority, 2007a) - either in drilling only after an Authorisation has been issued, failing to collect a water sample for analysis, or failing to conduct proper pumping tests.

Enforcement of conditions of Authorisations to construct boreholes

Due to inadequate technical capacity and insufficient technical staff in the WRA, conditions attached to Authorisations are not always observed. This is associated with the discussion above on borehole drilling supervision capacity.

6.4.6 Strategy

In order to comprehensively and systematically address the groundwater issues and challenges in the Athi Basin, Table 6-12 sets out 4 Strategic Themes with specific Strategies under each Theme. The Themes address Groundwater Resources Assessment, Allocation and Regulation, Groundwater Development, Groundwater Asset Management, and Conservation and Protection of Groundwater.

Table 6-12: Strategic Framework – Groundwater management

3	**Key Strategic Area:**	**Groundwater management**
3.1	**Theme:**	**Groundwater resources assessment, allocation, regulation**
3.1.1	Groundwater assessment – assess groundwater availability in terms of quantity	
Assessing groundwater resource quantity is an essential pre-requisite for any water management process. Nationally, the Kenya Groundwater Mapping Project (47 Counties, 2017-2023; Government of Kenya, 2017b) should be implemented and supported as relevant to the Athi Basin. In parallel, more detailed estimates of sustainable groundwater yield in priority areas / aquifers should be undertaken.		
3.1.2	Groundwater assessment – groundwater quality and use	
Abstraction surveys (quantity and quality) for Priority Aquifers and other affected aquifers should be undertaken in order to assess current groundwater use and quality across the Athi Basin.		
3.1.3	Update and improve permit database	
The permit database (PDB) in relation to groundwater requires considerable improvement if it is to be the vital planning tool it must become. The fully functional PDB should allow the following types of data to be extracted from it: a) Permitted groundwater abstraction by aquifer unit or sub-catchment (or both) b) Calculate unallocated groundwater for each aquifer unit OR sub-catchment (or both). This requires that each groundwater Permit is ascribed to a named and geographically defined aquifer unit. This aquifer classification process is a work in progress, relying as it does on the re-definition of aquifers. The PDB also needs to be broadened so as to allow the capture of digitised borehole completion records (BCRs).		

3	Key Strategic Area:	Groundwater management
3.1.4	Groundwater allocation	

National resource quality objectives should be developed. In relation to a groundwater resource, the resource quality objectives means the quality of all aspects of the resource and could include any or all of the following (Colvin et al., 2004):

a) Water levels, GW gradients; storage volumes; a proportion of the sustainable yield of an aquifer and the quality parameters required to sustain the groundwater component of the Reserve for basic human needs and baseflow to springs, wetlands, rivers, lakes, and estuaries.

b) Groundwater gradients and levels required to maintain the aquifer's broader functions.

c) The presence or absence of dissolved and suspended substances (naturally occurring hydrogeochemicals and contaminants).

d) Aquifer parameters (e.g. permeability, storage coefficient, recharge); landscape features characteristic of the aquifer type (springs, sinkholes, caverns); subsurface and surface ecosystems in which groundwater plays a vital function; bank storage for alluvial aquifers that support riparian vegetation.

e) Aquatic biota in features dependent on groundwater baseflow, such as rivers, wetlands, and caves, or biota living in the aquifer itself or the hyporheic zone. Terrestrial plants and ecosystems dependent on groundwater.

f) Land-use and water use which impact recharge quantity or quality. Subterranean activities, such as mining or waste disposal, that affect the aquifer directly. The control of land-based activities by aquifer protection zoning of land-use.

g) Any other groundwater characteristic.

It is clear that resource quality objectives can include any requirements or conditions that may need to be met to ensure that that the water resource is maintained in a desired and sustainable state or condition.

The Guidelines for the Development of Water Allocation Plans in Kenya (Water Resources Authority, 2019a) discusses the determination of water balances and accommodates both surface water and groundwater. Current groundwater potential by sub-basin in the Athi Basin should be determined from the assessment of available groundwater and the current use (from the abstraction survey). Groundwater allocation plans should be developed. Groundwater allocation varies according to the importance of, and knowledge base for, a given aquifer:

- Poor and Minor aquifers: 25% of test discharge in an individual borehole is the safe allocable volume. Where an aquifer is reasonably well described (i.e. representative transmissivity values are available, as is the width, length and hydraulic gradient across the aquifer), then Darcy's Law (Darcy, 1856) may be used to determine mean through-flow (Q = -k.i.A). In this case, total allocable water should be 25% of average through-flow.
- For Major aquifers, the approach proposed in the NWMP 2030 is proposed. The NWMP 2030 adopts a cautious approach to determining sustainable groundwater abstraction; this is defined as 10% of recharge, but specifically excludes the riparian zone, which it determines as total river length x 1km. Recharge was defined as annual renewable resource minus annual surface water runoff, with 'annual renewable resource' defined as precipitation minus evapotranspiration.
- For Strategic and Special aquifers that are not (or not yet) designated Priority Aquifers and subjected to modelling, the NWMP 2030 approach should be used.
- For Priority Aquifers that have been modelled, allocable groundwater is 10% of mean annual recharge. Mean annual recharge should, wherever possible, take into account both wet and dry years in order to recognise natural recharge variability.
- The allocation of groundwater from aquifers that experience episodic recharge or are fossil aquifers remains unresolved, e.g. the Merti aquifer (Blandenier, 2015). How they should be treated in Kenya requires further debate and ultimately, a policy decision.

All of the above require the completion of the aquifer classification exercise.

3.2	Theme:	Groundwater development
3.2.1	Aquifer recharge	

Estimates of recharge per sub-basin in the Athi Basin were undertaken as part of this Consultancy. These are not based on ground studies, geophysics, drilling or modelling; therefore, it is necessary to conduct a preliminary assessment of recharge areas from existing data.

Definition of Recharge Areas: At present, the accurate definition of the recharge areas for almost all aquifers remains unclear. This makes it difficult to protect such areas. (Exceptions: Kikuyu Springs Recharge Zone;

3	Key Strategic Area:	Groundwater management

Msambweni Aquifer; Chyulu Hills Aquifer). Recharge areas for Priority Aquifers should therefore be defined.

Augmenting/preserving natural recharge: The Sponge City Kajiado concept (Oord, 2017), aims to manage and improve natural recharge by protecting land where significant recharge occurs. Other 'Sponge City' initiatives may be possible in other ASAL Basement aquifers.

Managed aquifer recharge: First mentioned in the 1999 Policy document (Government of Kenya, 1999) and the Water Design Manual (Ministry of Water and Irrigation, 2005), Managed Aquifer Recharge is covered in the Water Resources Management Rules (2007). Efforts were made to encourage managed aquifer recharge by developing a Code of Practice that discussed methods and management approaches, and considered a few instances of MAR potential in Kenya (Water Resources Management Authority, 2007a). It has been developed further since (Water Resources Management Authority, 2015b; A Njuguna, personal communication, December 2018), but has yet to be published. A study of the potential for Managed Aquifer Recharge in Kenya, commissioned by the National Water Conservation & Pipeline Corporation in 2006, provides a useful introduction to MAR and describes a number of possible MAR schemes across the country.

At a practical level, sand dams (masonry or concrete weirs across sand rivers which accumulate coarse sands that act as a storage reservoir) also act as MAR structures (Borst & de Haas, 2006; Mutiso, 2003). These are in widespread use in ASALs underlain by siliceous metamorphic Basement and have been in use for decades.

Ad hoc Managed Aquifer Recharge: Ad hoc Managed Aquifer Recharge was observed during the 2010-11 borehole Census of Nairobi; at least one industry captured roof rainwater-runoff and directed this untreated water into an existing abstraction borehole.

Managed Aquifer Recharge potential in the Athi Basin: The scope of, and potential for, managed aquifer recharge in the Nairobi area was laid out in a Discussion Paper in 2009 (Water Resources Management Authority, 2009). The limited understanding of existing aquifers (extent, potential storage) limits the application of MAR. Identified potential MAR schemes in the NAS include:

- Kikuyu, Kiambu County (seasonal surface water flow, a dam, injection wells and recharge pits) – (National Water Conservation & Pipeline Corporation, 2006)
- Muguga, Kiambu County (seasonal floodwater and sinkhole recharge);
- West Nairobi, Nairobi County (MAR of existing boreholes with treated rainwater);
- Central Nairobi, Nairobi County (treated stormwater and injection boreholes);
- Kandizi/Nol Chora/Kandis/Kiserian area, Kajiado County (check dams on losing streams);
- Jomo Kenyatta International Airport, Nairobi County (treated runway runoff and injection boreholes);
- Dandora, Nairobi County (treated wastewater and injection boreholes).

Furthermore, managed aquifer recharge could also be employed as saltwater intrusion protection (northern Tiwi aquifer already salinizing). Infiltration basins could recharge rainwater runoff from the A14 Likoni-Lunga Lunga road and recharge this into the coral limestones between the Tiwi aquifer and the sea.

Also, recharge via sand dams in seasonal streams in areas underlain by siliceous metamorphic Basement in Kajiado, Machakos, Makueni and Taita-Taveta Counties (National Water Conservation & Pipeline Corporation, 2006) should be considered.

3.2.2 Local groundwater development

Areas of unexploited groundwater resources should be identified and linked to small centre water demand estimates to determine if groundwater resources could meet these demands. Local groundwater development in the Athi Basin is largely ad hoc at present, heavily under-written at the WWDA and County level for rural water supply (single or a few boreholes to meet demands of small rural centres, schools and other institutions).

3.2.3 Large-scale groundwater development

The potential for groundwater development at a large scale should be assessed as part of integrated planning for bulk water resources development (Refer to Strategy 8.2.1), specifically as part of updated master planning for bulk water resources development to Nairobi and Mombasa and as part of regional water supply schemes.

3.2.4 Conjunctive use

Areas of unexploited groundwater resources should be identified and linked to water demand estimates to determine if groundwater resources could meet these demands as part of conjunctive use schemes.

3.3 Theme: Groundwater asset management

3.3.1 Develop asset inventory

An asset inventory should itemise all dedicated groundwater equipment in a readily accessible database. The asset inventory shall be available to those staff that may need it, and particularly to staff who will plan and coordinate activities or studies that require specific assets to support them. The inventory should include a list of assets determined during a formal inspection and verification process, complete with supporting paperwork:

3	Key Strategic Area:	Groundwater management

- Vehicles/heavy plant; at present, WRA groundwater does not own or operate its own vehicles or groundwater plant. There may come a time when it will operate its own drilling rigs (to construct monitoring boreholes) or other dedicated equipment
- Office infrastructure (dedicated groundwater computers and printers, laptops/notebooks, PDAs, licensed software, storage facilities etc.)
- Laboratory infrastructure: it is not expected that groundwater sections would have laboratories tied exclusively to groundwater, but laboratory facilities must be expanded to include the capacity to measure groundwater -specific parameters, e.g. bromide, strontium and boron to determine extent/degree of seawater intrusion (to low ppm Limits of Detection, better than 0.01mg/L)
- Field equipment (geophysics equipment [surface and down-hole], GPS instruments, water chemistry meters and associated equipment, dipmeters and sonic dippers, groundwater sampling equipment, electro-magnetic flowmeters etc.)
- Static field equipment (monitoring boreholes, loggers/barometric loggers and telemetry [covering both pressure/water level and field chemistry parameters such as temperature and electrical conductivity], monitoring flowmeters owned by the WRA etc.)
- Mobile equipment that will be left in the field for the duration of a study (Automatic Weather Stations and associated meteorological equipment, rainfall samplers, evaporation pans, portable weirs, time-series water quality probes etc.)

An Asset Inventory database system should be developed:

- Each asset should be tagged with a unique number
- Each item and its tag number should be entered into the inventory database, together with all relevant details (year purchased/acquired, office allocated to, office lent to, last service or maintenance period, next recommended service/maintenance etc.). The database system must allow that major components (such as a multi-parameter water quality probe), are linked to related spare parts (such as individual parameter probes or calibration reagents).
- Where an item is available for rent to the public (such as geophysics equipment), the relevant details should be included in the inventory database; this will include, but not necessarily limited to, the following:
  - Rental cost (per day or per week, as relevant)
  - Rental requirements (items rented must be insured by the renter and proof of insurance provided to the WRA)
  - Any other condition of rental

Name, address and relevant details of the renter, and the anticipated duration of the rental period

3.3.2	Develop asset management plan

Asset management is necessary to ensure that assets are used for the correct purpose and contribute to meeting the objectives of the WRA at National, basin and sub-basin levels. The asset management plan should ensure that the location and status of all assets are known to relevant staff. An asset management plan should be developed which must list all equipment and facilities that require refurbishing, along with a corresponding programme and budget. This should involve appropriate consultation with basin and sub-basin offices:

- For each item, determine what refurbishment is required
- Draw up a priority list of the items to be refurbished, together with a deadline for its refurbishment
- Determine the cost and duration of the refurbishment process
- Draw up a Refurbishment Plan, containing the deadlines, costs and duration of refurbishment, and feed this into the annual procurement planning process
- When refurbishment commences, ensure that the process is monitored, and funds spent on it are tracked
- After refurbishment, update the Asset Inventory to reflect change of status
- Amend Asset Management Plan as necessary

The asset management plan will ensure that all equipment is fit for purpose at all times, and that equipment requiring servicing, maintenance or calibration is serviced, maintained or calibrated when it is required.

The Plan should also indicate:

- The value of each asset
- The need for spare parts, and what a practical spare parts/consumable inventory would be
- Maintenance frequency for all assets and the typical life cycle of the asset
- The frequencies of planned maintenance
- A calendar showing when each item must be released for maintenance;
- The type of maintenance required (some may be maintained in-house within the WRA; other items may require maintenance by a dedicated supplier, or even sent overseas for maintenance).
- The maintenance cost, or anticipated cost

The asset management plan will feed into the annual procurement planning process.

3	Key Strategic Area:	Groundwater management
3.4	Theme:	Conservation and protection of groundwater
3.4.1	Groundwater source protection	
Groundwater vulnerability assessment: Once a National Policy for the Protection of Groundwater has been formulated and put into place (see KSA 9), Vulnerability Assessments should be conducted for the Athi Basin i.t.o. groundwater. **Saltwater intrusion prevention:** As above for saltwater intrusion prevention; assess significance of Athi Basin groundwater saltwater intrusion, prioritise and select aquifers requiring active intervention to contain or reverse saltwater intrusion. Draw up Plans for intervention to prevent, mitigate or reverse seawater intrusion; **Groundwater conservation areas (GCAs):** As above for GCAs; assess which Athi Basin aquifers or parts of aquifers require formal protection. Draw up Plans for the protection of Priority Aquifers or parts of Priority Aquifers. **Groundwater dependent ecosystems (GDEs):** As above for GDEs; assess which Athi Basin aquifers contain important GDEs. Draw up Plans to protect important GDEs.		
3.4.2	Rehabilitation of polluted aquifers, springs and wells	
Where groundwater protections have failed, measures need to be taken to address polluted aquifers. Here aquifers, springs and wells are lumped together as 'aquifers'. **Define Athi Basin's polluted aquifers**: Use the Guidelines for Groundwater Quality Surveys in Kenya (Water Resources Authority, 2018e) to define the extent of polluted aquifers, and determine what pollutants are present. Follow guidance presented in the NWQMS (Ministry of Water and Irrigation, 2012). **For each polluted aquifer, determine the optimum and most cost-effective way to rehabilitate it. T**he approach to be adopted will depend on the following: - Whether the aquifer is confined or unconfined; - The nature of the pollutant; e.g. dense non-aqueous phase liquids (DNAPLs) require a different treatment approach – pump, treat, return - compared with an aquifer polluted with human wastewater – eliminate the pollution source(s) followed by natural attenuation and remediation; - Whether the source of the pollution is diffuse or from a point source; - The affected aquifer area. Prioritise aquifers for rehabilitation and implement rehabilitation programmes.		

6.5 Water Quality Management

6.5.1 Introduction

Water quality is the physical, chemical, biological and aesthetic properties of water that determine its fitness for its intended use, and that are necessary for protecting the health of aquatic ecosystems.

Water quality management is the maintenance of the fitness for use of surface and groundwater resources, on a sustainable basis, by achieving a balance between socio-economic development and water resources protection. Fitness for use is an evaluation of how suitable water is for its intended purpose (e.g. domestic, agricultural or industrial water supply) or for protecting the health of aquatic ecosystems. The fitness for use evaluation is based on scientific evidence in the form of water quality guidelines or standards for different water uses (e.g. drinking water standards). The business of water quality management is the ongoing process of planning, development, implementation and administration of Kenyan water quality management policies, the authorisation of water uses that impact on water quality, and monitoring and auditing all these activities.

This section provides an introduction of the key water pollutants responsible for the deterioration of water quality in the basin, the point and non-point sources associated with the pollutants, and overview of the water quality status and threats in the basin, and a strategic framework for water quality management in the basin.

6.5.2 Water Quality Standards and Guidelines

Kenya has standards for drinking water quality (Table 6-13) and for effluent discharge limits for discharges into sewers and water bodies (Table 6-14) which WRA has adopted for use. National guidelines and standards for the different water uses, such as for Irrigation, Fisheries and Livestock watering still need to be formulated.

Table 6-13: Kenya and WHO Standards for drinking water quality

Parameters	Unit	WHO Standards	(Kenya Bureau of Standards, 2007)
pH	pH Scale	6.5-8.5	6.5-8.5
Colour	mgPt/l	Max 15	Max 15
Turbidity	N.T.U	Max 5	Max 5
Conductivity (25^0 C)	µS/cm	Max 2500	-
Iron	mg/l	Max 0.3	Max 0.3
Manganese	mg/l	Max 0.1	Max 0.5
Calcium	mg/l	Max 100	Max 150
Magnesium	mg/l	Max 100	Max 100
Sodium	mg/l	Max 200	Max 200
Potassium	mg/l	Max 50	-
Total Hardness	$mgCaCO_3/l$	Max 500	Max 300
Total Alkalinity	$mgCaCO_3/l$	Max 500	-
Chloride	mg/l	Max 250	Max 250
Fluoride	mg/l	Max 1.5	Max 1.5
Nitrate	mgN/l	Max 10	-
Nitrite	mgN/l	Max 0.1	Max 0.003
Sulphate	mg/l	Max 450	Max 400
Free Carbon Dioxide	mg/l	-	-
Total Dissolved Solids	mg/l	Max 1500	Max 1000
Arsenic	µg/l	Max 10	Max 10
Total Suspended Solids	mg/l	-	-

Table 6-14: Kenya Effluent Discharge Standards into water bodies and sewers

Parameters	Unit	Effluent Discharge Standards	
		Discharge into environment	Discharge into public sewer
Temperature	^oC	±3 ambient temp.	20-30
pH	pH Scale	6.5-8.5	6-9
Conductivity	µ S/cm	-	-
BOD5 days at 20 ^0C	mgO_2/l	30	500
COD	mgO_2/l	50	1000
Total Alkalinity	$mgCaCO_3/l$	-	-
Total Suspended Solids	mg/l	30	250
Total Dissolved Solids	mg/l	1200	2000
Sulphides as S^{2-}	mg/l	0.1	2
Oil + Grease	mg/l	Nil	5 or 10
4 Hr Permanganate Value	mgO_2/l	-	-
Salinity	ppt	-	20
Nitrate	mgn/l	-	-
Turbidity	N.T.U	-	-
Dissolved Oxygen	MgO_2/l	-	30
Detergents (MBAS)	mg/l	Nil	15

Parameters	Unit	Effluent Discharge Standards	
		Discharge into environment	Discharge into public sewer
Heavy Metals – Chromium, Cr	mg/l	0.05	0.05
Lead, Pb	mg/l	0.01	1.0
`	mg/l	-	0.05
Copper, Cu	mg/l	1.0	1.0
Cadmium, Cd	mg/l	0.01	0.5
Zinc, Zn	mg/l	0.5	5.0
Arsenic, As	µg/l	0.02	0.02

6.5.3 Key water pollutants and pollution sources

In order to develop and successfully implement a Water Quality Management Plan for the Athi Basin, it is important to understand which key pollutants are typically present in river basins where urbanisation, agriculture and human settlements occur. These pollutants are listed and briefly described below.

Suspended sediments and erosion Sedimentation refers to the erosion; wash-off and silt load carried by streams and rivers and typically reflects the natural geophysical and hydrological characteristics of a catchment. Many Athi basin rivers carry naturally high suspended solid loads but it is aggravated by changes in land-use. Sediment loads have further increased through extensive agricultural activities and practices, construction activities, unpaved roads and road construction, over-grazing, destruction of the riparian vegetation, sand mining activities, and the physical disturbance of land by industrial and urban developments.

Microbiological pollution and pathogens Microbial pollution refers to the presence of micro-organisms and parasites which cause diseases in humans, animals and plants. The microbial content of water represents one of the primary determinants of fitness for use. Human settlements, inadequate sanitation and waste removal practices, stormwater wash-off, and sewage spills are the major sources of deteriorating microbiological water quality in Athi basin rivers.

Organic material and dissolved oxygen Organic pollution refers to the discharge of organic or bio-degradable material to surface water that consumes oxygen when they decay, leading to low dissolved oxygen concentrations in the water. The decomposition of biogenic litter (vegetation, paper, raw sewage, etc.) in urban streams can contribute to low oxygen concentrations in receiving streams. Low dissolved oxygen concentrations are detrimental to aquatic organisms and it affects the solubility of, inter alia, metals. Metals adhered onto bottom sediment particles in streams, lakes and reservoirs can dissociate under low or anoxic conditions, dissolving back into the water where it can affect aquatic biota.

Nutrients Nutrient enrichment refers to the accumulation of plant nutrients in rivers and lakes in excess of natural requirements resulting in nutrient enrichment or eutrophication which may impact on the composition and functioning of the natural aquatic biota. The most essential nutrients required by plants are nitrogen and phosphorus in various forms (NO_2, NO_3, NH_4, PO_4). The direct impact is the excessive growth of algae and macrophyte (rooted and free-floating water plants) leading to impacts on the attractiveness for recreation and sporting activities; the presence of toxic metabolites in cyanobacteria; the presence of taste- and odour-causing compounds in treated drinking water, and difficulty in treating the water for potable and/or industrial use.

Hydrocarbons Petroleum and petroleum-derived products are complex mixtures, mainly of hydrocarbons (compounds of only carbon and hydrogen) plus some other compounds of sulphur, nitrogen and oxygen, and a few additives. Common petroleum products include petrol, naphtha and solvents, aviation gasoline, jet fuels, paraffin, diesel fuel, fuel oils and lubricating oils. Hydrocarbon pollution are associated with wash off from road surfaces and parking lots, especially during the early season rains, and the dumping of used motor or cooking oil into stormwater drains.

Metals Metals include sodium (Na), potassium (K), magnesium (Mg), titanium (Ti), iron (Fe) and aluminium (Al). Trace metals can be divided into two groups: (i) those that occur naturally in trace amounts in most waters (and most of which are plant nutrients in small amounts) such as cobalt (Co), copper (Cu), manganese (Mn), molybdenum (Mo) and zinc (Zn), and (ii) those that do not usually occur in measurable amounts in natural waters, are potentially toxic in low concentrations, and have become widely distributed as a result of human activities, such as cadmium (Cd), lead (Pb) and mercury (Hg).

Solid waste and litter Urban stormwater runoff can be polluted by, inter alia, nutrients, low pH (acidity), micro-organisms, toxic organics, heavy metals, litter/debris, oils, surfactants and increased water temperature. While the impact of litter may appear to be mainly visual and of aesthetic importance, litter can have serious impacts on the aquatic ecosystem of urban streams and rivers.

Agrochemicals Agrochemicals refers to the pesticides and herbicides residues in surface waters that are harmful to aquatic ecosystems and/or users of the water. It includes pesticides or their residues such as chlorpyriphos, endosulfan, atrazine, deltamethrin, DDT & penconazole. These compounds can have chronic or acute impacts on aquatic biota and/or it can cause respiratory diseases in humans and animals. Sources include spray drift of pesticides/herbicides into surface water courses, the wash off pesticides into surface and groundwater during rainfall events or irrigation of crops, or accidental spillages at storage facilities or during loading operations.

Emerging pollutants There are a number of emerging pollutants that could be a cause for concern but very little is known about their status in Kenya. These often occur in low concentrations, are difficult and expensive to detect, and requires sophisticated analytical equipment for sample analysis. They include partially metabolised pharmaceuticals, endocrine disrupting chemicals (EDCs), persistent organic pollutants (POPs), Unintentionally Produced Persistent Organic Pollutants (UPOPS) and Nanoparticles. UPOPS are products listed under Annex C of the Stockholm Convention on POPS. Some of these UPOPS include: Hexachlorobenzene, Hexachlorobutadiene, Pentachlorobenzene, Polychlorobiphenyls, Polychlorinated dibenzo-p- dioxins and dibenzofurans, and Polychlorinated naphthalenes. UPOPS are produced due to incomplete combustion, during the manufacture of pesticides and some chlorinated compounds. Common sources are; burning of hospital wastes, municipal and hazardous wastes, vehicle emissions, peat, coal and wood burning. UPOPS have been linked to many human ailments including enzymatic and immune disorders and cancer. To reduce levels of UPOPS in the environment, best available technologies and practices should be used. As is the case in many developing countries, monitoring is required to develop a better understanding of the severity and extent of emerging pollutants in Kenya before strategies can be developed for its management.

Sources of pollution are generally divided into two categories, namely point sources and nonpoint sources.

- **Point sources** of pollution is one whose initial impact on a water resource is at a well-defined local point (such as a pipe or canal). The US EPA describes point sources of pollution as any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. Typical point sources of pollution are listed below:

Industrial point sources Effluent discharges from industries can have a significant impact on receiving water bodies. These can include high concentrations of BOD/COD, nutrients, heavy metals, acids, dyes, suspended solids, oils and grease, bacterial pathogens, chemicals, phenols, etc.

Wastewater treatment works (WWTWs) Wastewater treatment works (WWTWs) that discharge treated effluent into surface water streams are important point sources of pollution if they do not meet effluent standards. Domestic WWTWs are regarded as important sources of nutrients, organic matter (BOD/COD), suspended solids, human pathogens, and depending on the demographics, a source of partially metabolised pharmaceuticals and endocrine disrupting chemicals.

Mining and quarrying operations Mines can be significant source of pollution and pollutants such as heavy metals, suspended solids, salinity, sulphates, and acidification are associated with mining activities. High suspended sediment loads, and increased turbidity are associated with sand mining and washing operations.

Agricultural processing plants Agricultural processing plants such as coffee washing stations contribute significantly to the organic loads in receiving rivers and streams. The same applied to dairies and milking operations. Tea factories also produce wastewater that are rich in organic material. Fish farms can also have a major impact on water quality as the outflow from ponds can be high in BOD/COD, ammonium and nitrates from fish wastes and food residues.

Solid waste dumps and landfills Solid waste dumps and landfills can also be regarded as point sources of pollution. Pollutants in seepage/leachate from landfills include organic wastes from decomposing organic wastes, heavy metals from corroding metallic objects and old batteries, waterborne pathogens from discarded diapers and sewage sludge, acidic waters, hydro-carbons and oils from used motor and cooking oils, etc.

Pollution from dumpsites like Dandora in Nairobi and Kibarani in Mombasa is not well managed or regulated. There is little evidence to show that the sites were scientifically chosen taking into consideration all environmental factors in order to minimize pollution of both surface and ground water.

Instead of selective incineration, indiscriminate open burning of wastes, although prohibited is carried out. This then greatly pollutes the air with dioxins, furans etc. which contribute to respiratory illnesses. The wastes mainly from burning pesticides and related organic products produces wastes which may be classified as UPOPS (Unintentionally Produced Persistent Organic Pollutants). The production of these wastes at these sites and other similar dumpsites in Counties, goes against the Multilateral Environmental Agreements / Conventions (such as the Stockholm Convention on UPOPS) to which Kenya is a signatory.

It is recommended that urban solid wastes are collected and dumped at well geologically inspected and approved designated areas, from which little or no leachates can reach surface and groundwater sources during the rainy seasons. Burning should also be done if possible in incinerators to ensure complete combustion to minimize the production of UPOPS, in view of the fact that air pollution is currently poorly regulated and managed. In conclusion, solid wastes generated in urban centres should be carefully sorted out at source, collected and transported to designated dumpsites where further sorting is carried out and then disposed of according to well established disposal guidelines stipulated by NEMA; in order to minimize land, water and air pollution.

– **Mitigation measures:** the following are some remedial measures to forestall pollution from point sources:
  - Treatment of industrial waste discharges at source, before discharge into receiving water bodies
  - Ensuring that industrial waste discharges meet the stipulated Effluent Discharge Standards before being discharged
  - Regularly reviewing the performance and waste removal efficiency of WWT plants as well as carrying out effective operation and maintenance procedures
  - Preparing and implementing safe and sound mining and quarrying operation guidelines
  - Ensuring that solid waste is sorted at source and safely transported to the dumpsites for final sorting out and safe disposal
  - Ensuring that the dumping site is selected after an EIA has been carried out on the site, and that all urban centres have a dumping site for solid wastes
  - Enhancing capacity to carry out timely water quality monitoring to identify polluters and take legal action against them.

- **Nonpoint sources** (also called diffuse sources) of pollution whose initial impact on a water resource occurs over a wide area or long river reach (such as un-channelled surface runoff from agricultural land or stormwater and dry-weather runoff from a dense settlement). The US EPA describes nonpoint source pollution resulting from land runoff, precipitation, atmospheric deposition, drainage, seepage or hydrologic modification. Nonpoint source (NPS) pollution, unlike pollution from industrial and sewage treatment plants, comes from many diffuse sources. NPS pollution is caused by rainfall moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, and ground waters.

Agricultural nonpoint sources

Agriculture is a major nonpoint source of pollution. The following generic land use categories can contribute to nonpoint source pollution, particularly sediments, nutrients, and agrochemicals:

Livestock grazing can contribute to sediment yield through removal of the natural vegetative cover (overgrazing), while nutrients and pathogens are associated with livestock faecal matter. These impacts are aggravated and significant bank destabilisation (habitat destruction) can occur where livestock are allowed direct access to wetlands and rivers.

Croplands, vegetable gardens and flower growing tunnels are often a major rural source of sediment, particularly if good land management practices are not adhered to. Wash-off of nutrients from fertilizers and of agrochemicals (pesticides and herbicides) can also have a significant impact, where these are applied. Croplands are particularly vulnerable during the preparation of plots for planting and harvesting when the soil is disturbed.

Irrigation of crops can be a further source of nutrient (inorganic fertilizer), pesticides, and pathogens if manure is used as fertilizer.

Confined animal facilities, such as livestock enclosures (zero grazing), piggeries, and chicken farms, can contribute significant nutrient, organic matter (BOD) and pathogen loads from faecal waste, especially during storm runoff directly to a stream or river. This is the main concentrated agricultural source and may include dairies and piggeries.

Urban nonpoint sources

High levels of non-point sources of contamination, particularly organic material (BOD/COD), hydrocarbons, pathogens, and sediments are associated with formal urban areas and industrial activities with the urban boundaries. Their general character and impacts in Kenya are similar to those other developing countries, and are as follows:

Formal residential areas range from sparse small holdings on the outskirts of cities, through suburban and high density multi-stories apartments in the urban centre (informal settlements are dealt with below). They generally have some levels of waste management services (onsite sanitation, solid waste removal, and storm water drains). Residential areas cause increase storm runoff from impervious surfaces, with an associated wash-off of sediment, nutrients, pathogens, organic matter, litter, heavy metals, hydrocarbons and toxic substances. These impacts tend to increase with population density and are aggravated in areas where the waste management services are inappropriately used, overloaded or inadequately maintained. Increased streamflow and encroachment into the riparian zone cause habitat destruction.

Commercial and light industrial areas are generally located near the urban core and have similar water quality impacts to formal residential areas. Storm runoff increases with impervious area and heavy metal loading tends to be higher, associated with greater pedestrian and vehicle traffic. Pathogen and sediment wash-off can be similar or even higher than in formal residential areas due to the higher density of people. Garages and workshops are often a source of significant hydrocarbon pollution because there is no used oil recycling in Kenya. Fresh produce markets are a significant source of organic waste as peels and leaves from cleaning vegetables and fruit and vegetable cleaning often end up in stormwater drains.

Heavier industrial areas are located both within and on the edge of urban centres, and include the metal, food and beverage manufacturing, and agricultural product processing industries. They are generally associated with increased storm runoff and wash-off of heavy metals, toxic organics and nutrients, depending upon the processes and management practices at the site. Other water quality impacts are similar to light commercial areas.

Roads within and between urban centres are a major non-point source of heavy metals and hydrocarbons. Sediment, nutrient, litter, pathogens and organic matter loads from these roads are comparable to commercial and industrial areas. Unpaved and gravel roads in urban areas can cause severe soil erosion, sediment wash-off, and dust pollution.

Construction and urban development sites represent a significant source of sediment loads in urban areas; often an order of magnitude higher than other urban land uses. This also results in an increase in adsorbed contaminants, such as nutrients and heavy metals. Concrete wash water generally has a high pH due to the cement in the wash water.

Informal waste disposal sites represent a major concentrated source associated with formal residential and industrial areas. Pollutants include solid waste and litter, nutrients, organic matter, heavy metals, and toxic substances in surface wash-off or leachates form the sites.

Informal settlements	Informal settlements are a feature of many developing countries and include settlements in and around the formal urban areas, but which consist of informal shack dwellings, usually with no or limited waste management services. They include the low to medium density (5 to 30 dwellings per hectare) informal areas on the periphery of urban centres, as well as the very dense shack areas on marginal land within the urban centre. Water quality impacts increase with density, and are largely associated with inadequate services, namely pathogens and nutrients from the disposal of grey and black wastewater, litter from solid waste disposal, organic matter and sediment from storm water. These impacts are exacerbated, because these settlements are usually on the most marginal urban land (e.g. poor stormwater drainage) or within the riparian zone of urban rivers.
Artisanal & small-scale mining	It is estimated artisanal and small scale mining (ASM) operations such gold and gemstone mining provides employment to some 146000 people compared to the large scale mining that employs about 9000 workers (PACT and Alliance for Responsible Mining, 2018). A significant impact of ASM gold mining operations is the misuse of mercury and the discharge of mercury-cyanide complexes used in the extraction of gold, into aquatic systems. There are also substantial concerns related to deforestation. For gemstone mining, unsanitary mining camp conditions and bacterial pollution of scarce water sources is a major concern. All activities, including sand mining activities, would increase the sediment loads to rivers during rainfall events.
Gravel roads and erosion	Roads, and gravel roads can be a significant source of erosion and fine sediments. When roads are constructed, they create an interference with the natural drainage systems and collect water, channel it through culverts, increasing its volume and velocity, resulting in accelerated erosion downstream of a bridge or culvert. One of the areas most prone to erosion and gully formation is along the side of roads, especially gravel roads. Roads also act as a source of oil pollution due to vehicle maintenance often conducted next to a road.

- **Mitigation measures:** The following are some mitigation measures to forestall pollution form non-point sources:
  - Encourage the adoption and use of effective and sustainable crop and animal husbandry practices
  - Collection and treatment of storm water discharges from roads and farmlands, before discharge into receiving water bodies
  - Ensuring that storm water and farmland discharges meet the stipulated Effluent Discharge Standards before being discharged into a receiving water body
  - Encouraging the use of approved on-site sanitation facilities to contain faecal human wastes in informal settlements
  - Erecting sediment traps such as grass strips to trap sediment and eroded soil from gravel roads
  - Controlling the amounts of chemicals used in artisanal mining and ensuring that the chemicals do not find their way back into the river.
  - Preparing and implementing safe and sound mining and quarrying operation guidelines
  - Selection and designation of specific solid waste dump sites for every urban centre
  - Ensuring that solid waste is sorted at source and safely transported to the dumpsites for final sorting out and safe disposal
  - Ensuring that the dumping sites are selected after an EIA has been carried out on the sites, and that all urban centres have a dumping site for solid wastes
  - Enhancing capacity to carry out timely water quality monitoring to characterize pollution levels in water bodies.

6.5.3.1 Overview of heavy metals use and heavy metals pollution

The term “heavy metal’ refers to any metallic chemical element that has a relatively high density and is toxic to humans at low concentrations. Examples of heavy metals include mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), Lead (Pb), Zinc (Zn), Nickel (Ni), Cobalt (Co), and Copper (Cu).

The heavy metals most commonly associated with poisoning of humans are lead, mercury, arsenic and cadmium. Heavy metal poisoning may occur from industrial exposure, air or water pollution, foods, medicines, improperly coated food containers, or the ingestion of lead-based paints. High levels of heavy metals are toxic to soil, plants, aquatic life and humans.

Some of the common toxic heavy metals include arsenic, cadmium, lead, and mercury. Other than polluted water, some foods, l may also contain heavy metals.

Anthropogenic sources contributing heavy metal contamination include automobile exhaust which releases lead; smelting (arsenic, copper and zinc); insecticide (arsenic); and burning of fossil fuels which release nickel, vanadium, mercury.

The most common heavy metal pollutants in water and soil are arsenic, cadmium, chromium, copper, nickel, lead and mercury. Most common heavy metal pollution in freshwater comes from mining companies, as they use acids to release heavy metals from ores.

Metalloids are elements (e.g. arsenic, antimony, or tin) whose properties are intermediate between those of metals and solid non-metals or semiconductors.

Major sources of heavy metals in contaminated soils and water are:

- Fertilizers
- Pesticides
- Bio-solids/Sludge and Manures
- Waste water
- Metal Mining and Milling Processes and Industrial Wastes
- Air-Borne Sources

It is therefore evident that heavy metals can easily be found as pollutants in industrial effluents being discharged from many of Kenya's major towns and urban centres. The main threats to human health from heavy metals are associated with exposure to lead, cadmium, mercury and arsenic.

Heavy metals in water are determined in the Laboratory using Atomic Absorption Spectrophotometer (AAS). Heavy metals are not routinely determined in water samples by most laboratories, as only few Laboratories have installed and operate functional AASs. This means that in most cases there is no regular assay for heavy metals in water and waste water samples. This therefore makes it difficult to describe how serious the problem of heavy metal pollution is in the country, because of lack of data. However, in regions such as along Gucha- Migori River in LVS and River Yala in LVN, where it is known that mercury is being used in artisanal mining, regular heavy metals monitoring should be initiated. This will establish the levels of contamination in water, soil and fish, so that remedial action can be taken to safeguard both humans and the environment from the effects of heavy metal pollution.

Since heavy metals are likely to find their way into water courses from the major sources listed above, it is recommended that all Regional Laboratories procure AASs to be used for the analysis of heavy metals in water samples in all the six drainage basins.

6.5.4 Water Quality Status in the Athi Basin

Water resources in the Athi Basin exhibits symptoms of deterioration due to rapid urbanisation, inadequate sewerage infrastructure and wastewater treatment, increasing use of agro-chemicals in the horticulture and agricultural sectors, indiscriminate disposal of solid and liquid wastes, and destruction of natural infrastructure. This deterioration in water quality has grave economic impacts because it increases the cost of doing business as many enterprises are forced to treat water before being able to use it in their industrial processes, the increased cost to municipalities and cities to treat water to drinking water standards, reduced economic productivity and an increased number of days that are lost due to water-related illnesses and/or poor crop yields, threats to human health and livelihoods where people are exposed to poor water quality for domestic use, and it reduces the amount of water available for use as more water must be retained in rivers to dilute pollution to acceptable standards. Table 6-15 presents the mean values of the water quality parameters during 1883 and 1984.

Table 6-15: Water Quality of Athi River (1983-84)- Mean values

Parameter	Unit	Upper Zone (14 Falls)	Middle zone (Kibwezi)	Lower zone (Coast)
pH	pH Scale	***6.8***	***7.8***	***8.0***
Colour	Hazen	***70***	***-***	***90***
Turbidity	NTU	***20***	***90***	***65***
Permanganate value (20 min)	mgO2/l	***35***	***47***	***42***
Conductivity	uS/cm	245	305	594
Iron	Mg/l	2.0	-	-
Manganese	Mg/l	0.60	-	-
Calcium	Mg/l	8.2	16.0	26.0
Magnesium	Mg/l	3.5	8.5	19.0
Sodium	Mg/l	58.0	-	-
Potassium	Mg/l	9.0	-	-
Total hardness	Mg/l CaCO3	***45***	***76***	***161***
Total Alkalinity	Mg/l CaCO3	***64***	***123***	***193***
Chloride	Mg/l	22	14	63
Fluoride	Mg/l	0.72	0.53	1.10
Orthophosphate	Mg/l	0.36	0.23	0.06
Sulphate	Mg/l	7.3	6.8	42.0
TDS	***Mg/l***	***147***	***183***	***371***
BOD5	Mg/l O2	--	-	No analysis done
COD	Mg/l O2	-	-	No analysis done
Heavy metals		-	-	No analysis done
Pesticide residues		-	-	No analysis done

Source: JICA, Kenya NWMP 1992 Sectoral Report N, Environmental Conservation

From these results there is already evidence of a general trend in the increase in levels of the water quality parameters from the Upper to the Lower Athi. The high levels of colour and turbidity are indicative of slight catchment degradation, while the high Permanganate Value (PV) are indicative of organic pollution, which could be faecal in origin.

Water quality data after 1984 is scarce and hard to locate, while some of the data also appears to be unreliable and unrealistic, either due to misreporting or use of faulty or un-calibrated equipment and un-standardized reagents. However, by just observing the water of the rivers it is evident that the water quality status has been gradually deteriorating due to increased industrialization, population growth and urbanization.

6.5.4.1 Surface water

The **upper reaches of the Athi Basin** fall within the counties of Nairobi, Kiambu, Nyandarua, Kajiado and Machakos, the four rivers that drain the upper catchment of the Athi River System are the Nairobi River, Ngong-Motoine River, Ndarugu River, and the Kiserian-Kandisi/Mbagathi River.

Historically, it is logical and reasonable to state that the water quality in the upper reaches of Ndarugu, Nairobi, Ngong -Motoine, Kiserian-Kandisi/Mbagathi and Kirichwa Kubwa/Ndogo rivers, used to be good in the past. This is supported by the fact that Nairobi dam on Ngong- Motoine River used to serve as a water supply source for Nairobi City in the past. At that time there was little pollution of these water sources, since population was low and there were no big slums like Kibera or encroachment on riparian and forest land.

As years went by population grew and encroachment took root, giving rise to the deterioration of the upper reaches of these rivers, before crossing the Nairobi City. As the rivers cross Nairobi City they receive poorly treated effluent from the many types of industries situated in the city. The main ones being Textiles, Breweries, Metallurgical, Pharmaceuticals, Electroplating and Food processing. The rivers also receive partially treated sewage from Dandora and Kariobangi sewage works. There is also evidence of pollution from the poorly managed solid waste disposal site at Dandora, which reaches the rivers as leachate streams, which are also capable of polluting groundwater.

Up to about the mid-1970s the water quality in all four river systems exhibited minimal pollution. In fact, the Motoine/Ngong River which was used as the initial water source for Nairobi City is nowadays too polluted. Nairobi Dam on the Motoine-Ngong River has since become completely eutrophied and choked with invasive aquatic weeds (e.g. water hyacinth) as it receives domestic waste from the Kibera slums and surrounding estates. The Ndarugu River receives pollution mainly from the coffee, tea and flower farms in the Kiambu area. The river is laden with silt and sediment from the farms and deforested areas, and also could contain nutrients from the fertilizers used on the farms as well as pesticide residues. The Kiserian Kandisi river also gets polluted by effluents from the towns of Kiserian, Ongata Rongai and Athi river. All these rivers show high levels of colour and turbidity, bacterial contamination, diminished dissolved oxygen levels and moderately high levels of biochemical oxygen demand (BOD) and chemical oxygen demand (COD). Table 6-16 includes the water quality analysis results of the Athi River at Wamunyu, indicating high levels of nutrients (N and P Compounds).

Table 6-16: Water Quality of Athi River at Wamunyu

Date Sampled: 16/2/1999			**Date Analysed: 1/3/1999**	
Reason for Sampling: Green Water Problem at Wamunyu Water Supply, whose intake is at Athi River				
Parameter	**Unit**	**Result**	**WHO Standards**	**Remarks**
pH	pH Scale	9.2	6.5-8.5	High pH indicative of chemical pollution
colour	Hazen	Greenish	Max 15	Water is contaminated. Unpolluted water should not be coloured
Turbidity	NTU	70	Max 5	Water has high Turbidity
Permanganate value (20 min)	mgO2/l	4.0		
Conductivity	uS/cm	410	2500	
Iron	Mg/l	-	0.3	
Manganese	Mg/l	-	0.1	
Calcium	Mg/l	18	100	
Magnesium	Mg/l	6	100	
Sodium	Mg/l	60	200	
Potassium	Mg/l	9	50	
Total hardness	Mg/l CaCO3	68	500	
Total Alkalinity	Mg/l CaCO3	108	500	
Chloride	Mg/l	32	250	

Parameter	Unit	Result	WHO Standards	Remarks
Fluoride	Mg/l	1.0	1.5	
Nitrite	Mg/l	0.7	0.1	High level indicative of organic pollution
Sulphate	Mg/l	30	450	
TDS	Mg/l	286	1500	
BOD5	Mg/l O2	-	5	No analysis done
COD	Mg/l O2	-	50	No analysis done
Heavy metals		-		No analysis done
Pesticide residues		-		No analysis done
Total Colony Count	Colonies/ 100ml	-		No analysis done

Source: Ministry of Water Development Departmental Records, 1999

The most polluted river system is Nairobi River as it passes through the City of Nairobi and later receives effluent from Dandora/Rwai and Kariobangi Wastewater Treatment Works. This river is grossly polluted with industrial and domestic effluent and residues of oil and grease, surfactants and heavy metals. The river also has diminished levels of DO, high BOD and COD levels. In their current state the rivers forming Upper Athi are unsuitable for use as raw sources of water supply. Figure 6-12 shows the polluted status of a section of Upper Athi River.

Source: Photo taken by ISC, Nov. 2018, during Hydrometeorological review of WQM Stations

Figure 6-12: Colored and turbid and smelly polluted Upper Athi River at Munyu WQM Station

The Integrated Urban Development Plan for Nairobi (Water Resources Management Authority, 2013b) listed particular concerns about water pollution, sanitation, and solid waste management. The plan stated that the City's wastewater management has not kept up with increasing demands from growing population and it was found to be inadequate to treat amount of industrial and municipal effluent entering Nairobi River and other surface waters. It was found that a number of factories in Nairobi's industrial area discharged waste directly into Ngong River, making it the most polluted river in Kenya. Industrial waste effluents included petrochemicals and metals from micro-enterprises and "Jua-kali" enterprises. The plan stated that the Nairobi River also received improperly treated effluents from Dandora Wastewater Treatment Plant and several drainage channels that gathered storm water from Nairobi City (see Table 6-17 below). Domestic garbage from informal settlements that had no public waste collection services also found itself into rivers as did sewage from pit latrines and other on-site sewerage-disposal methods. Sanitation facilities were very basic in many informal settlements, consisting of earth drains, communal water points, pit latrines shared by many people, and no systematic solid-waste disposal. Improperly treated sewerage and uncollected garbage have contributed to vicious cycle of water pollution, water-borne diseases, poverty, and environmental degradation. Farmers along Nairobi River and its tributaries commonly used polluted waters and raw sewage for irrigation, exposing both farm workers and consumers to potential health problems. Almost half of the vegetables consumed in city of Nairobi are grown on banks of polluted rivers. With respect to sanitation the plan found that Nairobi faced enormous challenges in providing adequate public sanitation facilities, sewage disposal, and refuse collection. These problems are compounded as the population increases. Improperly treated sewerage and uncollected garbage have contributed to a cycle of water pollution, water-borne diseases, poverty, and environmental degradation. In terms of solid waste management, the plan found that waste management was growing problem in Nairobi due to increasing urbanization, rural-urban migration, rising standards of living, and rapid development associated with population growth. These increases have not been accompanied by equivalent growth in capacity to manage solid waste.

Table 6-17: Effluent water quality of Kenya Creameries and Tusker Breweries in Nairobi

Parameter	Unit	Kenya Creameries, Dandora, Nairobi		Tusker Breweries, Ruaraka, Nairobi		EAS Standards for Discharge into Water Courses
		Mean	Range	Mean	Range	
pH	**pH Scale**	**6.6**	**4.5- 11.1**	**6.3**	**4.7- 9.8**	**6.5-8.5**
Nitrite-N	mg/l	5.1	12.0	0.0	0.0	-
Nitrate-N	Mg/l	7.3	12.5	0.0	0.0	-
Ammoniacal-N	Mg/l	26.3	5.6 -76	64.5	19.2 - 160	-
Chloride	Mg/l	36.1	5.5 -230	24	4 - 52	-
TSS	**Mg/l**	**424**	**98 -2104**	**1928**	**96 -4824**	**30**
TDS	**Mg/l**		**284 -2332**	**2360**	**892 -5480**	**1200**
BOD5	**Mg/l**	**962**	**150-3200**	**3555**	**800 - 6600**	**30**
COD	**Mg/l**	**-**	**590-1849**	**6453**	**1204 - 12950**	**50**
Total Alkalinity	Mg/l	-	-	117	37 - 245	-
Heavy metals		-	-	-	-	No analysis done
Pesticide residues		-	-	-	-	No analysis done
Total Colony Count	Colonies/100ml	-	-	-	-	No analysis done

Source: Source: JICA, Kenya NWMP 1992 Sectoral Report N, Environmental Conservation; Kilani J.S & J. M. Nzainga, Characteristics of Selected Industry wastes in Kenya.

Table 6-17 shows that effluent from Kenya Creameries, Dandora varies from being acidic to alkaline. The high levels of BOD and COD are indicative of a polluting effluent which is discharged into Nairobi River, a tributary of Athi River. Additionally, it is also evident that from the above values of pH, TSS, TDS, BOD and COD from Tusker Breweries, this effluent is polluting the receiving water course, which is Nairobi River, a tributary of Athi.

Rivers in the upper Athi basin have continuously gained national importance in attempts to clean various sections particularly the Nairobi River. The announcement of a Master Plan for rehabilitation and restoration of the Athi Basin in 2016 builds up on restoration efforts for the river beginning in 1999, with support from UNEP on water quality assessments, public awareness and capacity-building. In 2001-2003 a second phase of rehabilitation targeted the Motoine-Ngong River, a tributary of the Nairobi River, and aimed at monitoring pollution. The third phase between 2004-2008 focused on restoring the Nairobi River ecosystem in order to provide clean water and a healthy environment in the urban areas of Nairobi city. The latter phase has seen the rehabilitation of several stretches of the Nairobi River evidenced by the restoration of water quality and biodiversity, particularly of fish species, invertebrates and otters. Even though some areas, such as those around the Kibera slum, remain highly polluted by human waste, the green zones, such as the areas around the Nairobi Arboretum through to Museum Hill towards the Globe Cinema round-about have greatly benefitted from these efforts.

In 2016 the Nairobi River Basin Rehabilitation Programme (MEMR, undated) was launched to rehabilitate and restore the Nairobi River Basin. The plan revolved around a ten-point strategy:

1. Creating an awareness and assessing social impacts
2. Survey and delineation of the Riparian reserve
3. Stopping illegal discharges
4. Completing work of 2.5 km Demo stretch
5. Relocating economic activities and informal settlements
6. Developing and implementing an integrated solid waste management system
7. Rehabilitation of Nairobi dam
8. Repairing and installing sewerage and associated infrastructure
9. Developing a Master Plan for economic utilization of riparian zone
10. Landscaping and beautification of the riparian zone.

The **middle Athi Basin** is comprised of the rivers Tsavo, Lumi, Nolturesh and Mzima springs. Due to the sparse population and reduced activities in the catchment, other than small scale farming and pastoralism, the main Athi and its tributaries are not prone to incidences of gross pollution. The only threat is mainly sediment from soil erosion and domestic sewage from urban settlements. There are gemstone mining activities in the Taita Taveta county, specifically the Mwatate and Voi sub-counties which probably contribute to sediment loads during the wet seasons but the main concerns are poor conditions at mine camps, including sanitation and hygiene-related illness associated with water scarcity, dust exposure during rock breaking (suspended sediment source in the rainy season), and underground instability (risks of collapse and rock falls). Sanitation is a concern but there are no formal sewerage infrastructure or wastewater treatment plants in the Makueni County. A sewerage system for Wote town is being planned. Sand harvesting the Makueni County is a concern and the county has developed a sustainable sand harvesting policy to protect subsurface water in river courses. In Kajiado County a need was identified to manage sand harvesting on a sustainable basis, to compile an inventory of major polluters and water users, and to design sewerage systems for all major towns. Figure 6-13 shows the polluted status of a section of middle Athi River.

Source: Photo taken by ISC, Nov. 2018, during Hydrometeorological review of WQM Stations

Figure 6-13: Coloured turbid and smelly, polluted Middle Athi River at Wamunyu WQM Station, South-East of Machakos

The rivers in the **Lower Athi** comprises the Sabaki, Ramisi, Umba, Mkurumudzi, Mwache rivers and the Challa and Jipe lakes. Unlike in the Upper and middle reaches of the Athi river system, water pollution is confined to urban settlements, and areas where there is evidence of catchment degradation. The water at these areas tend to have high suspended solids and high levels of organic matter contamination. Saline intrusion along the coast is also a major threat.

6.5.4.2 Groundwater

A comprehensive overview of groundwater quality is provided in section 6.4.5.2.

6.5.5 Strategy

In addition to the main objective of this Water Quality Management Plan, other objectives include:

- That the need for socio-economic development is balanced appropriately with the need to protect water quality for clean and safe water, and to enhance the quality of life of citizens and aquatic ecosystems,
- That a coherent approach to managing water quality are followed by government ministries and local authorities to ensure good governance of water quality,
- That there is an effective monitoring chain of data acquisition, information generation, and knowledge application so that water quality managers can make informed decisions about the management of water quality in the basin, and
- That water resource management institutions have the capacity and systems in place to efficiently manage water quality.

The water quality vision for the Athi Basin is to protect and restore the quality of water resources in the basin using structural and non-structural measures. Structural measures refer to the interception and removal of pollutants by means of installed structures such as traps, diversion, or treatment systems. Non-structural measures refer to pollution controls such as monitoring and enforcement of standards and by-laws, public awareness and anti-litter campaigns, pollution levies, street sweeping, etc.

Water quality management in the Athi Basin should be focused on managing the pollution problems in urban centres and maintaining the fitness for use of the middle and lower reaches of the Athi basin.

In order to comprehensively and systematically address the water quality issues and challenges in the Athi Basin, Table 6-18 sets out 3 Strategic Themes with specific Strategies under each Theme. The Themes address Effective Water Quality Data Collection, Information and Knowledge Management, Governance, and Pollution Control.

Table 6-18: Strategic Framework - Water Quality Management

4	**Key Strategic Area:**	**Water Quality Management (Surface water and groundwater)**
4.1	**Theme:**	**Effective water quality data collection, information generation and dissemination, and knowledge management**
It is not possible to manage what you don't measure. A good water quality monitoring system is essential to support effective management, enforcement and compliance assessment. Added to this, the timely sharing of the right data and information, in the required format, enables the development of relevant and applicable water quality management interventions. Continuous improvement of monitoring networks and laboratory services enables effective enforcement and compliance of laws and regulation and supports an adaptive management approach to water quality management. Targets and activities to support this goal relate to the implementation of the monitoring system designed for Kenya but focused on monitoring of the Athi catchment. This entails implementation of routine water quality monitoring of rivers and lakes, reservoirs, effluent discharges, urban rivers, and dams/lakes. It also refers to initiation of limited duration water quality surveys to investigate specific problems in collaboration with, for example, academic institutions and selected specialists. It includes the upgrading central and regional laboratories. Lastly, it is essential that all the data gathered by means of routine programs and surveys, be stored and managed in Mike Info to maintain the integrity of the data, and to generate information and routine reports that meet the needs of water resource managers. A number of strategies have been identified to support water quality monitoring.		
4.1.1	Implement routine surface and groundwater quality monitoring	
A national water quality monitoring programme was designed as part of the ISC project. This programme should be implemented in the Athi Basin by ensuring that capacitated technical staff have the resources to collect water samples and conduct in-field measurements on schedule, the water testing laboratories can analyse the water samples accurately and on-time, submit the analysis results to the Mike Info Water Quality database, and the data are reviewed, analysed, reported on, and acted on by catchment staff.		
4.1.2	Biological Water Quality Monitoring	
Develop the required capacity to undertake biomonitoring in Kenya to assess aquatic ecosystem health. Identify streams in the Athi Basin for piloting biomonitoring and undertake pilot studies. Integrate the results with the water quality monitoring network to assess the overall fitness for use and ecosystem health of water resources.		
4.1.3	Undertake survey of pollution sources	
There is a need to compile an inventory of surface water pollution sources (point sources), especially in the upper Athi Basin, and reconcile these against the discharge licences at NEMA and permits at WRA. This data should be used to assess compliance to effluent discharge standards and used in waste load allocation studies to assess the cumulative impact of sources concentrated in a specific river reach or sub-catchment. Effluent compliance monitoring should be undertaken at regular intervals.		
4.1.4	Upgrade water quality testing laboratories	
There is a need to upgrade the central and regional laboratories in the Athi Basin to support the national water quality monitoring programme that was designed as part of the ISC project. These include, inter alia, the recruitment of more technical staff, equipping the laboratory and stocking it with reagents, procuring Field Testing Kits, operationalising the LIMS in the central and regional laboratories and participating in proficiency tests to acquire the necessary accreditation and ISO certification to enhance data credibility.		
4.1.5	Institutionalise water quality data storage and management	
A centralised national water quality database was designed with Mike Info. The storage of all historical and new water quality data collected by WRA in the Athi Basin should be enforced. This database should also serve as the approved database for all reporting and assessment of water quality data in the Athi Basin.		
4.1.6	Design and implement routine water quality status reporting	
Routine water quality status reports should be designed and implemented to report on the water quality status in the Athi Basin, identify key water quality concerns, their causes and consequences, and recommend management actions to mitigate negative impacts.		

4	Key Strategic Area:	Water Quality Management (Surface water and groundwater)
4.2	**Theme:**	**Promote sound water quality management governance in the Athi Basin**

With so many institutions involved in different aspects of water quality management in the Athi Basin, it is inevitable that there may be uncertainty about the mandate of each institution with respect to water quality management. This objective can be met by clarifying the mandates, the and roles and responsibilities of the different institutions involved in the Athi Basin. This can be achieved by reviewing the mandates, and roles and responsibilities of institutions. It is also important that there be effective arrangements between role players with regard to water quality management to ensure that cooperative governance of water quality is achieved. This can be accomplished by establishing mechanisms for cooperation between government institutions on water quality management and pollution control issues.

Two strategies have been identified to help alignment, collaboration, and institutional efficiency.

4.2.1	Harmonise policies and strategies to improved water quality management

There are a number of institutions involved in different aspects of water quality and pollution management (e.g. WRA, NEMA, MoA, NIA, counties, basin authority, PCPB, etc.). Their policies, strategies and plans are not always aligned because they are responsible for different aspects of water resources management in the Athi Basin. WRA should advocate alignment of strategies to serve a common purpose of rehabilitating urban rivers and streams in the Athi Basin.

4.2.2	Coordination and cooperation mechanism on water quality issues established at a catchment level

WRA should establish a coordination and cooperation mechanism to ensure there is alignment of actions to address water pollution management in the Athi Basin.

Participate in river clean-up campaigns of rivers such as the Nairobi, Ngong, Mbagathi, Ruiru, Kamiti, Ruaraka, and Ndarugu. This can be achieved by using the inter-agency task-force to mobilize resources, carry out clean-ups, creating awareness, and where appropriate, demolishing structures in riparian buffers.

4.3	Theme:	Efficient and effective management of point and nonpoint sources of water pollution

The water quality challenges in the Athi Basin will require efficient and effective management of pollution sources, as well as mitigating the symptoms of pollution in rivers, reservoirs, and lakes.

Point sources - Monitoring of compliance with Kenyan domestic and industrial effluent standards should be strengthened. All effluent monitoring data should be stored in a central database (Mike Info in this case). Protocols should be implemented for enforcing standards, and for dealing with non-compliant dischargers. To meet this goal, producers of wastewater should be encouraged to treat wastewater at source. This can be achieved by identifying industrial polluters with no wastewater treatment and not meeting effluent standards and directing them to implement onsite wastewater treatment. It can also be achieved by requiring onsite wastewater treatment at all new industries being established. Consideration should also be given to the design and construction of centralised WWTWs and sludge treatment facilities for large urban centres, and to progressively connect households and large wastewater producers to the sewerage network. Lastly, the focal areas of the Kenya National Cleaner Production Centre (KNCPC) should be supported, and industries should be encouraged to participate in this initiative.

Nonpoint sources - Nonpoint sources of pollution probably have the greatest impacts on water quality in the Athi Basin.

Erosion and sedimentation from agricultural lands is probably a major concern and interventions to manage its impacts should be implemented. It has also been the focus of may soil conservation initiative undertaken in Kenya over many years. Reducing erosion and sedimentation also has a large positive impact on water pollution as many pollutants adhere onto sediment particles, and intercepting the particles before they enter water courses, also prevents these pollutants from entering streams, rivers, and lakes. To meet this objective, a number of target sources have been identified dealing with urban stormwater, riparian buffer strips, hydrocarbon pollution, runoff from informal settlements, other agricultural impacts, and runoff from unpaved roads.

The management of stormwater in urban areas is important because it is the conduit for transporting pollutants into urban streams, and eventually nearby rivers and lakes. This requires promoting the use of structural stormwater control and treatment facilities (e.g. instream detention ponds) in urban areas, as well as reducing stormwater runoff by improved rainfall infiltration systems, efficient drainage network, and improved rainwater harvesting by households, complexes, and commercial buildings. Riparian buffer strips is an important measure to intercepting and filter polluted runoff. The installation and maintenance of riparian buffer zones and vegetated buffer strips should be promoted and enforced. Hydrocarbon pollution from the dumping of used oil into stormwater drains can contaminate large volumes of water rendering it unfit for use. The installation of oil separators at all garages and vehicle workshops should be enforced, and illegal dumping of used oil at informal workshops should be policed and culprits be prosecuted.

Informal settlements, especially in the City of Nairobi, have a huge negative impact on urban water quality due to

4	**Key Strategic Area:**	**Water Quality Management (Surface water and groundwater)**
indiscriminate disposal of liquid and solid household wastes. The measures in the Urban Development Master Plan for the City of Nairobi dealing with water pollution, sanitation, and solid waste management should be supported. Agricultural also have impacts on nutrient enrichment and pollution from the use of agrochemical to control pests. To deal with these impacts, authorities should promote climate smart agriculture, encourage farmers to use a combination of organic and inorganic fertilisers on their fields, and promote integrated pest management and the use of biodegradable pesticides where possible. Roads, particularly unpaved roads have a large impact on erosion and sediment production. It is recommended that gravel road drainage infrastructure be maintained to reduce erosion, and to implement dust suppression measures on unpaved urban roads to manage wash-off of fine sediments into the stormwater drainage system during rainfall events. A number of strategies have been identified to focus management of water pollution.		
4.3.1	Improve sewerage systems and treatment	
Promote wastewater treatment at source, especially at industrial sites, housing estates, hospitals, etc. This could be in the form of septic tanks for households or package plants for larger housing or industrial estates. The objective is to improve the quality of effluent discharges before it enters the environment or sewerage network.		
4.3.2	Cleaner production methods	
Support initiatives by the Kenya National Cleaner Production Centre (KNCPC) to promote excellence in Resource Efficient and Cleaner Production in industries in the Athi Basin in order to reduce water usage and effluents, as well as their impacts on water quality in receiving water bodies.		
4.3.3	Urban stormwater, sanitation, and solid waste management, and protection of upper reaches of rivers.	
Control sediment pollution from construction sites and unpaved urban roads in urban areas by adopting best urban stormwater management practices such as erecting sediment traps or screens, sediment detention ponds, etc. Compel county governments to maintain sewerage infrastructure and fix leaks or blockages as a matter of urgency to minimise sewage leaks into stormwater drains. Promote solid waste removal in urban centres and disposal at solid waste disposal sites that meet best national or international design standards. Rehabilitate existing solid waste dumps to intercept and treat poor quality drainage water and prevent it from running into water courses. Compel county governments to delineate and maintain riverine buffer zones to prevent encroachment. Stop encroachment of wetlands.		
4.3.4	Sanitation management in informal settlements	
Protect receiving streams from pollution, especially urban rivers such as Ngong, Ongata Rongai, Ruiru, Kiambu and Nairobi by installing sewers or septic tanks to contain domestic wastes, by managing urban solid wastes, and monitoring receiving streams for BOD and COD. Create sewerage infrastructure to intercept and convey grey and black wastewater to wastewater treatment works. Control of organic pollution from unplanned and unsewered settlements/slums in all the major urban centres by planning to install sewers or septic tanks and promoting solid waste collection and removal from these settlements. Support international aid projects that are designed to upgrade informal settlements and slums.		
4.3.5	Management of hydrocarbon pollution	
Control of oil and grease pollution from petrol stations and oil storage facilities by ensuring that all are equipped with functional oil & grease traps and monitoring nearby surface and groundwater for hydrocarbons. Control dumping of used motor oil at informal workshops by promoting recycling of used oil, and monitoring stormwater drains for hydrocarbon pollution. Protect groundwater against hydrocarbon contamination near petrol stations and dump sites by drilling observation wells at high risk areas and monitoring boreholes for hydrocarbons.		
4.3.6	Sedimentation from unpaved roads	
Control sediment pollution from unpaved roads by erecting sediment traps or vegetated buffer strips next to dirt and paved roads. Maintain stormwater drainage to prevent erosion next to roads and rehabilitate dongas near roads.		

4	Key Strategic Area:	Water Quality Management (Surface water and groundwater)
4.3.7	Management of agricultural impacts on sediments, nutrients, and agrochemicals	
Control nutrients pollution from agricultural activities (N & P) in all farmed areas within the Basin by compiling & maintaining inventories of fertilizer use, and monitoring nutrients in receiving water bodies (rivers, reservoirs and lakes). Control agrochemical (pesticides and herbicides) residue pollution from farmlands by compiling an inventory of pesticide usage in the basin and monitoring affected water bodies for residues. Promote efficient use agrochemicals in the agricultural sector. Promote best irrigation management practices and encourage irrigators to retain, treat and recycle irrigation return flows before discharging it to the environment. Encourage adoption of good land management practices such as avoiding overstocking and overgrazing, avoiding cultivation on steep slopes or use terracing, minimum tillage, etc.		
4.3.8	Enforcement of effluent standards	
Use the results of compliance monitoring of effluent discharge licence or permit conditions to prosecute offenders that consistently violate their licence/permit conditions and demonstrate no intention of meeting them.		
4.3.9	Control discharges from sand mining operations.	
Control sediment pollution from sand harvesting operations by enacting by-laws for its control, delineating sand harvest areas away from river riparian, and implementing good sand mining guidelines to mitigate their impacts. See for example the River Sand Mining Management Guidelines of Malaysia for good management practices to consider.		
4.3.10	Rehabilitation of polluted aquifers, springs and wells	
See Strategy 3.4.2		
4.3.11	Promote wastewater re-use and wastewater recycling	
Kenya is a water scarce country and this strategy would ensure a saving in water usage. Water can be used severally either for irrigation, cooling or cleaning, before it is eventually discharged. This will be carried out bearing in mind the water quality requirements for these various uses. If necessary, use of economic and other incentives may be used to promote water re-use and water re-cycling technologies		
4.3.12	Evaluate the waste removal efficiency of existing Wastewater Treatment (WWT) and Sewage treatment works	
Many of the sewage treatment facilities in use in many major towns are old and have been in use for many years with poor maintenance being carried out on them. Some need urgent rehabilitation or a complete overhaul of the systems. In order to know whether to rehabilitate or completely overhaul the systems, an evaluation of the waste removal efficiency of the existing WWT and Sewage treatment works will need to be carried out.		

6.6 Climate Change Adaptation

6.6.1 Introduction

In the face of a changing climate, adaptation and resilience are Africa's and indeed Kenya's priority responses to address vulnerabilities and risks. The 15th African Ministerial Conference on the Environment 2015 strongly promoted investment in building resilience as a top funding priority and an integral part of national development funding. This aligns very well with Kenya's approach of mainstreaming climate adaptation in national and sub-national development planning.

The Kenya National Climate Change Response Strategy (NCCRS) (Government of Kenya, 2010b) acknowledged that the impacts of observed and projected climatic change pose serious threats to sustainable development. These predominantly relate to severe weather and changes in the climate extremes which will reduce the resilience in many sectors of the economy.

The Climate and Development Knowledge Network in their Government of Kenya Adaptation Technical Analysis Risk Report (Government of Kenya, 2012) identified various sectors in Kenya which are at-risk, either directly or indirectly, from climate change. These sectors include agriculture, livestock and fisheries, manufacturing, retail and trade, water, health, financial services, tourism, urban and housing sectors, infrastructure, energy, transport, natural resources and environment, political and social sectors.

The Climate Change Act 2016 aims to strengthen climate change governance coordination structures and outlines the key climate change duties of public and non-state actors. It establishes a high-level National Climate Change Council chaired by the President, a Climate Change Directorate as the lead technical agency on climate change affairs, and a Climate Change Fund as a financing mechanism for priority climate change actions/interventions. Climate desks/units have subsequently been established in certain line ministries staffed by relevant climate change desk officers. The Act is to be applied across all sectors of the economy, and by both the national and county governments. Mainstreaming of climate change has to some extent been undertaken at the county government level, where some counties have taken measures to include climate change in their County Integrated Development Plans (CIDPs) and to develop relevant county legislation.

The National Climate Change Action Plan (NCCAP) 2013 to 2017 (Government of Kenya, 2013b) sets out a vision for a low carbon development pathway for Kenya and lists specific adaptation and mitigation actions for each national planning sector to support this vision. One of the “big wins” identified in the draft NCCAP 2018-2022 relates to “improved water resources management”.

The draft NCCAP 2018-2022 (Government of Kenya, 2018) builds on the first Action Plan (2013-2017) and provides a framework for Kenya to deliver on its Nationally Determined Contribution (NDC) under the Paris Agreement of the United Nations Framework Convention on Climate Change. The draft NCCAP 2018-2022 guides the climate actions of the national and county governments, the private sector, civil society and other actors as Kenya transitions to a low carbon climate resilient development pathway. It identifies strategic areas where climate action over the next five years is linked to Kenya’s Big Four Agenda, recognising that climate change is likely to limit the achievement of these pillars. One of the “big wins” identified in the draft NCCAP 2018-2022 relates to “improved water resources management”. Of particular relevance to water resources management and planning is “Food and Nutrition Security” where food security may be threatened through climate change-driven declines in agricultural productivity. The draft NCCAP 2018-2022 also prioritises seven climate change actions (Table 6-19), three of which (nos. 1 to 3) align very strongly with the planning and management of water resources.

Table 6-19: Priority climate change actions (Government of Kenya, 2018)

1. Disaster Risk (Floods and Drought) Management	Reduce risks to communities and infrastructure resulting from climate-related disasters such as droughts and floods.
2. Food and Nutrition Security	Increase food and nutrition security through enhanced productivity and resilience of the agricultural sector in as low-carbon a manner as possible.
3. Water and the Blue Economy	Enhance resilience of the water sector by ensuring access to and efficient use of water for agriculture, manufacturing, domestic, wildlife and other uses.
4. Forestry, Wildlife and Tourism	Increase forest cover to 10% of total land area; rehabilitate degraded lands, including rangelands; increase resilience of the wildlife and tourism sector.
5. Health, Sanitation and Human Settlements	Reduce incidence of malaria and other diseases expected to increase because of climate change; promote climate resilient buildings and settlements, including urban centres, ASALs and coastal areas; and encourage climate-resilient solid waste management.
6. Manufacturing	Improve energy and resource efficiency in the manufacturing sector.

7. Energy and Transport	Climate-proof energy and transport infrastructure; promote renewable energy development; increase uptake of clean cooking solutions; and develop sustainable transport systems.

The Kenya NAP 2015 to 2030 (Government of Kenya, 2016) builds on the NCCRS and NCCAP and promotes adaptation as the main priority for Kenya, while also proposing that adaptation and development goals complement each other. Some of the key objectives of the NAP which are applicable to the Athi Basin Plan include understanding the importance of adaptation and resilience building actions in development; integrating climate change adaptation into national and county level development planning and budgeting processes; and enhancing the resilience of vulnerable populations to climate shocks through adaptation and disaster risk reduction strategies.

Within the context of the Athi Basin Plan, the objective of this component of the Plan is to understand the degree to which climate change will compromise the water resources sector and how those impacts will in turn alter the exposure to food security and to flood and drought risk. This component will also explore opportunities presented by climate change such as climate financing.

6.6.2 The changing climate in Kenya

Kenya's climate is already changing. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) presents strong evidence that surface temperatures across Africa have increased by 0.5-2°C over the past 100 years, and from 1950 onward climate change has changed the magnitude and frequency of extreme weather events.

The frequency of cold days, cold nights and frost has decreased; while the frequency of hot days, hot nights and heat waves has increased. Temperature increase has been observed across all seasons (see Figure 2-15 to Figure 2-17), but particularly from March to May. Variation between locations has occurred, with a lower rate of warming along the coast. Surface temperature trends of Nairobi and its environs show warming of more than 2.5°C in the past 50 years.

Rainfall patterns have also changed. The long rainy season has become shorter and drier, and the short rainy season has become longer and wetter, while overall annual rainfall remains low. The long rains have been declining continuously in recent decades, and droughts have become longer and more intense and tend to continue across rainy seasons. The frequency of rainfall events causing floods has increased in East Africa from an average of less than three events per year in the 1980s to over seven events per year in the 1990s and 10 events per year from 2000 to 2006, with a particular increase in floods. Droughts and heavy rainfall have become more frequent in eastern Africa in the last 30-60 years.

The current trend of rising annual temperatures is expected to continue in Kenya in all seasons. The IPCC Fifth Assessment Report (IPPC, 2014) noted that during this century, temperatures in the African continent are likely to rise more quickly than other land areas, particularly in more arid regions. Climate modelling for the East Africa region using a high-emissions scenario suggests that mean annual temperatures will increase by 0.9°C by 2035, 2.2°C by 2065 and 4.0°C by 2100. Draft National Climate Change Action Plan: 2018-2022.

The IPCC reports that precipitation projections are more uncertain than temperature projections and suggest that by the end of the 21st century East Africa will have a wetter climate with more intense wet seasons and less severe droughts. The proportion of rainfall that occurs in heavy events is expected to increase. Regional climate model studies suggest drying over most parts of Kenya in August and September by the end of the 21st century.

The climate of the Athi Basin is primarily forced by the topography of the basin, the proximity to the oceans and to the equator. These factors contribute to the range and variability in precipitation and temperature regimes. Projected future precipitation totals are varied across the basin yet tend to exhibit an increasing gradient from the south east (+2%) to the north west (+9%) for RCP4.5 (+3% - +12% for

RCP8.5) in the medium term. There is likely going to be increased variability between years and a consistent increase going forward will be unusual. This may result in years that have drought like character adjacent to flood seasons and an increase in the intensity of extreme events. The temperature anomaly also expresses an increase going from the coast to the inland areas for both day (+1.04°C to 1.18°C for RCP4.5 and 1.42°C to 1.62°C for RCP8.5) and night-time (+1.1°C to 1.3°C for RCP4.5 and +1.52°C to 1.78°C for RCP8.5) temperatures. These projections are in line with current observed climate trends.

6.6.3 Climate change impacts, hazards and vulnerabilities in Kenya

Climate change in Kenya is causing significant environmental and economic disruption. Heat, drought and floods are impacting Kenyans, and human health is increasingly at risk. Kenya's economy is very dependent on climate-sensitive sectors such as agriculture, water, energy, tourism, wildlife, and health, which increases vulnerability. The increasing intensity and magnitude of weather-related disasters in Kenya aggravates conflicts, mostly over natural resources, and contributes to security threats. Expected social, environmental and economic impacts associated with climate change in Kenya are summarized in Table 6-20. Aspects which relate to water resources management and planning are highlighted.

Table 6-20: Potential climate change impacts in Kenya (adapted from Government of Kenya, (2018))

Social impacts	
Flooding	Fluvial flooding leads to the greatest loss of human lives in Kenya. In the aftermath of floods, there are often cholera outbreaks while people also experience an upsurge of mosquito-borne diseases e.g. malaria and dengue fever. The impacts of coastal flooding can also be severe due to sea level rise. The coastal area in Kenya has the largest seaport in East Africa, tourism and fishing industries.
Droughts	Droughts in Kenya destroy livelihoods, trigger local conflicts over scarce resources and erode the ability of communities to cope. Drought can cause changes in the migratory patterns of animals and increase conflicts between people and animals. Kenya's ASALs are particularly vulnerable to the impacts of climate change: The highest incidence of poverty is found in these areas and women and men experience greater competition over resources, growing populations and lower access to infrastructure. The ASAL economy is also typically highly dependent on climate sensitive activities e.g. livestock and wildlife tourism.
Human conflict	Cross-border and cross-county conflict is often exacerbated by climate change. As temperatures rise and rainfall patterns change, some areas become less conducive for livestock, particularly cattle, leading to a reduction in herd numbers. Counties with more favourable conditions often enter into resource use conflicts as pastoralists from other counties move their animals to water and better pasture conditions.24 Cross border conflicts could also increase with neighbouring countries as pastoralists compete for food, water and grazing.
Migration	Migration linked to climate change does occur in Kenya - mainly as vulnerable groups are reliant on resource-based livelihoods. Reduced agricultural productivity and resource scarcity along with increased floods and droughts also contribute to movement of people.
Vulnerable groups	Vulnerable groups include remote and pastoralist communities, hunters and gatherers, fisher communities and people who live in urban slums. All of these are affected by climate change because of environmental degradation and growing competition for land and water.
Ocean acidification	Ocean acidification is expected to impact many ocean species., leading to declines with negative impacts on fisher communities that rely on these species for food and livelihoods.
Women	Women in their roles as primary caregivers and providers of food and fuel makes them more vulnerable when flooding and drought occur. Drought compromises hygiene for girls and women and has a negative effect on time management as they have to travel long distances to search for water.

Environmental impacts	
Droughts	The increased and abnormal frequency and severity of droughts in Kenya due to climate change, have serious environmental impacts.
Sea temperature	Rising sea temperatures in the Western Indian Ocean influence the coastal conditions associated with Kenya. It leads to coral bleaching and mortality on coral reef systems and is likely to affect the abundance and composition of fish species affecting the fisheries industry.
Rising sea levels	Rising sea levels are a concern for Kenya's coastline consisting of mangroves, coral reefs, sea grass and rocky, sandy and muddy shores. The rate of sea level rise along Africa's Indian Ocean coast is projected to be greater than the global average. This will lead to greater levels of / more frequent flooding, changing patterns of shoreline erosion, increased salinity of coastal aquifers, and modification of coastal ecosystems such as beaches, coral reefs and mangroves.
Ocean acidification	Ocean acidification is expected to impact many ocean species. Marine species that are dependent on calcium carbonate to build their shells and skeletons, such as corals, are also highly vulnerable.
Retreat of glaciers	The glaciers of Mount Kenya are declining and are expected to disappear in the next 30 years, largely because of climate change. Mount Kenya is one of the country's water towers and the source of numerous rivers and streams.
Desertification	Desertification in the ASALs can be attributed to climate change impacts, in addition to human activities. It is intensifying and spreading, reducing the productivity of the land and negatively affecting communities.
Land degradation	Climate change is a major factor contributing to land degradation, which encompasses changes in the chemical, physical and biological soil properties.
Loss of biodiversity	Climate change is contributing to a loss of Kenya's biodiversity including plant species, some animal species, and a decline in the productivity of fisheries in inland waters Climate change also has the potential to alter migratory routes and timings of species that use seasonal wetlands (such as migratory birds) and track seasonal changes in vegetation (such as herbivores). Furthermore, climate change also significantly affects marine ecosystems.
Deforestation and forest degradation	Deforestation and forest degradation in Kenya are largely a result of human activities, although climate change is likely to affect the growth, composition and regeneration capacity of forests resulting in reduced biodiversity and capacity to deliver important forest goods and services. Rising temperatures and long periods of drought will lead to more frequent and intense forest fires, rising temperatures will extend the ecosystem range of pests and pathogens with consequences on tree growth, survival, yield and quality of wood and non-wood products, and rising sea levels could submerge mangrove forests in low-lying coastal areas.42
Landslides	Landslides associated with heavy rainfall in regions with steep slopes could increase due to increased rainfall intensities associated with climate change.
Economic impacts	
GDP	The economic cost of floods and droughts is estimated to create a long-term fiscal liability equivalent to 2%-2.8% of GDP each year. Specifically, the estimated costs of floods are about 5.5% of GDP every seven years, while droughts account for 8% of GDP every five years.
Infrastructure and resources	Floods in Kenya regularly destroy and damage infrastructure such as roads, bridges, buildings, and telecommunication infrastructure as well as crops and livestock worth billions of shillings.
Hydroelectricity	Droughts depress the generation of hydroelectricity leading to an increase in generation of electricity from thermal sources that are costlier and produce greenhouse gas emissions.
Livelihoods and income generation	The impacts of drought are felt at the household level and are particularly devastating for pastoralists in the ASALs where livestock production – and specifically, semi-nomadic pastoralism – is the key income source.
Coastal assets	Sea level rise will impact coastal towns and communities through increased coastal erosion and flooding

6.6.4 Strategy

The climate change strategy for the Athi Basin strives towards a well-managed river basin exhibiting enhanced climate resilience against annual variability, El Niño–Southern Oscillation (ENSO) cycles, flooding and extreme events and continuous drought years. Furthermore, it envisions a basin that applies climate mitigation and mainstreaming into development, while comprehending and promoting adaptation practices.

As suggested previously, the climate of Kenya has already started to experience the effects of a changing climate. This will be exacerbated into the future with expected impacts including increased temperature, increased intensity and frequency of extreme events as well as unpredictable weather patterns.

The Government of Kenya Adaptation Technical Analysis Report (Government of Kenya, 2012) highlights the way forward as "*integrating climate change adaptation into the medium term planning and budgeting process at national level and ensuring that it is also captured during development of the County Development Profiles*" as well as considering and understanding the sectoral impacts of climate changes such that adaptation can "*address these impacts or maximise on the opportunities that some of the impacts provide*". The monitoring of the integration of climate change adaptation into long term developments is also required to ensure systems aren't compromised into the climate changed future.

In order to comprehensively and systematically address the range of climate change issues identified in the Athi Basin, Table 6-21 sets out 3 Strategic Themes with specific Strategies under each Theme. The Themes address an **Improved understanding of the impacts of climate change on water resources at appropriate scales, as well as Mitigation and Adaptation**.

Table 6-21: Strategic Framework - Climate Change Mitigation, Adaptation and Preparedness

5	**Key Strategic Area:**	**Climate Change Mitigation, Adaptation and Preparedness**
5.1	**Theme:**	**Improved understanding of impacts of climate change on water resources planning and management at appropriate spatial scales**
5.1.1	Quantify climate change impacts (rainfall & temperature) on surface water and groundwater resources and demands in the Athi Basin at appropriate scales for planning and management	
This is undertaken though research and public consultation processes, and where necessary, engaging with the private sectors for further insights. As the impacts will be felt in a practical sense, this process should focus more on the in-situ impacts, thresholds and exposer accounts rather than as a technical theoretical review.		
5.1.2	Assess relevance, and scale of potential social, environmental and economic climate change impacts as defined in NCCAP in Athi Basin and its relation to water resources planning and management; prioritise areas for interventions	
This will assess climatic trends to evaluate frequency and magnitude of events resulting in flooding events. Furthermore, the highlighting of hotspot area will act as a pre-emptive measure building resilience. Assessment of meteorological data relative to the ENSO cycle may provide forewarning into future drought occurrence and severity. Furthermore, there should be analysis of rainfall onset and cessation, particularly in rainfed agricultural areas and areas highly reliant on surface water rather than reticulation. Assessment of meteorological data relative to the ENSO cycle may provide forewarning into future drought occurrence and severity. Furthermore, there should be analysis of rainfall onset and cessation, particularly in rainfed agricultural areas and areas highly reliant on surface water rather than reticulation. Engage local private sector, NGOs and knowledgeable individuals to facilitate wider experience transfer of adaptation practices. Engage local private sector, NGOs and knowledgeable individuals to facilitate wider experience transfer of adaptation practices		
5.2	**Theme:**	**Climate change mitigation**
5.2.1	Promote the generation and use of clean energy	
Propagate the usage of renewable energy source just as hydropower, wind power and solar geysers		

5	Key Strategic Area:	Climate Change Mitigation, Adaptation and Preparedness
5.3	Theme:	Climate change adaptation
5.3.1	Promote climate resilient infrastructure	
Promote the development in low risk areas and increase setback from rivers and ocean interfaces. Build to increased threshold specifications to address future climate impacts for both road and stormwater infrastructure		
5.3.2	Climate-related disaster risk management	
Reduce the risk of disasters linked to climate change e.g. floods, droughts, health-related risks, crop production etc. by understanding the potential threats and risks and by implementing structural and non-structural mitigation measures.		
5.3.3	Promote agroforestry	
Enhance the CO2 sink by promoting varied land usage to increase biodiversity and minimise soil erosion and increase soil nutrients retention. Actively plant, living fences, medicinal and fruit trees.		
5.3.4	Mainstream climate change adaptation in water resources strategy, planning and management at basin and catchment level	
Implementation and enforcement of practical mainstreaming practices and enhance the awareness of potential climate impacts on communities to promote uptake of adaptation.		
5.3.5	Enhance resilience of agriculture sector through climate smart agriculture	
Employ likely increased stress impact principles promoting soil quality, better drainage and weed/disease control in agricultural practices		

6.7 Flood and Drought Management

6.7.1 Introduction

Floods and droughts are caused by extreme climatic events and can have devastating consequences for the socio-economic welfare of rural and urban communities and regions.

Flooding of land surfaces occurs when heavy rainfall leads to runoff volumes that exceed the carrying and storage capacities of stream channels and urban drainage systems. In the process, crop and grazing lands, villages and urban neighbourhoods become inundated, transport infrastructure destroyed, and powerlines flattened. Floods can cause displacement of people, loss of life (human and livestock), increases in water related-diseases, severe soil erosion, land-slides, increased food insecurity and significant losses to the economy of a region.

Drought can be defined as an extended period (consecutive months or years) of unusually low rainfall, depleted soil moisture and groundwater levels and a severe reduction in availability of surface water resources in streams, reservoirs and lakes. Drought can be referred to as a “creeping disaster” since its effects accumulate slowly and may linger for years after the termination of the event. Droughts can decimate dryland crop production, severely curtail irrigated crop production, cause severe loss of life of livestock and game, diminish freshwater fish-stocks, result in severely restricted municipal and industrial water supplies and give rise to substantial losses to the economy of a region.

It follows from the above that systematic preparedness planning for floods and droughts is an imperative to ensure mitigation of and protection against the above negative consequences of extreme floods and droughts.

6.7.2 Purpose of a Flood and Drought Management Plan

The purpose of a Flood and Drought Management Plan is to establish and guide a structured programme of actions aimed at ensuring the prevention of, mitigation of, timeous response to, and recovery from, the harmful impacts of floods and droughts across a specific Basin or catchment area.

6.7.3 Characteristics of floods and droughts in Athi Basin

6.7.3.1 Frequency and extent of floods

The frequency and extent of significant floods in Kenya have increased during the past six decades from about one flood period every four years, on average, to a near-annual event, as is illustrated by the following details:

- Between 1961 and 1997, Kenya experienced 8 individual years with widespread flooding, some of which included *Nairobi and eastern areas* in Athi Basin (Opere, 2013). The most devastating among these were the floods of 1997/98, the so-called El Nino Flood, with 1.5 million people affected, 770 000 displaced, 2000 human deaths, 2.3 million livestock lost and 100 000 km roads and 13 major bridges destroyed (Gathura, 2015). *Mombasa, Kilifi and Kwale* counties were particularly severely impacted.
- During the period 1998-2012, widespread flooding across Kenya was absent for only two of the years and during a number of these events *Nairobi and the central and eastern counties* in Athi Basin were impacted to varying degrees (Huho et al., 2016).
- Widespread flooding and occasional landslides during March–May 2013 displaced 140 000 people and led to 96 deaths. *Kajiado, Machakos and Nairobi counties* in Athi Basin were severely affected. (OCHA, 2013; Reliefweb, 2013).
- Widespread flooding and occasional landslides during October-December 2015 affected 240 000 people, displaced 104 000 and caused 112 deaths across the impacted areas. Athi Basin counties that were impacted were *Kilifi, Machakos and Nairobi* (International Federation of Red Cross, 2016a).
- Widespread flooding and occasional landslides during April and May 2016 displaced 48 000 people and caused 100 deaths. Athi Basin counties that were severely impacted were *Mombasa, Kwale, Kilifi and Nairobi* (International Federation of Red Cross, 2016b).
- During 2017, two different periods of significant flooding occurred in separate parts of Kenya - during May in south-eastern Kenya and during November in northern Kenya. The flooding in May severely impacted Athi Basin counties, *Mombasa, Taita Taveta and Kwale*, displacing 13 000 people, causing 17 deaths and destroying numerous roads and bridges. (Davies, 2017).
- Widespread flooding and various landslides during March-May 2018 impacted more than 800 000 people across Kenya, including in Athi Basin counties, *Taita Taveta, Kwale, Kilifi, Mombasa, Nairobi and Machakos*. About 300 000 people were displaced and 186 people lost their lives across the country. More than 8 500 hectares of crops were destroyed and some 20 000 livestock lost, while about 100 schools were flooded. (OCHA, 2018).

6.7.3.2 Flood-prone areas in Athi Basin

As is reported in the previous sub-section, Athi Basin counties that are frequently mentioned in historical flood damage reports are Kilifi, Kwale, Taita Teveta and Machakos, which are fully rural, as well as Nairobi and Mombasa, which are highly urbanised. The flood-prone areas in these counties are as follows (Water Resources Management Authority, 2015b):

- *Kilifi County*: The Lower Athi River flood-plain (also known as Lower Sabaki) experiences frequent inundations, which impact the many small-scale migratory settlements in that area.
- *Kwale County:* The most affected area by flooding is at Vanga, along the lower reaches of the Umba River, near the border with Tanzania.
- *Taita Taveta County:* Frequent flooding occurs in the small villages along the Lumi River, south of Taveta Town, as well as immediately upstream of Lake Jipe on the border with Tanzania.
- *Machakos County:* Frequent overbank flooding occurs at a number of locations along the Upper Athi River, including at Athi River Town.

- *Nairobi and Mombasa Counties:* Flooding in these counties are not river-induced but is rather due to inadequate and ineffective urban stormwater drainage systems.

6.7.3.3 Frequency and extent of droughts

During the most recent two decades Kenya has experienced five widespread multi-year droughts with devastating socio-economic and environmental consequences. Table 6-22 provides an outline of these five droughts. Most of the central and eastern counties of Athi Basin were severely impacted by these droughts.

