Ministry of Water, Sanitation and Irrigation

Tana 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

Water Resources Authority

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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 (WRA) 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 Resources Management Strategy. The 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 Resources 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. 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 Tana Basin. Integrated Water Resources 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 Tana Basin is to provide a clear pathway for the sustainable utilisation and development of the water resources of the Tana 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 Tana Basin was developed, which reads as follows:

To be the Leading Basin in Sustainable Water Conservation, Protection, Regulation, Management and Use for Socio-Economic Development and Ecosystem Services for All by 2040

E2. Biophysical environment

The Tana Basin has an area of 126 208 km2. The basin borders Somalia and the Indian Ocean coastline in the east, the Athi Basin to the south, the Ewaso Ng'iro North Basin to the north, and the Rift Valley Basin to the west. The basin accounts for 22% of Kenya's total area, however the population density is relatively low, and the basin houses only 15% of the total population. Major towns in the basin include Garissa, Thika, Lamu, Nyeri, Embu, Meru, Murang'a and Kitui. The upper parts of the basin receive high rainfall and include some of the most productive agricultural lands in the country. Parts of the central and north-eastern basin are arid and semi-arid.

The topography of the Tana Basin varies from the peak of Mount Kenya at 5 200 masl and the Aberdares in the west at 3 900 masl to the coastal area at sea level. Most of the middle and lower parts of the basin is flat, while the upper basin is mountainous with steep slopes along the southern slopes of Mount Kenya and the eastern slopes of the Aberdares Range and Nyambene Hills. Most of the basin consists of plains, with mountains and hillslopes in the upper part of the basin. There are also significant badlands along the Tana River above Garissa town. The Tana Basin is made up of mainly quaternary sediments and basement geology.

The Tana River is the main river in the basin and drains approximately 76% of the Tana Basin. It originates on the slopes of Mount Kenya and flows eastward until it reaches Garissa town, after which it flows southwards and pours into the Indian Ocean at the Tana Delta. Upstream tributaries include the Chania, Thiba, Maragua and Thika rivers. Eastwards-draining, seasonal tributaries join the main stem of the Tana River downstream of Garissa and include Nihunguthu, Maua, Komoli, Galole and Kokani rivers. Smaller rivers in the north-eastern part of the basin drain to Somalia and the Indian Ocean. The Tana River discharges into the Indian Ocean at the Tana Delta. Large losses occur along the lower parts of the Tana river system and in the central and eastern parts of the basin. These water losses are attributed to the arid climate conditions, high evaporation rates, topography and well-drained sandy soils in the region.

The Tana River hosts Kenya's largest and richest wetlands. As the River enters the Indian Ocean, before the coral reef drop off, the Tana River passes through a large floodplain of wetlands, riverine forests, woodlands, bushlands, fresh and brackish lakes, estuaries, mangroves and grasslands commonly referred to as the Tana Delta. The upper part of the Tana Basin also hosts wetlands along tributaries above the Seven Forks dams. These wetlands are under threat from expansion of agriculture. There are also other estuaries and mangroves associated with the coastal region of Tana Basin.

The Tana Basin is known for its hot and dry climate, which is brought about by the topography of the basin, and the movements of two air masses over the Inter-Tropical Convergence Zone (ITCZ). The upper part of the basin is classified as humid land, the coastal area as humid and semi-arid land and parts of the central area as arid and semi-arid. The mean annual precipitation across the basin varies from less than 450 mm in some areas in the north-east to as high as 1 900 mm along the watershed in the high-lying areas in the west and 1 000 mm along the coast. The mean annual precipitation across the basin is 673 mm. Average annual maximum day temperatures vary from 19°C to 35°C across the basin, while the average annual minimum night temperatures vary from 4°C to 23°C. Two periods of rainfall occur during the year, namely the long rains between March and May, and the short rains from October to November.

The climate change analysis which was undertaken as part of this Consultancy shows a general increase (between 0% and 10%) in mean annual rainfall across the Tana Basin by 2050, while maximum day temperatures are expected to increase by up to 1.3°C by 2050. There is likely going to be increased climate variability between years and a consistent increase going forward will be unusual. This may result in years that have a drought like character adjacent to flood seasons and an increase in the intensity of extreme events and will demand an adaptive resilience approach.

The main areas susceptible to flooding in the Tana Basin include the middle to upper zones of Tana River, Kirinyaga and Kitui counties as well as the lower slopes of Mount Kenya where flash floods and mudslides occur; Garissa and Tana River counties characterised by long-duration flooding when the Tana River overflows its banks at Garissa Town, the middle Tana River reaches, and the Tana River Delta; and local flooding in Garissa Town due to inadequate urban drainage infrastructure. Occasional riparian and floodplain damage also occur along other tributaries of the Tana River. In general, there is an inadequate capacity at local and regional level to manage flood-related disasters. Droughts are prevalent in the arid and semi-arid areas of the Tana Basin. The most affected counties are Kitui, Tana River, Lamu, Garissa, and parts of Tharaka-Nithi counties. Challenges during drought periods include the enforcement of water use control and restrictions, maintenance of the Reserve flows and the high demand for irrigation and livestock water supply.

The vegetation cover in the Tana Basin is mainly savanna vegetation. The coastal areas are covered with mosaics of forests as well as tropical rainforest, swamp forest and mangrove areas. The upper Tana has a region of high rainfall that is characterised by good vegetation cover, although this is also a region of agricultural land use and therefore vegetation cover has seasonal fluctuations. The lower and middle Tana is characterised by a semi-arid climate and reduced vegetation cover. This is a region of pastoralism with limited agriculture. There is improved vegetation cover in the protected forests in the coastal strip. Human encroachment is threatening the forest reserves in the basin and there has been a significant loss of vegetation cover.

Biodiversity in Tana Basin is linked to water resources and forest reserves or protected areas. The main biodiversity area is the Tana River Delta, which is known to include many endemic plants, primates, amphibians and reptiles. The Delta provides a habitat for 320 plant taxa and hosts seven plants on the IUCN Red list. It is a critical feeding and wintering ground for several migratory water birds, while the estuaries, mangroves and shorelines provide a habitat for a wide range of fish species. There are 19 National Parks/Reserves in the Tana Basin and the basin has three gazetted Water Towers and 18 non-gazetted Water Towers.

Land use in the Tana Basin includes forest, grassland/rangeland and agricultural use. The basin has a high population density and scattered urban and built-up areas in the upper sections of the basin with the dominant land use as rain-fed agriculture and rangeland.

E3. Socio-economic environment

Water plays a key role in the socio-economic environment in the Tana 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 total population of the Tana Basin in 2019 was estimated as 6.96 million, which is equivalent to a population density of 55 persons/km^2. Most of the population in the Tana Basin reside in rural settlements, with only 22% of the population currently being located in urban areas.