Table 6-22: Widespread Kenyan droughts during the last 20 years (Huho et al., 2016; Reliefweb, 2018)

Years	Impacts
2016-17	3.4 million people severely food insecure, of which 1.1 million are children. About 0.5 million people without access to clean water.
2011-12	3.75–4.3 million people in dire need of food.
2008-09	4.4 million people affected; 2.6 million people at risk of starvation, 70% loss of pastoral livestock.
2004-06	3.5 million people affected; 2.5 million close to starvation; 40 human lives lost; 40% cattle, 27% sheep and 17% goats lost.
1999-2001	4.4 million people affected.

6.7.3.4 Drought-prone areas in Athi Basin

The climate of Athi Basin counties, Kilifi, Kwale, Makueni, Kajiado, Kitui and Taita Taveta, can be categorized as semi-arid, with relatively low mean annual rainfall. Under these precarious climate conditions, it follows that, if consecutive rainfall seasons fail such as happened during each of the above years, emergency drought conditions would eventually develop in these six counties.

6.7.4 Existing flood and drought management measures and response plans

The following sections outline the various flood and drought management strategies/plans, relevant to the Athi Basin, that have been compiled during the recent past.

6.7.4.1 National Water Management Plan 2030, Volume III Part E – Athi Catchment Area

The Water Master Plan for the Athi Basin consists of eight component plans, one of which is a flood and drought disaster management plan.

Flood disaster management plan

The proposed components of a flood disaster management plan for the Athi Basin distinguishes between “structural” and “non-structural” measures, as follows:

- Establishment of community-based disaster management systems (“non-structural” measures) for the Lower Athi River and the Lower Lumi River, respectively. This would be by means of a simplified flood forecasting system based on water level observations in the upper reaches of the Athi and Lumi Rivers, respectively, and creation of evacuation routes and evacuation centres.
- Construction of a multi-purpose dam in the Lumi catchment to attenuate floods that are derived from Mount Kilimanjaro rainstorms (“structural” measure).
- Implementation of physical flood mitigation (increased channel capacity) and protection (dykes) (“structural” measures) as well as preparation of a flood hazard map at Vanga in Kwale county (“non-structural” measure).
- Implementation of urban drainage measures in Nairobi and Mombasa, respectively (“structural” measures).

Table 6-23: Summary and costing of the flood disaster management plan component of the Athi Basin water management plan extracted from NWMP 2030

CA	No.	Description	Project Cost for Structure (KSh million)	Project Cost for Non-Structure (KSh million)	Recurrent Cost* (KSh million /year)	Source	Remarks
Athi	A1	**Downmost Athi (Kilifi, Lower Sabaki)**	**84.96**	**39.96**	**0.62**		
	F	A1.1 Establishment of Community-based Flood Management System	84.96	39.96	0.62	Nyando MP	
	A2	**Lumi River (Taveta)**	**124.91**	**58.76**	**0.92**		
	A	A2.1 Construction of Multipurpose Dam	-		-		Lake Chala Dam
	F	A2.2 Establishment of Community-based Flood Management System	124.91	58.76	0.92	Nyando MP	
	A3	**Nairobi City**	**0.00**	**0.00**	**0.00**		
	H	A3.1 Implementation of Urban Drainage Measures	(38,270.73)		-	NWMP (1992)	US$360.0 million in 1992
	A4	**Kwale (Vanga)**	**155.93**	**30.00**	**0.15**		
	B	A4.1 River Training Works	155.93		-		
	D	A4.2 Preparation of Hazard Map		30.00	0.15		10M/M
	A5	**Mombasa**	**0.00**	**0.00**	**0.00**		
	H	A5.1 Implementation of Urban Drainage Measures	(4,948.62)		-	NWMP (1992)	US$46.55 million in 1992

Drought disaster management plan

The proposed components of a drought disaster management plan for the Athi Basin will be as follows:

- Preparation of drought operating rules for existing and proposed reservoirs as well as of restrictions placed on water supplies to the different water-user sectors.
- Establishment of a Basin Drought Conciliation Council for each of the six independent river systems in the Athi Basin, with legal status to avoid water conflict during droughts. Each Council's membership would comprise WMA regional staff, county staff and representatives of WRUAs.
- Establishment of a drought early warning system, based on existing KMD seasonal rainfall forecasts and utilised to commence with timely water restrictions.

6.7.4.2 Lumi River Basin Integrated Flood Management Plan (IFMP) (Water Resources Management Authority, 2013a)

The Lumi River IFMP is structured according to three different sets of flood types/problems in the Lumi catchment, impacting three different areas. These flood types/problems and proposed counter-acting measures are outlined in Table 6-24.

Table 6-24: Flood types/problems and counter-measures proposed for the Lumi River catchment (Water Resources Management Authority, 2013a)

Flood Type and Problem	Area	Causes	Counter-Measures
Increasing flood peaks and high sediment loads.	Upper and Middle Lumi catchment.	Soil erosion due to high rainfall on steep deforested slopes with clay soils with increasing cultivation.	Preventing illegal logging, systematic re-afforestation and constructing sediment deposition weirs.
Long periods of inundation of houses, cultivated lands and roads, leading to emergency conditions.	Lower Lumi and Lake Jipe riparian zones.	Aggradation of both Lower Lumi's channel bed and Lake Jipe's bed; breaches in river banks and existing dykes and canal sides; houses and toilets in inappropriate locations.	Community-based early warning systems; evacuation routes and centres; repair of breaches in river banks and canal sides; increased elevations and drainage of river crossings; dredging of Lumi and Lake Jipe's sediment depositions.
Flash floods, destruction of houses and river crossings; high sediment loads; leading to emergency conditions.	Tributaries of the Lower Lumi and Lake Jipe	Soil erosion due to deforested hill slopes with clay soils with increasing cultivation; poorly informed local communities.	Community-based early warning systems; evacuation routes and centres; increased elevations and drainage of river crossings; raised house and toilet floor levels.

6.7.4.3 Tana and Athi Rivers Development Authority (TARDA) Strategic Plan 2014 – 2018 (Tana and Athi Rivers Development Authority (TARDA), 2014).

The Strategic Plan 2014-2018 by the Tana and Athi Rivers Development Authority (TARDA) includes flood and drought mitigation in the context of Climate Change, as outlined in the extract presented in Table 6-25.

Table 6-25: TARDA strategy for flood and drought mitigation in the Athi and Tana River catchments

STRATEGIES	TASKS/INITIATIVES/ACTIVITIES	Indicators	Targets	YEAR					BUDGET KSH Millions	Source of funds
				1	2	3	4	5		
Climate Change Adaptation, flood and drought Mitigation	Develop Climate change adaptation strategy	Strategy Documents	1 per catchment						5	GOK, Grants
	Build capacity on Developing adaptation mechanism	No. Of Capacity building sessions on resilience	1 per catchment per annum						15	GOK, Grants
	Develop Climate change mitigation programs	No. Of climate change Adaptation Program	1 per catchment						90	GOK, Grants,PPP

6.7.4.4 Athi Catchment Area Catchment Management Strategy 2015 – 2022 (Water Resources Management Authority, 2015b)

In the Athi CMS, five levels of structural/non-structural intervention are envisaged: regional, sub-regional, county governments, WRUAs and local communities. Table 6-26 presents a generic summary of the proposed interventions.

Table 6-26: Levels of flood and drought management envisaged for the Athi Basin (Water Resources Management Authority, 2015b)

Focus at Regional Level		Focus at Local Level	
Structural	*Non-Structural*	*Structural*	*Non-Structural*
Development of large-scale infrastructure for flow regulation and storage.	Information gathering, analysis and dissemination.	Development of small scale infrastructure like river training, dykes, raised roads, evacuation centres, culverts, etc.	Flood and drought management activities mainstreamed in County Plans; e.g. early warning at local level, evacuation drills, flood hazard maps, public information on flood inundation.
	Development of analytical products such as inundation maps, drought hazard maps.	Development of rainwater harvesting structures such as water pans, small dams and roof-rainwater tanks.	Community flood and drought management committees formed to coordinate climate related issues.

Regarding the details and locations of the 21 individual interventions, the CMS elaborates the flood and drought management actions proposed in the NWMP 2030 Volume III Part E for the Athi Basin (Water Resources Management Authority, 2013b) presented in Section 6.1 above, with some elaborations similar to the details presented in Section 6.2 relating to the Lumi River IFMP (Water Resources Management Authority, 2013a).

6.7.5 Key achievements, challenges and constraints

The existing strategies and plans for the Athi Basin discussed in Section 6 identified a range of achievements, challenges and constraints with regard to flood and drought disaster management. These are outlined in the following sub-sections.

6.7.5.1 Achievements

- Studies have been completed stormwater drainage improvements in Mombasa and Nairobi.
- All target locations and areas in the Athi Basin for flood and drought management have been fully identified.
- A few community-based flood early warning systems have been established and operationalised.
- At various locations it has been shown that improvement in timely hydro-meteorological data collection can be achieved through installation of automatic stations and use of data loggers.
- The National Drought Management Authority (NDMA) has been established and it exercises its functions both at national level and Basin level, and in collaboration with county governments, also at county and community level. The Ending Drought Emergencies Common Programme Framework (EDE-CPF) has been operationalised and is now in its 3rd Medium-Term Plan (Government of Kenya, 2017a).
- A drought early warning system in terms of livelihood zones has been established through the NDMA by using KMD's rainfall forecasts for the purpose of communities' preparedness against drought disasters.
- During drought periods, the WRA Athi Regional Office institutes water use restrictions at the catchment level, applied at the eight major dams for domestic water supply purposes, namely, Ruiru, Theta, Mulima, Manooni, Muoni, Kikoneni, Maruba, and Kiserian.

- Two Integrated Flood Management Plans have been developed in the Lower Lumi and Lower Sabaki, and are currently under implementation phase.

6.7.5.2 Challenges

- Recurring urban flood disasters due to inadequate or deficient stormwater infrastructure.
- Ongoing urbanisation leading to increased urban populations.
- Ongoing encroachment of communities for crop and livestock farming in flood-prone zones.
- Increasing upland deforestation and soil degradation which compounds river siltation and subsequent flooding of riparian zones and floodplains.
- Ageing flood protection dykes that have become eroded or experience settlement or are overgrown by trees all of which resulting in breaching sooner or later.
- Expanding more widely the establishment of timely hydro-meteorological data collection and subsequent analysis necessary for setting up early warning systems.
- Adaptation required in the face of climate change impacts in the form of increased frequency of floods and droughts.

6.7.5.3 Constraints

- *Institutional complexity*: In terms of the Water Act 2016, a Basin Water Resources Committee (BWRC) for Athi Basin, ought to be in place to advise the WRA and county governments concerning flood mitigation activities, and, in collaboration with the NDMA, ought to be developing drought contingency plans for the ASAL counties and oversee their implementation as emergency response interventions. It has been a serious constraint that the Athi BWRC has not been established and operationalised. Without the BWRC being in place, the interfaces between the national roles of the NDMA and WRA and the local roles of county governments and WRUAs have remained fragmented and lacking an integrated Basin focus.

  However, because of ambiguities in the Water Act about whether BWRCs have advisory or executive functions, parliamentary processes are currently underway to amend the Water Act to limit the mandate of BWRCs to being purely advisory bodies. This change will likely leave a void that will have to be filled by much closer collaboration between counties (who have WRM functions), BWRCs, WRA's Regional and Sub-Regional Offices and the local structures of the NDMA.

- *Incoherent coordination of resource mobilisation:* A recent review of disaster preparedness in Kenya by the DFID (2017) found that coordination between national and local actors in humanitarian resource mobilisation was generally incoherent. Hence, this review concluded that international relief aid organisations and local NGOs have had to establish personal working relationships with institutional actors in each of the counties in which they operate to streamline collaboration by the county governments and other government agencies.
- *Institutional overlaps:* There is considerable overlap between the roles and functions of the NDOC and NDMU. Both institutions manage disaster response activities, the operations of both cut across both natural and man-made disasters, both collaborate closely with the National Police Service and Kenya Red Cross, amongst others. A further constraint is that the two entities are located in different Ministries.

  Furthermore, the mandate of NDMA also overlaps with the mandates of NDOC and NDMU. The Disaster Risk Management Bill, currently under consideration by Parliament, is aimed at bringing NDMA, NDOC and NDMU together as a new "Disaster Risk Management Authority."

- *Monitoring shortcomings*: WRA's surface water monitoring network is well-developed, but data quality is often poor due to inadequate operational and maintenance funding, vandalism of stations and, in some areas, flood damage of river gauging stations. The groundwater monitoring network is sparse, but is currently being extended to the Nairobi, Tiwi and Lamu aquifers.

  Furthermore, protocols for sharing of streamflow and meteorological data between government institutions and professional services providers for flood and drought monitoring, planning and early warning are not satisfactory.

- *Weak community preparedness*: WRA has delineated about 1200 sub-catchment areas across Kenya for WRUA establishments. A process for capacity building of WRUAs has been established through the WRUA Development Cycle, but much work still needs to be done.

6.7.6 Strategy

In previous Sections of this Report, many critical issues related to flood and drought management have been identified including the need for IFMPs (Figure 6-14).

In order to comprehensively and systematically address the flood and drought issues and challenges in the Athi Basin, Table 6-27 sets out 2 Strategic Themes with specific Strategies under each Theme. The Themes address Flood and Drought Management

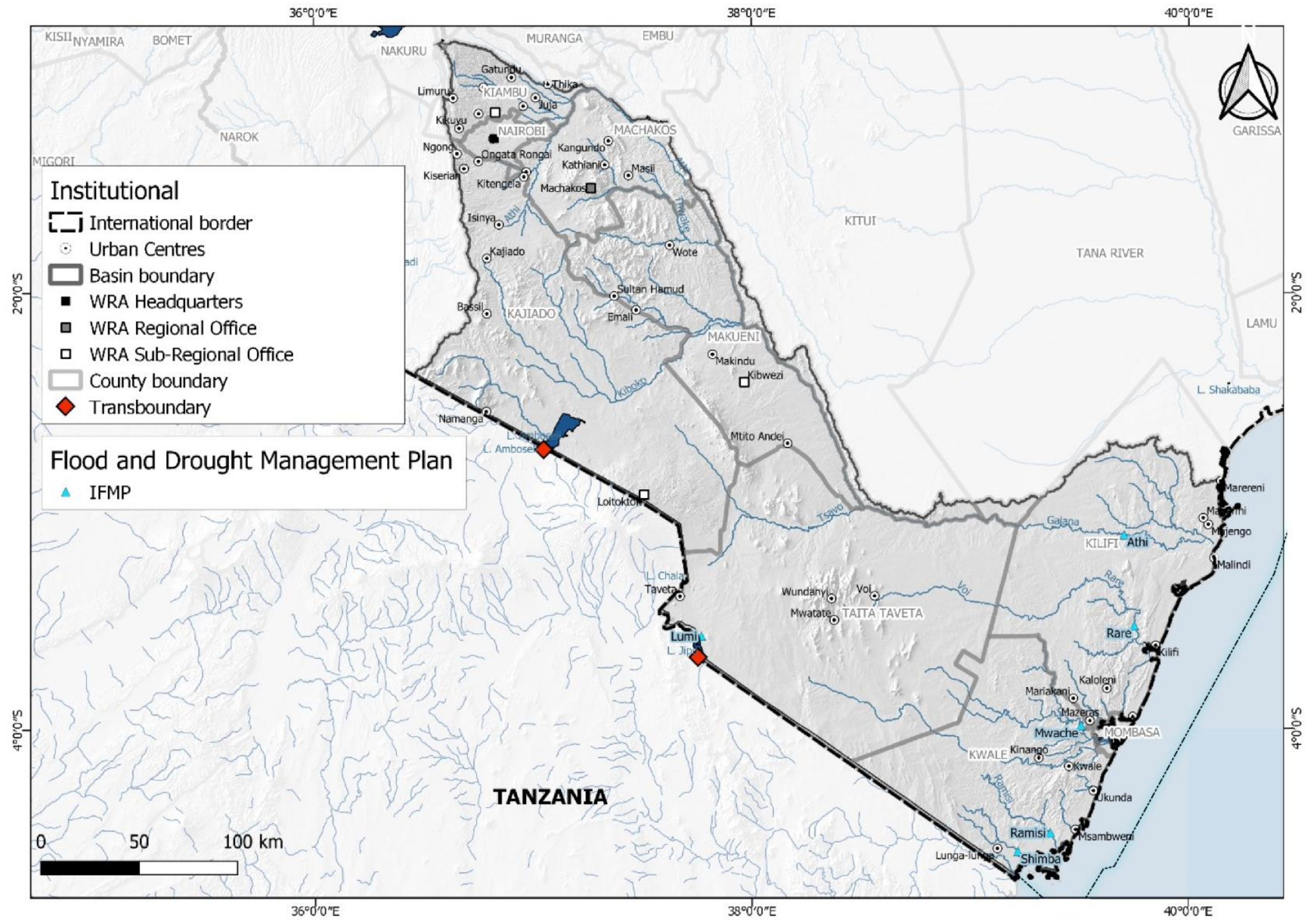

Figure 6-14: Flood management plan for Athi Basin

Table 6-27: Strategic Framework – flood and drought management

<table>
<tr><th colspan="2">Key Strategic Area 6</th><th>Flood and drought management</th></tr>
<tr><td>6.1</td><td>Theme:</td><td>Flood management</td></tr>
<tr><td>6.1.1</td><td colspan="2">Undertake flood risk mapping</td></tr>
<tr><td colspan="3">The most flood-prone counties in the Athi Basin are Kilifi, Kwale, Taita Teveta and Machakos, which are fully rural, as well as Nairobi and Mombasa, which are highly urbanised.
High-level assessments of the stormwater drainage problems and related infrastructure of the cities of Nairobi and Mombasa will be conducted, based on a review of recent studies of these problems and related proposals for resolving the ongoing flooding problems in these cities.
For the flood-prone rural counties, high-level assessments will be made of the flood exposure of each village and town in terms of proximity to river channels, floodplains and low-lying land, as well as vulnerable transport, access and escape routes and river crossings. Both the characteristics of past floods and flooding and the existing flood protection structures and drainage systems will be noted, and the risk of flooding will be determined by reviewing anecdotal information about the frequency of high water levels and long-duration inundations. In the case of the Lower Athi River (also known as the Lower Sabaki), a project is currently underway to model the flood behaviour of the river hydrodynamically and to map, with the aid of a LIDAR survey, the inundation zones for different recurrence interval flood events.
The above information will be systematised in a Flood Risk Register for the Athi Basin, which will provide a starting point for the Integrated Flood Management Plans discussed below.</td></tr>
<tr><td>6.1.2</td><td colspan="2">Formalise institutional roles and partnership collaborations.</td></tr>
<tr><td colspan="3">The government institutions and agencies and other stakeholders with partnership roles in flood management are as follows[3]:
- KMD
- NDMU (including its County Coordinators)
- NDOC
- National WRA and Regional and Sub-Regional WRA Offices
- County Governments and County Disaster Risk Management Committees
- BWRCs
- WRUAs
- Village Disaster Risk Management Committees
- Various Ministries; particularly Departments dealing with Roads, Railways and Health
- Kenya Red Cross Service
- International Relief Aid Agencies
- NGOs
Formalising and aligning the roles of and proactive partnership collaborations among the above entities are crucial to ensuring that the above objectives of the flood response protocol are achieved. To this end, it is proposed that an Athi Basin Flood Response Forum (FRF) be established that integrates all flood-relevant resource mobilisations and related interventions in the Athi Basin by the various collaboration partnerships listed above. The Athi Basin FRF must operate under the auspices of the KMD and, to ensure continuity, it must be served by a Secretariat. The Secretariat can be physically housed in the WRA Regional Office or in one of the WRA Sub-Regional Offices. Furthermore, the activities of the Athi Basin FRF must be systematised through the development of appropriate standard operating procedures (SOPs)[4].</td></tr>
<tr><td>6.1.3</td><td colspan="2">Develop flood response protocol</td></tr>
<tr><td colspan="3">The flood response protocol: The flood response protocol follows a multi-stakeholder approach and comprises a structured set of inter-connected institutional and partnership roles, focus areas and mechanisms to prepare for, respond to and recover from a flood disaster. The components of the flood response protocol are as</td></tr>
</table>

[3] There are currently three bills seeking to establish a National Disaster Management Authority and a National Disaster Management Fund. However, the three bills differ in content and structure e.g. proposed governance structure, membership and functions among other things. The mandates of NDMA, NDOC and NDMU overlap in various ways. The Disaster Risk Management Bill, currently under consideration by parliament, is aimed at bringing NDMA, NDOC and NDMU together as a new "Disaster Risk Management Authority." The sponsors of the bills will have to sit and agree on how to collapse the three bills into one or alternatively, the first bill to pass through all the stages of development will be adopted and the rest will be nullified.

[4] SOPs aim at: (1) Providing a list of major executive actions involved in responding to disasters and necessary measures needed for preparedness, response and relief; (2). Indicating various actions that should be taken and by which actors within their sphere of responsibilities – linking up with their contingency plans; (3) Ensuring that all concerned actors and agencies know the precise actions required of them at each stage of the response and that all actions are closely and continuously coordinated (DFID, 2017).

Key Strategic Area 6	Flood and drought management

follows:

- Formalised institutional roles and partnership collaborations.
- A flood preparedness plan that is understood by both institutional actors and communities in flood-prone zones.
- A key principle of the plan is that it is better to protect more people from the frequent smaller floods, than fewer people from the rarer larger floods. Flood early warning systems should be used to warn communities when larger floods may occur.
- SOPs that comprise sequential response actions: monitoring ⇨ early warning alerts ⇨ severity trigger alerts ⇨ pro-active resource mobilisations ⇨ emergency interventions ⇨ post-flood recovery interventions.

Objectives of the flood response protocol:

- Minimise the impacts of flooding on the safety and quality of life of affected communities.
- Minimise environmental impacts.
- Accelerate recovery of prior homestead environments, livelihoods and transport routes of affected communities.

6.1.4 Develop Integrated Flood Management Plans

An Integrated Flood Management Plan (IFMP) will be developed for each of the six individual catchments in the Athi Basin, namely the Athi, Lumi[5], Ramisi, Rare, Shimba and Mwachi River catchments. The IFMPs will be structured around the following topics:

- Overview of the natural conditions (topography, climate, soils, land-use, land-cover, hydrology) and the socio-economic make-up of each catchment.
- Overview of the statutory, institutional and civil society stakeholder context of each catchment.
- Characteristics of floods and flooding in each catchment, namely identifying all flood-prone locations, flash floods, long-duration overbank inundations, sediment dumping floods, etc.
- Overview of existing flood management/counter measures – both structural and non-structural.
- Analysis and costing of required flood management/counter measures at all flood-prone locations, categorised as follows: *prevention measures; protection measures; preparedness measures; flood early warning systems; emergency response measures*.
- Stakeholder participation in prioritising required flood management/counter measures at all flood-prone locations.
- Proposed Implementation Schedules of flood management/counter measures at all flood-prone locations.
- Funding sources for the proposed flood management/counter measures.

6.1.5 Implement flood management measures

The above proposed Implementation Schedules for the six catchment IFMPs that cover the Athi Basin, will be reviewed by the *Athi Basin FRF* and, through negotiation with representatives of each of the affected stakeholders and villages/communities, be re-prioritised according to both non-structural and structural measures that cover all the short-term, medium-term and long-term flood management/counter measures that are required across the Athi Basin at all flood-prone locations.

The above re-prioritised non-structural and structural flood management/counter measures will encompass the following: *prevention measures; protection measures; preparedness measures; flood early warning systems; emergency response measures*. These measures will be focused on flood-prone river reaches and floodplains in each of the six catchments in the Athi River Basin. Wherever feasible, *community-based* flood early warning and flood preparedness approaches will be followed.

The *Athi Basin FRF* will provide a platform for coordinating the resourcing and supervision of the funding of the above re-prioritised non-structural and structural flood management/counter measures. In all instances, labour-intensive approaches will be followed.

6.1.6 Capacity development

Capacity for flood management in the Athi Basin will be assessed according to three categories, namely, *organisational alignment/collaboration, technical skills and community preparedness.* The outcomes of these assessments will inform the strategy for development of capacity in each of the three categories.

Organisational alignment/collaboration: The strategy is to expand organisational capacity in the Athi Basin by aligning the flood response roles and responsibilities of the government institutions/agencies, International Relief Aid Agencies, Kenya Red Cross, NGOs and other stakeholders with partnership roles in flood management. The vehicle for this strategy will be the *Athi Basin Flood Response Forum (FRF)* introduced in Sub-Section 7.1.2.

Institutional technical skills: The strategy is to strategically expand institutional technical skills relevant to flood

[5] An IFMP for the Lumi River catchment was developed by NEWJEC (2013). That IFMP will be reviewed and updated during this process.

Key Strategic Area 6		Flood and drought management
response activities across three different sets of competencies, namely, (i) competence at translating Flood Early Warning Bulletin information to support prioritisation of resource mobilisations for humanitarian interventions; (ii) competence at logistical planning of required interventions followed by subsequent operationalisation; (iii) competence at communicating technical and logistical information in multi-stakeholder environments. *Community preparedness*: Community-based flood early warning drills as well as emergency evacuation drills will be prioritised by the Secretariat of the Athi Basin FRF. The resources and experience of the NDMU/NDOC (or their successor institution) can make valuable contributions to developing community self-help awareness in terms of flood management.		
6.2	**Theme:**	**Drought management**
6.2.1	Formalise institutional roles and partnership collaborations.	
The government institutions and agencies and other stakeholders with partnership roles in drought management are as follows[6]: - NDMA - NDMU (including its County Coordinators) - NDOC - KMD - National WRA and Regional and Sub-Regional WRA Offices - County Governments and County Disaster Risk Management Committees - BWRCs - WRUAs - Village Disaster Risk Management Committees - Ministry of Agriculture, Livestock and Fisheries as well as Ministry of Health - Kenya Red Cross Service - International Relief Aid Agencies - NGOs Formalising and aligning the roles of and proactive partnership collaborations among the above entities are crucial to ensuring that the above objectives of the drought response protocol are achieved. To this end, it is proposed that the *Athi Basin Drought Response Forum (DRF)* be established that integrates all drought-relevant resource mobilisations and related interventions in the Athi Basin by the various collaboration partnerships listed above. The *Athi Basin DRF* must operate under the auspices of the NDMA and, to ensure continuity, it must be served by a Secretariat. The Secretariat can be physically housed in one of the six drought-prone counties' offices. Furthermore, the activities of the *Athi Basin DRF* must be systematised through the development of appropriate standard operating procedures (SOPs.)		
6.2.2	Develop drought response protocol.	
The drought response protocol: The drought response protocol follows a *multi-stakeholder* approach and comprises a structured set of inter-connected institutional and partnership roles, focus areas and mechanisms to prepare for, respond to and recover from a drought disaster. The components of the protocol are as follows: - Formalised institutional roles and partnership collaborations. - A drought preparedness plan that is understood by both institutional actors and communities in drought-prone zones. - SOPs that comprise sequential response actions: monitoring ⇨ early warning alerts ⇨ severity trigger alerts ⇨ pro-active resource mobilisations ⇨ recovery interventions. Objectives of the drought response protocol: - Minimise the impact of water shortages on the quality of life of affected communities. - Minimise environmental impacts. - Ensure equitable allocation of water despite systematic restrictions of supply. - Accelerate restoration of prior homestead environments and livelihoods of affected communities.		
6.2.3	Improve drought preparedness.	
The above *Athi Basin DRF* must address five primary drought response needs, i.e. *drought monitoring, drought early warning, drought severity assessment, mitigation interventions and recovery interventions*.		

[6] There are currently three bills seeking to establish a National Disaster Management Authority and a National Disaster Management Fund. However, the three bills differ in content and structure e.g. proposed governance structure, membership and functions among other things. The mandates of NDMA, NDOC and NDMU overlap in various ways. The Disaster Risk Management Bill, currently under consideration by parliament, is aimed at bringing NDMA, NDOC and NDMU together as a new "Disaster Risk Management Authority." The sponsors of the bills will have to sit and agree on how to collapse the three bills into one or alternatively, the first bill to pass through all the stages of development will be adopted and the rest will be nullified.

Key Strategic Area 6	Flood and drought management
Currently, *drought monitoring, drought early warning* and *severity assessment* are conducted by the NDMA, who issues regular Drought Early Warning Bulletins for ASAL counties, with inputs from KMD, the above two Ministries and WRA Offices. Regarding *mitigation interventions* and *recovery interventions,* NDMA oversees two coordinating bodies at the national level that bring together various stakeholders in drought preparedness. These are the Kenya Food Security Meeting and the Kenya Food Security Steering Group. At the county level, this is organised under County Steering Groups. The drought severity assessments of the national and county-level coordinating structures of the NDMA relevant to the Athi Basin must be reviewed and deliberated by the collaboration partnership participants in the *Athi Basin DRF*. In the case of an adverse severity assessment, the Athi Basin DRF participants will have a common point of reference from which to launch and systematically coordinate their various drought-relevant resource mobilisations and related interventions in the Athi Basin.	
6.2.4	Develop drought early warning system
The NDMA currently issues regular Drought Early Warning Bulletins for ASAL counties. In the Athi Basin, Bulletins are issued for Kwale and Kilife counties. Bulletins must in future also be issued for additional Athi counties that are drought-prone, namely Taita Taveta, Makueni, Kajiado and Kitui. SOP responses based on the Bulletins' early warning findings and alerts must be an integrating force in the above *Athi Basin DRF*. The sub-county scale of the Bulletins' reporting ensures that such responses can be spatially accurately focused. Furthermore, such informed responses will secure appropriate and timeous resource mobilisations and humanitarian interventions across all the collaborating partnerships at county, sub-county and local community scales across the above six drought-prone counties in the Athi Basin. The Famine Early Warning Systems Network (FEWS NET), which produces monthly reports and maps detailing current and projected food insecurity in a number of regions in the world, has a Regional Office in Kenya and FEWS NET outputs will support the deliberations by the participants in the Athi Basin DRF.	
6.2.4	Capacity development
Capacity for drought management in the Athi Basin will be assessed according to three categories, namely, *funding*, *organisational alignment* and *institutional technical skills.* The outcomes of these assessments will inform the strategy for development of capacity in each of the three categories. *Funding*: The funding strategy is to secure a standing allocation from the recently established National Drought Emergency Fund (DEF) to the Athi Basin's six drought-prone counties to ensure that finance for early drought response will always be available when needed. This will avoid the hitherto time-consuming approach of emergency budgetary re-allocations, which is also counter-productive, because it takes resources away from the long-term development that should enhance resilience to drought. *Organisational alignment/collaboration*: The strategy is to expand organisational capacity in the Athi Basin by aligning the drought response roles and responsibilities of the government institutions/agencies, International Relief Aid Agencies, Kenya Red Cross, NGOs and other stakeholders with partnership roles in drought management. The vehicle for this strategy will be the *Athi Basin Drought Response Forum (DRF)* introduced in Sub-Section 7.2.1. *Institutional technical skills*: The strategy is to strategically expand institutional technical skills relevant to drought response activities across three different sets of competencies, namely, (i) competence at translating Drought Early Warning Bulletin information to support prioritisation of resource mobilisations for humanitarian interventions; (ii) competence at logistical planning of required interventions followed by subsequent operationalisation; (iii) competence at communicating technical and logistical information in multi-stakeholder environments.	

6.8 Hydrometeorological Monitoring

6.8.1 Introduction

An operational and well-maintained hydrometeorological network is critical to support the WRA with its key functions related to water resources planning, regulation and management in the Athi Basin. The WRA is responsible for all aspects related to the monitoring (quantity and quality) of surface and groundwater in Kenya, including the construction and maintenance of monitoring stations, related equipment, data collection, transmission, capturing and storage, and dissemination.

6.8.2 Issues related to hydrometeorological monitoring in the Athi Basin

A brief overview of the existing hydrometeorological monitoring network in the Athi Basin is provided in Section 2.4.8. The current network is inadequate, and the network is not being effectively operated. Data management and sharing platforms are not well established, and there is inadequate technical capacity for data processing, analysis and reporting. There is also inadequate maintenance of the monitoring stations. Although the WRA continuously rehabilitates and expands the hydromet monitoring network, issues such as ageing, vandalism and flood damage limit progress. Furthermore, there are challenges in monitoring meandering rivers, which occur in the lower Athi region.

Most of the operational river gauging stations in the Athi Basin are rated sections. Most are read manually by gauge readers. It has been reported that manual measurements are often difficult during high flow and flood events due to access challenges. Although procedures are in place to collect discharge data, compliance is often hampered due to logistical, financial and capacity constraints. Rating curves are updated yearly at the National office and distributed to the regional and subregional offices for use. Flow measurement for checking and updating rating curves are typically done manually with flow meters. However, local offices often do not have the necessary equipment and even fuel to travel to remote stations to conduct measurements. There is also minimal updated bathymetry data in all sub-regions. Stage records that are collected manually are entered into a database at the subregional office then sent to the regional office for recording. Headquarters receives a backup copy from the regional office on a monthly basis. Little is known about the quality control process.

Many different organisations including the WRA, Kenya Meteorological Department (KMD), regional police stations, primary and secondary schools, national parks, private enterprises, research institutions and agricultural offices operate meteorological stations throughout the basin. Due to the expansive and diverse set of owners and operators of meteorological stations throughout the Athi Basin, little accurate information is known about operational status, station types, parameters collected, operators, and even confirmed coordinates of meteorological stations.

The Athi Basin, with Nairobi City at its headwaters, poses a great water quality management challenge due to the discharge of untreated or partially treated industrial effluent and domestic sewage. To address this problem, will, as a start, require intensified monitoring and enforcement of the water permit conditions and effluent discharge guidelines. It has been observed that wetlands and marshlands in the basin have been mercilessly encroached on, thereby reducing their use as effluent filters. Currently, the water quality monitoring programme operated by WRA faces challenges of inadequately qualified and trained staff and also inadequate operational resources to facilitate regular sampling and laboratory analysis. In addition, because of inadequate equipment, existing laboratories are only able to carry out analysis for a handful of parameters. There is an urgent need to upgrade the central and regional laboratories in the Athi Basin including recruitment of more technical staff, equipping the laboratory and stocking it with reagents, procuring Field Testing Kits, and operationalising the LIMS in the central laboratory. Furthermore, the mandates and roles and responsibilities of the different institutions involved in water quality management in the Athi Basin need to be resolved to ensure that cooperative governance of water quality is achieved.

Groundwater monitoring in Kenya has improved significantly in the past decade. In the Athi Basin, there is currently a total of 40 groundwater monitoring points: 4 Strategic, 20 Major, 11 Minor and 3 Special (WRA, 2018c). Data quality is, however, patchy - most groundwater level data are collected from boreholes that are used as production boreholes. All too often, the data show dynamic as well as static water levels. This restricts the utility of water level data to determine long-term trends. This is changing, however: an additional 25 dedicated monitoring boreholes were being constructed in the Basin in 2018-19, which will be fitted with water level loggers and telemetry. Groundwater abstraction monitoring is done on an ad hoc basis at best - groundwater users are required to submit abstraction data monthly or quarterly as evidence to support their water charge payments, but these are rarely checked in the field by the WRA.

6.8.3 Hydromet monitoring network design

A key output from this Consultancy was the design of a hydrometeorological network for the Athi Basin. Details on the design approach as well as the proposed network are provided in "ISC Report D1-1: Hydromet Monitoring Network Design".

The following sections provide a brief overview of the proposed network.

6.8.3.1 Stream flow monitoring

The approach towards the design of a stream flow monitoring network for the Athi Basin entailed an assessment of the existing and historical network in the Athi Basin against specific criteria. The result is a stream flow monitoring network design for the Athi Basin consisting of 43 stations. The 43 stations include upgrades to some of the existing stations as well as operationalising the historical stations which have fallen into a state of disrepair. In addition to the refurbishment of some of the manual stations, 21 stations will be upgraded from manual to automatic, 6 from manual to telemetric, and 1 from one from automatic to fully telemetric.

Table 6-28: Proposed surface water monitoring network for the Athi Basin

Sub-Regional Office	Total Number of SW Stations			
	Telemetric	Automatic	Manual	TOTAL
Kiambu	1	3	3	**7**
Kibwezi	2	7	1	**10**
Loitokitok	1	4	0	**5**
Mombasa	4	5	4	**13**
Nairobi	1	4	3	**8**
TOTAL	**9**	**23**	**11**	**43**

The maps below display the locations of the streamflow gauging stations per SRO area.

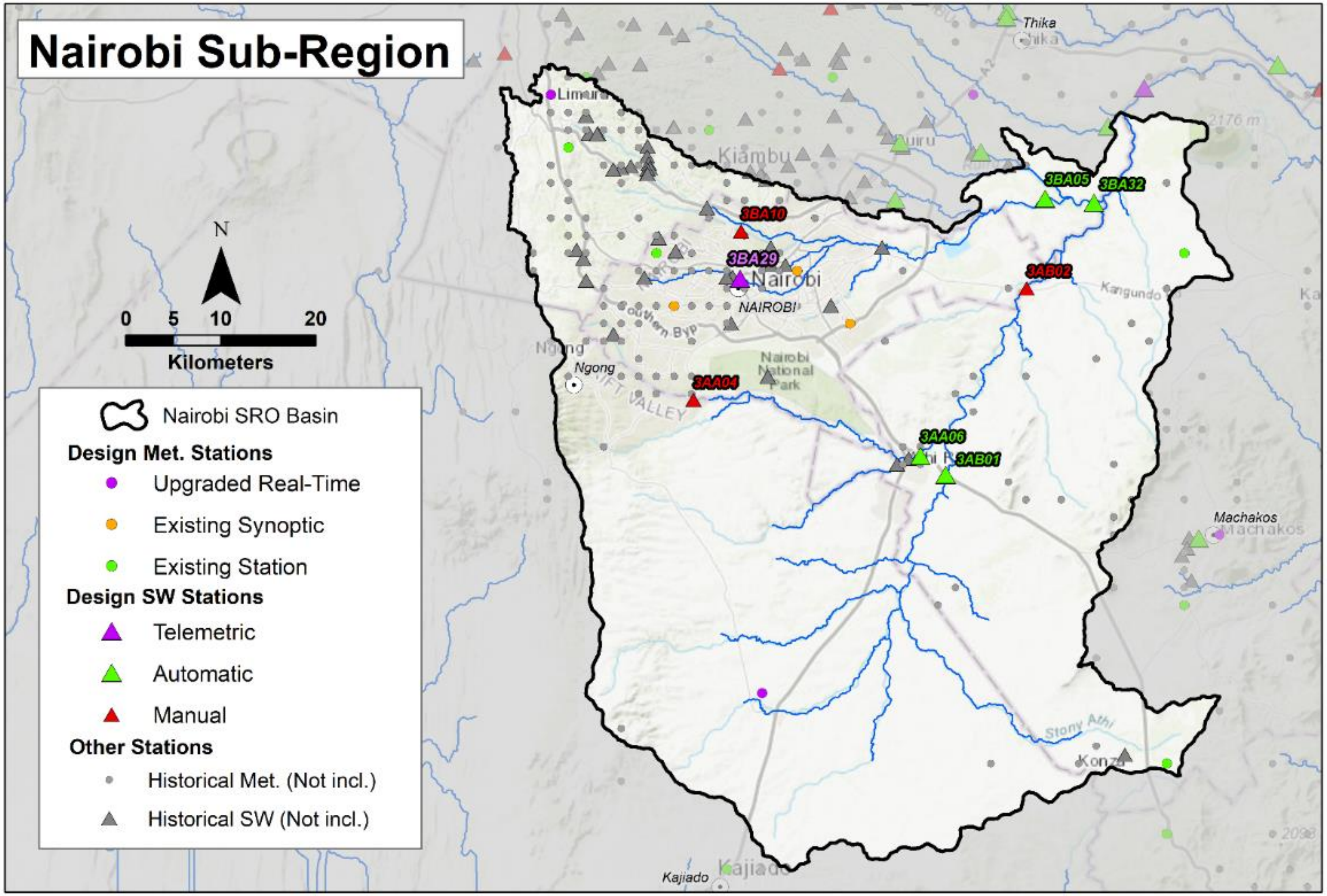

Figure 6-15: Nairobi sub-region: Proposed flow and met monitoring network

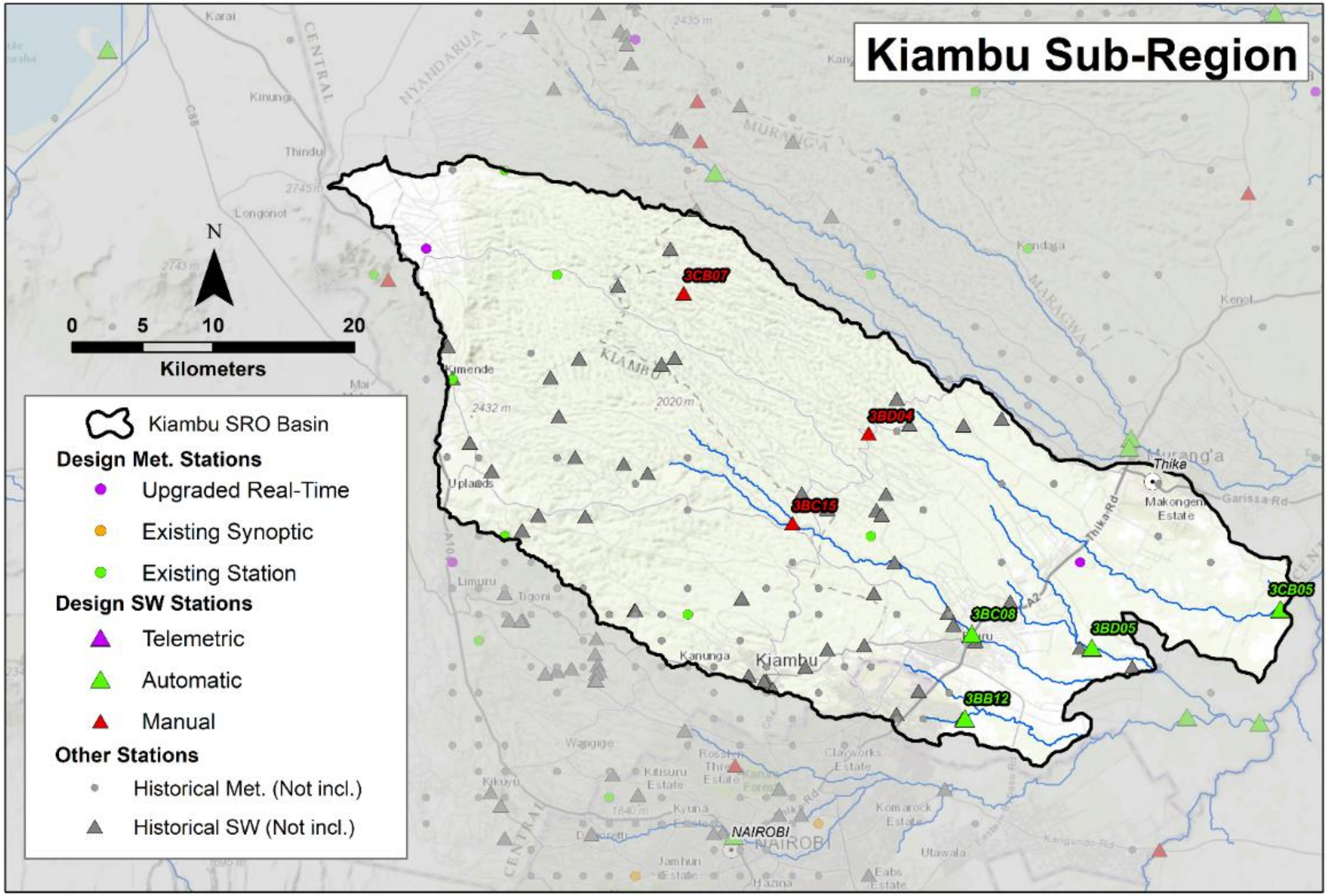

Figure 6-16: Kiambu sub-region: Proposed flow and met monitoring network

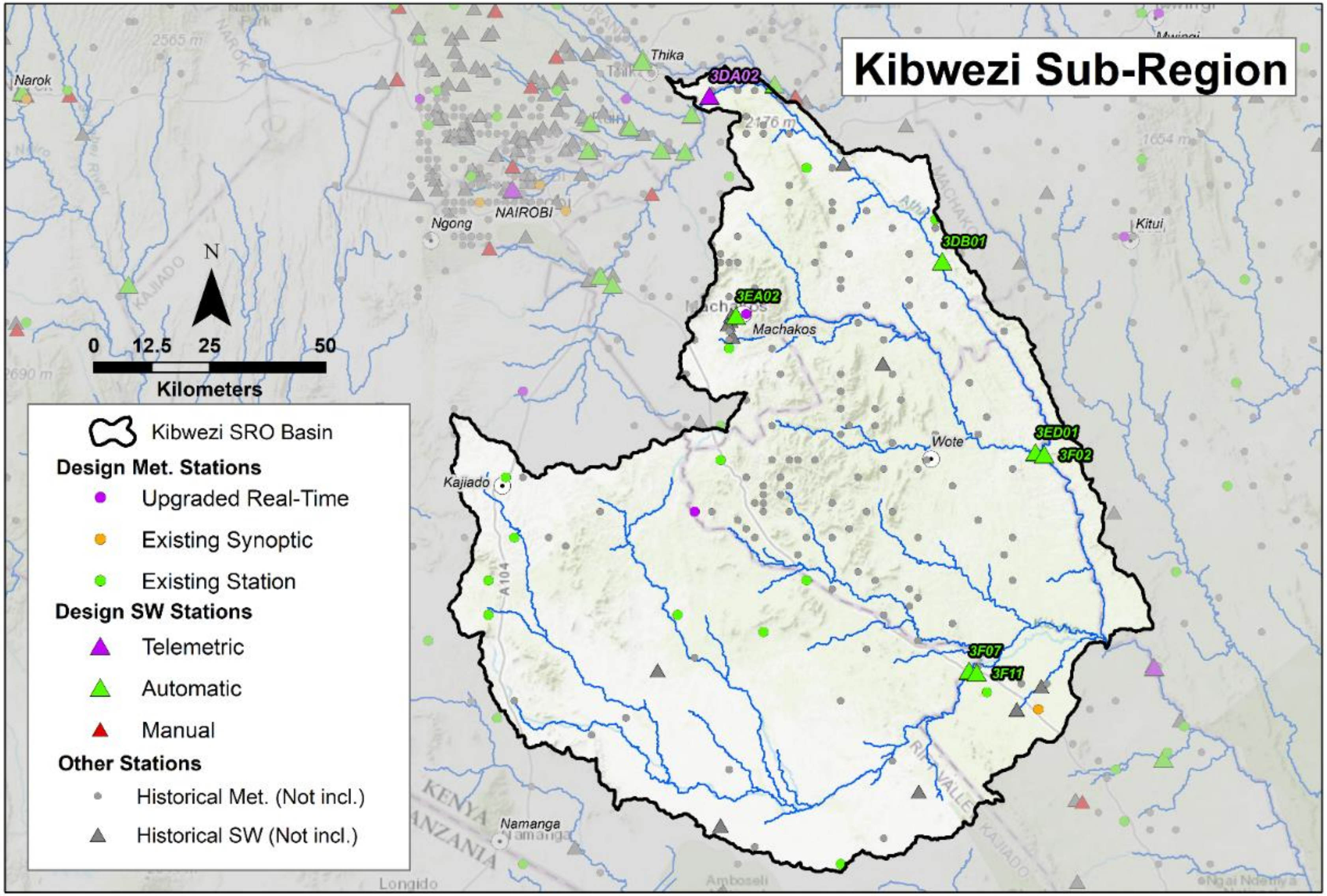

Figure 6-17: Kibwezi sub-region: Proposed flow and met monitoring network

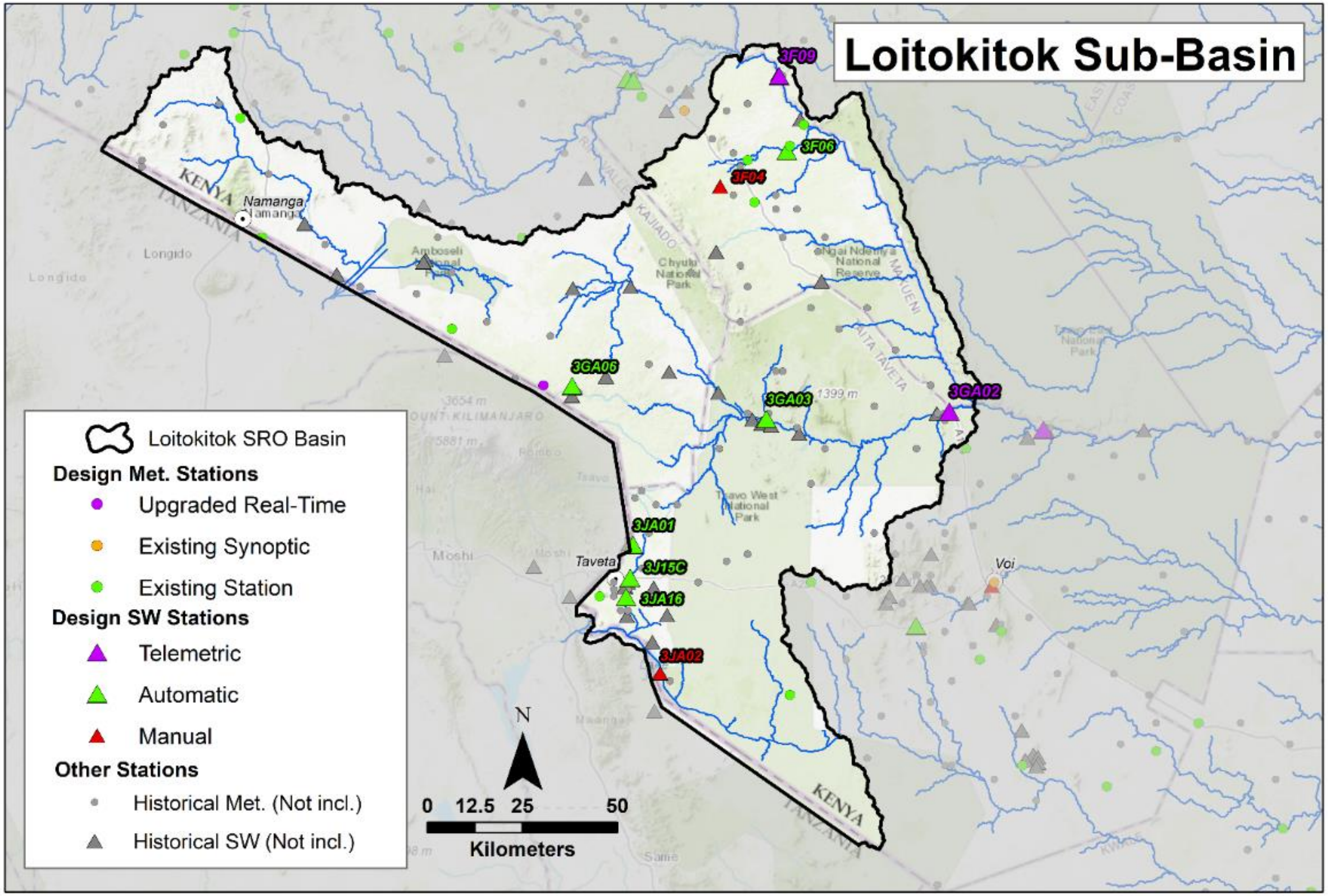

Figure 6-18: Loitokitok sub-region: Proposed flow and met monitoring network

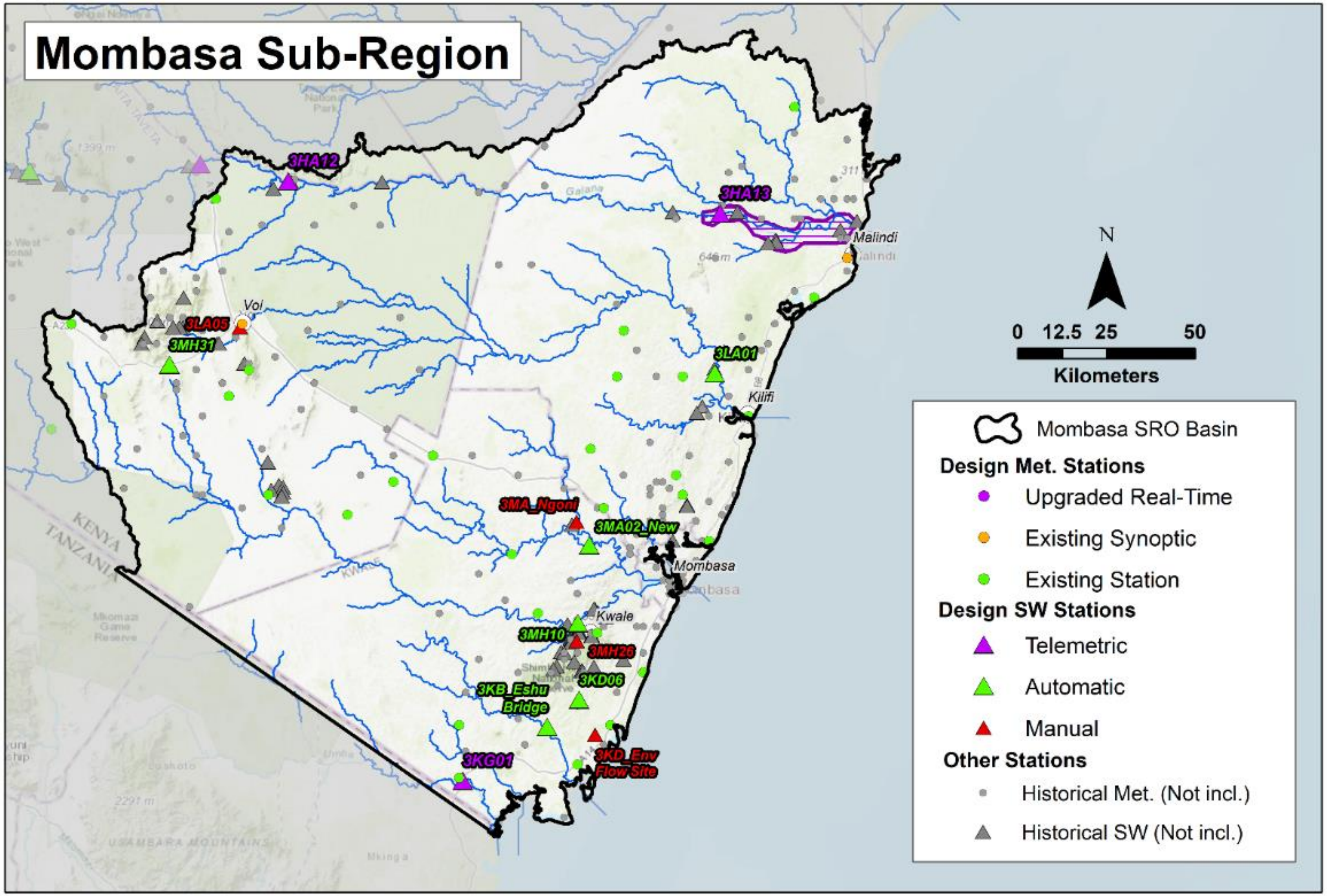

Figure 6-19: Mombasa sub-region: Proposed flow and met monitoring network

6.8.3.2 Monitoring of dam and lake levels

Two lake monitoring stations are proposed in the Athi Basin. One is located at Lake Chala, and is a currently non-operational manual station that will be upgraded to an automatic one. The other one is located at Lake Jipe, and is a currently operational manual station that will remain manual. Both stations are in Loitokitok SRO (Figure 6-18).

6.8.3.3 Meteorological monitoring

The approach towards the design of a meteorological network for the Athi Basin entailed an assessment of the historical meteorological network in the Athi Basin against specific criteria. The result is a meteorological network design for the Athi Basin consisting of 88 stations. 78 of these stations are currently operational, while 3 stations will entail the reinstatement of existing stations which are currently in a state of disrepair. In addition, there will be 7 new real-time rainfall stations combined as part of the real-time stream gage network, and 12 existing operational rainfall or full meteorological stations (3) upgraded to include real-time telemetry. Figure 6-15 to Figure 6-19 also display the proposed meteorological network for the Athi Basin.

Note: The proposed meteorological network is awaiting input from KMD.

6.8.3.4 Water quality monitoring

The approach towards the design of a water quality monitoring network for the Athi Basin entailed a comprehensive review of the existing water quality monitoring network in the Basin, a needs assessment and a detailed evaluation of the proposed network design against identified evaluation criteria. The result is a water quality monitoring network design as detailed below. Note that most of the surface water stations coincide with stream flow gauging stations which are currently operational or have been identified for rehabilitation. Out of the 45 stations proposed for groundwater quality monitoring, 29 of these will be located in the NAS.

Table 6-29: Proposed water quality monitoring network for Athi Basin

Athi Basin	Current stations (2018)	Proposed stations to be retained	Proposed stations to be discontinued	Proposed new stations	Total
Surface water	33	31	2	22	53
Effluent stations	21	21	0	7	28
Ground water	37	37	0	8	45
Total	**91**	**89**	**2**	**37**	**126**

Out of the total proposed stations, a number of them were proposed to be first priority (Table 6-30). Most of the first priority stations will be telemetric stations. In addition, a number of surface water stations were proposed to be baseline monitoring stations.

Table 6-30: Proposed baseline and first priority stations for Athi basin

Athi Basin	Proposed baseline monitoring stations	Proposed first priority stations
Surface water	8	18
Effluent stations	-	6
Ground water	-	5
Total	**8**	**29**

Surface Water

The proposed surface water station water quality network for the Athi Basin differentiates between Baseline, Impact, Trends, Compliance or Surveillance type stations. In general Baseline stations are established towards the uppermost reaches of rivers while Impact and Trends stations are towards the lower reaches. Compliance stations will become active once the Resource Quality Objectives are established and the rivers have been classified.

The design further specifies the monitoring focus of each station as either: Nutrient and Sediment Loads, Organic matter from domestic sewage and agro-based industries, Heavy metals from industries, Pesticide residues from use of Pesticides on farms or suitability of the water for domestic use or for irrigation. Thus, the stations broadly fall under each of the following Types of Monitoring:

- Sediment Load Monitoring (TSS, Sediment Load)
- Nutrients Monitoring (Nitrogen compounds, Phosphates, Silica)
- Organic Loads monitoring (BOD, DO, pathogenic organisms)
- Industrial Loads monitoring (Heavy metals, COD)
- Agro-chemical Loads monitoring (Pesticide residues)
- General WQ &PC Monitoring (suitability for irrigation, other common uses, water supplies, wildlife and livestock watering)

Some stations have been categorised as 1st Priority Stations: Most of these stations coincide with flow gauging stations that currently are automated or have been prioritized for automation. These stations will be fitted with Water Testing Multiparameter Sondes, capable of testing a wide range of parameters to be specified. In the meantime, it is recommended that all ROs and SROs in the Athi Basin should have Portable Water Testing Kits to ensure regular water quality testing at these stations. 1st Priority stations comprise of all National stations, Special Stations, Global stations (In-lake stations, Lake Shore stations), River mouth stations, Pollution Hotspots, Upstream of Dams, intakes for Water supplies and Transboundary stations. Samples drawn from these stations as a priority will be able to give a fair description of the surface water quality in the basin. 2nd Priority Stations constitute the remainder of the water quality monitoring network stations, from which samples will be taken and tested in accredited laboratories as is the current practice. The maps below display the locations of the proposed surface water quality stations per WRA sub-region.

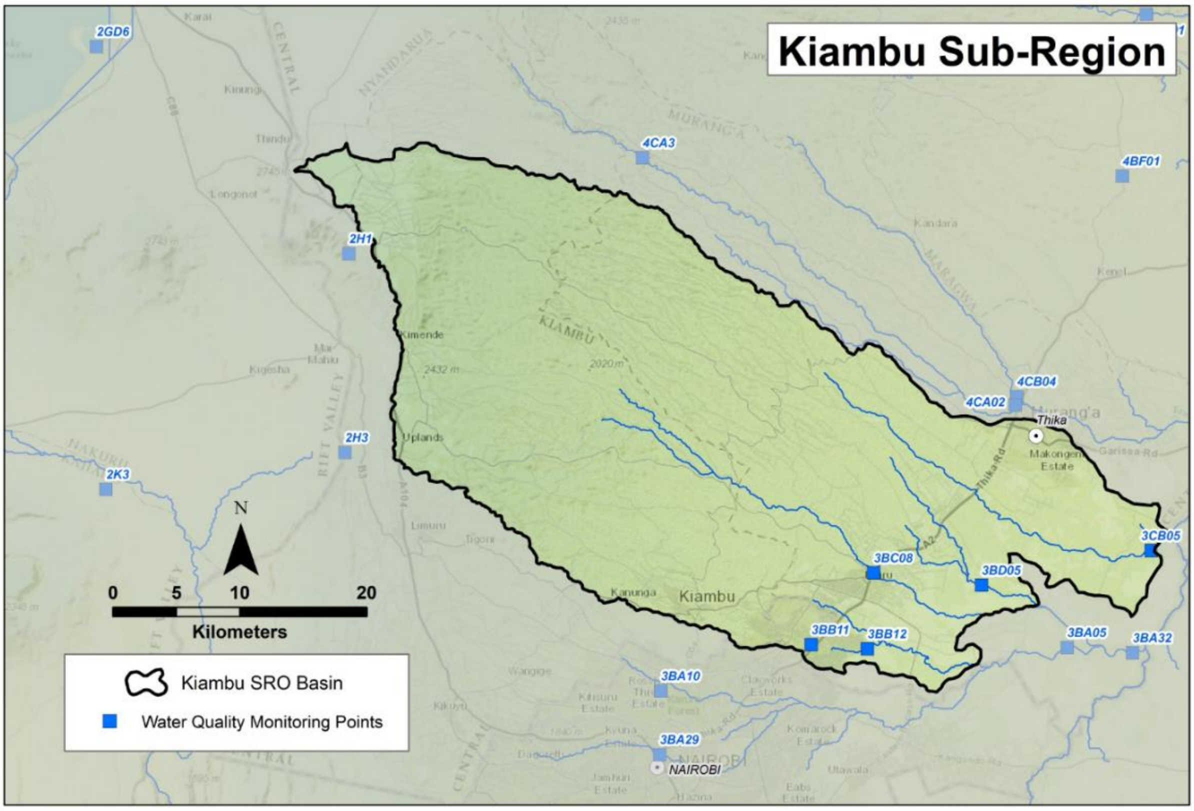

Figure 6-20: Kiambu sub-region: Proposed surface water quality monitoring points

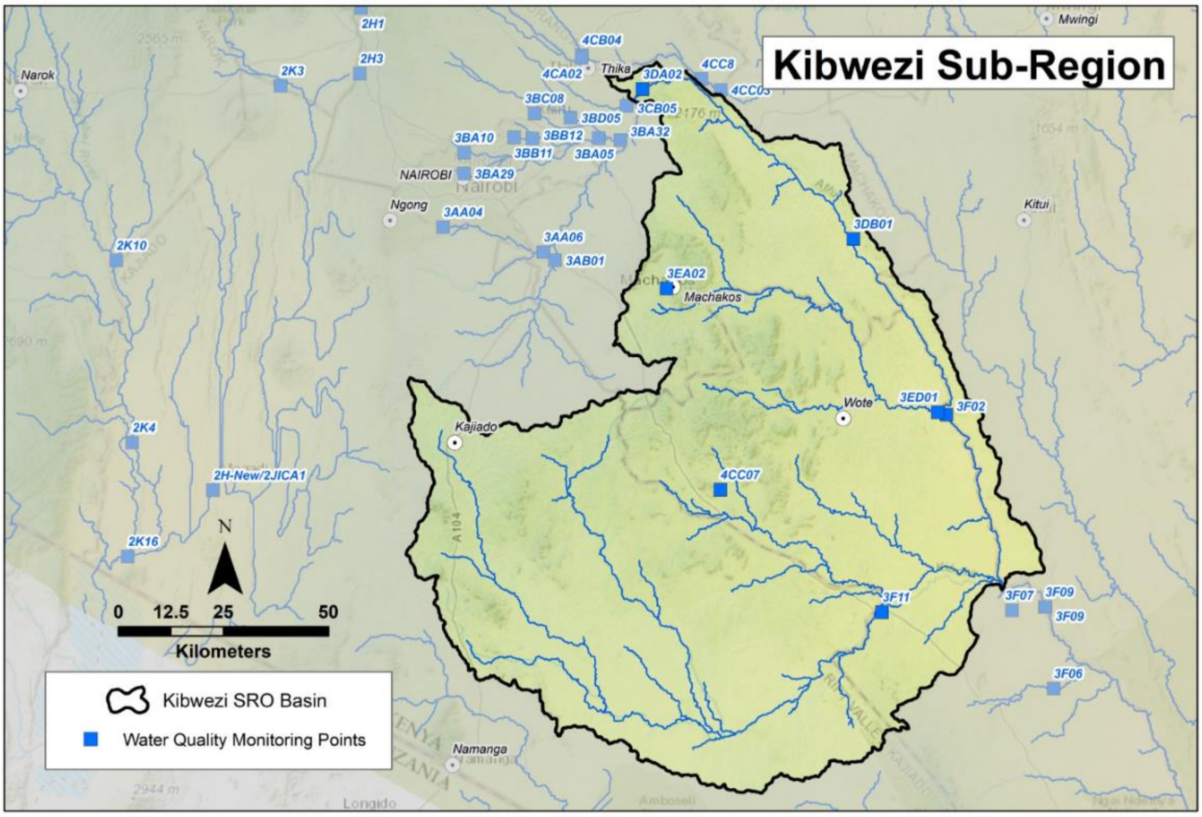

Figure 6-21: Kibwezi sub-region: Proposed surface water quality monitoring points

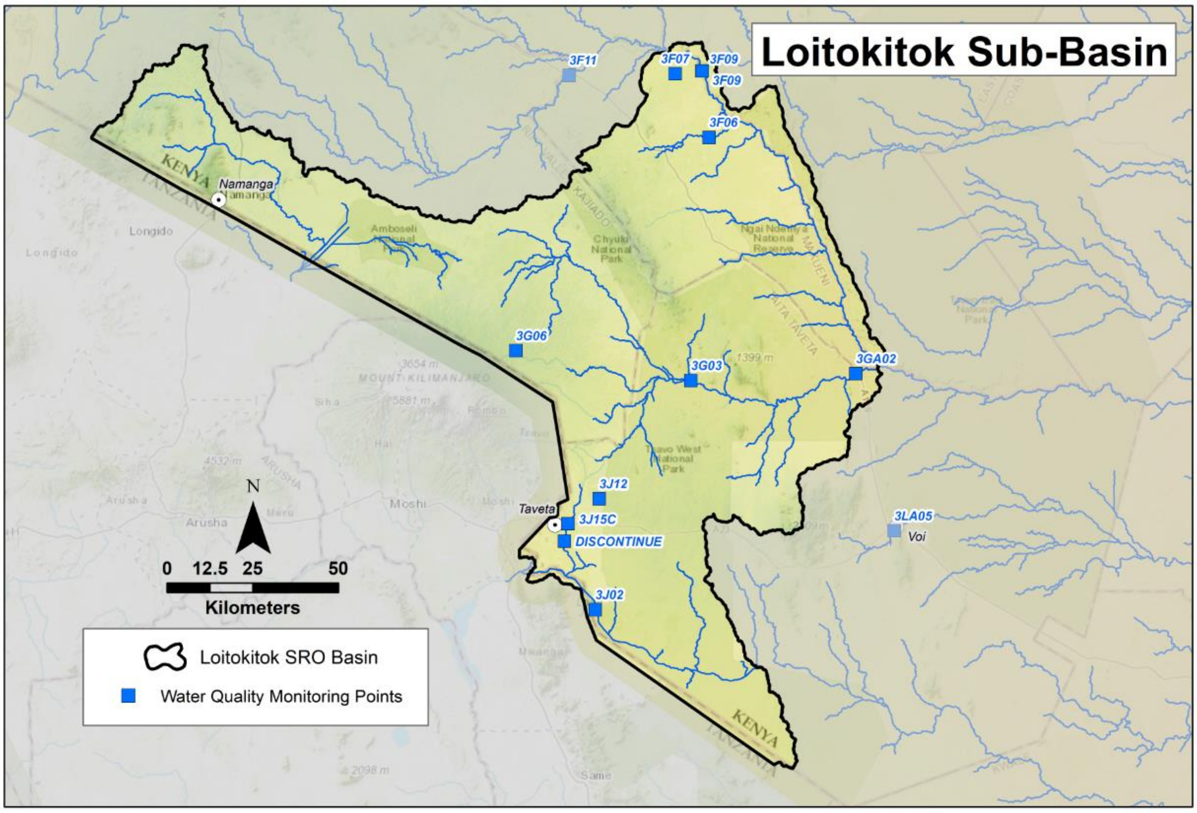

Figure 6-22: Loitokitok sub-region: Proposed surface water quality monitoring points

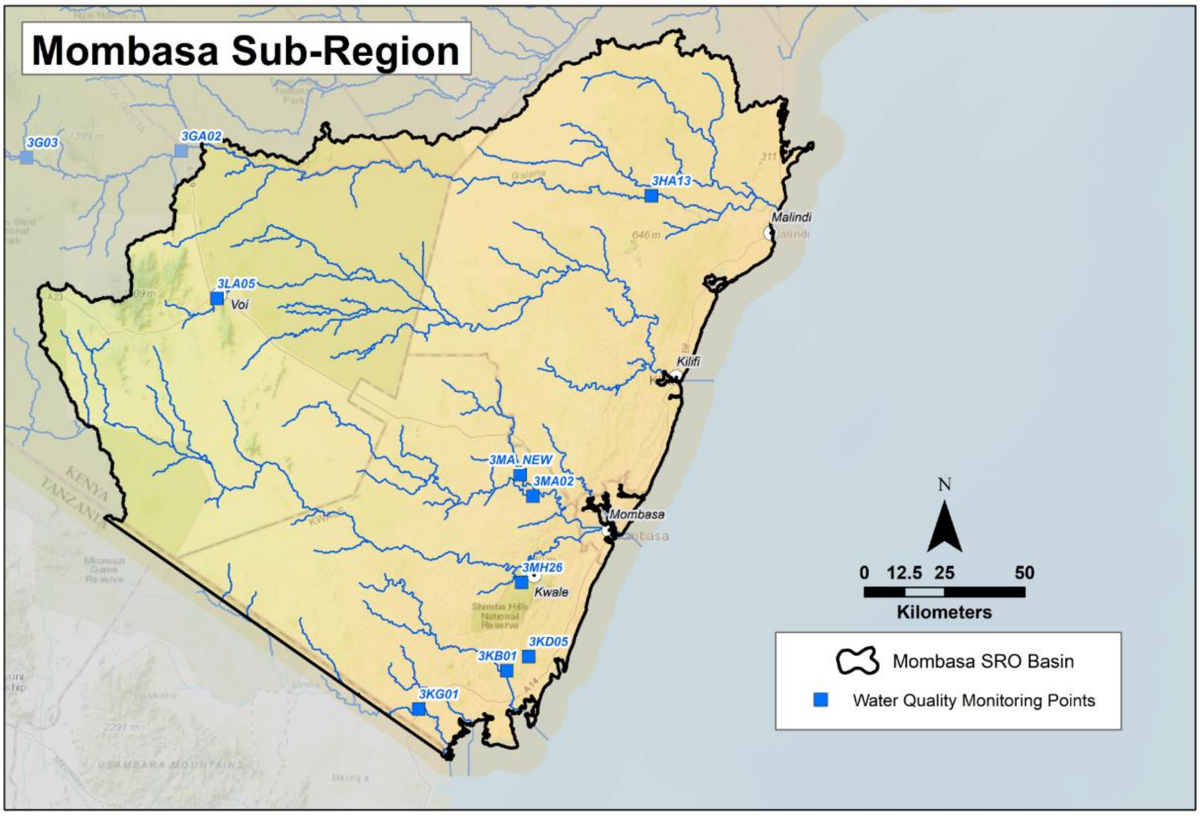

Figure 6-23: Mombasa sub-region: Proposed surface water quality monitoring points

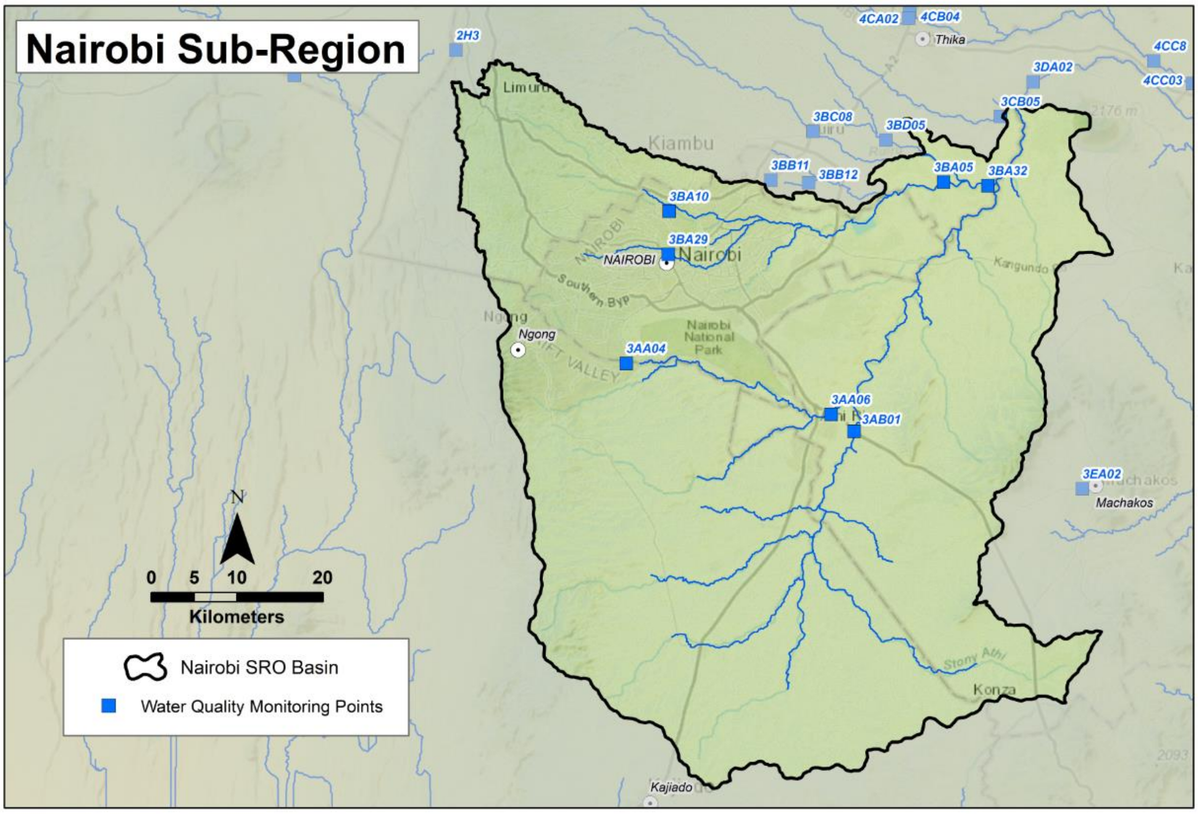

Figure 6-24: Nairobi sub-region: Proposed surface water quality monitoring points

Effluent monitoring stations

Effluent monitoring stations should be located as close to discharge points as possible and monitoring typically involves the sampling and analysis of samples collected from three related locations: the final effluent, upstream of the receiving stream and immediately downstream of the discharge outfall. Where these stations are known to be pollution hotspots, they have been designated as 1st Priority stations based on the pollution threat level, pollution loads and also based on past polluting history of the source. Most of the sources within the Athi Basin which have been identified in the selection of Effluent Monitoring stations are point sources of pollution. These may be broadly grouped into:

- Domestic Sewage outfalls from sewage works (from towns and cities)
- Industrial Effluent discharge from Factories (from towns and cities)
- Sugar Factories Effluent discharge
- Coffee Factories Effluent discharge
- Flower and Horticultural Farm discharges
- Sisal Waste discharges
- Dairies and Slaughter houses
- Hospital waste discharges

In many small towns, where no sewerage systems exist, human waste is still handled by Septic Tanks and Pit Latrines. When it rains and floods, many of the poorly constructed Septic tanks and Pit latrines fill up and overflow and pollute nearby streams. These locations should also be monitored. The critical parameters for domestic sewage are BOD and COD, while for Industrial effluent it is COD and Heavy metals, and oil and grease among others depending on the source.

Note: Coordinates of Effluent Quality Monitoring stations will need to be validated.

Groundwater quality monitoring stations

Historically, and under the Ministry of Water, all legally authorized Boreholes had Borehole Serial Nos. These were later changed, after the establishment of WRA, and each Region kept its own Borehole (BH) records. It is also a requirement that each BH shall have a BH Completion Report as well as a Water Quality (WQ) Analysis Report, hereby referred to as the Baseline Water Quality report. However, it has been observed that most BHs being monitored do not have BH IDs and neither are the BH completion reports available. It is recommended that this information be looked for and documented for all BHs. For BHs that do not have BH Completion Report or WQ Baseline Reports, it is proposed that the oldest WQ report on record be used as the BH WQ Baseline Report. If the BHs do not have any WQ test report, then a sample should be taken and analysed and its report preserved as the BH Baseline WQ report against which other subsequent future analyses can be compared. Most BH water samples can be easily analysed as for routine water quality analysis using Basic equipment.

Groundwater quality characteristics vary regionally. Ideally groundwater will show low concentrations of dissolved salts during the wet season and high concentrations during the dry season when recharge is minimal. No major WQ changes are expected unless there is accidental pollution. Ideally monitoring should be bi-annual instead of the recommended quarterly.

More groundwater quality (GWQ) monitoring stations have been proposed along the coastal belt to monitor sea water intrusion, while some GWQ monitoring BHs have also been proposed around the Base Titanium mine to monitor the possible GWQ impacts of the mine. New BHs specifically dedicated for groundwater measurements in the Nairobi suite aquifer is also supported.

The Prioritization of GWQ monitoring stations was based on Aquifer type and classification. All the aquifers within the basin are represented by at least one GWQ station and included in the 1st Priority list. Another factor considered is the population served by a BH. Most of the BHs proposed for WQ monitoring lack a complete set of coordinates. The few that had coordinates could also not be validated. It is suggested that during the launch of the revised WQM Network, with the aim of collecting the first set of samples for testing, the correct coordinates could be established as well as the validation of any other information.

Sampling/Monitoring frequency

The frequency of sampling or monitoring will be dependent on the nature and type of sampling stations. Generally, for groundwater sources, lakes and dams, which are not expected to undergo drastic WQ changes over time, the sampling frequency can be bi-annual. For river stations and effluent stations, whose water quality is constantly changing at short intervals, the recommended frequency of monitoring can vary from daily to quarterly. In general, and for most stations a sampling frequency of quarterly has been recommended, but this can be varied depending on the type of station and the circumstances prevailing.

Water Quality Design Parameters

The parameters to be tested for at each monitoring station have been identified and may be described as either Basic or Special parameters. Basic Parameters include pH, Colour, Turbidity, TSS, Conductivity, TDS, Chloride, Temperature, Coliforms, DO, Fluoride, Ammonia, Total Nitrogen, Nitrates, Nitrite, Total Phosphorus, Phosphates, Sulphates, Sodium, Potassium, Calcium, Manganese, Iron, Magnesium. Special Parameters refer to pesticide residues, heavy metals, hydrocarbons, oil and grease, sediment load, BOD and COD, and emerging special parameters such as organic micro-pollutants e.g. pharmaceuticals, hormones and chemical substances used in products and households.

At some stations, critical or important parameters have been identified, which should be given priority when testing. Such parameters would include Chromium downstream of a tannery; heavy metals downstream of a metallurgical industry; pesticide residues and nutrients downstream of an intensive farming area and BOD and COD downstream of a coffee de-pulping factory for example.

The selection of test parameters will typically be dictated by the data needs and issues in the river basin. Because of inadequate equipment currently, laboratories in Kenya are only able to carry out tests for a handful of parameters.

As a minimum requirement, all Regional Labs should be capable of analysing for all the basic parameters and where not possible, special parameters can be tested for at the CWTL. The CWTL in Nairobi should be elevated to a reference Laboratory to carry out advanced water quality analysis, and should be manned by qualified, trained and experienced staff.

Water Quality Design Equipment

Once the design parameters have been identified, equipment for the analysis of the parameters need to be selected for each station. These have been generally described as either Basic or Advanced Equipment. Basic Equipment is used for routine water quality testing. Such equipment would include a pH meter, Conductivity meter and UV-Vis Spectrophotometer among others. Advanced Equipment would include AAS and GLC and HPLC for the analysis of special parameters.

Laboratory Equipment

The current level of instrumentation in water quality laboratories is poor. The CWTL and all other labs need to be supported to procure basic water quality equipment and Field Water Test Kits, to be able to carry out their mandate. In general, Lab equipment can be categorized into 3 categories:
Field Water Test Kits: This mainly comprises of colorimeters and probes and versatile pocket meters such as pH meters, Turbidity and Conductivity meters, or the innovative Sondes/probes.
Basic Laboratory Equipment: UV/Vis spectrophotometer, flame photometer, analytical balance, top-pan balance, pH meter, conductivity meter, DO meter, water still, water bath, hot plate, refrigerator, flame photometer, turbidimeter, desiccators, computers, printers, fuming hood, titrators, ovens, centrifuges, incubators, rotary kilns, muffles, comparators, multi-probes and many assorted items.

Advanced Water Testing Equipment: Atomic Absorption Spectrophotometer (AAS), Gas Liquid Chromatography (GLC), High Pressure Liquid Chromatography (HPLC), and Inductively Coupled Plasma Mass Spectrophotometer (ICP-MS).

6.8.3.5 Flood early warning systems

One of the objectives of the design of the hydrometeorological network in Kenya relates to the strengthening of the network for flood early warning. Nineteen flood prone areas across Kenya were proposed for the installation of Flood Early Warning System (FEWS) (Table 6-31). FEWS priority regions are assessed based on populations impacted, types of flooding, required LiDAR and field surveys, and ground field visits. These were then graded and ranked through a consultative process to produce a list of the final seven flood-prone areas to be installed with FEWS (Table 6-31). The proposed flood-prone areas were discussed with stakeholders and selected on a national level, and not per basin, thus some basins do not have a proposed FEWS network.

Table 6-31: Flood prone areas across Kenya that have been proposed for the installation of FEWS

Flood Prone Areas proposed	River (if aplicable)	Final areas selected
Lake Victoria North Basin		
1. Lower Koitobos	Koitobos River	
2. Yala Swamp	Yala River	
3. Rambwa, Bunyala, Budalangi	Lower Nzoia River	

Flood Prone Areas proposed	River (if aplicable)	Final areas selected
Lake Victoria South Basin		
4. Kisumu		
5. Kano Plains	Awach Kano	1
6. Sondu River	Sondu River	2
7. Lower Gucha Migori	Lower Gucha Migori	3
8. Ahero	Lower Nyando River	4
Rift Valley Basin		
9. Narok Town	Enkare Narok	
10. Marigat, Ilchamus	Perkerra River	5
11. Lodwar	Lower Turkwel River	
Ewaso Ng'iro North Basin		
12. Isiolo	Isiolo River	
13. Rumuruti	Ewaso Narok	
14. Habaweisen	Ewaso Ng'iro	
Tana Basin		
15. Garissa, Hola, Ichara	Lower Tana River	6
Athi Basin		
16. Lower Sabaki	Sabaki River	7
17. Nairobi		
18. Kilifi		
19. Mombasa		

The Lower Sabaki River in the Athi Basin was proposed for a FEWS design. It comprises 4 telemetric stream flow gauging stations and 11 full telemetric meteorological Automatic Weather Stations. Details of the proposed stream flow and meteorological telemetric monitoring stations to inform the Lower Sabaki FEWS are listed in the Table 6-32 and Table 6-33, and shown in Figure 6-25.

Table 6-32: Lower Sabaki FEWS – Proposed telemetric stream flow gauging stations

ID	River	WRA SRO	Lat	Long	Operational status (2018)	Existing station type	ISC Design Station Type
3F09	Athi Kibwezi	Kibwezi	-2.20137	38.05809	Operational	Manual	Telemetric
3GA02	Tsavo	Loitokitok	-2.99584	38.46076	Non-operational	Manual	Telemetric
3HA12	Sabaki Cableway	Mombasa	-3.03889	38.68333	Non-operational	Manual	Telemetric
3HA13	Sabaki Baricho	Mombasa	-3.12090	39.77860	Operational	Automatic	Telemetric

Table 6-33: Lower Sabaki FEWS – Proposed telemetric meteorological stations

ID	Station Name	Lat	Long	Existing type	WRA SRO	Design parameters	Current status (2018)
9137010	Machakos District Office	-1.51667	37.26667	Manual	Kibwezi	Rainfall	Operational
9137012	Kiu Primary School	-1.90000	37.16667	Manual	Kibwezi	Rainfall	Operational
9236010	Mailwa Primary School	-2.33333	36.96667	Manual	Kibwezi	Rainfall	Operational
9237000	Makindu Meteorological Station	-2.28333	37.83333	Synoptic	Kibwezi	Full Met	Operational
9036191	Kiriita Forest Station - Kinale	-0.90000	36.61667	Manual	Kiambu	Rainfall	Operational
9137123	Mangu High School	-1.10000	37.03333	Manual	Kiambu	Rainfall	Operational
9237004	Loitokitok D.O.'S Office	-2.93333	37.50000	Manual	Loitokitok	Rainfall	Operational
9340009	Malindi Meteorological Station	-3.23333	40.10000	Synoptic	Mombasa	Full Met	Operational
9136087	Eastleigh Moi Airbase - Nairobi	-1.26667	36.86667	Synoptic	Nairobi	Full Met	Operational
9136161	Limuru District Office	-1.10000	36.63333	Manual	Nairobi	Rainfall	Operational
9136185	Kajiado Masai Rural Training Centre	-1.66667	36.83333	Manual	Nairobi	Rainfall	Operational

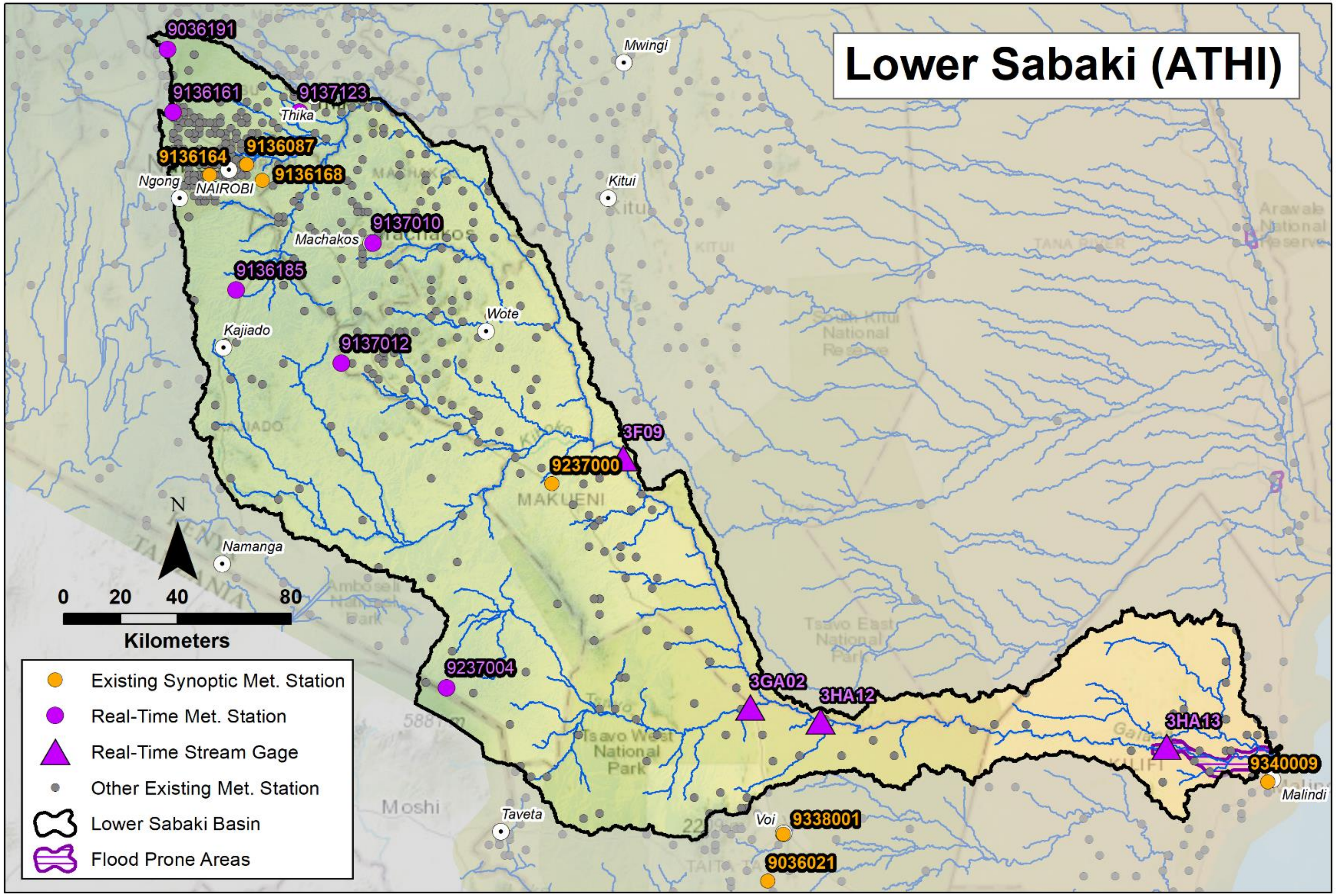

Figure 6-25: Proposed Lower Sabaki flood early warning hydro-met network

6.8.4 Strategy

In order to comprehensively and systematically address the hydrometeorological monitoring issues and challenges in the Athi Basin, Table 6-34 sets out 2 Strategic Themes with specific Strategies under each Theme. The Themes address Improvements to the Monitoring Network as well as Improved Data and Information Management.

Table 6-34: Strategic Framework - Hydrometeorological Monitoring

7	**Key Strategic Area:**	**Hydrometeorological Monitoring**
7.1	**Theme:**	**Improved monitoring network**
7.1.1	Surface water monitoring: River flow	
Under this Consultancy, the current flow gauging station network in the Athi Basin was assessed in terms of operational status, challenges, maintenance and equipment needs and data quality. Stations were prioritised for rehabilitation, for improvements and upgrades and for re-calibration. New station locations were identified based on pre-defined criteria and should be implemented according to the recommendations made in the Monitoring Network Design Report. A maintenance plan with budgets, timeframes and structured responsibilities should be prepared. The type of flow gauging stations to be installed should take into account that changes in river channel form due to floods often lead to changes in the rating curve, which requires re-calibration. Consideration should therefore also be given to fixed weirs (concrete structures) as opposed to rated sections.		
7.1.2	Monitoring: Dams and lakes	
The current instrumentation and level gauging network in dams and lakes in the Athi Basin should be assessed in terms of operational status, challenges, maintenance and equipment needs and data quality. Stations should be prioritised for rehabilitation where required, for improvements and upgrades and for re-calibration. New station locations should be identified based on pre-defined criteria and designed and implemented according to an implementation plan. A maintenance plan with budgets, timeframes and structured responsibilities should be prepared. Bathymetric surveys of dams and lakes should also be included in the plan.		
7.1.3	Groundwater monitoring	
Priority aquifers in the Athi Basin should be defined and monitoring requirements for each aquifer specified. A Groundwater Monitoring Network Design should be undertaken, and necessary monitoring instrumentation procured and installed in accordance with an Implementation Plan.		
7.1.4	Water quality monitoring: Surface water and groundwater	
Under this Consultancy, the current water quality monitoring network in the Athi Basin was assessed in terms of operational status, challenges, maintenance and equipment needs and data quality. Stations were prioritised for rehabilitation where required, for improvements and for upgrades. New station locations were identified based on pre-defined criteria and should be implemented according to the recommendations made in the Monitoring Network Design Report. A maintenance plan with budgets, timeframes and structured responsibilities should be prepared.		
7.1.5	Meteorological monitoring	
Under this Consultancy, the current rainfall station network in the Athi Basin was assessed in terms of operational status, challenges, maintenance and equipment needs and data quality. WRA stations were prioritised for rehabilitation where required, for improvements and for upgrades. New station locations were identified based on pre-defined criteria and should be implemented according to the recommendations made in the Monitoring Network Design Report. A maintenance plan with budgets, timeframes and structured responsibilities should be prepared. WRA's requirements as far as meteorological data needs in relation to water resources planning and management are concerned should be discussed with KMD and roles and responsibilities with regard to the design, upgrade and maintenance of the meteorological monitoring network should be clearly defined.		

7	Key Strategic Area:	Hydrometeorological Monitoring
7.1.6	Flood early warning monitoring network	
Under this Consultancy, the current flood early warning network in the Athi Basin was assessed in terms of operational status, challenges, maintenance and equipment needs and data quality. Stations were prioritised for rehabilitation where required, for improvements and for upgrades. New station locations were identified based on pre-defined criteria and should be implemented according to the recommendations made in the Monitoring Network Design Report. A maintenance plan with budgets, timeframes and structured responsibilities should be prepared WRA's requirements as far as meteorological data needs in relation to flood management are concerned should be discussed with KMD and roles and responsibilities with regard to the design, upgrade and maintenance of the meteorological monitoring network should be clearly defined.		
7.1.7	Metering of water use and abstractions	
Abstractions from dams and rivers as well as groundwater abstractions should be identified, prioritised and flow meters installed. The prioritisation and selection of meter locations and types should be dictated by a needs assessment in relation to data requirements e.g. for operational, monitoring of compliance, water balance or other purposes.		
7.2	**Theme:**	**Improved data and information management**
7.2.1	Enhanced data management	
Data protocols and procedures with regard to data collection, transfer, capture, storage, quality control and dissemination should be evaluated, standardised and improved where necessary in accordance with international best practice. Technical and computing capacity for processing, analysis and reporting of data should be addressed and enhanced. The MIKE Info database application which was developed for the WRA under this Consultancy should be employed by WRA SRO, RO and HQ staff to capture, store, quality control and manage hydromet data in accordance with training provided.		
7.2.2	Improved water resources information management systems	
The knowledge base tools which were developed under this Consultancy should be employed by WRA SRO, RO and HQ staff to manage and disseminate information related to water resources planning and management taking into consideration the specific needs and challenges across different organisations and institutions as stakeholders.		
7.2.3	Improved forecasting systems	
The real-time system developed under this Consultancy for accessing, visualizing and analysing hydromet observations in near real-time should be employed to inform decision making with regard to flood forecasting and water resources management. Shared mandates and responsibilities should be discussed and agreed with KMD.		

6.9 Water Resources Development

6.9.1 Introduction

The purpose of this Water Resources Development Plan relates to the planning and development of large-scale water resources and related infrastructure which will support socio-economic development in the Athi Basin to improve water availability and assurance of supply for current and projected future water use in the basin, while taking into consideration environmental sustainability. The rationale for the development of the Plan was to assess whether the basin's water resources are sufficient to meet the expected growth in water requirements with 2040 as the planning horizon. These water requirements refer not only to those in the Athi Basin but include the existing and anticipated additional volume of water to be transferred from the Tana Basin to the upper Athi Basin. The approach entailed an evaluation of the need for and the capacity of large-scale water resources development interventions such as dams and transfers, some of which include multi-purpose projects. Most of the interventions which were considered were already identified as part of previous planning studies. Another important consideration in the development of the water resources development plan relates to an acknowledgement of the significant time that it takes to implement large infrastructure projects in Kenya. Proposed schemes and development interventions up to 2040 were therefore limited to what was considered reasonable from a financial and practical perspective. The proposed schemes should be implemented in conjunction with management interventions i.e. water conservation and demand management initiatives. Such an approach, in combination with the phased development of new infrastructure, will allow an adaptive development strategy towards improving climate resilience.

6.9.2 Current water demands, resources development and supply reliability

The existing water resources developments in the Athi Basin mainly supply the urban domestic and industrial demands of Nairobi and its satellite towns, Mombasa and the major coastal towns as well as other major towns, and include eight dams, three of which have storage in excess of 1 MCM, inter- and intra-basin transfers and large-scale groundwater abstractions. A number of smaller dams and pans supply localised domestic, livestock and irrigation demand. In addition, there is one existing large-scale irrigation scheme and a number of small-scale and private irrigation schemes with a total area of 64 544 ha. These schemes are mainly supplied via run-of-river abstractions. There are currently no hydropower installations in the Athi Basin.

Ongoing water resource developments in the basin include:

- Thwake Multipurpose Dam (storage capacity 681 MCM) which is positioned on the confluence of the Thwake and Athi rivers. The multipurpose dam will supply water for domestic and irrigation water use, as well as provide hydropower generation.
- Mwache Multipurpose Dam, in Kwale County, with a planned capacity of 136 MCM, which will provide water for domestic, irrigation and livestock use to Kwale County as well as domestic water for Mombasa County and will also generate hydropower.
- The Northern Collector Project (Phase I) in Tana Basin, which is currently under construction. This scheme will take flood flows from the Maragua, Irati and Gikigie Rivers and divert them into a tributary flowing into Thika (Ndaka'ini) Dam. It will add up to 140 000 m^3/day (51.1 MCM/a) to Nairobi water supply.
- The Athi Water Service Board is actively pursuing the development of deep groundwater resources in the Kiunyu and Ruiru areas, with a proposed abstraction of 64 800 m^3/day (23.7 MCM/a).

Currently, the main demand for water in the Athi Basin is constituted by the urban domestic and industrial water requirements of Nairobi and Mombasa and their surrounding areas, as well as water required for mainly small-scale and private irrigation. The total current water requirement (2018) in the Athi Basin equates to 1 553 MCM/a.

Table 6-35: Current (2018) water demands in the Athi Basin

Sector	MCM/a
Irrigation	**1 028**
- Small scale / Private	984
- Large-scale	44
Domestic and Industrial	**490**
- Greater Nairobi	263
- Mombasa, Kwale, Kilifi	86
- Basin-wide	141
Livestock	**24**
Other	**11**
Total	**1 553**

6.9.3 Water resources development potential

The current (2018) total water demand in the Athi Basin (1 553 MCM/a) constitutes about 50% of the total water resources available for use (3 129 MCM/a).

The results of the water resources simulation which was undertaken for this Study estimated the total natural runoff in the Athi Basin as 2 555 MCM/a, equivalent to an average runoff coefficient of 5.2%. Most of this runoff is generated in the upper part of the basin and along the lower coastal areas. In many of the sub-basins, however, the flow is highly seasonal, and many rivers experience a significant reduction in flow during the low flow season. The current surface water demand in the Athi Basin was estimated as 1 170 MCM/a, which is about 45% of the surface water available - taking into consideration the ecological reserve (Q95), calculated as 156 MCM/a, and the 181 MCM/a of water which is currently imported into the Athi Basin from the Tana Basin.

The current groundwater use in the Athi Basin was estimated as 383 MCM/a, which is about 70% of the estimated sustainable groundwater yield (549 MCM/a).

It is important to realise that although the water balances might indicate that the total annual demand is less than the water resources available, supply deficits often occur during dry years and/or the dry season, when the demand exceeds availability of water in the rivers.

6.9.4 Future water requirements

The scenario evaluations which were undertaken as part of this Study (refer to Section 5), concluded that the planned large-scale irrigation development in the Athi Basin should be significantly reduced, and that only limited large-scale irrigation development can be accommodated, as it is constrained by the availability of water. Furthermore, the scenario analysis highlighted the imperative that water demand management is implemented in all urban areas, while irrigation efficiencies should also be improved. Such a future constitutes the recommended sustainable development future for the Athi Basin. Under this scenario, the total future (2040) water requirement in the Athi Basin is expected to be 2 442 MCM/a as detailed below.

Table 6-36: Future (2040) water demands in the Athi Basin

Sector	MCM/a
Irrigation - Small scale / Private - Large-scale	**1 416** 835 581
Domestic and Industrial - Greater Nairobi - Mombasa, Kwale, Kilifi - Basin-wide	**949** 540 212 197
Livestock	**63**
Other	**14**
Total	**2 442**

This represents an increase of 57% or 889 MCM/a compared to the 2018 water demand in the Athi Basin. It assumes that all of the proposed large-scale irrigation schemes, as identified in the NWMP 2030 and subsequent planning studies, have been implemented, while livestock as well as domestic and industrial demands have been projected to 2040. It also assumes a 20% reduction in future major urban water requirements through water demand management, as well as improved irrigation efficiencies and a significant reduction in the areal extent of the proposed-large scale irrigation schemes.

Annexure B2 summarises future (2040) water demands per sub-basin and per main user category.

6.9.5 Proposed water resources development plan

6.9.5.1 Overview

To ensure that the anticipated growth in future water requirements in the Athi Basin can be met, the development of water resources infrastructure for storage and regulation in the basin, as well as additional transfers into the Athi Basin from the Tana Basin will be required. The essence of the proposed water resources development plan for the Athi Basin up to 2040 is to address the expected growth in urban water demands in the greater Nairobi area as well as Mombasa and the coastal areas, to ensure water availability for the proposed large-scale irrigation development in the basin, and to improve existing and future water resources availability for smaller towns and basin-wide domestic, livestock and small-scale irrigation water demands. To achieve this, will require the following interventions:

- For the greater Nairobi area, it is proposed to construct 4 new dams in the upper Athi Basin, to implement the further phases of the Tana Transfer Scheme, and to develop the Ruiru and Kiunyu wellfields.
- For Mombasa and the coastal towns of Kilifi, Kwale and Malindi, it is proposed to construct 3 new dams, to expand the existing intra-basin transfers from Mzima Springs and the Baricho Wellfield and to expand and/or further develop the wellfields at Msambweni and Tiwi. The possibility of increasing the yield from the Marere Springs should also be considered.
- To meet the future domestic and industrial demands of small towns in and rural areas as well as livestock and small-scale irrigation water demands within the remainder of the Athi Basin, it is proposed that new dams already identified be implemented, that additional storage is provided in small dams and pans, and that additional boreholes are constructed.

Table 6-37 summarises the proposed water resources developments and interventions in the Athi basin with a planning horizon of 2040, while Figure6-26 displays the proposed developments.

Table 6-37: Water resources development plan for the Athi Basin

Item	2018	2040	Comment
Storage: Large dams (MCM)	11	1 231	4 new dams to supply Greater Nairobi 3 new dams to supply Mombasa 4 new dams to supply Towns / Small scale irrigation 2 of the new dams are multi-purpose dams
Storage: Small dams / pans (MCM)	12	127	To supply towns and local domestic and livestock demands and improve assurance of supply for small-scale and private irrigation
Groundwater use (MCM/a)	383	474	As conjunctive use with surface water storage
Irrigation area (ha)	64 544	105 950	The increase in irrigation area is mainly due to new large-scale schemes
Hydropower (MW)	0	94	As secondary benefit of multi-purpose dams

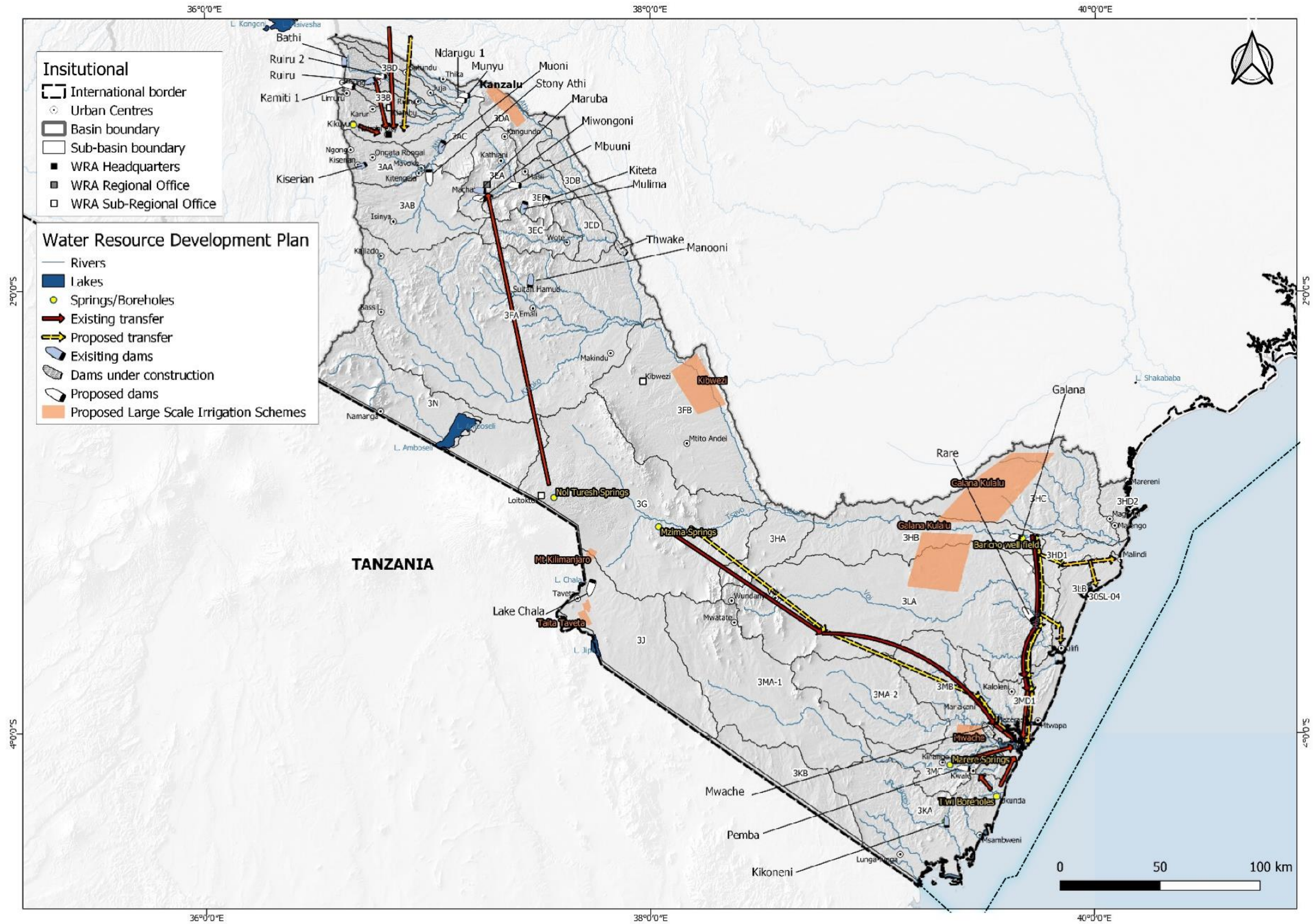

Figure 6-26: Proposed water resources developments in the Athi Basin

6.9.5.2 Water supply to Nairobi

The future water demands of Nairobi and its satellite towns (2040) significantly exceed the water available in the upper Athi Basin and it is imperative that further phases of Tana Transfers are implemented timeously, while three additional dams also need to be constructed in the Upper Athi Basin as well as Munyu Dam on the Athi River about 400 m downstream of the confluence of the Ndarugu and Athi Rivers - as an alternative to Ndarugu 1 Dam. These schemes combined, would significantly improve reliability of supply to Nairobi. Munyu Dam would still be able to supply to the Kanzalu Irrigation Scheme – however as a 2nd priority and at a reduced area. In addition to the above schemes, it is imperative that water demand management measures to reduce demand in Nairobi (aiming for a 20% reduction) are implemented as soon as possible, while a proper hydro-census in greater Nairobi should also be undertaken to evaluate groundwater use and potential as part of conjunctive use.

Current supply

Nairobi and its surrounding areas have the highest population density in Kenya and houses 15 of the 32 urban centres in the Athi Basin. It has a population of 4.46 million. The current water demand for Nairobi and its satellite towns is estimated at 263 MCM/a (720 000 m^3/day).

Existing supply sources to Nairobi include transfers from the Kikuyu Springs (4 000 m^3/day or 1.5 MCM/a) and the Ruiru Dam (22 800 m^3/day or 8.3 MCM/a) to the Nairobi City Water Supply System, with a combined transfer of about 10 MCM/a; and transfers from the Tana Basin, with a total transfer capacity of 181 MCM/a. The water is sourced from two dams in the Tana Basin, namely the Thika (or Ndaka'ini) and Sasumua dams. The Thika Dam has a storage capacity of 77 MCM. The Sasumua Dam has a storage capacity of 16 MCM. Currently, the Nairobi demand exceeds its water resources system supply capacity and consequently Nairobi is experiencing frequent restrictions and issues with regard to supply reliability.

Future supply

The 2012 Master Plan Study for Nairobi and its satellite towns (Ministry of Water and Irrigation & Athi Water Services Board, 2012) estimated that the water demand in the larger Nairobi area will increase to 507 MCM/a by 2035. Projecting this demand to 2040, based on more recent studies, results in an estimated 2040 demand of 675 MCM/a (1 850 000 m^3/day).

The water resources system model was used to assess various scenarios for meeting the future water demands of Nairobi and its satellite towns and these were incorporated into the scenario analysis. The results of the scenario analysis confirmed that in order to improve the current issues with regard to water availability and supply reliability in Nairobi as well as to meet the projected growth in water demands, investment in water resources infrastructure development is needed. The analysis took into consideration the hydrological variability of the upper Tana River as well as infrastructure capacity constraints associated with the transfer scheme components and assurance of supply.

Proposed water resources development linked to Nairobi supply entails that additional water would have to be transferred from the Tana Basin in accordance with the Master Plan (Ministry of Water and Irrigation & Athi Water Services Board, 2012) Scenario 3A (up to Phase 4), which incorporates the Ruiru and Kiunyu wellfield developments, the Northern Collector Phase 2 (1st and 2nd section), Maragua 4 Dam (60 MCM) and Ndarugu 1 Dam (225 MCM) as shown in Figure 6-27. Furthermore, additional dams would have to be constructed in the upper Athi Basin including Kamiti 1 Dam (16 MCM), Ruiru 2 Dam (8 MCM), and Stony Athi Dam (23 MCM). However, the results of the water resources analysis showed that although the above schemes will significantly improve the volume and reliability of supply to greater Nairobi, they will not be able to meet the projected 2040 demand at a 1:50 year assurance of supply. The option of using the proposed Munyu Dam (575 MCM), which would be located on the Athi River about 400 m downstream of the confluence of the Ndarugu and Athi Rivers, as an alternative to Ndarugu 1 Dam for supplying Nairobi, was therefore considered. (Munyu dam is the supply dam for the proposed Kanzalu Irrigation Scheme). The analysis showed that this option would achieve the required reliability of supply to Nairobi. Note that Munyu Dam would still be able to supply the Kanzalu Irrigation Scheme – however as a 2nd priority and with a reduced irrigation area. The proposed water resources developments to meet Nairobi's future water demand (up to 2040) are summarised below.

Table 6-38: Proposed water resources developments to supply Nairobi (2040)

Infrastructure	Capacity	Comment
Ruiru & Kiunyu Wellfields	Transfer +23.7 MCM/a	Exploratory boreholes constructed
Maragua 4 Dam S Mathioya Transfer	Storage 60 MCM Transfer +48.3 MCM/a	
NCT Phase II	Transfer +43.8 MCM/a	Includes Ngorongo pipeline and WTW
Kamiti 1 Dam	Storage 16 MCM	
Ruiru 2 Dam	Storage 8 MCM	
Stony Athi Dam	Storage 23 MCM	
Munyuy Dam	Storage 575 MCM	Munyu Dam preferred to Ndarugu 1 Dam; Includes 20 MW HP

In addition to the above schemes, it is imperative that water demand management measures to reduce demand in Nairobi (aiming for a 20% reduction) are implemented as soon as possible. It is also recommended that a more detailed options analysis be undertaken to confirm the sizing and phasing of infrastructure components. The options analysis should also be used to confirm (at a more detailed level of analysis) the benefits of Munyu Dam as opposed to Ndarugu 1 Dam. The locations of the existing and proposed schemes are shown on Figure 6-27.

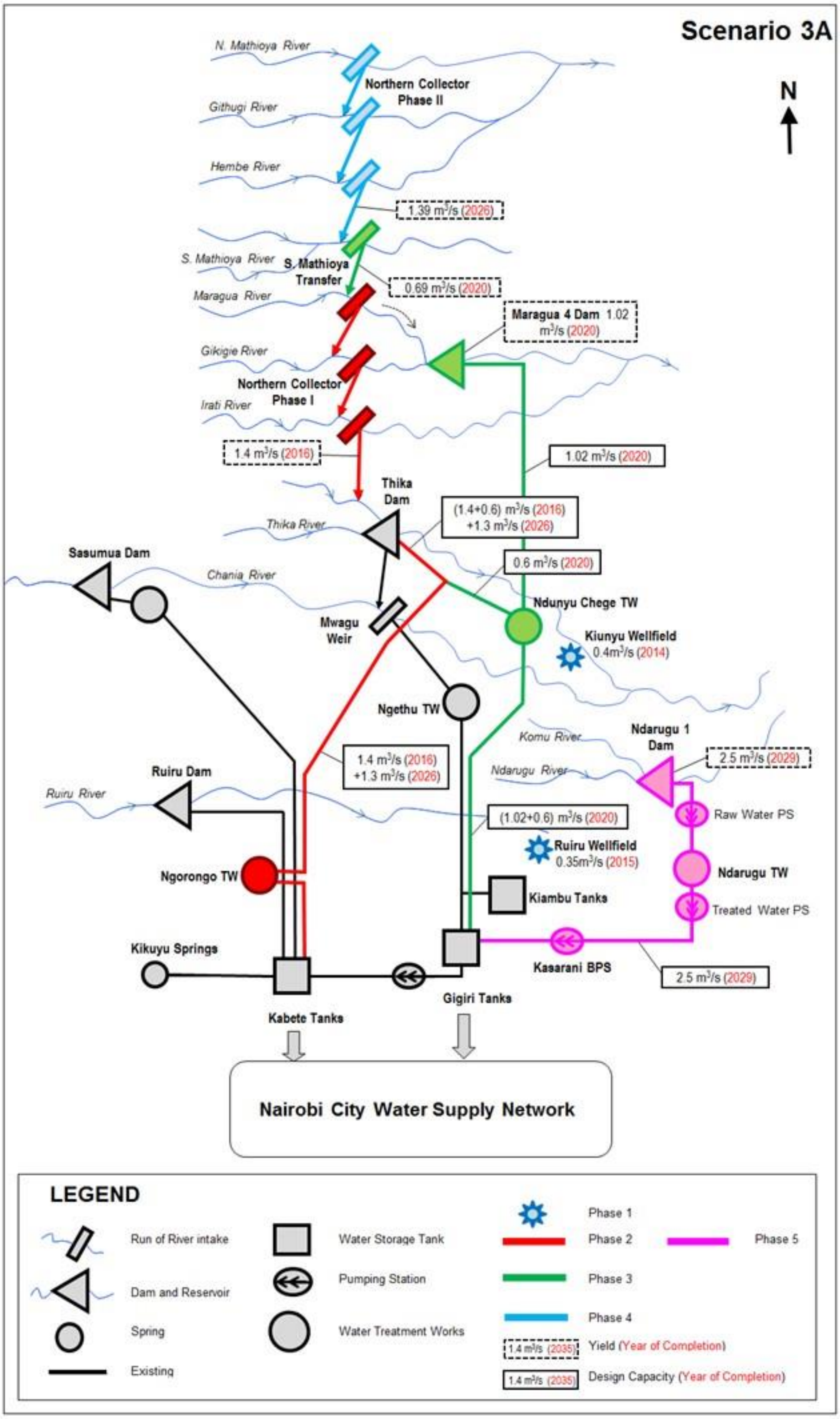

Figure 6-27: Scenario 3a for upgrading of bulk water supply system for Nairobi City (Ministry of Water and Irrigation & Athi Water Services Board, 2012)

6.9.5.3 Water supply to Mombasa and coastal area

The future water demands of Mombasa and the surrounding coastal towns could be met through significant expansion of existing groundwater supply sources, and through the utilisation of surface water sources which will require the construction of Pemba, Rare and Galana dams. The potential impacts of future major dams in the upper and middle Athi Basin and increased abstractions from Mzima Springs on the future yield of the Baricho Wellfield was found to be significant, which necessitates the construction of Galana Dam. Galana Dam, which were originally planned along the lower Sabaki River to supply the proposed Galana Kulalu Irrigation Scheme, should be utilised as an additional water resource to supply Mombasa. By integrating this dam into the Coastal Area water supply system, the future (2040) water demand will be met at a high assurance of supply. Galana Dam would still be able to supply to the Galana Kulalu Irrigation Scheme – however as a 2nd priority and with a reduced area. In addition to the above schemes, it is imperative that water demand management measures to reduce demand in Mombasa and the coastal area (aiming for a 20% reduction) are implemented as soon as possible, while a proper hydro-census in the greater Mombasa area should also be undertaken to evaluate groundwater use and potential as part of conjunctive use.

Mombasa and the main coastal towns of Kwale, Malindi and Kalifi have a population of 1.28 million. It has limited surface water resources and current water supply depends on intense use of water from springs and wellfields.

The 2013 Master Plan for Mombasa and the towns in the Coastal Province (Tahal Group, 2013) estimated that the current water demand of the greater Mombasa area (including Kwale, Malindi, Kilifi and Voi) equates to 86 MCM/a (236 000 m^3/day), which is significantly more than the current water supply capacity.

Current supply

The bulk water supply schemes that currently supply most of the potable water to the Coastal area include Mzima Springs, Baricho Wellfield, Marere Springs, and the Tiwi and Msambweni Aquifers:

The **Mzima Springs** are recharged by rainfall on the Chyulu Hills and naturally flow into three large pools which are the main sources of the Mzima tributary of the Tsavo River, one of the main tributaries of the Athi-Sabaki River. Some of the flow from the springs is intercepted for delivery by pipeline to Mombasa subject to maintaining the minimum environmental flow of 2.64 m^3/s into the Mzima tributary. The Tahal Group (2013) Master Plan Study found that, based on a 5-year flow record, the spring flows varied from a maximum of 5.9 m^3/s to a minimum of 2.6 m^3/s with a mean of 3.6 m^3/s. Flows of less than 3 m^3/s have occurred on average about once in 4 years. The existing 215 kilometre long, pre-stressed concrete pipeline which delivers water to the Mazeras and Changamwe Reservoirs in Mombasa was constructed in 1960. It is reported that there is a bottleneck in the pipeline which limits the pipeline conveyance capacity to about 35 000 m^3/day (0.4 m^3/s). There are also a number of existing and proposed abstractions from the pipeline.

The **Baricho Wellfield** is situated next to the lower Athi (Sabaki) River. Water is abstracted from a former channel of the river. The aquifer is recharged directly by the main river and its developable yield depends on the flow in the Sabaki River. The water that is abstracted is treated and delivered to Mombasa and the other coastal towns via a 107 km long rising main (pumped) pipeline (800 mm 95 km long and 600 mm 12 km long). Along the pipeline route boreholes deliver some additional water into the pipeline and some water is abstracted to supply other coastal towns. The existing supply capacity of the Baricho Wellfield is 83 000 m^3/day (Tahal Group, 2013).

Figure 6-28: Baricho Wellfield (Tahal Group, 2013)

The **Marere Springs** can supply about 12 000 m3/day (Tahal Group, 2013). However, only 8 000 m3/day is currently utilised on account of the limited capacity of the delivery pipeline.

The **Tiwi aquifer** currently supplies about 18 000 m^3/day to Likoni to the north (Mombasa County) and to Ukunda/Diani.Galu to the south (Kwale County). The aquifer is becoming salinized in places (Oiro & Comte, 2019).

The **Msambweni Wellfield**, which currently supplies the Mineral Sands Mine in Kwale County, has an estimated mean daily recharge of approximately 30 000m^3 (Ferrer et al., 2019). This aquifer currently provides bout 10 000m^3/d to the mine, leaving a balance of approximately 20,000m^3/d for allocation to other water users; tentatively, it has been proposed that 10 000m^3/d be provisionally allocated to public water supply operated by the Kwale Water and Sewerage Company and the balance to other groundwater users (Gro for GooD, 2018).

The current abstractions from the four groundwater sources currently supplying Mombasa and the coastal towns add up to 136 000 m^3/day.

Currently no significant surface water schemes supply Mombasa or the coastal towns.

Future supply

The projected 2040 demand for Mombasa and the coastal towns is estimated as 265 MCM/a (727 000 m^3/day) (Tahal Group, 2013). The water resources system model was used to assess various scenarios for meeting this future water demand at a high assurance of supply and these were incorporated into the scenario analysis.

The results of the scenario analysis confirmed that in order to improve the current issues with regard to water availability and supply reliability in Mombasa and the coastal towns, as well as to meet the projected growth in water demands, significant expansion of the existing groundwater supply sources would be required in conjunction with development of surface water sources through the construction of dams.

New groundwater resources developments include:

- A new pipeline from Mzima Springs to Mombasa with a capacity of 105 000 m3/day to supply water as follows: Consumers along the pipeline route: 35 000 m3/day; Mombasa: 54 000 m3/day; Voi/Maungu, Mwatate and Wundanyi at 16 000 m3/day. The EIA for this scheme was completed in May 2018 (Coast Water Services Board, 2018). The EIA concluded that the project would not compromise the well-being of the community, the ecology or other conditions and that the project should be allowed to commence. It was recommended that the project should be supported and that the necessary licences should be issued.
- Baricho wellfield abstraction to be increased to 180 000 m3/day (Ministry of Water and Irrigation & Coast Water Services Board, 2018). An additional water treatment works and a second pipeline to Mombasa would be required to convey this additional water to Mombasa, with offtakes to Malindi and Kalifi along the way.
- Utilising the full yield of the Marere Springs of 12 000 m3/day by upgrading the existing supply pipeline. (This may not be possible on account of environmental and cost considerations and should be investigated in more detail.)
- It has been estimated that the full potential yield of the Tiwi aquifer is about 20 000 m3/day and that of the Msambweni aquifer, about 30 000 m3/day. The additional 40 000 m3/day should therefore be considered as a potential future water resource for the coastal areas, once the Titanium mining activities reduce.

The yields of the existing and proposed future groundwater sources to supply Mombasa and the coastal towns are summarised below.

Table 6-39: Existing and Potential Groundwater Yields to supply Greater Mombasa

Aquifer	Existing Use m^3/day	Potential Yield m^3/day
Mzima Springs	35 000	105 000
Baricho Wellfield	83 000	180 000
Marere Springs	8 000	12 000
Tiwi Wellfield	13 000	20 000
Msambweni Wellfield	-	30 000
Total	**139 000**	**347 000**

Note that the above groundwater yields are uncertain and will need to be confirmed through more detailed studies.

There are limited opportunities for surface water schemes that could contribute to the bulk supply system for the coastal areas. The water resources model which was developed as part of this study was used to evaluate the ability of the proposed extensions to the existing groundwater supply schemes along with Mwache, Rare and Pemba dams to supply Mombasa, Kwale, Kilifi and Malindi at a high assurance of supply up to 2040. The analysis allowed the potential impacts of future major dams in the upper and middle Athi Basin and increased abstractions from Mzima Springs on the future yield of the Baricho Wellfield to be evaluated.

Proposed surface water resources developments include:

- **Mwache Dam** on the Mwache River to supply Mombasa and irrigators:
  - Domestic water demand: 71.4 million m^3/annum (196 000 m^3/day)
  - Irrigation: 15 million m^3/annum at 90% reliability
  - Environmental flow demand: 7.5 million m^3/annum at 100% reliability

  The water from the dam would be treated and delivered via a 12 km pipeline to the Changamwe Reservoirs supplying Mombasa.

Note: The water resources analysis undertaken as part of this Study simulated significantly different flows at the sites of the proposed Mwache Dam, while yields calculated at the proposed Rare Dam were *also different to yield values previously reported. The difference in hydrology and yields would need to be investigated in further detail.*

- The proposed **Rare Dam** (36 MCM) would be located less than 1 km from the existing delivery pipeline from the Baricho Wellfield to Mombasa and about 65 km from Mombasa. It is also a possibility to use the dam as buffer storage for excess raw water pumped from the Baricho Wellfield. Preliminary analyses indicated that this alternative would provide higher assured yields than a direct pipeline from Baricho to Mombasa.
- The proposed **Pemba Dam** (19 MCM) would be located about 28 km from Mombasa. The yield of this proposed dam was not previously evaluated and the estimated 1 in 10-year yield as part of this analysis was 12 MCM/a.

The analysis results showed that the above proposed groundwater and surface water schemes would not be able to meet the 2040 greater Mombasa demand at a 1:50 year assurance of supply. Re-use or desalination as additional supply options were also considered. However, preliminary analysis indicated that capital, operation and maintenance costs of these unconventional sources would not make them viable within the near future. As another option, Galana Dam, which would be located along the lower Sabaki River to supply the proposed Galana Kulalu Irrigation Scheme was assessed as an additional water resource to supply Mombasa. The analysis showed that by integrating this dam into the Coastal Area water supply system, the 2040 water demand will be met at a high assurance of supply. Galana Dam would still be able to supply to the Galana Kulalu Irrigation Scheme – however as a 2nd priority and with a reduced area.

Upgrades to existing and new water resources developments to meet Mombasa's future water demand (up to 2040) are summarised below:

Table 6-40: Proposed water resources developments to supply Mombasa, Malindi, Kalifi and Kwale (2040)

Infrastructure	Capacity	Comment
Mzima Springs extension	Total transfer 38.2 MCM/a	16.8 MCM/a supplied to users along route
Baricho Wellfield extension	Total transfer 43.5 MCM/a	Could be increased to 110 MCM/a if Galana Dam constructed
Tiwi / Msambweni Wellfield	Total transfer 18.2 MCM/a	-
Pemba Dam	Storage 19 MCM	-
Rare Dam	Storage 36 MCM	The need for and possible phasing of Rare and Galana dams to augment future supply of Mombasa, need to be investigated in more detail and optimised in terms of sizes and timing.
Galana Dam	Storage 498 MCM	

In addition to the above schemes, it is imperative that water demand management measures to reduce demand in Mombasa (aiming for a 20% reduction) are implemented as soon as possible.

Note: It is recommended that a more detailed options analysis be undertaken to confirm the sizing and phasing of infrastructure components. The options analysis should also be used to confirm (at a more detailed level of analysis) the optimal location and size of Galana Dam as a multipurpose dam, and to improve estimates of groundwater yields. In addition, the uncertainties associated with the yields of the Mwache and proposed Rare dams should be investigated in detail. This should involve improved flow measurements at the locations of the proposed dam sites.

6.9.5.4 Large-scale Irrigation development

What is evident from the water resources modelling and scenario analyses undertaken as part of this Study, is that the current extent of planned large-scale irrigation development in the Basin should be significantly reduced taking into consideration the available water in the basin. A sustainable area of 41 000 ha for additional large-scale irrigation development in the basin is proposed. To ensure reliable supply of water to large-scale irrigation developments (at 1 in 10-year reliability), fairly significant regulation of river flows would be required, especially during the dry season. New multipurpose storage dams to meet these large-scale irrigation demands include Munyu Dam, Thwake and Mwache dams (under construction) and Galana Dam. It is proposed to install 20 MW at Thwake Dam, 40 MW at Munyu Dam and 34 MW at Mwache Dam. Preliminary analyses have shown that the generation of hydropower at these dams will be limited if the dams are operated to meet domestic and irrigation demands as first priorities.

One of the main outcomes of the scenario analysis was the conclusion that the extent of planned large-scale irrigation development in the Basin should be significantly reduced, taking into consideration the available water in the basin. Furthermore, cost-benefit analyses which was undertaken indicated that careful consideration needs to be given to crop types to ensure the financial viability of schemes.

To ensure supply of water to large-scale irrigation developments, significant regulation of river flows would be required, especially during the dry season. New storage dams to supply these irrigation demands should preferably be multi-purpose, i.e. the dams should be designed to also reduce flood risk and to generate hydropower if possible.

The anticipated large-scale irrigation schemes in the Athi Basin, which have been promoted in previous studies include:

- Taita Taveta Irrigation Project: This project in Taita Taveta County will entail an area of 3 780 ha and will be supplied via a weir diversion on the Lumi River.
- Mt. Kilimanjaro Irrigation Project: This project is situated in Kajiado County and entails 1 500 ha to be irrigated from spring water.
- Kibwezi Irrigation Project: This scheme in Makueni County will ultimately entail 40 000 ha and will be supplied from Thwake multipurpose dam (681 MCM).
- Kanzalu Irrigation Project' This scheme of 15 000 ha is also in Makueni County and will be supplied from the proposed Munyu multipurpose dam (575 MCM) or via run-of river abstractions should Munyu Dam not be constructed.
- The new Galana Kulalu large-scale irrigation scheme is currently being developed along the Lower Sabaki River. This scheme, which will be supplied directly from the Sabaki River, will eventually have an area of about 400 000 ha, of which 163 000 ha will be located in the Athi Basin.

What is evident from the water resources modelling and scenario analyses undertaken as part of this Study, is that the estimated water demands associated with the above large-scale irrigation development in the Basin cannot be met at acceptable levels of assurance, even with storage. Although, some large-scale irrigation development can be accommodated, the extent of this planned development should be significantly reduced as shown below, to ensure that the assurance of supply is within acceptable limits (90%).

Table 6-41 displays the reduced areas of the proposed large-scale irrigation developments in the basin.

Table 6-41: Large scale irrigation areas (proposed)

Location	Area
Taita Taveta	2 300 ha
Kilimanjaro	700 ha
Kibwezi	15 000 ha
Kanzalu	9 000 ha
Galana Kulalu	16 300 ha
Mwache	2 000 ha
Total	**45 300 ha**

6.9.5.5 Hydropower development

It is proposed to install 20 MW at Thwake Dam and 40 MW at Munyu Dam, while Mwache Dam, soon to be constructed, will have 34 MW installed. Preliminary analyses have shown that the generation of hydropower at these dams will be limited, if the dams are operated to meet irrigation and/or domestic demands as first priorities, and that on average about 79 GWh/a will be generated.

6.9.5.6 Water to supply basin-wide domestic, irrigation and livestock demands

In order to meet future domestic and industrial demands in towns and rural settlements outside of the major urban centres, and to improve reliability of supply to small-scale irrigation, new or additional storage dams as well as local groundwater development should be implemented to provide carry-over storage and to meet supply deficits during dry years and/or the dry season when the demand exceeds availability of water in the rivers.

The water resources model, in conjunction with the groundwater availability assessment model, was used to determine surface water storage requirements and groundwater development per-sub-basin. The total additional storage volume (as local dams and pans) in the Athi Basin, which will be required to meet 2040 demands, amount to 115 MCM, while the total volume of additional groundwater development which will be required was estimated at 91 MCM/a. Table 7-36 provides estimates of additional surface water storage requirements as well as estimates of groundwater development per sub-basin. The surface water storage should be provided in dams and pans.

This includes proposed dams such as Kiteta (16 MCM), Mbuuni (10 MCM) and Miwongoni (1.6 MCM) to supply Machakos and Makueni counties, and the proposed Lake Chala Dam (6 MCM) in the Taita Taveta area. It is important to note that cost-benefit analyses which were undertaken showed that some of the proposed smaller dams might not be financially viable and this should be investigated in more detail during feasibility stage.

Table 6-42: Additional storage requirements and groundwater development to meet 2040 demands

Sub-basin	Groundwater (MCM/a)	Surface water storage (MCM)	Dams already identified
3AA	0.1	5.9	
3AB	1.5	15.1	Stony Athi (23 MCM)
3BC	0.0	8.8	
3CB	0.0	0.8	
3EA	0.0	11.8	Mbuuni (10 MCM); Miwongoni (1.6 MCM)
3EB	0.3	15.7	Kiteta (16 MCM)
3EC	1.0	1.8	
3ED	0.0	3.1	
3FA	2.9	0.0	
3FB	0.0	2.1	
3HC	15.9	0.0	
3HD1	0.3	0.0	
3HD2	3.0	0.0	
3J	0.0	39.8	Lake Chala (6 MCM)
3KA	3.3	0.0	
3LA	41.8	0.0	
3LB	2.4	0.0	
3MA1	0.0	2.8	
3MA2	14.8	20.6	Availability of water may constrain planned small-scale irrigation development
3MB	0.5	0.0	
3MC	1.1	0.0	
3N	1.9	0.0	
Total	**90.7**	**114.7**	

6.9.6 Project investment programme

The proposed water resources developments were grouped into schemes for implementation.

Note: Schemes which are already at an advanced stage of implementation were not considered as part of the project investment programme, which specifically deals with future schemes. Schemes which were deemed to already be at an advanced stage of planning and implementation include the planned transfer schemes from the upper Tana River to Nairobi which form part of the upgrading of the bulk water supply system for Nairobi. Similarly, Thwake and Mwache dams were treated as confirmed and these schemes were therefore not evaluated as part of the assessment of future schemes.

Individual future schemes were evaluated using multi-criteria analysis. Most of the criteria which were employed in the evaluation correspond to the indicators which were used as part of the scenario analysis (refer to Section 5.6). However, additional indicators such as benefit-cost ratio and water productivity as well as qualitative indicators were introduced as part the scheme multi-criteria analysis. Scheme yields at 90% assurance of supply were incorporated in the benefit-cost analysis to estimate potential future water revenue streams.

Table 6-43 displays the decision matrix for the scheme multi-criteria analysis. The analysis used the unit vector normalisation method, while ordinal ranking was used for weighting. In ordinal ranking, the order of ranking assigned to criteria is important, while the absolute differences between criteria values is not, due to it being disproportionate and/or difficult to quantify. The indicator analysis provides a wide array of indicators, which cannot be assessed against each other; thus, ordinal ranking was the suitable option.

Table 6-43: Scheme multi-criteria analysis - Decision matrix

				Kamiti 1 Scheme	Kiteta Scheme	Lake Chala Scheme	Mbuuni Scheme	Miwongoni Scheme	Pemba Scheme	Rare Scheme	Ruiru2 Scheme	Stony Athi Scheme	Munyu Scheme	Galana Scheme	Kilimanjaro Irrigation	Taveta Irrigation Scheme
				Kamiti 1 Dam (16MCM); Nairobi supply	Kiteta Dam (16MCM); Makueni & Machakos Counties supply	Lake Chala Dam (6MCM); Taita Taveta County supply	Mbuuni Dam (10MCM); Machakos County supply	Miwongoni Dam (1.6MCM); Machakos supply	Pemba Dam (19MCM); Mombasa & Kwale Supply	Rare Dam (36MCM); Mombasa supply	Ruiru2 Dam (8MCM); Nairobi supply	Stony Athi Dam (23MCM); Nairobi supply	Munyu Dam (575MCM); Nairobi supply; Hydropower installed (40 MW); Kanzalu Irrigation (9,000ha); Flood control	Galana Dam (498MCM); Mombasa supply; Galana Kulalu Irrigation (16,300ha)	Kilimanjaro Irrigation (675ha)	Taveta Irrigation (2,268ha)
ENVIRONMENT	Footprint areas	Environmentally sensitive areas	Area (km2)	0	0	0.24	0	0	0.31	1.56	0.02	0	0	92.54	4.98	2.26
		Carbon emissions dams	tons	0	0	802.12	0	0	10822	12295	1585	0	53568	59475	0	0
		Carbon emissions LIR	tons	0	0	0	0	0	0	0	0	0	85344	287240	1118	7517
	Downstream areas	Floodplain area inundated	% change from baseline	79	62	67	100	33	100	100	-62	-28	-43	-83	-15	-84
		Ecological stress	Index (-5 to 0)	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-2	-4
		Wet duration	% change from baseline	236	254	11	227	-24	719	1077	78	-80	-35	-56	-6	-20
	Water quality	Phytoplankton growth potential	Average growth potential %	26	0	16	64	63	85	95	48	72	65	91	0	0
		Aquatic macrophytes growth potential	Index (-5 to 0)	0	0	0	0	0	0	0	0	0	0	-1	-5	0
SOCIAL	Water availability	Riparian users	% change from baseline	9	100	100	100	-100	100	100	-25	100	-44	100	-29	-8
	Community health and safety	Malaria endemicity	Malaria endemicity (km2)	0.16	0.36	0.14	0.09	0.05	0.78	1.63	0.06	0.82	11.32	29.98	0.57	1.35
	Food security and livelihoods	Formal irrigation schemes	Area (km2)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	90	163	7	23
		Impact on recession agriculture	% change from baseline	79	62	67	100	33	100	100	-62	-28	-43	-83	-15	-84
		Fish production (dams/lakes)	Tons/annum	15	12	4	7	2	25	41	7	29	293	92	0	0
		Change in fish productivity	% change from baseline	236	254	11	227	-24	719	1077	78	-80	-35	-56	-6	-20
		Loss of productive land	Area (km2)	0.22	0	0.44	0.13	0.07	1.87	2.52	0.10	0.22	23.89	11.78	0.68	4.10
		Loss of natural resources	Area (km2)	0	0	0.24	0	0	0.31	1.56	0.02	0	0	92.54	4.98	2.26
	Displacement	Physical displacement	Number people	314	475	129	290	156	382	245	211	347	17413	346	17	1207
ECONOMIC	Energy	Avg energy	GWh/annum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23	0.00	0.00	0.00
	Food production	Crop production (formal irrigation)	Ton/annum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	348300	22800	10125	0
		Fish production (dams/lakes)	Ton/annum	15	12	4	7	2	25	41	7	29	293	92	0	0
	Employment	Employment formal irrigation	Number people	0	0	0	0	0	0	0	0	0	22500	40750	1688	5670
		Employment hydropower	Number people	0	0	0	0	0	0	0	0	0	58	0	0	0
	Sediment	Volume of dam silted	Index (-5 to 0)	-5	-5	-5	-5	-5	-5	-5	-5	-5	-4	-4	0	0
	Financial	BCR Index	Ratio	1.08	0.33	0.22	1.38	1.25	3.04	1.48	2.58	1.34	2.31	2.36	0.56	1.09
	Flood control	Flood control potential	Ratio (Dam capacity/MAR)	2.41	3.75	0.12	0.27	0.77	0.33	0.68	0.19	0.46	0.78	0.32	0.00	0.00
	Water productivity	Water productivity formal irrigation	Million USD/MCM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.47	0.03	0.12	0.00
		Water productivity hydropower	Million USD/MCM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
QUALITATIVE	Preparedness for implementation		5 Ready for implementation, 0 Not started	2	2	2	3	3	3	3	3	2	0	0	2	2
	Public perception/buy-in		5 Full public support, -5 Very contentious	3	3	3	4	3	4	4	3	4	-1	2	3	3
	Scale of impact		5 Basin wide and beyond, 1 Very local	1	2	1	1	1	2	1	1	1	3	3	1	2
	Transboundary implications		5 Beneficial, -5 Detrimental	1	1	-1	0	0	1	1	1	1	1	2	0	0
	Potential downstream / environmental impact		5 Beneficial, -5 Detrimental	0	0	-1	0	0	0	0	0	0	-2	-3	0	-2
	Fatal flaw		0 None, -5 Flawed	0	0	0	0	0	0	0	0	0	-1	0	0	0

The outcome of the multi-criteria analysis provided a ranking of future schemes as shown in Table 6-44.

Table 6-44: Ranked water resources development schemes

1	**Munyu Scheme**	Munyu Dam (575MCM)
		Nairobi supply
		Hydropower installed (40 MW)
		Kanzalu Irrigation (9,000ha)
		Flood control
2	**Galana Scheme**	Galana Dam (498MCM)
		Mombasa supply
		Galana Kulalu Irrigation (16,300ha)
3	**Kiteta Scheme**	Kiteta Dam (16MCM)
		Makueni & Machakos Counties supply
4	**Pemba Scheme**	Pemba Dam (19MCM)
		Mombasa & Kwale Supply
5	**Kamiti 1 Scheme**	Kamiti 1 Dam (16MCM)
		Nairobi supply
6	**Rare Scheme**	Rare Dam (36MCM)
		Mombasa supply
7	**Mbuuni Scheme**	Mbuuni Dam (10MCM)
		Machakos County supply
8	**Stony Athi Scheme**	Stony Athi Dam (23MCM)
		Nairobi supply
9	**Ruiru2 Scheme**	Ruiru2 Dam (8MCM)
		Nairobi supply
10	**Miwongoni Scheme**	Miwongoni Dam (1.6MCM)
		Machakos supply
11	**Taveta Irrigation Scheme**	Taveta Irrigation (2,268ha)
12	**Lake Chala Scheme**	Lake Chala Dam (6MCM)
		Taita Taveta County supply
13	**Kilimanjaro Irrigation Scheme**	Kilimanjaro Irrigation (675ha)

Based on the above ranking and taking into consideration schemes where implementation is imminent, current and future levels of water supply deficits based on projected growth curves in water demand, an investment programme (Table 6-45) was developed which provides information on the timing / phasing of schemes and associated capital, operations and maintenance expenditure from 2020 to 2040.

Table 6-45: Athi Basin Water Resources Development Investment Plan

Proposed Infrastructure Development							Expenditure (USD Million)																						
									Phasing (Year)																				
Scheme	Storage / Transfer Volume	1:10 yield (MCM/a)	Purpose				Feasibility ESIA / Design	Capital	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Nairobi Water Resources Development	Capacity		Water Supply	Hydropower	Flood Control	LS Irrigation	197	1315																					
Ruiru and Kiuny Wellfields	24 MCM/a	-	💧				1	5	4	2																			
Maragua 4 Dam and S. Mathioya Transfer	48 MCM/a	-	💧				49	329						25	25	110	110	110											
NCT Phase II	44 MCM/a	-	💧				38	256											19	19	85	85	85						
Kamiti 1 Dam	16 MCM	3.4	💧				9	60																9	30	30			
Ruiru 2 Dam	8 MCM	7.2	💧				7	48														7	24	24					
Stony Athi Dam	23 MCM	6.2	💧				11	76												11	38	38							
Munyu Dam	575 MCM; 40 MW	156	💧	💧		💧	81	541	41	41	180	180	180																
Mombasa, Malindi, Kalifi and Kwale Water Resources Development							218	1455																					
Mzima Springs Upgrade	38 MCM/a	-	💧				83	556	42	42	185	185	185																
Baricho Wellfield Upgrade	44 MCM/a	-	💧				35	237				18	18	118	118														
Tiwi/Msambweni Wellfield Development	18 MCM/a	-	💧				1	4						1	2	2													
Pemba Dam	19 MCM	12	💧				10	68	5	5	34	34																	
Rare Dam	36 MCM	7.4	💧				17	110																	17	55	55		
Galana Dam	498 MCM	91	💧			💧	72	480										72	240	240									
Other Water Resources Developments			💧				114	757																					
Kiteta Dam	16 MCM	1.2	💧				9	58					9	29	29														
Thwake Dam	681 MCM; 20 MW	193	💧	💧		💧	88	585	195	195	195																		
Lake Chala Dam	6 MCM	1.3	💧				6	42	3	3	21	21																	
Mbuuni Dam	10 MCM	6.3	💧				7	48							7	24	24												
Miwongoni Dam	1.6 MCM	0.1	💧				4	24	2	2	12	12																	
Small dams / pans % Boreholes							43	287																					
Small dams throughout basin	115 MCM	-	💧				36	243	18	18	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
Groundwater development in basin	91 MCM	-	💧				7	44	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Large Scale Irrigation Schemes (cost excl. associated dams)							123	821																					
Kibwezi Irrigation Extension	15 000 ha	-				💧	44	296						44	74	74	74	74											
Galana Kulalu Irrigation	16 300 ha	-				💧	40	268										40	67	67	67	67							
Kanzalu Irrigation	9 000 ha	-				💧	27	177						27	59	59	59												
Mwache Irrigation	2 000 ha	-				💧	3	21	8	16																			
Mt Kilimanjaro Irrigation	700 ha	-				💧	2	14												2	7	7							
Taita Taveta Irrigation	2 300 ha	-				💧	7	45										7	23	23									
								O&M Cost	0	10	26	38	47	51	58	65	72	77	86	95	100	105	108	109	110	113	115	115	115
								Total Annual Cost (USD Million)	**321**	**337**	**669**	**503**	**455**	**310**	**388**	**349**	**354**	**395**	**450**	**472**	**312**	**325**	**233**	**157**	**172**	**213**	**185**	**130**	**131**

6.9.7 Strategy

In order to comprehensively and systematically address the water resources development challenges in the Athi Basin, Table 6-46 sets out 9 Strategic Themes with specific strategies under each theme. The Themes include Water resources assessment, allocation and regulation, Water resources planning, Water storage and conveyance, Groundwater development, Hydropower development, Water for agriculture, Water based tourism and recreation, Non-conventional water resources and System operation.

Table 6-46: Strategic Framework – Water resources development

8. Key Strategic Area		**Water resources development**
8.1	**Theme:**	**Water resources assessment, allocation and regulation**
8.1.1	Surface water resources assessment– surface water availability at relevant scales	
Before decisions are made regarding water resources developments, it is critical to have reliable information on availability of surface water at relevant spatial scales for planning, management and allocation. The existing hydrological and systems models which have been configured for each basin, need to be refined as appropriate for decision making.		
8.1.2	Groundwater resources assessment– groundwater availability	
Refer to Strategy 3.1.1		
8.1.3	Assess water use and fitness for use	
It is imperative that information with regard to current water use is improved through abstraction surveys. This relates to both water quantity and quality.		
8.1.4	Update and improve permit database	
The accuracy and completeness of the information in the PDB are questionable. The PDB should be checked and updated (based on the abstraction survey data) to ensure that it is a true reflection of the state of water allocation.		
8.1.5	Water allocation	
Water allocations should be re-assessed based on the improved understanding of water availability and current water use at relevant spatial scales. Allocation should be informed by updated water balances which should take into account the reserve and resource quality objectives.		
8.2	**Theme:**	**Water Resources Planning**
8.2.1	Updated planning for bulk water resources development	
The existing large-scale, integrated bulk water supply systems (storage, conveyance, treatment) which supply Nairobi and Mombasa and surrounding areas as well as regional water supply schemes should be optimised and expanded in line with water demand projections. Enough lead time should be allowed for the implementation of the future phases. The conjunctive use of surface and groundwater to meet urban and rural demands should be investigated. The existing inter- and intra-basin transfers within the Athi Basin should be assessed in terms of water resource sustainability and/or infrastructure capacity constraints. Enough lead time should be allowed for the implementation of the future phases.		
8.3	**Theme:**	**Water storage and conveyance**
8.3.1	Implement large dams: complete relevant feasibility and impact studies and plans; design and construct	
To utilise the available water resources in the basin and to improve the reliability of supply will require significant storage of water during the wet seasons – specifically as part of the water supply systems to Nairobi and Mombasa and for the large-scale irrigation schemes being planned. The proposed dams should be investigated in more detail and implemented in line with the investment plan.		

8. Key Strategic Area		**Water resources development**
8.3.2	Maintenance of existing dams	
There is a need to dredge existing dams to improve the capacity volume. Enhanced catchment management will decrease erosion and siltation of existing dams, and dredging will be required on a less frequent basis.		
8.3.4	Infrastructure development - small dams and pans	
At sub-basin scale, there is a need for storage of surface water on tributaries to improve the reliability of supply for local domestic, livestock and small-scale irrigation use. Studies should be initiated and an infrastructure development programme should be compiled to guide the phased implementation of storage at sub-basin scale		
8.3.4	Provide other types of storage	
Sand dams, artificial recharge and water harvesting should be investigated and implemented where feasible to provide storage of water during the wet season for use during the dry season, especially in areas without reliable river flows.		
8.3.4	Basin transfers	
The Athi Basin has a number of inter and intra-basin transfers which convey water from springs, abstraction points and adjacent basins to demand nodes. Proposed expansion of these transfers should be implemented timeously to ensure reliability of supply in line with future water demands.		
8.4	**Theme:**	**Groundwater development**
8.4.1	Develop groundwater resources	
Implement under Strategic Theme 3.2		
8.5	**Theme:**	**Hydropower development**
8.5.1	Large scale hydropower development	
Whereas the primary purpose of the proposed large dams in the Athi Basin, due to the high water demands in the basin, will be urban supply and/or irrigation, the dams can also be used for hydropower generation. The possibility of retrofitting existing large dams with hydroelectric power generation capabilities should also be investigated.		
8.5.2	Small scale hydropower development	
Potential sites for the development of small-scale hydropower plants, especially in the upper Athi Basin, should be investigated based on pre-defined criteria including hydrological variability etc.		
8.6	**Theme:**	**Water for agriculture**
8.6.1	Large scale irrigation development: Develop new / expand existing irrigation schemes. Limit to max sustainable areas	
Although some large-scale irrigation development can be accommodated in the Athi Basin, the extent of the originally proposed developments should be scaled down in light of constraints associated with water availability and assurance of supply.		
8.6.2	Promote water conservation in irrigation	
Small scale irrigation in the basin should be encouraged due to the significant socio-economic benefits associated with this. However, water supply should be improved and/or expanded by means of storage (small dams) and boreholes.		
8.6.3	Compile infrastructure development program for small scale irrigation. Develop new / expand existing irrigation schemes	
Small scale irrigation in the basin should be improved due to the significant socio-economic benefits associated with this. Water supply should be improved and/or expanded by means of storage (small dams) and boreholes.		
8.6.4	Aquaculture development	

8. Key Strategic Area		Water resources development
The new large dams to be developed within the basin will provide opportunities for aquaculture and this should be promoted.		
8.6.5	Improved water supply reliability at local scale through construction of small dams / pans and/or development of local groundwater resources to provide carry-over storage during the dry season	
Implement under Strategies 8.3.2 and 3.2.2		
8.7	**Theme:**	**Water based tourism and recreation**
8.7.1	Promote water-based tourism and recreation	
Adventure tourism, leisure activities, recreational activities and resorts should be promoted in the vicinity of large dams, especially at dams situated close to major cities.		
8.8	**Theme:**	**Non-conventional water resources**
8.8.1	Seawater desalination	
The feasibility of seawater desalination as an alternative and/or integrated supply option to Mombasa should be evaluated as part of a detailed feasibility study.		
8.8.2	Rainwater harvesting	
Rainwater harvesting should be promoted in urban and rural areas. Especially in rural areas, harvested water can be used for some domestic purposes and gardening.		
8.8.3	Reuse	
The feasibility of re-use as an alternative and/or integrated supply option to Mombasa should be evaluated as part of a detailed feasibility study.		
8.8.4	Water Conservation and Demand Management	
WCDM should be implemented as an immediate option to reduce water demand in Nairobi and Mombasa.		
8.9	**Theme:**	**Water resources systems operation**
8.9.1	Optimise system operating rules	
The operation of the bulk water systems supplying Nairobi and Mombasa should be integrated and optimised, taking into consideration new dams and large-scale irrigation schemes to be constructed along the main Athi River.		
8.9.2	Conduct Annual Operating Analyses (AOA) to decide need for and severity of restrictions for the coming year based on current storage levels and anticipated demands	
Annual operating analyses, taking into consideration the current storage state, projected water demands and infrastructure constraints should be conducted for the bulk water supply systems in the Athi Basin to inform decision with regard to curtailment of water use and the need for/phasing of new augmentation schemes.		

6.10 Institutional Strengthening and Enabling Environment

6.10.1 Introduction

In effect, the key aspect of any institutional reform process is to find an appropriate balance between operational functionality and the need for effective oversight and governance. Despite the various efforts that have been targeted at improving the institutional framework in the Athi Basin, there still remain challenges that warrant dynamic and progressive approaches to address them. Thus, this Plan provides the opportunity to integrate institutional reforms with the various elements of water resources management and development, noting that these reforms are an important part of ensuring that this Plan is implemented. Whilst, the various technical dimensions of this Plan are of significant importance, it does need to be highlighted that the ability of institutions to implement, oversee and review approaches accordingly will determine the efficacy of the basin plan.

Noting the variability of the climate and the potential impacts of climate change, the ability of institutions to manage adaptively will become increasingly important. In addition, the importance of the Athi Basin in terms of Kenya's socio-economic development cannot be underestimated. This will require strengthened inter-governmental approaches and inter-sectoral partnerships. These will be imperative noting the importance of the water-food-energy nexus, and will need to not only ensure improved levels of inter-sectoral planning, but equally improved effectiveness and efficiency from better implementation alignment as well as coordinated oversight. This is especially important when one notes the ongoing capacity constraints that face most sectors.

Whilst there will be ongoing pressures to develop and use water resources to enable socio-economic growth and development in the Athi Basin, the need to ensure that this takes place in a sustainable manner will become increasingly imperative. The shifts towards strengthening the regulatory role of the Water Resources Authority (WRA), aligned to the Water Act 2016, are important and will have an impact on the institutional roles and responsibilities within the Athi Basin. Hence, the drive to enable better coordinated resource development will be balanced by an improvement in the regulatory response by WRA. This will mirror and support the drive at a national level to strengthen catchment-based water resources management.

6.10.2 Institutional framework and challenges

The institutional framework in the Athi Basin is currently undergoing a transition in line with the water sector reforms. At the basin level, WRA operates through the Regional Offices (ROs) and Sub-Regional Offices (SROs) with respective offices spread across the Basin. These offices are facing various challenges including inadequate human resources, inadequate office space and equipment, inadequate vehicles and/or fuel, insufficient laboratory facilities, inefficient systems and tools, inadequate data and insufficient financing - which is partly due to inefficient revenue collection systems. These require an institution-wide approach to strengthen the regulatory role of WRA. In this regard, there is currently poor compliance with permit conditions and a range of unlawful activities that are enabled through inadequate enforcement.

At the same time, there is a need to improve the catchment-based management of water resources within the Athi basin. This needs to take place through a range of approaches to address various challenges. There is a need to transition from the Catchment Area Advisory Committees (CAACs) to the Basin Water Resources Committees (BWRCs) as the representative basin area management entity. The BWRCs are yet to be established, but in terms of operational functionality, the BWRCs have an advisory role similar to their predecessor, the CAACs. The advisory nature of the CAACs was problematic in the sense that there was often limited consideration of their inputs, leaving the CAACs as effectively redundant. Noting the need to strengthen catchment-based management in the Athi Basin, there is a dire need to put in place dynamic measures to prevent the BWRCs from running into similar challenges as the CAACs and to ensure that the guidance provided by the BWRCs is considered and translated into implementable actions wherever possible. WRA is currently exploring options that will ensure better operational functionality of the BWRCs given the current setting.

Additionally, the Constitution of Kenya 2010 introduced the County Governments (CGs) into the water resources management space with a mandate on catchment conservation in their respective jurisdictions. There are teething challenges on how to better coordinate water resource management efforts cohesively between WRA and the Counties. These challenges include inadequate awareness of the CGs roles in catchment conservation and what this means for WRA in the overall regulation of management and use of the resource. It is anticipated that the BWRCs will provide a platform to ensure better coordination between WRA and the CGs, especially as the CGs are members of the BWRCs.

Water Resources User Associations (WRUAs) are an important organ at the community level to ensure better water resources management. There have been a few successes with some WRUAs in the Athi Basin, but predominantly there are challenges with capacity of the WRUAs along with financing gaps for the WRUAs that affect their sustainability.

Lastly, noting the importance of inter-sectoral approaches to support improved water resources management and development, there is currently insufficient partnerships and stakeholder engagement to foster these integrated approaches.

6.10.3 Strategies

The Institutional Strengthening Plan for the Athi Basin is aligned with the overall vision for the Basin and focusses on *establishing an effective institutional framework in the Basin to ensure good governance.* This supports the e*nhancement of human and institutional capacities for sustainable management of the water, land, ecosystems and related resources.* The aim of the Plan is focused upon the incremental strengthening of the institutional frameworks to enable improved water resource governance within the Athi Basin. Noting the pressures upon the resource as well as the need to support ongoing socio-economic development within the basin, the need to have institutions that have clarity in roles and responsibilities, that have the capacity and systems to achieve their mandates, and that are supported by sustainable financing frameworks, is imperative. The Plan therefore focused upon developing the institutional frameworks whilst supporting the enabling environment to underpin and sustain the operational implementation of this institutional framework.

The two tables below set out Key Strategic Areas and Strategic Themes to achieve this objective and provides specific strategies under each theme.

Table 6-47: Strategic Framework – Institutional Strengthening

9	**Key Strategic Area:**	**Strengthen the Institutional Frameworks**
9.1	**Theme:**	**Promote improved and sustainable catchment management**
9.1.1	Strengthen WRA's regulatory role	
The Water Act 2016, aligned to the Constitution of Kenya 2010, provides for the strengthening of the regulatory functioning of the WRA. Towards this end there is a need to separate out the regulatory and management functions of the Authority and provide different reporting lines for these differing functions. This will enable WRA to focus on its regulatory functions and in the longer-term work towards the delegation of management and operational functions to the BWRCs when they are established, the County Governments and WRUAs. Acknowledging that the process of establishing the BWRCs may be lengthy, and the need to strengthen the institutional capacity of the Counties and WRUAs will require time, there is need for WRA to establish interim modalities to bridge this gap and to ensure a smooth transition. This will require an optimisation of the ROs and the SROs supported by a capacity building drive (see KSA 11). At the same time, there is a need for the ongoing improvement and strengthening of the regulatory approaches utilised by the WRA. This will include a number of enabling factors (see KSA 10) but also requires a clarification of roles and responsibilities across the entire institutional framework. This will include working with various sector stakeholders to support the improved harmonisation of legislation and regulatory instruments across a range of sectors. This will need to incorporate the development of operational modalities across institutions as well as across administrative and hydrological boundaries.		
9.1.2	Strengthen BWRCs	
The BWRCs have more representation from different stakeholders in the Basin and will thus enable improved engagement across a wider range of stakeholders as well as inter-sectoral issues. There are lessons to be learned from the CAACs and these need to be translated into improved operational modalities for the BWRCs. These lessons include ensuring adequate and sustainable financing, ensuring frequent and well-structured engagements of the members of the BWRCs, WRA providing secretariat and technical assistance services, clear communication and reporting channels between WRA and the BWRCs, modalities for WRA taking on board recommendations of BWRCs, detailed guidelines on appointing members to the committees including qualifications, operationalisation guidelines, prescribed remuneration for the committee members and continued training and capacity building for the members. In addition, strengthening the BWRCs will include WRA providing secretariat services through the ROs and SROs. There is need to provide appropriate channels for enabling recommendations made by the Committee to be taken on board by WRA for further action. This will need to be supported by designated line		

9	Key Strategic Area:	Strengthen the Institutional Frameworks
functions within WRA that do not dilute the WRAs regulatory authority. Training and capacity building will be an ongoing requirement for the BWRCs including a thorough on-boarding upon establishment. This would include not only the more technical dimensions of water resource management, but also a range of skills to enable sound governance.		
9.1.3	Strengthen County Governments engagements in WRM in the basin	
The introduction of County Governments into the management frameworks provides an opportunity for improved management at local levels. The key role of county governments to support localised socio-economic development is crucial and therefore there is a very important need to align planning instruments to ensure that the sustainable development of water resources does underpin this developmental agenda. To date, engagements with the County Governments are unstructured, partly borne from a lack of clarity as to institutional mandates, roles and responsibilities. WRA needs to clarify these roles and responsibilities and to introduce more structured strategic planning and operational engagement. The BWRCs will provide a platform for structured engagements with the county governments, at a governance and strategic level, however, there is need to explore more ways of engaging with the Counties at the basin and sub basin level for day to day issues that may arise. Training and capacity building (see KSA 10) is required for the county governments as well as awareness creation which can be achieved through a collaborative partnership approach with the counties. In addition, the ongoing development of protocols for the sharing information and knowledge exchange need to be established to provide the necessary information required for decision making.		
9.1.4	Strengthen WRUAs	
WRUAs play an important role in sub-catchment management, but there are a range of institutional and capacity challenges that require resolution to enable WRUAs to be more effective. The institutional linkages between county governments and the WRUAs are important and ways to improve and strengthen these will be an important part of improving localised operational water resource management and development. WRUAs have had sustainability issues and exploring approaches that enhance their livelihoods while promoting catchment management will be an added advantage. More importantly, a more sustainable financing approach for WRUAs' activities is most needed to ensure financial sustainability of WRUAs. There is a need to provide training and capacity building to the members periodically on matters relating to WRM. Equally, improvements in information dissemination are needed to ensure community members can understand the message being passed across.		
9.2	**Theme:**	**Guidelines, codes of practice and manuals**
9.2.1-9.2.4	Develop guidelines, codes of practice and manuals	
Technical guidelines, codes of practice and manual which are relevant to water resources planning and management need to be updated and/or developed based on international best practice and aligned with the policy and legal framework which dictates.		

Table 6-48: Strategic Framework – Enabling environment to support effective water resources planning and management

10	Key Strategic Area:	Enabling environment to support effective water resources planning and management
10.1	**Theme:**	**Develop institutional capacity**
10.1.1	Strengthen policies and regulatory instruments	
Updating WRA's standards, policies and regulations in line with the WA2016 is needed. This should be followed by awareness creation and training and capacity building for the new standards, policies and regulations. Respective tools to support the new legislative instruments should also be developed to aid the implementation phases. Development of these tools should adopt a participatory approach in consultation with major stakeholders to ensure buy in and ownership of the new legislative instruments that will trickle down to implementation.		
10.1.2	Development of technical and management capacity	
Across the institutional framework there is a need to develop a range of technical and managerial skills to improve the institutional ability to deliver on mandate. This includes not only ensuring appropriate levels of staffing, but also the upskilling and training of staff to be able to perform functions to the required technical and managerial levels. This will need to take place in alignment with the ongoing work to clarify institutional roles and responsibilities (see KSA 10) and will look to introduce training opportunities across institutions supported by a basin level capacity building framework. Thus, training interventions will support the ongoing development of a community of practice within the basin and will enable more effective inter-institutional functionality.		

10	Key Strategic Area:	Enabling environment to support effective water resources planning and management
10.1.3	Strengthen partnerships	
The importance of inter-sectoral engagement in water resource management and development has increasingly been recognised. This will support the development of more aligned planning approaches to both management and development, as well as provide additional capacity support when and where appropriate. This could also introduce efficiencies that adjust institutional capacity requirements. To this end, there is a need for the development of a partnership framework that provides the basis for the approach towards partnerships. This will then be implemented through the ongoing development of partnership arrangements over time.		
10.1.4	Strengthen stakeholder engagement	
The importance of stakeholder engagement cannot be over emphasised. The improvement in the development of water resource management and development solutions, the improvement in alignment of operational activities and the development of a sense of ownership of the management regime all provide the basis for more robust and sustainable management. There is a clear understanding that there is a need to improve upon the levels of stakeholder engagement and this cuts across the various institutions that play a role in water resource management and development. In this regard, the development of an agreed upon basin-wide framework for engagement is a key first step, supported then by the implementation of this framework. A key element of this, will include improving the functionality of the existing forum.		
10.1.5	Improved research	
Noting the impacts that climate variability and climate change will have upon the water resources of the Athi basin, together with the need to support ongoing development, there will be an ongoing need to develop innovative solutions to the ongoing challenges of water resource management and development. Research towards finding these innovative approaches and technologies will become increasingly important. Developing the network of supporting research institutions will be an important step together with providing the appropriate communication and engagement channels that enables exchange of information. A key challenge has always been ensuring that the research agenda is supportive of the challenges that the sector is experiencing, and so the need to ensure ongoing exchange is critical.		
10.1.6	Innovative financing	
Ensuring adequate financial resources to support integrated water resources management at the basin level is a significant challenge evidenced by the financial hurdles for catchment-based institutions such as the WRA ROs and SROs, the former CAACs and forums. Embracing innovative internal and external resource mobilisation strategies is needed. This needs to factor in new entities in the sector such as the County Governments and other water sector institutions. The private sector provides opportunities for innovative financing for water resources management and should therefore be explored to complement the budget allocated for water resources management from the national fiscus. Internal and external resource mobilisation strategies will be implemented concurrently because of the very crucial role financing plays as a key enabler for IWRM implementation.		

Image source: Mwangi Kirubi, 2015. Kinale Forest. Available Online at https://flic.kr/p/BGTSCR

Way Forward

7 Way Forward

7.1 Introduction

This section establishes a link between the findings and outcomes of the basin planning process and the effective implementation of the recommended strategies within the framework of IWRM. It provides a high-level summary of the main outcomes of the basin planning process, contextualises the Basin Plan and recommends specific interventions for implementation of the Plan.

It is imperative to note that monitoring and evaluation of the Basin Plan be done to ensure that implementation is on track, to measure short and long-term impacts and to evaluate the impacts in order to modify the plan or its implementation (if necessary). Monitoring and evaluation needs to be guided by an efficient, effective and sustainable M&E system. Formal monitoring results should be shared with wider stakeholders and funders.

It is also important to remember that the Plan is a "living document", which should accommodate adjustments and/or updates. Ideally the Basin Plan should be reviewed and updated every five years.

7.2 Key Outcomes

The main challenges associated with water resources development and management in the Athi Basin relate to water quality and reliable water availability, which are exacerbated by various management and institutional challenges. The rationale for the development of this Basin Plan was to assess whether the basin's water resources are sufficient to meet the expected growth in water requirements with 2040 as the planning horizon.

This Basin Plan is a key deliverable towards the overall objective of the KWSCRP namely to strengthen WRA's capacity in terms of tools, skills and infrastructure to deliver on its mandate for water resources regulation in the country. It constitutes an Integrated Water Resources Management and Development Plan for the Athi Basin, which considers the environmental, social and economic aspects of the river basin, addresses the key issues and challenges, and ensures that these aspects are integrated into an overall management strategy. It aims to achieve a sustainable balance between the utilisation, development and protection of water resources and provides a clear pathway for the sustainable utilisation and development of the water resources of the Athi Basin.

The main objective for development of water resources in the Athi Basin should be to address Nairobi and satellite towns urban demands, Mombasa and Coastal towns urban demands, smaller towns and basin-wide domestic, livestock and small-scale irrigation water demands, and large-scale irrigation development in the basin. This will be achieved through the following activities:

- The future water demands of Nairobi and its satellite towns (2040) significantly exceed the water available in the upper Athi Basin and it is imperative that further phases of Tana Transfers are implemented timeously, while three additional dams also need to be constructed in the Upper Athi Basin as well as Munyu Dam on the Athi River about 400 m downstream of the confluence of the Ndarugu and Athi Rivers - as an alternative to Ndarugu 1 Dam. These schemes combined, would significantly improve the reliability of future water supply to Nairobi. Munyu Dam would still be able to supply to the Kanzalu Irrigation Scheme – however as a 2nd priority and at a reduced area. In addition to the above schemes, it is imperative that water demand management measures to reduce demand in Nairobi (aiming for a 20% reduction) are implemented as soon as possible, while a proper hydro-census in the greater Nairobi area should also be undertaken to evaluate groundwater use and potential as part of conjunctive use.

- The future water demands of Mombasa and the surrounding coastal towns could be met through significant expansion of existing groundwater supply sources, and through the utilisation of surface water sources which will require the construction of Pemba, Rare and/or Galana dams. The potential impacts of future major dams in the upper and middle Athi Basin and increased abstractions from Mzima Springs on the future yield of the Baricho Wellfield was found to be significant, which highlights the importance of considering the construction of Galana Dam. Galana Dam, which was originally planned along the lower Sabaki River to supply the proposed Galana Kulalu Irrigation Scheme, could be utilised as an additional water resource to supply Mombasa. By integrating this dam into the Coastal Area water supply system, future (2040) water demands will be met at a high assurance of supply. Galana Dam would still be able to supply to the Galana Kulalu Irrigation Scheme – however as a 2nd priority and with a reduced area. In addition to the above schemes, it is imperative that water demand management measures to reduce demand in Mombasa and the coastal area (aiming for a 20% reduction) are implemented as soon as possible, while a proper hydro-census in the greater Mombasa area should also be undertaken to evaluate groundwater use and potential as part of conjunctive use.
- What is evident from the water resources modelling and scenario analyses undertaken as part of this Study, is that the current extent of planned large-scale irrigation development in the Basin should be significantly reduced taking into consideration the available water in the basin and the expected rapid growth in urban water demands. A sustainable area of about 45 000 ha for large scale irrigation development in the basin is proposed. To ensure reliable supply of water to large-scale irrigation developments, fairly significant regulation of river flows would be required, especially during the dry season. New multipurpose storage dams to meet these large-scale irrigation demands include Munyu Dam, Thwake and Mwache dams (under construction) and Galana Dam.
- It is proposed to install 20 MW at Thwake Dam, 40 MW at Munyu Dam and 34 MW at Mwache Dam. Preliminary analyses have shown that the generation of hydropower at these dams will be significant but limited if the dams are operated to meet domestic and irrigation demands as first priorities.
- In order to meet future demands for domestic supply to towns and rural settlements outside of the major urban centres, for livestock as well as for supply to small-scale irrigation, new or additional storage (small dams) as well as local groundwater development should be implemented

In order to comprehensively and systematically address the range of water resources related issues and challenges in the Athi Basin and unlock the value of water as it relates to socio-economic development, ten key strategic areas were formulated for the Athi Basin. Strategic themes and strategies under each Key Strategic Area along with a prioritised implementation / action plan were prepared. It is important to ensure that the implementation of the sub-plans, strategies, and actions emanating from this Basin Plan are aligned with relevant legislative, policy and institutional principles and guided by internationally accepted standards for good practice to attain the goals of social acceptability, economic viability and technical sustainability.

7.3 Context

Within a global context, the adoption of the United Nations Sustainable Development Goals (SDGs) (UN, 2015) is an opportunity to enact an integrated approach to water resources management. Consequently, the Key Strategic Areas (KSAs) which lie at the heart of the Athi Basin Plan provide various synergies with the SDGs. Furthermore, it is important to note that the successful implementation of the Athi Basin Plan will depend on the degree to which concurrent and future planning in the basin, at various levels, is aligned with the proposed sub-plans, strategies, and actions within the Athi Basin Plan.

7.3.1 Linkages with the sustainable development goals

Since adoption of the UN 2030 Agenda for Sustainable Development, the Government of Kenya, as a member of the United Nations, has committed to the integration of the SDGs into national and county policy and planning frameworks. The UN 2030 Agenda is based on global sustainable development goals and covers the five critical pillars: people, planet, prosperity, peace and partnerships. It contains 17 goals and 169 targets that provide broad guidelines for sustainable development. The 17 Goals are all interconnected and the aim is that these should be achieved by 2030. Although SDG 6 is directly related to water, under IWRM all the SDGs are considered important. This Basin Plan includes actions that not only address specific issues associated with each KSA, but also integrate measures to achieve a number of SDGs. Figure 7-1 shows the Integration of the SDGs into the Basin Plan.

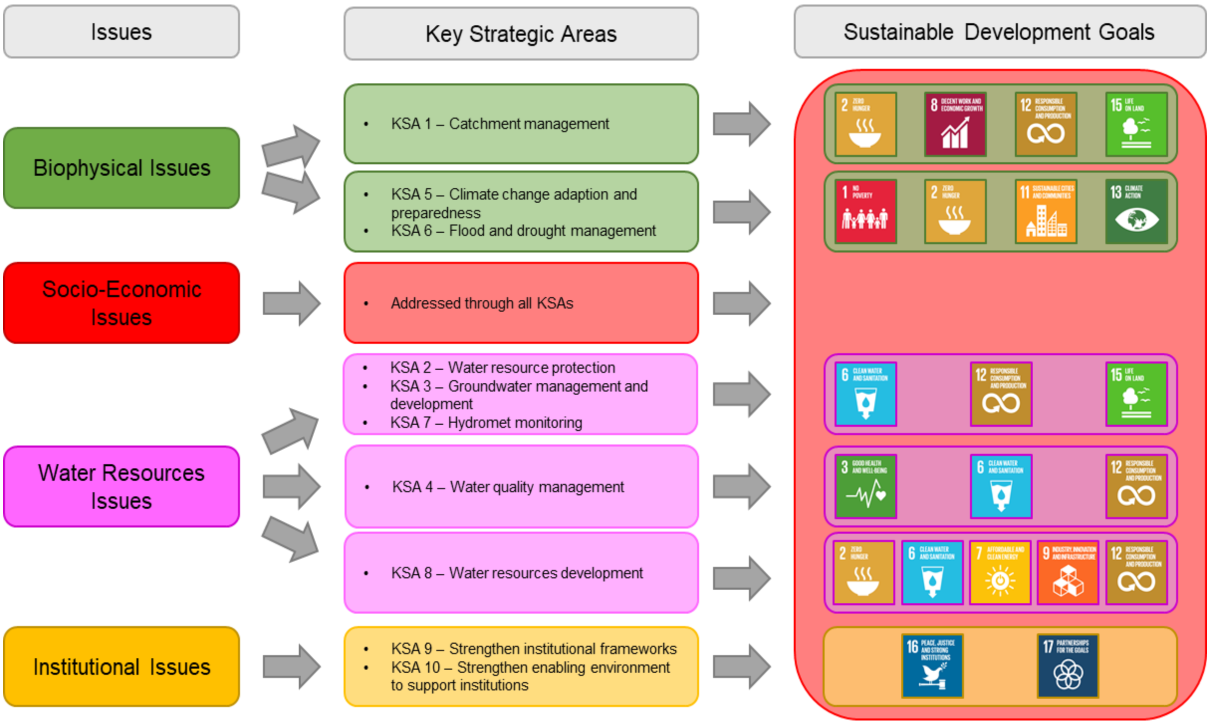

Figure 7-1: Integration of the SDGs into the Athi Basin Plan

7.3.2 Linkages with existing plans

This Basin Plan acts as the latest legislative document for the WRA. Essentially it enforces the CMS (2015-2022) as it provides a vision and framework for the management of water resources and related land resources in the basin. The Plan supplements the National Water Master Plan and acts as the main document for the development of the sub-catchment management plans, which the Water User Associations (WRUAs) will implement. Whereas this Basin Plan contextualizes the SCMPs, the SCMPs remain the resource mobilization tools that WRUAs will use to source implementation funds and other resources. The county government is also involved in implementation activities, and as such will be required to review the Basin Plan and SCMPs to ensure the County Integrated Development Plans (CIDPs) are linked and synchronised with the overall basin planning initiatives. The regional development authorities (TARDA and CDA) and the Water Works Development Authorities (AWWDA, Tanathi WWDA, CWWDA) in the Athi Basin will also need to review their proposed and existing projects to align with the recommendations of the Basin Plan.

7.4 Roadmap for the basin plan

In order to ensure the successful implementation of the strategies and actions presented in the Athi Basin Plan as well as effective monitoring and evaluation thereof, institutional role players need to be coordinated, key institutions linked to implementation need to be strengthened, and financial resources need to be mobilised. In parallel, implementation of critical as well as longer-term activities must begin as soon as possible. These four steps are presented in Figure 7-2 and provide a roadmap to take the implementation of the basin plan forward. The following four sub chapters deal with each of these steps.

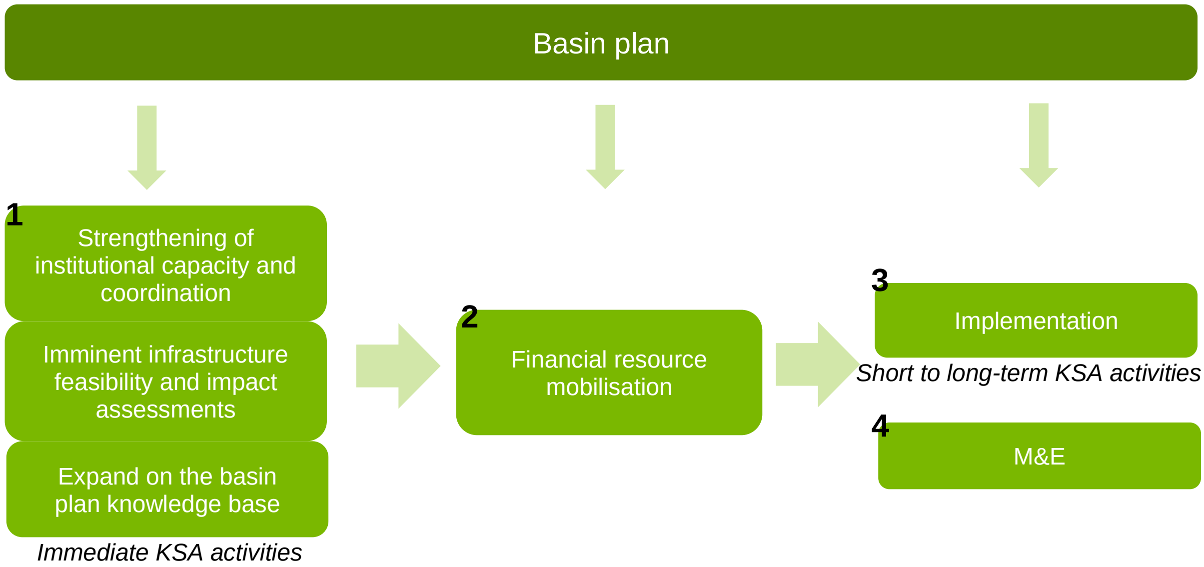

Figure 7-2: Roadmap for implementation of the Basin Plan

7.4.1 Immediate actions

7.4.1.1 Strengthening of institutional capacity and coordination

Strong institutions are necessary for effective governance. Not only must they be strong, but they must be well linked with partner institutions. On a national scale, there are many role players working in similar areas, and poor coordination can result in the duplication of efforts and failure of implementation. It is therefore not surprising that effective implementation must be rooted in strong institutions and partnerships.

Having strong institutions also provides invaluable benefits for securing external financing. When completing a risk assessment, strong institutions with good coordination mechanisms will have a much lower risk profile than their counterparts, making them an attractive investment opportunity for both development partners and the private sector.

IWRM requires the integration of various activities for the equitable and efficient management and sustainable use of water. There are many role players involved, at different scales (i.e. national to local scale), and before any activity is initiated it is critical to ensure that there are platforms in place for engagement.

The KSAs can also be used as a planning tool for key role players, without these institutions needing to sit in the same room. For example, should KFS want to implement a reforestation program, they can refer to the basin plan for information on which institutions and organisations they should collaborate with, and over what timelines implementation should take place.

Table 7-1: Implementation plan role players

		KSA1	KSA2	KSA3	KSA4	KSA5	KSA6	KSA7	KSA8	KSA9	KSA10
Ministries	MoWSI	☑	☐	☑	☑	☐	☑	☐	☑	☑	☑
	MoALF	☑	☐	☐	☑	☑	☑	☐	☑	☐	☐
	MoEF	☑	☐	☐	☑	☑	☐	☐	☐	☐	☐
	MoLPP	☑	☐	☐	☐	☑	☐	☐	☐	☐	☐
	MoICNG	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐
	MoTIHUDPW	☐	☐	☐	☑	☑	☐	☐	☐	☐	☐
	MoH	☐	☐	☐	☑	☑	☑	☐	☐	☐	☐
	MoEn	☐	☐	☐	☐	☑	☐	☐	☑	☐	☐
	MoDASAL	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐
National	WRA	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
	AFA	☑	☐	☐	☑	☐	☐	☐	☐	☐	☐
	NEMA	☑	☑	☐	☑	☐	☐	☐	☑	☐	☐
	KWTA	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐
	KFS	☑	☐	☐	☐	☑	☐	☐	☐	☐	☐
	NLC	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐
	WASREB	☐	☐	☐	☑	☐	☐	☑	☑	☐	☐
	KNCPC	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐
	KURA	☐	☐	☐	☑	☑	☐	☐	☐	☐	☐
	NECC	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐
	EPRA	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐
	KeRRA	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐
	NIA	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐
	PCPB	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐
	KALRO	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐
	NWHSA	☐	☐	☐	☐	☑	☐	☐	☑	☐	☐
	KenGen	☐	☐	☐	☐	☑	☐	☐	☑	☐	☐
	KMFRI	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐
	KMD	☐	☐	☐	☐	☑	☑	☑	☐	☐	☐
	NDMA	☐	☐	☐	☐	☑	☑	☐	☐	☐	☐
	NDOC	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐
	KPLCO	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐
	CETRAD	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐
Basin	BWRC	☑	☑	☑	☑	☐	☑	☐	☑	☑	☑
	WWDA	☑	☐	☐	☑	☐	☐	☑	☑	☑	☐
	DRMC	☐	☐	☐	☐	☑	☑	☐	☐	☐	☐
Local	CG	☑	☑	☑	☑	☑	☐	☐	☑	☑	☑
	WRUA	☑	☑	☑	☑	☑	☐	☑	☑	☑	☑

7.4.1.2 Imminent infrastructure feasibility and impact assessments

In addition to strengthening institutions and coordination, feasibility studies and impact assessments need to begin now for many large and important infrastructure projects, in order for construction to be completed timeously. In the Athi basin, feasibility studies should be initiated for those schemes which have been identified for implementation in the short term. In addition, relevant studies and designs related to the development of small-scale groundwater as well as the construction of small dams and pans should be treated as urgent. These are necessary for building the resilience of local communities and economies, including those that will eventually be supplied from large schemes.

7.4.1.3 Expand on the basin plan knowledge base

Several high-level studies were presented in this basin plan, such as those for determining groundwater availability, and climate change predictions. These are an important foundation but do require additional and more in-depth analysis. Strong scientific studies provide the necessary scientific base to leverage external financial support and develop informed policies.

7.4.1.4 Immediate implementation activities

The timelines of the KSAs have been developed in such a way as to stagger the activity implementation across four planning horizons: immediate (2020 – 2022), short-term (2022 – 2025), medium-term (2025 – 2030) and long-term (2030 – 2040). The 'immediate' time-frame has specifically been developed to provide direction on which activities will be most beneficial to institutional strengthening.

These immediate activities will also require funding, and the key role players and other relevant partners should develop strategies for generating financing. However, it is likely that the financing may have to come from the institutions themselves. This can be considered as a long-term investment – by investing now in strengthening institutional capacity, finances will be more easily mobilised for future activities. These immediate activities are also relatively cheap in comparison to larger catchment size activities, or infrastructure activities.