The population of the Tana Basin is expected to increase significantly due to high projected growth rates, and an influx of people to urban areas.

Small-scale irrigation and pastoralism make up a large portion of the employment in the Tana Basin. The formal sector is made up of both public and private enterprises which have been legally established or are listed with the registrar of companies. Most formal employment is in the urban centres. The sources of livelihood vary across the basin, from formal employment in the urban areas to subsistence agriculture and crop/livestock production in the pastoral and farming areas. Conflicts are likely to occur due to limited resources and increased migration paths. There is limited economic activity in the Tana Basin and the average poverty rate in the Basin is at 40%.

The Tana Basin spans across fourteen counties. Populations in some of the semi-arid counties are occasionally facing food crises due to chronic drought. Tana River County is the most food-insecure area within the Tana Basin, with between 15 to 20% of households having poor or borderline food consumption.

About 25% of the total population in the basin is supplied directly from springs and boreholes. Almost half of the urban population receives piped water from a Water Service Provider (WSP), while 29% of the rural population receives piped water from a WSP. Most of the urban and rural populations make use of septic tanks and pit latrines for sanitation. There are currently no sewerage systems in place in the rural areas, and only 7% of the urban population has access to formal sewerage systems.

It is anticipated that flooding risks would increase in the basin due to urbanisation and the effects of climate change and that the increase in temperatures due to climate change would provide an environment conducive for malaria vectors to thrive. Murang'a, Kirinyaga, Isiolo, Tana River, Kitui and Machakos counties are the high-risk counties for malaria.

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 Tana 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 Tana 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 TANA Basin were classified

Biophysical issues	**Climate:** Inadequate flood preparedness; Inadequate drought preparedness; Climate change **Environment:** Poor land use and catchment 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; 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

The total Tana River natural runoff equals 7 082 MCM/a. More than 80% of the runoff in the Tana River originates upstream of the proposed High Grand Falls dam site. About 40% of the runoff in the Tana River originates upstream of Masinga Dam. The central part of the basin does not contribute any significant flow. There are significant losses along the lower Tana River and in the catchments joining the Tana River downstream of Garissa. The rivers in the Tana Basin show a distinct seasonality in monthly flows with two peak flow seasons, the highest in April/May and a second, slightly lower peak in November/December. River flows are lowest in August and September. Most tributaries are characterised by very low flows during the dry season.

The annual groundwater recharge for the Tana Basin was estimated at 4 479 MCM/a, with a sustainable annual groundwater yield of 693 MCM/a. This is very similar to the Kenya National Water Master Plan 2030 sustainable groundwater yield estimate of 675 MCM/a for the Tana Basin. Good groundwater potential is found in the north-western part of the Tana basin, as well as the eastern part adjoining the coast.

Projected sub-basin precipitation and temperature changes under climate change scenario RCP 4.5 were superimposed on the hydrological model of the Tana Basin to assess the potential impacts on runoff. Natural runoff in the basin is expected to increase in most sub-basins by between 2% and 6%, with some sub-basins slightly lower or higher. The total surface water runoff from the Tana Basin is projected to increase with 4% to 7 365 MCM/a under RCP 4.5. It was found that the groundwater recharge in the basin will increase by 7% to 4 792 MCM/a, while the potential groundwater yield is expected to increase by 8% to 745 MCM/a under RCP 4.5.

The total current estimated water demand (2018) in the Tana Basin equates to 1 867 MCM/a as shown below. Most of the water is needed for irrigation and domestic / industrial use.

Table E-2: Current water requirements in the Tana Basin per main sector (MCM/a)

Sector	Total (MCM/a)
Irrigation	**1 407**
– Small scale / Private	880
– Large-scale	527
Domestic and Industrial	**217**
Urban centres	39
Basin-wide	178
Livestock	**48**
Exports (to Nairobi)	**181**
Other	**14**
Total	**1 867**

The 2018 water balance in the Tana Basin in terms of natural surface water runoff and sustainable groundwater yield, the ecological reserve and current (2018) water demands in the Tana Basin is summarised below. The current water demand constitutes about 24% of the total water resources available for use.

Table E-3: Tana (2018) Basin water balance (MCM/a)

	Surface water	Groundwater	Total
Natural / Available water	7 082	693	7 775
Ecological reserve	(355)	-	(355)
	Total		**7 420**
		Water demand (2018)	(1 867)
		Balance	**5 553**

The scenario evaluations which were undertaken as part of this Study concluded that the expected growth in irrigation and urban centre water demands by 2040 will result in a significant reduction in supply reliability. A key priority for the development of water resources in the Basin should therefore concern improved water supply to the main urban centres and for irrigators. The scenario analysis highlighted the imperative that water demand management be implemented in all urban areas, while irrigation efficiencies should also be improved. Such a future constitutes the recommended sustainable development future for the basin. Under this scenario, the total future (2040) water requirement in the basin is projected as 4 370 MCM/a as detailed in Table E4. The majority of the demand will be for irrigation. This represents a significant increase compared to the 2018 water demand in the basin. The additional water which will be required to meet future demands in the Tana Basin is less than the estimated remaining surface water and groundwater resources potential which is still available for development in the basin. However, to optimise the use of available water in basin will require the development of infrastructure for storage and regulation.

Table E4: Projected future (2040) water demands in the Tana Basin per main sector

Sector	Total water demand (MCM/a)
Irrigation – Small scale / Private – Large-scale	**3 161** 765 2 396
Domestic and Industrial – Urban centres – Basin-wide	**753** 234 519
Livestock	**98**
Exports	**337**
Other	**21**
Total	**4 370**

Water quality in the Tana 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. The quality of water resources has deteriorated due to increased anthropogenic activities, with both point- and non-point sources of pollution being prevalent in the area. Unsustainable farming practices and poor management of croplands is evident in many parts of the basin. Major water pollution threats include municipal waste in the upper basin, industrial waste, sedimentation and agrochemicals. Water quality issues also stem from inadequate monitoring and compliance control, the use of fertilisers, poor waste disposal management and sedimentation of water bodies.

The Tana Basin currently has 69 recorded stream flow monitoring stations. Of these, only 59 are known to be currently operational. Most of the stations are manually operated as rated sections. However, many stations are inaccessible during floods and rating curves are not updated regularly. There are currently no lake monitoring stations in the Tana Basin. There are currently 64 surface water quality and 10 effluent stations in the Tana Basin. However, 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 analysis on a handful of parameters as listed below. There are currently 27 groundwater quality monitoring stations in the Tana Basin. There is also a total of 41 groundwater level monitoring points across the Basin; however, only 18 of these were operational in 2018 (seven Strategic, six Major, five Minor and none in Special aquifers). One borehole is a dedicated monitoring site. The vast majority of aquifers are not monitored, and of the monitored wells, most of them are manually dipped. Maintenance of monitoring wells is a serious concern.