Table 7-2: Immediate implementation activities

KSA	Priority activities (immediate)	% of total KSA budget
KSA 1 Catchment Management		8%
– Increase awareness of sustainable catchment management with relevant ministries, WRUAs, CGs etc. through training, brochures, social media, internet, factsheets, forums and workshops. – Devolve ownership of catchment management activities to WRUAs through SCMP development. – Embed catchment-based water conservation and management activities related to crop and livestock production in SCMPs – Embed catchment-based soil conservation and management activities related to crop and livestock production in SCMPs – Embed conservation agriculture and improved farm management activities related to crop and livestock production in SCMPs – Coordinate approach to forestry management – roles, responsibilities and mandates		
KSA 2 Water resource protection		6%
– Classify all significant water resources in the Athi Basin (conducted prior to Reserve and resource quality objectives determination) – Determine the Reserve for prioritised water resources in the Athi Basin (note Reserve required for resource quality objectives) – Determine the Resource Quality Objectives for prioritised water resources in the Athi Basin		
KSA 3 Groundwater management		12%
– Implement aquifer mapping and groundwater modelling across the Athi basin – Complete aquifer classification – Improve estimates of sustainable groundwater yield in priority areas using advanced techniques – Prepare groundwater abstraction plan and undertake groundwater abstraction and water quality survey – Undertake groundwater balance to determine sustainable yield available – For each aquifer in the basin, develop Allocation Plan and disaggregate to sub-basins		

KSA	Priority activities (immediate)	% of total KSA budget
KSA 4 Water quality management		2%
– Implement national water quality monitoring programme in the Athi Basin by ensuring technical staff are capacitated and laboratories can analyse the samples accurately and on time – Ensure data submitted to Mike Info WQ database, and that the data are reviewed, analysed, reported on, and acted on by catchment staff – Develop capacity to undertake biomonitoring in Kenya to assess aquatic ecosystem health. – Identify streams in the Basin for piloting biomonitoring and undertake pilot studies – Compile an inventory of surface water pollution sources, especially in the upper Athi Basin – Upgrade central and regional laboratories in the Basin to support the national water quality monitoring programme – All historical and new water quality data collected by WRA in the basin stored in Mike Info – Advocate for alignment of strategies to serve a common purpose of rehabilitating urban rivers and streams in the Basin – Establish a coordination and cooperation mechanism to ensure there is alignment of actions to address water pollution management in the Athi Basin. – Embed water quality management activities related to domestic water use, crop and livestock production in SCMPs		
KSA 5 Climate change adaptation and preparedness		13%
– Quantify climate change impacts (rainfall & temperature) on surface water and groundwater resources and demands in the Athi Basin at appropriate scales for planning and management – Assess potential social impacts: flooding; droughts; human conflict; migration; vulnerable groups; ocean acidification; agriculture; food production – Assess potential environmental impacts: droughts; sea temperature; rising sea levels; ocean acidification; desertification; lad degradation; loss of biodiversity; deforestation; forest degradation – Assess potential economic impacts: irrigation water requirements; crop type and yield; GDP; public Infrastructure; hydropower; coastal assets; livelihoods and income generation. Incorporate flexible adaptation infrastructure principles in infrastructure planning and investment plans		
KSA 6 Flood and drought management		13%
– Government institutions/agencies and other stakeholders with partnership roles in flood management will form the Athi Basin Flood Response Forum (FRF) under the auspices of the KMD to integrate all flood-relevant resource mobilisations and related interventions in the Athi Basin. – Establish a Secretariat for the Athi Basin FRF with accommodation in the WRA Regional Office. – Develop appropriate SOPs for the Athi Basin FRF. – Organisational alignment/ collaboration: The Athi Basin Flood Response Forum (FRF) will expand organisational capacity in the Athi Basin by aligning the flood response roles and responsibilities of the government institutions/agencies, International Relief Aid Agencies, Kenya Red Cross, NGOs and other stakeholders with partnership roles in flood management. – Establish a Secretariat for the Athi Basin DRF with accommodation in the Offices of one of the drought-prone counties. – Organisational alignment/ collaboration: Basin Drought Response Forum (DRF) will expand organisational capacity in the Basin by aligning the drought response roles and responsibilities of the government institutions/ agencies, International Relief Aid Agencies, Kenya Red Cross, NGOs and other stakeholders with partnership roles in drought management.		
KSA 7 Hydrometeorological Monitoring		3%
– Develop implementation programme and implement metering of bulk water use and abstractions (surface and groundwater) – Use MIKE Info database developed under ISC for capturing, storing and managing all hydromet data. Data protocols and procedures with regard to data collection, transfer, capture, storage, quality control and dissemination should be evaluated, standardised and improved where necessary in accordance with international best practice. Technical and computing capacity for processing, analysis and reporting of data should be addressed and enhanced. – Use Knowledge base tools developed under ISC for dissemination of information products related to water resources management. – Use real-time system developed under ISC for accessing, visualizing and analysing hydromet observations in near real-time to inform decision making with regard to flood forecasting and water resources management. Refer to “Real-time data platform – Installation and Training Report, Sep 2018”		

KSA	Priority activities (immediate)	% of total KSA budget
KSA 7 Water Resources Development		10%
– Implement 4 large dams: complete relevant feasibility and impact studies and plans for schemes to be implemented soon – Develop programme for implementation of small dams & pans. Undertake relevant studies. Identify locations and types of dams to improve assurance of supply to local urban, domestic, small scale irrigation and livestock water users; complete relevant feasibility and impact studies and plans. – Phased design and construction of identified small dams / pans in accordance with proposed investment plan		
KSA 9 Strengthen the Institutional Frameworks		41%
– Separate out regulatory and management functions of the Authority and provide different reporting lines for these. Parallel improvement and strengthening of the regulatory approaches utilised by the WRA. – Updating WRA's standards, policies and regulations in line with the WA2016 – Develop tools and systems to support implementation of the new legislative instruments – Hold stakeholder consultations for developing legislative instruments and implementation tools – Translate lessons learnt from CAACs into improved operational modalities. – Provision of secretariat services through Ros and SROs. – Appropriate channels formed for recommendations from BWRCs to be taken on board by WRA. – Clarify roles and responsibilities. – Introduce more structured strategic planning and operational engagement. – Develop a basin or sub-basin level platform for engagement with county government. – Strengthen linkages between county governments and WRUAs. – Develop a Policy on Transboundary Waters incorporating relevant elements of Treaty obligations – Updating WRA's standards, policies and regulations in line with the WA2016 – Complete the development of a National Policy for the Protection of Groundwater with all key stakeholders involved. – Review cross-sector policies, legislation and regulations relating to wastewater; streamline/clarify the roles of the Line Ministries, WRA, NEMA, the Counties and WSPs in relation to wastewater, to eliminate the dual mandates that the WRA and NEMA currently operate under in relation to 'polluter pays' and these agencies' revenue – Develop / Update Guidelines on: – Relevant Codes of Practice for Water Resources Planning and Management – Develop / Update National Manuals relevant to WRPM		
KSA 10 Strengthen the enabling environment to support institutions		21%
– Development of technical and management capacity through focused training, continuous professional development, bursary schemes, audits, incentive schemes – Develop a partnerships framework – Identify potential partners – Strengthen existing partnerships, particularly on a local level – Undertake stakeholder consultations – Develop and strengthen guidelines for MOU drafting and development – Develop a basin-wide stakeholder engagement framework – Undertake stakeholder analysis – Implement the stakeholder engagement framework – Strengthen stakeholder engagement platforms i.e. forums – Strengthen links with tertiary education / research institutions – Incorporate R&D into WRM planning and decision making – Establish a network of supporting research institutions – Develop strategic partnerships for R&D – Promote innovative financing for basin level institutions (BWRCs, WRUAs, forums) – Develop internal resource mobilization strategies – Develop external resource mobilization strategies – Exploring private sector financing channels – Strategic partnerships for resource mobilization		

7.4.2 Financial resource mobilisation

Resource mobilisation refers to the various activities involved in making better use of existing resources to maximum benefit, whilst ensuring the ongoing acquisition of additional resources to ensure the achievement of organisational intent. These resources include financial resources, but also includes human resources and their organisational management, equipment, services, and technical cooperation. The range of these resources and their impact is outlined in the resource mobilisation position paper.

Section 7.4.1.1 outlined the importance of developing strong institutions for financing. Part of this strengthening refers to developing the human and organisational resources. While this is a vital component, financial resources are needed to strengthen these other resources, as well as implement projects.

A review of successive WRA performance reports reflects the challenges that WRA has faced financially, and shows successive funding gaps (WRA, 2017). These have considerable institutional implications for the WRA that require consideration in developing an approach to not only strengthen the WRA, but to also underpin this with a sustained funding regime. Without this strategic intent to coherently develop the business model together with resource mobilization, the overall sustainability of the institution is at risk.

There are numerous forms of external financing, each with their own type of stakeholders and investment mechanisms.

- Innovative financing avenues can include philanthropic and public, water funds and facilitates, payment for ecosystem services, effluent charges, climate change funding schemes, carbon finance, corporate grants, impact investments and conservation finance.
- The key stakeholders and partners for these avenues can include development agencies, governments, multilateral development banks, public private partnerships, private or state banks, private sector, NGOs, asset managers and international councils and secretariats.
- The investment mechanisms can include grants, subsidies, guarantees, soft/hard loans, guaranteed philanthropy, result based payments, equity, loans, environmental impact bonds and microfinance.

It is important to note that different KSA activities will require different levels of partnership and will therefore have to tap into different financing avenue. Using the resource mobilization strategy as a base, it will be necessary for the WRA or the key implementing agency (as outlined in the KSA) to develop a resource mobilization and financier engagement strategy that is applicable to each specific activity.

7.4.3 Implementation

Having initiated the coordinated strengthening of institutional capacity as well as resource mobilisation as immediate critical actions (discussed in Section 6.4.2), other activities in each KSA should be considered for implementation. These activities are typically costlier and have a longer implementation horizon. They also often deal with more physical interventions, and therefore require a stronger local presence and engagement.

An Implementation Plan for each KSA for the Athi Basin is presented in **Annexure E**, which provides a clear intent and prioritised plan of action. The implementation plan is set up considering implementation:

- theme priority (i.e. critical, very important, important)
- activities (i.e. implementation actions)
- indicators to measure outcomes of activities (refer to Section 6.4.4)
- implementation horizon (i.e. immediate (1-2yr), short (2-5yr), medium (6-10yr) or long (11-20yr) term)

- responsibility for activity (i.e. at the basin scale, national scale, local scale and key stakeholders)
- estimated budgets for implementation of activities are provided (Table 7-3) with possible funding sources per activity identified
- corresponding CMS Strategic Actions are linked to each activity as applicable

7.4.4 Monitoring and evaluation

Monitoring and evaluation (M&E) is essential to ensure that plan implementation is on track, to measure short and long-term impacts and to evaluate the impacts in order to modify the plan or its implementation (if necessary) (Global Water Partnership, 2006). M&E systems can be costly and often require significant human, data and financial resources. However, the cost of no M&E may be considerably higher when Basin Plan implementation is inefficient and ineffective. It is therefore necessary to develop an efficient, effective and sustainable M&E system, which can be implemented within existing or planned for resources and line functions. Interpreting and acting on the data is as important as data collection.

It is extremely important that the KSAs are monitored and evaluated on a regular basis. How often, and when, monitoring is carried out will be dictated by what is being measured (i.e. environmental improvements will have different timescales to budget expenditure). M&E will also provide an indication of where delays or diversions are being experienced. Monitoring also provides an evidence base to show funders that their money is being used effectively, to identify where more funding is required to tackle new issues or try new actions where stubborn problems remain. Formal monitoring results are often shared with wider stakeholders and funders, whilst informal monitoring will be restricted to those managing the process.

Lastly, and most importantly, the KSAs and Plans are “living documents” and should not stay static, as circumstances are not static. M&E allows for timely adjustments and/or updates. Ideally the Basin Plan should be reviewed and updated every five years – using the results of monitoring to identify what can and cannot be achieved when revising the plan.

7.4.4.1 Monitoring framework

Key components of a M&E include the selection of M&E indicators and ensuring feedback of the results into the decision-making and implementation processes. A proper M&E system, whose results are shared among stakeholders, also fosters accountability and transparency, and is likely to generate broad-based support for Basin Plan implementation. M&E will aid the successful implementation of the Basin Plan by ensuring that targets and goals set out in the plan are achieved and that problems regarding implementation are detected early and addressed.

7.4.4.2 Targets and indicators

Monitoring of the Athi Basin Plan and achievements should be done on the basis of the Implementation Plan (refer to **Annexure E**) and should be guided by the specific result-based targets/indicators described in the Implementation Plan. This will include M&E of progress in terms of implementation programmes and actual against planned expenditure, among others. For individual projects/programmes, more detailed step-wise M&E indicators could be identified for each projects/programme so that progress can be adequately tracked and evaluated. The evaluation will be based on the monitoring results and possible additional data collected and will provide feedback into the decision-making process which could lead to adjustments in the plan and its implementation.

Table 7-3:Summarised Basin plan budget under the 10 Key Strategic Areas

Key Strategic Areas and Themes		Budget (USD Million)				
		2020-2022	2022-2025	2025-2030	2030-2040	Total
KSA 1	**Catchment management** Promote improved and sustainable catchment management Sustainable water and land use and management practices Natural resources management for protection & sustainable use Rehabilitation of degraded environments	10.4	44.4	40.3	29.1	**124**
KSA 2	**Water resources protection** Classification of water resources Reserve determination Determine Resource Quality Objectives Conserve and protect ecological infrastructure	0.3	0.8	1.8	1.9	**5**
KSA 3	**Groundwater management and development** Groundwater resource assessment, allocation and regulation Groundwater development Groundwater asset management Conservation and protection of groundwater	13.1	35.7	29.1	27.2	**105**
KSA 4	**Water quality management** Effective data collection, information generation, dissemination, knowledge management Promote sound water quality management governance Efficient and effective management of point and nonpoint sources of water pollution	4.1	31.5	91.5	122.0	**249**
KSA 5	**Climate change adaptation and preparedness** Understand impacts of climate change on water resources at appropriate spatial scales Climate change mitigation Climate change adaptation	4.9	13.0	12.4	5.6	**39**
KSA 6	**Flood and drought management** Flood management Drought management	7.7	40.4	4.5	7.8	**60**
KSA 7	**Hydromet monitoring** Improved monitoring network Improved information management	1.0	13.1	8.5	6.0	**29**

Key Strategic Areas and Themes		Budget (USD Million)				
		2020-2022	2022-2025	2025-2030	2030-2040	Total
KSA 8	**Water resources development** Surface water resource assessment, allocation and regulation Water resources planning Water storage and conveyance Groundwater development Hydropower development Water for agriculture Water based tourism and recreation Non-conventional water resources Water resources systems operation	550	2 030	1 630	1 176	**5 387**
KSA 9	**Strengthen Institutional frameworks** Promote improved and sustainable catchment management Guidelines, codes of practice and manuals	5.3	2.6	2.9	2.0	**13**
KSA 10	**Strengthen enabling environment to support institutions** Develop institutional capacities to support improved IWRM&D	5.3	9.0	4.4	6.0	**25**
	Total	**600**	**2 222**	**1 826**	**1 387**	**6 035**

7.4.4.3 Reporting and dissemination

The reporting system, to be implemented by the responsible authority under each Activity, would have to be designed in such a way that progress is tracked, and that problems encountered, and the measures taken to address the problems, are reported on a quarterly and annual basis. In addition, systematic periodic evaluation and objective assessment of the progress made towards the achievement of the overall goal and vision will have to be done.

Reporting takes two forms. The first relates to reporting on progress on the Implementation Plan as a whole. This should be undertaken by a task team that meets bi-annually. The second relates to the reporting on the achievement of the specific actions and targets. It is important to report on progress of the activities and targets using the indicators. The timeframe for carrying out assessments must be realistic, i.e. it must provide time for projects to be implemented and take effect. A standard reporting timeframe is 2-3 years, depending on the targets and the longevity of the Implementation Plan. It is important to note that the institutions that were tasked specific activities are responsible for reporting on the activity specific indicators. This may result in several institutions reporting on the same target.

It is important to ensure the effective communication of progress against the targets, to all stakeholders involved, as well as the general public is carried out in order to build trust in the Basin Plan. Communication can take the form of newspaper articles, an updated progress chart on a webpage or regular newsletter. The overall responsibility for the development of the M&E component should sit with WRA and it would be outlined in the Institutional Organisation and Governance Strategy. Data and information needs would have to be coordinated with the Information Management Strategy, while WRA would be responsible for ensuring implementation and coordinating or carrying out the actual monitoring on a regular basis.

The format of an M&E Sheet would be similar to the implementation tables (**Annexure E**). This is then used as a scorecard and can be kept as records to follow progress. It useful to have the activities in time-order as well i.e. short, medium and long, so it is easy to follow what should be done immediately. A scoring matrix would be needed, so that the same rating can be used in the future which is not subjective. Possible scoring types could include:

- Measurement against set targets, e.g. expressed as % or numbers achieved
- Fixed measurement e.g. hectares or number of schemes
- Qualitative / subjective evaluation, which could e.g. be on a scale from 1 to 5

An M&E example from the implementation plan is shown in Table 7-4 below.

Table 7-4: Monitoring and Evaluation example

Key Strategic Area 1:		Catchment Management						
Strategic Objective:		To ensure integrated and sustainable water, land and natural resources management practices						
Strategic Theme 1.2:		Sustainable water and land use and management practices						
Theme priority:		Critical						
Strategy		Activities	Indicators (M&E)	Timeframe	Responsibility			
					National	Basin	Local	Other
1.2.1	Promote water conservation and management at catchment level	Embed catchment-based water conservation and management activities related to crop and livestock production in SCMPs: E.g. improved water use efficiency; water harvesting and storage; groundwater protection and infiltration	Improved understanding of water conservation and management; Reduction in water use; Increased water storage and water availability in the sub-catchment; Increased groundwater recharge	Immediate	WRA MoWSI KWTA MOALF	BWRC WWDA	WRUA CG	CBO
		Promote catchment-based water conservation and management principles with relevant MDAs through training, forums and conferences.	Level of awareness regarding water conservation and management; Number trainings/forums/conferences held	Short-term	WRA MoWSI MoALF KWTA	BWRC WWDA	CG WRUA	CBO KALRO

An example associated M&E sheet is shown in Table 7-5.

Table 7-5: Monitoring and Evaluation example sheet

Key Strategic Area 1:		Catchment Management				
Strategic Objective:		To ensure integrated and sustainable water, land and natural resources management practices				
Strategic Theme 1.1:		Rehabilitation of degraded environments				
Theme priority:		Important				
Strategy		Activities	Indicators (M&E)	Scoring	Notes/Progress	Date
1.2.1	Promote water conservation and management at catchment level.	Embed catchment-based water conservation and management activities related to crop and livestock production in SCMPs: E.g. improved water use efficiency; water harvesting and storage; groundwater protection and infiltration	Improved understanding of water conservation and management	No. of programs	Note on the improved understanding	Capture date
			Reduction in water use	Water use	Note on the water use reductions related to individual activities	Capture date
			Increased water storage and water availability in the sub-catchment	Water availability	Note on activities related to increased water storage and water availability	Capture date
			Increased groundwater recharge	Groundwater use	Notes on activities related to groundwater recharge	Capture date
		Promote catchment-based water conservation and management principles with relevant MDAs through training, forums and conferences.	Level of awareness regarding water conservation and management;	No. of programs	Note on the improved awareness	Capture date
			Number trainings/forums/conferences held	No. of training/forum/conference	Notes on improved awareness	Capture date

Image source: Ninara, 2014. Tsavo River. Available Online at https://flic.kr/p/qgiLLs

Conclusion

8 Conclusion

Integrated Water Resources Management is based on the equitable and efficient management and sustainable use of water. It recognises that water is an integral part of the ecosystem, a natural resource, and a social and economic good, whose quantity and quality determine the nature of its utilisation(Global Water Partnership, 2006) (Global Water Partnership, 2006). This emphasises the importance of an integrated approach towards water resources planning, development and management - focusing on an enabling environment, institutional framework and setting up the management instruments required by institutions to understand mandates, roles and responsibilities to effectively and seamlessly do their job.

The Athi Basin Plan provides a status quo of the current water resources management situation and a plan for future management. There is no correct administrative model, but the principles of IWRM allow for selecting, adjusting and applying a mix of tools for a given situation and agreeing on milestones and timeframes critical for success.

This Basin Plan is a key deliverable towards the overall objective of the KWSCRP namely to strengthen WRA's capacity in terms of tools, skills and infrastructure to deliver on its mandate for water resources regulation in the country. It constitutes an Integrated Water Resources Management and Development Plan for the Athi Basin, which considers the environmental, social and economic aspects of the river basin, addresses the key issues and challenges, and ensures that these aspects are integrated into an overall management strategy. It aims to achieve a sustainable balance between the utilisation, development and protection of water resources and provides a clear pathway for the sustainable utilisation and development of the water resources of the Athi Basin.

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10 Annexures

Annexure A: Analytical tools

Annexure B: Data at sub-basin level

Annexure C: Basin Planning: Policies, legislation and institutions

Annexure D: Stakeholder information

Annexure E: Implementation Plans

Annexure F: Costing

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Bringing ideas to life

A1: Erosion risk and land use capability

Erosion risk in the Athi Basin was determined by using the Revised Universal Soil Loss Equation (RUSLE) model (Renard, Foster, Weesies, & Porter, 1991). The RUSLE model is used widely to predict long-term rates of inter-rill and rill erosion from field or farm size units subject to different management practices. RUSLE is a lumped model which assumes spatially homogeneous hillslopes. A raster-based GIS soil erosion risk assessment tool for the Athi Basin was developed, which calculates the mean annual gross soil erosion at a cell level as the product of six factors:

$$A = R_i \times K_i \times L_i \times S_i \times C_i \times P_i \qquad (1)$$

where:

subscript $i = i^{th}$ cell

A_i = the average annual soil loss per unit area within the cell ($t \cdot ha^{-1} \cdot a^{-1}$)

R_i = rainfall-runoff erosivity factor ($MJ \cdot mm \cdot ha^{-1} \cdot h^{-1} \cdot a^{-1}$)

K_i = the soil erodibility factor ($t \cdot h \cdot MJ^{-1} \cdot mm^{-1}$)

L_i = the slope length factor

S_i = the slope steepness factor

C_i = the cover management factor

P_i = the conservation support practice factor

Input data for each erosion factor in the RUSLE model were collected from various sources as presented in Table A1-1.

Modelling the sediment production potential is based on the relatively constant factors associated with topography and soils. These factors are unlikely to change significantly over the short-term as they relate to the geomorphology of the Basin. Rainfall is dependent on climatic factors, therefore is inherently variable. The management factors (i.e. crop and practice) are more variable, as they are dependent on the conservation management measures and seasonal rainfall. A wider study in Kenya (Dunne, 1979) indicated that land use was a dominant control of sediment yield, although runoff and topography were also recognised as important. It was also determined that yield from agricultural land and grazed land was significantly greater than from forested basins, with variability in cultivated land.

Rainfall erosivity

One of the key drivers of erosion is rainfall erosivity. Although rainfall itself will not necessarily result in high levels of erosion, intense prolonged rainfall will act to increase soil erosion rates. Rainfall erosivity has a high impact on soil erosion as it provides the energy required to detach soil particles. As shown in Figure A1-1, rainfall erosivity is very high in the upper, more humid part of the upper Athi Basin and lower in the more semi-arid gentler plains of the upper basin. It is also important to note that Nairobi occurs downstream of areas with high levels of rainfall erosivity and topography landforms which transition from very steep to more gentle slopes. This is indicative of a zone of deposition, where wetlands provide important flood attenuation services. The increased urbanization and reduction of the functioning of wetlands in this area decreases the landscape’s resilience to increasing rainfall erosivity and may exacerbate urban flooding issues. Rainfall erosivity is lower in the semi-arid plains and wetland areas of the Middle Athi Basin. The more mountainous areas and footslopes also have a higher rainfall erosivity (i.e. footslopes of Mt Kilimanjaro, Chuyula Hills and Machakos/Wote regions). The rainfall erosivity is moderately low in the Lower Athi Basin, with the coastal regions having higher erosivity

Table A1-1: Identified sources of input data for GIS based RUSLE model

	Factor	Input / Reference Data	Data type (Extent)	Resolution (arc-seconds)	Parameters used / derived
Output	**A**	-	Grid	1	-
Input	**R**	a) Global Rainfall Erosivity coverage based on the Global Rainfall Erosivity Database (GloREDa) b) CHIRPS precipitation dataset	a) Grid (Global) b) Grid (Global)	a) 30 b) 180	a) R Factor b) Mean Annual Precipitation (MAP)
	K	a) Soil and terrain database for Kenya (ver. 2.0) (KENSOTER) b) SOTER-based soil parameter estimates (SOTWIS) for Kenya - c) ISRIC SoilGrids	a) Microsoft Access Database / Vector geometry (Kenya) b) Microsoft Access Database / Vector geometry (Kenya) c) Grid (Global)	a) n/a b) n/a - c) 8	a) , b), c) sand, clay, silt and organic carbon fractions. Soil structure, soil permeability, surface stoniness
	LS	SRTM Digital Elevation Data 1-arc second	Grid (Global)	1	Derived surface slope, flow direction, flow accumulation, specific contributing area
	C	Cloud filtered Landsat Imagery	Grid (Global)	1	Normalized Difference Vegetation Index (NDVI)
	P	a) RCMRD Kenya Crop Mask 2015 b) RCMRD Kenya Sentinel2 LULC 2016 land cover c) Google Earth d) Limited field visits	a) Grid and Vector (Kenya) b) Grid (Kenya) c) Satellite imagery (Global) d) Local	a) 1 b) 1 c) n/a d) n/a	- Main Crop type • Crop extent • Visual inspection of practice type • Visual confirmation of practice type

.

Soil erodibility

A second key driver of erosion relates to soil characteristics. The Upper Athi Basin is associated with more recent lava deposits, which support fertile soils, overlying ancient basement rocks. The Athi Plains form the southern part of the lava plains from which rise piles of volcanic ash and lava. The primary soil type in Nairobi City is red Nitisols, while the upper Athi River basin mainly consists of Vertisols, low-nutrient Ferralsols and Cambisols. According to the Soil Atlas of Africa (Jones, 2013): Nitisols have a high clay content and are iron rich. These soils support a wide range of crops, particularly coffee, and fertiliser is required for annual cropping; Verisols are clay-rich soils which are productive if managed properly; Cambisols are young soils with good nutrient holding capacity; and Ferrasols have low nutrient levels and nutrient retention with a sandy/silt texture. These soil characteristics add to the high soil erodibility in this upper region, particularly along the steep upper slopes as shown in Figure A1-1.

The Athi Plains form the southern part of the lava plains from which rise piles of volcanic ash and lava - Mt Kilimanjaro and Chuyula Hills being remnants of this volcanic history. The middle Athi River basin is dominated by Lixisols, low-nutrient Ferralsols and Vertisols. According to the Soil Atlas of Africa (Jones, 2013): Lixisols are common in dry savannah regions and are slightly acidic with high clay content and low nutrient retention; Ferrasols have low nutrient levels and nutrient retention with a sandy/silt texture; and Vertisols are clay-rich soils which are productive if managed properly. These soil characteristics add to the high soil erodibility in this region.

Along the coast of the Athi Basin, the geology is made up of quaternary and tertiary sediments. These are coastal sediments consisting of soils and alluvial beach sands. The Lower Athi River basin is dominated by reddish Luvisols, Solonetz, Vertisols and Fluvisols. According to the Soil Atlas of Africa (Jones, 2013): Luvisols are slightly acidic with high clay content and high mineral nutrient content; Solonets are an alkaline, clay-rich subsoil with a high sodium content. These soils mainly support natural habitats and are utilised for grazing; Vertisols are clay-rich soils which are productive if managed properly; and Fluvisols are found in flood plains, lakes, deltas or marine deposits. These soil characteristics add to the moderately high soil erodibility in the lower Athi Basin.

Vegetation cover

Vegetation cover is important when it comes to soil erosion, as dense vegetation cover will act to protect the land from erosion, whilst overgrazed land is more exposed. The density of vegetation cover reflects the influence of cropping practices, vegetation canopy and general ground cover. Maintaining a dense and diverse vegetation cover is important for catchment management as it reduces erosion. Water availability has an important control over vegetation growth. The humid, highlying part of the Upper Athi Basin generally has good vegetation cover due to natural forests. The semi-arid plains along the lower ares have limited cover provided by the vegetation. Figure A1-1 shows the spatial variation of vegetation cover in the Upper Athi Basin. (Note: A high cover management factor indicates poor vegetation cover and vice versa). It shows that the semi-arid plains n the middle Athi Basin have a higher cover factor (i.e. poorer vegetation cover) than the steeper footslopes of Mt Kilimanjaro, Chuyula Hills and the coastal regions of the Lower Athi Basin.

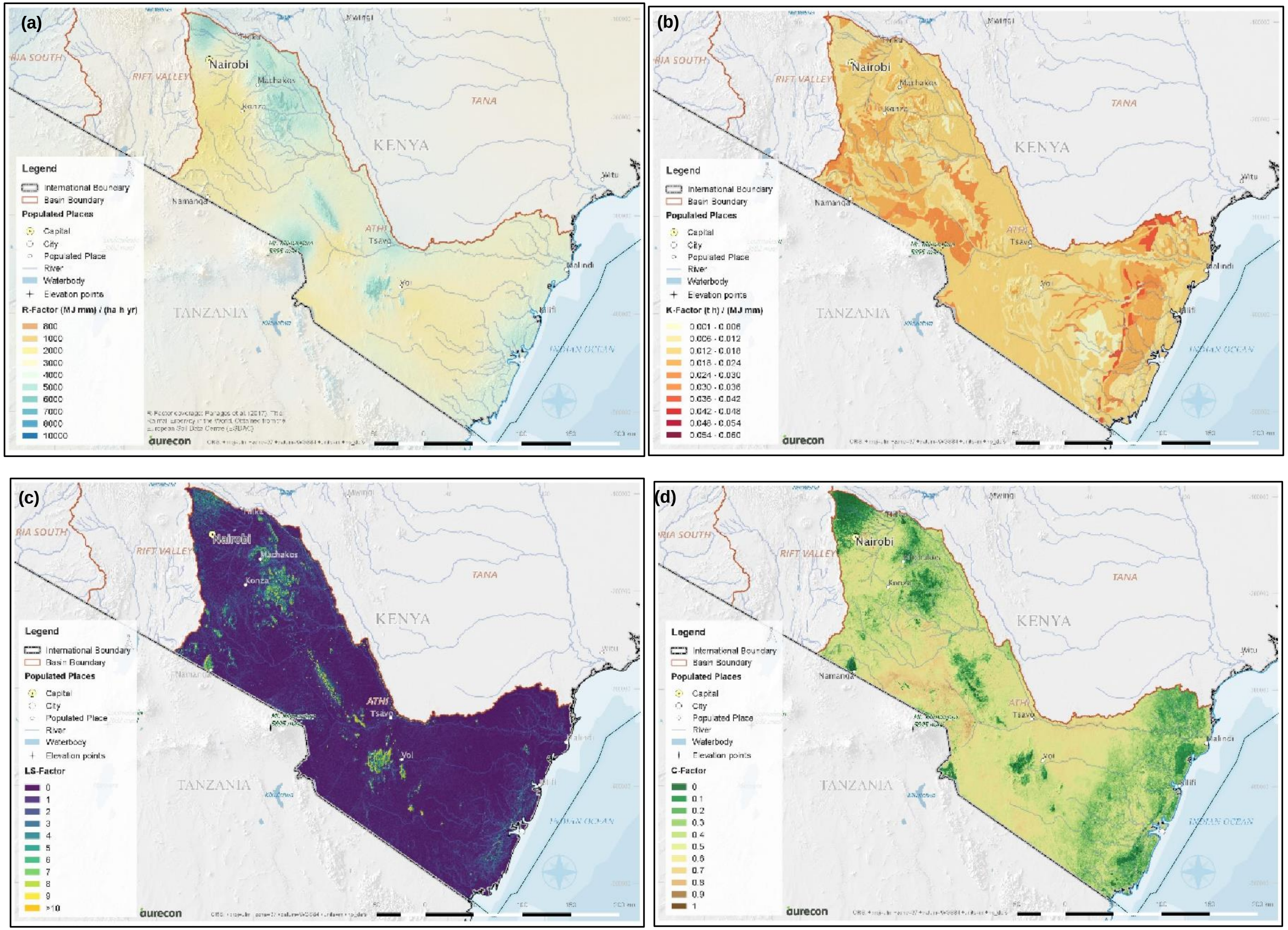


Figure A1-1: RUSLE factor maps for Athi Basin (a) rainfall-runoff erosivity, (b) soil erodibility, (c) slope length and slope steepness, (d) cover management factor

Estimated soil loss

Applying the RUSLE-based soil erosion risk assessment tool to the Athi Basin, using the flow chart as shown in Figure A1-2, resulted in estimates of soil erosion risk (expressed as long-term average soil loss per unit area) as displayed in Figures A1-3 and A1-4. It should be noted that Figure A1-4 is based on an assumed conservative conservation support practice (P) factor value of 1.

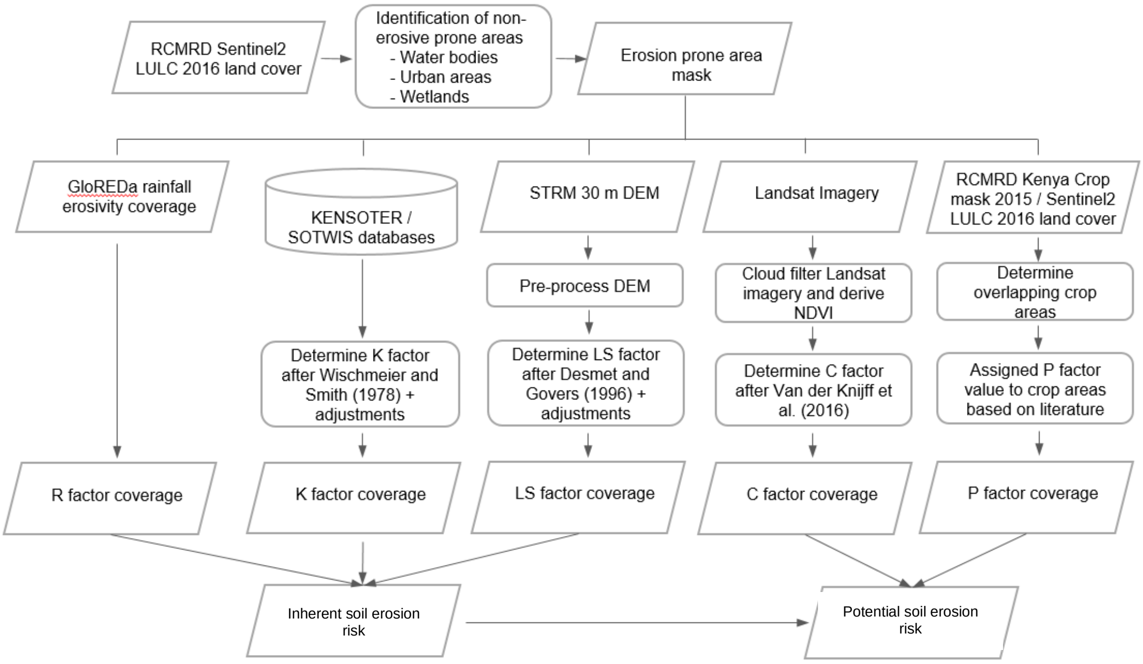


Figure A1-2: Modelling flow chart for soil erosion risk in Kenya

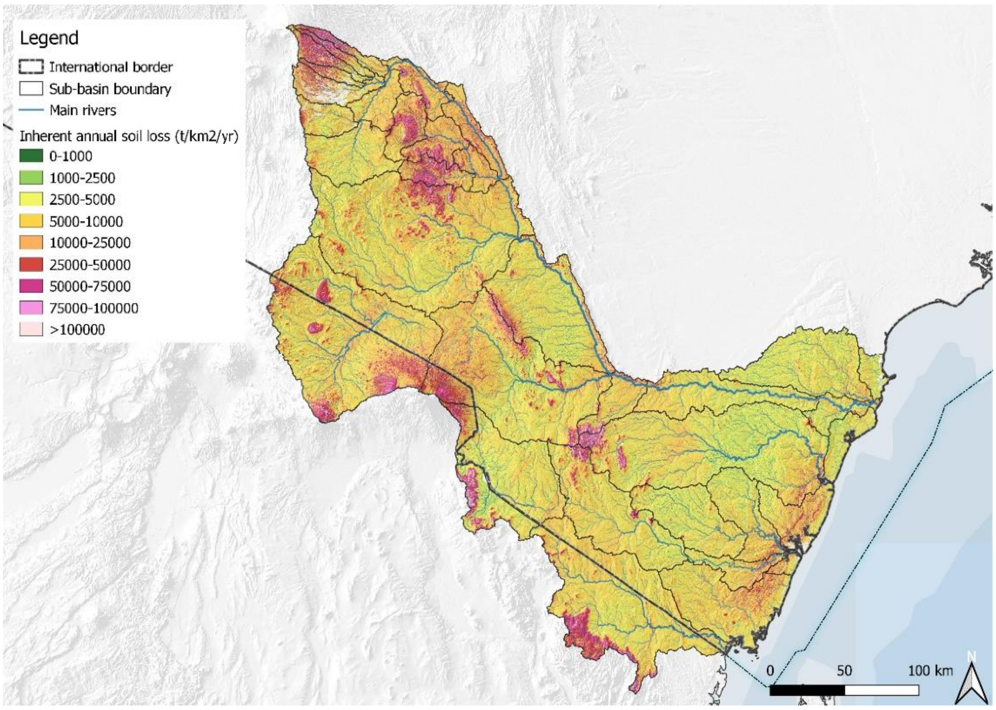


Figure A1-3: Athi Basin Inherent Soil Erosion Risk (C and P Factor not factored)

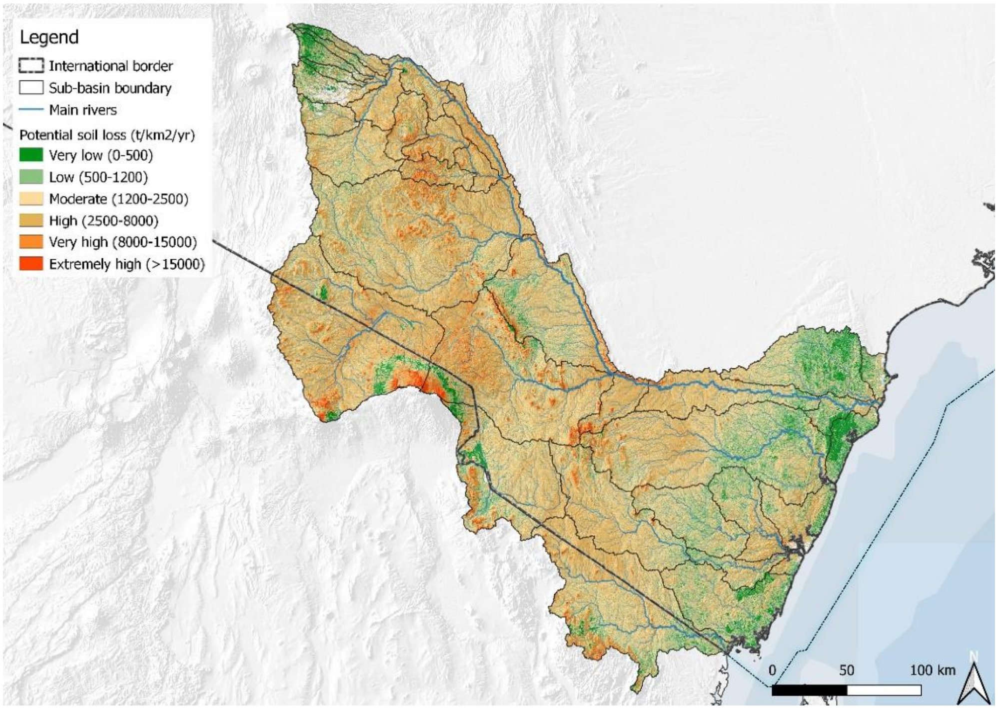


Figure A1-4: Athi Basin Soil Erosion Risk

When comparing the inherent soil erosion risk to the potential soil erosion risk it is apparent that vegetation cover in protected areas and gazetted forests provide significant protection from soil erosion. Protected areas and gazetted forests have very low rates of erosion, although at the foot slopes of Kitui County Mountain ranges the erosion rates are high due to limited vegetation cover.

There is a moderate level of erosion in Upper Athi within Ruiru (3BC) and Nairobi (3BA) sub-basins. The Aberdare forest provides a dense cover that protect soils from erosion and overland transport. These soils with indigenous forest and tea cultivation land use have a higher structural permeability and generate little surface runoff, which produces limited sediment. Lower down there is a rapid increase in erosion as soil is more exposed to rainfall under coffee and horticulture land uses. Erosion estimates are very high in Thwake (3EA, 3EB, 3ED) and Keite (3EC) sub-basins. In general, the sub-basins associated with the forested upper areas have low levels of erosion risk, whereas the foothills display higher risk. The semi-arid plains have a moderate to high erosion risk, in part due to the limited vegetation cover exposing soils to water erosion. Extremely high erosion risk occurs on the peaks of hills and mountains without vegetation cover.

Table A1-2: Athi Basin mean factors, inherent soil loss and potential soil loss

Sub-basin	Mean R	Mean K	Mean LS	Mean inherent soil loss (t/km^2/yr)	Mean C	Mean potential soil loss (t/km^2/yr)	Erosion risk
3AA	2681	0.03	1.3	8860	0.3	2611	High
3AB	2201	0.02	1.2	6332	0.4	2662	High
3AC	3491	0.02	1.2	10074	0.4	3888	High
3BA	3527	0.03	1.4	15736	0.3	2629	High
3BB	3974	0.03	1.6	21282	0.2	1908	Moderate
3BC	4415	0.03	2.5	36416	0.1	1510	Moderate
3BD	4280	0.03	2.3	33657	0.2	2073	Moderate

Sub-basin	Mean R	Mean K	Mean LS	Mean inherent soil loss (t/km²/yr)	Mean C	Mean potential soil loss (t/km²/yr)	Erosion risk
3CB	4380	0.03	2.3	33550	0.2	2712	High
3DA	4371	0.02	1.8	17815	0.3	3612	High
3DB	4434	0.02	1.6	15930	0.3	5271	High
3EA	4188	0.02	2.5	23482	0.3	4715	High
3EB	4622	0.02	2.3	23082	0.3	5212	High
3EC	4531	0.02	3.3	32377	0.2	6228	High
3ED	4472	0.02	1.5	15202	0.3	4709	High
3FA	3075	0.02	1.3	9307	0.4	3681	High
3FB	3650	0.02	1.0	8451	0.4	3039	High
3G	3577	0.03	1.2	10853	0.5	4606	High
3G_T	4173	0.03	3.0	30357	0.2	6077	High
3HA	4013	0.02	1.6	15630	0.5	5734	High
3HB	3278	0.03	0.7	5693	0.5	2918	High
3HC	3259	0.02	0.6	4831	0.3	1248	Moderate
3HD1	3439	0.02	0.8	6306	0.3	1699	Moderate
3HD2	3503	0.02	0.6	4890	0.4	1439	Moderate
3J	2831	0.02	0.8	5612	0.5	2602	High
3J_T	3571	0.02	2.1	22148	0.3	3539	High
3KA	3556	0.02	1.1	8595	0.2	1599	Moderate
3KB	3324	0.02	0.9	6911	0.4	2996	High
3KBT	3547	0.02	1.6	13311	0.3	2933	High
3LA	3081	0.02	1.0	7663	0.4	2403	Moderate
3LB	3791	0.02	0.6	4672	0.2	740	Low
3MA1	3144	0.02	1.1	8739	0.4	2967	High
3MA2	2664	0.03	0.8	5338	0.4	1826	Moderate
3MB	3128	0.03	0.8	6919	0.3	2369	Moderate
3MC	3288	0.02	1.2	9576	0.3	2190	Moderate
3MD1	4119	0.02	1.1	10626	0.3	2680	High
3MD2	4007	0.02	1.2	11162	0.3	2686	High
3N	2770	0.03	1.4	9565	0.5	4156	High
3N_T	2960	0.03	1.8	14408	0.5	4878	High

Sediment yield

Soil erosion involves the detachment, transport and eventual deposition of soil particles (Lal, 2001). Energy for these processes is provided for by physical (wind/water), gravity (landslides), chemical (weathering) or tillage sources. Sediment particles, once picked up by water, actually spend a relatively short time being transported and in fact more time in storage (Meade, 1982). This means that an understanding of the source (i.e. sediment potential areas) and sink (i.e. depositional areas) zones are needed in order to understand the impact of sedimentation. Erosion acts as the source of sediment, which travels downstream and has indirect impacts. These impacts can be seen when sediment travels in suspension, i.e. turbidity impacts to biodiversity, and when sediment stops moving and is deposited, i.e. sedimentation impacts to biodiversity and infrastructure. On the one hand deposited sediment renews soil fertility and lines channels of canal beds against seepage, but on the other hand it reduces capacity of reservoirs, inlet channel and irrigation canals (Ali, 2014). High sediment loads transported by the river during flood seasons has major influences on operation of reservoirs and in general reduces storage capacity. When in suspension sediment becomes a pollutant in its own right, as it limits light penetration and healthy plant growth. When sediment settles on the river bed it may smother aquatic habitats and impact fish spawning grounds. Nutrient rich sediments (especially sediments linked to agricultural lands) create turbid conditions which may result in eutrophication where fish species may be unable to survive.

Tracing the pathway of sediment from the upper Athi Basin, to the sea indicates that there are various landforms which are linked to deposition zones, acting as sediment “traps” or buffer zones. These landforms such as lakes, alluvial plains, wetlands and delta plains are areas where sediment will likely be deposited. Infrastructure such as dams will also trap sediments, the scale of this relating to the dam storage capacity as well as location within a catchment.

Based on the characteristics in Table A1-3, sediment delivery ratios were estimated for each sub-catchment and sediment yield values calculated. The estimates were validated based on previous studies in the basin.

Table A1-3: Physiographic catchment characteristics contributing to sediment dynamics of Athi Basin

Factor	Basin
Basin area (m^2)	66,815
Annual Rainfall (mm)	749
Elevation (masl)	0-2600
Climate	Mainly semi-arid with upper humid area
Topography	Upper rift mountains to lower coastal areas
Vegetation	Mainly savanna grasslands with interspersed forest
Land-use	Mainly rain fed agriculture, potential erosion due to poor land use. Nairobi and Malindi main urban centers within Athi Basin potential erosion due to increased stormwater runoff during wet season. Sand mining also contributes to erosion impacts.
Connectivity (upper)	Within the Upper Athi catchments (i.e. Athi, Chania, Thwake and Keite Rivers) the landforms change from mountains and foothills to plains. There are 6 existing dams of limited capacity and there are wetlands near Nairobi and upper Athi. Although there are dams and wetlands within these catchments, it is unlikely that that they are acting to disconnect the sediment movement as they are located in high lying areas.
Connectivity (middle)	Within the Middle to Lower Athi sub-basins (i.e. Olkeju Ado, Selengei, Kiboko, Muoni and Athi Rivers) the landforms have more depositional features, in particular within the tributaries of the Athi (i.e. Olkeju Ado, Selengei, Kiboko, Muoni Rivers). Lokerish and Tsavo also have wetland depositional features.
Connectivity (lower)	Galana River flows along a plain towards the sea, and the upper Gandi and Koromi Rivers have wetland features, although these wetlands are unlikely to act to disconnect the catchments from sediment flow as they occur in the upper reaches. The upper Voi and upper Mwamandi Rivers also have wetlands in their upper reaches.

Table A1-4 summarises the erosion potential and sediment yield in the Athi Basin.

Table A1-4: Long term average soil loss estimates per sub-basin in the Athi Basin

Sub-Basin	Area (km^2)	Potential soil loss (t/km2/a)	Incremental sediment yield (t/km2/a)
3AA	738	2611	548
3AB	1796	2662	559
3AC	805	3888	589
3BA	911	2629	403
3BB	261	1908	362
3BC	496	1510	272
3BD	304	2073	394
3CB	398	2712	515
3DA	783	3612	600
3DB	825	5271	693
3EA	861	4715	943
3EB	831	5212	1019
3EC	704	6228	1370
3ED	533	4709	1111
3FA	9927	3682	718
3FB	4177	3039	713
3G	6589	4606	875
3G_T	582	6077	1337
3HA	905	5734	780
3HB	2280	2918	769
3HC	2942	1248	262
3HD1	659	1699	748
3HD2	446	1439	273
3J	2716	2602	468
3J_T	1625	3539	637
3KA	3010	1599	288
3KB	1610	2996	629
3KBT	4748	2933	645
3LA	7662	2403	505
3LB	800	740	163
3MA1	3566	2967	564
3MA2	2205	1826	384
3MB	1677	2369	452
3MC	777	2190	523
3MD1	1385	2680	590
3MD2	205	2686	591
3N	3036	4156	748
3N_T	5305	4878	1073

Land use capability

To assist with the assessment of land capability and sustainable land use in the Basin, a GIS-based land capability tool was developed based on the USDA Land Capability Classification System as defined in Table A1-5. The USDA Land Capability Classification relies on the following principles (Klingebiel & Montgomery, 1961):

- Areas of land are put into classes ranging from best (Class I) to worst (Class VIII),
- Land allocated to a particular capability class has the potential for the use specified for that class and for all classes below it.

Placing soils in these classes allows for an understanding of the crop and management constraints. The suitability of soils is as follows:

- Order A: Arable land – high potential land with few limitations (Class I and II)
- Order B: Arable land – moderate to severe limitations (Class III and IV)
- Order C: Grazing and forestry land (Class V, VI and VII)
- Order D: Land not suitable for agriculture (Class VIII)

Table A1-5: Relationship between USDA soil capability classification classes and intensity with which each class can be used safely (Davidson, 1992)

Soil Capability					GRAZING			CULTIVATION				Description	Soil/Terrain parameter			Soil/terrain parameter mix summary
Orders		Classes	WILDLIFE	FORESTRY	Limited	Moderate	Intense	Limited	Moderate	Intense	Very Intense		Slope	Erosion	Soil Depth	
Arable	A	I	x	x	x	x	x	x	x	x	x	Soils have slight limitations that restrict their use.	S1	E1	D1	Gentle slope, very low erosion, deep soils
		II	x	x	x	x	x	x	x	x		Soils have moderate limitations that reduce the choice of plants or require moderate conservation practices.	S2	E1, E2	D1	Gentle to moderate slope, very low to low erosion, deep soils
	B	III	x	x	x	x	x	x	x			Soils have severe limitations that reduce the choice of plants or require special conservation practices.	S3	E1-E3	D1 - D2	Moderate slope, very low to moderate erosion, deep to medium deep soils
		IV	x	x	x	x	x	x				Soils have very severe limitations that reduce the choice of plants or require very careful management, or both.	S4	E1-E4	D1 - D2	Moderate slope, very low to high erosion, deep to medium deep soils
Non- arable	C	V	x	x	x	x	x					Soils have little or no hazard of erosion but have other limitations, impractical to remove, that limit their use mainly to pasture, range, forestland, or wildlife food and cover.	S4	E1-E5	D1 - D2	Moderate slope, very low to very high erosion, deep to medium deep soils
		VI	x	x	x	x						Soils have severe limitations that make them generally unsuited to cultivation and that limit their use mainly to pasture, range, forestland, or wildlife food and cover.	S5	E1-E5	D1 - D2	Steep slope, very low to high erosion, deep to medium deep soils
		VII	x	x	x							Soils have very severe limitations that make them unsuited to cultivation and that restrict limit their use mainly to grazing, forestland, or wildlife.	S5	E1-E5	D2 - D3	Steep slope, very low to high erosion, medium to shallow soils
	D	VIII	x									Soils and miscellaneous areas have limitations that preclude their use for commercial plant production and limit their use to recreation, wildlife, or water supply or for aesthetic purposes.	S6	E1-E6	D2 - D3	Very steep slope, very low to high erosion, medium to shallow soils

Davidson (1992) categorised the USDA Classes in terms of the intensity of soil disturbance that is "safe" and introduced soil and terrain as useful physical parameters to define Classes, i.e. Slope Class (Table A1-6), Erosion Hazard Class (Table A1-7) and Soil Depth Class (Table A1-8**Error! Reference source not found.**).

Table A1-6: Slope Class for input to the Soil capability classification

Slope Class	Slope (%)
S1	0-5
S2	5-8
S3	8-12
S4	12-20
S5	20-40
S6	40-100

Table A1-7: Erosion Hazard Class for input to the Soil capability classification

Erosion Hazard Class	Erosion Hazard	Erosion (t/ha.yr)
E1	Very Low	0-5
E2	Low	5-12
E3	Medium	12-25
E4	High	25-80
E5	Very High	80-150
E6	Extremely High	>150

Table A1-8: Slope Depth Class for input to the Soil capability classification

Soil Depth Class	Soil Depth (mm)
D1	>300
D2	200
D3	<100

Using the USDA Land Capability Classification System in conjunction with Davidsons's land usability criteria, the Athi Basin was assessed in terms of land capability (excluding meteorological conditions).. It is evident that the tops of hills and mountains have a soil capability of 8 and steep slopes have a soil capability of 5-7 (i.e. non-arable land). Most of the Basin has a soil capability of 1-3 (i.e. arable land). Overlaying Land Capability with the current land use in the Basin, provides an indication of the level of sustainable land use in the basin under current conditions. Sustainable land use occurs where crops occur on arable land, and unsustainable land use occurs where crops occur on non-arable land.

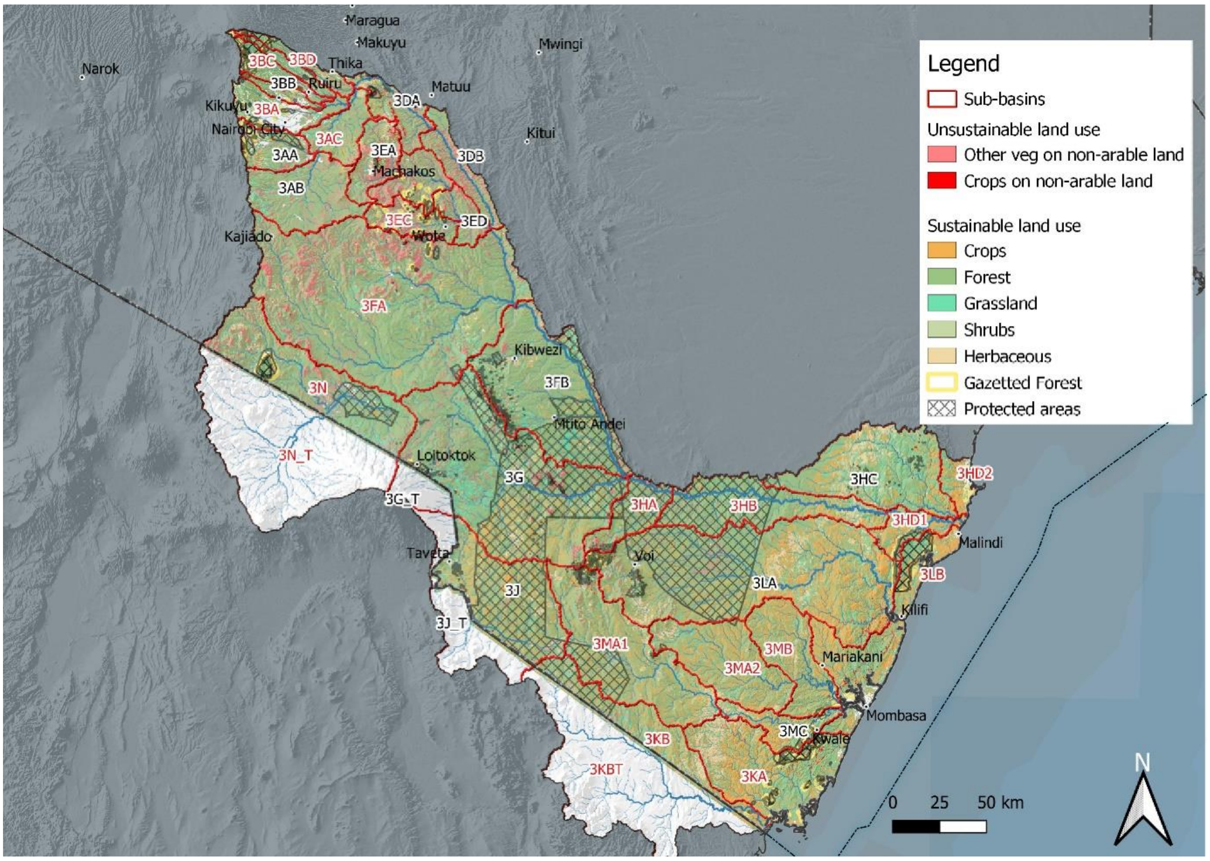


Figure A1-5: Sustainability of current land use in the Athi Basin

A2: Climate analysis

The scale of future climate impacts varies based on the anthropogenic mitigation of factors responsible for currently experienced changes. The mitigation scenarios account for several variances of potential global economic and environmental development and are quantified as the Representative Concentration Pathways (RCP).

In line with industry standards, the scenarios considered for this analysis were the RCP4.5 (likely) and RCP8.5 (worst case) scenarios. These RCPs show the change from pre-industrial insolation watts per m^2 resulting from the emissions. RCP 4.5 – likely best case – emissions stabilise from 2040 and decrease thereafter. RCP 8.5 represents the very high greenhouse gas emission scenario – emissions don't stabilise, worst case scenario with a focus on economic advancement at the expense of environmental sustainability. These emission scenarios give light to the varying potential climatic futures based on human development goals in the present and near future.

For these RCPs, Table A2-1 shows estimated concentrations of greenhouse gases viz. CO2, CH4 and N2O based on a combination of assessment models (MESSAGE (Riahi, Gruebler, & Nakicenovic , 2007), AIM (Hijioka , Matsuoka, Nishimoto, & Masui, 2008)), GCAM (Wise, et al., 2009), IMAGE (van Vuuren, et al., 2007)), global carbon cycle, and atmospheric chemistry and climate models. They also integrate assumed land use changes and sector-based emissions of greenhouse gasses from present day levels. The present greenhouse gasses include the sectoral assessment of energy supply, industry, transport, and buildings with contributions of 47%, 30%, 11% and 3% respectively (IPCC, Summary for Policymakers, 2014).

Table A2-1: Representative Concentration Pathways

	CO_2 (ppm)	CH_4 and N_2O (ppm)	Resulting radiative forcing ($W.m^{-2}$)	Scenario
RCP 4.5	538	92	4.5	Best case - Medium scenario
RCP 8.5	936	377	8.5	Worst case

The greenhouse gas concentrations under different RCPs are used as input for the coupled model ensembles of the IPCC Assessment Report Five (IPCC, Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects, 2014) (AR).

Using climate projection data requires the acknowledgement of various uncertainties. The IPCC projections rely on forty different GCMs with different accuracies forecasting to the varying RCP scenarios. These RCPs are themselves estimates of potential future thermal forcings, as informed by adherence to emission policies and potential future technologies. The downscaling of the IPCC data required robust constraining parameters to present a more accurate local projection. In areas where observational data is limited, these constraining parameters have increased uncertainty. Results obtained, and recommendations made based on these data should be used as a guideline to adapt/mitigate to a potential future climate rather than a definitive one. This is particularly prevalent when noting the significant disparity even in the current variability of rainfall regimes. This is influenced by things like topography, wind, vegetation and even ocean currents. Beyond that, a further layer of complexity is added with looking at rainfall intensity, diurnal and seasonal onsets before accounting for short and long-term influences such as the diurnal, seasonal, inter annual cycles, the ENSO cycles as well as decadal changes. When projecting precipitation changes into a semi unknown future these uncertainties are further exacerbated. The projection parameters are therefore presented in terms of a probability of changes highlighting the most likely range of precipitation experienced in the future. The probabilities also allow for the possibility of more extreme anomalous occurrence of events in both directions i.e. probability of more extreme rainfall days as well as less extreme rainfall days.

The climate of the Athi Basin is primarily forced by the topography of the basin and its proximity to the oceans and the equator. These factors contribute to the range and variability in precipitation and temperature regimes. The basin is semi-arid with the exception of more humid areas to the far north and a few isolated areas in the central and coastal areas. Flood and drought events do occur in the Athi basin, yet to a lesser degree than other basins in Kenya. The climate analysis which was undertaken as part of the Athi Basin Plan, focused on projected climate trends and analysed multiple spatial and temporal source datasets with the intention of better conveying the interactions between and impact on communities, water security and the environment as a result of projected climate change. Temporal analysis, of varying resolutions, informed likely anomalous climatic characteristics such as shifts in seasonality, extreme events occurrence, precipitation intensity and volumes.

Data to be used in climate analysis need to be of sufficient duration and resolution to account for the cycles of natural meteorological variability as well as any climate change signal embedded in the data. While there is currently a dearth of climate change data of sufficient length and integrity for trend analysis available, SIMCLIM (CLIMSystems, 2005) and CORDEX (Gutowski et al, 2016) data were used to inform the analysis of climate change impacts as part of the development of this Basin Plan.

SimCLIM data is downscaled to 5km resolution from the IPCC AR5 climate models. It presents the monthly projection from 1996 to 2100 through selected models or a model ensemble, with different environmental sensitivities. SimCLIM is native to ESRI ArcGIS 10.3 and provides the basis for all spatial climate analysis and long-term trends.

CORDEX (A Coordinated Regional Climate Downscaling Experiment) data is downscaled to 45km resolution and has a daily temporal scale to 2100. The high temporal resolution of this data gives an indication of intra-seasonal meteorological characteristics. High resolution data has several advantages over the large scale GCMs, chief among them the increased spatial and temporal resolution. Having spatial higher resolution provides greater local context between areas of interest, while daily scale temporal scales allow for analysis such as extreme events or accumulation anomalies that is not possible in monthly data. The CORDEX experiments seeks to downscale the GCMs utilised in the IPCC AR5 analysis.

The GCM models listed in Table A2-2 were utilised for downscaling in this analysis.

Table A2-2: GCM model input

Model	Institute
CCCma-CanESM2	Canadian Centre for Climate Modelling and Analysis
CNRM-CERFACS-CNRM-CM5	Météo-France / Centre National de Recherches Météorologiques
CSIRO-QCCCE-CSIRO-Mk3-6-0	Commonwealth Scientific and Industrial Research Organization& Queensland Climate Change Centre of Excellence
ICHEC-EC-EARTH	Irish Centre for High-End Computing & -Earth consortium
IPSL-IPSL-CM5A-MR	Institut Pierre Simon Laplace
IROC-MIROC5	Model for Interdisciplinary Research on Climate
MOHC-HadGEM2-ES	Met Office Hadley Centre
MPI-M-MPI-ESM-LR	Max-Planck-Institut für Meteorologie
NCC-NorESM1-M	Norwegian Climate Centre & Norwegian Earth System Model 1
NOAA-GFDL-GFDL-ESM2M	National Oceanic and Atmospheric Administration & Earth System Model - Geophysical Fluid Dynamics Laboratory

Precipitation and Temperature

The climate analysis showed a general increase (between 2% and 9%) in mean annual precipitation (MAP) across the Athi Basin by 2050, with the average MAP across the basin increasing from 749 mm to 802 mm by 2050 under RCP 4.5.

Day and night temperatures in the basin are expected to increase by up to 1.18°C and 1.3°C respectively by 2050 (RCP 4.5).

To assess the expected impacts on more localised precipitation in the Athi Basin as result of climate change, four sub-basins were selected for detailed analyses namely: 3DA and 3FA (North West Athi), as well as 3HA and 3MB (South East Athi). The sub-basins and river nodes are illustrated in Figure A2-1.

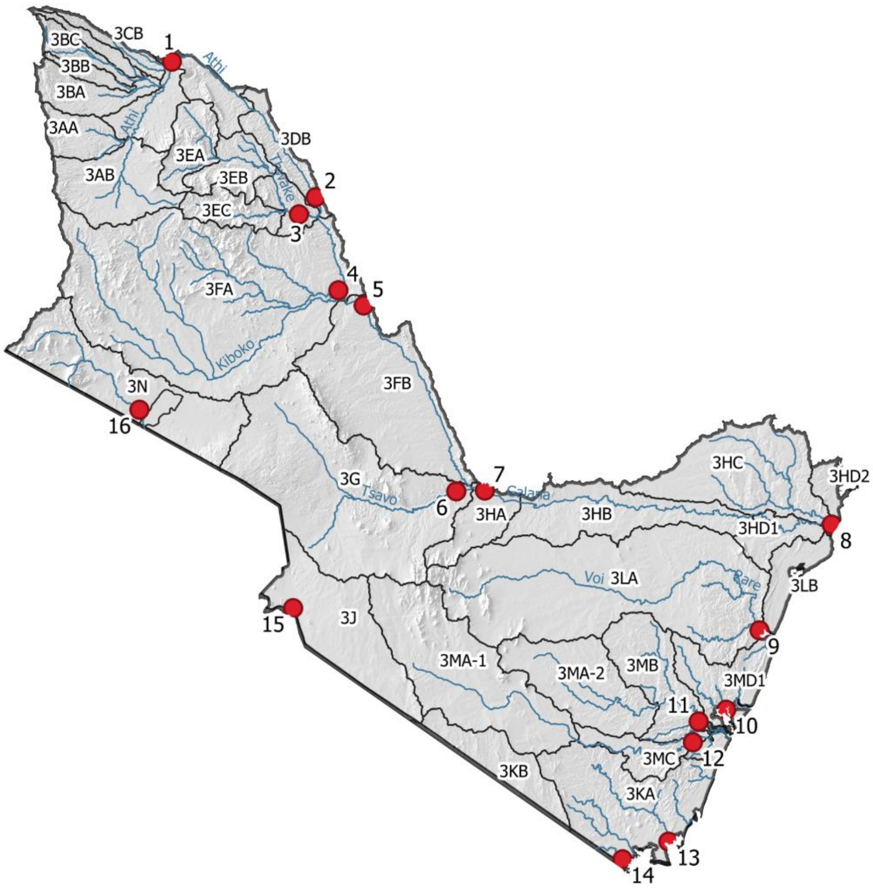


Figure A2-1: Athi Basin with sub-basins and river nodes

75th percentile precipitation values corresponding to the RCP4.5 scenario were used in the analysis. Figure A2-2 illustrates the anticipated changes in precipitation in the selected sub-basins. Changes were expressed as monthly percentage change from the average monthly historical precipitation (period between 1980-2000) to the average monthly future precipitation (period between 2040-2060).

Figure A2-2 indicates a consistent intensifying trend in future precipitation in all four sub-basins. The rainfall increases significantly during September and October, consequently shifting the short rainy season from starting at the end of October to starting in September, and intensifying it. Furthermore, the rainfall in February and March also increases significantly leading up to the long rainy season, consequently shifting the long rainy season from starting in March to starting in February. There is a general decrease in rainfall during the dry season from April to July. The north-western sub-basins also appear to be wetter in future than the south-eastern sub-basins.

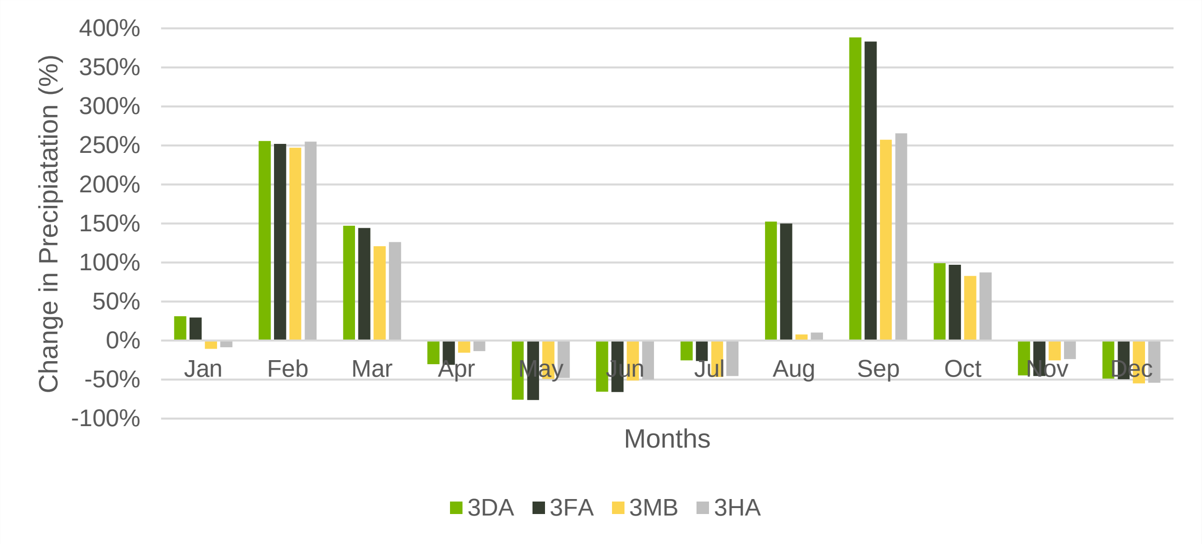


Figure A2-2: Percentage change in monthly precipitation for the period 2040 to 2060 compared to 1980 to 2000 in four sub-basins

Figure A2-3 to Figure A2-6 illustrate the historical monthly average precipitation (1980 to 2000), the monthly average future precipitation (2040 to 2060), as well as the associated percentage change in each of the four sub-basins. Evident from the figures is the significant increase in precipitation depth for September to October during the short rainy season. The increase in precipitation during September results in a future precipitation similar in magnitude to the historical October precipitation, suggesting that the short rainy season would start in September in future. Precipitation is expected to decrease during November and December (originally part of the short rainy season), suggesting that the short rainy season shortened and intensified in magnitude.

Figure A2-3 to Figure A2-6 further illustrate the significant increase in precipitation depth from February to March and significant decrease in precipitation depth from April to May. The increase in precipitation during February results in a future precipitation similar in magnitude to the historical March precipitation, suggesting that the long rainy season would start in February in future. Furthermore, the decrease in precipitation depth during April and May suggest that the long rainy season is likely to shift earlier, with a higher intensity.

The decrease in rainfall from April to July shows a decrease in precipitation depth during the dry season. Overall the precipitation will likely be more intense during the shifted rainfall seasons and drier during the dry seasons.

Figure A2-7 to Figure A2-10 present the range of monthly precipitation as box and whisker plots for both historical (1980 to 2000) precipitation as well as future (2040 to 2060) expected precipitation.

The figures show a significant increase under climate change in mean precipitation for September accompanied by a significant increase in the range of precipitation depths, suggesting that September precipitation will become more variable (see Figure A2-6a) as an example). Similarly, the figures show an increase in mean precipitation for October, February and March under climate change, as well as an increase in the precipitation range. During November, December, April and May, the mean precipitation decreases significantly coupled with an increase range in precipitation depths. This suggests higher precipitation variability during the short and long rainy seasons, as well as more intense precipitation events.

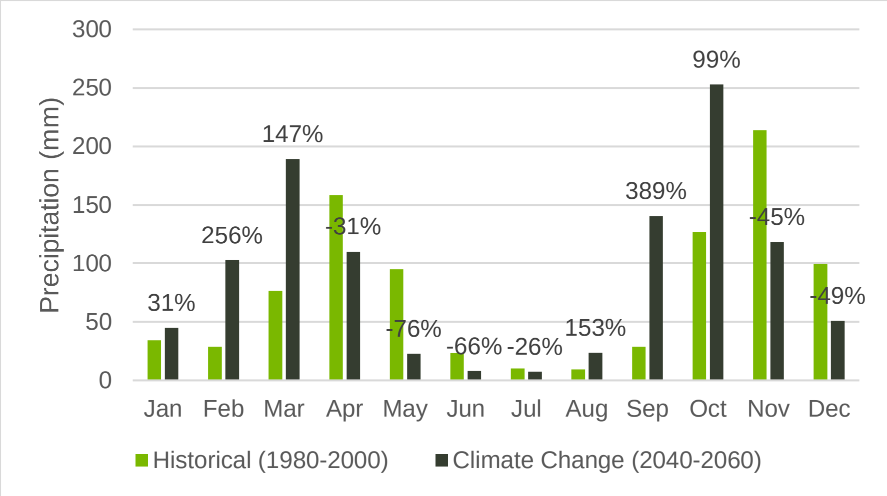


Figure A2-3: Percentage change - monthly avg. precipitation sub-basin 3DA

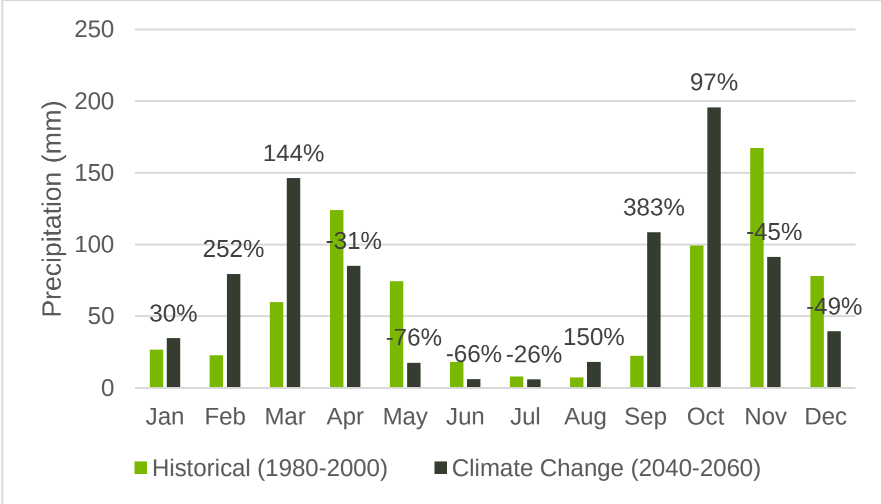


Figure A2-5: Percentage change - monthly avg. precipitation sub-basin 3FA

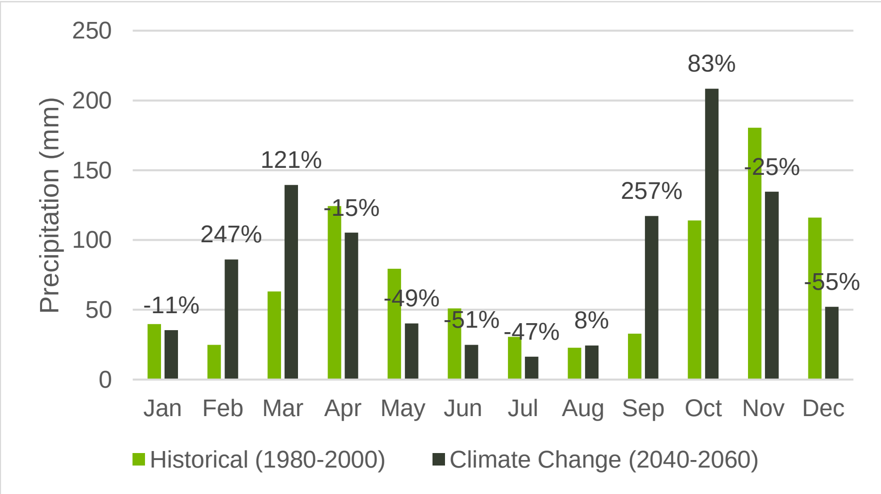


Figure A2-4: Percentage change - monthly avg. precipitation sub-basin 3MB

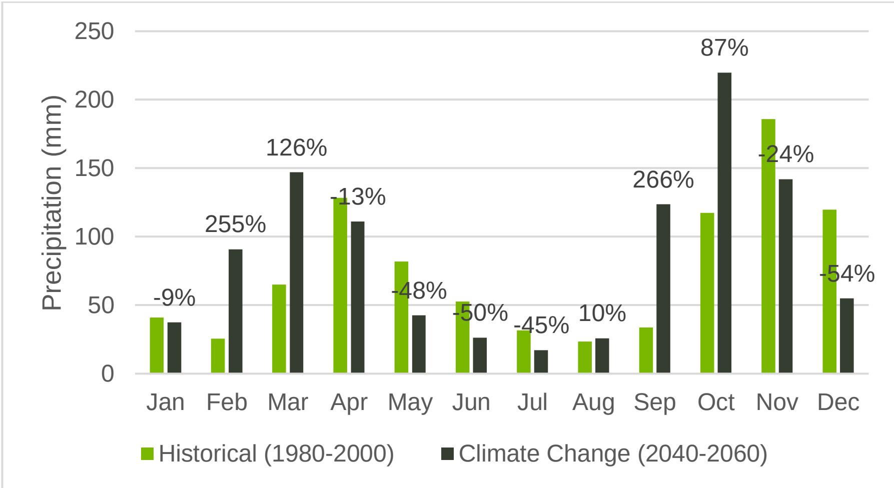


Figure A2-6: Percentage change - monthly avg. precipitation sub-basin 3HA

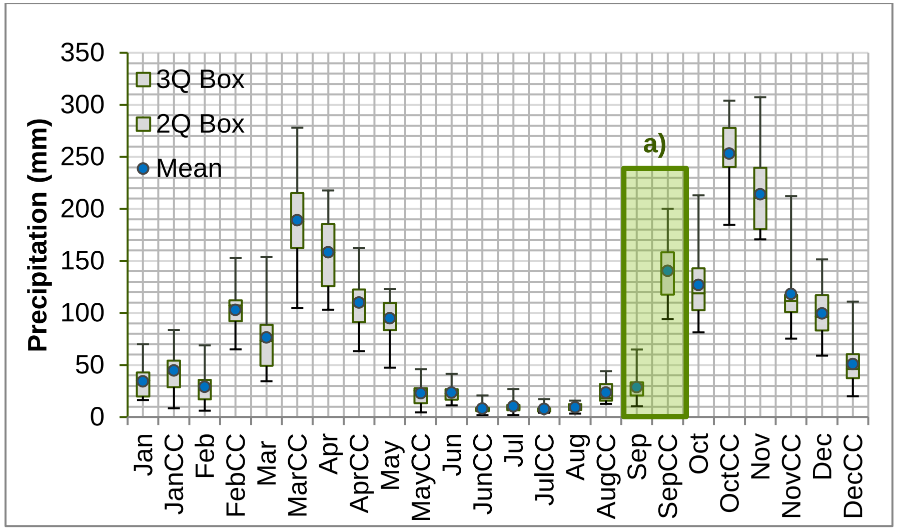


Figure A2-7: Precipitation box-plots for sub-basin 3DA

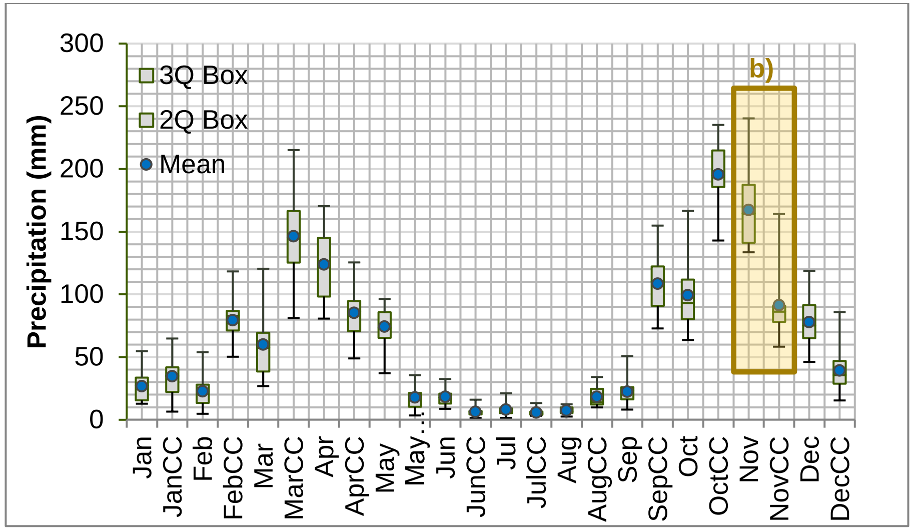


Figure A2-9: Precipitation box-plots for sub-basin 3FA

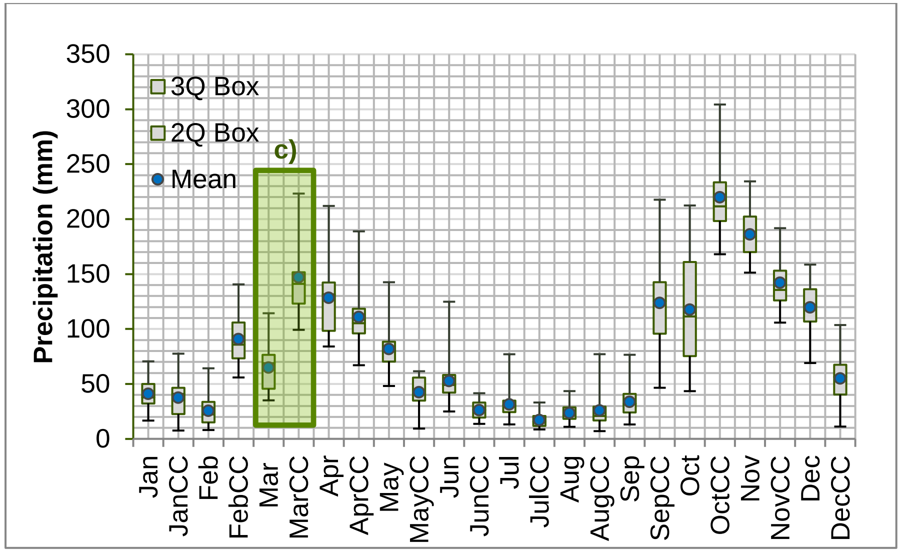


Figure A2-8: Precipitation box-plots for sub-basin 3HA

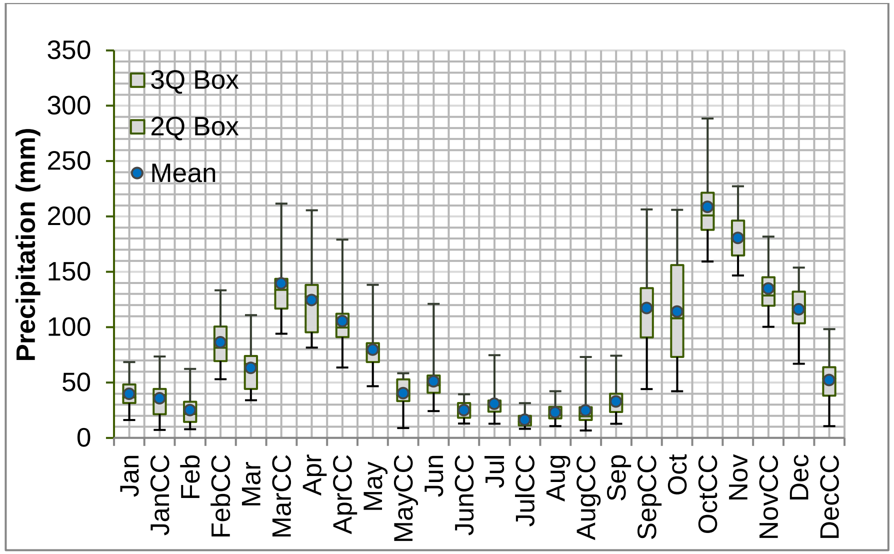


Figure A2-10: Precipitation box-plots for sub-basin 3MB

Stream Flow

Projected sub-basin precipitation and temperature changes under climate change scenario RCP 4.5 were superimposed on the hydrological model of the Athi Basin to assess the potential impacts on runoff. A simulation period of 1960 to 2017 was used. The analysis showed that the natural runoff in most western sub-basins increases by up to 15%, while in the eastern sub-basins a decrease by up to 2.5% is expected. The total surface water runoff from the Athi Basin is projected to increase with 4% by 2050 under RCP 4.5.

To assess the expected impacts on stream flow in the Athi Basin as result of climate change, four river nodes were selected: Node 1 and Node 4 in the upper western catchment; and Node 7 and Node 11 in the lower eastern catchment. The river nodes within the Athi Basin are indicated by red dots in Figure A2-1.

Figure A2-11 shows the percentage change in monthly average natural flow under climate change at each river node. The flow is expected to increase during all moths for nodes 1, 4 and 7. The natural flow is only expected to decrease during the dry season in July to September as well as in October for node 11. The average flow is thus expected to increase during the 'long' and 'short' rainy season as well as during the dry season. However, it is evident from node 11 that the flow does not increase as significantly as for the other nodes, suggesting that the eastern catchments of the Athi basin may become drier. Note that the high percentage increase in precipitation (Figure A2-2) during September, October and February and March results in a smaller magnitude percentage increase in flow (Figure A2-11) due to evapotranspiration and evaporation as result of increased temperatures.

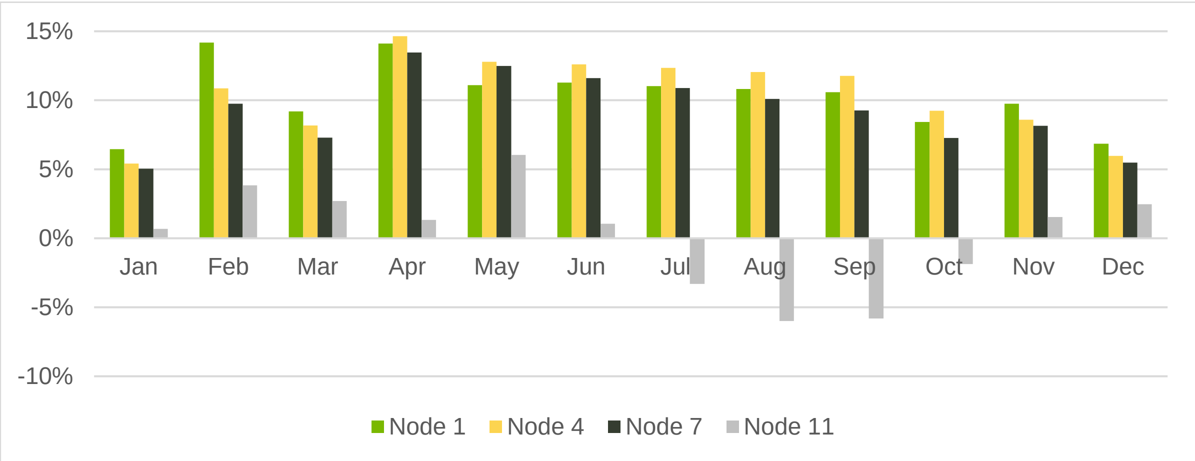


Figure A2-11: Percentage change between historical naturalised flow and naturalised flow with climate change

Figure A2-16 to Figure A2-19 illustrate the historical and future (climate change) monthly average flow, as well as the associated percentage change pertaining to each node, while Figure A2-12 to Figure A2-15 present flow duration curves for each node as well as the associated percentage change for different exceedance probabilities under climate change.

With respect to node 1 (Figure A2-16), high flows with a low exceedance probability (less than 20%) are expected to experience a smaller relative increase compared to lower flows associated with high exceedance probabilities (greater than 80%); suggesting that the rivers will be able to better sustain low flows in dry season. Furthermore, even though a decrease in monthly average flow is expected during April to September, the increased flows over the period between January to March increase the average low flow in the river, specifically for node 1 (upper western catchment), suggesting a high rainfall-runoff response in the steep catchment. Node 4, node 7 and node 11 portray a general increased magnitude in flow peaks in both the high flows and low flows.