E6. Current water resources development and water allocations

Existing large-scale water resources developments in the Tana Basin include seven large dams. Two of these dams (Sasamua and Thika) are located in the upper tributaries of the Tana River and supply about 181 MCM/a of water to Nairobi via an inter-basin transfer. The other five dams are located along the main Tana River in the upper basin and constitute the so-called Seven Forks Hydro Scheme, which involves a cascading system to produce hydropower. The dams include Masinga, Kamburu, Gitaru, Kindaruma and Kiambere. The installed hydropower capacity at these five dams total 595 MW. To provide adequate flow during the dry periods, water is stored at the upstream Masinga Dam and released during the dry season. In addition to these hydropower installations, there are five smaller run-of-river installations in the upper part of the basin with a total installed capacity of about 31 MW. In addition to the inter-basin transfers, water is also transferred inside the basin from Kiambere Dam to Mwingi Town (0.5 MCM/a capacity) and from Masinga Dam to the town of Kitui (3 MCM/a capacity).

The total current (2018) irrigated area in the Tana Basin, which include large-scale and small-scale as well as private irrigation, is estimated as 98 930 ha. Eight large-scale irrigation schemes exist in the basin with a total area of about 26 000 ha. These schemes include Mwea, Kibirigwi, Muringa and Mitunguu in the upper basin, as well as Bura, Hola, Tana River and Tana Delta schemes along the lower Tana River.

Construction on various large dams in the Tana Basin is about to start, is currently underway, or has started but are currently on hold due to contractual and/or other issues. These dams include Yatta Dam on the Thika River for domestic and irrigation supply, Thiba Dam on the Nyamindi River – mainly to be used for supplying Mwea Irrigation Scheme Extension, Karimenu II Dam on the Karimenu River from where water will be transferred to Kiambu and Nairobi counties, and Umaa Dam on the Nzeu River – to be used for domestic water supply. In addition, the Government of Kenya has approved the construction of the High Grand Falls Dam at Kivuka along the Tana River. The dam, which forms part of the LAPSSET project, will be located on the borders Tharaka-Nithi, Kitui and Tana River counties.

Most of the water currently consumed in the Tana Basin is for irrigation, followed by domestic and industrial use. Water is mainly sourced directly from rivers and small dams and pans - except for the Thika and Sasamua dams in the upper basin from where water is transferred to Nairobi. Supply reliability in most parts of the basin is medium to high due to the generally good availability of surface and groundwater. However, frequent shortages are experienced during the dry season due to lack of storage, often exacerbated by the late start of the wet season. Non-consumptive use in the basin relates to the generation of hydropower, with close to 40% of Kenya's energy needs being supplied from the hydropower installations along the Tana River.

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

E7. Evaluation of scenarios

Scenario evaluation was undertaken to assess different development and management scenarios and to identify a sustainable development pathway for the Tana 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 Tana 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 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.

- **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

- **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 Tana 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:
  - The implementation of Ndiara, Chania B and Thika 3 A dams in the upper Tana Basin, as further augmentation of transfer to the Athi basin, does not have to take place before 2040
  - Mutuni and Kitimui dams not included as options for water supply to Kitui
  - Future areas of irrigation schemes reduced:
    - Mwea: New total area 10 100 ha
    - Kaagari-Gaturi: New area 3 300 ha
    - Mitunguu: Area 1 600 ha (no expansion)
  - 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.

In order to provide a scientific-based, transparent and consistent approach towards the evaluation of water resources development and management alternatives (scenarios) in the Tana 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 Tana Basin. The main outcomes of the scenario evaluation with relevance to water resources development in the basin are summarised below:

- The supply deficits for current urban and rural domestic as well as irrigation water requirements in the Tana Basin typically vary between 20% and 40%, mainly due to shortfalls during the dry season and/or during droughts.
- Within the Tana Basin, projections for growth in urban and rural domestic, livestock and irrigation water requirements by 2040, will necessitate significant interventions for the development of water resources to ensure water availability at an acceptable assurance of supply. This will demand a combination of new storage dams, intra-basin transfers, water demand management measures, conjunctive use depending on groundwater availability and quality, as well as consideration of measures for rainwater harvesting.

- Even taking into consideration the existing and planned inter-basin transfers from the upper Tana Basin to the Athi Basin, which is a priority, there is still significant water resources available for development in the Tana Basin.
- The planned 700 MW hydropower installation at High Grand Falls Dam, the construction of Karura (67 MW) and the installation of an additional 32 MW at Kindaruma Dam, will increase the hydropower generated in the Tana Basin by more than 100%
- Existing and planned hydropower installations along the upper and middle Tana River, including the proposed High Grand Falls Dam, should be operated and optimised in order to maximise energy output towards meeting the future energy requirements of Kenya. This will demand integrated, basin wide operating rules taking into consideration inter-basin transfers in the upper Tana Basin, hydropower optimisation, flood control and irrigation requirements along the lower Tana River as well as water requirements in urban centres supplied from the existing and planned large dams.
- The proposed High Grand Falls Dam will be able to support extensive irrigation along the lower Tana River at a high assurance of supply, will generate hydropower, will provide flood control, and will supply various towns along the lower Tana River including Lamu Port (via a transfer), where significant growth in water demand is expected linked to the LAPSSET development.
- The addition of Kora Dam, downstream of High Grand Falls Dam, will facilitate the re-regulation of releases (mainly hydropower) from High Grand Falls Dam. This will allow the expansion of irrigation and improve irrigation efficiencies without having a negative impact on the operation of High Grand Falls in terms of hydropower and flood control as priority functions.
- The Northern Collector Tunnel Phase 1 scheme will increase the average transfer volume to the Athi Basin by about 50 MCM/a. The completion of the Maragua 4 Dam and related infrastructure as well as the Northern Collector Tunnel Phase 2 Transfer, representing Phases 3 and 4 of the bulk water upgrade as recommended in the Master Plan for Nairobi and Satellite Towns (Ministry of Water and Irrigation & Athi Water Services Board, 2012), will increase the transfer volume to the Athi Basin by another 92 MCM/a on average. The implementation of Ndiara, Chania B and Thika 3 A dams in the upper Tana Basin, as further augmentation of transfer to the Athi basin, does not have to take place before 2040.
- The new Umaa Dam in conjunction with an extension of the current transfer capacity from Masinga Dam, should be able to meet the expected growth in the urban water requirements of Kitui Town up to 2040. The construction of Kitimui and Mutuni dams, as water sources for supplying Kitui Town, could therefore be delayed.
- Almost 80% of the planned large-scale irrigation development in the upper Tana Basin is feasible. This will, however, require the construction of large and small dams to ensure a high reliability of supply e.g. Thiba and Thuchi dams.
- The maximum area of large-scale irrigation along the lower Tana River, which will be supported by High Grand Falls and Kora dams at a high assurance of supply, is in the order of 106 000 ha.
- In order to reduce the loss in storage in existing and proposed large dams in the basin due to sedimentation, catchment management measures and programmes should be implemented in the upstream catchments where erosion risk has been identified as high.
- 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.
- 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.
- It is recommended 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. Environmental flood releases which will ensure the health of the Tana River Delta, should be incorporated in the operating rules of Kora and High Grand Falls dams.

E8. Proposed development pathway

The essence of the proposed water resources development plan for the Tana Basin, up to 2040, is to unlock the significant irrigation potential in the basin, especially along the lower Tana River; to ensure a reliable supply of water to meet the expected growth in urban water demands, including the significant growth which is foreseen in Lamu Port associated with LAPSSET; to increase hydropower production in the basin; to implement the identified schemes which will export water to the Athi Basin; to improve existing and future water resources availability for smaller towns and basin-wide domestic, livestock and small-scale irrigation water demands; and to unlock socio-economic development through multi-purpose water resources development projects in the basin, including flood control. This will necessitate the construction of small-scale and large-scale storage, transfer and regulation infrastructure and increased groundwater abstraction. In addition, water demand management should be implemented for both small and large-scale irrigation and for urban centres.

E9. Water resources development investment plan

To meet the above objectives, will require the following interventions:

- Construction of High Grand Falls Multipurpose Dam. The dam, which forms part of the LAPSSET Project, will support extensive irrigation along the lower Tana River at a high assurance of supply, generate hydropower, provide flood control, and supply various towns along the lower Tana River including Lamu Port (via a transfer) where significant growth in water demand is expected linked to the LAPSSET development. In conjunction with the construction of High Grand Falls Dam, rehabilitation and expansion of existing as well as the implementation of new large-scale irrigation schemes along the lower Tana River should be initiated.
- Kora Dam, downstream of High Grand Falls Dam, to re-regulate hydropower releases from High Grand Falls Dam. This dam will allow further expansion of large-scale irrigation along the lower Tana River as part of future phases.
- Completion of the Northern Collector Tunnel Phase 1 and implementation of the Maragua 4 Dam and the Northern Collector Tunnel Phase 2 Transfer Schemes to increase the transfer capacity to the Athi Basin for meeting future water demands in the Greater Nairobi area.
- Construction of Thiba and Thuchi dams in the upper basin to improve the reliability of supply to existing irrigation schemes and to allow expansion of the Mwea and Kaagari-Gaturi irrigation projects and rehabilitation of the Usueni-Wikithuki Irrigation project along the upper Tana River.
- Completion of Umaa Dam on the Nzeu River to supply Kitui Town and completion of Karimenu 2 Dam on the Karimenu River to supply Kiambu and Nairobo counties.
- Increasing the capacities of the current intra-basin transfers from Masinga and Kiambere dams to Kitui and Mwingi towns.
- Finalise implementation of Yatta Dam on the Thika River to improve water supply to Matuu Town and assurance of supply for the users along the Yatta Canal.
- 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.
- Implementation and enforcement of the Q95 flow downstream of proposed dams and large-scale irrigation schemes to maintain the ecological health of the rivers. In addition, it is important that seasonal flood releases are made from High Grand Falls Dam to mimic the natural floods along the lower Tana River up to the Delta.
- Installation of 700 MW hydropower at High Grand Falls Dam, installation of an additional 32 MW at Kindaruma Dam and the implementation of Karura Scheme (67 MW) between Kindaruma and Kiambere dams on the main Tana River.

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

Table E5. Tana Basin Water Resources Development Investment Plan

Proposed Infrastructure Development - Water Resources, Hydropower & Large-Scale Irrigation									Expenditure (USD Million)																				
Scheme	Storage / Transfer Volume	1:10 yield (MCM/a)	Purpose: Water Supply	Hydropower	Flood Control	LS Irrigation	Feasibility ESIA / Design	Capital	Phasing (Year) 2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Multi-purpose Dam Projects							**315**	**2100**																					
High Grand Falls Project (incl. HP)	5700 MCM, 700 MW	4000	●	●	●	●	315	2100	158	158	525	525	525	525															
Inter-basin Transfers							**88**	**585**																					
Maragua 4 / S Mathiyoua diversio	105 MCM/a	-	●				49	329	Cost included in Athi Basin Plan																				
NCT Phase II		-	●				38	256	Cost included in Athi Basin Plan																				
Intra-basin Transfers							**90**	**601**																					
Masinga Dam to Kitui	23 MCM/a	-	●				5	34												5	17	17							
Kiambere Dam to Mwingi	2 MCM/a	-	●				3	17				3	9	9															
Nanigi Barrage to Lamu	102 MCM/a	-	●				83	550								83	275	275											
Hydropower							**34**	**225**																					
Kindaruma upgrade	+32 MW	-		●			1	6					1	6															
Karura	67 MW	-		●			33	219									33	110	110										
Dams - water supply (urban & irrigation)							**24**	**161**																					
Umaa	1 MCM	0.2	●				2	14	9	7																			
Karimenu 2	14 MCM	4.5	●				9	59	39	29																			
Yatta	35 MCM	15	●				13	88	57	44																			
Dams - large scale irrigation							**94**	**629**																					
Kora	537 MCM	see HGF				●	74	492																		37	37	246	246
Thiba	11 MCM	4.2				●	9	59	38	30																			
Thuci	23 MCM	10	●			●	12	78								12	78												
Small dams / pans & Boreholes							**79**	**527**																					
Dams and pans	159 MCM	-	●				55	367	28	28	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
Groundwater (Boreholes)	333 MCM/a	-	●				24	160	20	20	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Large Scale Irrigation Schemes (cost excl. associated dams)							**292**	**1945**																					
Kaagari Gaturi	3 300 ha	-				●	10	65									10	33	33										
Usueni Wikithuki	5 800 ha	-				●	17	114							17	57	57												
Rahole	8 000 ha	-				●	24	158							24	79	79												
Bura	Expand by 400 ha	-				●	1	6							1	3	3												
Hola	Expand by 5 000 ha	-				●	12	79							12	39	39												
Tana Delta	Expand by 28 000 ha	-				●	66	440								66	110	110	110	110									
Masalani	30 000 ha	-				●	89	591														89	197	197	197				
Kora	25 000 ha	-				●	74	493																		74	164	164	164
O&M Cost									3	6	19	33	47	61	62	67	84	98	105	108	109	110	116	121	127	128	132	143	154
Total Annual Cost (USD Million)									**351**	**320**	**571**	**588**	**609**	**628**	**142**	**433**	**795**	**652**	**383**	**250**	**153**	**243**	**340**	**345**	**351**	**265**	**361**	**581**	**591**