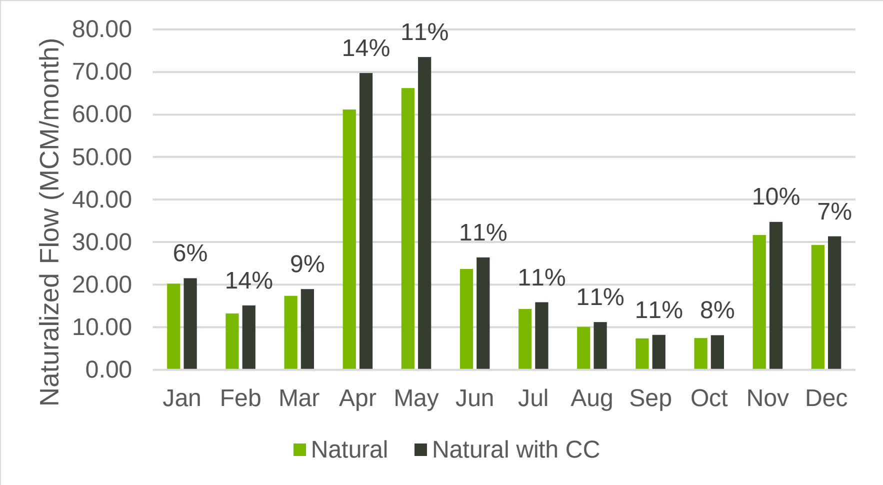


Figure A2-12: Monthly average flows and percentage change under current and future climate conditions – Athi Node 1

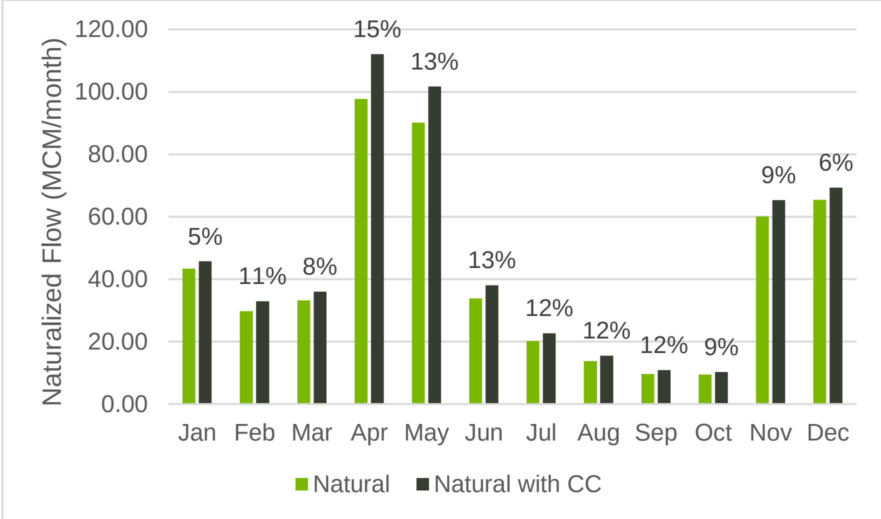


Figure A2-13: Monthly average flows and percentage change under current and future climate conditions - Athi Node 4

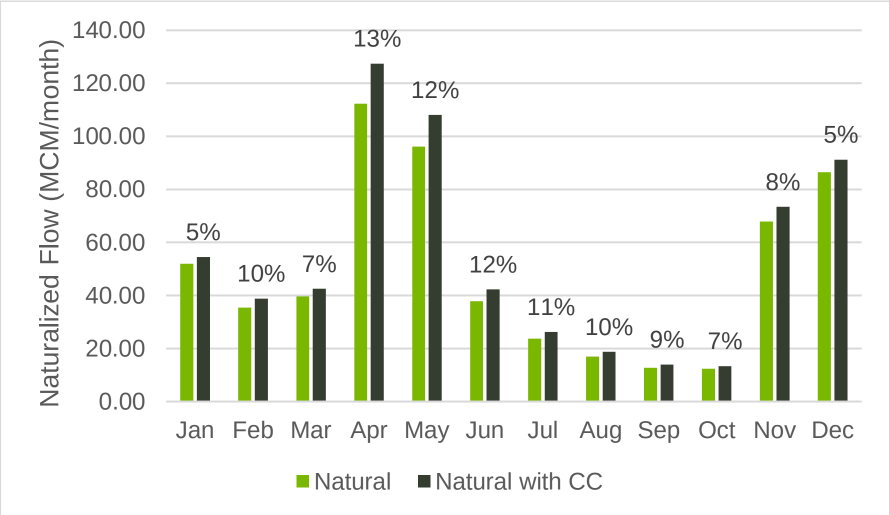


Figure A2-14: Monthly average flows and percentage change under current and future climate conditions – Athi Node 7

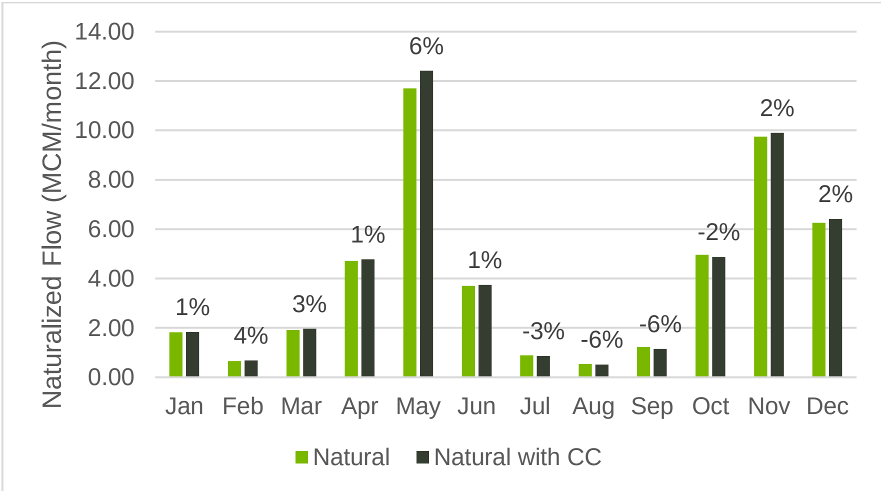


Figure A2-15: Monthly average flows and percentage change under current and future climate conditions - Athi Node 11

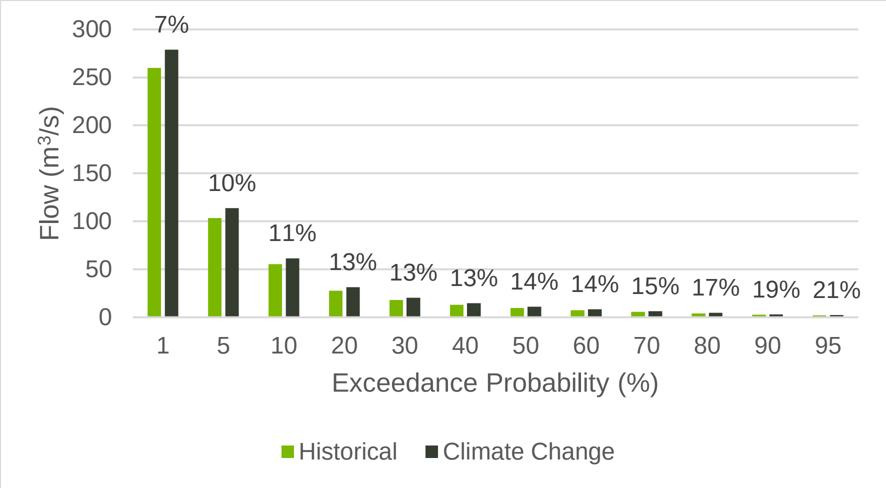


Figure A2-16: Monthly flow exceedance and percentage change under current and future climate conditions – Athi Node 1

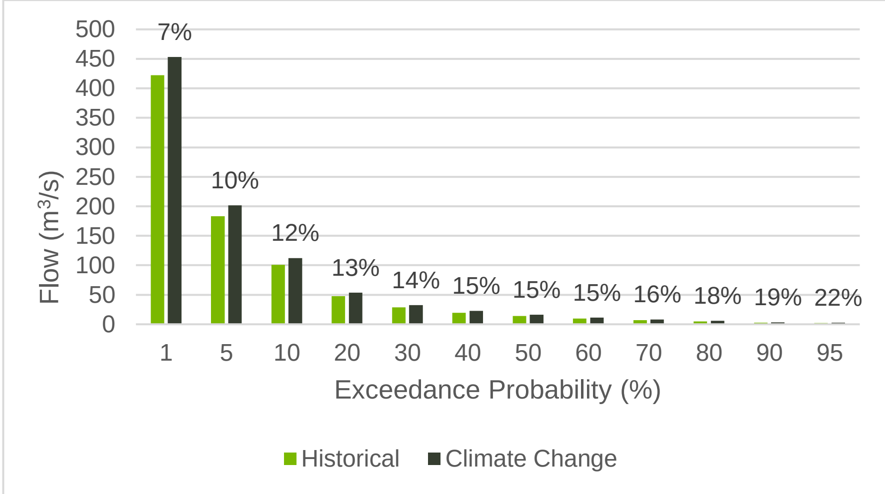


Figure A2-17: Monthly flow exceedance and percentage change under current and future climate conditions – Athi Node 4

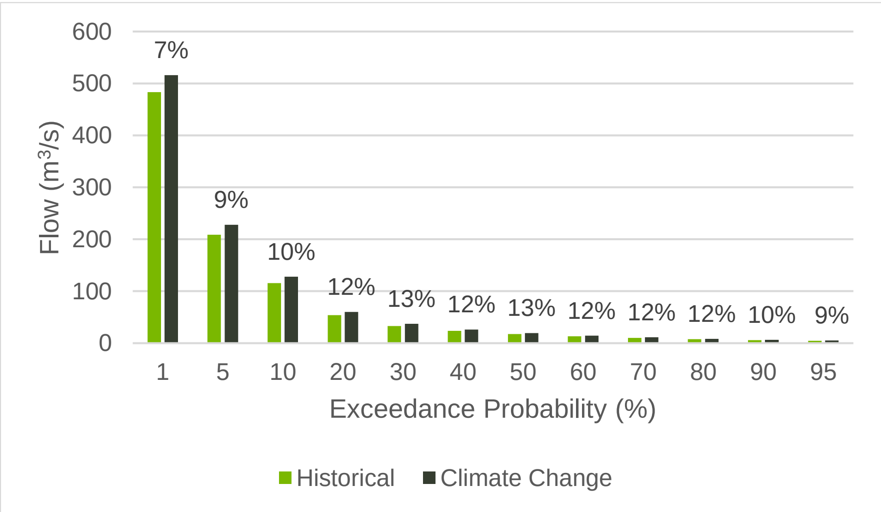


Figure A2-18: Monthly flow exceedance and percentage change under current and future climate conditions – Athi Node 7

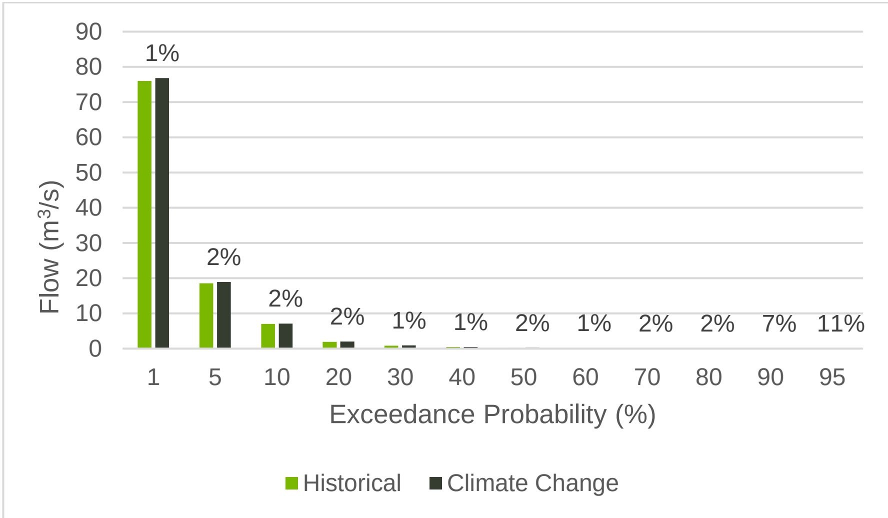


Figure A2-19: Monthly flow exceedance and percentage change under current and future climate conditions – Athi Node 11

A3: Surface water resources modelling

The main objectives of the surface water resources analysis for the Athi Basin are to quantify the available surface water within the basin under natural conditions in both space and time, as well as to assess the present-day (baseline) surface water availability. This has been achieved through the development of a water resources systems model of the basin, which simulates the hydrological network, water demands and water resources infrastructure. MIKE HYDRO Basin, which incorporates the NAM rainfall-runoff model, was used as the water resources system model.

Hydrometeorological data collection and review

The Water Resources Authority (WRA) rainfall database contains historical daily data at 139 rainfall stations in the Athi Basin, with data availability ranging from 1926 up to 2010. Of these, 37 stations with good quality records were selected. Raw data availability at each station is displayed in Figure A3-1, while the locations of the stations are shown in Figure A3-2.

Using monthly gap-filling tools, the station records were patched. The monthly gap filled data were disaggregated to daily data using nearby station daily rainfall patterns.

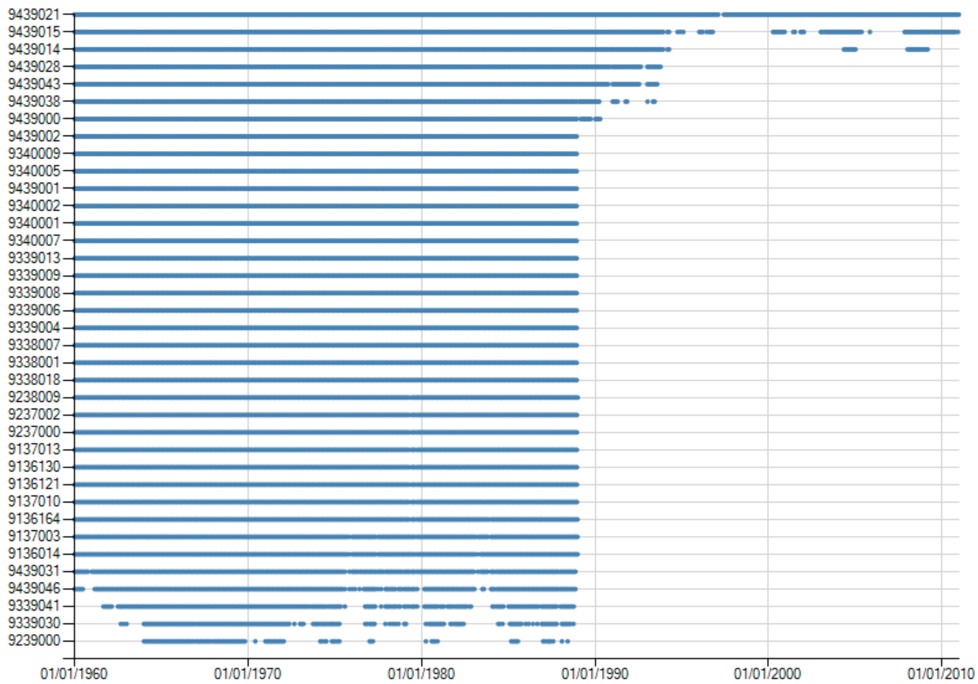


Figure A3-1: Data availability at selected rainfall stations

As the majority of the WRA data only extended up to Dec 1989, the Climate Hazards Group InfraRed Precipitation with Stations data (CHIRPS) dataset (Funk et al, 2015) was used to extend the rainfall datasets at the selected stations from 1989 to 2010. The CHIRPS dataset was identified for potential use, due to its relatively high resolution compared to other blended station data and satellite blended precipitation datasets. CHIRPS is a 30+ year quasi-global rainfall dataset, spanning 50°S - 50°N (and all longitudes). CHIRPS incorporates 0.05° resolution satellite imagery with in-situ station data to create gridded rainfall time series starting in 1981 to near-present. CHIRPS was developed to support the United States Agency for International Development Famine Early Warning Systems Network (FEWS NET) and is freely available. CHIRPS data been used in studies to quantify the hydrologic impacts of decreasing precipitation and rising air temperatures in the Greater Horn of Africa, as well as support effective hydrologic forecasts and trend analyses in south-eastern Ethiopia (Funk, et al., 2015). CHIRPS daily precipitation data (Jan 1989 - Jan 2017) were extracted for multiple 0.05° grid cells corresponding to selected rainfall stations locations. The extracted CHIRPS records were used to extend the gap-filled observed rainfall records providing point rainfall time series for the period from Jan 1960 to Jan 2017.

Due to the relatively few rainfall stations in the Athi Basin, as well as the limited availability of high elevation and near recent observed precipitation data, a Mean Annual Precipitation (MAP) surface for the basin was generated using the CHIRPS rainfall dataset (see Figure A3-3).

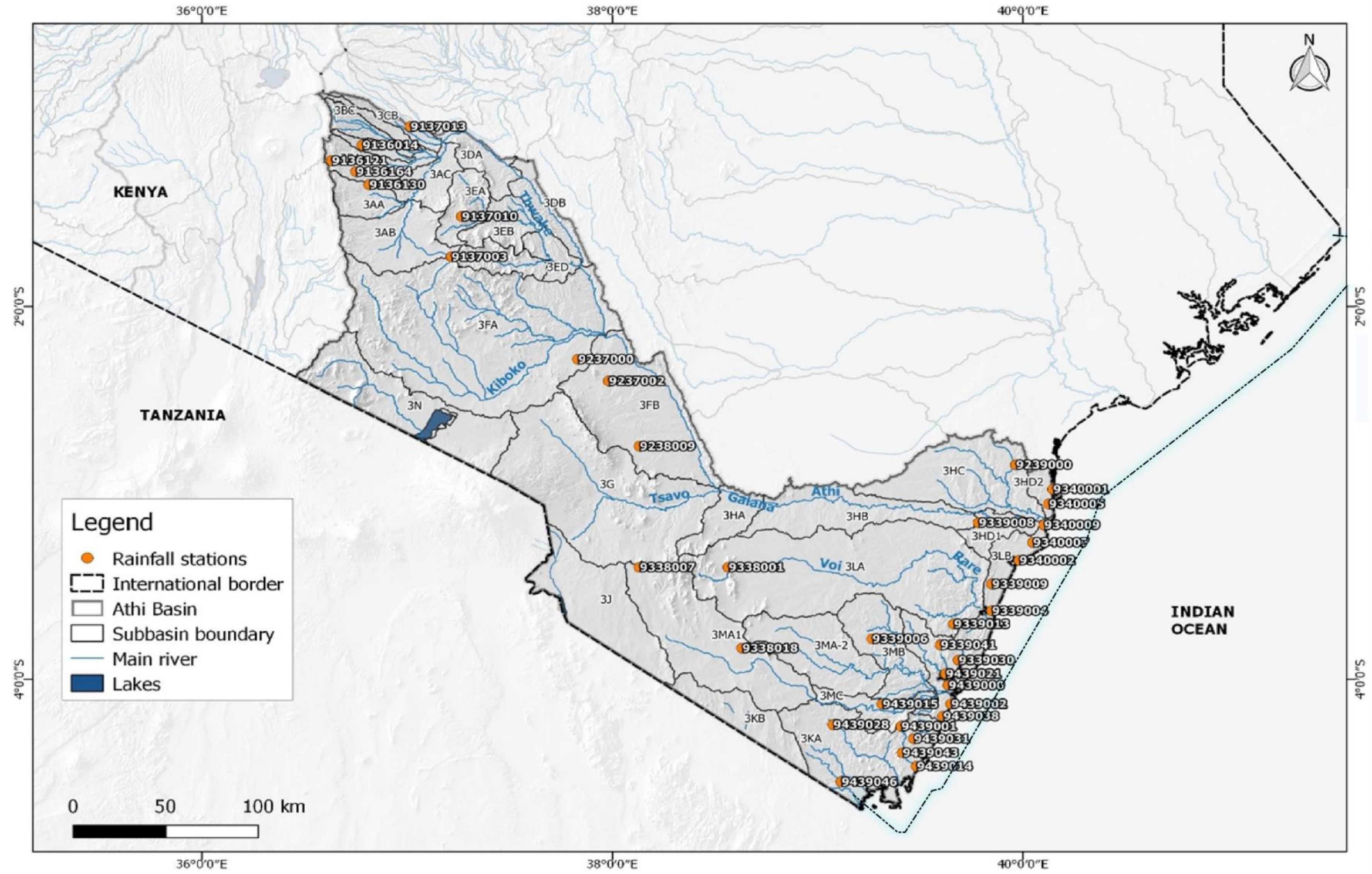


Figure A3-2: Location of selected rainfall stations

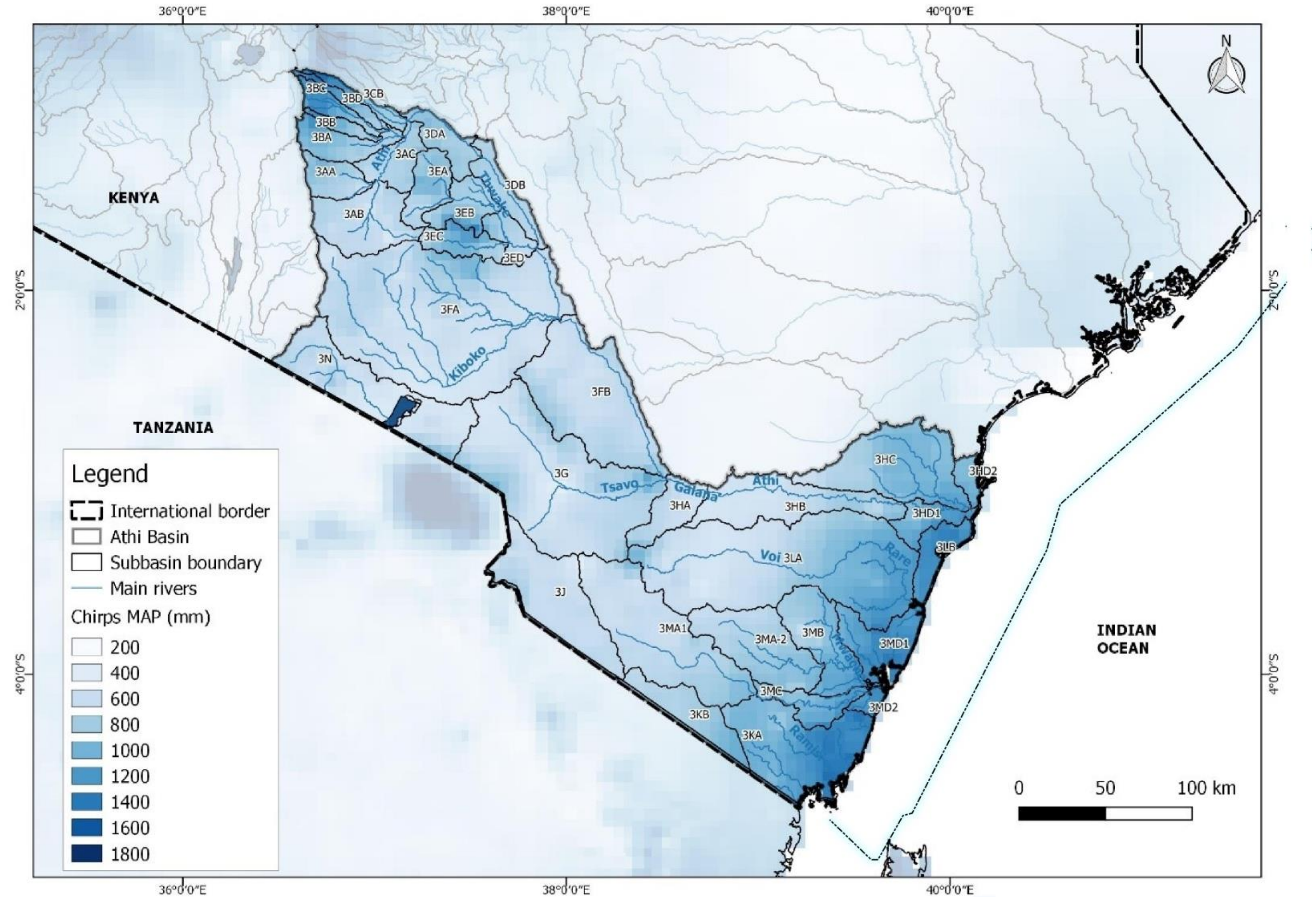


Figure A3-3: Mean Annual Precipitation

Streamflow data

In total, the Athi Basin has historical daily water level records of varying quality and completeness for approximately 200 streamflow stations. Historical spot flow measurements of water level and discharge are available at 70 stations, with converted discharge records only available at 29 stations. A review of the available discharge records based on station location, records length, and data quality, resulted in an initial selection of 15 stations which are representative of the upper, middle and lower sections of the basin. Data availability at these stations, as sourced from WRA, is shown in Figure A3-4. Record periods at these stations vary between 6 and 28 years, however some stations are characterised by significant periods of missing data.

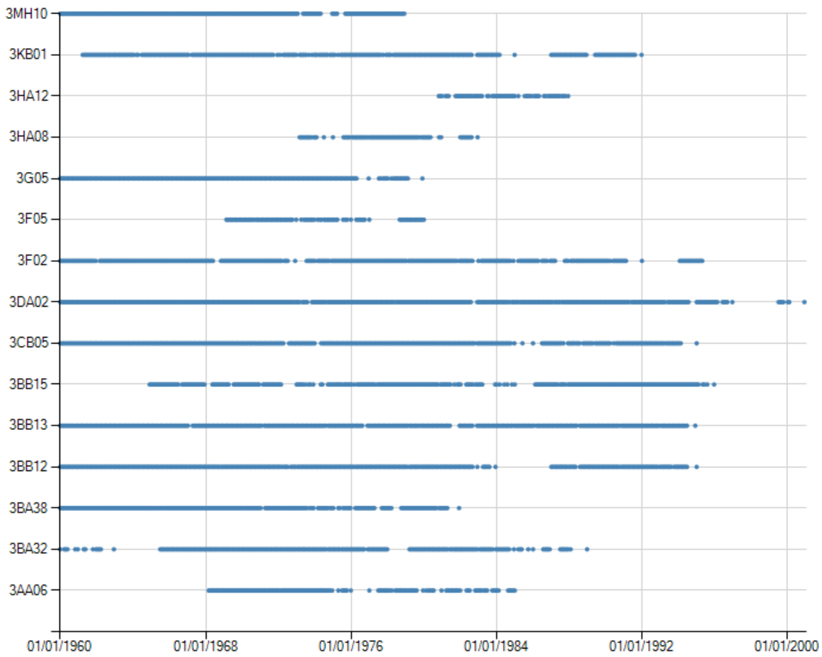


Figure A3-4: Data availability at selected river gauging stations

After quality control, which involved graphical analysis, mass plots and statistical analyses, anomalies and inconsistencies in some of the station records were identified. Eventually, only 12 stations were selected as listed in Table A3-1. These stations were used for calibration and validation of the rainfall-runoff model. Their locations within the basin are indicated in Figure A3-5.

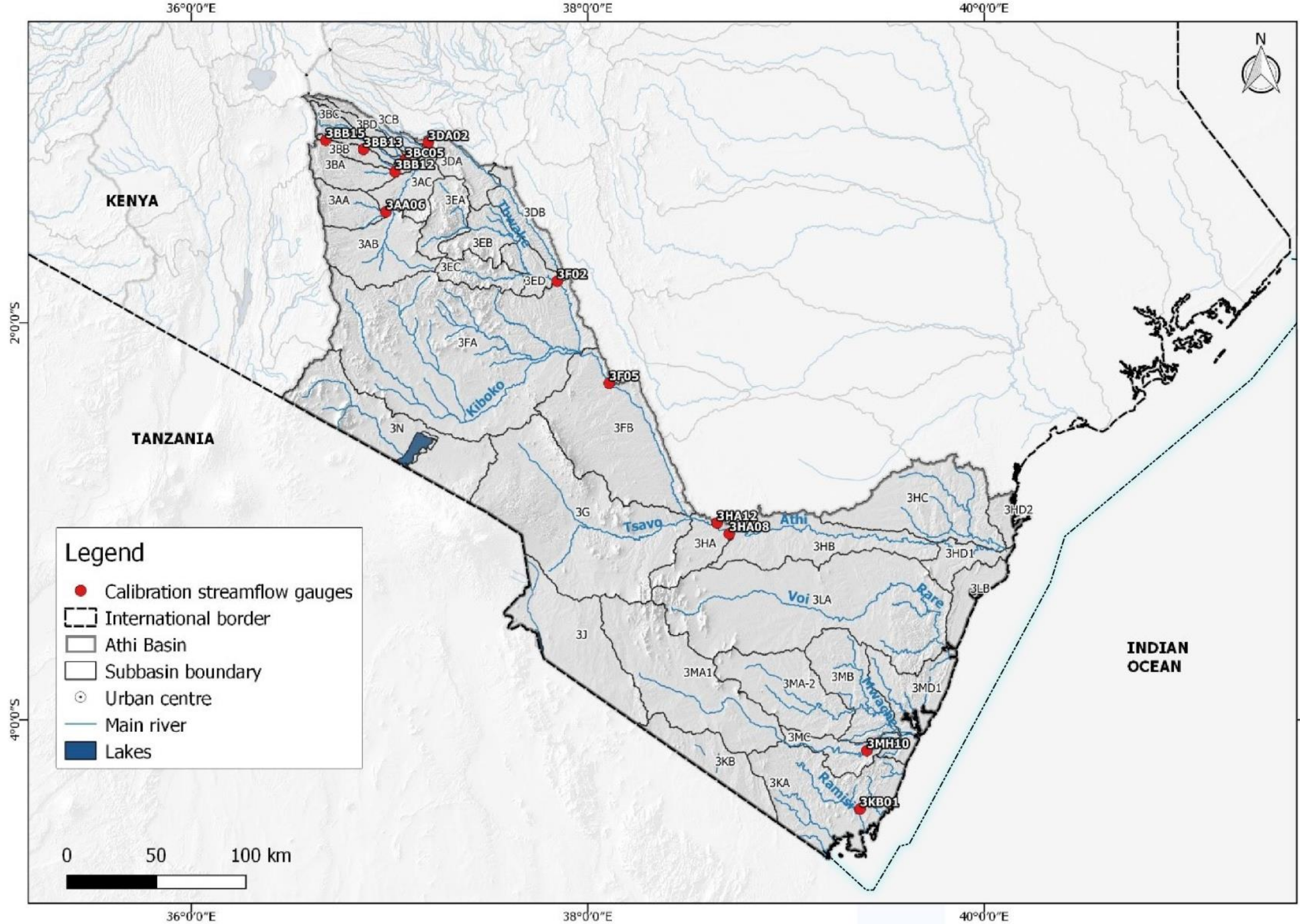


Figure A3-5: Locations of selected streamflow gauging stations

Table A3-1: Selected streamflow gauges for model calibration and validation

Station ID	Name	Longitude (°)	Latitude (°)	Catchment Area (km^2)
3AA06	Athi	36.9819	-1.4403	720
3BB12	Kamiti	36.9708	-1.1972	234
3BB13	Kiu	36.9583	-1.2000	102.4
3BB15	Kamiti	36.6778	-1.0794	14.8
3CB05	Ndarugu	37.1611	-1.1306	296.5
3DA02	Athi Munyu	37.1944	-1.0917	5720
3F02	Athi Mavindini	37.8458	-1.7903	10,206
3F05	Athi Kibwezi	38.1083	-2.3042	20,551
3HA08	Sabaki Lugard	38.6917	-3.0417	31,810
3HA12	Sabaki Cableway	38.6833	-3.0389	31,806
3KB01	Ramisi	39.3733	-4.4500	1,358
3MH10	Demba	39.4083	-4.1556	1,023

Evaporation data

Potential or reference evapotranspiration (ETo) data is one of the key inputs for rainfall runoff modelling. An analysis of evaporation data in the WRA repository was undertaken to assess data availability. The WRA database contains seven evaporation stations in the Athi Basin. However, stations are plagued with data availability issues with three stations containing no data as shown in Figure A3-6.

Observed evaporation data were thus considered insufficient for water resources modelling and gridded temperature data from the US National Oceanic and Atmospheric Administration (NOAA) was rather used to derive potential evaporation estimates in the basin. The NOAA dataset was derived from observed temperature data and consists of gridded average temperature data with a spatial resolution of 0.5° (approximately 50km over the equator) and a temporal resolution of one month for the period 1948-2017. The temperature based Blaney-Criddle method was used to convert the temperature data to monthly gridded reference ETo.

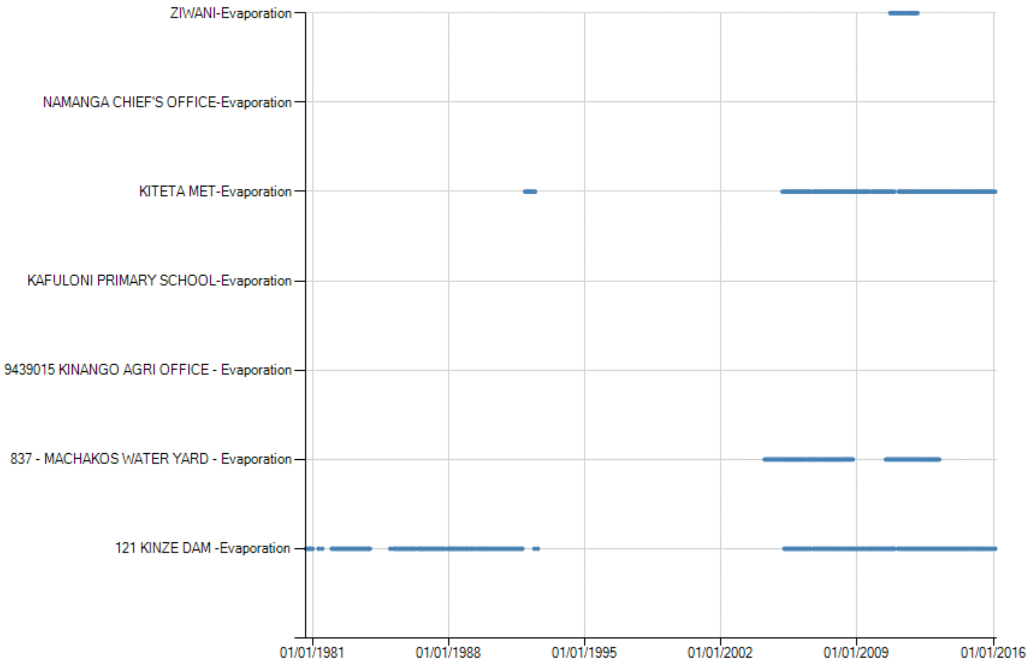


Figure A3-6: Data availability at evaporation stations

Water Resources Model

MIKE HYDRO Basin is a commercially-available, multipurpose, map-based decision support tool developed by the Danish Hydraulics Institute (DHI) for integrated river basin analysis, planning and management (DHI, 2017). It is designed for analysing water sharing issues at international, national and local river basin level and includes the lumped and conceptual NAM rainfall-runoff model.

In essence, the purpose of the water resources simulation modelling as part of this study, was to provide a tool to determine the natural, current and future surface water balance of the Athi Basin and to assess the impacts of future development opportunities in an integrated manner to support future water allocations and planning. The model was used, firstly, to evaluate the historic (natural) and present-day (baseline) water balance of the Basin and will be used to simulate the water balance under alternative future development, land-use and climate-change scenarios during the next model development phase.

Based on the availability of historical rainfall data (see Section **Error! Reference source not found.**), a simulation period from 1 Jan 1960 to 1 Jan 2017 was determined for the model simulations, which were conducted at a daily time-step.

The water resources modelling task involved the sequential steps listed below, each of which is discussed in more detail in the following sections:

1. Model sub-catchment delineation
2. Assignment of hydro-meteorological time series data to model sub-catchments
3. Model calibration and validation
4. Configuration of natural and present-day models

Catchment delineation

River network generation and catchment delineation of model sub-catchment areas within the Athi Basin were based on the HydroSHED hydrologically conditioned 90 m SRTM DEM (NASA, 2009), processed within MIKE HYDRO Basin's catchment delineation tool. Sub-catchment areas were delineated upstream of points of interest such as WRA sub-basin outlets (i.e. 3AA, 3AB…), streamflow gauging stations, existing and proposed dams, tributary confluences, river diversion or abstraction points and proposed water resources development schemes. Figure A3-7 presents an overview of the Athi Basin containing the final delineated model sub-catchments. In total, 89 sub-catchments were delineated, while 6 sub-catchments were constructed as 'Sketched' catchments - typically to accommodate water transfers or springs.

Assignment of hydro-meteorological data

The NAM rainfall-runoff model, which is incorporated in the MIKE HYDRO Basin model, requires rainfall and evaporation time series data to be assigned to each model sub-catchment.

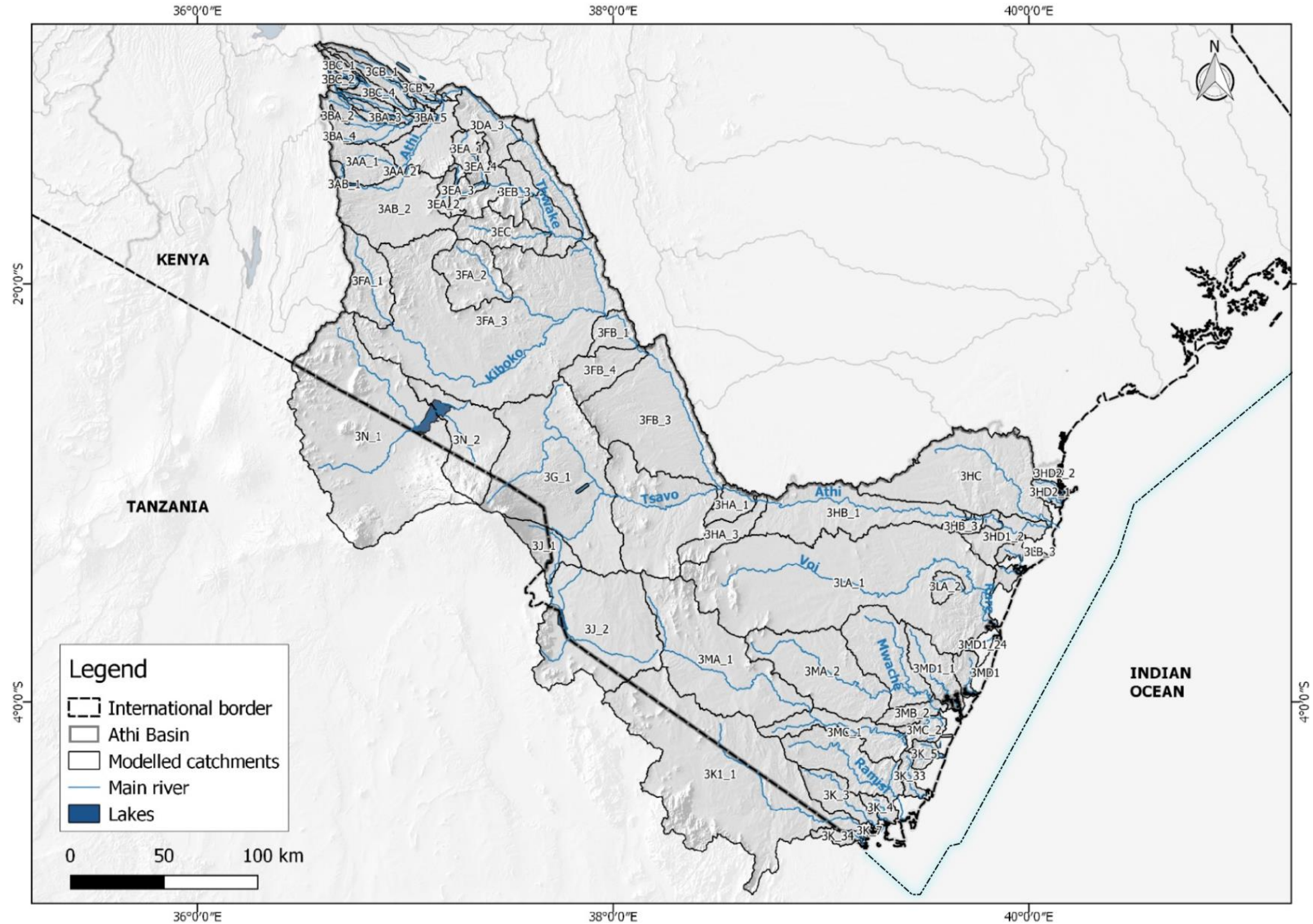


Figure A3-7: Delineated model sub-catchments in the Athi Basin

The point rainfall data at the 37 rainfall stations across the Basin (see Section 2.1) were converted from units of millimetres per day to % MAP per day for the simulation period (1960 – 2017). Point rainfall time series were then converted to catchment (areal) rainfall time series with the use of Thiessen Polygons, resulting in a single, daily % MAP file for each modelled sub-catchment. The conversion of rainfall units from % MAP back to mm, was achieved though multiplication with the sub-catchment MAPs extracted from the CHIRPS-based MAP coverage.

Based on the constructed ETo surface for the Athi Basin as discussed in Section 0, areal averaged monthly ETo values for each model sub-catchment were calculated and assigned. An example of calculated daily ETo values at locations in the upper, middle and lower Basin is shown in Figure A3-8.

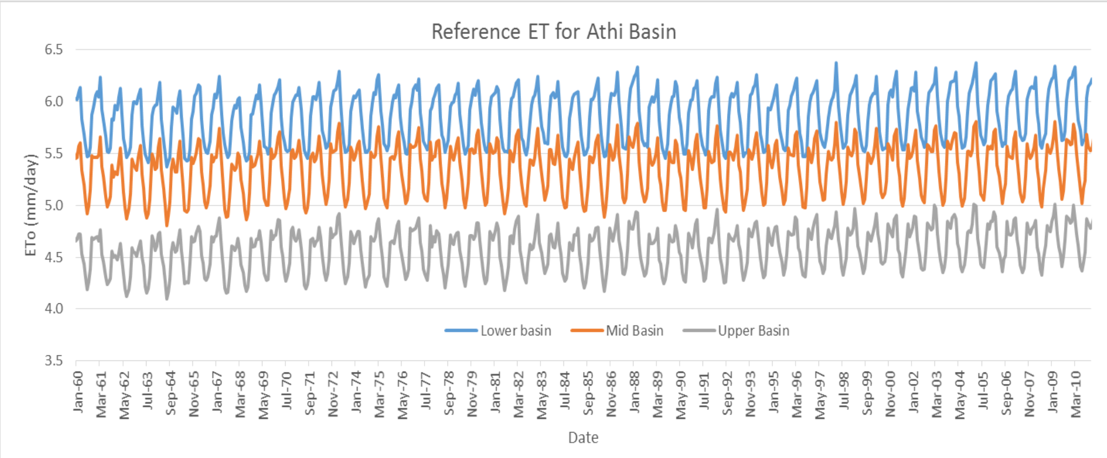


Figure A3-8: Typical reference ETo values in the upper, middle and lower Athi Basin

Model Calibration

The calibration of the NAM rainfall-runoff model in the Athi Basin was dependent on the availability of concurrent and good quality historical precipitation and streamflow data, as discussed in Section **Error! Reference source not found.** and Section 0. On this basis, 8 of the 12 selected flow gauging stations were chosen as calibration locations. The majority of potential calibration periods at these stations occurred between 1960 and 1980 - due to better observed data availability and apparent superior data quality compared to more recent time periods. Although the relatively undeveloped state of the identified calibration catchments during this time period meant that the catchments could be considered close to their 'natural' state, historical water demand data for calibration periods, from the WRA database, were added to downstream observed streamflow records at the calibration sites in order to 'naturalise' the observed flow records before calibration. A description of the NAM rainfall-runoff model calibration parameters is provided in Table A3-2.

Table A3-2: NAM rainfall-runoff calibration parameters

Category	Parameter Name	Parameter Abbreviation	Description	Typical Values
Surface-rootzone:	Maximum water content in surface storage	UMax	Represents the cumulative total water content of the interception storage (on vegetation), surface depression storage and storage in the uppermost layers (a few cm) of the soil.	10 mm-20 mm
Surface-rootzone:	Maximum water content in root zone storage	LMax	Represents the maximum soil moisture content in the root zone, which is available for transpiration by vegetation.	50 mm-300 m

Category	Parameter Name	Parameter Abbreviation	Description	Typical Values
Surface-rootzone:	Overland flow runoff coefficient	CQOF	Determines the division of excess rainfall between overland flow and infiltration.	0-1
Surface-rootzone:	Time constants for routing interflow	CKIF	Determines the amount of interflow, which decreases with larger time constants.	500 hrs - 1000 hrs
Surface-rootzone:	Time constants for routing overland flow	CK1	Determine the shape of Hydrograph peaks. The routing takes place through two linear reservoirs (serially connected) with different time constants, expressed in hours. High, sharp peaks are simulated with small time constants, whereas low peaks, at a later time, are simulated with large values of these parameters.	3 hrs - 48 hrs
Surface-rootzone:	Time constants for routing overland flow	CK2		
Surface-rootzone:	Root zone threshold value for overland flow	TOF	Determines the relative value of the moisture content in the root zone (L/Lmax) above which overland flow is generated. The main impact of TOF is seen at the beginning of a wet season, where an increase of the parameter value will delay the start of runoff as overland flow.	0% - 70% of Lmax. Max value 0.99
Surface-rootzone:	Root zone threshold value for interflow	TIF	Determines the relative value of the moisture content in the root zone (L/Lmax) above which interflow is generated.	-
Groundwater	Root zone threshold value for GW recharge	TG	Determines the relative value of the moisture content in the root zone (L/Lmax) above which groundwater (GW) recharge is generated. The main impact of increasing TG is less recharge to the groundwater storage.	0% - 70% of Lmax. Max value 0.99
Groundwater	Time constants for routing base flow	CKBF	Can be determined from the Hydrograph recession in dry periods. In rare cases, the shape of the measured recession changes to a slower recession after some time.	-
Groundwater	Lower base flow/recharge to lower reservoir	CQLow	Percentage recharge to the lower groundwater reservoir as percentage of the total recharge.	0% - 100%
Groundwater	Time constant for routing lower base flow	CKLow	Specified for CQLow > 0 as a baseflow time constant, which is usually larger than the CKBF.	-

Simulated streamflow sequences were calibrated against naturalised observed flow records through the iterative adjustment of the NAM model parameters until the ‘goodness of fit’ between the simulated and observed flow records was within acceptable standards. ‘Goodness of fit’ was assessed based on graphical comparison of time series and scatterplots, while various metrics and statistical indices such as average annual flow, standard deviation of annual flow, seasonality index, coefficient of determination and the Nash-Sutcliffe coefficient of efficiency were considered.

The Nash-Sutcliffe Efficiency (NSE) is a normalised statistic used to assess the predictive power of hydrological models by determining the relative magnitude of the residual variance compared to the measured data variance (Nash and Sutcliffe, 1970). NSE indicates how well the plot of observed versus simulated data fits the 1:1 line. NSE ranges between $-\infty$ and 1, with NSE equal to 1 being the optimal value. Values between 0 and 1 are generally viewed as acceptable levels of performance, whereas values smaller than 0 indicates that the mean observed value is a better predictor than the simulated value, which indicates unacceptable performance (Moriasi et al., 2007).

Calibrated NAM parameters at the calibration gauges are presented in Table A3-3 with calibration performance metrics per gauge summarised in Table A3-4. Calibration plots are presented in Figure A3-9 to Figure A3-16.

Table A3-3: Calibrated NAM model parameters

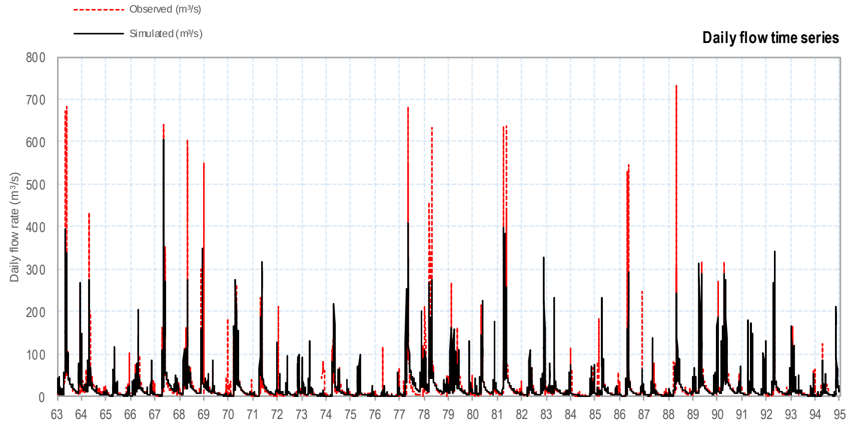
Gauge		Surface-rootzone							
Parameter Set	Gauge	Umax	Lmax	CQOF	CKIF	CK1	CK2	TOF	TIF
no.	ID	mm	mm	-	h	h	h	-	-
1	3AA06	8	275	0.5	200	30	-	0.05	0
2	3BB12	4	150	0.3	200	30	-	0.1	0
3	3CB05	2	100	0.5	200	30	-	0.4	0.2
4	3DA02	8	220	0.3	400	40	-	0.2	0.1
5	3F02	18	270	0.4	600	40	80	0.1	0.4
6	3F05	8	350	0.1	600	40	-	0.05	0.5
7	3KB01	15	275	0.5	400	40	-	0.1	0
8	3MH10	18	375	0.2	400	40	-	0.4	0.5

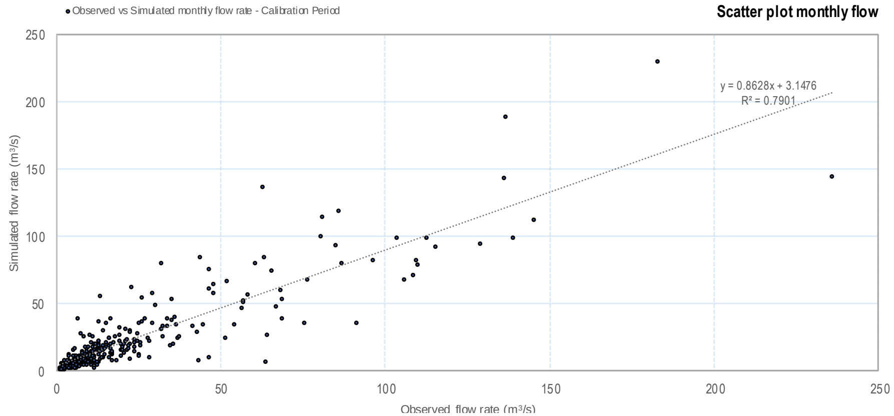
Gauge		Groundwater			
Parameter Set	Gauge	TG	CKBF	CQLow	CKLow
no.	ID	-	h	%	h
1	3AA06	0.6	1000	30	4500
2	3BB12	0.2	2000	40	4500
3	3CB05	0.4	1500	30	4500
4	3DA02	0.75	2000	30	4500
5	3F02	0.9	1500	30	4500
6	3F05	0.2	1500	-	-
7	3KB01	0.75	400	40	7000
8	3MH10	0.6	1000	40	7000

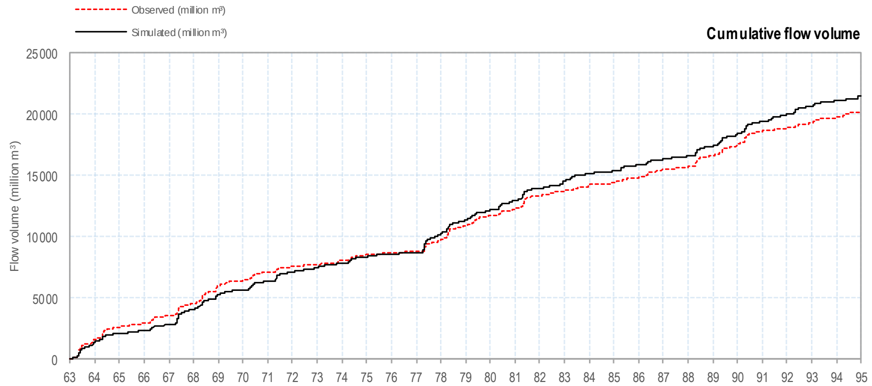
Table A3-4: Calibration performance metrics

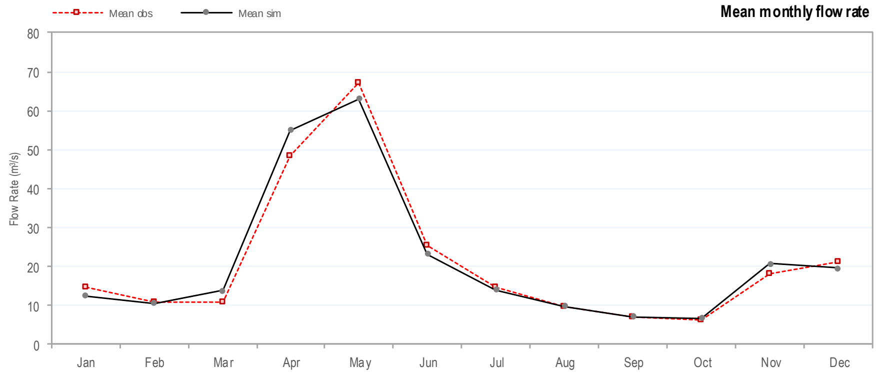
Station number	Catchment Area (km^2)	Calibration Period	Observed MAR (Mm^3)	Simulated MAR (Mm^3)	Coefficient of Determination (r^2)	Water Balance Error (WBL)	Nash-Sutcliffe efficiency (NSE)
3AA06	720	Jan 68 – Jan 73	43.9	45.5	0.831	3.6%	0.332
3BB12	234	Jan 63 – Jan 70	64.7	62.7	0.865	-3.2%	0.689
3CB05	297	Jan 67 – Jan 85	137.2	121.9	0.502	-12.5%	0.231
3DA02	5720	Jan 63 – Jan 95	666.6	672.7	0.790	0.9%	0.528
3F02	10,206	Jan 63 – Jan 72	1,123	1,067	0.772	-5.2%	0.297
3F05	20,551	Mar 69 – Apr 72	914	1040	0.873	12.1%	0.449
3KB01	1,358	Jan 61 – Jan 79	93.1	90.9	0.776	-2.4%	0.416
3MH10	1,023	Jan 61 – Jan 68	48.2	46.7	0.819	-3.1%	0.426

Calibration Results: 3DA02 - Athi at Munyu Catchment Area: 5720.1km³ 9/20/2018 5:33 PM









Node no. N26|Net flow to node

Node no. N26|Net flow to node

Performance Metrics

Coeff. of Determination (r^2) 0.790

Nash-Sutcliffe Coeff. of Efficiency 0.528

	Observed	Simulated	%Difference	Target %		Observed
Mean Annual Runoff (MAR) Jan- Dec [Mm³]	666.6	672.7	0.9%	± 4%	Unit runoff [mm]	116.5
Annual Standard Deviation [Mm³]	440.3	363.9	-21.0%	± 6%	MAP [mm]	900
Seasonal Index	35.68	30.18	-18.2%	± 8%	Runoff %	13%

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	14.5	10.7	10.9	48.2	67.1	25.4	14.6	9.6	7.1	6.1	18.2	21.1	21.1
Simulated	12.4	10.5	13.8	54.9	63.1	23.1	14.0	9.7	7.1	6.7	20.6	19.6	21.3
%difference	-16.7%	-2.3%	20.9%	12.2%	-6.3%	-9.9%	-4.3%	0.8%	0.4%	9.9%	11.6%	-7.8%	0.9%

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Figure A3-9: Calibration plot for streamflow gauge 3DA02

Calibration Results: 3AA06 - Mbagathi

Catchment Area: 720.03 km²

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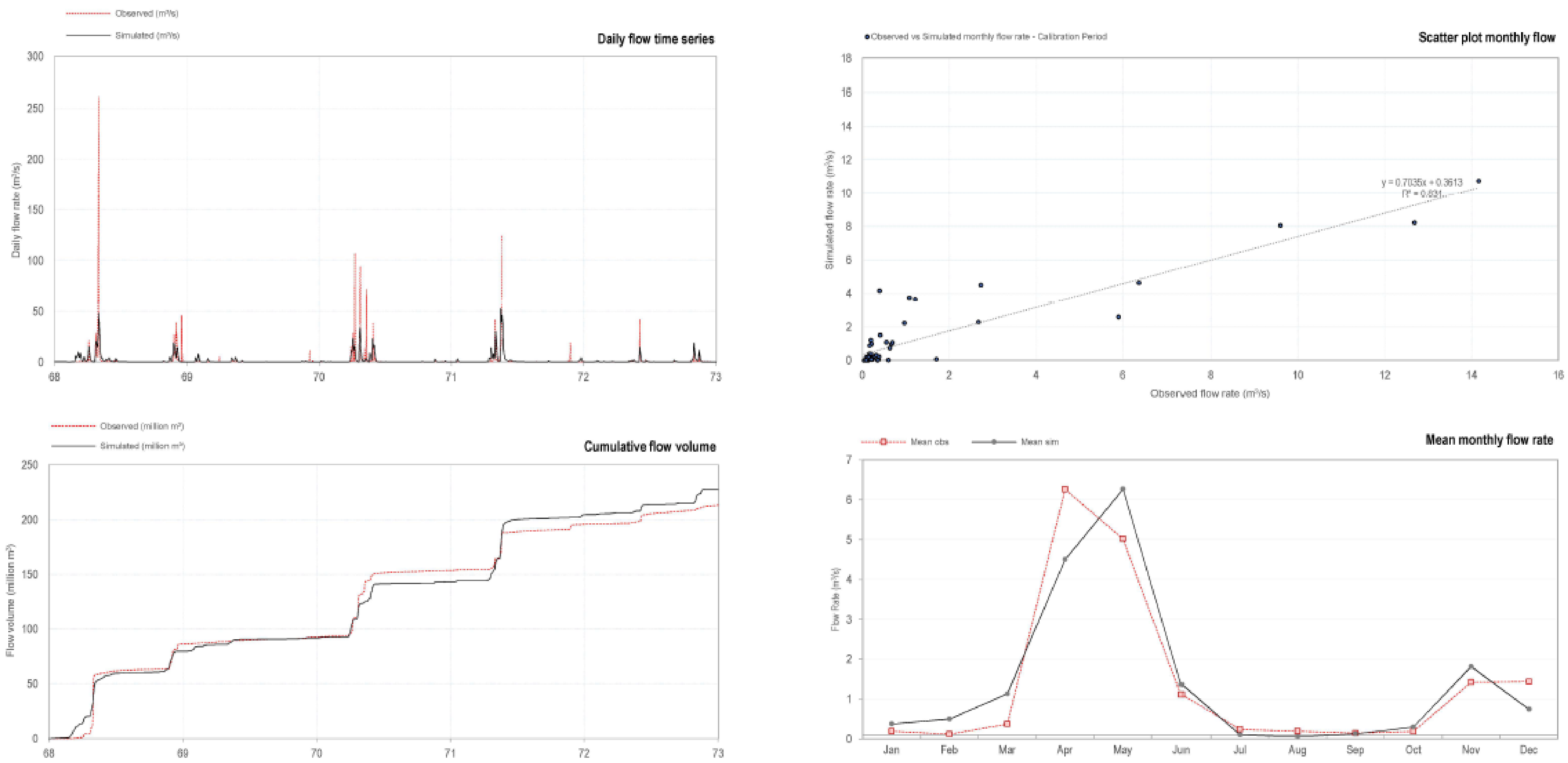

Performance Metrics

Node no. N483|Net flow to node

Coeff. of Determination (r^2) 0.831

Nash-Sutcliffe Coeff. of Efficiency 0.332

	Observed	Simulated	% Difference	Target %
Mean Annual Runoff (MAR) Jan- Dec [Mm³]	43.9	45.5	3.6%	± 4%
Annual Standard Deviation [Mm³]	Insufficient	27.5	Insufficient	± 6%
Seasonal Index	71.28	45.82	-55.6%	± 8%

	Observed
Unit runoff [mm]	61.0
MAP [mm]	784
Runoff %	8%

Node no. N483|Net flow to node

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	0.2	0.1	0.4	6.3	5.0	1.1	0.2	0.2	0.1	0.2	1.4	1.4	1.4
Simulated	0.4	0.5	1.1	4.5	6.3	1.4	0.1	0.1	0.1	0.3	1.8	0.7	1.4
% difference	49.3%	75.7%	67.1%	-38.9%	19.8%	18.8%	-134.1%	-216.5%	-13.9%	36.9%	21.8%	-92.2%	3.5%

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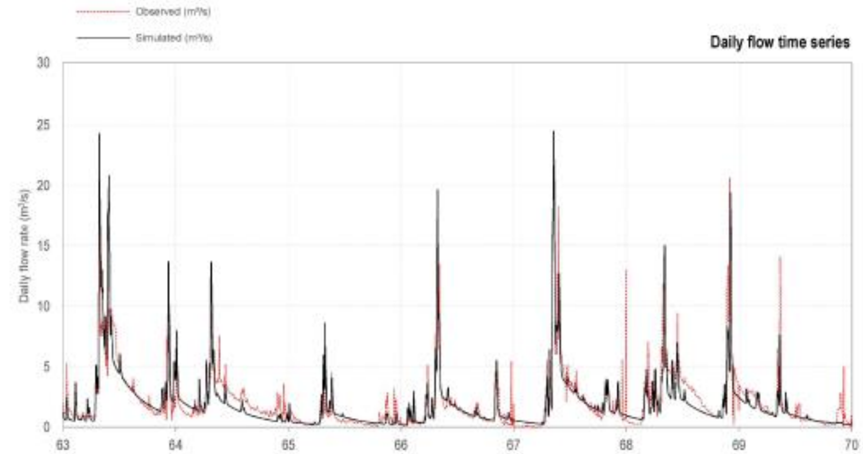
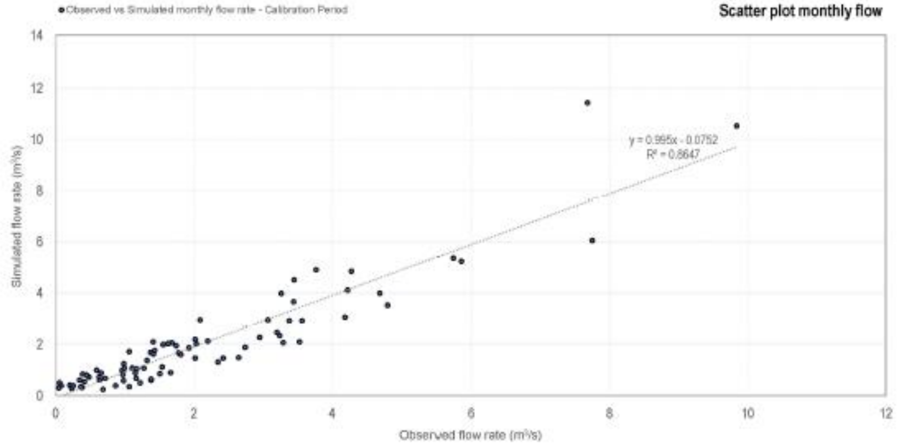
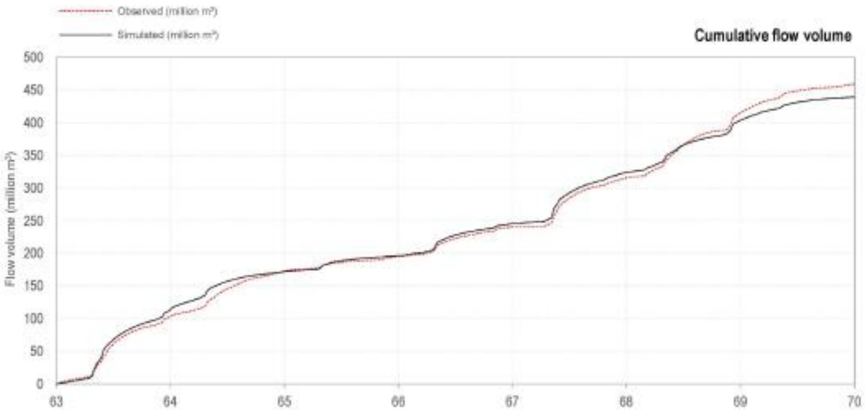
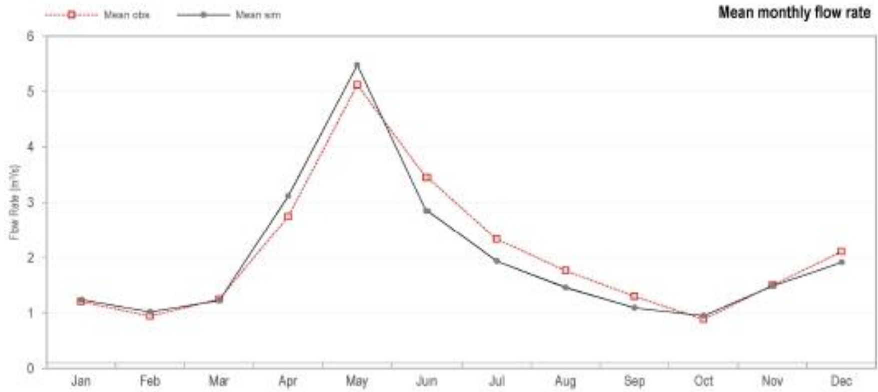
Figure A3-10: Calibration plot for streamflow gauge 3AA06

Calibration Results: 3BB12 -   Catchment Area: 234.02 km²   8/20/2018 12:58 PM









Performance Metrics

Node no. N56|Net flow to node

Coeff. of Determination (r^2) 0.865

Nash-Sutcliffe Coeff. of Efficiency 0.689

	Observed	Simulated	% Difference	Target %
Mean Annual Runoff (MAR) Jan- Dec [Mm³]	64.7	62.7	-3.2%	± 4%
Annual Standard Deviation [Mm³]	33.4	30.4	-10.0%	± 6%
Seasonal Index	26.09	23.04	-13.2%	± 8%

	Observed
Unit runoff [mm]	276.6
MAP [mm]	974
Runoff %	28%

Node no. N56|Net flow to node

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	1.2	0.9	1.3	2.7	5.1	3.4	2.3	1.8	1.3	0.9	1.5	2.1	2.1
Simulated	1.2	1.0	1.2	3.1	5.5	2.8	1.9	1.5	1.1	1.0	1.5	1.9	2.0
% difference	2.6%	7.5%	-2.5%	12.0%	6.5%	-21.1%	-20.2%	-21.0%	-19.2%	7.0%	-1.0%	-10.0%	-3.2%

Figure A3-11: Calibration plot for streamflow gauge 3BB12

Calibration Results: 3CB05 - Catchment Area: 296.48 km²

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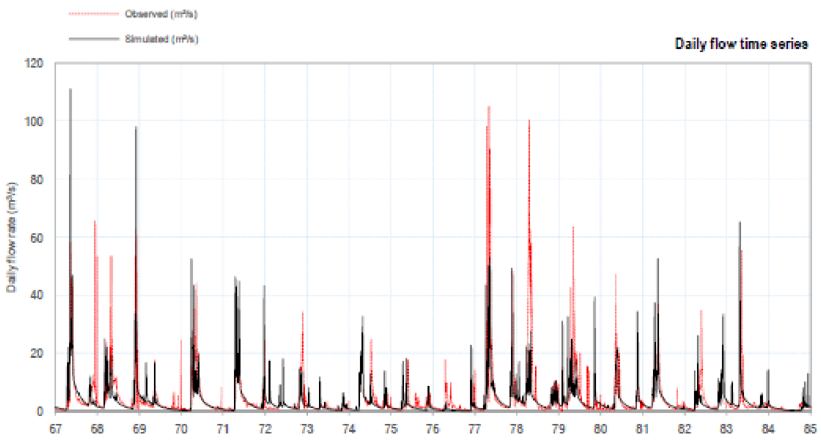

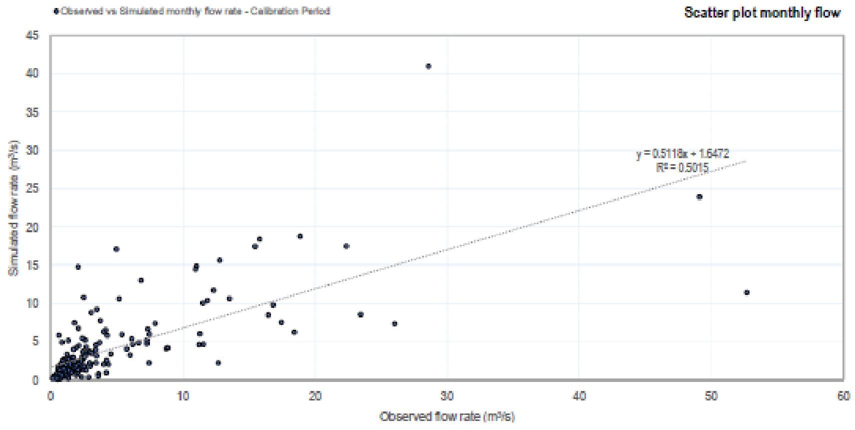

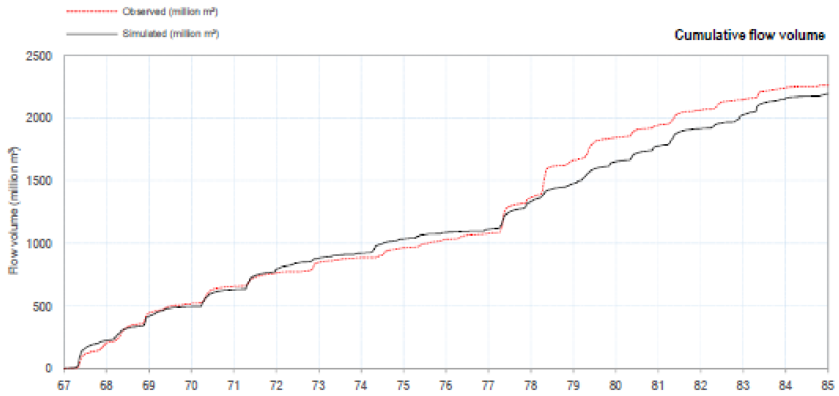

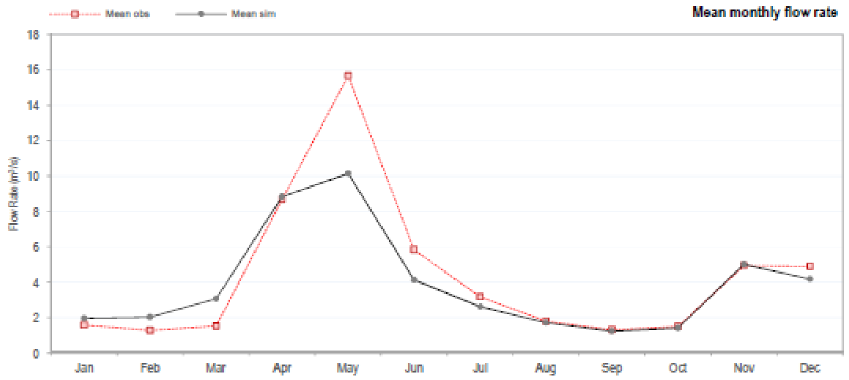

Performance Metrics

Node no. N24|Net flow to node

Coeff. of Determination (r^2) 0.502

Nash-Sutcliffe Coeff. of Efficiency 0.231

	Observed	Simulated	% Difference	Target %
Mean Annual Runoff (MAR) Jan- Dec [Mm³]	137.2	121.9	-12.5%	± 4%
Annual Standard Deviation [Mm³]	62.8	60.6	-3.6%	± 6%
Seasonal Index	36.49	24.85	-46.8%	± 8%

	Observed
Unit runoff [mm]	462.6
MAP [mm]	1021
Runoff %	45%

Node no. N24|Net flow to node

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	1.6	1.3	1.5	8.7	15.7	5.8	3.2	1.8	1.3	1.5	4.9	4.9	4.3
Simulated	2.0	2.0	3.1	8.8	10.1	4.1	2.6	1.7	1.2	1.4	5.0	4.2	3.9
% difference	18.9%	36.7%	50.3%	1.9%	-54.4%	-41.3%	-21.2%	-4.1%	-6.0%	-5.5%	1.5%	-17.4%	-12.5%

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Figure A3-12: Calibration plot for streamflow gauge 3CB05

Calibration Results: 3F02 - Athi(Mavindini) Catchment Area: 10206 km²

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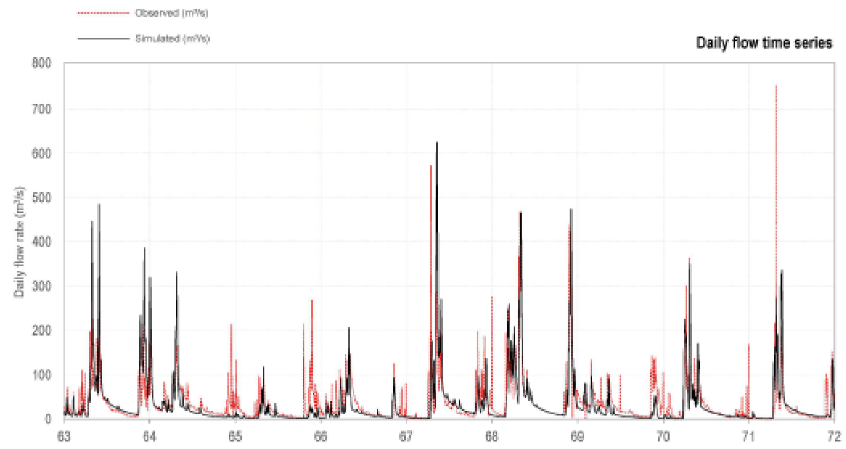

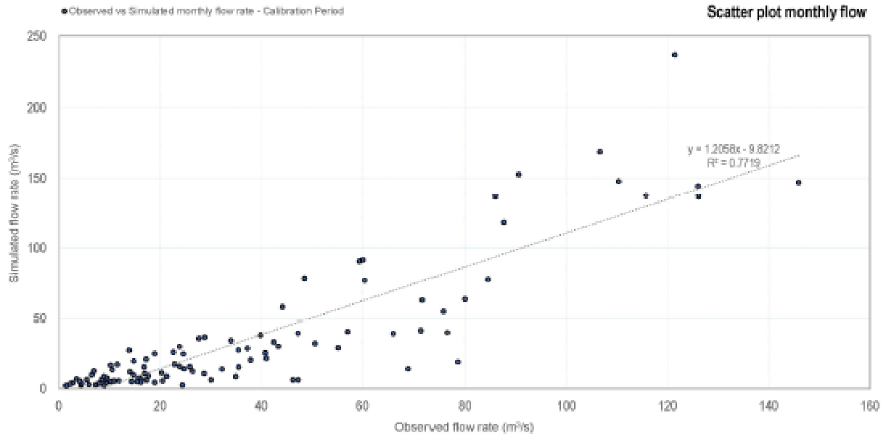

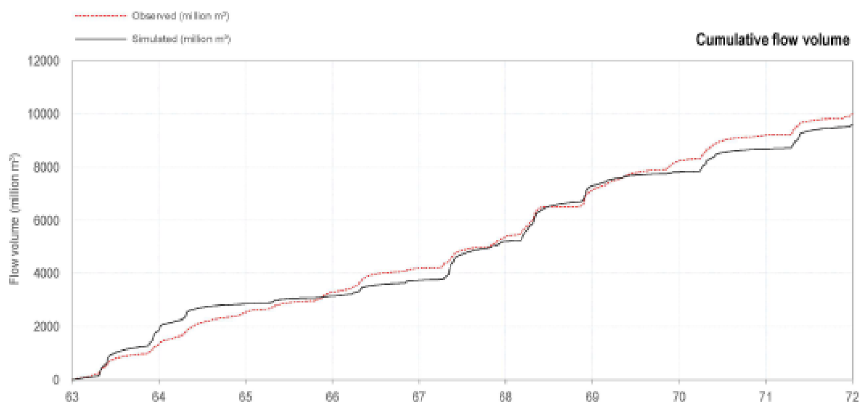

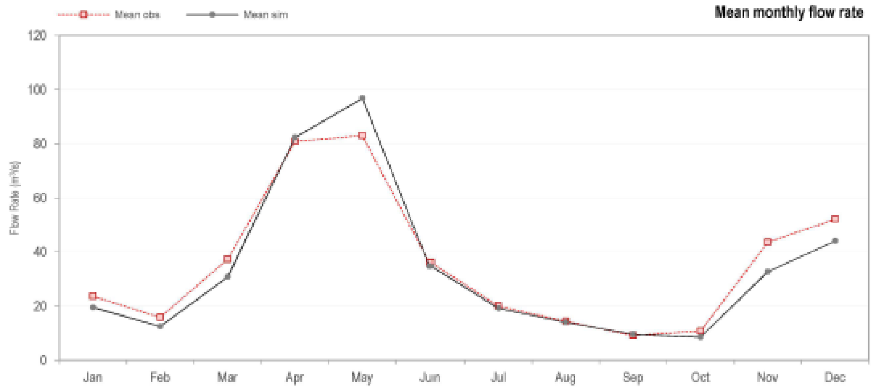

Performance Metrics

Node no. N262|Net flow to node

Coeff. of Determination (r^2) 0.772

Nash-Sutcliffe Coeff. of Efficiency 0.297

	Observed	Simulated	% Difference	Target %
Mean Annual Runoff (MAR) Jan- Dec [Mm³]	1122.6	1067.1	-5.2%	± 4%
Annual Standard Deviation [Mm³]	557.1	617.0	9.7%	± 6%
Seasonal Index	20.61	27.71	25.6%	± 8%

	Observed
Unit runoff [mm]	110.0
MAP [mm]	800
Runoff %	14%

Node no. N262|Net flow to node

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	23.7	15.8	37.3	80.9	83.0	36.0	20.0	14.4	9.2	10.8	43.5	52.3	35.6
Simulated	19.5	12.5	30.8	82.3	96.8	34.7	19.1	14.0	9.6	8.5	32.7	44.0	33.8
% difference	-21.4%	-26.2%	-21.1%	1.7%	14.2%	-3.8%	-4.3%	-2.6%	4.8%	-26.9%	-33.1%	-18.7%	-5.2%

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Figure A3-13: Calibration plot for streamflow gauge 3F02

Calibration Results: 3F05 - Catchment Area: 20551 km²

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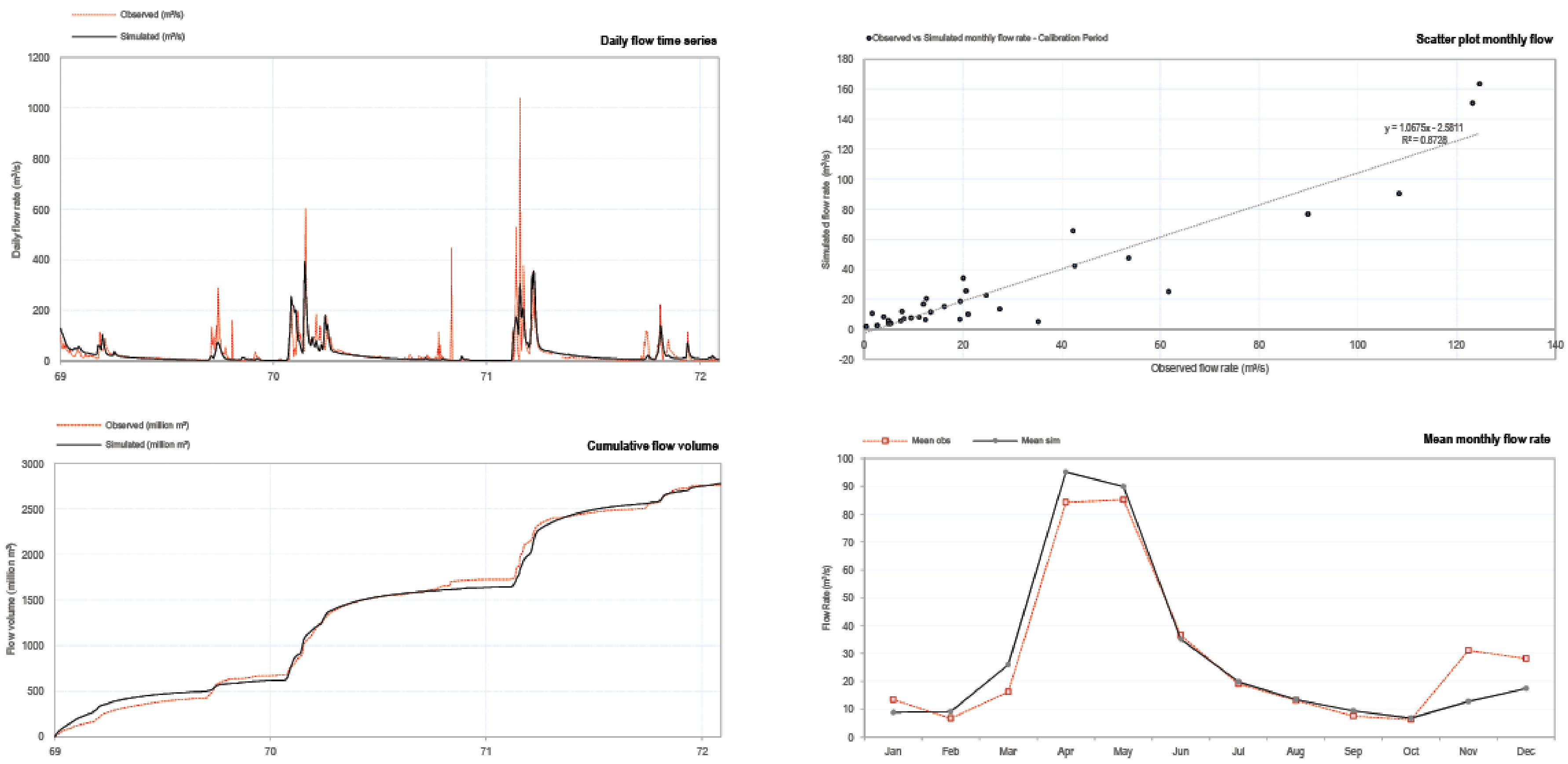

Node no. N62|Net flow to node

Node no. N62|Net flow to node

Performance Metrics

Coeff. of Determination (r^2) 0.873

Nash-Sutcliffe Coeff. of Efficiency 0.449

	Observed	Simulated	% Difference	Target %
Mean Annual Runoff (MAR) Jan- Dec [Mm³]	913.6	1039.7	12.1%	± 4%
Annual Standard Deviation [Mm³]	Insufficient	13.5	Insufficient	± 6%
Seasonal Index	Insufficient	41.13	Insufficient	± 8%

	Observed
Unit runoff [mm]	44.5
MAP [mm]	700
Runoff %	6%

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	13.4	6.7	16.2	84.3	85.2	36.5	19.1	13.1	7.5	6.3	31.1	28.1	29.0
Simulated	8.9	9.1	26.0	95.1	89.9	35.1	19.8	13.4	9.4	6.8	12.8	17.4	33.0
% difference	-51.3%	26.2%	37.6%	11.4%	5.2%	-4.0%	3.6%	2.3%	20.2%	7.5%	-143.3%	-61.5%	12.2%

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Figure A3-14: Calibration plot for streamflow gauge 3F05

Calibration Results: 3KB01 - Ramisi Catchment Area: 1358.1 km²

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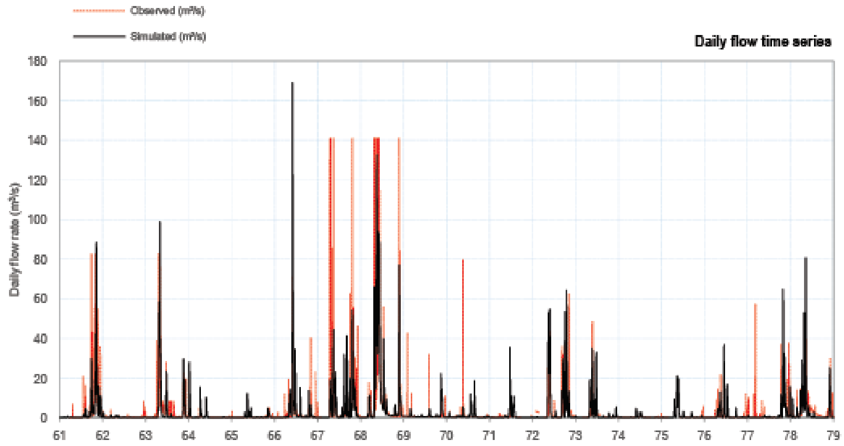

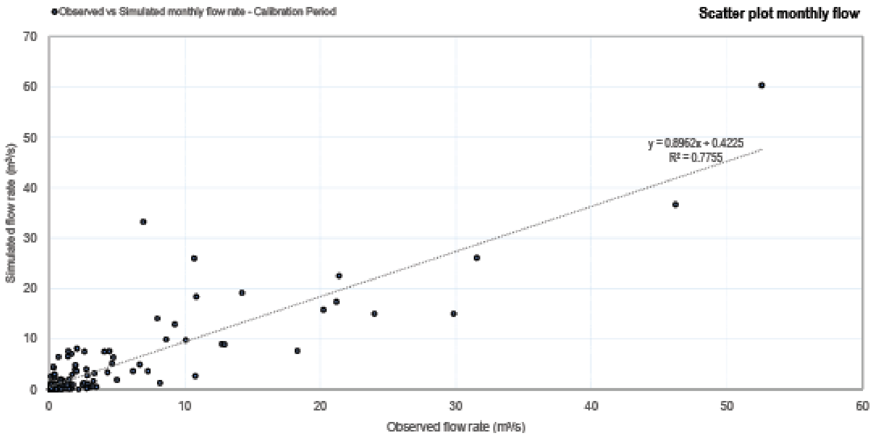

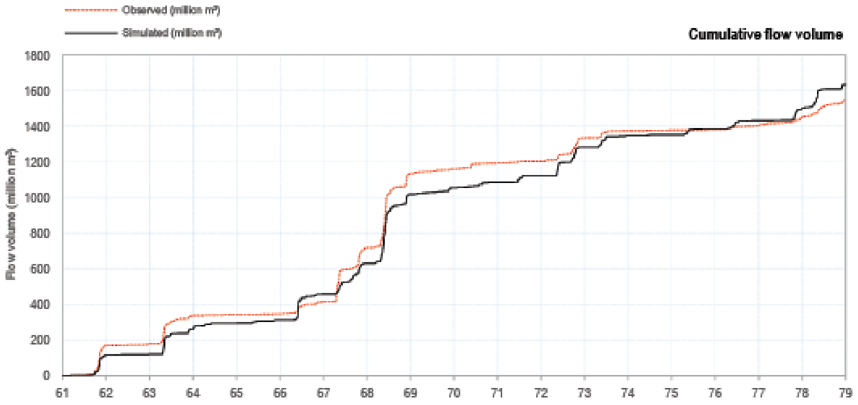

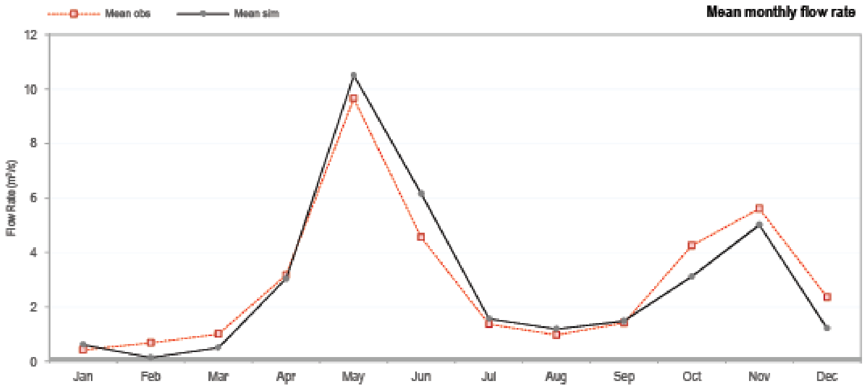

Node no. N212|Net flow to node

Node no. N212|Net flow to node

Performance Metrics

Coeff. of Determination (r^2) 0.776

Nash-Sutcliffe Coeff. of Efficiency 0.416

	Observed	Simulated	% Difference	Target %
Mean Annual Runoff (MAR) Jan- Dec [Mm³]	93.1	90.9	-2.4%	± 4%
Annual Standard Deviation [Mm³]	143.5	93.0	-54.3%	± 6%
Seasonal Index	42.16	32.13	-31.2%	± 8%

	Observed
Unit runoff [mm]	68.5
MAP [mm]	807
Runoff %	8%

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	0.4	0.7	1.0	3.2	9.7	4.6	1.4	1.0	1.4	4.3	5.6	2.3	2.9
Simulated	0.6	0.1	0.5	3.0	10.5	6.2	1.6	1.2	1.5	3.1	5.0	1.2	2.9
% difference	31.5%	-397.7%	-100.1%	-4.6%	8.1%	26.0%	12.7%	18.3%	4.8%	-36.9%	-11.9%	-95.5%	-2.5%

MHB results file: P:\Projects\113699 Implem Support Consultant WRP & ManT DEL SERV\11 TASK 2 BASIN PLANNING\Modelling\Mike Hydro Basin Models\Athi Basin\Baseline_eWAthi_e4_natural_evap.mhydro - Result Files\RiverBasin_ATHI BASIN.dfs0

Document: P:\Projects\113699 Implem Support Consultant WRP & ManT DEL SERV\11 TASK 2 BASIN PLANNING\Modelling\Mike Hydro Basin Model\Calibration\Output - e4[MHB_Calibration_sheet_v2_3KB01.xlsx]Calibration

Figure A3-15: Calibration plot for streamflow gauge 3KB01

Calibration Results: 3MH10 - Catchment Area: 4236.6 km²

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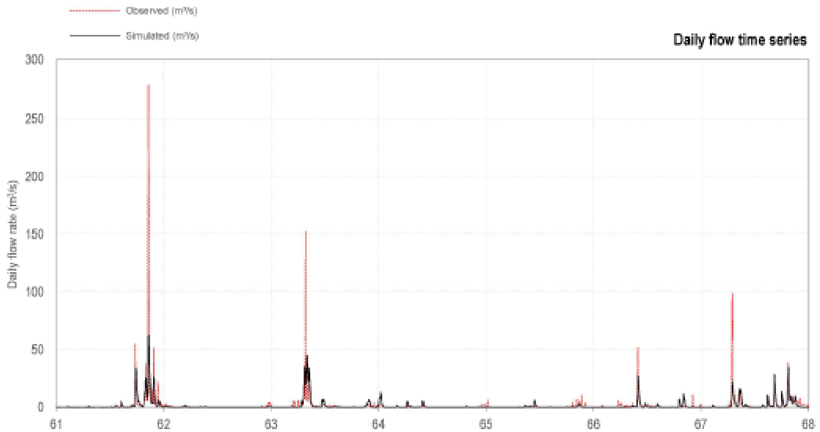

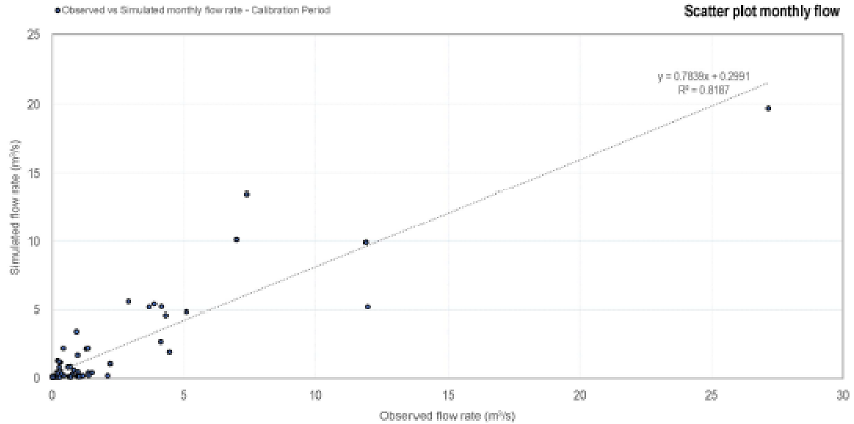

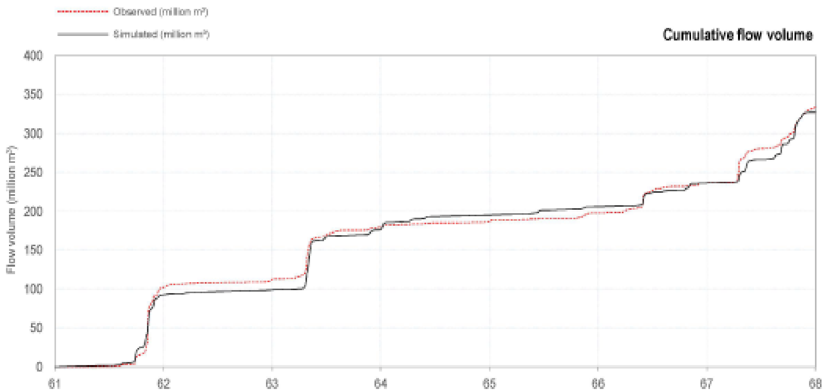

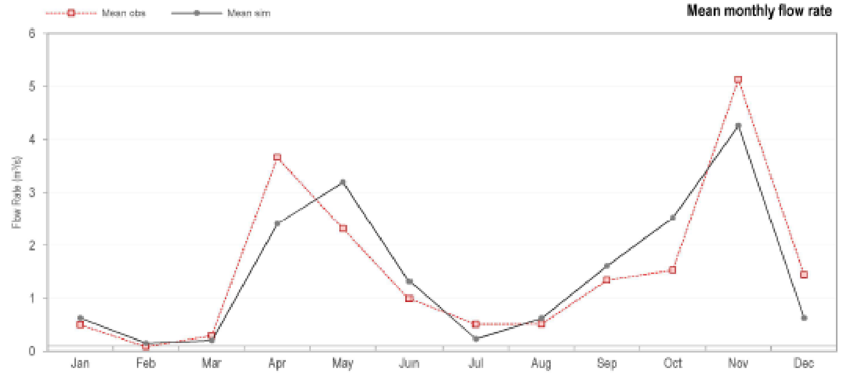

Performance Metrics

Node no. N211|Net flow to node

Coeff. of Determination (r^2) 0.819

Nash-Sutcliffe Coeff. of Efficiency 0.426

	Observed	Simulated	% Difference	Target %
Mean Annual Runoff (MAR) Jan- Dec [Mm³]	48.2	46.7	-3.1%	± 4%
Annual Standard Deviation [Mm³]	41.6	38.7	-7.6%	± 6%
Seasonal Index	24.06	24.19	0.5%	± 8%

	Observed
Unit runoff [mm]	11.4
MAP [mm]	1023
Runoff %	1%

Node no. N211|Net flow to node

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	0.5	0.1	0.3	3.7	2.3	1.0	0.5	0.5	1.3	1.5	5.1	1.4	1.5
Simulated	0.6	0.2	0.2	2.4	3.2	1.3	0.2	0.6	1.6	2.5	4.3	0.6	1.5
% difference	20.4%	43.5%	-45.5%	-52.0%	27.4%	24.7%	-117.0%	17.9%	16.5%	39.2%	-20.5%	-131.5%	-3.0%

MHB results file: P:\Projects\113699 Implem Support Consultant WRP & Man'7 DEL SERV\11 TASK 2 BASIN PLANNING\Modelling\Mike Hydro Basin Models\Athi Basin\Baseline_e4\Athi_e4_natural_evap.mhydro - Result Files\RiverBasin_ATHI BASIN.dfs0

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Figure A3-16: Calibration plot for streamflow gauge 3MH10

Model Validation

The calibrated NAM rainfall-runoff model was validated by comparing observed and simulated flows at three other flow gauging stations representative of the upper and middle parts of the basin respectively. Validation results are presented below.