E10. Basin Plan for the Tana Basin

In order to comprehensively and systematically address the range of water resources related issues and challenges in the Tana Basin and to unlock the value of water as it relates to socio-economic development, ten key strategic areas were formulated for the Tana 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	8.7	42.7	38.2	28.4	**118**
	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					
KSA 2	Water resources protection	0.3	0.8	1.8	1.9	**5**
	Classification of water resources					
	Reserve determination					
	Determine Resource Quality Objectives					
	Conserve and protect ecological infrastructure					
KSA 3	Groundwater management and development	31.1	67.6	58.1	57.2	**214**
	Groundwater resource assessment, allocation and regulation					
	Groundwater development					
	Groundwater asset management					
	Conservation and protection of groundwater					
KSA 4	Water quality management	4.1	31.6	91.5	121.9	**249**
	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					
KSA 5	Climate change adaptation and preparedness	4.9	13.0	12.4	8.6	**39**
	Understand impacts of climate change on water resources at appropriate spatial scales					
	Climate change mitigation					
	Climate change adaptation					

Key Strategic Areas and Themes		Budget (USD Million)				
		2020-2022	2022-2025	2025-2030	2030-2040	Total
KSA 6	Flood and drought management	8.2	40.4	2.1	3.6	**54**
	Flood management					
	Drought management					
KSA 7	Hydromet monitoring	1.0	13.1	8.5	6.0	**29**
	Improved monitoring network					
	Improved information management					
KSA 8	Water resources development	396	2 479	2 144	1 979	**6 997**
	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					
KSA 9	Strengthen Institutional frameworks	4.9	2.6	2.9	2.0	**12**
	Promote improved and sustainable catchment management					
	Guidelines, codes of practice and manuals					
KSA 10	Strengthen enabling environment to support institutions	5.3	9.0	4.4	6.0	**25**
	Develop institutional capacities to support improved IWRM&D					
Total		**463**	**2 699**	**2 363**	**2 215**	**7 743**

E11. Roadmap for the Basin Plan

In order to ensure the successful implementation of the strategies and actions presented in the Tana 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.

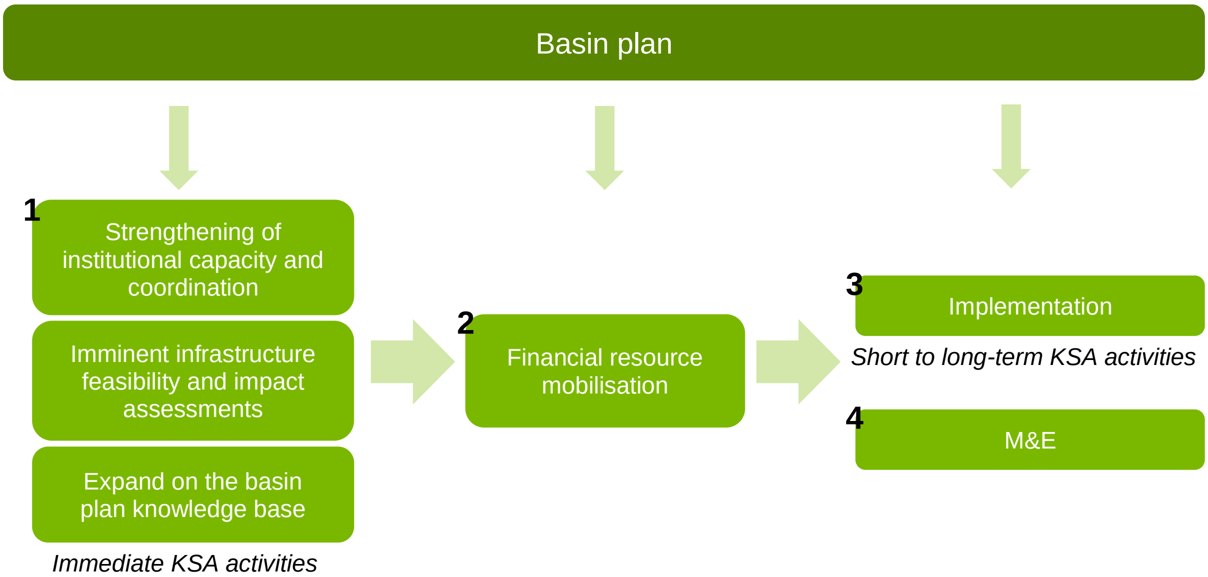

Figure E1: Roadmap for implementation of the Basin Plan

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Abbreviations and Acronyms

AGR	Artificial groundwater recharge
AMP	Aquifer Management Plan
ASAL	Arid or Semi-Arid Land
ASDS	Agricultural Sector Development Strategy
ASM	Artisanal and small-scale mining
ATAR	Adaptation Technical Analysis Report
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
CBA	Cost-benefit analysis
CDA	Coast Development Authority
CFA	Community Forest Association
CGs	County Governments
CIDP	County Integrated Development Plan
CITES	Convention on International Trade in Endangered Species of Wild Fauna & Flora
CMS	Catchment Management Strategy
CMUs	Catchment Management Units
COD	Chemical Oxygen Demand
CORDEX	Coordinated Regional Climate Downscaling Experiment
CRA	Commission on Revenue Allocation
CRBC	China Roads and Bridge Corporation
DCF	Drought Contingency Fund
DEC	District Environmental Committee
DEF	Drought Emergency Fund
DEM	Digital Elevation Model
DFID	Department for International Development (United Kingdom)
DHI	Danish Hydraulics Institute
DNAPL	Dense non-aqueous phase liquid
DO	Dissolved Oxygen
DSS	Decision Support System
DWF	Dry weather flow
EDC	Endocrine disrupting chemical
EDE-CPF	Ending Drought Emergencies Common Programme Framework
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EMCA	Environmental Management and Coordination Act
ENR	Environment and Natural Resource
ENSO	El Niño–Southern Oscillation
EPC	Export Promotion Council

EPV	Export Production Village
EPZ	Export Processing Zone
ERS	Economic Recovery Strategy
FAO	Food and Agriculture Organization (agency of the United Nations)
FEWS	Flood Early Warning System
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
GDE	Groundwater dependent ecosystem
GDP	Gross Domestic Product
GIS	Geographical Information System
GMP	Groundwater Management Plan
GoK	Government of Kenya
GW	Groundwater
GWMATE	Groundwater Management Advisory Team (2002-2011), supported by the World Bank group
HQ	Head-quarters
ICZM	Integrated Coastal Zone Management
IDA	International Development Association
IPCC	Intergovernmental Panel on Climate Change
ISGEAG	Improving Sustainable Groundwater Exploration with Amended Geophysics
IUCN	International Union for Conservation of Nature
IWRM	Integrated Water Resources 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
KNBS	Kenya National Bureau of Statistics
KNCPC	Kenya National Cleaner Production Centre
KSA	Key Strategic Area
KWSCRP	Kenya Water Security and Climate Resilience Project
KWT	Kenya Wildlife Trust
KWS	Kenya Wildlife Service
KWTA	Kenya Water Towers Agency
LAPSSET	Lamu Port-South Sudan-Ethiopia Transport
LIMS	Laboratory Information Management System
LPG	Liquefied Petroleum Gas
LSRWSS	Large Scale Rural Water Supply Scheme
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
masl	Metres above sea level
MAR	Mean Annual Runoff

MCM	Million Cubic Metre
MEMR	Ministry of Environment and Mineral Resources
M&E	Monitoring and Evaluation
MoWI	Ministry of Water and Irrigation
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
MWSI	Ministry of Water, Sanitation and Irrigation
NAP	National Adaptation Plan
NAS	Nairobi Aquifer Suite
NAWARD	National Water Resources Database
NCCAP	National Climate Change Adaptation Plan
NCCRS	National Climate Change Response Strategy
NDEF	National Drought Emergency Fund
NDMA	National Drought Management Authority
NDMU	National Disaster Management Unit
NDOC	National Disaster Operations Centre
NEMA	National Environment Management Authority
NEP	National Environment Policy
NERA	National Electrification and Renewable Energy Authority
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
OECD	Organisation for Economic Co-operation and Development
O&M	Operating and maintenance
PDB	Permit Database
POPs	Persistent organic pollutants
PPP	Public Private Partnership
PV	Photovoltaic
RCP	Representative Concentration Pathways
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
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
WKCDD&FMP	Western Kenya Community Driven Development and Flood Mitigation Project
WFP	World Food Programme
Wp	Watt peak
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

Image source: SGT R.A. Ward 1998. 'Aerial photograph of the flooded Tana River'. Available online at https://en.wikipedia.org/wiki/Tana_River_(Kenya)#/media/File:DM-SD-01-06042.jpg

01

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 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 Water 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 Resources 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 Resources 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 one Basin Plans for each of 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 Tana Basin.

Figure 1-1: Tana Basin location map

1.2 Objectives of the Tana 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 for the Tana Basin is to provide a clear pathway for the sustainable utilisation and development of the water resources of the Tana 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.

1.3 Approach to the development of the Tana Basin Plan

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

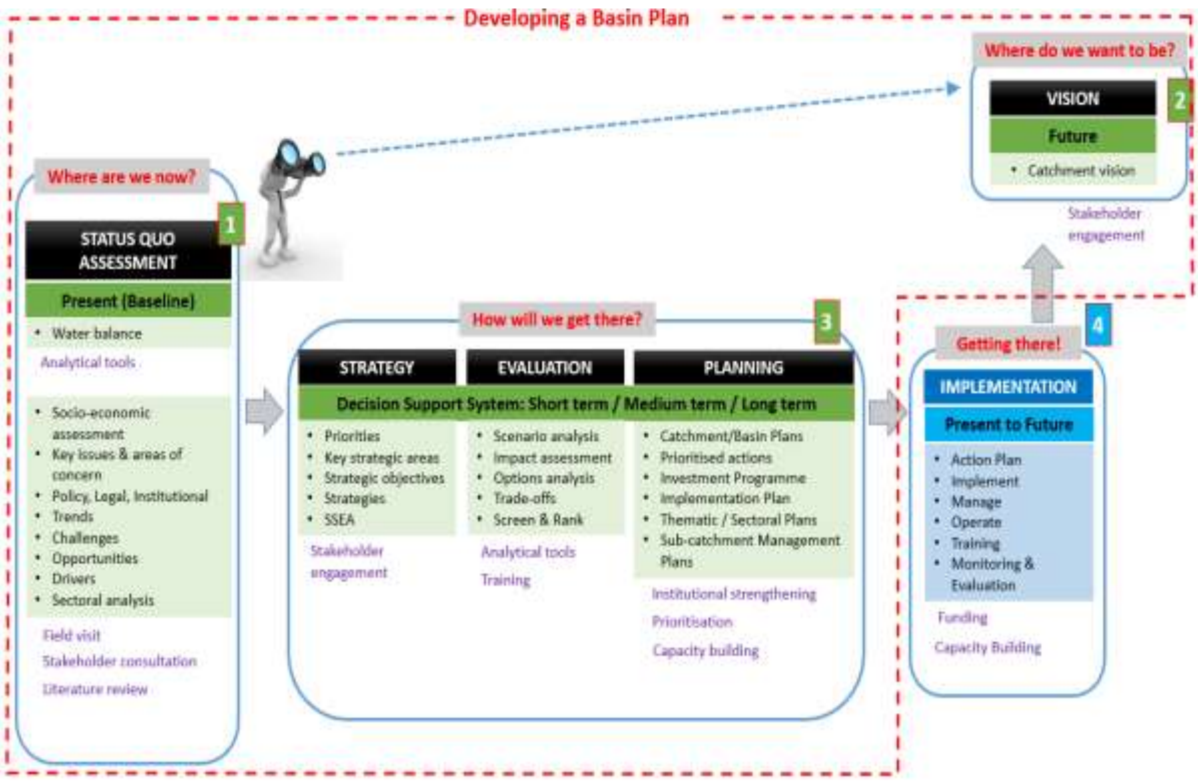


Figure 1-2: Conceptual approach to basin planning

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 Tana Basin.