Calibrated NAM parameters for the catchment upstream of streamflow gauge 3BB12 were transferred to the upstream tributary catchment of gauge 3BB13. Validation performance metrics are presented below while a comparison of daily simulated and observed flows is shown in Figure A3-17. The validation was deemed to be acceptable.

Table A3-5: Validation at Gauge 3BB12

Station number	Catchment Area (km^2)	Calibration Period	Observed MAR (Mm^3)	Simulated MAR (Mm^3)	Coefficient of Determination (R^2)	Water Balance Error (WBL)	Nash-Sutcliffe efficiency (NSE)
3BB13	102.4	Jan-63 – Dec 69	29.1	27.6	0.8	-5.5%	0.629

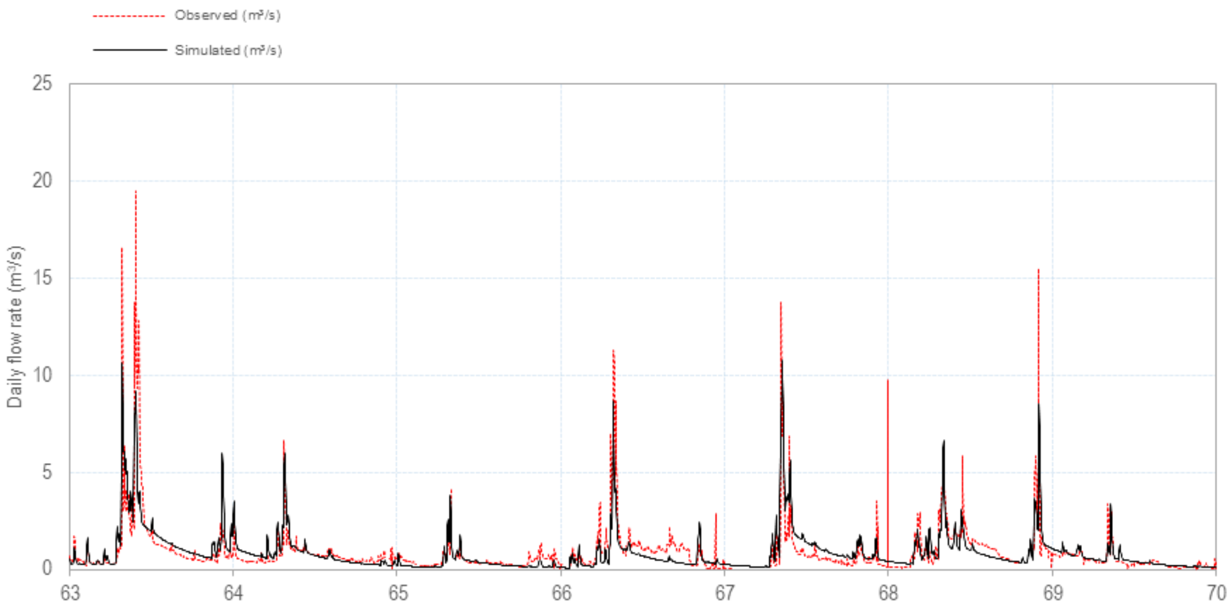

Figure A3-17: Gauge 3BB13 validation (1963-1969)

The observed streamflow records at gauges 3HA12 and 3HA08, which are both situated on the Athi River downstream of the Tsavo confluence, were used for validation. Due to significant periods of missing data in the observed records, especially during the high flow season, limited calibration metrics could be employed for comparison purposes as shown below.

Table A3-6: Validation at Gauges 3HA12 and 3HA08

Station number	Catchment Area (km^2)	Calibration Period	Observed MAR (Mm^3)	Simulated MAR (Mm^3)	Coefficient of Determination (R^2)	Water Balance Error (WBL)	Nash-Sutcliffe efficiency (NSE)
3HA12	31,806	Jan 80 – Dec 86	Insufficient data	1,185.6	0.78	Insufficient data	0.256
3HA08	31,810	Mar 76 – Dec 81	Insufficient data	1,568.2	0.68	Insufficient data	0.193

A visual comparison of observed vs. simulated flows confirmed a reasonable fit between simulated and observed flows, with particular emphasis on flow recession curves and low flows during the dry seasons as shown in Figure A3-18 and Figure A3-19 below.

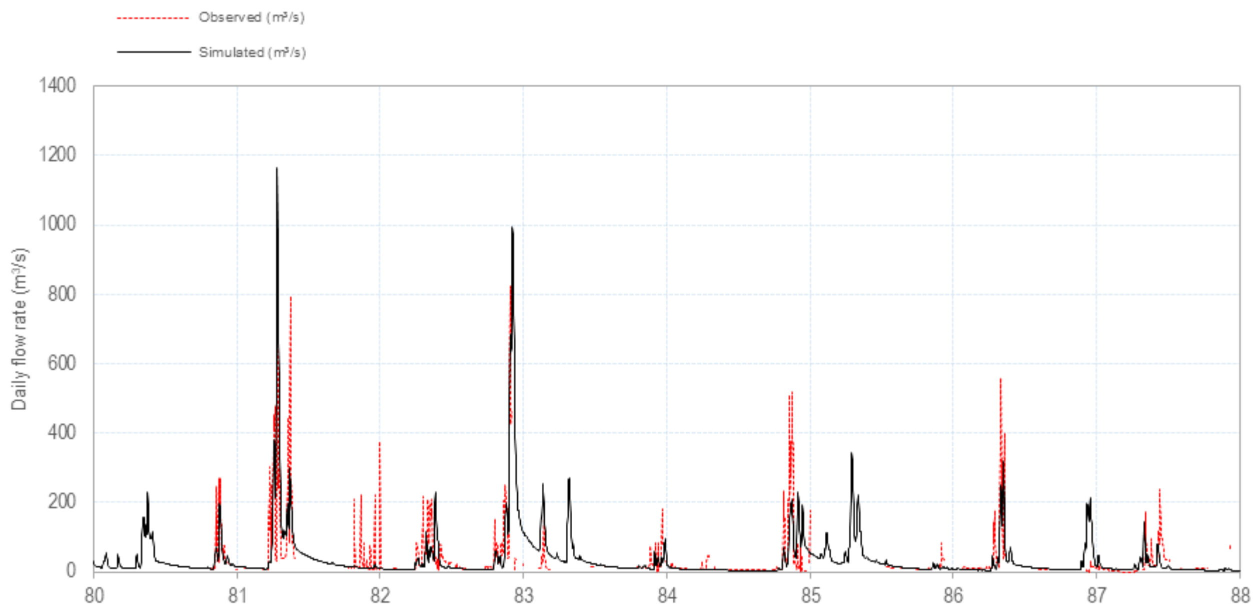

Figure A3-18: Gauge 3HA12 validation (1980-1986)

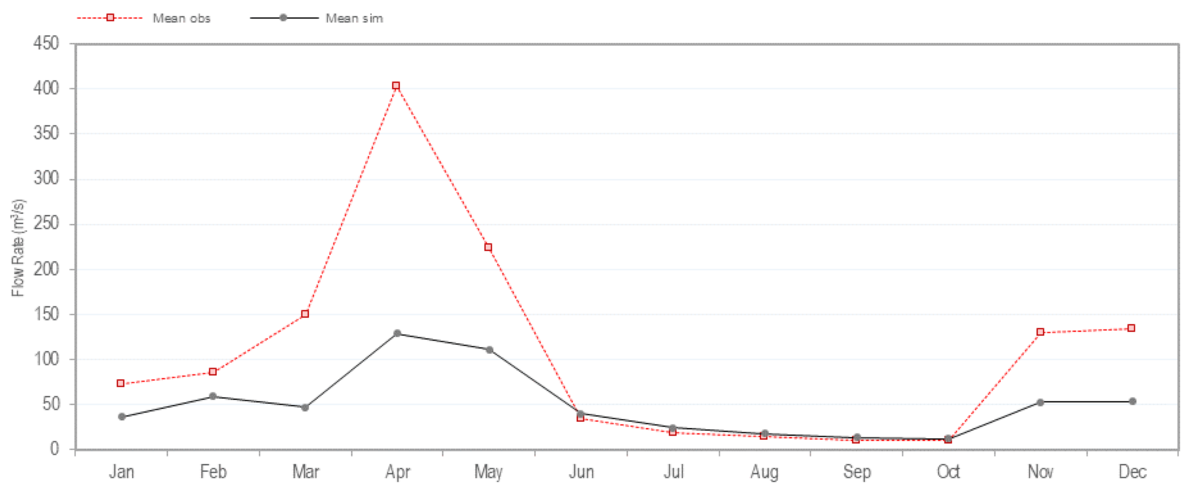

Figure A3-19: Gauge 3HA08 validation: mean monthly flow rate (1976-1980)

Model configuration

Assignment of calibrated NAM parameters to uncalibrated sub-catchments was based on a number of hydrological and physiographical criteria including proximity to the calibrated catchments, similarity in vegetation cover, soil depth and catchment MAP. For uncalibrated model sub-catchments situated between multiple calibrated catchments, transition parameter sets based on average parameter values were assigned (see Table A3-7). Table A3-8 presents the parameters assigned to each model sub--catchment.

Table A3-7: Transition NAM model parameters

Parameters		**Surface-rootzone**							
Para meter Set	Calibration Gauge	Umax	Lmax	CQOF	CKIF	CK1	CK2	TOF	TIF
no.	ID	mm	mm	-	h	h	h	-	-
9	3BB12/ 3AA06	6	220	0.4	200	30	-	0.1	0
10	3BB12/ 3CBO5	3	125	0.4	200	30	-	0.25	0.1
11	3KB01/ 3MH10	15	325	0.35	400	40	-	0.25	0.25

Parameters		**Groundwater**			
Parameter Set	Calibration Gauge	TG	CKBF	CQLow	CKLow
no.	ID	-	h	%	h
9	3BB12/ 3AA06	0.4	1500	35	4500
10	3BB12/ 3CBO5	0.3	1750	35	4500
11	3KB01/ 3MH10	0.675	700	40	7000

Table A3-8: NAM model parameters assigned to model sub-catchments

General			Gauge	Surface-rootzone								Groundwater			
Catchment Identifier	Catchment Name	Area	Calibration Gauge	Umax	Lmax	CQOF	CKIF	CK1	CK2	TOF	TIF	TG	CKBF	CQLow	CKLow
ID	-	km^2	ID	mm	mm	( )	h	h	h	( )	( )	( )	h	%	h
C33	3AA_1	663.0	3AA06	8	275	0.5	200	30		0.1	0	0.6	1000	30	4500
C261	3AA_2	5.6	3AA06	8	275	0.5	200	30		0.1	0	0.6	1000	30	4500
C264	3AA_3	51.3	3AA06	8	275	0.5	200	30		0.1	0	0.6	1000	30	4500
C183	3AB_1	18.7	3DA02	8	220	0.3	400	40		0.2	0.1	0.8	2000	30	4500
C52	3AB_2	1769.1	3DA02	8	220	0.3	400	40		0.2	0.1	0.8	2000	30	4500
C55	3AC	894.6	3DA02	8	220	0.3	400	40		0.2	0.1	0.8	2000	30	4500
C218	3BA_1	684.5	3BB12/3AA06	6	220	0.4	200	30		0.1	0	0.4	1500	35	4500
C217	3BA_2	23.9	3BB12/3AA06	6	220	0.4	200	30		0.1	0	0.4	1500	35	4500
C59	3BA_3	120.6	3BB12	4	150	0.3	200	30		0.1	0	0.2	2000	40	4500
C184	3BA_4	1.4	3AA06	8	275	0.5	200	30		0.1	0	0.6	1000	30	4500
C54	3BA_5	29.6	3DA02	8	220	0.3	400	40		0.2	0.1	0.8	2000	30	4500
C161	3BB_1	14.8	3BB12	4	150	0.3	200	30		0.1	0	0.2	2000	40	4500
C159	3BB_2	116.8	3BB12	4	150	0.3	200	30		0.1	0	0.2	2000	40	4500
C160	3BB_3	102.4	3BB12	4	150	0.3	200	30		0.1	0	0.2	2000	40	4500
C186	3BC_1	95.7	3BB12/3CBO5	3	125	0.4	200	30		0.3	0.1	0.3	1750	35	4500
C188	3BC_2	86.1	3BB12/3CBO5	3	125	0.4	200	30		0.3	0.1	0.3	1750	35	4500
C187	3BC_3	12.7	3BB12/3CBO5	3	125	0.4	200	30		0.3	0.1	0.3	1750	35	4500
C57	3BC_4	311.6	3BB12/3CBO5	3	125	0.4	200	30		0.3	0.1	0.3	1750	35	4500
C60	3BD_1	283.5	3CB05	2	100	0.5	200	30		0.4	0.2	0.4	1500	30	4500
C158	3BD_2	19.3	3DA02	8	220	0.3	400	40		0.2	0.1	0.8	2000	30	4500
C157	3CB_1	296.5	3CB05	2	100	0.5	200	30		0.4	0.2	0.4	1500	30	4500
C190	3CB_2	91.3	3DA02	8	220	0.3	400	40		0.2	0.1	0.8	2000	30	4500
C58	3CB_3	14.7	3DA02	8	220	0.3	400	40		0.2	0.1	0.8	2000	30	4500
C156	3DA_1	12.1	3DA02	8	220	0.3	400	40		0.2	0.1	0.8	2000	30	4500
C191	3DA_2	69.7	3F02	18	270	0.4	600	40	80	0.1	0.4	0.9	1500	30	4500
C56	3DA_3	691.6	3F02	18	270	0.4	600	40	80	0.1	0.4	0.9	1500	30	4500
C230	3DB	816.6	3F02	18	270	0.4	600	40	80	0.1	0.4	0.9	1500	30	4500
C182	3EA_1	278.2	3F02	18	270	0.4	600	40	80	0.1	0.4	0.9	1500	30	4500
C180	3EA_2	76.9	3F02	18	270	0.4	600	40	80	0.1	0.4	0.9	1500	30	4500
C179	3EA_3	258.3	3F02	18	270	0.4	600	40	80	0.1	0.4	0.9	1500	30	4500
C50	3EA_4	168.5	3F02	18	270	0.4	600	40	80	0.1	0.4	0.9	1500	30	4500
C265	3EA_5	49.2	3F02	18	270	0.4	600	40	80	0.1	0.4	0.9	1500	30	4500
C192	3EB_1	0.5	3F02	18	270	0.4	600	40	80	0.1	0.4	0.9	1500	30	4500
C178	3EB_2	340.2	3F02	18	270	0.4	600	40	80	0.1	0.4	0.9	1500	30	4500
C37	3EB_3	465.3	3F02	18	270	0.4	600	40	80	0.1	0.4	0.9	1500	30	4500

General			Gauge	Surface-rootzone								Groundwater			
Catchment Identifier	Catchment Name	Area	Calibration Gauge	Umax	Lmax	CQOF	CKIF	CK1	CK2	TOF	TIF	TG	CKBF	CQLow	CKLow
ID	-	km^2	ID	mm	mm	( )	h	h	h	( )	( )	( )	h	%	h
C38	3EC	703.1	3F02	18	270	0.4	600	40	80	0.1	0.4	0.9	1500	30	4500
C226	3ED	567.6	3F02	18	270	0.4	600	40	80	0.1	0.4	0.9	1500	30	4500
C227	3FA_1	984.4	3F05	8	350	0.1	600	40		0.1	0.5	0.2	1500		
C177	3FA_2	1030.0	3F05	8	350	0.1	600	40		0.1	0.5	0.2	1500		
C194	3FA_3	7908.8	3F05	8	350	0.1	600	40		0.1	0.5	0.2	1500		
C164	3FB_1	421.9	3F05	8	350	0.1	600	40		0.1	0.5	0.2	1500		
C49	3FB_3	3070.1	3KB01/3MH10	15	325	0.4	400	40		0.3	0.3	0.7	700	40	7000
C176	3FB_4	738.9	3KB01/3MH10	15	325	0.4	400	40		0.3	0.3	0.7	700	40	7000
C169	3G_1	4539.5	3MH10	18	375	0.2	400	40		0.4	0.5	0.6	1000	40	7000
C263	3G_1 Mzima Springs	0.0													
C42	3G_2	2567.5	3MH10	18	375	0.2	400	40		0.4	0.5	0.6	1000	40	7000
C165	3HA_1	339.1	3KB01/3MH10	15	325	0.4	400	40		0.3	0.3	0.7	700	40	7000
C262	3HA_2	4.1	3KB01/3MH10	15	325	0.4	400	40		0.3	0.3	0.7	700	40	7000
C44	3HA_3	576.6	3KB01/3MH10	15	325	0.4	400	40		0.3	0.3	0.7	700	40	7000
C170	3HB_1	2140.2	3KB01/3MH10	15	325	0.4	400	40		0.3	0.3	0.7	700	40	7000
C231	3HB_2	12.4	3MH10	18	375	0.2	400	40		0.4	0.5	0.6	1000	40	7000
C232	3HB_3	100.2	3MH10	18	375	0.2	400	40		0.4	0.5	0.6	1000	40	7000
C45	3HB_4	42.4	3MH10	18	375	0.2	400	40		0.4	0.5	0.6	1000	40	7000
C46	3HC	2929.2	3MH10	18	375	0.2	400	40		0.4	0.5	0.6	1000	40	7000
C245	3HD1_1	83.8	3MH10	18	375	0.2	400	40		0.4	0.5	0.6	1000	40	7000
C47	3HD1_2	545.5	3MH10	18	375	0.2	400	40		0.4	0.5	0.6	1000	40	7000
C126	3HD2_1	189.3	3MH10	18	375	0.2	400	40		0.4	0.5	0.6	1000	40	7000
C241	3HD2_2	142.1	3MH10	18	375	0.2	400	40		0.4	0.5	0.6	1000	40	7000
C259	3J_1	582.2	3MH10	18	375	0.2	400	40		0.4	0.5	0.6	1000	40	7000
C237	3J_2	3449.3	3MH10	18	375	0.2	400	40		0.4	0.5	0.6	1000	40	7000
C168	3K_2	1358.1	3KB01	15	275	0.5	400	40		0.1	0	0.8	400	40	7000
C104	3K_3	593.3	3KB01	15	275	0.5	400	40		0.1	0	0.8	400	40	7000
C64	3K_33	188.4	3KB01/3MH10	15	325	0.4	400	40		0.3	0.3	0.7	700	40	7000
C225	3K_34	155.0	3KB01/3MH10	15	325	0.4	400	40		0.3	0.3	0.7	700	40	7000
C260	3K_4	189.1	3KB01/3MH10	15	325	0.4	400	40		0.3	0.3	0.7	700	40	7000
C67	3K_5	179.5	3KB01/3MH10	15	325	0.4	400	40		0.3	0.3	0.7	700	40	7000
C244	3K_7	2366.7	3KB01/3MH10	15	325	0.4	400	40		0.3	0.3	0.7	700	40	7000
C99	3K1_1	6526.5	3KB01/3MH10	15	325	0.4	400	40		0.3	0.3	0.7	700	40	7000
C239	3LA_1	7515.4	3KB01/3MH10	15	325	0.4	400	40		0.3	0.3	0.7	700	40	7000
C174	3LA_2	208.0	3KB01/3MH10	15	325	0.4	400	40		0.3	0.3	0.7	700	40	7000
C116	3LB_1	129.2	3MH10	18	375	0.2	400	40		0.4	0.5	0.6	1000	40	7000
C242	3LB_3	512.9	3MH10	18	375	0.2	400	40		0.4	0.5	0.6	1000	40	7000

General			Gauge	Surface-rootzone								Groundwater			
Catchment Identifier	Catchment Name	Area	Calibration Gauge	Umax	Lmax	CQOF	CKIF	CK1	CK2	TOF	TIF	TG	CKBF	CQLow	CKLow
ID	-	km^2	ID	mm	mm	( )	h	h	h	( )	( )	( )	h	%	h
C115	3LB_4	138.1	3MH10	18	375	0.2	400	40		0.4	0.5	0.6	1000	40	7000
C61	3MA_1	3360.1	3MH10	18	375	0.2	400	40		0.4	0.5	0.6	1000	40	7000
C91	3MA_2	2207.9	3KB01/3MH10	15	325	0.4	400	40		0.3	0.3	0.7	700	40	7000
C173	3MB_1	1411.6	3KB01	15	275	0.5	400	40		0.1	0	0.8	400	40	7000
C93	3MB_2	302.3	3KB01	15	275	0.5	400	40		0.1	0	0.8	400	40	7000
C167	3MC_1	876.5	3KB01	15	275	0.5	400	40		0.1	0	0.8	400	40	7000
C94	3MC_2	271.4	3KB01/3MH10	15	325	0.4	400	40		0.3	0.3	0.7	700	40	7000
C96	3MD1_1	703.1	3KB01/3MH10	15	325	0.4	400	40		0.3	0.3	0.7	700	40	7000
C97	3MD1_2	236.7	3KB01/3MH10	15	325	0.4	400	40		0.3	0.3	0.7	700	40	7000
C123	3MD1_24	172.6	3KB01/3MH10	15	325	0.4	400	40		0.3	0.3	0.7	700	40	7000
C243	3MD2	96.9	3KB01/3MH10	15	325	0.4	400	40		0.3	0.3	0.7	700	40	7000
C258	3N_1	6806.4	3F05	8	350	0.1	600	40		0.1	0.5	0.2	1500	0	0
C257	3N_2	1542.3	3MH10	18	375	0.2	400	40		0.4	0.5	0.6	1000	40	7000
C266	3MD1	242.7	3KB01/3MH10	15	325	0.4	400	40		0.3	0.3	0.7	700	40	7000
C267	3BC_5	45.1	3BB12/3CBO5	3	125	0.4	200	30		0.3	0.1	0.3	1750	35	4500
C273	3J_3 Lumi Springs	0.0													

A Natural MIKE HYDRO Basin model of the Athi Basin was configured. The Natural model represents the pristine state of the basin before any man-made influences, i.e. no water use and no water related infrastructure. Figure A3-20 displays the Natural model configuration for the Athi Basin. The relatively high spatial resolution that was adopted for model construction, in terms of number of model sub-catchments, is evident.

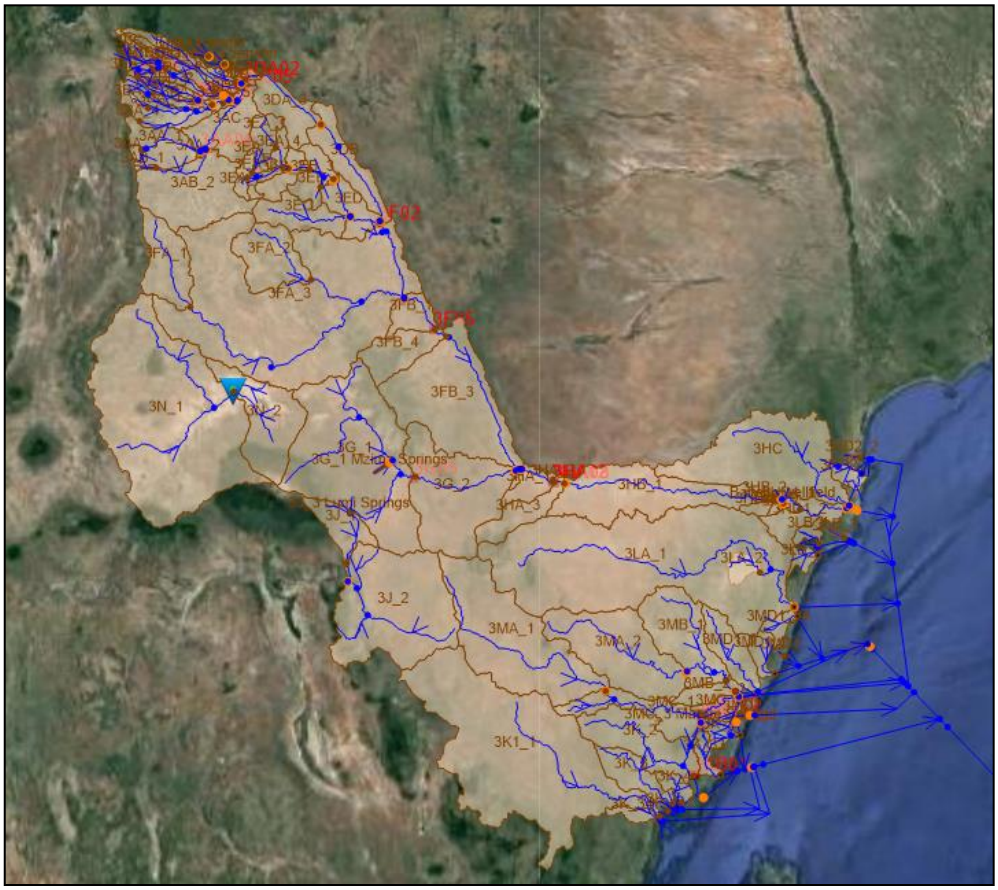

Figure A3-20: Athi basin Natural model configuration in MIKE HYDRO Basin

A4: Groundwater

The process used to quantify the groundwater potential followed four steps:

i. Develop a weighting system for the four groundwater yield-related criteria that takes the five groupings (from very high to very low) into account. The weightings provide numerical values to the groups whereby a favourable groundwater area is afforded a higher value than a poor groundwater area. These values are referred to as Group Weights in Table A4-1.
ii. Assign weightings to each of the four groundwater yield-related criteria (termed Layer Weight in Table A4-1). This step caters for placing greater value on Regional Permeability and Recharge than Secondary Permeability and Landforms as the former two criteria were considered to have a greater impact on groundwater availability than the latter two criteria.
iii. For each of the four groundwater yield-related criteria obtain a score by multiplying the Weights by the Layer Weights, and then summing the scores for the four groundwater yield-related criteria to give the percentage of groundwater recharge that could potentially be available for use.
iv. Multiply the percentage obtained in (iii) above by the groundwater recharge values obtained in Section 3.4 to obtain the rate at which groundwater is potentially available for use (Figure A4-1).

Table A4-1: The Weights and Layer Weights for the four groundwater yield-related criteria

Layer	Criteria	Layer weight	Groups and Group Weights					
			1	2	3	4	5	Total
1	Regional permeability	0.3	Very High 40	High 25	Medium 20	Low 10	Very Low 5	100
2	Secondary permeability	0.2	Very High 35	High 30	Medium 20	Low 10	Very Low 5	100
3	Landforms	0.2	Very High 40	High 30	Medium 15	Low 10	Very Low 5	100
4	Recharge	0.3	Very High 35	High 30	Medium 20	Low 10	Very Low 5	100

Using this GIS-based approach to estimate the abstractable proportion of recharge gives the following extreme values:

- An area rated as Very High for all four groundwater yield-related criteria gives an abstractable proportion of recharge value of 37.5%.
- An area rated as Very Low for all four groundwater yield-related criteria gives an abstractable proportion of recharge value of 5%.

This range is similar to the ~5 % to ~50 % that were obtained in neighbouring Ethiopia and South Sudan (ENTRO, 2016).

Note: For a detailed description of the approach which was followed for the assessment of groundwater resources, refer to "ISC Report C2-1: National Groundwater Potential Assessment".

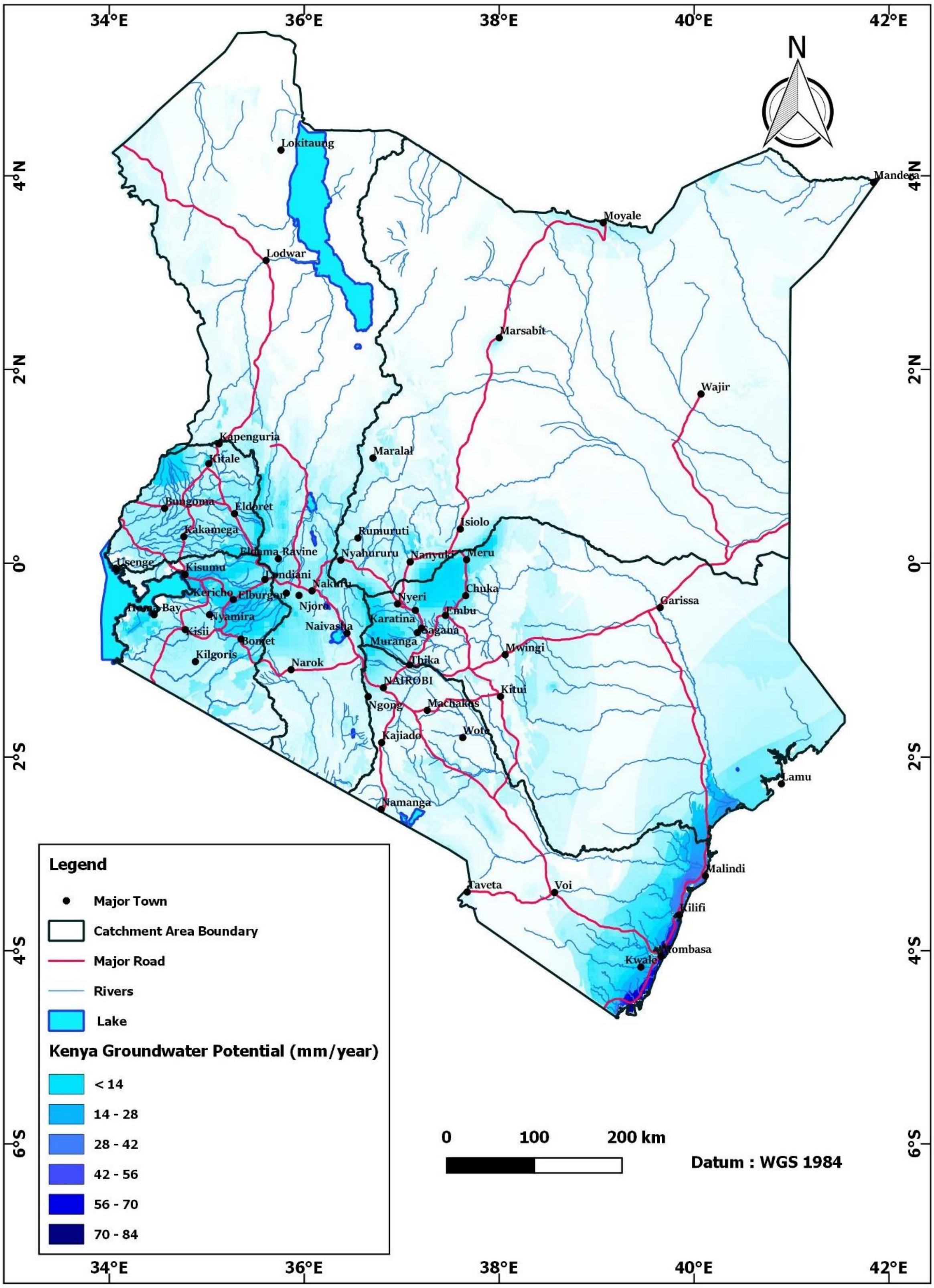

Figure A4 -1: Groundwater Potential in mm/year

A5: Environmental flows

In order to provide a scientific, high level approach towards the determination of provisional environmental flows to be used at basin-level water resource planning, so-called "Holding EFlows" were determined as ecological water requirements for sensitivity analysis purposes. These flows are coarse and provisional and their purpose is to provide interim numbers for insertion into basin-level water resource plans. They should not be used in detailed design, planning and operation of developments. Information for these latter purposes should come from higher confidence, more comprehensive EFlow assessments.

Note: *A detailed description of the methodogy which was used to derive the EFlows is presented in a stand-alone report: "KWSCRP: Holding environmental flows requirements for selected Kenyan rivers, Southern Waters, 2018".*

In essence the approach involved 5 key steps:

- Delineate the rivers into homogeneous biophysical river zones and social areas and assign representative nodes.
- Calculate the Hydrological Index (HI) for the rivers and use these to access EFlows recommendations for rivers with similar HI from the South African Desktop Model (Hughes & Münster, 2000).
- Review EFlows assessments done in similar southern and eastern African rivers to provide guidance on Holding EFlows allocations.
- Obtain naturalised and 'current day' (c. 2017) hydrological records for the study rivers for use in cross-checking the Holding EFlows against reality.
- Use Steps 2, 3 and 4 to estimate Holding EFlows to maintain the study rivers in a range of ecological conditions.

The approach also provided for the determination of the present ecological condition of representative reaches based on a "Habitat Integrity Method". Table A5-1 defines the ecological categories as used in the assessment of current ecological condition.

Table A5-1: Ecological condition and scores (Kleynhans, 1996)

CATEGORY	DESCRIPTION	SCORE (%)
A	Unmodified, natural	90-100
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.	80-90
C	Moderately modified. A loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.	60-79
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.	40-59
E	The loss of natural habitat, biota and basic ecosystem functions is extensive.	20-39
F	Modifications have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.	0

The EFlows assessment for the Athi Basin delineated the Basin into 33 sub-basins with two main components: the Athi River and its main tributaries, the Kiboko and Tsavo: and the rivers on the coastal plain. Nodes were assigned to represent each of the river types. The nodes were positioned at the downstream end of the reaches they represent. The current ecological condition of the rivers at the node locations were assessed at desktop level using a habitat integrity scoring method with limited field visits. Figure A5-1 indicates the locations of the representative nodes as well as the ecological condition of 12 representation reaches in the basin, while Table A5-2 summarises the hydro-geomorphological characteristics and the present ecological condition of the representative nodes in the Athi Basin.

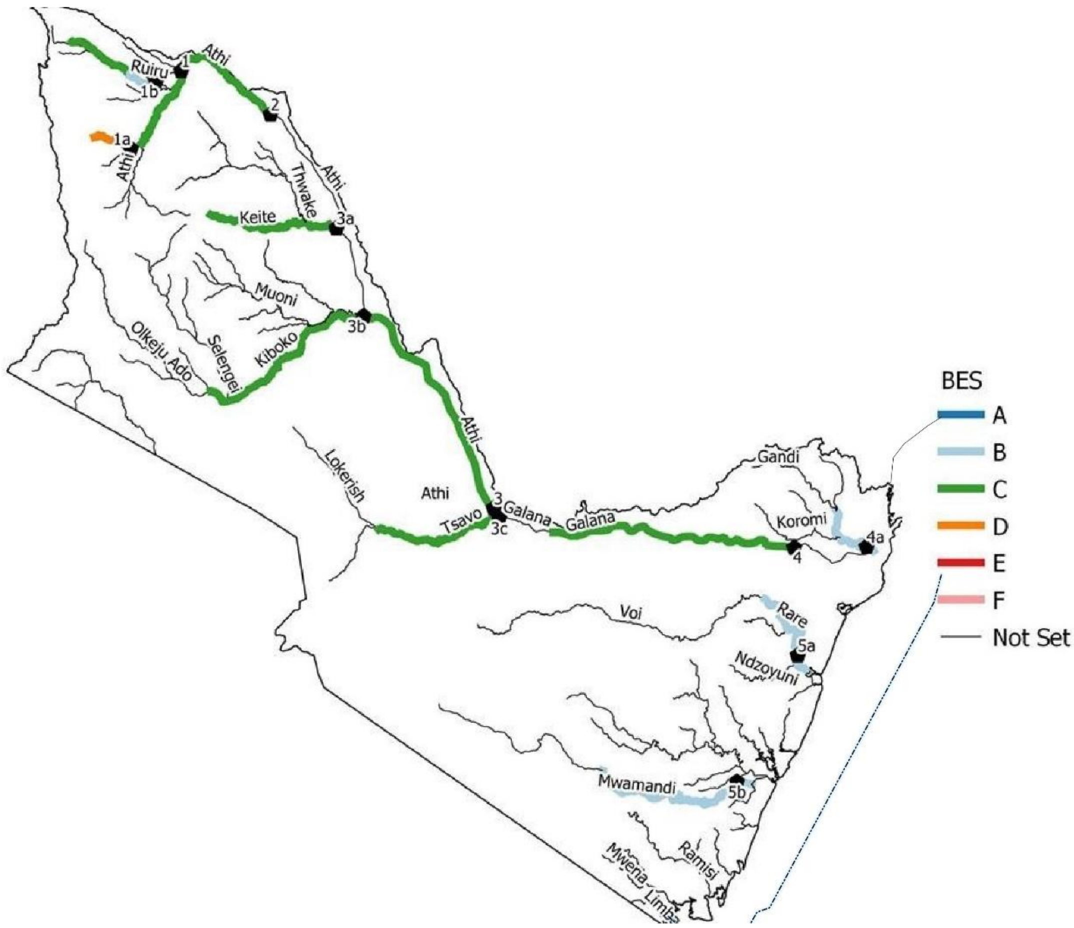

Figure A5-1: Ecological condition of 12 representative reaches in the Athi Basin

Table A5-2: Main hydro-geomorphological characteristics and 2018 ecological condition of representative nodes in the Athi River Basin

Node		River	Description	Ecological Condition	Rowntree et al. (2000)	Rosgen (1994)	Coordinates	
#	Code						X	Y
1	1a	Mbagathi	d/s town	D (45.8%)	Upland Plain	F	36.972	-1.499
2	1b	Ruiru	u/s confluence Thirika	B (86.7%)		F	37.077	-1.167
3	1	Athi	d/s Mbagathi River	C (63.3%)		F	37.183	-1.123
4	2	Athi	Downstream end of Upper Foothills	C (70.2%)	Upper Foothill	B	37.557	-1.305
5	3a	Keite	d/s confluence Athi	B (86.6%)	Lower Foothill	C	37.832	-1.780
6	3b	Kiboko	u/s confluence Muoni extensive wetlands	A (90.9%)		-	37.946	-2.147
7	3c	Tsavo	u/s confluence Athi	A (100%)		F	38.255	-3.079
8	3	Athi	Downstream end of Lower Foothills	B (82.3%)		C	38.490	-2.949
9	4	Galana	u/s estuary	A (100%)	Lowland	E	39.747	-3.113
10	4a	Ghandi	u/s confluence Athi	A (98.7%)		E	40.049	-3.109
11	5a	Rare	u/s confluence Ndzovuni	B (86.2%)	-	E	39.761	-3.562
12	5b	Mwamandi	Extensive wetlands	B (81.2%)	-	E	39.507	-4.090

The Holding EFlows, as a percentage of natural flows, for all sub-basins in the Athi Basin are summarised in Table A5-3. It is important to note that further assessments would be required for all surface and groundwater resources in order to define the Resource Directed Measures for the Water Resource Management cycle.

Table A5-3: Holding EFlows as percentage of natural monthly flows in the Athi Basin

Longitudinal zone	Sub-basins	HI	Ecological Category	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep
Upland Floodplain	3AA	27.7	A	52.8	100.0	100.0	52.8	52.8	52.8	100.0	100.0	52.8	52.8	52.8	52.8
			B	39.0	85.5	85.5	39.0	39.0	39.0	85.5	85.5	39.0	39.0	39.0	39.0
			C	25.8	57.0	57.09	25.8	25.8	25.8	57.0	57.0	25.8	25.8	25.8	25.8
			D	15.4	37.6	37.6	15.4	15.4	15.4	37.6	37.6	15.4	15.4	15.4	15.4
	3AB, 3AC, 3BA, 3BB, 3BC, 3BD, 3CB	5.4 – 6.3	A	73.0	100.0	100.0	73.0	73.0	73.0	100.0	100.0	73.0	73.0	73.0	73.0
			B	60.0	90.0	90.0	60.0	60.0	60.0	90.0	90.0	60.0	60.0	60.0	60.0
			C	40.0	60.0	60.0	40.0	40.0	40.0	60.0	60.0	40.0	40.0	40.0	40.0
			D	25.5	39.5	39.5	25.5	25.5	25.5	39.5	39.5	25.5	25.5	25.5	25.5
Transitional, Upper Foothills	3DA	5.3	A	73.0	100.0	100.0	73.0	73.0	73.0	100.0	100.0	73.0	73.0	73,0	73.0
			B	60.0	90.0	90.0	60.0	60.0	60.0	90.0	90.0	60.0	60.0	60.0	60.0
			C	40.0	60.0	60.0	40.0	40.0	40.0	60.0	60.0	40.0	40.0	40.0	40.0
			D	25.5	39.5	39.5	25.5	25.5	25.5	39.5	39.5	25.5	25.5	25.5	25.5
Lower Foothills	3DB, 3EA, 3EB, 3ED, 3EC, 3FA, 3FB, 3HA	5.9 – 6.1	A	73.0	100.0	100.0	73.0	73.0	73.0	100.0	100.0	73.0	73.0	73.0	73.0
			B	60.0	90.0	90.0	60.0	60.0	60.0	90.0	90.0	60.0	60.0	60.0	60.0
			C	40.0	60.0	60.0	40.0	40.0	40.0	60.0	60.0	40.0	40.0	40.0	40.0
			D	25.5	39.5	39.5	25.5	25.5	25.5	39.5	39.5	25.5	25.5	25.5	25.5
	3G	12.3	A	66.3	100.0	100.0	66.3	66.3	66.3	100.0	100.0	66,3	66.3	66.3	66.3
			B	53.0	88.5	88.5	53.0	53.0	53.0	88.5	88.5	53.0	53.0	53.0	53.0
			C	35.3	59.0	59.0	35.3	35.3	35.3	59.0	59.0	35.3	35.3	35.3	35.3
			D	22.1	38.9	38.9	22.1	22.1	22.1	38.9	38.9	22.1	22.1	22.1	22.1

Lowland	3HB, 3HC, 3HD1	5.2 – 5.9	A	73.0	100.0	100.0	73.0	73.0	73.0	100.0	100.0	73.0	73.0	73.0	73.0
			B	60.0	90.0	90.0	60.0	60.0	60.0	90.0	90.0	60.0	60.0	60.0	60.0
			C	40.0	60.0	60.0	40.0	40.0	40.0	60.0	60.0	40.0	40.0	40.0	40.0
			D	25.5	39.5	39.5	25.5	25.5	25.5	39.5	39.5	25.5	25.5	25.5	25.5
Coastal	3J, 3KA, 3KB, 3LA, 3LB, 3MA1, 3MC, 3MA2, 3MB, 3MD1, 3MD2, 3N	3.9 – 6.6	A	73.0	100.0	100.0	73.0	73.0	73.0	100.0	100.0	73.0	73.0	73.0	73.0
			B	60.0	90.0	90.0	60.0	60.0	60.0	90.0	90.0	60.0	60.0	60.0	60.0
			C	40.0	60.0	60.0	40.0	40.0	40.0	60.0	60.0	40.0	40.0	40.0	40.0
			D	25.5	39.5	39.5	25.5	25.5	25.5	39.5	39.5	25.5	25.5	25.5	25.5

A6: Multi-criteria analysis-indicators

Name	Environmentally sensitive area (EN1.1)
Type	Environment (EN)
Category	Footprint (1)
Motivation	Protection of ecologically sensitive areas will serve to protect the biodiversity and ecosystem services associated with such areas.
Description	Extent of ecologically sensitive area within dam / irrigation scheme footprint
Units	km2

Source Data
Ecologically Sensitive Areas refer to those areas located within the primary impact zones that have been, or could potentially be, classified into one of the IUCN protected area management categories (www.iucn.org). The IUCN categories provide a global standard for defining and recording protected areas and are increasingly being incorporated into government legislation (www.iucn.org). The IUCN Protected Areas Categories System are as follows:
Category Ia – Strict Nature Reserve
Category Ib – Wilderness Area
Category II – National Park
Category III – Natural Monument or Feature
Category IV – Habitat / Species Management Area
Category V – Protected Landscape e.g. Water Towers
Category VI – Protected area with Sustainable Use of Natural Resources
Typical areas in Kenya that could potentially be classified using the IUCN system include:
Wetlands. Points identified as wetlands of international importance (www.ramsar.org).
Birds. Points identified as Important Bird Areas (www.birdlife.org)
National parks and reserves
Gazetted water towers

Method of calculation: Interrogation of spatial data (GIS)
Intersect dam full supply / irrigation scheme clearing area with environmentally sensitive area(s)

References
African Development Bank (ADB) 2004. Group Policy on the Environment. February 20094.
Birdlife International. Important Bird Areas Programme. (www.birdlife.org).
International Finance Corporation (IFC). 2012. Performance Standard 6. Biodiversity Conservation and Sustainable Management of Living Natural Resources.
NEPAD 2003. Action plan for the environment initiative of the New Partnership for Africa's Development.
Ramsar (www.ramsar.org).
BirdLife International and NatureServe (2011) Bird species distribution maps of the world. BirdLife International, Cambridge, UK and NatureServe, Arlington, USA.

Name	Carbon emissions (EN1.2)
Type	Environment (EN)
Category	Footprint (1)
Motivation	Woody vegetation located within the area of inundation or irrigation area to be cleared could lead to generation of greenhouse gases.
Description	Potential carbon emission within dam footprint due to flooding and decomposition of woody biomass inundated; Potential carbon emission within irrigation scheme footprint due to clearing and burning of natural vegetation.
Units	million ton

Source Data
Woody biomass (Mg/ha) Carbon Dioxide Information Centre: Geographical Distribution of Woody Biomass Carbon in Tropical Africa: An Updated Database for 2000 (https://cdiac.ess-dive.lbl.gov/)

Method of calculation: Interrogation of spatial data (GIS)
Intersect dam full supply / irrigation scheme clearing area with woody biomass spatial data in Mg/ha.

References
African Development Bank (ADB) undated draft. Energy Sector Policy of the African Development Bank Group.
EDF 2007. Prefeasibility study of Mandaya Hydropower Project, Ethiopia. Eastern Nile Power Trade Programme Study. Module M5. Report prepared by EDF and Scott Wilson for the Eastern Nile technical Regional Office.
Gibbs, H.K. and S. Brown. 2007. Geographical Distribution of Woody Biomass Carbon in Tropical Africa: An Updated Database for 2000, NDP-055b. Available at [http://cdiac.ornl.gov/epubs/ndp/ndp055/ndp055b.html] from the Carbon Dioxide Information Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee. doi: 10.3334/CDIAC/lue.ndp055.2007.
Global Land Cover 2000 Database. European Commission, Joint Research Centre, 2003. http://www-gen.jrc.it/glc2000.
Scanlon, A., Kile, R., and Blumstein, B. 2004. Sustainable hydropower - guidelines, compliance standards and certification. United Nations Symposium on Hydropower and Sustainable Development, Beijing 27-29 October 2004. Hydro Tasmania, Australia.
World Commission of Dams. 2000. Dams and development a new framework for decision-making. The Report of the Word Commission on Dams. London: Earthscan Publications, Thanet Press

Name	Floodplain inundation (EN2.1)
Type	Environment (EN)
Category	Downstream areas (2)
Motivation	Floodplains provide significant ecosystem services including biodiversity support, nursery areas for fish, and production of various natural resources, including timber, thatching grass and medicinal plants.
Description	Extent of floodplain inundation in river reach downstream of dam during wet season
Units	% Change from baseline

Source Data
Water resources simulation model output:
Timeseries of flow in river reach downstream of proposed dam

Method of calculation: Timeseries analysis
Identify wettest month from Natural time series
Extract annual wettest month timeseries from Baseline and Scenario simulation results
Calculate median wettest month flow rates for Baseline and Scenario
Calculate change in wettest month median flow rate: Scenario compared to Baseline % change

References
Opperman, J.J., Moyle, P.B., Larsen, E.W., Florsheim, J.L., Manfree, A.D. Floodplains: Processes and Management for Ecosystem Services. University of California Press, 2017. Available at https://www.jstor.org/stable/10.1525/j.ctv1xxt6n

Name	Ecological stress (EN2.2)
Type	Environment (EN)
Category	Downstream areas (2)
Motivation	Wet and dry season low flows and within year flow variability are important drivers of instream ecological processes and associated river health. Aquatic biota have evolved life history strategies to cope with the natural stress regime, and any changes to the natural stress regime (increase or decrease) tend to reduce biodiversity because these changes produce conditions suitable to a few taxa only.
Description	Ecological stress rating in river reach downstream of proposed dam or large abstraction due to anticipated changes in key flow components
Units	Index (-5 to 0)

Source Data
Water resources simulation model output:
Timeseries of flow in river reach downstream of proposed dam / abstraction point

Method of calculation: Timeseries analysis
Dry season low flow
Identify driest month from Natural time series
Extract annual dry season timeseries for three consecutive dry months (driest month and adjacent months) from Baseline and Scenario simulation results
Calculate median dry season flow rate for Baseline and Scenario
Calculate change in dry season median flow rate: Scenario compared to Baseline % change
Wet season base flow
Identify wettest month from Natural time series
Extract annual wet season baseflow timeseries as average of months immediately before and after wettest month from Baseline and Scenario simulation results
Calculate median wet season base flow rate for Baseline and Scenario
Calculate change in wet season base flow median flow rate: Scenario compared to Baseline % change
Within year flow variability
Extract annual flow amplitudes - difference between max and min monthly flow rate - from Baseline and Scenario simulation results
Calculate median of annual flow amplitudes for Baseline and Scenario
Calculate change in median flow amplitude: Scenario compared to Baseline % change
Rating

		Dry / Wet Season Low Flows	Annual Flow variation
0	Zero	0	0
-1	Negligible	<20% gain <17% drop	6 - 10% gain 5 - 9% drop
-2	Low	20 - 49% gain 17 - 34% drop	11 - 24% gain 10 - 19% drop
-3	Moderate	50 - 99% gain 35 - 49% drop	25 - 99% gain 20 - 49% drop
-4	High	100 - 149% gain	100 - 399% gain

			50 - 59% drop	50 - 79% drop
	-5	Very High	>150% gain >60% drop	400>% gain <80% drop
ass				

References
Hijri, R., and Panella, T. 2003. Evolving policy reforms and experiences for addressing downstream impacts in World Bank Water Resources Projects. Rivers Research & Applications 19: 667-681.
World Bank. 2001. Making Sustainable Commitments: An Environment Strategy for the World Bank. World Bank: Washington, DC.
World Commission on Dams. 2000. Dams and Development: A New Framework for Decision Making. Earthscan Publications: London.

Name	Wet season duration (EN2.3)
Type	Environment (EN)
Category	Downstream area (2)
Motivation	The length of the wet season is important for biological production, flushing of fine sediments, channel maintenance and floodplain inundation.
Description	Duration of wet season (high flows) in river reach downstream of dam
Units	% Change from baseline

Source Data
Water resources simulation model output:
Timeseries of flow in river reach downstream of proposed dam

Method of calculation: Timeseries analysis
Identify 20th percentile exceedance flow rate from Natural time series
Calculate number of days during which the Natural 20th percentile flow rate is exceeded in Baseline and Scenario simulations
Calculate change in number of exceedance days: Scenario compared to Baseline % change

References
Opperman, J.J., Moyle, P.B., Larsen, E.W., Florsheim, J.L., Manfree, A.D. Floodplains: Processes and Management for Ecosystem Services. University of California Press, 2017. Available at https://www.jstor.org/stable/10.1525/j.ctv1xxt6n

Name	Phytoplankton growth potential (EN3.1)
Type	Environment (EN)
Category	Water quality (3)
Motivation	Retention time in dams is easy to measure and is directly related to the potential for phytoplankton biomass and algal blooms, such as potentially toxic blue-green algae (cyanobacteria), Microcystis. Rivers usually do not support large populations of plankton, except in their lower reaches, where current speeds are slow. The development of plankton populations is generally associated with standing water. Impoundments provide ideal conditions for the development of plankton, which respond rapidly to changes in flow conditions on account of their rapid life histories, which are typically measures in days or weeks. The availability of nutrients decreases as retention time increases, so small impoundments with short retention times can cause water quality to deteriorate for downstream users, whereas impoundments with long retention time can serve to improve water quality for downstream users.
Description	Potential for phytoplankton growth
Units	Phytoplankton growth risk (%)

Source Data
Water resources simulation model output
Timeseries of inflow into proposed dam
Timeseries of proposed dam storage volume

Method of calculation: Timeseries analysis
y = x1.59 (0.13) (0.99x)
where y = phytoplankton growth potential (%); x = retention time (days), calculated from the median annual storage divided by mean annual inflow into reservoir

References
Coveney, M. F., J. C. Hendrickson, E. R. Marzolf, R. S. Fulton, J. Di, C. P. Neubauer, D. R. Dobberfuhl, G. B. Hall, H. W. Paerl, and E. J. Phlips. 2011. Chapter 8. Plankton. In: St. Johns River water Supply Impact Study. St. Johns River Water Management District, Palatka, FL, USA. St. Johns River Water Management District, Palatka, Florida.
Wagner-Lotkowska, K. Izydorczyk, T. Jurczak & M. Tarczynska, P. Frankiewicz 2004. Ecohydrological methods of algal bloom control. In: Zalewski, M & Wagner-Lotkowska (Eds). Chapter 12: Reservoir & lake management: Improvement of Water Quality. Integrated watershed management – Ecohydrology 7 Phytotechnology Manual. United Nations Environmental Programme.

Name	Aquatic macrophytes growth potential (EN3.2)
Type	Environment (EN)
Category	Water quality (3)
Motivation	Floating macrophytes reduce the availability of light and oxygen in the water, with detrimental implications for biodiversity. The plants provide ideal habitat for bilharzia snails, and also increase evapotranspiration losses.
Description	Potential for macrophyte growth
Units	Aquatic macrophyte growth risk (%)

Source Data
Water resources simulation model output
Timeseries of flow in river reach downstream of proposed irrigation scheme return flow
Timeseries of irrigation scheme return flows
Nitrogen export coefficient

Method of calculation: Timeseries analysis
y = 108 / (1+((x/2.29)-0.83))
where y = aquatic macrophyte growth potential (%); x = total nitrate concentration (mg/l) in receiving river immediately downstream of irrigation discharge point

References

Coetzee, J. A and Hill, M. P. 2012. The role of eutrophication in the biological control of water hyacinth, Eichhornia crassipes, in South Africa. Biocontrol 57: 247-261.
Byrne, M., Hill, M., Robertson, M., King, A. J., Katembo, N., Wilson, J. Brudwig, R., Fisher, J. 2010. Integrated management of Water Hyacinth in South Africa. Development of an integrated management plan for water hyacinth control, combining biological control, herbicidal control and nutrient control, tailored to the climatic regions of South Africa. Water Research Commission Report No TT 454/10. Pretoria.
National Agricultural Research Organization (NARO) 2008. The national invasive species strategy, action plan and policy guidelines for Uganda. Report submitted to CABI, under the UNEP/GEF Project: Removing barriers to invasive plant management in Africa (UNEP/GEF Project No GFL 2328-2711-4890.

Name	Water availability for riparian users (SL1.1)
Type	Social (SL)
Category	Water availability (1)
Motivation	Upstream storage and flow regulation as well as large river abstractions may negatively impact dry season water availability in the river downstream and could impact riparian users
Description	Change in water availability during dry season
Units	% Change from baseline

Source Data
Water resources simulation model output
Timeseries of flow in river reach downstream of proposed dam / abstraction point

Method of calculation: Timeseries analysis
Identify driest month from Natural time series
Extract annual dry season timeseries for three consecutive dry months (driest month and adjacent months) from Baseline and Scenario simulation results
Calculate median dry season flow rate for Baseline and Scenario
Calculate change in dry season median flow rate: Scenario compared to Baseline % change

References

Matunda, J.M. Sustainable management of riparian areas in Kenya:a critique of the inadequacy of the legislative framework governing the protection of sustainable management of riparian zones in Kenya. University of Nairobi, 2015.

Name	Malaria susceptibility (SL2.1)
Type	Social (SL)
Category	Community health and safety (2)
Motivation	The increased availability of open water (dams) and wetted areas (irrigation schemes) could potentially increase the risk of malaria
Description	Susceptibility of areas where new irrigation schemes and/or dams are proposed to malaria based on the WHO malaria incidence map for Africa
Units	Malaria endemicity (%)

Source Data
WHO Malaria incidence map of Africa (https://www.who.int/gho/map_gallery/en/)

Method of calculation: Interrogation of spatial data (GIS)
Intersect dam full supply / irrigation scheme clearing area with WHO Malaria prevalence map and calculate average % malaria endemicity in footprint area(s)

References

Kibret, S., Lautze, J., McCartney, M., Nhamo, L., Yan, G. 2019. Malaria around large dams in Africa: effect of environmental and transmission endemicity factors. Malaria Journal 18, Article number 303 (2019)

World Health Organisation: Global Health Observatory Data. Available at https://www.who.int/data/gho

Name	Commercial irrigation (SL3.1)
Type	Social (SL)
Category	Food security and livelihoods (3)
Motivation	Development of large-scale, commercial irrigation stimulates the economy, creates jobs, improves food security and improves socio-economic conditions
Description	Extent of proposed large-scale irrigation schemes
Units	km2

Source Data
Planned large scale irrigation (km2)

Method of calculation: Interrogation of spatial data (GIS)
Sum all proposed large-scale irrigation scheme areas in study area

References

Gwiyani-Nkhomo, B. Irrigation development and its socioeconomic impact on rural communities in Malawi. Development Southern Africa, Vol 28, 2011 – Issue 2

Name	Recession agriculture (SL3.2)
Proxy	Floodplain inundation (EN2.1)
Type	Social (SL)
Category	Food security and livelihoods (3)
Motivation	Recessional agriculture is a form of agricultural cultivation that takes place on a floodplain. Farmers practice recessional agriculture by successively planting in the flooded areas after the waters recede. A reduction in annual flood levels could impact recession agriculture.
Description	Extent of floodplain inundation in river reach downstream of dam during wet season
Units	% Change from baseline

Source Data
Water resources simulation model output:
Timeseries of flow in river reach downstream of proposed dam

Method of calculation: Timeseries analysis
Identify wettest month from Natural time series
Extract annual wettest month timeseries from Baseline and Scenario simulation results
Calculate median wettest month flow rates for Baseline and Scenario
Calculate change in wettest month median flow rate: Scenario compared to Baseline % change

References

Opperman, J.J., Moyle, P.B., Larsen, E.W., Florsheim, J.L., Manfree, A.D. Floodplains: Processes and Management for Ecosystem Services. University of California Press, 2017. Available at https://www.jstor.org/stable/10.1525/j.ctv1xxt6n

Name	Fish production - dams (SL3.3)
Type	Social (SL)
Category	Food security and livelihoods (3)
Motivation	This indicator is linked to areas that will become inundated through impoundment, and therefore represents the additional fish habitat created by impoundments.
Description	Potential fisheries production
Units	ton per annum

Source Data
Water resources simulation model output:
Timeseries of surface area in proposed impoundment

Method of calculation: Timeseries analysis
y = 13.143 x 0.8305
where y = fish production (t/a); x = median area of inundation over simulation period (km2)

References

Bassa, G. K. 1986. Fishery resources of Southern Sudan. In A.B. Zahlan (ed.): The Agricultural sector of Sudan: Policy and systems studies, 291-299. London (UK), Ithaca Press.
Food and Agricultural Organisation of the United Nations (FAO) 2007. African water resource database. GIS-based tools for inland aquatic resource management. 2 Technical manual and workbook. CIFA Technical Paper 33/2.
Halls, A. S 1999. Spatial Models for the Evaluation and Management of Inland Fisheries. Final Report. FIR Plansys 23220 01 20, MRAG Ltd. London.
Welcomme, R. L. 2011. An overview of global catch statistics for inland fisheries. ICES Journal of Marine Science 68(8): 1751-1756.
Witte, F., de Graaf, M., Mkumbo, O. C., El-Moghraby, A. I. and Sibbing, F. A. 2009. Fisheries production in the Nile System. Dumont, H. J. (ed.). The Nile: origin, Environments, Limnology and Human Use. Springer. Monographiae Biologicae 89: P 723-747.

Name	Fish production - river (SL3.4)
Proxy	Wet season duration (EN2.3)
Type	Social (SL)
Category	Food security and livelihoods (3)
Motivation	The length of the wet season is important for biological production, flushing of fine sediments, channel maintenance and floodplain inundation.
Description	Duration of wet season (high flows) in river reach downstream of dam
Units	% Change from baseline

Source Data
Water resources simulation model output:
Timeseries of flow in river reach downstream of proposed dam

Method of calculation: Timeseries analysis
Identify 20th percentile exceedance flow rate from Natural time series
Calculate number of days during which the Natural 20th percentile flow rate is exceeded in Baseline and Scenario simulations
Calculate change in number of exceedance days: Scenario compared to Baseline % change

References
Opperman, J.J., Moyle, P.B., Larsen, E.W., Florsheim, J.L., Manfree, A.D. Floodplains: Processes and Management for Ecosystem Services. University of California Press, 2017. Available at https://www.jstor.org/stable/10.1525/j.ctv1xxt6n
Whitehead, P.J.P. Ministry of Forest Development, Game and Fisheries. The river fisheries of Kenya. The East African Agricultural Journal , April, 1960

Name	Productive land use (SL3.5)
Type	Social (SL)
Category	Food security and livelihoods (3)
Motivation	Protection of land that is currently productive will maintain livelihoods and social structures
Description	Extent of productive land area within dam / irrigation scheme footprint
Units	km2

Source Data
World Bank Global Land Cover (Globcover): The GlobCover project has developed a service capable of delivering global composites and land cover maps using as input observations from the 300m MERIS sensor on board the ENVISAT satellite mission. The GlobCover 2009 land cover map is derived by an automatic and regionally-tuned classification of a time series of global MERIS (MEdium Resolution Imaging Spectrometer) FR mosaics for the year 2009. The global land cover map counts 22 land cover classes defined with the United Nations (UN) Land Cover Classification System (LCCS). (https://datacatalog.worldbank.org/dataset/global-land-cover-2009)

Method of calculation: Interrogation of spatial data (GIS)
Intersect dam full supply / irrigation scheme clearing area with GlobCover dataset
GlobCover productive land-use categories:

Post-flooding or irrigated shrub or tree crops

Post-flooding or irrigated herbaceous crops

Rainfed croplands

Rainfed herbaceous crops

Rainfed shrub or tree crops (cash crops, vineyards, olive tree, orchards…)

Mosaic cropland (50-70%) / vegetation (grassland/shrubland/forest) (20-50%)

Mosaic cropland (50-70%) / grassland or shrubland (20-50%)

Mosaic vegetation (grassland/shrubland/forest) (50-70%) / cropland (20-50%)

Mosaic grassland or shrubland (50-70%) / cropland (20-50%)

Mosaic forest (50-70%) / cropland (20-50%)

References
Perez-Hoyos, A., Rembold, F., Kerdiles, H., Gallego, J. Comparison of global land cover datasets for cropland monitoring. Remote sensing, Nov 2017. Available at https://www.mdpi.com/journal/remotesensing

Name	Access to natural resources (SL3.6)
Proxy	Environmentally sensitive area (EN1.1)
Type	Social (SL)
Category	Food security and livelihoods (3)
Motivation	Protection of ecologically sensitive areas will serve to protect natural resources.
Description	Extent of ecologically sensitive area within dam / irrigation scheme footprint
Units	km2

Source Data

Ecologically Sensitive Areas refer to those areas located within the primary impact zones that have been, or could potentially be, classified into one of the IUCN protected area management categories (www.iucn.org). The IUCN categories provide a global standard for defining and recording protected areas and are increasingly being incorporated into government legislation (www.iucn.org). The IUCN Protected Areas Categories System are as follows: Category Ia – Strict Nature Reserve Category Ib – Wilderness Area Category II – National Park Category III – Natural Monument or Feature Category IV – Habitat / Species Management Area Category V – Protected Landscape e.g. Water Towers Category VI – Protected area with Sustainable Use of Natural Resources Typical areas in Kenya that could potentially be classified using the IUCN system include: Wetlands. Points identified as wetlands of international importance (www.ramsar.org). Birds. Points identified as Important Bird Areas (www.birdlife.org) National parks and reserves Gazetted water towers

Method of calculation:	Interrogation of spatial data (GIS)
Intersect dam full supply / irrigation scheme clearing area with environmentally sensitive area(s)	

References

African Development Bank (ADB) 2004. Group Policy on the Environment. February 20094.
Birdlife International. Important Bird Areas Programme. (www.birdlife.org).
International Finance Corporation (IFC). 2012. Performance Standard 6. Biodiversity Conservation and Sustainable Management of Living Natural Resources.
NEPAD 2003. Action plan for the environment initiative of the New Partnership for Africa's Development.
Ramsar (www.ramsar.org).
BirdLife International and NatureServe (2011) Bird species distribution maps of the world. BirdLife International, Cambridge, UK and NatureServe, Arlington, USA.

Name	Physical displacement (SL4.1)
Type	Social (SL)
Category	Displacement (4)
Motivation	Displacement impacts are classified as physical and economic displacement. Physical displacement is associated with the displacement of local communities due to dam inundation, and or area taken up by irrigation schemes and canals.
Description	Physical displacement of people due to inundation by proposed dam / establishment of planned irrigation scheme
Units	number of people

Source Data Africa High Resolution Population Density Maps (www.un-spider.org/links-and-resources/data-sources/africa-high-resolution-population-density-maps) WorldPop database (https://www.worldpop.org/)

Method of calculation:	Interrogation of spatial data (GIS)
Intersect dam full supply / irrigation scheme clearing area with population density spatial data	

References

Facebook Connectivity Lab and Center for International Earth Science Information Network - CIESIN - Columbia University. 2016. High Resolution Settlement Layer (HRSL). Source imagery for HRSL © 2016 DigitalGlobe. Accessed DAY MONTH YEAR.
Lloyd, C. T., Sorichetta, A., Tatem A. High resolution global gridded data for use in population studies. Scientific Data 4, Article number 170001 (2017)

Name	Energy generated (EC1.1)
Type	Economic (EC)
Category	Energy (1)
Motivation	Hydropower generation is a key benefit linked to water resources development and stimulates socio-economic development at local, national and regional levels
Description	Average hydropower generated
Units	GWh/a

Source Data Water resources simulation model output: Timeseries of hydropower output at HP node

Method of calculation:	Timeseries analysis
Calculate average energy (GWh/a) generated over simulation period	

References

Degefu, D. M., He, W., Zhao, J.H. Hydropower for sustainable water and energy development in Ethiopia. Sustainable Water Resources Management 1, 305-314 (2015)

Name	Crop production (EC2.1)
Type	Economic (EC)
Category	Food production (2)
Motivation	Increased food production through irrigation is a key benefit linked to water resources development. It creates food security and stimulates socio-economic development.
Description	Crop yield
Units	million ton/a

Source Data
Water resources simulation model output:
Timeseries of crop water requirements
Timeseries of crop water deficit
Typical crop yields as provided by Food and Agricultural Organisation FAOSTAT (http://www.fao.org/faostat/en/#home)

Method of calculation: Timeseries analysis
Calculate maximum crop yield (t) based on irrigation scheme area (km2) and FAO crop yield (t/ha)
y = 1.4493x2 + 3.0897x -0.6197
where y = actual crop yield as proportion of maximum crop yield (%); x = water applied ratio (%)

References
Stone, L.R., Sclegel, A.J., Khan, A.H., Klocke, N.L., Aiken, R.M. Water supply/yield relationships developed for study of water management. Journal of natural resources and life sciences education. Vol 35 (2006)

Name	Fish production - dams (EC2.2)
Proxy	Fish production - dams (SL3.3)
Type	Economic (EC)
Category	Food production (2)
Motivation	This indicator is linked to areas that will become inundated through impoundment, and therefore represents the additional fish habitat created by impoundments.
Description	Potential fisheries production
Units	ton per annum

Source Data
Water resources simulation model output:
Timeseries of surface area in proposed impoundment

Method of calculation: Timeseries analysis
y = 13.143 x 0.8305
where y = fish production (t/a); x = median area of inundation over simulation period (km2)

References
Bassa, G. K. 1986. Fishery resources of Southern Sudan. In A.B. Zahlan (ed.): The Agricultural sector of Sudan: Policy and systems studies, 291-299. London (UK), Ithaca Press.
Food and Agricultural Organisation of the United Nations (FAO) 2007. African water resource database. GIS-based tools for inland aquatic resource management. 2 Technical manual and workbook. CIFA Technical Paper 33/2.
Halls, A. S 1999. Spatial Models for the Evaluation and Management of Inland Fisheries. Final Report. FIR Plansys 23220 01 20, MRAG Ltd. London.
Welcomme, R. L. 2011. An overview of global catch statistics for inland fisheries. ICES Journal of Marine Science 68(8): 1751-1756.
Witte, F., de Graaf, M., Mkumbo, O. C., El-Moghraby, A. I. and Sibbing, F. A. 2009. Fisheries production in the Nile System. Dumont, H. J. (ed.). The Nile: origin, Environments, Limnology and Human Use. Springer. Monographiae Biologicae 89: P 723-747.

Name	Urban supply (EC3.1)
Type	Economic (EC)
Category	Water supply (3)
Motivation	Reliable supply of water to urban areas is imperative for economic growth and investment
Description	Water supplied to urban areas
Units	% of demand supplied

Source Data
Water resources simulation model output:
Timeseries of urban demand
Timeseries of urban water user deficit

Method of calculation: Timeseries analysis
Urban supply ratio (%) = mean annual supply (MCM) / mean annual demand (MCM)

References

Stéphanie dos Santos, E. Adams, G. Neville, Y. Wada, A. de Sherbinin, et al.. Urban growth and water access in sub-Saharan Africa: Progress, challenges, and emerging research directions. Science of the Total Environment, Elsevier, 2017, 607-608, pp.497 – 508.

Name	Rural supply (EC3.2)
Type	Economic (EC)
Category	Water supply (3)
Motivation	Reliable supply of water to rural areas is imperative for health and social welfare
Description	Water supplied to rural users
Units	% of demand supplied

Source Data
Water resources simulation model output:
Timeseries of rural demand
Timeseries of rural water user deficit

Method of calculation: Timeseries analysis
Rural supply ratio (%) = mean annual supply (MCM) / mean annual demand (MCM)

References

Cook, J., Kimuyu, P., Wittington, D. The costs of coping with poor water supply in rural Kenya. Water resources research. Vol 52 (2). Jan 2016. Available at https://doi.org/10.1002/2015WR017468

Name	Irrigation supply (EC3.3 & EC3.4)
Type	Economic (EC)
Category	Water supply (3)
Motivation	Reliable supply of water to irrigation areas is imperative for good crop yields
Description	Water supplied to irrigation users
Units	% of demand supplied

Source Data
Water resources simulation model output:
Timeseries of irrigation demand
Timeseries of irrigation water user deficit

Method of calculation: Timeseries analysis
Irrigation supply ratio (%) = mean annual supply (MCM) / mean annual demand (MCM)

References

Stone, L.R., Sclegel, A.J., Khan, A.H., Klocke, N.L., Aiken, R.M. Water supply/yield relationships developed for study of water management. Journal of natural resources and life sciences education. Vol 35 (2006)

Name	Flood reduction (EC4.1)
Type	Economic (EC)
Category	Flood damage (4)
Motivation	Large dams provide flood attenuation with potential flood risk reduction downstream
Description	Storage provided by dam as proportion of total natural runoff
Units	Ratio

Source Data
Water resources simulation model output:
Timeseries of inflow sequence into proposed dam
Full storage volume of proposed dam

Method of calculation: Timeseries Analysis
Flood reduction benefit = Dam volume (MCM) / Natural Mean Annual Runoff at dam location (MCM)

References

Volpi, E., Di Lazzaro, M., Bertola, M., Viglione, A. Fiori, A. Reservoir Effects on Flood Peak Discharge at the Catchment Scale. Water Resources Research, Vol 54 (11)

Name	Employment – Commercial irrigation (EC5.1)
Type	Economic (EC)
Category	Macro-economic (5)
Motivation	Development of large-scale, commercial irrigation creates jobs
Description	Extent of proposed large-scale irrigation schemes and potential income
Units	number of jobs

Source Data
Planned large scale irrigation (km2)
Water resources simulation model output:
Timeseries of crop water requirements

Timeseries of crop water deficit Typical crop yields - Food and Agricultural Organisation FAOSTAT (http://www.fao.org/faostat/en/#home) Potential crop income - Food and Agricultural Organisation FAOSTAT (http://www.fao.org/faostat/en/#home) Primary and secondary economic indicators

Method of calculation:	Macro-economic analysis
Use macro-economic model (Annexure A6) to analyse the impacts of commercial irrigation on regional economic activity and job creation	

References

Neubert, S. Poverty oriented irrigation policy in Kenya: Empirical results and suggestions for reform. German Development Institute, Discussion Paper. Dec 2007

Name	Employment – Hydropower generation (EC5.2)
Type	Economic (EC)
Category	Macro-economic (5)
Motivation	Development of hydropower creates direct and indirect employment
Description	Energy generated through hydropower
Units	number of jobs

Source Data Water resources simulation model output: Timeseries of hydropower output at HP node Primary and secondary economic indicators

Method of calculation:	Macro-economic analysis
Use macro-economic model (Annexure A6) to analyse the impacts of energy generation on regional economic activity and job creation	

References

Renner, M., García-Baños, C., Khalid, A. The International Renewable Energy Agency. Renewable Energy and Jobs Annual Review 2019. International Renewable Energy Agency

Name	Health cost related to water quality (EC5.3)
Type	Economic (EC)
Category	Macro-economic (5)
Motivation	Poor water quality leads to direct and indirect costs associated with health issues
Description	Health costs related to poor water quality
Units	Relative to baseline

Source Data Refer to Indicators EN3.1 and EN3.2 Primary and secondary economic indicators

Method of calculation:	Macro-economic analysis
Use macro-economic model (Annexure A6) to analyse the potential impacts of poor water quality on health cost.	

References

Clough, J. Africa’s Water Quality A Chemical Science Perspective A report by the Pan Africa Chemistry Network. March 2010

Name	Water resources development’s contribution to GDP growth (EC5.4)
Type	Economic (EC)
Category	Macro-economic (5)
Motivation	Water resources development and efficient management increases GDP
Description	GDP growth as a function of water resources development
Units	Relative to baseline

Source Data Refer to Annexure A6 Primary and secondary economic indicators

Method of calculation:	Macro-economic analysis
Use macro-economic model (Annexure A6) to analyse the potential impacts of water resources development on GDP.	

References

Blignaut, J, Van Heerden, J. The impact of water scarcity on economic development initiatives. Water SA vol.35 n.4 Pretoria Jul. 2009

Name	Sediment load (EC6.1)
Type	Economic (EC)

Category	Sediment (6)
Motivation	Land use cover and management affect erosion risk and potential sediment yield
Description	Potential soil loss and sediment loads in rivers
Units	Ratio (Potential sediment load / Baseline sediment load)

Source Data Refer to Annexure A1

Method of calculation: Refer to Annexure A1	Spatial Analysis

References

Lahlou, A. Environmental and socio-economic impacts of erosion and sedimentation in north Africa. Erosion and Sediment Yield: Global and Regional Perspectives (Proceedings of the Exeter Symposium, July 1996). IAHS Publ. no. 236, 1996. 491

A7: Macro-economic analysis

Background

To understand the role of water resources to the current economy and the potential for future development in Kenya, a set of macro-economic indicators were developed which relate to economic policy assessments, GDP, employment and government expenses. The purpose of this was to assess how alternative water resources development scenarios in individual river basins compare in terms of macro-economic impacts through water resources system components (irrigation, hydropower, etc. and macro-economic sectors (e.g. agriculture, manufacturing, etc.). Furthermore, it allows comparison of economic impacts linked to investments in water resources system components among the six river basins in Kenya and provide insight into the sectoral and total economic value of water resources development priorities and policies for Kenya.

Methodology

Both Primary and Secondary economic indicators were used in the macro-economic analysis.

Primary Economic Indicators

To analyse the impacts of regional water resources development on regional economic activity, Gross Value Added (GVA) was used for measuring gross regional domestic product as a measure of the output of entities smaller than the national economy. GVA is defined as GDP + subsidies - (direct, sales) taxes. The Kenya National Bureau of Statistics reports regional economic activity, as GVA, by 17 economic sectors. This was determined as overly detailed for the scope of this analysis and consequently the 17 sectors were aggregated to 4 economic sectors that better link to outputs of water resources analyses. The aggregation is presented in Figure A7-1.

Figure A7-1: Aggregation of Macro-Economic Sectors for the Hydro-Economic Analysis

1	Agriculture, forestry and fishing
2	Mining and quarrying
3	Manufacturing
4	Electricity supply
5	Water supply; waste collection
6	Construction
7	Wholesale and retail trade; repair of motor vehicles
8	Transport and storage
9	Accommodation and food service activities
10	Information and communication
11	Financial and insurance activities
12	Real estate activities
13	Professional, technical and support services
14	Public administration and defence
15	Education
16	Human health and social work activities
17	Other service activities

1	Agriculture
2	Industry, Commerical, & Services
3	Electric Genearation
4	Transport

Secondary Economic Indicators

Secondary indicators which were utilised and related to water resources analysis outputs include Employment and Government spending in the Health Sector.

Table A7-1 displays the relationship between the Economic Indicators and the water resources model outputs as incorporated into the Macro-Economic analysis.

Table A7-1: Linkages between the Economic Indicators and Hydro-Model Indicators

Economic Sector	Water Sector	Water resources model output	Units
Agriculture	Irrigation Supply	Irrigation supply	MCM/a
Industry, Commercial, Services	Urban Water Supply	Urban water supply	MCM/a
Energy	Hydropower Generation	Hydropower generated	GWh/a
Transport	Flood Control	Storage in large dams	Flood Control Index
Employment – Agriculture	Irrigation Area	Irrigation area	Hectare Irrigated
Employment -Industry	Energy Generation	Hydropower generated	GWh/a
Health Cost	Water Quality	Water quality index	Water Pollution Index

Data

The Kenya National Bureau of Statistics spatially disaggregated the Gross Domestic Product of Kenya to County level. The estimation for 17 economic sectors and 47 counties revealed that there are significant differences in the size of economy across counties. The average contribution per county to GVA over the period 2013-2017 is approximately 2.1 percent with a standard deviation of 3.2. As may be expected, this indicates large disparities in the size of GDP across the counties. Nairobi County takes the lead, contributing approximately 21.7 percent of GDP over the period, followed by Nakuru (6.1%), Kiambu (5.5%) and Mombasa counties (4.7%) (KNBS, 2019).

Table A7-2 shows estimates of GVA at current prices by County and by industry (sector). The breakdown indicates how much each county contributed to each economic activity. For instance Samburu Counry contributed KSh 10,847 million to the Agriculture, Forestry and Fishing sector in 2017.

Table A7-2: Gross Value Added (GVA) at current prices by county and by industry (sector).

		SECTORAL GVA (KSH Millions)					
ID	**County**	**Agriculture**	**Industrial**	**Energy**	**Transport**	**Services**	**Total**
30	BARINGO	53633	357	413	4737	33726	92866
36	BOMET	114076	5314	205	2512	37462	159569
39	BUNGOMA	107829	2024	433	10388	62835	183509
40	BUSIA	50020	453	246	3253	32740	86712
28	ELGEYO	127967	527	209	3579	27249	159531
14	EMBU	39794	2644	6503	10599	44194	103734
7	GARISSA	16845	1712	318	1410	19109	39394
43	HOMA	68247	958	486	5708	38799	114198
11	ISIOLO	3325	52	162	1030	11281	15850
34	KAJIADO	15954	7897	2789	7899	73266	107805
37	KAKAMEGA	95193	9451	975	7504	69440	182563
35	KERICHO	62765	13867	853	5787	53527	136799
22	KIAMBU	132421	54081	9533	29094	196789	421918
3	KILIFI	38319	11790	1471	11411	56304	119295
20	KIRINYAGA	41208	8110	826	9763	40929	100836
45	KISII	85550	3338	1149	9578	63931	163546
42	KISUMU	51445	24721	4106	19636	94581	194489
15	KITUI	41799	755	960	7147	50899	101560
2	KWALE	39610	1747	730	4198	39993	86278
31	LAIKIPIA	35489	823	723	5904	38156	81095
5	LAMU	18699	174	340	4171	9002	32386
16	MACHAKOS	56112	48155	9019	12736	106838	232860
17	MAKUENI	47606	1050	373	5276	46619	100924
9	MANDERA	14169	206	581	1155	18990	35101
10	MARSABIT	16078	85	259	337	17314	34073
12	MERU	124381	8401	1025	19072	76767	229646
44	MIGORI	40861	8726	352	6648	39750	96337
1	MOMBASA	1459	48506	20546	88308	173303	332122
21	MURANGA	89003	9679	1675	7005	65656	173018
47	NAIROBI	4102	375282	26878	184845	901216	1492323
32	NAKURU	301349	15408	36932	30640	133133	517462
29	NANDI	71213	4709	489	3300	39980	119691
33	NAROK	120355	2322	653	4601	51295	179226
46	NYAMIRA	56634	6728	489	3268	36120	103239
18	NYANDARUA	209519	1815	400	4269	29200	245203
19	NYERI	92859	5996	1703	12263	62140	174961
25	SAMBURU	10847	76	123	1234	14223	26503
41	SIAYA	50685	1282	390	3858	39050	95265
6	TAITA	19858	828	567	3109	27019	51381
4	TANA	18333	68	73	924	14100	33498
13	THARAKA	38740	317	210	2381	26044	67692
26	TRANS	50628	1058	810	7958	56229	116683
23	TURKANA	41493	153	2066	7750	26839	78301
27	UASIN-GISHU	63017	8628	1042	17552	72034	162273
38	VIHIGA	20160	2017	547	2292	34034	59050
8	WAJIR	20032	465	22	258	16382	37159
24	WEST	19311	2862	69	3904	20639	46785

Figure A7-2 presents total GVA by county with the six Kenya River Basins overlaid, while Figure A7-3 presents Agricultural GVA per county. These figures show how spatially varied the GVA values are-both within river basins and between river basins.

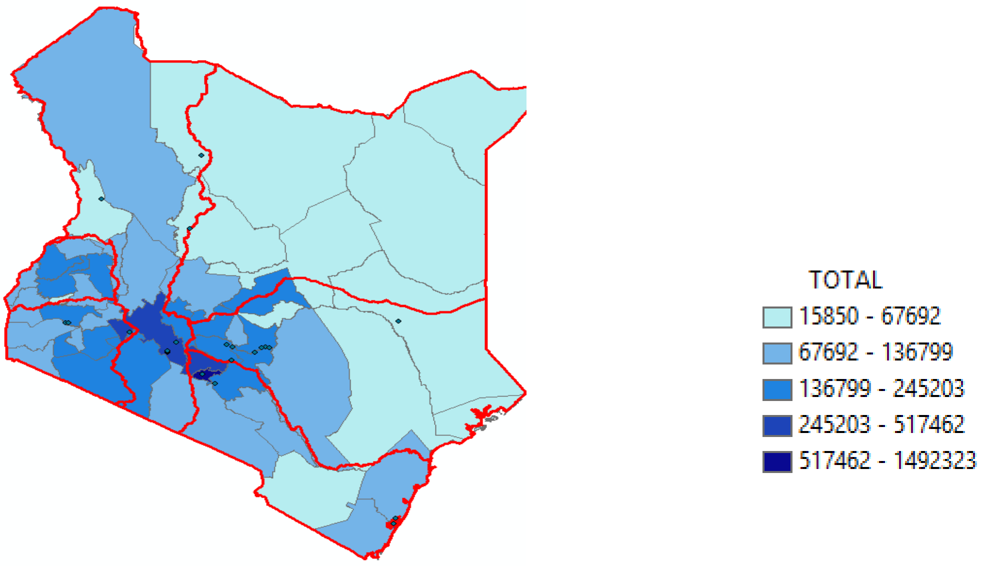

Figure A7-2: TOTAL GVA by County (KSH Millions)

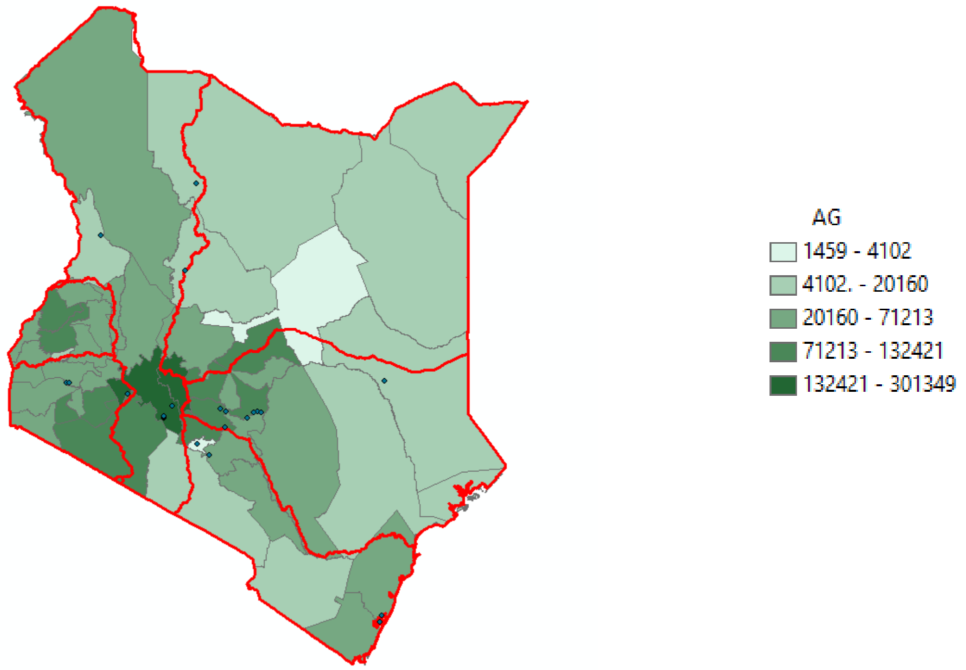

Figure A7-3: Agricultural GVA by County (KSH Millions)

Since the Hydro-Model Indicators are provided at River Basin level, the economic indicators needed to be calculated likewise. Using GIS tools, the area of each County in each river basin was estimated (Table A7-3) and a matrix of weights from Country to River basin was developed. With this matrix the GVA per river basin could be estimated. Figures A7-4 and A7-5 show River Basin GVAs for Total GVA and Agricultural GVA respectively.

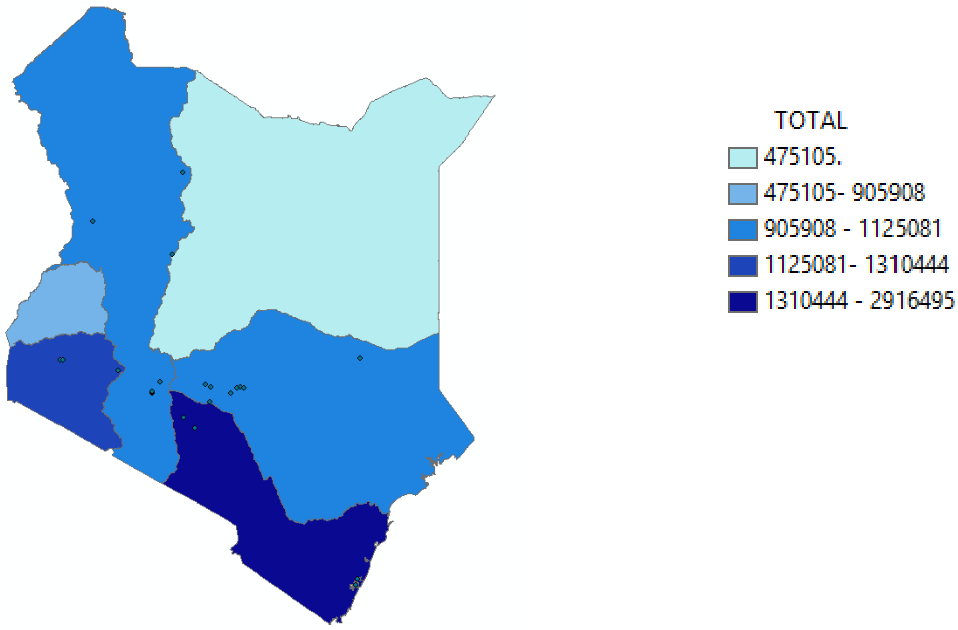

Figure A7-4: TOTAL GVA by River Basin'

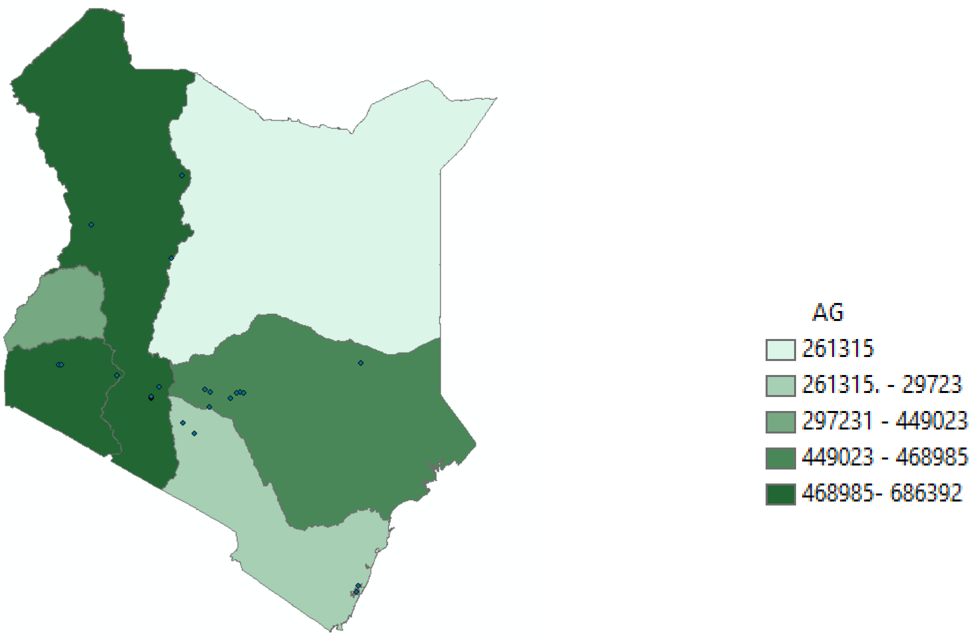

Figure A7-5: Agricultural GVA by River Basin

Table A7-3. TOTAL GVA by County

		BASIN					
ID	County	ACA	ENNCA	LVNCA	LVSCA	RVCA	TCA
30	BARINGO					100%	
36	BOMET				100%		
39	BUNGOMA			100%			
40	BUSIA			100%			
28	ELGEYO				35%	65%	
14	EMBU						100%
7	GARISSA		32%				68%
43	HOMA				100%		
11	ISIOLO		89%				11%
34	KAJIADO	64%				36%	
37	KAKAMEGA			100%			
35	KERICHO				100%		
22	KIAMBU	78%				11%	12%
3	KILIFI	85%					15%
20	KIRINYAGA						100%
45	KISII				100%		
42	KISUMU				100%		
15	KITUI	4%					96%
2	KWALE	100%					
31	LAIKIPIA		88%			12%	
5	LAMU						100%
16	MACHAKOS	66%					34%
17	MAKUENI	100%					
9	MANDERA		100%				
10	MARSABIT		79%			21%	
12	MERU		47%				53%
44	MIGORI				100%		
1	MOMBASA	100%					
21	MURANGA						100%
47	NAIROBI	100%					
32	NAKURU				16%	84%	
29	NANDI			64%	36%		
33	NAROK				50%	50%	
46	NYAMIRA				100%		
18	NYANDARUA		38%			62%	
19	NYERI		30%				70%
25	SAMBURU		77%			23%	
41	SIAYA			52%	48%		
6	TAITA	100%					
4	TANA						100%
13	THARAKA						100%
26	TRANS			91%		9%	
23	TURKANA					100%	
27	UASIN-GISHU			100%			
38	VIHIGA			76%	24%		
8	WAJIR		100%				
24	WEST					100%	

Figure A7-6 displays the locations of existing electrical power generation stations across Kenya, whjch were used, along with the locations of proposed hydropower stations, to assess energy benefits.