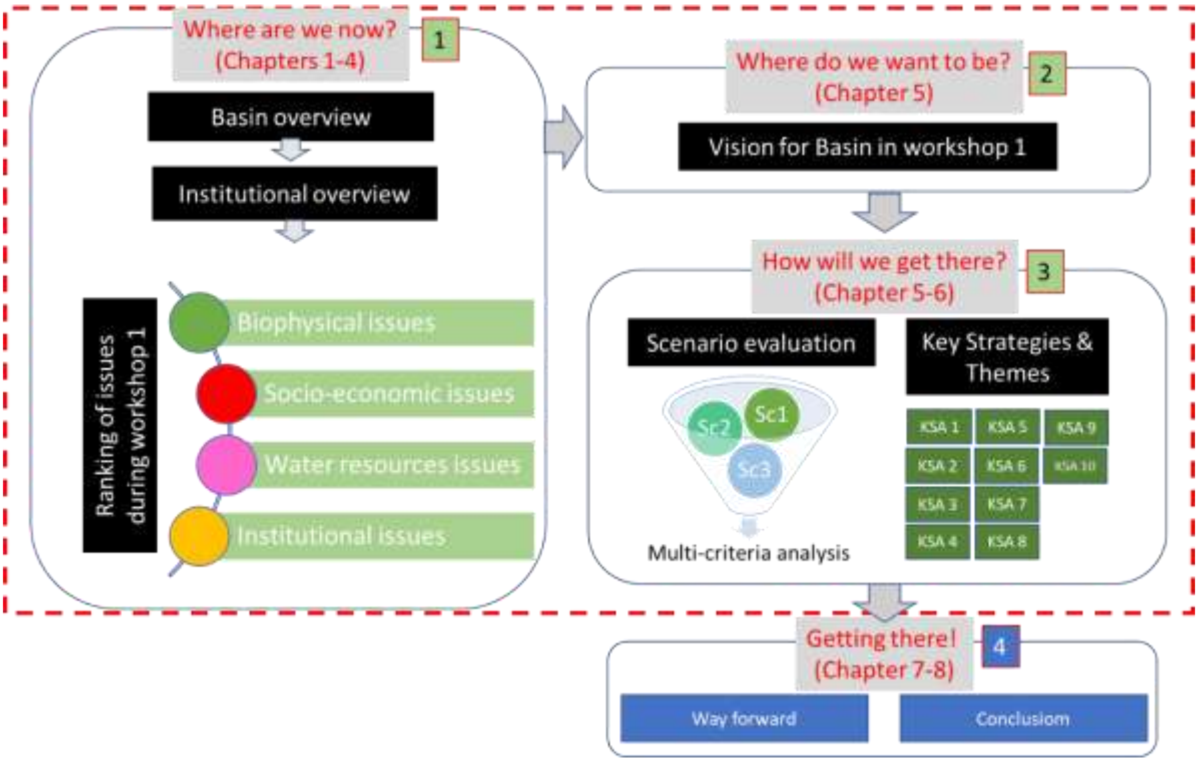


Figure 1-3: Key stages in development of Tana Basin Plan

1.4 Structure of the Tana 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.

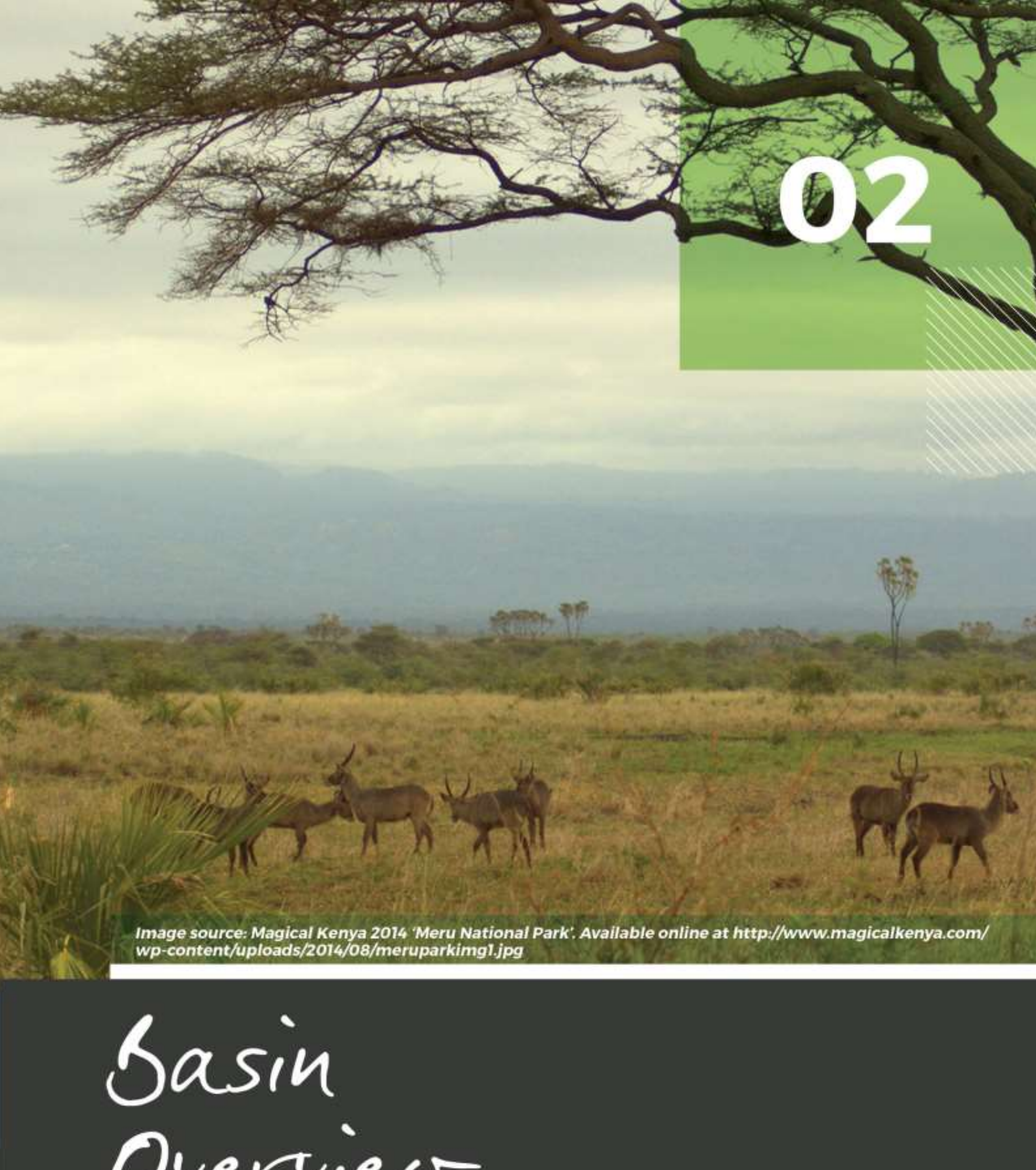


Image source: Magical Kenya 2014 'Meru National Park'. Available online at http://www.magicalkenya.com/wp-content/uploads/2014/08/meruparkimg1.jpg

Basin Overview

2 Basin Overview

2.1 Introduction

The Tana Basin has a catchment area of 126 208 km^2 [1]. The basin borders Somalia and the Indian Ocean coastline in the east, the Athi Basin to the south, the Ewaso Ng'iro North Basin to the north, and the Rift Valley Basin to the west (Figure 2-1). The catchment accounts for 22% of Kenya's total area, however the population density is relatively low, and the catchment houses only 15% of the total population.