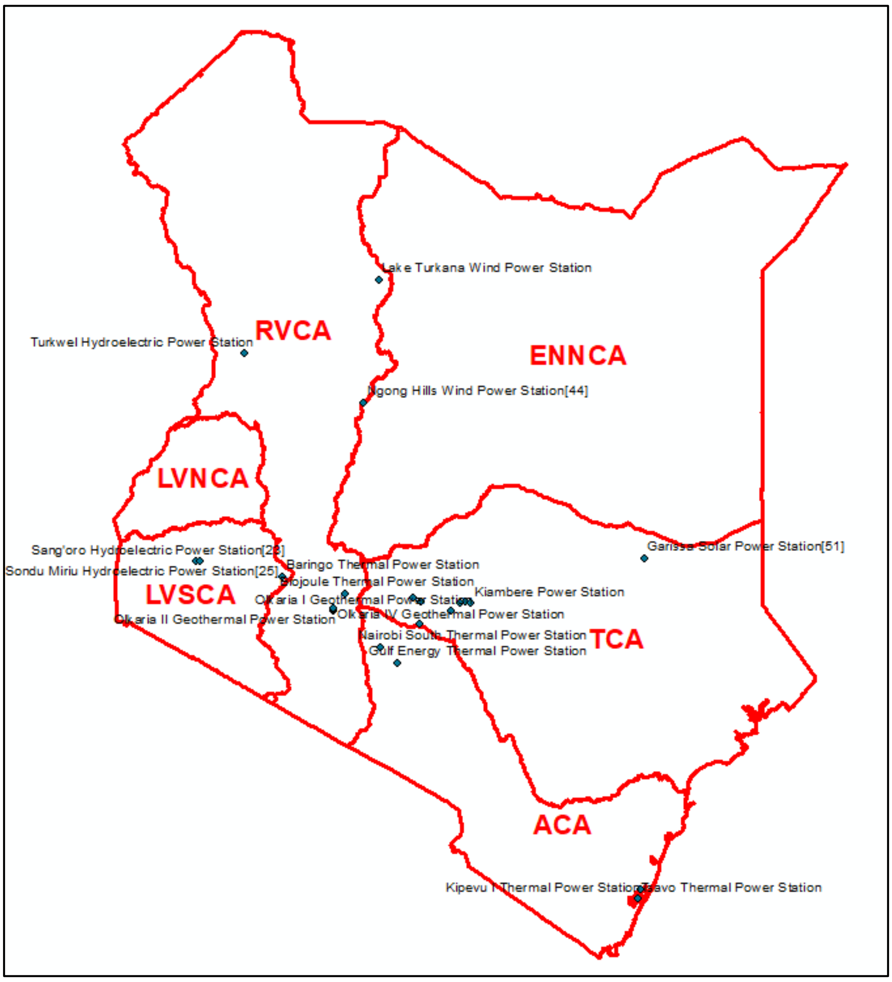

Figure A7-6: Electric Generation Stations in relation to river basins

Estimation of macro-economic indicators

Using the 2017 GVA data aggregated to the six river basins and the outputs from the water resources Baseline (current day) model, data coefficients were determined for each river basin, which were then used to generate primary and secondary economic indicators based on the water resources model outputs for each river basin and each scenario.

References

a) Power Africa, 2015 Development of Kenya's Power Sector 2015-2020
b) Trading Economics, 2019, Kenya - Total electricity output, https://tradingeconomics.com/kenya/total-electricity-output-gwh-wb-data.html
c) KNBS, 2019, Gross County Product. Kenya National Bureau of Statistics.

B1: Water availability, current water demands (2018) and water balance per sub-basin

Subbasin	Area (km2)	MAP (mm)	Water resources potential (MCM/a)			Q95 (MCM/a)	Current water demand (MCM/a)					Water balance	
			Natural Surface Runoff	Groundwater sustainable yield	Total		Irrigation	Livestock	Domestic / Industrial	Wildlife & Fisheries	Total	(MCM/a)	%
3AA	646	761	65	3.6	69	0.01	18.6	0.3	0.0	0.3	19.2	49	72%
3AB	1604	621	46	6.6	53	0.00	31.0	0.9	0.0	0.3	32.2	21	39%
3AC	803	725	49	3.9	53	0.00	8.6	0.9	0.0	0.3	9.9	43	81%
3BA	772	881	120	5.3	125	4.21	43.1	1.3	265.2	0.3	309.8	0	0%
3BB	210	965	82	3.2	85	9.93	16.3	0.3	8.7	0.3	25.7	49	58%
3BC	454	1072	162	3.3	165	19.76	25.9	0.9	62.8	0.3	90.0	56	34%
3BD	272	993	96	3.7	100	8.15	18.1	0.3	7.4	0.3	26.1	65	66%
3CB	361	1003	116	3.4	119	9.84	26.3	0.3	4.2	0.3	31.1	78	66%
3DA	694	799	51	3.1	54	0.03	6.8	0.6	0.3	0.3	8.1	46	85%
3DB	733	701	26	2.4	29	0.00	5.4	0.6	2.7	0.3	9.1	20	69%
3EA	746	800	57	2.6	60	0.00	6.0	0.9	8.5	0.3	15.8	44	74%
3EB	723	844	56	2.1	58	0.00	7.4	0.6	0.0	0.3	8.4	49	85%
3EC	631	903	65	2.4	68	0.00	6.7	0.6	0.5	0.3	8.1	59	88%
3ED	509	716	19	1.7	21	0.00	6.4	0.3	5.4	0.3	12.5	9	41%
3FA	8905	578	305	34.1	339	0.47	64.5	3.8	9.2	0.3	77.7	261	77%
3FB	3797	629	82	11.8	93	0.1	57.2	0.9	6.4	0.3	64.8	29	31%
3G	6378	658	134	15.9	149	82.0	146.1	1.6	0.3	0.3	148.3	0	0%
3HA	825	613	11	1.0	12	0.0	34.6	0.0	0.0	0.3	34.9	0	0%
3HB	2060	585	15	5.8	20	0.0	89.3	0.3	0.0	0.3	90.0	0	0%
3HC	2629	873	41	47.1	88	0.0	30.0	0.3	0.0	0.3	30.7	57	65%
3HD1	763	1029	35	15.5	50	0.0	8.3	0.0	0.0	0.3	8.6	42	83%
3HD2	226	922	25	21.7	46	0.1	12.5	0.0	0.0	0.3	12.8	33	72%
3J	3618	666	112	5.8	118	15.8	98.3	0.3	0.1	0.3	99.0	3	2%
3KA	2735	1093	236	29.5	265	1.5	6.9	2.2	16.1	0.3	25.5	238	90%
3KB	5996	826	8	64.6	73	0.0	0.0	0.0	0.0	0.3	0.3	72	100%
3LA	6931	762	62	75.0	137	0.0	66.8	1.6	6.1	0.3	74.7	62	45%
3LB	707	1245	2	37.3	39	0.0	5.0	0.0	10.2	0.3	15.5	23	60%
3MA1	3016	644	5	0.5	5	0.0	61.7	0.6	0.0	0.3	62.6	0	0%
3MA2	1981	755	27	29.0	56	0.0	88.6	0.6	0.0	0.3	89.6	0	0%
3MB	1538	906	99	26.1	125	0.0	1.1	0.6	0.0	0.3	2.0	123	98%
3MC	1030	987	71	17.9	88	3.0	1.4	0.3	2.0	0.3	4.0	81	92%
3MD1	1216	1181	146	46.3	192	0.8	0.3	0.9	73.8	0.3	75.4	116	60%
3MD2	92	1234	28	7.7	36	0.4	0.2	0.0	0.0	0.3	0.5	35	98%
3N	2831	656	104	8.7	113	0.2	29.0	0.9	0.0	0.3	30.3	82	73%
Total	**66559**	**-**	**2555**	**549**	**3103**	**156**	**1028**	**24**	**490**	**11**	**1553**	**-**	**-**

B2: Future (2040) water demands per sub-basin

Subbasin	Future water demand (MCM/a)				
	Irrigation	Livestock	Domestic / Industrial	Wildlife & Fisheries	Total
3AA	25.6	0.8	17.0	0.4	43.8
3AB	42.7	2.5	28.9	0.4	74.5
3AC	11.8	2.5	9.2	0.4	23.9
3BA	59.3	3.3	40.1	0.4	103.1
3BB	22.5	0.8	15.0	0.4	38.7
3BC	35.6	2.5	24.4	0.4	62.9
3BD	24.9	0.8	16.5	0.4	42.7
3CB	36.3	0.8	23.8	0.4	61.3
3DA	9.4	1.6	7.1	0.4	18.5
3DB	7.4	1.6	5.8	0.4	15.3
3EA	8.3	2.5	6.9	0.4	18.0
3EB	10.2	1.6	7.6	0.4	19.9
3EC	9.2	1.6	6.9	0.4	18.1
3ED	8.8	0.8	6.2	0.4	16.3
3FA	88.8	9.8	63.3	0.4	162.3
3FB	78.7	2.5	52.1	0.4	133.7
3G	201.2	4.1	131.7	0.4	337.4
3HA	47.6	0.0	30.5	0.4	78.6
3HB	123.0	0.8	79.5	0.4	203.7
3HC	41.4	0.8	27.1	0.4	69.6
3HD1	11.4	0.0	7.3	0.4	19.1
3HD2	17.2	0.0	11.1	0.4	28.7
3J	135.4	0.8	87.4	0.4	224.1
3KA	9.5	5.7	9.8	0.4	25.5
3KB	0.0	0.0	0.0	0.4	0.4
3LA	92.0	4.1	61.6	0.4	158.1
3LB	6.9	0.0	4.4	0.4	11.8
3MA1	85.0	1.6	55.6	0.4	142.6
3MA2	122.0	1.6	79.3	0.4	203.4
3MB	1.5	1.6	2.0	0.4	5.5
3MC	1.9	0.8	1.8	0.4	4.9
3MD1	0.4	2.5	1.9	0.4	5.2
3MD2	0.2	0.0	0.1	0.4	0.8
3N	39.9	2.5	27.2	0.4	69.9
Total	**1416**	**63**	**949**	**14**	**2442**

C1. Environmental management

C1.1. Framework

To ensure quality of attention to environmental and social factors that affect the sustainable utilisation of water and allied resources in the LVS Basin, the legislative, policy and institutional framework for environmental management should govern the development, and implementation of the strategies, sub-plans and actions emanating from this LVS Basin Plan. This framework needs to be understood if the LVS Basin Plan is to attain the goals of social acceptability, economic viability and technical sustainability in line with internationally accepted standards for good practice.

- ***The Constitution of Kenya, 2010:*** is the supreme law in the Country providing the broad framework regulating all existence and development aspects of interest to the people of Kenya, and along which all national and sectoral legislative documents are drawn. Its Chapter V is entirely dedicated to land and environment, and a number of environmental principles feature in various parts. The Constitution embodies social and economic rights of an environmental character, such as the right to water, food and shelter, the right of every person to a clean and healthy environment, and the right to have the environment protected for the benefit of present and future generations through legislative measures.

- ***The National Environment Policy, 2012:*** provides a holistic framework to guide the management of the environment and natural resources in Kenya. It further ensures that the linkage between the environment and poverty reduction is integrated in all government processes and institutions to facilitate and realize sustainable development at all levels in the context of green economy enhancing social inclusion, improving human welfare and creating opportunities for employment and maintaining the healthy functioning of ecosystem.

- ***The Environmental Management and Coordination Act, 1999 (as amended 2015) Cap 387 (EMCA):*** is the framework law on the environment in Kenya. The EMCA was enacted to provide an appropriate legal and institutional framework for the management of the environment in Kenya. The Act was amended in May 2015 and took effect on 17 June 2015.

  The Act aims to improve the legal and administrative coordination of the diverse sectoral initiatives in the field of environment in order to enhance the national capacity for its effective management. In addition, the Act seeks to align the 77 sector specific legislations pertaining to the environment in a manner designed to ensure greater protection of the environment. This is in line with national objectives and sustainable development goals enunciated in the Agenda 21 of the Earth Summit held in Rio de Janeiro in 1992. The ultimate objective is to provide a framework for integrating environmental considerations into the country's overall economic and social development. In terms of environmental management, the EMCA provides a comprehensive legal and institutional framework for the handling of all environmental issues in Kenya and covers all sectoral laws.

  EMCA does not repeal the sectoral legislation but seeks to coordinate the activities of the various institutions tasked to regulate the various sectors. These institutions are referred to as Lead Agencies in EMCA.

The EMCA is supported by several subsidiary Regulations such as Solid Waste Management Regulations (2006), Environmental Management and Coordination (Water Quality) Regulations (2006) and Emissions Regulations (2007), as well as other pertinent International Environmental Regulations.

C1.1.1. National institutions

National institutions in Kenya who are involved with biodiversity and ecosystems management are listed below.

Table C1-1: Institutions and Ministries with mandates for biodiversity and ecosystems management

Ministry/ institution	Main roles and responsibilities	Legislative framework
Water Resources Authority (WRA)	Regulation of the management and use of water resources. This is done through permitting, b) support preparation of the Government's plans and programs for the protection, conservation, control and management of water resources through formulation of National Management strategy, c) formulation and enforcement of standards, procedures and Regulations for the management and use of water resources and flood mitigation. Protection of catchment areas, conservation of ground water, power to require permit applications or re-applications, agreements as to protection of sources of water, etc.,regulation of abstraction of ground water.	Water Act (2016).
Water Resource User Associations (WRUAs)	Ensure cooperative management of water resources at the sub-basin and community level.	Water Act (2016).
Ministry of Forestry and Wildlife	Formulate forestry and wildlife policies, initiate and oversee drafting of relevant legislation, sector coordination and guidance, monitoring and evaluation.	Forests Act (No. 7 of 2005) Wildlife (Conservation and Management) Act (Cap 376)
Kenya Wildlife Service (KWS)	Conserve wildlife and their ecosystems; National Ramsar administrative authority.	Wildlife (Conservation and Management) Act (Cap 376).
Kenya Forestry Service (KFS)	Conserve, develop and sustainably manage Kenya's forest resources for the country's social-economic development.	Forests Act (No. 7 of 2005).
Ministry of Environment and Mineral Resources	Formulate environmental laws and policies, monitor, protect, conserve and manage the environment and natural resources by ensuring sustainable utilisation.	Environmental Management and Coordination (Amendment) Act, 2015
National Environment Management Authority (NEMA)	Coordinate environmental management; provide guidance on the development of wetland management plans; ensure compliance of environmental laws.	Environmental Management and Coordination Act (No. 8 of 1999).
Ministry of Fisheries Development	Formulate policies, oversee drafting of relevant legislation, policy formulation, sector coordination and guidance, monitoring and evaluation.	Fisheries Act (Cap 378).
National Museums of Kenya (NMK)	Promote Kenya's heritage by collecting and preserving artefacts and research.	National Museums and Heritage Act (No. 6 of 2006).

Ministry/ institution	Main roles and responsibilities	Legislative framework
District Environmental Committees (DECs)	Provide technical support for environmental management including all ecosystems and integrate wetland protection into district development plans.	Environmental Management and Coordination Act (No. 8 of 1999).

The institutional framework for the implementation of EMCA and its Regulations include:

- The National Environment Council (The Council): is responsible for policy formulation and directions for the purposes of the EMCA. The Council also sets national goals and objectives and determines policies and priorities for the protection of the environment.
- The National Environmental Management Authority (NEMA): is the body charged with overall responsibility of exercising general supervision and co-ordination over all matters relating to the environment and to be the principal instrument of government in the implementation of all policies relating to the environment. Activities of NEMA are handled by three core directorates: Enforcement, Education and Policy.
- Lead Agencies: Lead Agencies are defined in Section 2 of EMCA as any Government ministry, department, parastatal, and State Corporation or local authority in which any law vests functions of control or management of any element of the environment or natural resource.
- County Environmental Committees (CEC): are the District level bodies chaired by respective County Commissioners and bringing together representatives from all the ministries; representatives from local authorities within the province/district; two farmers/pastoral representatives; two representatives from NGOs involved in environmental management in the province/district; and a representative of each regional development authority in the province/district. To each CEC in the country is attached a County Environmental Coordinator who serves as the secretary to the CEC, and as the NEMA Officer on the ground, is charged with responsibility of overseeing environmental coordination among diverse sectors.

C1.1.2. Strategic Environmental Assessment (SEA)

Role of SEA

Strategic Environmental Assessment (SEA) in the context of the Kenyan Environmental legislation refers to a range of analytical and participatory approaches that aim to systematically integrate environmental consideration into ***policies, plans and programmes*** and evaluate the interlinkages with economic and social considerations.

In the SEA process, likely significant effects of a policy, plan, or program on the environment, which may include secondary, cumulative, synergistic, short, medium and long term, permanent and temporary impacts are identified, described and evaluated in an environmental report.

This process extends the aims and principles of Environmental Impact Assessment (EIA) upstream in the decision-making process, beyond the project level and when major alternatives are still open (NEMA, 2011). SEA represents a proactive approach to integrating environmental considerations into the higher levels of decision making, consistent with the principles outlined in Agenda 21 (UNEP, 2007).

SEA can play an advocacy role, where its primary purpose is to raise the profile of the environment, and typically this would occur when the SEA is applied to a plan, policy or programme that has already been developed. In the context of the LVS Basin Plan however, SEA might be a better used in an integrative role, where the focus is on combining environmental, social and economic considerations into the planning process. In this way the SEA can promote an integrated system of planning that incorporates sustainability objectives at a policy, plan or programme level (DEAT, 2004).

There are a number of strategic decisions that are typically taken at the policy, plan and programme level that have an influence on downstream projects and developments. The role of SEA is to allow for the decision-maker to proactively determine the most suitable development type for a particular area, before development proposals are formulated and subjected to EIA (DEAT, 2004). In this way SEA can strengthen future EIAs by considering a broader range of alternatives, addressing cumulative effects, and facilitating the enhancement of a chosen level of environmental quality at a strategic level, thereby providing better context for EIA processes. The role of SEA and the role of EIA are complimentary, and SEA has the potential to make the EIA process more powerful. These tools can be utilised by WRA, BWRCs and WRUAs to vet the environmental integrity of developments in the LVS basin that are linked to water resources management. Developments that are most likely to have negative impacts on the resources can be prevented trough public consultation phases or public commenting phases.

Table C1-2: Comparison between the different roles offered through SEA and EIA (adapted from DEAT, 2004)

SEA: Policy, Plan and Programme Level	EIA: Project Level
Is pro-active and can inform future development proposals	Is reactive to a development proposal decision already taken
Is used to assess the effect of the existing environmental and socio-economic conditions on development opportunities and constraints	Is used to assess the effect of a proposed development on the environment and socio-economic conditions
Relates to areas, regions or sectors of development	Relates to a specific project
Enables the development of a framework against which positive and negative impacts can be measured	Enables the identification of project-specific impacts
Is a process aimed at the development of a sustainability framework to inform continuous decision-making over a period of time	Has a well-defined beginning and end and focuses on informing a specific decision
Is focussed on maintaining a chosen level of environmental quality and socio-economic conditions	Is focused on the mitigation of negative impacts and the enhancement of positive impacts
Has a wide perspective and includes a low level of detail to provide a vision and framework	Has a narrow perspective and includes intricate detail

Key aspects typically addressed under a SEA include developing baseline information, determining compatibility of proposed project interventions with the basin environment conditions, identifying and evaluating the significant environmental impacts of the proposed interventions in the basin plan, assessing the environmental costs and benefits of the proposed projects to the local and national economy, and evaluating and selecting the best project alternatives from the various options.

Issues to be considered are broad and generally relatem to destruction of the physical environment through deforestation and degradation, loss of biodiversity-destruction of flora and flora, increased human-wildlife conflict, increased demand for forest products, environmental pollution and catchment degradation, contamination of rivers, wetlands and ground water resources, climate change and related disasters like floods, drought, pests and diseases, overgrazing, increased urbanization, poor governance and weak institutions, and consumer rights and access to information.

The SEA provides every stakeholder a *locus standi* to address environmental degradation and undertaking specific EIA's for interventions proposed in the basin plan.

Specifically, the SEA will offer various opportunities among them:

- Improved processes of environmental administration and governance, so that the purpose and expectations of the various policies and legislation are fully attained.
- Enhanced engagement of communities and wider stakeholders in the basin in environmental issues and governance.
- Capacity building of all stakeholders to allow the processes of environmental administration and governance in the basin to be conducted with best practices and underlying goals as provided in the various statutes and policies.

SEA Challenges

Some of the expected challenges in implementing the SEA process include:

- Inadequate participation of the key stakeholders in the SEA process and conflicting mandates in the governance framework of the key natural resources in the basin.
- Lack of effective coordination among implementing agencies and institutions in the basin
- Lack of effective political will during the implementation of the SEA recommendations
- Lack of a benefit sharing framework of the key natural resources in the basin within the framework of an agreed public private partnership
- Lack of adequate resources to implement the recommendations in the SEA

Legislative Framework for SEA

The legislative framework for SEA in the Kenyan context includes:

- ***The Environmental Management and Coordination Act, 1999 (as amended 2015) Cap 387 (EMCA):*** Prior to amendment in 2015, EMCA addressed itself primarily to Environmental Impact Assessment (Section 58). However, the EMCA (as amended 2015) now also addresses Strategic Environmental Assessment. EMCA (as amended) Article 57 (A) (1) states that "*all Policies, Plans and Programmes for implementation shall be subject to Strategic Environmental Assessment*". It describes plans, programmes and policies as those that are-
    - Subject to preparation or adoption by an authority at regional, national, county or local level, or which are prepared by an authority for adoption through a legislative procedure by Parliament, Government or if regional, by agreements between the governments or regional authorities, as the case may be;
    - Determined by the Authority as likely to have significant effects on the environment.
- ***The Environmental (Impact Assessment and Audit) Regulations, 2003:*** Recognizes SEAs as a measure of environmental impact assessment at a strategic level for policy, plans and programmes. The Regulation's Part VI Sections 42 and 43 address Strategic Environment Assessments:
    - Section 42(1) requires Lead Agencies in consultation with NEMA to subject all policy, plans and programmes for implementation to a Strategic Environment Assessments.
    - Section 42(3) commits the Government and all Lead Agencies to incorporate principles of SEA in the development of sector or national policy.
    - Section 43(1) provides the requisite content for a Strategic Environmental Impact Report.
    - Section 43(2) requests certain information within the policy, plan or programme.

    - Section 43(3) commits the Government and all Lead Agencies to incorporate principles of SEA in the development of sector or national or regional policy.

- ***National Guidelines for Strategic Environmental Assessment in Kenya, (NEMA, Revised 2011):*** Increasingly, NEMA was faced with the challenges of the inadequacy of EIA to deal with cumulative, synergistic, secondary and long-term impacts. These impacts are better addressed if policies, plans and programmes are subjected to an SEA process. Consequently, NEMA formulated the National SEA guideline to give an understanding on the of the general principles, basic steps of SEA application, the tools and techniques to be adopted, the final output of the SEA process and enhance the practice of SEA in Kenya.

- ***Draft Environmental (Strategic Assessment, Integrated Impact Assessment and Audit) Regulations, 2018:*** NEMA has recently prepared draft Regulations, and as these are intended to repeal the Environmental (Impact Assessment and Audit) Regulations, 2003, their content will likely be of consequence to the LVS Basin Plan and its sub-plans. The overall objective of the Draft Environmental Regulations (2018) is to align processes with the EMCA following its amendment in 2015. The regulations also seek to address emerging issues such as environmental and social safeguard procedures; and Climate Change. Part VI 41(1) to 50(3) details the requirements for SEA.

Process of SEA

The SEA process described follows those set out in the **Draft** Environmental Regulations (2018). These regulations have undergone public consultation: stakeholder forums were held in March 2018, and a national validation workshop was held in Nairobi on 4th April 2018. It is therefore anticipated that these regulations will be enacted imminently.

The Draft Environmental Regulations (2018) (Section 41(1)) require that NEMA in consultation with county governments, Lead Agencies, institutions and private entities subject all proposals for policies, plans or programmes to an SEA, and describe the objectives of such a study in Section 42(2). The following legislated steps required for an SEA are described in Sections 42(1) to 50(3):

- **Step 1 - Screening:**
    - Step 1.1 – Programme Brief: The policy, plan or programme brief is to be submitted to NEMA for screening.
    - Step 1.2 – NEMA Review: NEMA will undertake a screening process and determine the need for an SEA. If an SEA is required, then NEMA will request a scoping study with the objective of defining the geographical and thematic scope of the assessment, and Step 2 is then applicable.
- **Step 2 – Scoping:**
    - Step 2.1 – Scoping Study: A licensed lead environmental expert/firm is to be appointed to undertake the scoping study.
    - Step 2.2 – Public Consultation: Consultation with the relevant government authorities, agencies and public is to be undertaken to obtain comment. The first of two mandatory public meetings is to be held in the Scoping stage.
    - Step 2.3 - Scoping Report: The licensed lead environmental expert/firm is to prepare and submit a Scoping Report to NEMA. The mandatory content of the Scoping Report is provided in Section 41(4).
- **Step 3 – Scoping Report Review:**

  - Step 3.1 – NEMA Review: NEMA are to review the adequacy of the Scoping Report, and either approve it (thereby instructing the commencement of the SEA); or request additional information. Once the Scoping report is approved, then Step 4 is applicable.

- **Step 4 – SEA:**
  - Step 4.1 – SEA Study: The team of experts will undertake the SEA, and the mandatory process of conducting an SEA is described in Section 44(3)
  - Step 4.2 – Public Consultation: Consultation with the relevant government authorities, agencies and public is to continue to be undertaken to obtain comment. The second of two mandatory public meetings is to be held in the SEA stage.
  - Step 4.3 – SEA Report: A draft SEA Report is to be prepared and submitted to NEMA. The mandatory content of the SEA Report is provided in Section 44(2).
- **Step 5 – Draft SEA Report Review:**
  - Step 5.1 – NEMA Review: NEMA are to review the adequacy of the Draft SEA Report, once approved, Step 5.2 is applicable.
  - Step 5.2 – Organs of State: NEMA is to dispatch copies of the Draft SEA Report to the relevant County Government, Lead Agencies and stakeholders for comment within a stipulated timeframe.
  - Step 5.3 – General Public: NEMA are to provide notice of the availability of the draft report for comment and make it available for comment to the general public (as per specific public consultation steps described in Sections 46(2)(3)(4) and (5)) for a stipulated timeframe.
  - Step 5.4 – NEMA Review: Upon closure of the comment period, NEMA are to review the draft SEA Report and make comments on their review that are to be sent to the SEA team for inclusion in the draft SEA Report (a Technical Advisory Committee may be appointed by NEMA to undertake a detailed review, in which case their comments are also to be included in the draft SEA Report)
- **Step 6 – Revised SEA Report:**
  - Step 6.1 – Update Draft SEA: The draft SEA is to be revised to incorporate all comments and a Revised SEA Report is to be submitted to NEMA.
  - Step 6.2 – Validation Workshop: Upon verification of the revised report, the SEA team in consultation with NEMA is to hold a validation workshop with the public and stakeholders, and the report is to be updated accordingly as the "Final" version.
- **Step 7 – Final SEA Report:**
  - Step 7.1 – Final Submission: The Final SEA Report is to be submitted to NEMA together with the requisite forms as per Section 48.
  - Step 7.2 – Record of Decision: NEMA are to determine a Record of Decision within the requisite timeframes, and if this is an approval then NEMA are to include written conditions which are to be accepted by the proponent before implementing the plan or programme. If this is a rejection, then NEMA are to provide reasons for this.
- **Step 8 – Monitoring & Evaluation:**
  - Step 8.1 – Annual Reports: The proponent is to undertake monitoring and evaluation of the policy, plan or programme, and submit annual report to NEMA.
  - Step 8.2 – NEMA Evaluation: NEMA is to undertake a formal evaluation of the monitoring results within three years.

SEA in the context of the LVS Basin Plan

The SEA for the LVS Basin will in general conduct a detailed project life cycle analysis to identify known and/or foreseeable impacts, which can be positive or negative, and to develop mitigation and management measures to ensure sustainability of the projects identified under the Basin Plan.

The main recommendations for the LVS Basin Plan in terms of the legislated requirements for SEA are:

1. In the context of the LVS Basin Plan and its sub-plans, SEAs should be instituted as a set of core assessment activities that are integrated into all phases of the planning processes, rather than as separate procedures. This integrated assessment approach should evolve gradually and retain flexibility, initially through simple technical assessments and moving towards more sophisticated, open processes as the plans become more focused and concrete. The SEAs should be a continuous process that also addresses institutional and governance considerations at different tiers of decision-making.
2. A Programme Brief (as per Step 1 of the SEA Process described above) for the LVS Basin Plan should be prepared and submitted to NEMA, who can determine whether an SEA is required for the entire plan, or whether SEA's might be better applied to sub-plans and their resulting plans and programmes when more information is available, and when a defined stakeholder group can be determined.
3. The World Bank (2005) suggests that to better influence policies, plans or programmes, the SEA process should move towards a continuous process that also addresses institutional and governance considerations. It is recommended that the SEA activities that are immediately applied to the LVS Basin planning process include a detailed stakeholder analysis:

- There is a need to carry out a mapping and analysis of key institutions in the National and County Governments, civil and private sectors and their overlapping mandates while identifying opportunities for synergy. A detailed stakeholder analysis that is undertaken early on can offer great value to the LVS Basin planning process and can include a governance and institutional assessment to determine how these currently operate and are envisaged to change in the basin. Specifically, integrating SEA activities early on into the basin planning can offer various opportunities:
    - Improved processes of environmental administration and governance, so that the purpose and expectations of the various policies and legislation are fully attained.
    - Enhanced engagement of communities and wider stakeholders in the basin in environmental issues and governance.
    - Capacity building of all stakeholders to allow the processes of environmental administration and governance in the basin to be conducted with best practices and underlying goals as provided in the various statutes and policies.

4. Environmental problems are typically complex, uncertain, and occur at various scales affecting multiple people at different levels. In many cases, the problems are also caused by people. This therefore demands transparent decision-making and buy-in that considers the views of people interested in or affected by a given project. Stakeholder engagement is therefore increasingly embedded into environmental management.

   According to the SEA guidelines, the Kenyan government asks three relatively simple questions of a proposed plan:

    - Has there been effective co-operation between the SEA team and those responsible for developing the PPP?
    - Was there effective public involvement?
    - Was there effort to involve less powerful stakeholders in the consultation?

As detailed in the Inception and Interim Reports for the LVS Basin Plan, stakeholder consultation is deeply embedded into this process across Tasks 2 (Basin Planning) and 4 (Stakeholder Consultation). The focus of the stakeholder engagement included in these phases is to learn from the local ecological knowledge with existing catchment management practices; and to provide an enabling environment for implementation of the plans.

It is important to note that should the relevant plans go through an SEA and/or EIA process, the relevant stakeholder engagement guidelines must be followed, unless otherwise agreed upon with the NEMA. Such requirements would include making the SEA and/ or EIA reports available to the public for comment and provide opportunity to engage through public meetings. As has already been considered in Tasks 2 and 4, efforts to engage with vulnerable stakeholders must be specifically considered, considering alternative approaches where necessary.

As part of the decision-making process, the NEMA uses the submitted copies of the SEAs/ EIAs to distribute to the necessary commenting authorities. This provides another opportunity for the public to review and comment on the proposal before the NEMA provides an authorisation. During this time, it is important to consider the SEA and EIA regulations, and appoint a specific SEA expert to undertake this exercise.

C1.1.3. Environmental Impact Assessment (EIA)

Role of EIA

An EIA in the context of the Kenyan Environmental Legislation refers to a systematic examination that is conducted to determine whether a **programme, activity or project** will have any adverse impacts on the environment.

The main purpose of an EIA is to determine and evaluate the environmental implications of development and to inform decision-making at a project level. An EIA process focuses on the positive and negative environmental and social impacts of a specific development project once it has been designed, and proposes measures to mitigate the negative impacts, while maximising the positive ones (DEAT, 2004). The EIA process is seen as a tool to facilitate informed decision-making on sustainable development in Kenya.

The EIA process integrates environmental considerations into all stages of the planning and development process of a project and requires post-impact monitoring and management. Principles for good environmental assessment practice, includes (DEAT, 2002):

- Focus on the main issues.
- Involve the appropriate persons and groups.
- Link information to decisions about the project.
- Present clear options for mitigation for impacts and for sound environmental management.
- Provide information to decision-makers in a useful form.

Legislative Framework for EIA

The legislative framework for EIA in Kenya is set out below:

- ***The Environmental Management and Coordination Act, 1999 (as amended 2015) (EMCA):*** The Act provides a number of mechanisms to protect the environment one of which is environmental impact assessment. Project activities that are subject to an EIA process are set out in the Second Schedule of the EMCA. Sections 58 – 67, deal with the EIA process. All EIA's need to be undertaken by a NEMA registered and licensed EIA/EA expert.

- ***The Environmental (Impact Assessment and Audit) Regulations, 2003:*** Recognises EIA as a means to determine whether a programme, activity or project will have an adverse impact on the environment.
    - Part I Section 4(1) prohibits anyone from implementing a project that is likely to have a negative environmental impact, or for which an EIA is required under the Act or Regulations, unless an EIA has been concluded and approved.
    - Part II Sections 7 – 10 set out the requirements and process for Project Report; and NEMA will either issue a license if satisfied that the project will not have significant environmental impact or that the report discloses sufficient mitigation measures OR will request an EIA if the project will have a significant environmental impact or that the report discloses insufficient mitigation measures.
    - Part III Sections 11 - 17 set out the requirements and process for Environmental Impact Assessment Study.
- ***Draft Environmental (Strategic Assessment, Integrated Impact Assessment and Audit) Regulations, 2018:*** Refers to Integrated EIA rather than EIA, although by definition this is deemed to be the same thing. The Regulation's requirements for an Integrated EIA differ from the previous 2003 Regulations in that the anticipated potential risks of a project or activity will dictate whether a simpler process termed a Project Report is necessary, or whether a full Integrated EIA is necessary.
    - Part I Section 4(1) prohibits anyone from implementing a project that is likely to have a negative environmental impact, or for which an EIA is required under the Act or Regulations, unless an Integrated EIA has been concluded and approved.
    - Part III sets out the requirements for a Project Report.
    - Part IV sets out the requirements for an Integrated EIA.

Process of EIA

The EIA processes described below follows those set out in the Draft Environmental Regulations (2018). Depending on the potential risk (low, medium or high) of a project activity, the proponent will either submit a Project Report or an EIA Study Report to the Authority:

- Part III 10 (1) require anyone undertaking a project listed as low or medium risk of the Second Schedule of the Act, to prepare a Project Report (low to medium risk projects and activities).
- Part IV 15(1) requires that an Integrated EIA study be undertaken for all high-risk projects tabulated in the Second Schedule of the Act (high risk projects and activities).

The following legislated steps required for a Project Report are described in Sections 10(1) to 14(4):

- **Step 1 – Project Report Preparation:**
    - Step 1.1 - Describe Project: The Project Report is to include content as required in Section 10(1)(a) to (o), which in summary includes project information, location and activities proposed, potential environmental; economic and socio-cultural impacts and possible mitigation options, accident and health and safety action plans, public participation issues, a climate change vulnerability assessment and an environmental management plan.
    - Step 1.2 – Public Consultation: Consultation with the public including at least one public meeting. The aim of the meeting would be to explain the project and it's social, economic and environmental impacts, and collate all oral or written comments on the proposed project and

attach the evidence of such public participation in the Project Report through signed attendance register, minutes and photographs.

  - Step 1.3 – Project Report Preparation: The licensed lead environmental expert/firm is to prepare a Project Report to NEMA.

  - Step 1.4 – Form 9 Application: an application for an environmental impact assessment license is to be submitted to NEMA and the appointed agent in the County.

- **Step 2 – Project Report Review:**

  - Step 2.1– Organs of State: NEMA is to dispatch copies of the Project Report to the relevant County Government, Lead Agencies and stakeholders for comment within a stipulated timeframe.

- **Step 3 – Project Report Determination:**

  - Step 3.1 – Decision: NEMA are to issue a license if the project will have no significant impact on the environment, or that the project report discloses sufficient mitigation measures. If this is a rejection then NEMA are to provide reasons for this and are to advise on suitable alternatives (in which case Step 3.2 is applicable).

  - Step 3.2 – Appeal: The proponent may appeal the decision within the stipulated timeframes.

The following legislated steps required for an Integrated EIA are described in Sections 15(1) to 31(2):

- **Step 1 – Scoping:**

  - Step 1.1 – Scoping Report: A scoping study is to be undertaken as per Section 15(3) and a Scoping Report of a content as described in Section 15(4) is to be prepared.

  - Step 1.2 - Terms of Reference: A ToR for the Integrated EIA is to be prepared.

  - Step 1.3 – Public Notification: Notification of the project intentions to the public is to be undertaken in accordance with Section 20(1).

- **Step 2 – Scoping Report Review:**

  - Step 2.1 – Submit to NEMA: The Scoping Report and ToR is to be submitted to NEMA for approval. Upon approval, Step 2.1 is applicable.

  - Step 2.1 – Appoint Team: A competent team of licensed environmental assessment experts are to be appointed to undertake the Integrated EIA.

- **Step 3 – Integrated EIA:**

  - Step 3.1 – Integrated EIA study: An Integrated EIA study is to be undertaken as per Section 19(a) to (d), and an Integrated EIA Report of a content as described in Section 21(1)(a) to (q) is to be prepared and submitted to NEMA.

- **Step 4 – Integrated EIA Review:**

  - Step 4.1 – Organs of State: NEMA is to dispatch copies of the report to the relevant Lead Agencies for comment within a stipulated timeframe.

  - Step 4.2 – General Public: NEMA are to provide notice of the availability of the report for comment and make it available for comment to the general public (as per specific public consultation steps described in Sections 24(1)(3) and (4) for a stipulated timeframe.

- Step 4.3 – Public Hearing: Upon receipt of written comment, NEMA may hold a public hearing as per Section 25 (1) to (7).

- **Step 5 – License:**

Step 5.1 – Record of Decision: NEMA are to determine a Record of Decision within the requisite timeframes, and if this is an approval then NEMA are to issue a license and include written conditions which are to be accepted by the proponent before implementing the project. If this is a rejection, then NEMA are to provide reasons for this.

C2. Catchment Management

C2.1. Legal and institutional environment

C2.1.1. National level

- At a National level natural resource use provides employment and income. Within the Lake Victoria North Basin small scale irrigation and pastoralism make up the majority of employment opportunities.
- The key ministries in Kenya responsible for enacting policies related to catchment management are the Ministry of Water and Sanitation, Ministry of Agriculture and Irrigation; and Ministry of Environment and Forestry.
- National policies and legislation feed into the local-level catchment management, where projects are implemented on the ground. It is therefore important to understand the underlying policies driving these projects as in most cases similar strategies are being implemented by different institutions.
- The National Environmental Management Agency (NEMA) is responsible for coordinating environmental management; providing guidance on the development of environmental management plans and ensure compliance of environmental laws. The Kenya Water Towers Agency (KWTA) is responsible for management of Kenya's water towers. Kenya Forest Service (KFS) has a mandate to conserve, develop and sustainably manage Kenya's forest resources for the country's socio-economic development. Kenya Wildlife Service (KWS) has a mandate to conserve and manage wildlife in Kenya, and to enforce related laws and regulations. KWS is also the RAMSAR Administrative Authority.

C2.1.2. Basin and sub-basin level

- County governments' Integrated Development Plans (IDPs) are meant to provide an overall framework for development in each county. The plans aim to coordinate the work of both levels of government in a coherent plan to improve the quality of life for all the people and contribute towards devolution. The first plans cover the period 2013 to 2017, the second plans over 2018 to 2022.
- The County governments rely on technical input and advice from the different agencies with a mandate to govern natural resources. A major issue is the mandates related to wetlands and riparian lands.

C2.1.3. National plans and policies

- The **Kenya Vision 2030 (2008)** set targets such as improved water and sanitation, increased agricultural production, a clean environment and more energy production by 2030. All of these cross-cutting targets impact catchment management.
- The **Kenya National Policy on Water Resource Management and Development (NPWRMD, 1999) p**rovides specific policy objectives including protection of water resources, supply of water while ensuring safe disposal of wastewater and environmental protection**.**
- In accordance with the Kenya Vision 2030 goal that agricultural production increase by 10% by 2019, various agriculture policies and strategies have been developed to guide this development (SEE IRR SECT ANAL). Transformation of smallholder, subsistence agriculture to modern agriculture was identified as a fundamental component, as was increased irrigation. An **Irrigation and Drainage Master Plan** was prepared in 2009 (MWI, 2009). This was followed by the **National Water Master Plan** (JICA, 2013) which evaluated irrigation potential against availability of water. Other ongoing national projects involve improving rainwater harvesting and storage for agriculture; rehabilitation and protecting water catchments; and implementing the irrigation flagship projects.
- The **National Environment Policy (NEP, 2013)** provides the goal of a better quality of life for present and future generations through sustainable management and use of natural resources. Guiding principles include an ecosystem approach to management, sustainable resource use as well as inclusion of communities in decision making.
- The **2010 Constitution in Article 69** recognises the importance of forests for sustainable development, the provides for the state to work towards increasing the country's forest cover to 10% of the land area of Kenya. The Constitution provides for two tiers of Government with the national government being responsible for policy development and regulation. The second tier of governance are 47 geographical units of devolved government, known as counties. Lake Victoria North Basin has nine counties, although some counties cross hydrological boundaries. These counties may be involved in various functions which are closely linked to catchment management.
- The **Water Act (2016)** gives the Water Resources Authority (WRA) a clear role in the regulation of water resources. However, there are some ambiguities in the Water Act that require resolution.
- The **Agriculture, Fisheries and Food Authority Act (Act No 13 of 2013)** provides for the regulation and promotion of agriculture. This is supported through the establishment of the Agriculture, Fisheries and Food Authority (AFFA) that is charged with, in consultation with County Governments, administering the **Crops Act (Act No 16 of 2013)** and the **Fisheries Act (CAP 378 of 1989)**.
- Directorates of the Agriculture, Fisheries and Food Agency (AFFA) include coffee; nuts and oil; fibre; horticultural crops; food crops; sugar; tea; pyrethrum and other industrial crops. The drive to increase agricultural development will require ongoing development in irrigation capacity. As such, a **draft Irrigation Bill** was developed in 2015 intended to repeal the Irrigation Act (CAP 347 of 2013). This amendment bill has yet to be enacted and provides for the establishment of a National Irrigation Development Service and strengthening of irrigation regulations.
- The **Environmental Management and Coordination Act (EMCA, 1999)** provided Kenya's first framework for environmental legislation. The EMCA recognises the importance of improving the legal alignment and administration across the various sectors that are engaged in the management and development of environmental resources.

- The **Forest Conservation and Management Act (2016)** mandates the Directorate of Natural Resources-Forest Conservation to formulating forest policies, initiating and overseeing drafting of relevant legislation, sector coordination and guidance, monitoring and evaluation.
- The **Wildlife Conservation and Management Act (2013)** mandates the Directorate of Natural Resources-Wildlife Conservation in formulating wildlife policies, initiating and overseeing drafting of relevant legislation, sector coordination and guidance, monitoring and evaluation.

C3. Water resources protection

C3.1. Legal and institutional environment

C3.1.1. National level

- The mandate for protecting water resources in Kenya falls on the **Water Resources Authority (WRA)** (the Authority) through Part III of the **Water Act of 2016** under the "Regulation of the Management and Use of Water Resources". A specific aspect which is addressed in the Act relates to the Authority "*prescribing criteria for classifying water resources for the purpose of determining Water Resources Quality Objectives for each Class of Water Resource*". Classifying and determining Water Resource Quality Objectives provide a series of measures to achieve protection while at the same time acknowledging the important role of water resources in supporting social and economic development. Further to the above, where the Authority considers a water resource vulnerable, special measures may be published in a Gazette to declare the catchment area a Protected Area. The Authority may then impose requirements or regulations and prohibit activities to ensure the protection of the area and water resources. The same is considered for the conservation of groundwater for public interest.
- The **National Environmental Management Authority (NEMA)** is responsible for coordination of environmental management, and the **Kenya Water Towers Agency (KWTA)** for coordination of the protection, rehabilitation, conservation, and sustainable management of Kenya's water towers, wetlands and biodiversity hotspots. Environmental Committees provide technical support for environmental management and provide input to provincial/district development plans.

C3.1.2. Basin and sub-basin level

- The 2016 Water Act outlines the designation of Basin areas, with functions of **Basin Water Resource Committees (BWRCs)** within each Basin clearly stated. Furthermore, the Act defines the establishment and functions of **Water Resource Users Associations (WRUAs)** i.e. associations of water resource users at the sub-basin level in accordance with Regulations prescribed by the Authority. These associations are community based for collaborative management of water resources and resolution of conflicts concerning the use of water resources.
- Protection of water resources in Kenya therefore starts at the National level with the WRA developing policies and legislation for protection of water resources. BWRCs then enact these measures to fulfil the water resource quality objectives for each class of water resource in a basin and need to put in place measures for sustainable management of the water resources; whilst at the sub-basin level more local level community-based management occurs through WRUAs.

C3.1.3. National plans and policies

- The **Kenya Vision 2030 (2008)** set targets such for a clean environment by 2030.

- The **Kenya National Policy on Water Resource Management and Development (NPWRMD, 1999)** provides specific policy objectives including protection of water resources.
- In the **Water Act (2016)**, the specific functions of the WRA which relate to water resources protection include:
    - formulate and enforce standards, procedures, and regulations for the management and use of water resources
    - regulate the management and use of water resources
    - receive water permit applications for water abstraction, water use and recharge and determine, issue and vary water permits; and enforce the conditions of those permits
    - In addition, the WRA has the power to:
    - collect, analyse and disseminate information on water resources
    - monitor compliance by water users with the conditions of permits and the requirements of the Act
    - issue permits for inter-basin water transfer
    - delegate regulatory functions to the Basin Water Resource Committees
- Part V of the **Environmental Management and Coordination Act (EMCA, 1999)** focuses on the protection and conservation of the environment. According to the Act, certain activities in relation to a river, lake or wetland require an environmental impact assessment. The Minister may also declare a lake shore, wetland, coastal zone or river bank to be a protected area and impose restrictions to protect them. The Minister may issue general and specific orders, regulations or standards for the management of a lake shore, wetland, coastal zone or river bank. Although it is acknowledged that environmental issues cut across different sectors, the Act emphasises the principles and provides guidance for improved environmental management.
- Other areas of relevance to water resources protection in Kenya, which are regulated by various government departments, include: protection of traditional interests of local communities customarily resident within or around a lake shore, wetland, coastal zone or river bank or forests defined as protected; protection of hill tops, hill sides, mountain areas and forests for sustainable utilisation and protection of water catchment areas; protection of forests on private land; conservation of biological resources in situ (related to buffer zones near protected areas and alien invasive species management); protection of environmentally significant areas; and protection of the coastal zone
- Consistency across the Water Act (2016) and the EMCA (1999) in relation to water resources protection is important to allow for a coordinated approach. In the Water Act (2016), as has been defined above, water resources have a wide-ranging definition ranging from surface water to groundwater resources; whilst the EMCA (1999) focuses on the surface water resources (river, lake, wetland, coastal zone) as well as the upper catchment areas. Although this is an institutional issue, it impacts the protection and management strategies for water resources.

C4. Groundwater management

C4.1. Legal and institutional environment

C4.1.1. National plans and policies

- The **Water Act (2016)** defines protection of groundwater under Section 22/23 and groundwater use is managed through Section 47 and 104.
- The **National Land Use Policy (2017)** considers surface and underground water bodies.

- Part VIII (Conservation Orders, Easements and Incentives, Wildlife Conservation Orders and Easements), S. 65 (4) of the **Wildlife Conservation and Management Act (2013)** which states, inter alia, "a wildlife conservation order or easement may be created so as to" (d), "preserve the quality and flow of water in a dam, lake, river or aquifer".
- The **Draft National Policy Groundwater Resources Development and Management (2013)** highlights a number of specific issues:
    - The availability and vulnerability of groundwater resources in Kenya are poorly understood;
    - The institutional arrangements for groundwater management in Kenya, including groundwater management capacity and financing are weak;
    - There is very limited integrated water resources management in Kenya, with groundwater and surface water typically being treated as separate water resources; and
    - There is very limited groundwater quality management in Kenya.
- Section 23 of the **Agriculture, Fisheries and Food Authority Act (2013)** relates to land preservation guidelines, on preservation of soil.
- Section 5.3 (Required Policy and Legal Reforms) of the **National Water Harvesting and Storage Management Policy (2010)**, recommended the formulation of a Policy on Ground Water Protection
- Section 5.1 of the **Draft National Policy on Trans-Boundary Waters (2009) relates to s**ustainable management and equitable utilization of trans-boundary water resources (para. 38: provision for "groundwater conservation areas" with respect to transboundary waters)
- Part XI of the **Water Resources Management Rules (2007)** relates to Protected Areas and Groundwater Conservation Areas.
- Section 25 of the **National Museums and Heritage Act (2006)** relates to the declaration of monuments.
- Section 2.1.2 of a **Sessional Paper No. 1 of 1999 on National Policy on Water Resources Management and Development indicates** "In addition, groundwater conservation zones need to be identified to avoid depletion of this resource".
- Part V of the **Environmental Management and Co-ordination Act (1999)** relates to the Protection and Conservation of the Environment, inter alia.
- **Masterplan for the Conservation and Sustainable Management of Water Catchment Areas in Kenya (MEMR, 2012)**
- **Kenya Water Towers Status Report; Saving our Future & Heritage, A Call To Action (KWTA, 2015).**

C5. Climate change adaptation

C5.1. Legal and institutional environment

C5.1.1. National level

- The Kenya Agricultural and Livestock Research organisation have a **National Strategy on Genetic Resources within the context of climate change (2016-2021)**

- The Ministry of Agriculture and Irrigation, Ministry of Transport, Infrastructure, Housing and Urban Development have a **Blue Economy Strategy (2017)**
- The National Treasury Ministry of Interior and Coordination have **Kenya's Disaster Risk Financing Strategy (2018-2022)** and **National Disaster Risk Management Policy (2017)**
- The National Drought Management Authority have a **National Drought Management Authority Act (No 4 of 2016), Ending Drought Emergencies Strategy** and **Public Finance Management (National Drought Emergency Fund) Regulations, 2018**.
- The Ministry of Energy has an **Energy Bill (2017)** – Part 3, section 43; Part 4, section 74 (i); and Part 9 address climate change-related issues.
- The Ministry of Environment and Forestry has an **Environmental Management and Coordination Act, 1999 (Cap. 387), Green Economy Strategy and Implementation Plan (GESIP 2016-2030)** and **Kenya Strategic Investment Framework on Sustainable Land Management (2017-2027).**
- The Kenya Forest Services and Ministry of Environment and Forestry have a **National Forest Programme (2017) – chapter on climate change and REDD + Readiness Plan and analysis (2013-2017)**
- The Ministry of Health has a **Health Act (No 21 of 2017)** – section on environmental health and climate change (Part VII, sections 68 and 69)
- The Ministry of Transport, Infrastructure, Housing and Urban Development has a **Kenya Building Research Centre: Strategic Plan, 2017/18-2021/22**
- The Ministry of Lands and Physical Planning has a **National Spatial Plan (2015-2045)**
- The Ministry of Transport, Infrastructure, Housing and Urban Development has an **Action Plan to reduce CO2 Emissions from Aviation (2015), Executive Order: The Nairobi Metropolitan Area Transport Authority (2017), Kenya National Aviation Action Plan for International Civil Aviation Organisation (ICAO) and Mitigation plan for International Maritime Organisation (IMO) (2017)**
- The Ministry of Water and Sanitation Water Act (No 43 of 2016) – establishes **National Water Harvesting and Storage Authority, Draft Water Harvesting and Storage Policy (2018) Basin and sub-basin level**

C5.1.2. Basin and Sub-basin level

- The Kenya Vision 2030 – the country's development blueprint – recognised climate change as a risk that could slow the country's development. Climate change actions were identified in the Second Medium Term Plan (MTP) (2013-2017). The Third Medium Term Plan (2018-2022) recognised climate change as a crosscutting thematic area and mainstreamed climate change actions in sector plans.

- The County Governments have a key delivery role in implementing the Climate Change Act, 2016, having jurisdiction, as set out in the Fourth Schedule (Part 2) of the Constitution, over sectors relevant for climate change such as agriculture, soil and water conservation, forestry, water and sanitation, and health. Article 203(2) of the Constitution requires that County governments be allocated a minimum of 15% of national revenue received annually, but the allocation often surpasses the minimum thus giving County governments considerable scope to influence climate change investments.

C5.1.3. National plans and policies

- **East African Climate Change Master Plan (EACCCMP, 2011-2031)** provide a long-term vision and a basis for Partner States to operationalise a comprehensive framework for adapting to and mitigating climate change, in line with the EAC Protocol on Environment and Natural Resources Management and with international climate change agreements.

- **East African Community Climate Change Policy and Strategy (2010)** was developed by the **East African Community (EAC)** Secretariat. This document guides partner countries with the preparation and implementation of collective measures to address climate change in the region.

- The **East African Community Climate Change Policy and Strategy (2010)** was developed by the **East African Community (EAC)** Secretariat. This document guides partner countries with the preparation and implementation of collective measures to address climate change in the region.
- The **African Union Agenda 2063** commits to climate change action to prioritise adaptation. It calls on member countries to implement the Programme on Climate Action in Africa, including climate resilience in agriculture.
- The **African Forest Landscape Restoration Initiative (AFR100)** aims to bring 100 million hectares of land in Africa into restoration by 2030.
- The **Constitution of Kenya** (2010) demands sustainable development and provides for the right to a clean and healthy environment through legislative and other measures.
- **National Climate Change Response Strategy (2010)** is Kenya's National Climate Change Response Strategy was the first national policy document on climate change. It aimed to advance the integration of climate change adaptation and mitigation into all government planning, budgeting and development objectives.
- Kenya's **National Climate Change Action Plan, 2013-2017** was a five-year plan that aimed to further Kenya's development goals in a low carbon climate resilient manner. The plan set out adaptation, mitigation and enabling actions.
- Kenya's **National Adaptation Plan 2015-2030** was submitted to the UNFCCC in 2017. The NAP provides a climate hazard and vulnerability assessment and sets out priority adaptation actions in the 21 planning sectors in MTP II.
- Kenya's **Nationally Determined Contribution (NDC) (2016)** under the Paris Agreement of the UNFCCC includes mitigation and adaptation contributions. In regard to adaptation, "Kenya will ensure enhanced resilience to climate change towards the attainment of Vision 2030 by mainstreaming climate change into the Medium Term Plans (MTPs) and implementing adaptation actions". The mitigation contribution "seeks to abate its GHG emissions by 30% by 2030 relative to the BAU scenario of 143 MtCO2-eq." Achievement of the NDS is subject to international support in the form of finance, investment, technology development and transfer and capacity development.
- The **Climate Change Act (No 11 of 2016)** is the first comprehensive legal framework for climate change governance for Kenya. The objective of the Act is to "Enhance climate change resilience and low carbon development for sustainable development of Kenya." The Act establishes the National Climate Change Council (Section 5), Climate Change Directorate (Section 0), and Climate Change Fund (Section 25).
- The objectives of the **Kenya Climate Smart Agriculture Strategy (KCSAS)** are to adapt to climate change and build resilience of agricultural systems while minimising greenhouse gas emissions. The actions will lead to enhanced food and nutritional security and improved livelihoods.
- The **Climate Risk Management Framework (2017)** for Kenya integrates disaster risk reduction, climate change adaptation, and sustainable development so that they are pursued as mutually supportive rather than stand-alone goals. It promotes an integrated climate risk management approach as a central part of policy and planning at National and County levels.

- The **National Climate Change Framework Policy (2018)** aims to ensure the integration of climate change considerations into planning, budgeting, implementation and decision-making at the National and County levels and across all sectors.
- The **National Climate Finance Policy (2018)** promotes the establishment of legal, institutional and reporting frameworks to access and manage climate finance. The goal of the policy is to further Kenya's national development goals through enhanced mobilisation of climate finance that contributes to low carbon climate resilient development goals.
- The Government of Kenya **Big Four Agenda (2018-2022)** establishes priorities areas for 2018 to 2022 of ensuring food security, affordable housing, increased manufacturing and affordable healthcare. Sector plans and budgets are to be aligned to the Big Four priorities.
- The **Climate Change Act, 2016 is** Key legislation guiding Kenya's climate change response, setting the legal basis for mainstreaming climate change considerations and actions into sector functions. The Act seeks to provide the "*framework for enhanced response to climate change and to provide for mechanisms and measures to achieve low carbon climate development*". The Act promotes a mainstreaming approach which includes integrating climate change in all sectors and at all levels. The Act applies to all sectors of the economy and at national and county levels. Specific objectives of the Act, that relate to water resources planning and development, include:
    - mainstream climate change responses into development planning, decision making and implementation;
    - build resilience and enhance adaptive capacity to the impacts of climate change;
    - formulate programmes and plans to enhance the resilience and adaptive capacity of human and ecological systems to the impacts of climate change
    - mainstream and reinforce climate change disaster risk reduction into strategies and actions of public and private entities;
    - mainstream the principle of sustainable development into the planning for and decision making on climate change response; and
    - integrate climate change into the exercise of power and functions of all levels of governance, and to enhance cooperative climate change governance between the national government and county governments.
- The Constitution of Kenya advances gender equality, stating in Chapter 4, the Bill of Rights that "women have the right to equal opportunities in political, economic and cultural spheres," and in order to achieve that equality, requires that government to put in place and implement affirmative actions that deliver equity for women. This commitment to gender equality and implementation of gender equity is taken up in section 7(6) of the Climate Change Act, 2016 that requires the President to ensure compliance with the two thirds gender principle when appointing members to the National Climate Change Council. Further, section 8(2)(c) of the Climate Change Act, 2016 obligates the Cabinet Secretary responsible for climate change affairs to formulate and implement a national gender and intergenerational responsive public education and awareness strategy.

C6. Flood and drought management

C6.1. Legislative and institutional environment

C6.1.1. National level

- The Constitution of Kenya (2010) requires the National Government to perform a wide range of water resource management functions. Relevant here is Section 24: Disaster management – The National Government will institute **integrated flood and drought management plans** to address water related disasters such as floods, droughts and landslides.

- The Water Act (No. 43 of 2016) provides a statutory foundation for flood and drought management plans. The Water Act aims "to provide for the regulation, management and development of water resources, water and sewerage services". Section 12 of the Act establishes a national Water Resources Authority (WRA) whose functions are "to formulate and enforce standards, procedures and regulations for the management and use of water resources and **flood mitigation**". The WRA must also "provide information and advice to the Cabinet Secretary for formulation of policy on national water resource management, water storage and **flood control strategies**".
- Section 32 of the Act establishes a national Water Storage Authority (WSA) whose functions and powers are "to undertake on behalf of the national government, the development of national public water works for water resources storage and **flood control**; collect and provide information for the formulation by the Cabinet Secretary of the national water resources storage and **flood control strategies**". The WSA must also "undertake on behalf of the national government **strategic water emergency interventions during drought**; and advise the Cabinet Secretary on any matter concerning national public water works for water storage and **flood control**".
- The National Drought Management Authority (NDMA) Act (No.4 of 2016) provides an important statutory foundation for drought management plans. The NDMA is an agency of the Government of Kenya under the Ministry of Planning and Devolution, mandated "to establish mechanisms **which ensure that drought does not result in emergencies** and that the impacts of climate change are sufficiently mitigated". The NDMA exercises its functions both at national level and Basin level, and in collaboration with county governments, also at county and community level. However, the NDMA's primary focus is on the 23 drought-prone counties, known as the ASAL (Arid and Semi-Arid Lands) counties.
- The National Disaster Operations Centre (NDOC) is responsible for **coordinating all disaster response operations in the country** – and was leading the country's El Niño flood response in 2015. It does this through partnering with other actors such as the police and the Kenya Red Cross. NDOC was established in 1997, following the El Niño floods, within the Ministry of Interior. Besides response, NDOC also plays a preparedness role by managing the country's disaster loss database. It has also led disaster drills for man-made disasters.
- The National Disaster Management Unit (NDMU) was established in 2013 as an effective and competent disaster management unit with an established command structure, budget and Standard Operating Procedures (SOPs) based on best practices. The NDMU, together with stakeholders, formulated the National Emergency / Disaster Plan and SOPs which were signed off in 2014. The Plan and SOPs recognizes the existence of other National and contingency plans. The National Plan and SOPs is anchored in the medium-term Phase Two of Vision 2030 in that it promotes safety, security and **protecting Kenyan assets from adverse impacts of hazards and disasters**.
- The mandates of the NDMA, NDOC and NDMU clearly overlap. The **Disaster Risk Management Bill**, currently under consideration, is aimed at bringing NDMA, NDOC and NDMU together as a new "Disaster Risk Management Authority".
- The Kenya Meteorological Department (KMD) of the Ministry of Environment and Mineral Resources issues regular short-term and seasonal rainfall forecasts for the whole country which form part of the structure of Kenya's **drought preparedness**.

C6.1.2. Basin and Sub-Basin level

- Section 27 of the Water Act specifies establishment of Basin Water Resources Committees responsible for the management of the water resources within a particular Basin area, with various powers and functions, among which is to advise the Water Resources Authority and county governments concerning **flood mitigation activities**. Each county government in a Basin has one representative on the Basin Water Resources Committee, which, in collaboration with the NDMA, must **develop drought contingency plans** for the ASAL counties and oversee their implementation as emergency response interventions. (It should be noted that at the time of writing the Basin Water Resources Committee for the Lake Victoria North Basin has not been established.)

- Section 29 of the Water Act specifies establishment of Water Resource Users Associations (WRUAs) at the sub-basin level as community-based associations for collaborative management of water resources and resolution of conflicts concerning the use of water resources. The Basin Water Resources Committees may contract WRUAs as agents **to perform certain duties** in water resource management.
- The NDMA issues regular **drought early warning bulletins** on a county basis which cover various bio-physical indicators, as well as a range of socio-economic impact indicators.

C6.1.3. National plans and policies

- The Water Resources Management Authority (WRMA) Strategic Plan for 2012 – 2017 (WRMA, 2013) specifies six strategic objectives for the WRMA covering the five financial years 2012/13 to 2016/17. Each strategic objective is served by various underlying strategies. Under strategic objective 5, "To heighten the national development agenda on water resources", two of the underlying strategies are "Develop i**ntegrated River Basin flood management plans**" and "Develop and implement programs to **strengthen communities' preparedness/adaptation** to impacts of climate change."
- Under the National Water Master Plan 2030 (known as NWMP 2030), developed as part of the above Strategic Plan, five development plans and three management plans were developed for each of six Basin areas that cover the whole of Kenya (WRMA, 2013). A **flood and drought management plan** featured among the latter three plans.
- The Ending Drought Emergencies Common Programme Framework (EDE-CPF) (NDMA, 2017) has three components: drought risk and vulnerability reduction, drought early warning and early response, and institutional capacity for drought and climate resilience and comprises six sets of interrelated action plans for ensuring **ongoing drought preparedness**. The EDE-CPF is currently being operationalised through its 3rd Medium-Term Plan 2018-2022 and is mainly focused on the ASAL counties (NDMA, 2017).

#	Category/Organization	Contact/Address	Phone	E-mail/Website
Government of Kenya				
1	Ministry of Water and Sanitation	Josephine Ngari Assistant Government Chemist Maji House, Upper Hill		www.water.go.ke
2	Water Resources Authority	Mohammed Shurie, CEO, NHIF Building, 10th floor, Upper Hill	0202732291 02729048/9	www.wra.go.ke
3	Ministry of Environment and Forestry	NHIF Building, 12th Floor, Upper Hill	0202730808/9 0202725707	www.environment.go.ke +254 20 2725707
4	Kenya Forest Service	Karura, off Kiambu Road, Opposite CID HQ Nairobi	020-2014663 020-2689882	info@kenyaforest service.org
5	Kenya Forestry Research Institute (KEFRI)	Muguga, off Nairobi - Nakuru highway	02010651/2	info@kefri.org https://www.kefri.org
6	Kenya Wildlife Service (KWS)	Lang`ata Road Nairobi	0202379407 0202379408 0202379409	kws@kws.go.ke www.kws.go.ke
7	Ministry of Agriculture, Livestock, Fisheries and Irrigation	State Department of Irrigation, 5th Floor Maji House, Upper Hill Phanuel Webi, Deputy Director Maurice Opondo, Deputy Director (Agr. Water Management)	0202918870	Info@kilimo.go.ke http://www.kilimo.go.ke
8	National Irrigation Board	Raphael Ogendo Deputy General Manager, Infrastructure, Irrigation and Drainage Vicncent Kabuti, Deputy General Manager, Planning, Strategy and Research Risper Okumbe Irrigation Engineer Unyunyizi House Lenana Road, Nairobi	0202711380	rogendo@nib.or.ke vkabuti@nib.or.ke rokumbe@nib.or.ke https://nib.or.ke
9	Kenya Water Towers Agency	Dr. Winnie Musila Director, Planning and Ecosystem Assessment, 15th floor, NHIF Bldg.	020 2711437	www.kwta.go.ke
10	National Environmental Management Agency (NEMA)	Popo Road, South C, off Mombasa Road		dgnema@nema.go.ke https://www.nema.go.ke
11	Water Sector Trust Fund	1st Floor, CIC Plaza, Mara Road, Upper Hill, Nairobi	020 272 90 17/8	https://waterfund.go.ke

12	National Water Harvesting and Storage Agency	Dunga Road-Industrial Area, Nairobi	020 696 4000	info@waterauthority.go.ke www.waterauthority.go.ke
13	The Water Services Regulatory Board (WASREB)	5th Floor NHIF Building Ngong Road, Nairobi	0202733561	info@wasreb.go.ke
14	Kenya Meteorological Department	Peter Ambenje, Actg. Director, Dagoretti Corner, Ngong Road, Nairobi	0203867880, 0203876957 0203873682	director@meteo.go.ke info@meteo.go.ke
15	Climate Change Secretariat	Eng. Moses Omedi Coordinator Ministry of Environment and Forestry NHIF Bldg, 12th Floor	0202730808/9 0202725707	http://www.kccap.info +254 20 2725707
16	National Drought Management Authority (NDMA)	8th Floor, Lonrho House, Standard Street, Nairobi	0202224324 0202227982	info@ndma.go.ke https://www.ndma.go.ke
17	Kenya Electricity Generating Company PLC (KENGEN)	Engineer Willis Ochieng Stima Plaza, Phase III, Nairobi	0203666000	www.erc.go.ke pr@kengen.co.ke
County Government				
1	Council of Governors	Mrs. Jacqueline Mogeni Chief Executive Officer Delta House, Rhapta Road, Nairobi		https://cog.go.ke
2	Nairobi City/County Government	Mario Kainga, Director Water and Sanitation Department, City Hall Plaza, City Hall Way		kkaingongo@gmail.com mariokainga@yahoo.com http://www.nairobi.go.ke
NGOs				
1	KEWASNET	Samson M. Shivaji, CEO Suite 2 Rosami court, Muringa Road	202656281	info@kewasnet.co.ke http://kewasnet.co.ke
2	WWF	Mvuli Park, Mvuli Rd., off Raphta Rd. Westlands, Nairobi		Info@wwfkenya.org
3	Kenya Red Cross	Nairobi South C Red Cross Road Off Popo Road, Nairobi	0203950000 0207030370	info@redcross.or.ke http://www.redcross.or.ke
4	The Nature Conservancy	Mr. Fred Kihara Water Funds Advisor Africa Regional Office 31 El Molo Drive, Off James Gichuru Road, Lavington, Nairobi		fkihara@tnc.org www.nature.org
5	Wetlands International	Ms. Julie Mulonga Director Woodlands Road, Woodlands Court, Off Dennis Pritt Road Ngong Road, Nairobi		kenya@wetlands-africa.org www.wetlands.org/africa

Private Sector				
1	Tullow Kenya B.V.	Johana Ekwam Westlands Office Park Waiyaki Way,Nairobi		johanaekwam@tullowoil.com
2	Kenya Water Industry Association	House 311, Villa Franca Estate, Imara Daima, Mombasa Road, Nairobi		info@kwia.co.ke kwiawater@gmail.com
3	Kenya National Chamber of Commerce & Industry (KNCCI)	Heritan House, Ground Floor, Woodlands Rd., off Argwings Kodhek Rd., Opposite Dept. of Defence HQs	0203927000	info@kenyachamber.or.ke http://www.kenyachamber.or.ke
4	Kenya Association of Manufacturers (KAM)	15 Mwanzi Road opp West Gate Mall, Westlands, Nairobi	020 232481	info@kam.co.ke www.kam.co.ke
5	Nairobi Water and Sewerage Company	Eng. Philip Gichuki Managing Director, Nairobi City Water and Sewerage Company Kampala Rd, Off Enterprise Road, Nairobi		https://nairobiwater.co.ke www.nature.org/africa-water
6	East African Breweries, Ltd.	Ruaraka, Nairobi and Tusker House Thika Road, Nairobi	0208644000	https://www.tuko.co.ke
Development Partners				
1	African Development Bank	Gabriel Negatu, Director Serge N'Guessan, Deputy Director Khushee Tower Longonot Road, Upper Hill, Nairobi	020 2712925/ 020 2712926/ 020 2712928	g.negatu@afdb.org s.nguessan@afdb.org
2	JICA	Masahito Miyagawa, Representative, Water and Environment Rahimtulla Tower, 10th-11th floors, Upper Hill Rd., Nairobi	0202775000	Miyagawa.Masahito@jica.go.jp https://www.jica.go.jp/kenya
	SNV – Netherlands Development Organization	Ngong Lane, Off Ngong Road, Nairobi	020 2405898	www.snvworld.org/Kenya/SnvKindex.htm
Other				
1	Nairobi Water Fund	Eng. Philip Gichuki Managing Director and CEO, Nairobi City Water and Sewerage Company Kampala Rd, off Enterprise Road, Nairobi		https://nairobiwater.co.ke www.nature.org/africa-water

2	Tana and Athi Rivers Development Authority (TARDA)	Mr Steven Ruimuku Managing Director Queensway House, 7th Floor, Kaunda Street City Centre, Nairobi	0203341782/7/8 0203341784	info@tarda.co https://www.tarda.co.ke
3	LAPSSET Corridor Development Authority	Mr. Silvester Kasuku Managing Director Director General Chester House, 2nd Floor, Koinange Street Nairobi	0202219098 0202218968	info@lapsset.go.ke www.lapsset.go.ke
4	Nairobi River Rehabilitation and Restoration Program	See under Nairobi City/County Government, NWSC and AfDB above for contact information		

Key Strategic Area 1:	Catchment Management													
Strategic Objective:	**To ensure integrated and sustainable water, land and natural resources management practices**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
Strategic Theme 1.1:	**Promote improved and sustainable catchment management**											Strategic theme 1.1 total:	**5**	
Theme priority:	**Very Important**													
1.1.1	**Promote sustainable land development and planning**													
i	MDAs and private sector to incorporate NEMA Environmental Sustainability Guidelines into relevant policies	NEMA Guidelines reflected in relevant policies		Short-term	NEMA MoWSI MoALF MoEF WRA KWS KWTA AFA	BWRC WWDA	CG WRUA	WSP CFA Private sector	-	0.9	-	-	0.9	MoEF NEMA CG
ii	Increase awareness of sustainable catchment management with relevant ministries (e.g. MWSI, MoALF, MoEF), WRUAs, CGs etc. through training, brochures, social media, internet, factsheets, forums and workshops.	Level of awareness re sustainable catchment management; Number workshops, trainings.	LA08 PA43	Immediate	WRA MoWSI MoALF MoEF NEMA	BWRC	CG WRUA	Media Development partner CFA CBO	1.8	-	-	-	1.8	MoWSI MoEF
iii	Integrate County Spatial Plan into the CIDPs including construction, restoration, rehabilitation and protection.	County Spatial Plans developed		Medium-term	MoLPP MoALF		CG WRUA		-	-	0.9	-	0.9	CG
1.1.2	**Strengthen participatory approaches**													
i	Devolve ownership of catchment management activities to WRUAs through SCMP development.	Sustainable catchment management activities incorporated in SCMPs; Number SCMPs developed	LA07	Immediate	WRA KWS KFS KWTA	BWRC	WRUA CG	CFA CBO	1.55	-	-	-	1.55	MoWSI WSTF
Strategic Theme 1.2:	**Sustainable water and land use and management practices**											Strategic theme 1.2 total:	**11**	
Theme priority:	**Critical**													
1.2.1	**Promote water conservation and management at catchment level**													
i	Embed catchment-based water conservation and management activities related to crop and livestock production in SCMPs: E.g. improved water use efficiency; water harvesting and storage; groundwater protection and infiltration	Improved understanding of water conservation and management; Reduction in water use; Increased water storage and water availability in the sub-catchment; Increased groundwater recharge	LA10	Immediate	WRA MoWSI KWTA MOALF	BWRC WWDA	WRUA CG	CBO	1.55	-	-	-	1.55	CG
ii	Promote catchment-based water conservation and management principles with relevant MDAs through training, forums and conferences.	Level of awareness regarding water conservation and management; Number trainings/forums/conferences held	LA10 PA43 WA16 WA17	Short-term	WRA MoWSI MoALF KWTA	BWRC WWDA	CG WRUA	CBO KALRO	-	1.55	-	-	1.55	CG
1.2.2	**Promote soil conservation and management at catchment level**													
i	Embed catchment-based soil conservation and management activities related to crop and livestock production in SCMPs: E.g rangeland management; erosion and runoff control measures; gully management and sediment trapping; stream/river bank management.	Improved understanding of soil conservation and management; Improved soil conservation within farms and rangeland; Sustainable land management; Improved soil conservation within Water Towers; Improved soil conservation within gazetted forests; Rangeland health; Reduced sedimentation	LA10	Immediate	WRA MoALF KWTA	BWRC	CG WRUA	NGO CFA CBO	3.09	-	-	-	3.09	MoWSI MoALF CG

Key Strategic Area 1:	Catchment Management													
Strategic Objective:	**To ensure integrated and sustainable water, land and natural resources management practices**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
ii	Promote catchment-based soil conservation and management with relevant MDAs through training, forums and conferences.	Level of awareness regarding catchment-based soil conservation and management; Number trainings/forums/conferences held	LA10 PA43	Medium-term	WRA MoWSI MoALF NEMA	BWRC	CG WRUA	NGO KALRO CBO	-	-	1.55	-	1.55	MoWSI MoALF CG
1.2.3	**Promote conservation agriculture and improved farm management**													
i	Embed conservation agriculture and improved farm management activities related to crop and livestock production in SCMPs: E.g. climate smart agriculture; conservation agriculture; soil fertility management; natural farming; agroecological farming	Improved understanding of conservation agriculture; Number of times each farmer's land is tilled and total ha tilled; Concentration of soil carbon (g/km soil); Nutrients in soil; Active climate smart agriculture inclusive of conservation tillage, crop rotation/intercropping and soil cover; Active nutrient management; Number of farmers adopting climate smart agriculture and conservation agriculture	PA43	Immediate	WRA MoALF MoWSI MoEF NEMA	BWRC	WRUA CG	KALRO CFA CBO	1.55	-	-	-	1.55	MoWSI MoALF CG
ii	Promote conservation agriculture and improved farm management with relevant MDAs through training, forums and conferences.	Level of awareness re conservation agriculture and improved farm management; Number of training forums		Medium-term	WRA MoALF MoWSI MoEF KFS NEMA	BWRC	CG WRUA	KALRO CBO	-	-	1.55	-	1.55	MoWSI MoALF CG
Strategic Theme 1.3:	**Natural resources management for the protection and sustainable use of natural resources**												Strategic theme 1.3 total:	**73**	
Theme priority:	**Critical**													
1.3.1	**Improved wetlands and lake management**													
i	Delineate and classify lakes and wetlands at basin scale and conduct status quo assessment for significant wetlands considered as part of Resource Directed Measures	Significant lakes and wetlands - health and services assessed, delineated and classified	LA12-14	Short-term	MoEF NEMA WRA MoWSI NLC	BWRC	CG WRUA	CBO Wetlands International	-	1.8	-	-	1.8	MoEF
ii	Establish an effective and efficient institutional and legal framework for integrated management and wise use of wetlands which will enhance and maintain functions and values derived from wetlands in order to protect biological diversity and improve livelihood of Kenyans.	Clear mandates, roles and responsibilities regarding lake and wetland management		Short to medium-term	MoWSI MoEF WRA NEMA	BWRC	CG WRUA	Wetlands International	-	1.8	1.8	-	3.6	MoEF MoWSI
iii	Promote communication, education and public awareness among stakeholders regarding the importance of sustainable lake and wetland utilisation	Level of awareness regarding sustainable lake and wetland utilization; Regulatory compliance with National Wetlands Conservation and Management Policy; Number stakeholder consultation forums held	LA17	Short-term	MoEF NEMA WRA MoEd	BWRC	CG WRUA	Media NGO CBO	-	1.8	-	-	1.8	MoEF
iv	Improve scientific information and knowledge base on Kenyan wetland ecosystems through research and specific studies.	Number of research papers published; Number of studies completed; Improved knowledge base; Knowledge management system established.		Short to medium-term	MoEF NEMA WRA		WRUA	NGOs Universities	-	1.8	1.8	-	3.6	MoEF WSTF

Key Strategic Area 1:	Catchment Management													
Strategic Objective:	**To ensure integrated and sustainable water, land and natural resources management practices**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
v	Strengthen institutional capacity on conservation and management of wetlands through training and capacity building.	Enhanced institutional capacity towards effective lake and wetland management; Number of staff trained		Medium-term	MoEF NEMA WRA MoWSI	BWRC WWDA	WRUA CG	CETRAD	-	-	1.8	-	1.8	MoEF
vii	Promote innovative planning and integrated management approaches towards wetlands conservation and management in Kenya through training, and capacity building.	Enhanced innovative planning and management for sustainable lake and wetland management; Regulatory compliance with National Wetlands Conservation and Management Policy.		Medium to long-term	MoEF NEMA WRA MoWSI	BWRC WWDA	CG WRUA	CETRAD	-	-	1.8	1.8	3.6	MoEF
viii	Promote partnership and cooperation at regional and international levels for the management of transboundary wetlands and migratory species.	Enhanced partnerships and cooperation regarding sustainable lake and wetland management and utilization; Number international treaties/agreements signed; Number joint initiatives done for wetland protection		Short to long-term	MoWSI MoEF WRA NEMA AFA MoFA MoEACRD		CG WRUA	NGO	-	0.2	0.2	0.4	0.8	MoEF
ix	Enforce wetland and lake buffers.	Wetland and lake buffers enforced	LA18-19	Short to long-term	NEMA WRA MoWSI		CG WRUA	NGO	-	1.8	1.8	3.6	7.2	MoEF
1.3.2	**Promote alternative and sustainable livelihoods**													
i	Promote alternative and sustainable livelihoods through local level initiatives.	Increase in alternative and sustainable livelihoods; Reduced encroachment and destruction of natural resources	PA26	Short to medium-term	MoALF MoEF		WRUA CG	KALRO CBO	-	4.64	4.64	-	9.27	MoALF WSTF
ii	Promote agroforestry (i.e. live fencing, medicinal trees, fodder trees, fruit trees) through local level initiatives.	Increase in Agroforestry; Increase in tree coverage; Number households supported through agroforestry		Short to long-term	KFS MoEF KWTA MoALF		WRUA CFA CG	KEFRI CBO	-	1.55	1.55	3.09	6.18	KFS MoALF
1.3.3	**Improved solid waste management**													
i	Implement improved household waste management with help of the county governments and other stakeholders.	Reduced household waste issues; Recycled waste products	LA23	Short-term	NEMA NETFUND MoEF MoH		CG	CBO NGO	-	1.8	-	-	1.8	MoEF CG
ii	Implement improved village waste management with help of the county governments and other stakeholders.	Reduced village waste issues; Reduced point source water pollution; Public Private Partnerships in waste collection	LA23	Short-term	NEMA NETFUND MoEF MoH		CG	NGO CBO Private sector	-	1.8	-	-	1.8	MoEF CG
iii	Consider developing recycling or buy-back centers as an alternative to current solid waste management.	Reduced solid waste	LA24	Medium-term	NEMA NETFUND MoEF MoH		CG	NGO CBO Private sector	-	-	1.8	-	1.8	CG
iv	Identify and map solid waste hotspots in 9 counties.	No. solid waste hotspots identified; Maps produced	LA20	Medium-term	NEMA NETFUND MoEF MoH		CG WRUA		-	-	1.8	-	1.8	CG
1.3.4	**Improved forestry management**													
i	Coordinate approach to forestry management – roles, responsibilities and mandates	Clear understanding of roles and responsibilities regarding forestry management; Reduced duplication of efforts in conservation; Increased inter-agency collaboration		Immediate	KWS KWTA KFS MoEF NEMA		CG WRUA	NGO CFA	0.9	-	-	-	0.9	MoEF CG

Key Strategic Area 1:	Catchment Management													
Strategic Objective:	**To ensure integrated and sustainable water, land and natural resources management practices**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
ii	Promote international best practice in sustainable plantation forestry through training, and capacity building.	Forest density; Selection of beneficial trees for forest reserves; Number of people trained		Medium to long-term	KFS MoEF			CFA	-	-	0.2	0.4	0.6	MoEF
iii	Enhance protection of forest reserves through community involvement and enforcement	Protected forest density; Number of community groups involved		Short to long-term	KWS KWTA KFS MoEF		CG WRUA	CFA	-	1.8	1.8	3.6	7.2	MoEF
iv	Prevent slash and burn agriculture	Ha of forest preserved		Short-term	AFA MoEF KFS KWTA		CG	CFA	-	0.9	-	-	0.9	MoEF CG
1.3.5	**Removal of alien invasive species**													
i	Develop national program for utilising and controlling identified alien invasive species	Alien invasive control Plan		Short-term	KWS KWTA KFS MoEF NEMA			KEFRI	-	0.1	-	-	0.1	MoEF
1.3.6	**Improved fisheries management**													
i	Promote sustainable development and management of fisheries for maximum social and economic benefit.	Sustainable fishing		Short to medium-term	AFA MoALF		CG	KMFRI	-	0.9	0.9	-	1.8	AFA
1.3.7	**Improved energy management**													
i	Develop and enforce sustainable charcoal strategy.	Reduction in production and use of charcoal		Short to medium-term	MoEF NEMA KFS MoEn EPRA		CG	NGO CBO	-	0.9	0.9	-	1.8	MoEF
ii	Promote renewable energy sources.	No. renewable energy schemes implemented		Medium to long-term	MoEF NEMA MoEn EPRA REREC		CG	KenGen	-	-	3.6	7.2	10.8	CG
1.3.8	**Improved sand mine management**													
i	Collaborate with county governments in developing and implementing a sand harvesting policy.	Sand harvesting policy	LA09	Short-term	NEMA		CG		-	0.9	-	-	0.9	MoEF
ii	Enforcement of Sand Conservation and Utilisation Act	Regulated sand harvesting		Medium-term	NEMA		CG WRUA		-	-	0.45	-	0.45	MoEF
iii	Initiate study to identify alternative sources of building materials other than sand.	Alternative building materials identified and used	LA11	Short-term	NEMA WRA NCA				-	0.2	-	-	0.2	MoEF
iv	Initiate cross-boundary sand management in the basin	Coordination framework to standardize sand management and regulation developed		Medium-term	NEMA WRA		CG		-	-	0.45	-	0.45	MoEF

Key Strategic Area 1:	Catchment Management													
Strategic Objective:	**To ensure integrated and sustainable water, land and natural resources management practices**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
Strategic Theme 1.4:	**Rehabilitation of degraded environments**											Strategic theme 1.4 total:	**35**	
Theme priority:	**Very Important**													
1.4.1	**Rehabilitation and Restoration Plan**													
i	Prepare rehabilitation and restoration program for Basin: Land, Riparian areas, Forests, Mining areas in collaboration with stakeholders.	No. rehabilitation and restoration programs developed	LA15	Short to medium-term	NEMA WRA KFS KWS KWTA MoALF	BWRC	CG WRUA	CBO CFA	-	1.8	1.8	-	3.6	MoEF
1.4.2	**Land restoration and rehabilitation of specific priority areas**													
i	Identify, review and update catchment degradation hotspot areas.	Catchment degradation hotspots identified	LA06	Short-term	WRA NEMA KFS KWTA	BWRC	CG WRUA		-	0.9	-	-	0.9	CG
ii	Collaborate with county governments in Soil and Water conservation measures (Strategy 1.2.2).	Soil and water management improvement; Number of collaborations	LA10	Short-term	WRA	BWRC	CG WRUA	NGO CBO	-	1.8	-	-	1.8	CG
1.4.3	**Site specific rehabilitation of degraded riparian areas**													
i	Identify and map urban river hotspot areas for clean-up campaigns.	Urban river hotspot areas identified and mapped	LA20	Short-term	WRA NEMA		CG WRUA		-	0.9	-	-	0.9	MoEF CG
ii	Carry out river clean-up activities in identified hotspot areas in collaboration with counties and key stakeholders.	Hotspots cleaned; Number of stakeholders engaged in clean-ups	LA21	Short-term	WRA NEMA		CG WRUA	CBO	-	1.8	-	-	1.8	MoEF CG
iii	Increase/maintain natural riparian vegetation cover.	Natural riparian vegetation cover increased/maintained	LA18	Short to long-term	WRA NEMA KFS		CG WRUA	CBO	-	1.8	1.8	3.6	7.2	CG
1.4.4	**Site specific rehabilitation of degraded wetlands.**													
i	Identify, review and update wetland degradation hotspot areas.	Wetland degradation hotspots identified and mapped		Short-term	NEMA WRA		CG	NGO CBO	-	0.9	-	-	0.9	MoEF CG
ii	Develop rehabilitation and restoration program for degraded wetlands.	Wetland rehabilitation program		Short-term	NEMA WRA NLC	BWRC	CG WRUA	NGO CBO	-	0.9	-	-	0.9	MoEF CG
iii	Increase/maintain natural wetland vegetation cover.	Natural wetland vegetation cover increased	LA18	Short to long-term	WRA NEMA KWS		CG WRUA	NGO CBO	-	1.8	1.8	3.6	7.2	MoEF CG
1.4.5	**Site specific rehabilitation of Gazetted forests or protected forests that have been degraded**													
i	Recommend identified areas for gazettement.	Gazette areas identified	LA16	Short-term	KFS WRA NEMA KWTA		CG		-	0.2	-	-	0.2	KFS
ii	Increase/maintain natural vegetation cover in protected areas	Natural vegetation cover increased/maintained; Number of indigenous species planted	LA18	Short to long-term	KWS KWTA KFS			CFA	-	1.8	1.8	3.6	7.2	MoEF KFS, KWTA

Key Strategic Area 1:		Catchment Management													
Strategic Objective:		**To ensure integrated and sustainable water, land and natural resources management practices**													
Strategy		**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
						National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
iii	Undertake reforestation in prioritised degraded forest areas. Consider soil and water conservation techniques and beneficial/natural trees.		Ha forest cover increased; Number of indigenous trees planted		Short to medium-term	KWS KWTA KFS			CFA	-	1.8	1.8	-	3.6	MoEF KFS
1.4.6	**Mining area rehabilitation**														
i	Rehabilitate degraded sand mining areas.		Rehabilitated sand mining areas		Short-term	NEMA		CG WRUA		-	0.9	-	-	0.9	MoEF CG
ii	Rehabilitate prioritised abandoned mines and/or mining areas at active mines.		Revegetated mining areas and soil conservation techniques implemented		Short to medium-term	NEMA		CG WRUA		-	0.9	0.9	-	1.8	MoEF CG

Key Strategic Area 2:	Water Resource Protection													
Strategic Objective:	**To protect and restore the quality and quantity of water resources of the basin using structural and non-structural measures**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
Strategic Theme 2.1:	**Classification of water resources**											Strategic Theme 2.1 total:	**0.1**	
Theme priority:	**Very critical**													
2.1.1	**Determine the baseline for Resource Directed Measures: Surface and groundwater assessments at appropriate scales to inform the classification of water resources in the basin.**													
i	Implement under Strategies: 8.1.1: Surface water resources assessment - surface water availability at relative scales 3.1.1: Groundwater assessment – assess groundwater availability in terms of quantity and quality													
2.1.2	**Determine Class of water resources**													
i	Classify all significant water resources in the Basin (conducted prior to Reserve and resource quality objectives determination)	Water resources classified; Water resources classification report	LA03-04	Immediate	WRA NEMA				0.05	-	-	-	0.05	WRA
Strategic Theme 2.2:	**Ecological Reserve**											Strategic Theme 2.2 total:	**2.5**	
Theme priority:	**Very Important**													
2.2.1	**Reserve determination**													
i	Determine the Reserve for prioritised water resources in the Basin (note Reserve required for resource quality objectives)	Reserve determined	LA01 WA11	Immediate	WRA		CG		0.05	-	-	-	0.05	WRA
2.2.2	**Reserve compliance**													
i	Increase Reserve awareness through training, brochures, social media, internet, factsheets and SCMPs.	Level of awareness regarding Reserve; Number of trainings and awareness campaigns undertaken	WA17	Short to medium-term	WRA		WRUA		-	0.2	0.2	-	0.4	WRA WSTF
ii	Monitor and enforce Reserve compliance: Dam owners and operators, abstractors.	Environmental flows met	LA02 WA15	Medium to long-term	WRA	BWRC	WRUA		-	-	1	1	2	WRA WSTF
Strategic Theme 2.3:	**Resource quality Objectives**											Strategic Theme 2.3 total:	**0.2**	
Theme priority:	**Critical**													
2.3.1	**Set resource quality objectives**													
i	Determine the resource quality objectives for prioritised water resources in the Basin	Resource quality objectives set	LA05 WA29	Immediate	WRA NEMA	BWRC	CG WRUA		0.2	-	-	-	0.2	WRA
Strategic Theme 2.4:	**Conservation and protection of ecological infrastructure**											Strategic Theme 2.4 total:	**2.0**	
Theme priority:	**Important**													
2.4.1	**Integrate environmental considerations into basin development and planning**													
i	Ensure compliance with Kenyan environmental legislation in planning policies, plans and programs related to basin planning and development	SSEAs successfully completed; Categorise and protect environmentally sensitive areas; Identify and define environmentally sensitive areas		Short to long-term	WRA NEMA	BWRC	WRUA		-	0.15	0.15	0.3	0.6	WRA
2.4.2	**Groundwater protection**													
i	Implement under Strategy 3.4.1 Groundwater source protection													
2.4.3	**Riparian areas protection**													
i	Protect and conserve prioritized riparian areas	Riparian areas defined and protected	WA36	Short to medium-term	NEMA WRA		WRUA		-	0.2	0.2	-	0.4	WRA

Key Strategic Area 2:		Water Resource Protection													
Strategic Objective:		**To protect and restore the quality and quantity of water resources of the basin using structural and non-structural measures**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
2.4.4	**Ecosystem services protection**													
i	Protect and conserve sensitive ecosystems which provide important ecological services.	Environmentally sensitive areas protected	WA36	Short to medium-term	NEMA		WRUA		-	0.2	0.2	-	0.4	WRA
ii	Give monetary value to ecological infrastructure and ecosystem services	Payment for ecosystem services initiated		Long-term	WRA NEMA		WRUA		-	-	-	0.6	0.6	WRA WSTF

Key Strategic Area 3:	Groundwater Management													
Strategic Objective:	**The integrated and rational management and development of groundwater resources**													
Strategy	**Activities**	**Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022 - 2025**	**2025 - 2030**	**2030 - 2040**	**Total cost**	
Strategic Theme 3.1:	**Groundwater resources assessment, allocation, regulation**											Strategic theme 3.1 total:	**16**	
Theme priority:	**Critical**													
3.1.1	**Groundwater assessment – assess groundwater availability in terms of quantity**													
i	Implement aquifer mapping and groundwater modelling across the basin	Groundwater resources mapped	LA26	Immediate to short-term	WRA				2.25	2.25	-	-	4.5	WRA MoWSI
ii	Complete aquifer classification.	Aquifers classified		Immediate	WRA				0.05	-	-	-	0.05	WRA
iii	Improve estimates of sustainable groundwater yield in priority areas using advanced techniques	High confidence estimates of sustainable yield	WA12	Immediate to medium-term	WRA MoWSI				0.9	0.9	0.9	-	2.7	WRA MoWSI
3.1.2	**Groundwater assessment – assess groundwater quality and use**													
i	Prepare groundwater abstraction plan and undertake groundwater abstraction and water quality survey	Groundwater abstraction survey successfully completed		Immediate to short-term	WRA MoWSI	BWRC	CG	WRUA	1.8	1.8	-	-	3.6	WRA MoWSI
ii	Develop groundwater allocation plan for strategic aquifers, particularly the Nairobi Aquifer suite	Groundwater allocation plan successfully completed		Immediate to short-term	WRA MoWSI	BWRC	CG	WRUA	0.05	0.05	-	-	0.1	
3.1.3	**Update and improve permit database**													
i	Reconcile PDB with groundwater abstraction survey results	PDB reconciled with groundwater abstraction survey results		Short-term	WRA				-	0.18	-	-	0.18	WRA
ii	Revise/adapt PDB to reflect new proposed Aquifer Classification	Revised PDB		Short to medium-term	WRA				-	0.9	0.9	-	1.8	WRA
iii	Develop system for on-line updating of drilling contractor information to improve borehole data capture via an online system	Revised PDB		Short to medium-term	WRA				-	0.45	0.45	-	0.9	WRA
3.1.4	**Groundwater allocation**													
i	Set National Resource Quality Objectives (RQOs)	Implement under Strategy 2.3.1: Set Resource Quality Objectives												
ii	Undertake groundwater balance to determine sustainable yield available	Groundwater balance	WA02	Immediate to short-term	WRA				0.05	0.05	-	-	0.1	WRA
iii	For each aquifer in the basin, develop Allocation Plan and disaggregate to sub-basins.	Athi Basin Water Allocation Plans	WA13	Immediate to short-term	WRA	BWRC	CG	WRUA	1	1	-	-	2	WRA
Strategic Theme 3.2:	**Groundwater development**											Strategic theme 3.2 total:	**29**	
Theme priority:	**Very important**													
3.2.1	**Aquifer recharge**													
i	Conduct preliminary assessment of recharge areas from existing data. Define recharge areas for Priority Aquifers.	Groundwater recharge areas defined; Recharge water quality, quantity and mechanism determined		Short-term	WRA				-	0.9	-	-	0.9	WRA

Key Strategic Area 3:	Groundwater Management													
Strategic Objective:	**The integrated and rational management and development of groundwater resources**													
Strategy	**Activities**	**Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022 - 2025**	**2025 - 2030**	**2030 - 2040**	**Total cost**	
ii	Roll out Managed Aquifer Recharge studies in the basin	Managed Aquifer Recharge studies in the Athi Basin		Medium to long-term	WRA		CG	WSP Private sector (industry, agric., mining)	-	-	0.9	1.8	2.7	WRA
3.2.2	**Local groundwater development**													
i	Assess allocable groundwater potential close to local demand centers and determine if groundwater resources could meet local demands.	Implement under Strategy 8.2.1: Updated planning for bulk water resources development												
ii	Implement groundwater abstraction schemes in accordance with groundwater development planning	Successful implementation of groundwater schemes in collaboration with Water Service Providers.		Short to long-term	WRA		CG	WSP	7	9	12	23	51	MoWSI
3.2.3	**Large scale groundwater development**													
i	Assess allocable groundwater potential close to major demand centers and determine if groundwater resources could meet demands.	Implement under Strategy 8.2.1: Updated planning for bulk water resources development												
ii	Mzima Springs	Extension works completed		Short-term	MoWSI	WWDA			3	-	-	-	3	MoWSI
iii	Baricho aquifer	Extension works completed		Medium-term	MoWSI	WWDA			-	10	-	-	10	MoWSI
iv	Marere Springs	Extension works completed		Medium-term	MoWSI		CG WSP		-	1	-	-	1	MoWSI
v	Msambweni aquifer	GW development completed		Medium-term	MoWSI		CG WSP		-	3	-	-	3	MoWSI
vi	Ruiru and Kiunyu Wellfields	GW development completed		Medium-term	MoWSI		WSP		-	4	-	-	4	MoWSI
3.2.4	**Conjunctive use**													
i	Implement under Strategies 3.2.2 and 3.2.3													
Strategic Theme 3.3:	**Groundwater asset management**									Strategic theme 3.3 total:			**5**	
Theme priority:	**Important**													
3.3.1	**Develop asset inventory**													
i	Develop a needs assessment for groundwater management needs	Needs assessment completed		Short-term	MoWSI WRA			WSP	-	0.05	-	-	0.05	MoWSI
Ii	Acquire necessary equipment and accessories for groundwater management	Equipment/accessories acquired		Short-term	MoWSI WRA			WSP	-	0.9	-	-	0.9	MoWSI
Iii	Establish Asset Inventory.	Asset inventory compiled (number of boreholes, Spatial data, Mechanical and Electrical Equipment; Civil infrastructure etc)		Short-term	MoWSI WRA			WSP	-	2.7	-	-	2.7	MoWSI
iv	Commission or develop an Asset Inventory database system.	Asset inventory database in place		Short-term	MoWSI WRA			WSP	-	0.1	-	-	0.1	MoWSI

Key Strategic Area 3:	Groundwater Management													
Strategic Objective:	**The integrated and rational management and development of groundwater resources**													
Strategy	**Activities**	**Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022 - 2025**	**2025 - 2030**	**2030 - 2040**	**Total cost**	
3.3.2	**Develop asset management plan**													
i	Prepare groundwater asset management plan	Groundwater asset management plan		Short to medium-term	WRA			WSP	-	0.54	0.54	-	1.08	MoWSI
Strategic Theme 3.4:	**Conservation and protection of groundwater**											Strategic theme 3.4 total:	**6**	
Theme priority:	**Important**													
3.4.1	**Groundwater source protection**													
i	Assess Athi Basin groundwater Vulnerability	Groundwater vulnerability assessed	LA25	Short-term	WRA				-	0.1	-	-	0.1	WRA
ii	Assess significance of Athi Basin groundwater to saltwater intrusion, prioritise and select aquifers requiring active intervention to contain or reverse saltwater intrusion	Saltwater intrusion studies		Short-term	WRA				-	0.1	-	-	0.1	WRA
iii	Assess which Athi Basin aquifers or parts of aquifers require formal protection.	Groundwater conservation areas (GCAs) identified		Short-term	WRA				-	0.05	-	-	0.05	WRA
iv	Assess which Athi Basin aquifers contain important GDEs	Groundwater dependent ecosystems (GDEs) identified		Short-term	WRA				-	0.05	-	-	0.05	WRA
v	Develop an Athi Basin groundwater Protection Plan	Athi Basin groundwater protection plan	LY08	Short-term	WRA MoWSI NEMA MoICNG		CG WRUA	WSP Private sector (industry, agric., mining)	-	0.2	-	-	0.2	WRA
vi	Implement groundwater protection measures	Number of protected aquifers		Short to long-term	WRA				-	1	1	2	4	WRA
3.4.2	**Rehabilitate of polluted aquifers, springs and wells**													
i	Define Athi Basin's polluted aquifers.	Athi Basin polluted aquifers identified	LA27	Short-term	WRA				-	0.2	-	-	0.2	WRA
ii	For each polluted aquifer, determine the optimum and most cost-effective way to rehabilitate it.	Rehabilitation plans for polluted aquifers	LA28	Short to medium-term	WRA				-	0.2	0.2	-	0.4	WRA
iii	Prioritise aquifers for rehabilitation and implement rehabilitation programmes.	Implementation of prioritised rehabilitation plans	LA28	Medium to long-term	WRA		WRUA		-	-	0.2	0.4	0.6	WRA

Strategy	Activities	Target/Indicators (M&E)	CMS Strategic Action	Implementation horizon	Key role players				Budget (USD Million)					Funding source
					National	Basin	Local	Other	2020 - 2022	2020 - 2022	2025 - 2030	2030 - 2040	Total cost	
Key Strategic Area 4:	**Water Quality Management**													
Strategic Objective:	**Efficient and effective management of water quality to ensure that water user requirements are protected in order to promote sustainable socio-economic development in the basin**													
Strategic Theme 4.1:	**Effective water quality data collection, information generation and dissemination, and knowledge management**											Strategic theme 4.1 total:	**10**	
Theme priority:	**Critical**													
4.1.1	**Implement routine surface and groundwater quality monitoring**													
i	Implement national water quality monitoring programme in the Athi Basin by ensuring technical staff are capacitated and laboratories can analyse the samples accurately and on time.	Number of samples collected and analysed	WA38	Immediate	WRA	WWDA			1	-	-	-	1	WRA
ii	Ensure data submitted to Mike Info WQ database, and that the data is reviewed, analysed, reported on, and acted on by catchment staff.	Number Water quality reports produced		Immediate	WRA				0.2	-	-	-	0.2	WRA
4.1.2	**Biological Water Quality Monitoring**													
i	Develop capacity to undertake biomonitoring in Kenya to assess aquatic ecosystem health.	Number of scientists capacitated to undertake biomonitoring; pilot sites identified and monitoring implemented; results integrated with WQ monitoring results	WA33-35	Immediate	WRA NEMA		WRUA	Universitie s KEWI	0.4	-	-	-	0.4	WRA
ii	Identify streams in the Athi Basin for piloting biomonitoring and undertake pilot studies.	Number biomonitoring sites; Number reports on pilot studies	WA33-35	Immediate	WRA NEMA			Universitie s KEWI	0.3	-	-	-	0.3	WRA
iii	Integrate the biomonitoring results with the water quality monitoring network to assess the overall fitness for use and ecosystem health of water resources.	State of the rivers report; Number of biomonitoring indices set	WA33-35	Short to long-term	WRA NEMA				-	0.1	0.1	0.1	0.3	WRA
4.1.3	**Undertake survey of pollution sources**													
i	Compile an inventory of surface water pollution sources.	Surface water pollution inventory	WA20-21	Immediate	WRA NEMA		WRUA		0.3	-	-	-	0.3	WRA NEMA
ii	Reconcile identified pollution sources against discharge licenses at NEMA and permits at WRA.	Reconciliation report	WA22	Short-term	WRA NEMA				-	0.05	-	-	0.05	WRA NEMA
iii	Undertake waste load assessment to assess cumulative impact of pollution sources concentrated in a specific river reach or sub-catchment	Number waste load assessments completed		Short to medium-term	WRA NEMA				-	0.2	0.2	-	0.4	WRA NEMA
iv	Effluent compliance monitoring should be undertaken at regular intervals	Number operational monitoring points and frequency of monitoring; Monitoring programme in place	WA23	Short to long-term	WRA NEMA WASREB			WSP	-	1.25	1.25	2.5	5	WRA NEMA
4.1.4	**Upgrade water quality testing laboratories**													
i	Upgrade central and regional laboratories in the Athi Basin to support the national water quality monitoring programme. These include, inter alia, the recruitment of more technical staff, equipping the laboratory and stocking it with reagents, procuring Field Testing Kits, operationalising the LIMS in the central and regional laboratories and participating in proficiency tests to acquire the	Laboratory upgrade plan completed, Upgrade plan implemented, LIMS operational, Q&A implemented, data sent to Mike Info; Number adequately equipped laboratories; Number ISO accreditations; Number trained staff	WA37	Immediate for central laboratory, short-term for regional laboratories	WRA NEMA		CG	CWTL	0.5	0.5	-	-	1	WRA MoWSI

Key Strategic Area 4:	Water Quality Management													
Strategic Objective:	**Efficient and effective management of water quality to ensure that water user requirements are protected in order to promote sustainable socio-economic development in the basin**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020 - 2022**	**2020 - 2022**	**2025 - 2030**	**2030 - 2040**	**Total cost**	
	necessary accreditation and ISO certification to enhance data credibility.													
4.1.5	**Institutionalise water quality data storage and management**													
i	All historical and new water quality data collected by WRA in the Athi Basin stored in Mike Info.	Historical data captured & quality controlled; Data from laboratories captured on time & quality controlled		Immediate	WRA NEMA				0.25	-	-	-	0.25	WRA
4.1.6	**Design and implement routine water quality status reporting**													
i	Routine water quality status reports should be designed and implemented to report on the water quality status in the Athi Basin, identify key water quality concerns, their causes and consequences, and recommend management actions to mitigate negative impacts.	WQ Status Reports produced		Short to long-term	WRA NEMA				-	0.25	0.25	0.5	1	WRA
Strategic Theme 4.2:	**Promote sound water quality management governance in the Athi Basin**											Strategic theme 4.2 total:	**2**	
Theme priority:	**Very Important**													
4.2.1	**Harmonise policies and strategies towards improved water quality management**													
i	Advocate for alignment of strategies to serve a common purpose of rehabilitating urban rivers and streams in the Athi Basin.	Policies and strategies reviewed for discrepancies; Policies and strategies aligned		Immediate to short-term	WRA NEMA MoALF MoWSI MoEF				0.5	0.5	-	-	1	WRA NEMA
4.2.2	**Coordination and cooperation mechanism on water quality issues established at a catchment level**													
i	Establish a coordination and cooperation mechanism to ensure there is alignment of actions to address water pollution management in the Athi Basin.	Inter-agency coordination body established and operational	WA39 WA43	Immediate	WRA NEMA	BWRC	CG WRUA	NGO CBO	0.1	-	-	-	0.1	WRA NEMA
ii	Embed water quality management activities related to domestic water use, crop and livestock production in SCMPs	Improved understanding of pollution sources in sub-catchments; Active water quality management; Number SCMPs developed with embedded water quality management activities		Immediate	WRA	BWRC	WRUA CG		0.5	-	-	-	0.5	WRA
iii	Promote water quality management with relevant MDAs through training, forums and conferences.	Level of awareness re water quality management; Number of participants at forums/conferences; Number of people trained on water quality management		Short-term	WRA	BWRC			-	0.05	-	-	0.05	WRA NEMA
Strategic Theme 4.3:	**Efficient and effective management of point and nonpoint sources of water pollution**											Strategic theme 4.3 total:	**237**	
Theme priority:	**Important**													
4.3.1	**Improve sewerage systems and treatment**													
i	Prepare rehabilitation plan for existing sewerage systems in urban areas incl. sewer pipes, pump stations, wastewater treatment works etc.	Number rehablitation plans		Short-term			CG	WSC	-	1.8	-	-	1.8	MoWSI

Key Strategic Area 4:		Water Quality Management													
Strategic Objective:		**Efficient and effective management of water quality to ensure that water user requirements are protected in order to promote sustainable socio-economic development in the basin**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020 - 2022**	**2020 - 2022**	**2025 - 2030**	**2030 - 2040**	**Total cost**	
ii	Implement rehabilitation plan for sewerage system incl. rehabilitation of existing wastewater treatment	Number successful completion of rehab works; Number of treatment works operating efficiently		Medium to long-term			CG	WSC	-	-	27	27	54	MoWSI
iii	Prepare wastewater master plan for major urban centres: assess current capacity of wastewater treatment works, required and projected capacity, maintenance needs and budgets and capex budgets for expansion.	Number wastewater master plans completed		Short-term	MoWSI		CG	WSC	-	0.5	-	-	0.5	MoWSI
iv	Construct new sewerage systems in urban areas and connect to existing / new WWTWs. Increase wastewater treatment capacity in urban areas by expanding existing / constructing new wastewater treatment plants.	Number new sewerage systems completed (area); Number existing WWTWs expanded; Number new WWTWs; Increased percentage in waste water treatment coverage		Medium to long-term			CG	WSC	-	-	36	72	108	MoWSI
v	Promote wastewater treatment at source, especially at industrial sites, housing estates, hospitals, etc. With the objective of improving the quality of effluent discharges before it enters the environment or sewerage network.	Number of onsite WWT facilities; Current vs historical effluent quality; Number of Effluent Discharge Control Plans (ECDPs) in place		Short to long-term	NEMA WRA		CG	Industries Household s NGO	-	1.8	1.8	3.6	7.2	MoWSI
4.3.2	**Cleaner production methods**													
i	Support initiatives by the Kenya National Cleaner Production Center (KNCPC) to promote excellence in Resource Efficient and Cleaner Production in industries in the Athi Basin in order to reduce water usage and effluents, as well as their impacts on water quality in receiving water bodies.	Water consumption vs international norms; Effluent quality vs international norms; Current vs historical river water quality; Number initiatives on cleaner production increased		Short to medium-term	NEMA WRA KNCPC			Industries	-	0.5	0.5	-	1	MoWSI
4.3.3	**Urban stormwater, sanitation, and solid waste management, and protection of upper reaches of rivers**													
i	Control sediment pollution from construction sites and unpaved urban roads in urban areas by adopting best urban stormwater management practices such as erecting sediment traps or screens, sediment detention ponds, etc.	Number urban stormwater BMPs implemented.		Short to medium-term	NEMA WRA KURA		CG	NGO	-	2.7	2.7	-	5.4	CG
ii	Compel County Governments to maintain sewerage infrastructure and fix leaks or blockages as a matter of urgency to minimise sewage leaks into stormwater drains.	Number maintenance projects completed; Number of sewage blockages repaired; Tonnage of solid waste removed	WA39 WA43	Short-term	WRA NECC	WWDA	CG	WSP	-	2.25	-	-	2.25	WRA
iii	Promote solid waste removal in urban centres and disposal at solid waste disposal sites that meet best national or international design standards.	Improved solid waste collection, transportation, treatment and disposal		Short-term	WRA NEMA		CG		-	2.25	-	-	2.25	CG

Key Strategic Area 4:	Water Quality Management													
Strategic Objective:	Efficient and effective management of water quality to ensure that water user requirements are protected in order to promote sustainable socio-economic development in the basin													
Strategy	Activities	Target/Indicators (M&E)	CMS Strategic Action	Implementation horizon	Key role players				Budget (USD Million)					Funding source
					National	Basin	Local	Other	2020 - 2022	2020 - 2022	2025 - 2030	2030 - 2040	Total cost	
iv	Refurbish existing solid waste dumps to intercept and treat poor quality drainage water and prevent it from running into water courses.	Number drainage systems constructed to intercept the leachate		Medium to long-term	WRA NEMA		CG		-	-	2.25	4.5	6.75	CG
4.3.4	**Sanitation management in informal settlements**													
i	Protect receiving streams from pollution, especially urban rivers such as Ngong, Ongata Rongai, Ruiru, Kiambu and Nairobi by installing sewers or septic tanks to contain domestic wastes, by managing urban solid wastes, and monitoring receiving streams for BOD and COD.	Number of sewers or septic tanks installed; Number of solid waste handling sites constructed; Number of water samples collected and analysed for BOD and COD; Reduction in number of non-designated dump sites		Short to medium-term	WRA NEMA NLC MoH			NGOs involved in urban upliftment	-	2.7	2.7	-	5.4	CG MoWSI
ii	Control of organic pollution from unplanned and un-sewered settlements/slums in all the major urban centres through installing sewers or septic tanks and promoting solid waste collection and removal from these settlements.	Length of sewers installed; No septic tanks installed; Tonnage of solid waste removed; Number solid waste service providers registered and active		Short to medium-term	WRA	WWDA	CG		-	9	9	-	18	CG MoWSI
iii	Support international aid / private sector projects that are designed to upgrade informal settlements and slums.	Number aid projects supported; Number of households supported		Medium to long-term	WRA MoTIHUDPW		CG	NGO	-	-	1.8	1.8	3.6	CG MoWSI
4.3.5	**Management of hydrocarbon pollution**													
i	Control of oil and grease pollution, spillage and leakages from petrol stations, trucks, pipelines and oil storage facilities by ensuring that all are equipped with functional oil and grease traps, and by monitoring nearby surface and groundwater for hydrocarbons.	Number of oil & grease traps installed; Number water samples collected and analysed for hydrocarbons; Reduced level of hydrocarbons in surface water and ground water		Short to long-term	NEMA WRA MoPM MoTIHUDPW		CG Local Government	Petrol stations Workshops	-	0.9	0.9	1.8	3.6	NEMA WRA
ii	Control dumping of used motor oil at informal workshops by promoting recycling of used oil, and monitoring stormwater drains for hydrocarbon pollution.	Volume of used oil recycled; Streams complying with Oil & Grease standards; Number informal workshops recycling used oil and using recycled oil		Short-term	WRA EPRA		CG		-	0.9	-	-	0.9	NEMA CG
iii	Protect groundwater against hydrocarbon contamination near petrol stations and dump sites by drilling observation wells at high risk areas and monitoring boreholes for hydrocarbons	Groundwater complying with Oil & Grease standards; Number observation wells drilled		Short-term	WRA EPRA		CG		-	0.5	-	-	0.5	WRA
4.3.6	**Sedimentation from unpaved roads**													
i	Control sediment pollution from unpaved roads by erecting sediment traps or vegetated buffer strips next to dirt and paved roads. Maintain stormwater drainage to prevent erosion next to roads and rehabilitate erosion gullies near roads.	Number of sediment traps installed; Number of buffer strips established; Reduction in sediment loads in samples analysed; Length of erosion gullies rehabilitated		Medium to long-term	MoTIHUDPW WRA KURA KeRRA		CG		-	-	1.8	3.6	5.4	CG

Key Strategic Area 4:		Water Quality Management													
Strategic Objective:		Efficient and effective management of water quality to ensure that water user requirements are protected in order to promote sustainable socio-economic development in the basin													
Strategy		Activities	Target/Indicators (M&E)	CMS Strategic Action	Implementation horizon	Key role players				Budget (USD Million)					Funding source
						National	Basin	Local	Other	2020 - 2022	2020 - 2022	2025 - 2030	2030 - 2040	Total cost	
4.3.7	**Management of agricultural impacts on sediments, nutrients, and agrochemicals**														
i		Control nutrients pollution from agricultural activities (N & P) in all farmed areas within the Basin by compiling & maintaining inventories of fertilizer use, and monitoring nutrients in receiving water bodies (rivers, reservoirs and lakes).	Inventory of fertilizer use established and maintained; Monitoring implemented; Number samples collected and analysed for nutrient content		Short to medium-term	WRA MoALF NEMA NIB		CG	Large commercia l farmers	-	0.5	0.5	-	1	WRA
ii		Control agrochemical (pesticides and herbicides) residue pollution from farmlands by compiling an inventory of pesticide usage in the basin, and monitoring affected water bodies for residues. Promote efficient use of agrochemicals in the agricultural sector.	Inventory of pesticide use established and maintained; Monitoring implemented; Number of samples collected and analysed for agrochemical components		Short to medium-term	WRA MoALF NEMA NIB PCPB		CG	Large commercia l farmers	-	0.45	0.45	-	0.9	CG
iii		Promote best irrigation management practices and encourage irrigators to retain, treat and recycle irrigation return flows before discharging it to the environment.	Compliance with nutrient objectives in rivers and lakes; Number of farmers practicing best irrigation management practices		Medium to long-term	WRA MoALF NEMA NIB		CG	Large commercia l farmers	-	-	1.8	3.6	5.4	MoALF CG
iv		Training and awareness creation on nutrient pollution, agrochemical residue pollution, best irrigation management practices and good land management practices.	Number of training forums held; Number of farmer participants		Short-term	WRA MoALF NIB KALRO		CG WRUA	CBO Local farmers	-	1.8	-	-	1.8	MoALF CG
4.3.8	**Enforcement of effluent standards**														
i		Use the results of compliance monitoring of effluent discharge license or permit conditions to prosecute offenders that consistently violate their license/permit conditions and demonstrate no intention of meeting them.	Number of polluters prosecuted		Medium to long-term	NEMA WRA		CG	WWTW operators	-	-	0.5	1	1.5	WRA NEMA
4.3.9	**Control discharges from sand mining operations.**														
i	Implement under Strategy 1.3.8: Improved sand mine management														
4.3.10	**Rehabilitation of polluted aquifers, springs and wells**														
i	Implement under Strategy 3.4.2: Rehabilitate polluted aquifers, springs and wells														

Key Strategic Area 5:	Climate Change Mitigation, Adaptation and Preparedness													
Strategic Objective:	**To implement climate change mitigation measures in the water resources sector and to ensure water resource development and management are adapted and resilient to the effects of climate change**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Area**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2020 - 2025**	**2025-2030**	**2030 - 2040**	**Total cost**	
Strategic Theme 5.1:	**Improved understanding of impacts of climate change on water resources planning and management at appropriate spatial scales**										Strategic theme 5.1 total:		**1**	
Theme priority:	**Critical**													
5.1.1	**Quantify climate change impacts (rainfall & temperature) on surface water and groundwater resources and demands in the Athi Basin at appropriate scales for planning and management**													
i	Use climate change databases, historical data and analytical tools (ISC and other) to identify trends and quantify climate change impacts on surface water and groundwater availability at relevant temporal and spatial scales: rainfall intensity; frequency of extreme rainfall events; rainfall seasonality; inter-and intra-annual rainfall variability; rainfall-runoff relationships; stream flow; groundwater recharge; irrigation demands	Quantification of climate trends and change impacts on surface water and groundwater availability at sub-basin scale	PA01 PA02 PA03 PA04 PA05 PA06	Immediate to short-term	WRA KMD				0.1	0.1	-	-	0.2	WRA
5.1.2	**Assess relevance, and scale of potential social, environmental and economic climate change impacts as defined in NCCAP in Athi Basin and its relation to water resources planning and management; prioritise areas for interventions**													
i	Assess potential social impacts: flooding; droughts; human conflict; migration; vulnerable groups; ocean acidification; agriculture; food production	Prioritised list of social impacts related to climate change in basin; Map of hotspots/high risk areas		Immediate to medium-term	NDMA NDOC CETRAD				0.1	0.1	0.2	-	0.4	WRA
ii	Assess potential environmental impacts: droughts; sea temperature; rising sea levels; ocean acidification; desertification; lad degradation; loss of biodiversity; deforestation; forest degradation	Prioritised list of environmental impacts related to climate change in basin		Immediate to medium-term	MoEF NEMA KFS CETRAD				0.1	0.1	0.2	-	0.4	WRA
iii	Assess potential economic impacts: irrigation water requirements; crop type and yield; GDP; public Infrastructure; hydropower; coastal assets; livelihoods and income generation.	Prioritised list of economic impacts related to climate change in basin; Economic valuation of impacts in the basin		Immediate to medium-term	MoEF MoALF	CETRAD			0.1	0.1	0.2	-	0.4	WRA
Strategic Theme 5.2:	**Climate change mitigation**										Strategic theme 5.2 total:		**12**	
Theme priority:	**Very important**													
5.2.1	**Promote the generation and use of clean energy**													
i	Make use of efficient energy technologies and techniques at household level (e.g. energy efficient lightbulbs, Solar cooker, Solar electrification, Solar borehole pump, Wind pump, Micro hydropower, Biogas digester, Energy efficient stoves and ovens, Heat retention cooker)	Ratio of energy efficient to non-efficient technology used in households; Number of energy saving technologies adopted; Number of households trained on the use of energy saving techniques		Medium to long-term	MoEn KPLCO			Private sector Households	-	-	3	6	9	MoEn CG
ii	Improve policies regarding renewable energy	The extent to which policies address renewable energy		Short-term	MoEn				-	0.1	-	-	0.1	MoEn
iii	Increase generation of clean energy	kWh of clean energy generated		Medium to long-term	MoEn KENGEN				-	-	1	2	3	MoEn

Key Strategic Area 5:	Climate Change Mitigation, Adaptation and Preparedness													
Strategic Objective:	To implement climate change mitigation measures in the water resources sector and to ensure water resource development and management are adapted and resilient to the effects of climate change													
Strategy	Activities	Target/Indicators (M&E)	CMS Strategic Area	Implementation horizon	Key role players				Budget (USD Million)					Funding source
					National	Basin	Local	Other	2020-2022	2020 - 2025	2025-2030	2030 - 2040	Total cost	
Strategic Theme 5.3:	Climate change adaptation											Strategic theme 5.3 total:	25	
Theme priority:	Very important													
5.3.1	**Promote climate resilient infrastructure**													
i	Incorporate flexible adaptation infrastructure principles in infrastructure planning and investment plans	Flexible approaches in which infrastructure is proactively designed/phased to accommodate climate uncertainty.		Immediate to short-term	MoLPP MoTIHUDPW		Local town planning CG		4.5	4.5	-	-	9	MoEF
ii	Promote improved capacity of stormwater systems and gutters	% of urban stormwater caught in stormwater systems; Number of dwellings with gutters		Short to medium-term	MoTIHUDPW NWHSA		Property owners Local town planning CG		-	4.5	4.5	-	9	MoEF CG
iii	Promote thermally resilient road and rail infrastructure using heat resistant materials	Number of infrastructure projects using heat resistant materials		Medium to long-term	MoTIHUDPW KENHA KURA		Property owners Local engineers and construction companies		-	-	0.3	0.6	0.9	MoEF
5.3.2	**Climate-related disaster risk management**													
i	Floods	Implement under Strategic Theme 6.1: Flood management												
ii	Droughts	Implement under Strategic Theme 6.2: Drought management												
iii	Increase food security through enhanced resilience of the agricultural sector	Increased food security		Short to medium-term	MoALF NDMA	Disaster management committees	CG	NGO	-	1	1	-	2	MoALF
iv	Reduce the incidence of malaria and other diseases expected to increase due to climate change	Reduced incidence of diseases		Short to medium-term	MoH		CG		-	1	1	-	2	MoH
5.3.3	**Promote agroforestry**													
i	Promote alternative and sustainable livelihoods	Implement under Strategy 1.3.2												
5.3.4	**Mainstream climate change adaptation in water resources strategy, planning and management at basin and catchment level**													
i	Implementation and enforcement of climate change regulatory frameworks in the water sector	Number of regulatory frameworks being implemented and enforced; Level of compliance		Short to medium-term	WRA MoWSI		CG WRUA		-	1	1	-	2	WRA
ii	Create awareness amongst communities of the upstream and downstream impacts of climate change throughout the basin	Level of awareness regarding climate change and adaptation measures at basin level	PA07 PA08 PA09	Short-term	WRA KMD		Local councilors CG WRUA		-	0.5	-	-	0.5	WRA
iii	Increase water storage	Implement under Strategic Theme 8.3: Water storage and conveyance												
5.3.5	**Enhance resilience of agricultural sector through climate smart agriculture**													
i	Promote conservation agriculture and improved farm management	Implement under Strategy 1.2.3												

Strategy	Activities	Target/Indicators (M&E)	CMS Strategic Theme	Implementation horizon	Key role players: National	Basin	Local	Other	Budget (USD Million): 2020-2022	2020-2025	2025-2030	2030-2040	Total cost	Funding source
Key Strategic Area 6:	**Flood and Drought Management**													
Strategic Objective:	**Establish and guide a structured programme of actions aimed at ensuring prevention, mitigation, timeous response and recovery from harmful impacts of floods & droughts**													
Strategic Theme 6.1:	**Flood management**											Strategic theme 6.1 total:	**17**	
Theme priority:	**Critical**													
6.1.1	**Undertake flood risk mapping**													
i	Conduct high-level assessments of the flood exposure of each village and town, as well as related transport, access and escape routes and river crossings.	Record of successful assessments.	WA45 WA46	Short-term	WRA	Athi Basin FRF; WRA RO	CG		-	1.5	-	-	1.5	MoWSI WRA
ii	Review proposals in recent studies on resolving stormwater drainage problems and related infrastructure failures in Nairobi and Mombasa.	Record of successful assessments.		Short-term	WRA	Athi Basin FRF; WRA RO	CG		-	0.2	-	-	0.2	MoWSI
iii	Review the recent flood inundation risk mapping of the Lower Athi River.	Record of successful assessments.		Short-term	WRA	Athi Basin FRF; WRA RO	CG		-	0.1	-	-	0.1	MoWSI
Iv	Systematise the above information in a Flood Risk Register for the Athi Basin.	Flood Risk Register	WA47	Medium-term	WRA	Athi Basin FRF	CG		-	-	0.1	-	0.1	MoWSI
6.1.2	**Formalise institutional roles and partnership collaborations**													
i	Government institutions/agencies and other stakeholders with partnership roles in flood management will form the *Athi Basin Flood Response Forum (FRF)* under the auspices of the KMD to integrate all flood-relevant resource mobilisations and related interventions in the Athi Basin.	Establishment of the Athi Basin FRF; Number of stakeholder consultations held		Immediate	KMD; NDMU; NDOC	WRA RO; BWRC; MoH RO; MoTIHUDPW RO	Flood-prone county DRM Committee; WRUA; Village DRMC; CG	International Relief Aid agencies; Kenya Red Cross Society; NGO	0.2	-	-	-	0.2	KMD
ii	Establish a Secretariat for the *Athi Basin FRF* with accommodation in the WRA Regional Office.	Establishment of Secretariat; Records of meetings		Immediate	KMD; NDMU; NDOC	WRA RO	WRUA		0.5	-	-	-	0.5	KMD WRA
iii	Develop appropriate SOPs (standard operating procedures) for the *Athi Basin FRF.*	Agreement on SOPs		Immediate to short-term	WRA; KMD; NDMU; NDOC				0.02	0.03	-	-	0.05	KMD WRA
6.1.3	**Develop flood response protocol**													
i	Develop a flood response protocol through a multi-stakeholder approach with the following components: Formalised institutional roles and partnership collaborations; flood preparedness plans for flood-prone zones; key principle: better to protect more people from the frequent smaller floods, than fewer people from the rarer larger floods; flood early warning systems used to alert communities about larger floods; standard operating procedures (SOPs) that comprise sequential flood response actions.	Agreement on flood response protocol.	WA47	Short-term	KMD; NDMU; NDOC	Athi Basin FRF	WRUA		-	0.1	-	-	0.1	KMD WRA

Key Strategic Area 6:	Flood and Drought Management													
Strategic Objective:	Establish and guide a structured programme of actions aimed at ensuring prevention, mitigation, timeous response and recovery from harmful impacts of floods & droughts													
Strategy	Activities	Target/Indicators (M&E)	CMS Strategic Theme	Implementation horizon	Key role players				Budget (USD Million)					Funding source
					National	Basin	Local	Other	2020-2022	2020-2025	2025-2030	2030-2040	Total cost	
6.1.4	**Develop Integrated Flood Management Plans (IFMPs)**													
i	Develop an IFMP for the Athi River catchment.	IFMP completed.	WA51	Short-term	WRA	Athi Basin FRF	CG		-	0.5	-	-	0.5	WRA
ii	Review and update the IFMP for the Lumi River catchment.	IFMP completed.	WA51	Short-term	WRA	Athi Basin FRF	CG		-	0.1	-	-	0.1	WRA
iii	Develop an IFMP for the Ramisi River catchment.	IFMP completed.	WA51	Short to medium-term	WRA	Athi Basin FRF	CG		-	0.05	0.05	-	0.1	WRA
iv	Develop an IFMP for the Rare River catchment.	IFMP completed.	WA51	Short to medium-term	WRA	Athi Basin FRF	CG		-	0.05	0.05	-	0.1	WRA
v	Develop an IFMP for the Shimba River catchment.	IFMP completed.	WA51	Medium-term	WRA	Athi Basin FRF	CG		-	-	0.1	-	0.1	WRA
vi	Develop an IFMP for the Mwache River catchment.	IFMP completed.	WA51	Medium-term	WRA	Athi Basin FRF	CG		-	-	0.2	-	0.2	WRA
6.1.5	**Implement flood management measures**													
i	The *Athi Basin FRF* will prioritise the Implementation Schedules of each of the above six IFMPs. These non-structural and structural flood management/ counter measures will encompass the following: prevention measures; protection measures; preparedness measures; flood early warning systems; emergency response measures. These measures will be focused on flood-prone river reaches and flood-plains in each of the above flood-prone catchments in the Athi Basin. Wherever feasible, community-based flood early warning and flood preparedness approaches will be followed. Flash-flood-/mudslide-prone zones will receive a special focus.	All items on the Flood Risk Register completed; Implementation reports		Medium to long-term	WRA	Athi Basin FRF; WRA RO; BWRC; MoH RO; MoTIHUDPW RO	Flood-prone county DRM Committees; WRUA; Village DRMC	International Relief Aid agencies; NGO	-	-	1.8	3.6	5.4	WRA
ii	The *Athi Basin FRF* will provide a platform for coordinating the resourcing and supervision of the funding of the above re-prioritised non-structural and structural flood management/ counter measures. In all instances, labour-intensive approaches will be followed.	All items on the Flood Risk Register completed; Number of proposals submitted		Medium to long-term	WRA	Athi Basin FRF; WRA RO; BWRC; MoH RO; MoTIHUDPW RO	Flood-prone county DRM Committees; WRUA; Village DRMC	International Relief Aid agencies; NGO	-	-	1.2	2.4	3.6	WRA
6.1.6	**Capacity development**													
i	*Organisational alignment/ collaboration:* The *Athi Basin Flood Response Forum (FRF)* will expand organisational capacity in the Athi Basin by aligning the flood response roles and responsibilities of the government institutions/agencies, International Relief Aid Agencies, Kenya Red Cross, NGOs and other stakeholders with partnership roles in flood management.	Well-functioning Athi Basin FRF; Partnership & Collaboration working agreement	WA52	Immediate	KMD; NDMU; NDOC	Athi Basin FRF; WRA RO; BWRC; MoH RO; MoTIHUDPW RO			0.1	-	-	-	0.1	KMD

Key Strategic Area 6:	Flood and Drought Management													
Strategic Objective:	**Establish and guide a structured programme of actions aimed at ensuring prevention, mitigation, timeous response and recovery from harmful impacts of floods & droughts**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Theme**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2020-2025**	**2025-2030**	**2030-2040**	**Total cost**	
ii	*Institutional technical skills:* Strategically expand institutional technical skills relevant to flood response activities across three different sets of competencies: (i) competence at translating Flood Early Warning Bulletin information to support prioritisation of resource mobilisations for humanitarian interventions; (ii) competence at logistical planning of required interventions followed by subsequent operationalisation; (iii) competence at communicating technical and logistical information in multi-stakeholder environments.	Increased effectiveness of the Athi Basin FRF participants at translating Flood Early Warning Bulletin information, logistical planning and communicating technical and logistical information.	WA54 WA56	Short-term	KMD; NDMU; NDOC; WRA	Athi Basin FRF; WRA RO; BWRC; MoH RO; MoTIHUDPW RO	Flood-prone county DRM Committees; WRUA; Village DRMC	Media	-	0.3	-	-	0.3	KMD
iii	*Community preparedness*: Community-based flood early warning drills as well as emergency evacuation drills will be prioritised by the Secretariat of the *Athi Basin FRF*, with the support of the NDMU/NDOC.	Communities successfully trained; Number of warning drills held	WA44	Short to long-term	KMD; NDMU; NDOC	Athi Basin FRF	Flood-prone county DRM Committees; WRUA; Village DRMC		-	0.9	0.9	1.8	3.6	KMD
Strategic Theme 6.2:	**Drought management**											Strategic theme 6.2 total:	**44**	
Theme priority:	**Very Important**													
6.2.1	**Formalise institutional roles and partnership collaborations**													
i	Establish a Secretariat for the *Athi Basin DRF* with accommodation in the Offices of one of the drought-prone counties.	Establishment of Secretariat		Immediate	NDMA; NDMU; NDOC				4.5	-	-	-	4.5	NDMA
ii	Develop appropriate SOPs for existing *Athi Basin Drought Response strategies*.	Agreement on SOPs		Short-term	NDMA; NDMU; NDOC; WRA		WRUA		-	4.5	-	-	4.5	NDMA
iii	Update existing stakeholder maps with respect to drought within the Athi basin.	Stakeholder maps generated; Number of key players identified		Short to medium-term	WRA		WRUA		-	0.09	0.09	-	0.18	WRA
6.2.2	**Develop drought response protocol**													
i	Develop a drought response protocol through a multi-stakeholder approach with the following components: Formalised institutional roles and partnership collaborations; drought preparedness plans for drought-prone zones; standard operating procedures (SOPs) that comprise sequential drought response actions; equitable allocation of water despite systematic restrictions of supply.	Agreement on drought response protocol.		Short-term	NDMA; NDMU; NDOC; MoDASAL	Athi Basin Drought Response			-	9	-	-	9	NDMA
6.2.3	**Improve drought preparedness**													
i	The *Athi Basin Drought Response strategy* must address five primary drought response needs, i.e. drought monitoring, drought early warning, drought severity assessment, mitigation interventions and recovery interventions.	Agreement on Athi Basin Drought Response mandate.		Short-term	NDMA; NDMU; NDOC; KMD	Athi Basin Drought Response	WRUA		-	4.5	-	-	4.5	NDMA

Key Strategic Area 6:	Flood and Drought Management													
Strategic Objective:	Establish and guide a structured programme of actions aimed at ensuring prevention, mitigation, timeous response and recovery from harmful impacts of floods & droughts													
Strategy	Activities	Target/Indicators (M&E)	CMS Strategic Theme	Implementation horizon	Key role players				Budget (USD Million)					Funding source
					National	Basin	Local	Other	2020-2022	2020-2025	2025-2030	2030-2040	Total cost	
ii	Drought monitoring, drought early warning and severity assessment will continue to be conducted by the NDMA, who issues regular Drought Early Warning Bulletins for ASAL counties.	Continuity of Drought Early Warning Bulletins		Short-term	NDMA; KMD; MoDASAL	Athi Basin Drought Response			-	4.5	-	-	4.5	NDMA
iii	Drought severity assessments by the national and county-level coordinating structures of the NDMA relevant to the Athi Basin must be reviewed and deliberated by the collaboration partnership participants in the Athi *Basin Drought Response strategy*. In the case of an adverse severity assessment, the Athi *Basin Drought Response* participants will have a common point of reference from which to systematically coordinate their various drought-relevant resource mobilisations and related interventions in the Athi Basin.	Successful collaboration by Athi Basin Drought Response participants in drought severity assessments and resulting mobilisations and interventions.		Short-term	NDMA	Athi Basin Drought Response	Drought-prone county DRM Committees; WRUA; Village DRMC	International Relief Aid agencies; Kenya Red Cross Society; NGO	-	1.8	-	-	1.8	NDMA
6.2.4	**Strengthen existing drought early warning systems**													
i	The NDMA issues regular Drought Early Warning Bulletins for ASAL counties. In the Athi Basin, Bulletins are issued for Kwale and Kilifi counties. Bulletins will in future also be issued for additional Athi counties that are drought-prone, namely Taita Taveta, Makueni and Kajiado.	Number of additional drought-prone Athi counties issuing Drought Early Warning Bulletins		Immediate	NDMA	Athi Basin Drought Response	CG		0.15	-	-	-	0.15	NDMA
ii	SOP responses based on the Bulletins' early warning findings and alerts will be an integrating force in the Athi Basin Drought Response. The sub-county scale of the Bulletins' reporting ensures that such responses can be spatially accurately focused. SOP responses will secure appropriate and timeous resource mobilisations and humanitarian interventions across all the collaborating partnerships at county, sub-county and local community scales across the five drought-prone counties in the Athi Basin.	Successful implementation of SOPs on sub-county and local community scales.		Short-term	NDMA	Athi Basin Drought Response	Drought-prone county DRM Committees; WRA SRO; WRUA; Village DRMC	International Relief Aid agencies; Kenya Red Cross Society; NGO	-	5	-	-	5	NDMA, CG
iii	The monthly reports and maps detailing current and projected food insecurity in a number of regions in the world by the Famine Early Warning Systems Network (FEWS NET) will support the deliberations by the participants in the *Athi Basin Drought Response Strategy*.	Continuity in the use of FEWS NET monthly reports and maps.		Short-term	NDMA; Kenya Food Security Steering Group	Athi Basin Drought Response	WRUA		-	0.45	-	-	0.45	NDMA
6.2.5	**Capacity development**													
i	*Funding:* Secure a standing allocation from the recently-established National Drought Emergency Fund (DEF) to the Athi Basin's ASAL counties to ensure that finance for early drought response will always be available when needed.	Success at attaining an allocation from the National DEF.		Short-term	NDMA	Athi Basin Drought Response; National Treasury		International Relief Aid agencies	-	4.5	-	-	4.5	NDMA

Key Strategic Area 6:		Flood and Drought Management														
Strategic Objective:		**Establish and guide a structured programme of actions aimed at ensuring prevention, mitigation, timeous response and recovery from harmful impacts of floods & droughts**														
Strategy		**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Theme**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**						**Funding source**
						National	**Basin**	**Local**	**Other**	**2020-2022**	**2020-2025**	**2025-2030**	**2030-2040**	**Total cost**		
ii		*Organisational alignment/ collaboration: Athi Basin Drought Response Strategy* will expand organisational capacity in the Athi Basin by aligning the drought response roles and responsibilities of the government institutions/ agencies, International Relief Aid Agencies, Kenya Red Cross, NGOs and other stakeholders with partnership roles in drought management.	Well-functioning Athi Basin Drought Response.		Immediate	NDMA	Athi Basin Drought Response; WRA RO; BWRC; MoALF RO; MoWSI RO; MoH RO	Drought-prone county DRM Committees; WRA SRO; WRUA; Village DRMC	International Relief Aid agencies; Kenya Red Cross Society; NGO	2.25	-	-	-	2.25		NDMA
iii		*Institutional technical skills:* Strategically expand institutional technical skills relevant to drought response activities across three different sets of competencies: (i) Translating Drought Early Warning Bulletin information to support prioritisation of resource mobilisations for humanitarian interventions; (ii) Logistical planning of required interventions followed by subsequent operationalisation; (iii) Communicating technical and logistical information in multi-stakeholder environments.	Increased effectiveness of Athi Basin Drought Response, participants at prioritising resource mobilisations, logistical planning and communicating technical and logistical information.	WA54 WA56	Short-term	NDMA	Athi Basin Drought Response; WRA RO; BWRC; MoALF RO; MoWSI RO; MoH RO	Drought-prone county DRM Committees; WRA SRO; WRUA; Village DRMC	International Relief Aid agencies; Kenya Red Cross Society; NGO	-	2.25	-	-	2.25		NDMA

Key Strategic Area 7:	Hydrometeorological Monitoring													
Strategic Objective:	An operational and well-maintained hydromet network supported by effective and functional data management and information management systems.													
Strategy	Activities	Target/Indicators (M&E)	CMS Strategic Action	Implementation horizon	Key role players				Budget (USD Million)					Funding source
					National	Basin	Local	Other	2020-2022	2022-2025	2025-2030	2030-2040	Total cost	
Strategic Theme 7.1:	Improved monitoring network											Strategic Theme 7.1 total:	27	
Theme priority:	Critical													
7.1.1	Surface water monitoring: River flow													
i	Upgrade existing river flow gauging network based on recommendations in Monitoring Network Design Report (Interim Report 2 Volume 7A)	Number of operational stream flow gauges; Number of data sets recorded	MA04	Short-term	WRA KMD		WRUA		-	2.6	-	-	2.6	WRA
7.1.2	Monitoring: Dams and lakes													
i	Survey bathymetry; install level gauge, upgrade existing dam and lake gauging network (based on recommendations in Monitoring Network Design Report), settlement beacons on the crest, flow measuring gauge (V-notch) at any seepage collection points along the toe of the dam for dams for water level monitoring	Number of operational dam & lake instruments and gauges; Number of bathymetric surveys completed	LA07	Short to medium-term	WRA				-	0.5	0.5	-	1	WRA
7.1.3	Groundwater monitoring													
i	Design groundwater monitoring programme, to include defining Priority Aquifers and incorporating spring monitoring where relevant	Groundwater monitoring programme developed		Short to medium-term	WRA			WSP	-	4	4	-	8	WRA
ii	Acquire necessary tools for groundwater monitoring (rigs, loggers, telemetry etc.)	Plant/accessories acquired		Short to long-term	WRA			WSP	-	1	1	2	4	WRA
iii	Implement groundwater monitoring programme	Number of operational groundwater monitoring stations		Medium to long-term	WRA			WSP	-	-	1	2	3	WRA
7.1.4	Water quality monitoring: Surface water and groundwater													
i	Upgrade existing water quality monitoring network based on recommendations in Monitoring Network Design Report (Interim Report 2 Volume 7A)	Number of operational water quality monitoring stations		Short to medium-term	WRA				-	1	1	-	2	WRA
7.1.5	Meteorological monitoring													
i	Upgrade existing WRA rainfall station network based on recommendations in Monitoring Network Design Report (Interim Report 2 Volume 7A)	Number of operational WRA rainfall stations, Number of complete datasets		Short-term	WRA KMD				-	1	-	-	1	WRA
7.1.6	Flood early warning monitoring network													
i	Implement the lower Sabaki River flood Early Warning System based on recommendations in Monitoring Network Design Report (Interim Report 2 Volume 7A)	Operational FEWS monitoring network		Short-term	WRA KMD				-	1	-	-	1	WRA
7.1.7	Metering of water use and abstractions													
i	Develop implementation programme and implement metering of water use and abstractions (surface and groundwater)	No. operational water use and abstraction meters		Short to long-term	WRA WASREB		WWDA	WSP Private sector	-	1	1	2	4	WRA

Key Strategic Area 7:	Hydrometeorological Monitoring														
Strategic Objective:	An operational and well-maintained hydromet network supported by effective and functional data management and information management systems.														
Strategy	Activities	Target/Indicators (M&E)	CMS Strategic Action	Implementation horizon	Key role players				Budget (USD Million)					Funding source
					National	Basin	Local	Other	2020-2022	2022-2025	2025-2030	2030-2040	Total cost	
Strategic Theme 7.2:	Improved data and information management											Strategic Theme 7.2 total:	2	
Theme priority:	Critical													
7.2.1	Enhanced data management													
i	Use MIKE Info database developed under ISC for capturing, storing and managing all hydromet data. Data protocols and procedures with regard to data collection, transfer, capture, storage, quality control and dissemination should be evaluated, standardised and improved where necessary in accordance with international best practice. Technical and computing capacity for processing, analysis and reporting of data should be addressed and enhanced.	Readily available, up-to-date and quality controlled hydromet data	MA09	Immediate to short-term	WRA				0.5	0.5	-	-	1	WRA
7.2.2	Improved water resources information management systems													
i	Use Knowledge base tools developed under ISC for dissemination of information products related to water resources management.	Knowledge products disseminated	MA12	Immediate to short-term	WRA				0.25	0.25	-	-	0.5	WRA
7.2.3	Improved forecasting systems													
i	Use real-time system developed under ISC for accessing, visualizing and analysing hydromet observations in near real-time to inform decision making with regard to flood forecasting and water resources management. Refer to Interim Report 1 Volume 7: Real-time System Report.	Operational forecasting system	MA11	Immediate to short-term	WRA				0.25	0.25	-	-	0.5	WRA

Key Strategic Area 8:	Water Resources Development and Management													
Strategic Objective:	To develop water resources as a key driver for sustainable economic and social development													
Strategy	Activities	Target/Indicators (M&E)	CMS Strategic Action	Implementation horizon	Key role players				Budget (USD Million)					Funding source
					National	Basin	Local	Other	2020-2022	2022-2025	2025-2030	2030-2040	Total cost	
Strategic Theme 8.1:	Water Resource assessment, allocation and regulation											Strategic theme 8.1 total:	16	
Theme priority:	Critical													
8.1.1	**Surface water resources assessment – surface water availability at relevant scales**													
i	Refine existing water resources models to improve estimates of surface water availability at relevant spatial scales for planning, management and allocation	Surface water resources availability and quantity mapped	WA02	Short-term	WRA				-	0.5	-	-	0.5	WRA
8.1.2	**Groundwater resources assessment – groundwater availability**													
i	Implement under Strategy 3.1.1: Groundwater assessment – assess groundwater availability in terms of quantity													
8.1.3	**Assess water use and fitness for use**													
i	Undertake surface water abstraction survey	Number of abstraction surveys completed	WA05	Short to medium-term	WRA			WRUA	-	5	5	-	10	WRA
ii	Undertake groundwater abstraction survey	Implement under Strategy 3.1.2: Groundwater assessment – assess groundwater quality and use												
8.1.4	**Update and improve permit database**													
i	Reconcile PDB with surface water and groundwater abstraction survey results	Updated PDB	WA14	Short to medium-term	WRA				-	1.25	1.25	-	2.5	WRA
8.1.5	**Water allocation**													
i	Set Resource Quality Objectives (RQOs) for surface water and groundwater in the Athi Basin	Implement under Strategy 2.3.1: Set Resource Quality Objectives												
ii	Conduct surface water balance at relevant spatial scale; Determine allocation status	Water balances; Allocation status report	WA07	Short-term	WRA				-	0.5	-	-	0.5	WRA
iii	Conduct groundwater balance at relevant spatial scale; Determine allocation status	Implement under Strategy 3.1.4: Groundwater allocation												
iv	Develop surface water allocation plans at sub-basin level	Water Allocation Plans		Short-term	WRA				-	2.5	-	-	2.5	WRA
v	Develop groundwater allocation plans at sub-basin level	Implement under Strategy 3.1.4: Groundwater allocation												
Strategic Theme 8.2:	Water resources planning											Strategic theme 8.2 total:	6	
Theme priority:	Critical													
8.2.1	**Updated planning for bulk water resources development**													
i	Update Nairobi Master Planning: Optimise large-scale, integrated bulk water supply system supplying Nairobi: Sources, Transfers, Dams, Treatment Works, Bulk distribution network, Conjunctive use - Assess full supply area of proposed Munyu Dam and investigate establishment of new WWTW for Nairobi due to potential inundation of Dandora stabilisation ponds (See Strategy 4.3.1).	Up to date integrated master plan indicating detailed timelines, phasing and budgets	WA74	Short-term	WRA MoWSI NWHSA	WWDA	CG	WSC WSP	-	1	-	-	1	WSC MoWSI

Strategy	Activities	Target/Indicators (M&E)	CMS Strategic Action	Implementation horizon	Key role players				Budget (USD Million)					Funding source
Key Strategic Area 8:	**Water Resources Development and Management**													
Strategic Objective:	**To develop water resources as a key driver for sustainable economic and social development**													
					National	Basin	Local	Other	2020-2022	2022-2025	2025-2030	2030-2040	Total cost	
ii	Update Mombasa and Coastal Area Master Planning: Optimise large-scale, integrated bulk water supply system supplying Mombasa, Kwale, Malindi, Kalifi: Sources, Transfers, Dams, Treatment Works, Bulk distribution network, Desalination, Conjunctive use.	Up to date integrated master plan indicating detailed timelines, phasing and budgets	WA74	Short-term	WRA MoWSI NWHSA	WWDA	CG	WSC WSP	-	1	-	-	1	WSC MoWSI
iii	Prefeasibility/Feasibility of regional water supply schemes to meet major towns, rural domestic and/or small-scale irrigation demands: Sources, Transfers, Dams, Treatment, Bulk distribution network, Conjunctive use	Up to date master plan for rural water supply in Athi Basin indicating detailed timelines, phasing and budgets	WA74	Short-term	WRA MoWSI NWHSA	WWDA	CG		-	4	-	-	4	WWDA MoWSI
Strategic Theme 8.3:	**Water storage and conveyance**											Strategic theme 8.3 total:	**4399**	
Theme priority:	**Very important**													
8.3.1	**Implement large dams: complete relevant feasibility and impact studies and plans; design and construct**													
I	Munyu Dam (575 MCM)	Dam construction completed and successful commissioning	WA74	Immediate to short-term	NWHSA MoWSI	WWDA	CG		82	622	-	-	704	MoWSI
ii	Pemba Dam (19 MCM)			Immediate to short-term	NWHSA MoWSI	WWDA	CG		10	68	-	-	78	MoWSI
iii	Lake Chala Dam (6 MCM)			Immediate to short-term	NWHSA MoWSI	WWDA	CG		6	42	-	-	48	MoWSI
iv	Galana Dam (498 MCM)			Medium to long-term	NWHSA MoWSI	WWDA	CG		-	-	312	240	552	MoWSI
v	Kiteta Dam (16 MCM)			Short to medium-term	NWHSA MoWSI	WWDA	CG		-	38	29	-	67	MoWSI
vi	Mbuuni Dam (10 MCM)			Medium-term	NWHSA MoWSI	WWDA	CG		-	-	55	-	55	MoWSI
vii	Miwongoni Dam (2 MCM)			Short-term	NWHSA MoWSI	WWDA	CG		-	28	-	-	28	MoWSI
viii	Kamiti1 Dam (16 MCM)			Long-term	NWHSA MoWSI	WWDA	CG		-	-	-	69	69	MoWSI
ix	Ruiru2 Dam (8 MCM)			Long-term	NWHSA MoWSI	WWDA	CG		-	-	-	53	53	MoWSI
x	Rare Dam (36 MCM)			Long-term	NWHSA MoWSI	WWDA	CG		-	-	-	127	127	MoWSI
xi	Thwake Dam (681 MCM)			Immediate to short-term	NWHSA MoWSI	WWDA	CG		390	195	-	-	585	MoWSI
xii	Stony Athi Dam (23 MCM)			Long-term	NWHSA MoWSI	WWDA	CG		-	-	-	87	87	MoWSI
8.3.2	**Maintenance of existing dams**													
i	Dredging of existing dams	Number of dams dredged		Long-term	NWHSA MoWSI	WWDA	CG		-	4	2	2	8	MoWSI

Strategy	Activities	Target/Indicators (M&E)	CMS Strategic Action	Implementation horizon	Key role players				Budget (USD Million)					Funding source
					National	Basin	Local	Other	2020-2022	2022-2025	2025-2030	2030-2040	Total cost	
Key Strategic Area 8:	**Water Resources Development and Management**													
Strategic Objective:	**To develop water resources as a key driver for sustainable economic and social development**													
8.3.4	**Infrastructure development - small dams and pans**													
i	Develop programme for implementation of small dams & pans. Undertake relevant studies. Identify locations and types of dams to improve assurance of supply to local urban, domestic, small scale irrigation and livestock water users	Dam construction programme and investment plan – town and rural supply; Relevant feasibility studies and reports	WA74	Immediate to short-term	NWHSA MoWSI	WWDA	CG WRUA		1	1	-	-	2	MoWSI
ii	Phased design and construction of identified small dams / pans: 115 MCM total storage	Number new dams constructed in accordance with international best practice	WA74	Immediate to long-term	NWHSA MoWSI	WWDA	CG WURA		36	81	81	81	279	MoWSI
8.3.4	**Provide other types of storage**													
i	Sand dams	Number of sand dams	WA74	Short to medium-term	NWHSA MoWSI	WWDA	CG		-	14	14	-	28	MoWSI
ii	Artificial recharge	Successful implementation and operation of AR schemes	WA74	Short to medium-term	NWHSA MoWSI	WWDA	CG		-	4.5	4.5	-	9	MoWSI
8.3.4	**Inter-basin transfers**													
i	Tana transfer: S Mathiyou link (48 MCM/a) / Maragua4 Dam (60 MCM)	Transfer volume (supply volume)	WA74	Short to medium-term	MoWSI	WWDA	CG		-	25	355	-	380	MoWSI
ii	Tana transfer: Northern Collector Tunnel Phase II (44 MCM/a)			Medium to long-term	MoWSI	WWDA	CG		-	-	19	274	293	MoWSI
8.3.4	**Intra-basin transfers**													
i	Nol-turesh pipeline refurbish	Transfer volume (supply volume)	WA74	Medium-term	MoWSI	WWDA	CG		-	-	35	-	35	MoWSI
ii	Mzima Springs transfer pipeline upgrade (38 MCM/a)			Short-term	MoWSI	WWDA	CG		-	640	-	-	640	MoWSI
iii	Baricho Wellfield and transfer upgrade (44 MCM/a)			Short to medium-term	MoWSI	WWDA	CG		-	154	118	-	272	MoWSI
Strategic Theme 8.4:	**Groundwater development**													
Theme priority:	**Important**													
8.4.1	**Develop groundwater resources**													
i	Implement under Strategic Theme 3.2: Groundwater development													
Strategic Theme 8.5:	**Hydropower development**											Strategic theme 8.5 total:	**21**	
Theme priority:	**Important**													
8.5.1	**Large-scale hydropower development**													
i	Install hydropower at Thwake Dam (20 MW)	Large scale hydropower generation and integration with grid	WA74	Short-term	KENGEN MoEn				-	4	-	-	4	KENGEN, MoEn
ii	Install hydropower at Mwache Dam (34 MW)			Short-term	KENGEN MoEn				-	6	-	-	6	KENGEN, MoEn
iii	Install hydropower at Munyu Dam (40 MW)			Short-term	KENGEN MoEn				-	8	-	-	8	KENGEN, MoEn

Key Strategic Area 8:	Water Resources Development and Management													
Strategic Objective:	**To develop water resources as a key driver for sustainable economic and social development**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
8.5.1	**Small-scale hydropower development**													
i	Investigate possibility of retrofitting existing dams with hydroelectric power generation capabilities.	Number of retrofitted dams	WA74	Immediate to short-term	KENGEN MoE				0.5	0.5	-	-	1	KENGEN, MoEn
ii	Assess potential for the development of small-scale hydropower plants, especially in the upper Athi Basin.	Small-scale hydropower generation and supply		Immediate to medium-term	KENGEN MoE				0.5	0.5	0.5	-	1.5	KENGEN, MoEn
Strategic Theme 8.6:	**Water for agriculture**											Strategic theme 8.6 total:	**932**	
Theme priority:	**Critical**													
8.6.1	**Large scale irrigation development: Develop new / expand existing irrigation schemes. Limit to max sustainable areas**													
i	Kibwezi (15 000 ha)	Irrigation area		Short to medium-term	WRA MoWSI MoALF NIB	WWDA	CG		-	44	296	-	340	MoWSI
ii	Mwache (2 000 ha)	Irrigation area		Immediate	WRA MoWSI MoALF NIB	WWDA	CG		24	-	-	-	24	MoWSI
iii	Taita Taveta (2300 ha)	Irrigation area		Medium to long-term	WRA MoWSI MoALF NIB	WWDA	CG		-	-	30	23	53	MoWSI
iv	Kanzalu (9 000 ha)	Irrigation area		Short to medium-term	WRA MoWSI MoALF NIB	WWDA	CG		-	27	157	-	184	MoWSI
v	Mt Kilimanjaro (700 ha)	Irrigation area		Long-term	WRA MoWSI MoALF NIB	WWDA	CG		-	-	-	16	16	MoWSI
vi	Galana Kulalu (13 600 ha)	Irrigation area		Medium to long-term	WRA MoWSI MoALF NIB	WWDA	CG		-	-	107	201	308	MoWSI
8.6.2	**Promote water conservation in irrigation**													
i	Increase water use efficiency through the rehabilitation or improvement of irrigation technologies and techniques, and through the use of smart metering	Water efficiency in irrigation		Short to long-term	WRA MoWSI MoALF NIB	WWDA	CG		-	1	1	1	3	MoWSI
8.6.3	**Compile infrastructure development program for small scale irrigation. Develop new / expand existing irrigation schemes**													
i	Develop new small-scale irrigation schemes	Number of new small-scale irrigation schemes		Short to long-term	WRA MoALF NIB MoWSI	BWRC	CG WRUA		-	0.3	0.3	0.4	1	MoALF

Key Strategic Area 8:	Water Resources Development and Management													
Strategic Objective:	**To develop water resources as a key driver for sustainable economic and social development**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
ii	Provide farmers with appropriate technologies to abstract water from rivers and shallow boreholes: Treadle pumps, small motorised pumps, construct small weirs	Number of small-scale farmers using technology. Food security.		Short-term	WRA MoALF NIB MoWSI		CG WRUA		-	0.8	-	-	0.8	MoALF
iii	Refurbish existing small-scale irrigation schemes	Number of refurbished small-scale irrigation schemes		Short to long-term	WRA MoALF NIB MoWSI		CG WRUA		-	0.4	0.4	0.8	1.6	MoALF
8.6.4	**Aquaculture development**													
i	Promote aquaculture opportunities in basin - linked to new dams and improved flow regulation	Increased awareness of aquaculture		Short to medium-term	MoALF KMFRI	WWDA	CG		-	0.2	0.2	-	0.4	MoALF
ii	Develop aquaculture manual	Aqua culture manual		Medium-term	MoALF KMFRI	WWDA	CG		-	-	0.05	-	0.05	MoALF
iii	Rehabilitate aquaculture ponds and construct new ponds	Aquaculture development		Medium to long-term	MoALF KMFRI	WWDA	CG		-	-	0.1	0.1	0.2	MoALF
8.6.5	**Improved water supply reliability at local scale through construction of small dams / pans and/or development of local groundwater resources to provide carry-over storage during the dry season**													
i	Implement Under Strategies 8.3.2 and Strategy 3.2.2													
Strategic Theme 8.7:	**Water based tourism and recreation**											Strategic theme 8.7 total:	**0.2**	
Theme priority:	**Important**													
8.7.1	**Promote water-based tourism and recreation**													
i	Promote adventure tourism, leisure activities, recreational activities and resorts linked to large dams, especially at dams situated close to major cities.	Increase in water-based tourism		Short to long-term	KTF MoTW		CG	Tour operators	-	0.05	0.05	0.07	0.17	Private
Strategic Theme 8.8:	**Non-conventional water resources**											Strategic theme 8.8 total:	**11**	
Theme priority:	**Very important**													
8.8.1	**Seawater desalination**													
i	Evaluate seawater desalination as an alternative and/or integrated supply option to Mombasa as part of updated masterplan study (see Strategy 8.2.1)	Decision on desalination as a source of supply		Short-term	WRA MoWSI				-	0.15	-	-	0.15	WRA
ii	Implement desalination plant for water supply to Mombasa	Desalination plant implemented and commissioned		Not costed at this stage										
8.8.1	**Rainwater harvesting**													
i	Rainwater harvesting should be promoted - especially in rural areas.	Increased awareness of rainwater harvesting		Short-term	WRA MoWSI NWHSA		WRUA	NGO	-	0.1	-	-	0.1	WRA
ii	Supply and install tanks for rainwater harvesting.	Number of rainwater tanks installed		Short to medium-term	WRA MoWSI NWHSA	WWDA	WRUA	NGO	-	4	4	-	8	WRA

Strategy	Activities	Target/Indicators (M&E)	CMS Strategic Action	Implementation horizon	Key role players				Budget (USD Million)					Funding source
					National	Basin	Local	Other	2020-2022	2022-2025	2025-2030	2030-2040	Total cost	
Key Strategic Area 8:	**Water Resources Development and Management**													
Strategic Objective:	**To develop water resources as a key driver for sustainable economic and social development**													
8.8.2 Reuse														
i	Evaluate re-use as an alternative and/or integrated supply option to Mombasa as part of updated masterplan study. (See 8.2.1)	Decision on re-use as a source of supply		Short-term	WRA MoWSI WASREB				-	0.15	-	-	0.15	WRA
ii	Implement re-use plant for water supply to Mombasa	Re-use plant implemented and commissioned		Not costed at this stage										
8.8.2 Water Conservation and Demand Management														
i	Evaluate WCDM as an integrated option to reduce water demand in urban centres	WCDM Measures; improved water efficiency and supply		Short-term	WRA, MoWSI WASREB		CG	WSP	-	0.15	-	-	0.15	WRA
ii	Implement WCDM measures	Adoption of water saving techniques		Short to medium-term	WRA MoWSI WASREB		CG	WSP	-	1	1	-	2	CG
Strategic Theme 8.9:	**Water resources systems operation**											Strategic theme 8.9 total:	3	
Theme priority:	**Important**													
8.9.1 Optimise system operating rules														
i	Evaluate and improve operation of existing and future integrated bulk water supply systems to Nairobi maximise yield. Develop curtailment rules.	Optimised system operating rules - multipurpose dams, user priority classification, curtailment rules		Medium-term	WRA MoWSI	WWDA	WRUA		-	-	0.85	-	0.85	MoWSI
ii	Evaluate and improve operation of existing and future integrated bulk water supply systems to Mombasa to maximise yield. Develop curtailment rules.			Medium-term	WRA MoWSI	WWDA	WRUA		-	-	0.85	-	0.85	MoWSI
iii	Develop and implement operating rules for proposed multipurpose dams e.g. Thwake, Munyu etc.			Short-term	WRA MoWSI	WWDA	WRUA		-	0.2	-	-	0.2	MoWSI
iv	Evaluate and improve operation of existing stand-alone dams supplying individual towns and/or small-scale irrigation. Develop curtailment rules. Consider conjunctive use.	Optimised system operating rules - multipurpose dams, user priority classification, conjunctive use, curtailment rules; Number of operating rules registered with NEMA		Short to medium-term	WRA NEMA WASREB	WWDA	WRUA		-	0.1	0.1	-	0.2	MoWSI
8.9.2 Conduct Annual Operating Analyses (AOA) to decide need for and severity of restrictions for the coming year based on current storage levels and anticipated demands														
i	Configure planning models and undertake annual operating analysis	AOA Reports		Short to long-term	WRA MoWSI WASREB	WWDA	WRUA		-	0.15	0.1	0.15	0.4	MoWSI
8.9.3 Maintenance of piped network														
i	Monitor and evaluate NRW	NRW reports / Reconciliation strategies per water service area		Short to medium-term	WRA WASREB	WWDA	WSP		-	0.1	0.08		0.18	WASREB WSP
Ii	Reduce NRW through maintenance of piped network, leak detection, replacing of old pipes, minimisation of spillages, pressure management, introduction of district metering areas, configuration of	Improved (reduced) NRW as depicted in reports		Medium to long-term	WRA WASREB	WWDA	WSP		-	-	0.07	0.15	0.22	WASREB WSP

Key Strategic Area 8:	Water Resources Development and Management													
Strategic Objective:	**To develop water resources as a key driver for sustainable economic and social development**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
	reticulation network models and eliminating illegal connections.													

Key Strategic Area 9:		Institutional Strengthening													
Strategic Objective:		To achieve an appropriate balance between operational functionality and the need for effective oversight and governance.													
Strategy		Activities	Target/Indicators (M&E)	CMS Strategic Action	Implementation horizon	Key role players				Budget (USD Million)					Funding source
						National	Basin	Local	Other	2020-2022	2022-2025	2025-2030	2030-2040	Total cost	
Strategic Theme 9.1:		Promote improved and sustainable catchment management										Strategic Theme 9.1 total:		8	
Theme priority:		Critical													
9.1.1	**Strengthen WRAs regulatory role**														
i		Separate out regulatory and management functions of the Authority and provide different reporting lines for these. Parallel improvement and strengthening of the regulatory approaches utilised by the WRA.	Regulatory and Management functions separated out.		Immediate	WRA, MoWSI				0.7	-	-	-	0.7	WRA GoK Donors
ii		Updating WRA's standards, policies and regulations in line with the WA2016	Guidelines, regulations		Immediate	WRA, MoWSI				0.5	-	-	-	0.5	WRA GoK Donors
iii		Undertake training and capacity building for the new legislative instruments	Training manuals, guidelines, regulations, workshops		Immediate to short-term	WRA	BWRC			0.4	0.4	-	-	0.8	WRA GoK Donors
iv		Hold stakeholder consultations for developing legislative instruments and implementation tools	Stakeholder engagement strategy; Stakeholder meetings held		Short-term	WRA, MoWSI			Private sector	-	0.15	-	-	0.15	WRA GoK Donors
v		Develop tools and systems to support implementation of the new legislative instruments	Guidelines, regulations, systems		Medium-term	WRA, MoWSI	BWRC			-	-	0.79	-	0.79	WRA GoK Donors
vi		Improve awareness creation of new legislative instruments and implementation tools	Brochures, media dissemination packages, information dissemination platforms	PA33	Medium-term	WRA, MoWSI	BWRC	CG		-	-	0.45	-	0.45	WRA GoK Donors
9.1.2	**Strengthen BWRCs**														
i		Translate lessons learnt from CAACs into improved operational modalities.	Improved channels of operation.		Immediate	WRA	CAAC			0.25	-	-	-	0.25	WRA GoK Donors
ii		Provision of secretariat services through ROs and SROs.	Secretariat services through ROs and SROs		Immediate to long-term	WRA				0.2	0.1	0.1	0.1	0.5	WRA GoK Donors
iii		Appropriate channels formed for recommendations from BWRCs to be taken on board by WRA.	Improved channels of communication.		Immediate	WRA	BWRC			0.07	-	-	-	0.07	WRA GoK Donors
iv		On-going training and capacity building.	Continued education on WRM		Short to long-term	WRA, MoWSI			Development partners	-	0.07	0.07	0.14	0.28	WRA GoK Donors
9.1.3	**Strengthen county governments engagements in WRM in the Basin**														
i		Clarify roles and responsibilities for county governments.	Clear roles and responsibilities for county governments		Immediate	MoWSI, WRA		CG		0.16	-	-	-	0.16	WRA GoK Donors
ii		Introduce more structured strategic planning and operational engagement.	Improved planning and operations		Immediate	MoWSI, WRA		CG		0.35	-	-	-	0.35	WRA GoK Donors
iii		Develop a basin or sub-basin level platform for engagement with county government.	Improved engagement	PA42	Immediate to medium-term	WRA	BWRC	CG, WRUA		0.4	0.3	0.3	-	1	WRA GoK Donors

Strategy	Activities	Target/Indicators (M&E)	CMS Strategic Action	Implementation horizon	Key role players				Budget (USD Million)					Funding source
					National	Basin	Local	Other	2020-2022	2022-2025	2025-2030	2030-2040	Total cost	
Key Strategic Area 9:	**Institutional Strengthening**													
Strategic Objective:	**To achieve an appropriate balance between operational functionality and the need for effective oversight and governance.**													
9.1.4	**Strengthen WRUAs**													
i	Strengthen linkages between county governments and WRUAs.	WRUAs linked with county governments	PA42	Immediate to long-term	WRA		CG, WRUA		0.3	0.3	0.3	0.6	1.5	WRA GoK Donors
ii	Ongoing training and capacity building.	Improved capacity	PA43 PA45	Short to long-term	WRA				-	0.1	0.1	0.2	0.4	WRA GoK Donors
Strategic Theme 2.2:	**Guidelines, codes of practice and manuals**											Strategic Theme 9.2 total:	**5**	
Theme priority:	**Very important**													
9.2.1	**Develop policies**													
i	Develop a Policy on Transboundary Waters incorporating relevant elements of Treaty obligations	Transboundary Waters Policy signed by all relevant governments		Immediate to short-term	EAC Govts of South Sudan, Ethiopia and Somalia, Ministry of Foreign Affairs, MoWSI, WRA				0.3	0.3	-	-	0.6	WRA GoK Donors
ii	Complete the development of a National Policy for the Protection of Groundwater with all key stakeholders involved.	National Policy for the Protection of Groundwater		Immediate to short-term	WRA, MoWSI				0.1	0.15	-	-	0.25	WRA GoK Donors
iii	Revise the National Water Quality Management Policy	Implement under Strategy 4.2.1: Harmonise policies and strategies towards improved water quality management												
iv	Review cross-sector policies, legislation and regulations relating to wastewater; streamline/clarify the roles of the Line Ministries, WRA, NEMA, the Counties and WSPs in relation to wastewater, to eliminate the dual mandates that the WRA and NEMA currently operate under in relation to 'polluter pays' and these agencies' revenue	Reviewed policies, legislation and regulation relating to wastewater		Immediate	WRA, MoWSI, NEMA, KFS		CG	WSP	0.5	-	-	-	0.5	WRA GoK Donors
9.2.2	**Develop guidelines to support specific water resources management activities**													
i	Develop / Update Guidelines on: - the allocation of GW from fossil aquifer or aquifers that experience episodic recharge - GW vulnerability assessments - preventing/containing saltwater intrusion - defining and protecting groundwater-dependent ecosystems (GDEs) - definition and selection of Priority Aquifers, including guidance on the development of monitoring networks, the selection of appropriate instrumentation and the installation of monitoring networks - dam safety - water allocation and water quality	Guidelines and thresholds for groundwater and surface water		Immediate	MoWSI, WRA, NEMA				0.7	-	-	-	0.7	WRA GoK Donors

Key Strategic Area 9:		Institutional Strengthening														
Strategic Objective:		**To achieve an appropriate balance between operational functionality and the need for effective oversight and governance.**														
Strategy		**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
						National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
9.2.3 Develop Codes of Practice															
i	Relevant Codes of Practice for Water Resources Planning and Management		Codes of Practice completed		Immediate	MoWSI, WRA				0.35	-	-	-	0.35	WRA GoK Donors
ii	Enforce new and existing Codes of Practice in relation to WRPM		Codes of Practice compliance		Short to long-term	MoWSI, WRA		CG		-	0.5	0.5	1	2	WRA GoK Donors
9.2.4 Develop manuals															
i	Develop / Update National Manuals relevant to WRPM		National Manuals updated/ completed		Immediate to medium-term	MoWSI, WRA		CG	WSP, private sector (industry, agriculture, mining)	0.25	0.25	0.25	-	0.75	WRA GoK Donors

Key Strategic Area 10:	Enabling environment to support effective water resources planning and management													
Strategic Objective:	**To enhance human and institutional capacities for sustainable management of the water, land, ecosystems and related resources**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
Strategic Theme 10.1:	**Development of institutional capacities to support improved water resource management and development**											Strategic Theme 10.1 total:	**25**	
Theme priority:	**Very Important**													
10.1.1 Strengthen policies and regulatory instruments														
Implement under Strategy 9.1.1: Strengthen WRAs regulatory role														
10.1.2 Enhancement of technical and management capacity														
i	Development and enhancement of technical and management capacity through focused training, continuous professional development, bursary schemes, audits, incentive schemes	Improved capacity of personnel and institutions		Short to long-term	WRA				-	0.78	0.78	1.56	3.12	WRA
10.1.3 Strengthen partnerships														
i	Develop a partnerships framework	Partnerships framework developed		Immediate	WRA, MoWSI			Private sector	0.35	-	-	-	0.35	WRA
ii	Identify potential partners	Inventory of potential partners		Immediate	WRA, MoWSI		CG	Private sector, Development partners	0.5	-	-	-	0.5	WRA
iii	Undertake stakeholder consultations	Stakeholder engagement strategy		Immediate to short-term	WRA, MoWSI			Development partners	0.12	0.13	-	-	0.25	WRA, private sector
iv	Undertake awareness creation and information dissemination activities	Brochures, information dissemination packages		Immediate to short-term	WRA		CG	Development partners	0.12	0.13	-	-	0.25	WRA
v	Develop and strengthen guidelines for MOU drafting and development	Partnerships framework, improved guidelines for MOU development		Short-term	WRA				-	1.5	-	-	1.5	WRA
vi	Strengthen existing partnerships, particularly on a local level	Existing partnerships strengthened		Immediate	WRA		WRUA	CG, NGO, Development partners	0.35	-	-	-	0.35	WRA
10.1.4 Strengthen stakeholder engagement														
i	Develop a basin-wide stakeholder engagement framework	Stakeholder engagement strategy developed		Immediate	WRA				0.09	-	-	-	0.09	WRA
ii	Undertake stakeholder analysis	Identified stakeholders		Immediate	WRA	BWRC	CG, WRUA		0.15	-	-	-	0.15	WRA
iii	Implement the stakeholder engagement framework	Stakeholder engagement, workshops, forums, expos held; Level of participation		Short to long-term	WRA	BWRC	CG, WRUA	NGO	-	0.2	0.2	0.4	0.8	WRA
iv	Strengthen stakeholder engagement platforms i.e. forums	Improved guidelines for forums; Improved stakeholder participation		Immediate to short-term	WRA	BWRC	WRUA		0.45	0.45	-	-	0.9	WRA
v	Undertake awareness creation and information dissemination activities	Brochures, media dissemination packages		Short-term	WRA	BWRC	CG	Media	-	0.45	-	-	0.45	WRA

Key Strategic Area 10:	Enabling environment to support effective water resources planning and management													
Strategic Objective:	**To enhance human and institutional capacities for sustainable management of the water, land, ecosystems and related resources**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
10.1.5	**Improved research**													
i	Strengthen links with tertiary education / research institutions	Number of tertiary institutions linked		Immediate to medium-term	WRA, Research institutions				1.2	1.2	1.2	-	3.6	WRA
ii	Incorporate R&D into WRM planning and decision making	R&D plan incorporated		Immediate to short-term	WRA, Research institutions				0.15	0.1	-	-	0.25	WRA
iii	Invest in R&D to strengthen WRM	Financing for R&D		Short to long-term	WRA, Research institutions		CG	Private sector	-	2	2	4	8	WRA, Research institutions
iv	Establish a network of supporting research institutions	Network of research institutions		Immediate to medium-term	WRA, Research institutions				0.1	0.1	0.1	-	0.3	WRA, Research institutions
v	Manage data and knowledge generation and collation	Data generated, information generated, knowledge generated		Short-term	WRA, Research institutions				-	1.05	-	-	1.05	WRA, Research institutions
vi	Disseminate data, information and knowledge	Brochures, media dissemination packages, information dissemination platforms		Short-term	WRA, Research institutions			Media	-	0.45	-	-	0.45	WRA, Research institutions
vii	Develop strategic partnerships for R&D	Strategic partnerships for R&D; MoUs signed by institutions		Immediate to medium-term	WRA, Research institutions				0.1	0.1	0.1	-	0.3	WRA, research institutions
10.1.6	**Innovative financing**													
i	Promote innovative financing for basin level institutions (BWRCs, WRUAs, forums)	Secured financing		Immediate	WRA, WSTF	BWRC	WRUA, Forums	Development partners	0.25	-	-	-	0.25	WRA
ii	Develop internal resource mobilization strategies	Income generated		Immediate	WRA, MoWSI, WSTF	BWRC			0.5	-	-	-	0.5	WRA
iii	Develop external resource mobilization strategies	Income generated; Grants secured	PA58 PA59	Immediate	WRA, MoWSI, WSTF	BWRC		Development partners	0.45	-	-	-	0.45	WRA
iv	Exploring private sector financing channels	Private sector financing secured	PA62 PA63 PA64	Immediate to short-term	WRA	BWRC		Private sector	0.15	0.15	-	-	0.3	WRA, private sector
v	Strategic partnerships for resource mobilization	Financing secured, strategic partnerships framework		Immediate to short-term	WRA, MoWSI			Development partners, Private sector	0.23	0.23	-	-	0.46	WRA, sector institutions

F1: Development costs

Major projects

Estimated project costs for specific, proposed major projects were extracted from relevant planning and design study reports where available, and from prices reported on relevant agency and government department websites, escalated to 2020 prices. Key information sources and institutions which were consulted include NWMP 2030, JICA, 2013; IDA Funding Agency Project Appraisal Reports; Kenya Vision 2030 Flagship Projects *(**http://www.vision2030.go.ke/publication/vision-2030-flagship-projects-progress-report-nov-2014/**)**;*** Blue Economy Bankable Projects *(Kenya conference on sustainable blue economy. Nairobi, Nov 2018, Ondimu et al.);* Kenya National Investment Profile *(Water for agriculture and Energy. 2015. FAO, AgWA);* Kenya National Water Harvesting and Storage Authority *(**http://www.waterauthority.go.ke/**);* Kenya National Irrigation Board; Regional Development Authorities; Water Works Development Agencies

Dams

For major dams, the approach described above for Major projects was followed. The unit cost for major dams amounts to approximately USD 1 Million per MCM of storage provided.

For minor dams (typically between 1 MCM and 30 MCM storage), where no specific cost information was readily available, a cost curve was developed based on cost estimates done as part of the NWMP (JICA, 2013), extrapolated to 2020 prices as shown below.

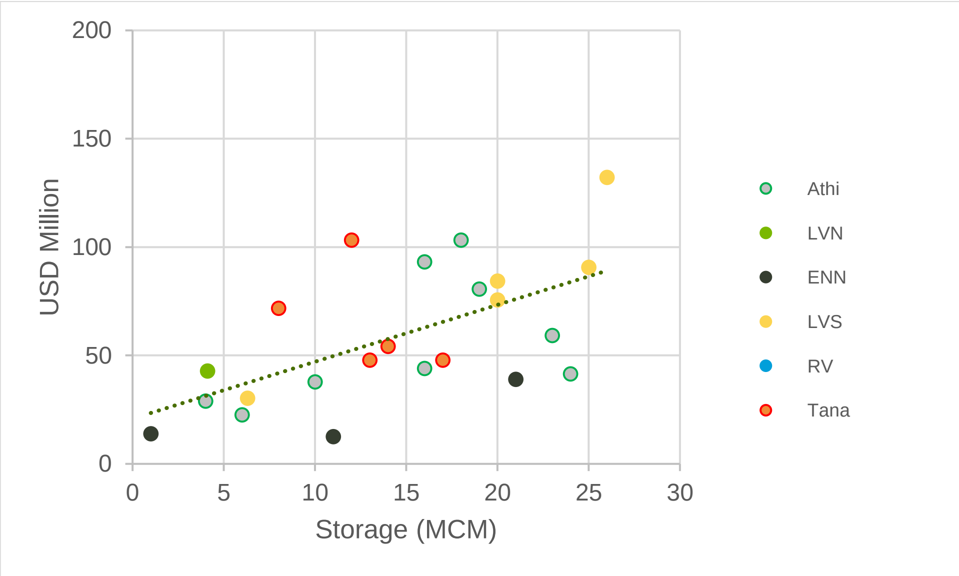

Figure F-1: Cost curve for dams smaller than 30 MCM

For small dams and pans, cost estimates obtained from Water Works Development Agencies project budgets were analysed and used to derive the following unit costs:

- 20 000 m^3 pan: USD 100 000
- 50 000 m^3 pan: USD 150 000
- 50 000 m^3 small dam: USD 175 000
- 100 000 m^3 small dam: USD 300 000

Irrigation

For large irrigation projects, the approach described above for Major projects was followed.

For schemes where no specific cost information was readily available, the following unit costs (complete) for large-scale and small-scale irrigation were derived:

- Large-scale irrigation: USD 19 700 /ha
- Small-scale irrigation: USD 9 500 /ha

The unit costs were based on information provided in the following sources: NWMP 2030 (JICA, 2013); FAO Investment Centre Technical Paper 5, Irrigation: Africa South of Sahara. Rome 1986; Kenya National Irrigation Board; IWMI Research Report 109. Costs and performance of irrigation projects: A comparison of Sub-Saharan Africa and other developing regions. (Inocencio et al, 2007)

Hydropower

For many of the planned major hydropower projects, the cost of the hydropower installation was included with the development cost of the dam.

Otherwise, a unit installation cost of USD 200 000 per MW installed was used based on international rates *(https://www.hydro.org/)*

Boreholes

For large groundwater development projects, the approach described above for Major projects was followed.

For individual boreholes, a cost of USD 20 000 per borehole was used based on typical costs in Kenya. This includes drilling and equipping of borehole with independent power supply. An average yield of 4.4 m3/h per borehole was assumed *(https://constructionreviewonline.com/2018/03/water-borehole-services-kenya/)*

Bulk Water Transfers

For bulk water transfer projects, the approach described above for Major projects was followed. Where no specific information was available, tunnels were costed at a unit cost of USD 50 million/km.

Hydromet network

Costs associated with the procurement, installation and commissioning of monitoring stations and hydromet equipment were based on information and typical unit costs provided by WRA offices and/or suppliers.

Cost Benefit Analysis (2020)

- Electricity price: 0.15 USD million/GWh. *(https://www.globalpetrolprices.com/Kenya/electricity_prices/)*
- Water supply price - urban: 2.9 USD/m3; Water supply price - rural: 1.65 USD/m3. (Gulyani, S et al. Water for the urban poor: Water markets, Household demand and Service preferences in Kenya. Water supply and sanitation sector board discussion paper series. Paper No. 5. Jan 2005)
- Irrigation: Unit crop yields and producer prices *(http://www.fao.org/countryprofiles/index/en/?iso3=KEN); Kenya Horticulture Validated Report 2015 – 2016. AFA – Horticultural Crops Directorate* (Avg. County values)
- Operation and Maintenance: Dams and hydropower - 2.5% of capital cost per annum; Irrigation- 0.5% of capital cost per annum.
- Discount rate: 10%

F2: Management costs

A stepwise approach for estimating costs associated with the implementation of management actions was followed:

i. Decide on the appropriate implementing agency at national, basin, county or local scale, based on defined mandates in relation to specific KSA activities. Implementing agencies include national government, sub-regional offices, county governments and WRUAs.
ii. The type of implementing agency defines the number of offices/units per Basin in the budget estimation calculation. In the case of a site- specific activity, such as the development of IFMPs, the number of sites was used to estimate the budget.
iii. Allocate budget over four time frames based on personal experience, professional consultation fees, management cost estimates as per NWMP 2030 and reference to local information. Timeframes are 2020-2022 (2 years), 2022-2025 (3 years), 2025-2030 (5 years) and 2030-2040 (10 years).
iv. Timeframes indicate which activities should be completed immediately (2022) or in the short (2025), medium (2030) or long-term (2040), as well as the duration of this implementation.

F3: General

- Upfront costs - Planning/Feasibility, Environmental Assessment, Design: 15% of capital cost
- Infrastructure replacement costs were not considered
- Annual inflation rate: 5%
- Exchange rate: 1 USD = 100 KES
- Desalination and water re-use plants were not costed as part of this Plan. Rather, the Plan recommended that the construction of such plants as alternatives to conventional surface water and groundwater resources development projects, be investigated in more detail for possible implementation in the next planning horizon.