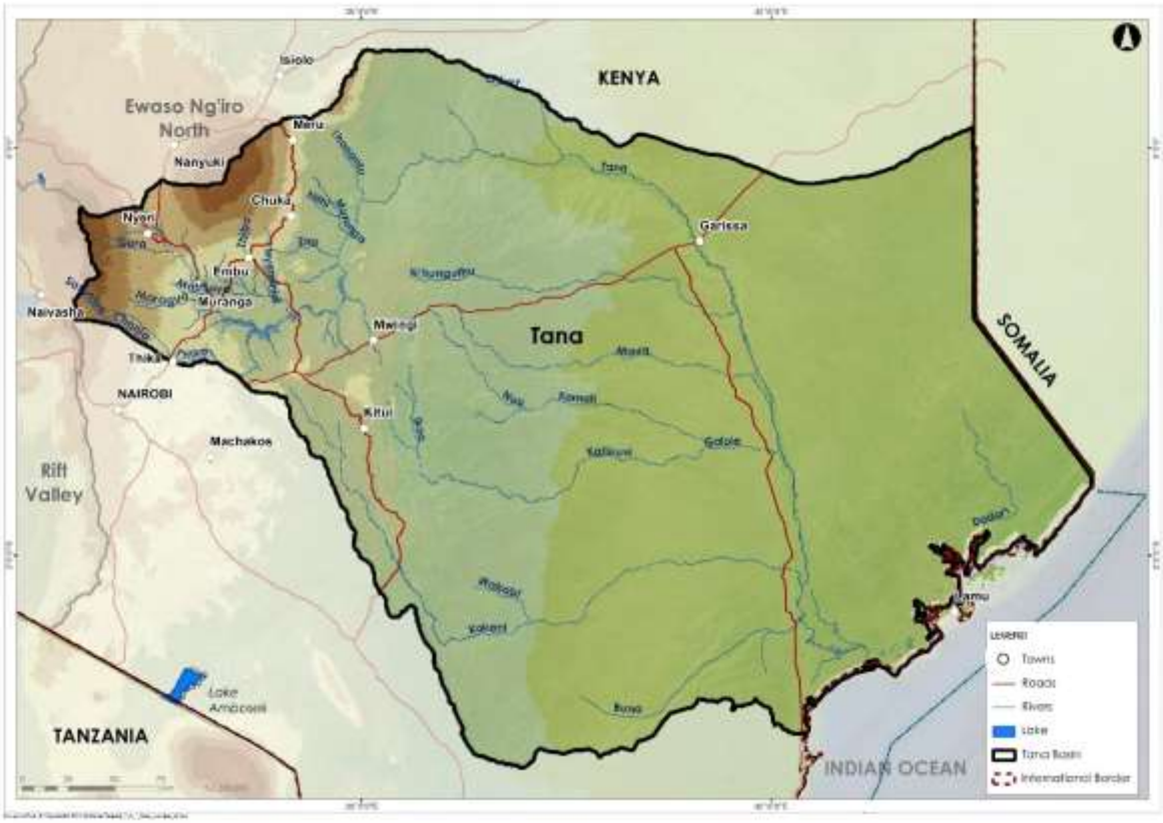


Figure 2-1: Overview map of Tana Basin

There are 14 counties within the Tana Basin, 8 of which are fully enclosed within the basin (Figure 2-2). Some counties cross hydrological boundaries and as such have to engage with multiple BWRCs and WRA offices. The main counties situated within the Tana Basin are as follows: Nyeri, Kiambu, Murang'a, Kirinyaga, Embu, Tharaka-Nithi, Meru, Isiolo, Garissa, Tana River, Kitui, Machakos, Kilifi and Lamu.

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

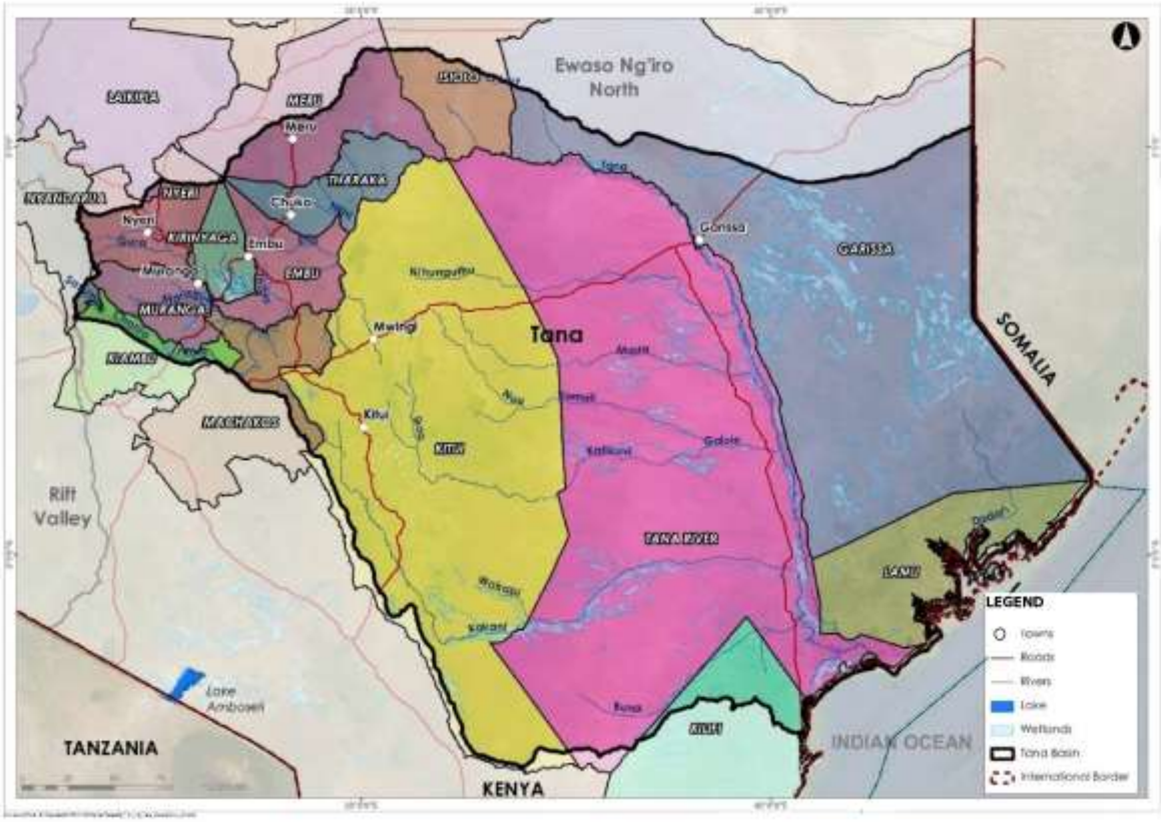


Figure 2-2: Counties within the Tana Basin

The major towns in the catchment include Garissa, Thika, Lamu, Nyeri, Embu, Meru, Murang'a and Kitui. Thika is the largest town in the catchment, with industrial activities such as brewing and beverages, food processing, textiles, tobacco and steel. Embu is known for its extensive coffee processing industry. The upper parts of the catchment receive high rainfall and include some of the most productive agricultural lands in the country. Parts of the central and north-eastern basin are arid and semi-arid.

2.2 Bio-physical

2.2.1 Physiography

2.2.1.1 Topography and landforms

The topography of the Tana Basin varies from the peak of Mount Kenya at 5 200 masl and the Aberdares in the west at 3 900 masl to the coastal area at sea level (Figure 2-3). Most of the middle and lower parts of the basin is flat, while the upper catchment is mountainous with steep slopes along the southern slopes of Mount Kenya and the eastern slopes of the Aberdares Range and Nyambene Hills, as shown in Figure 2-4.

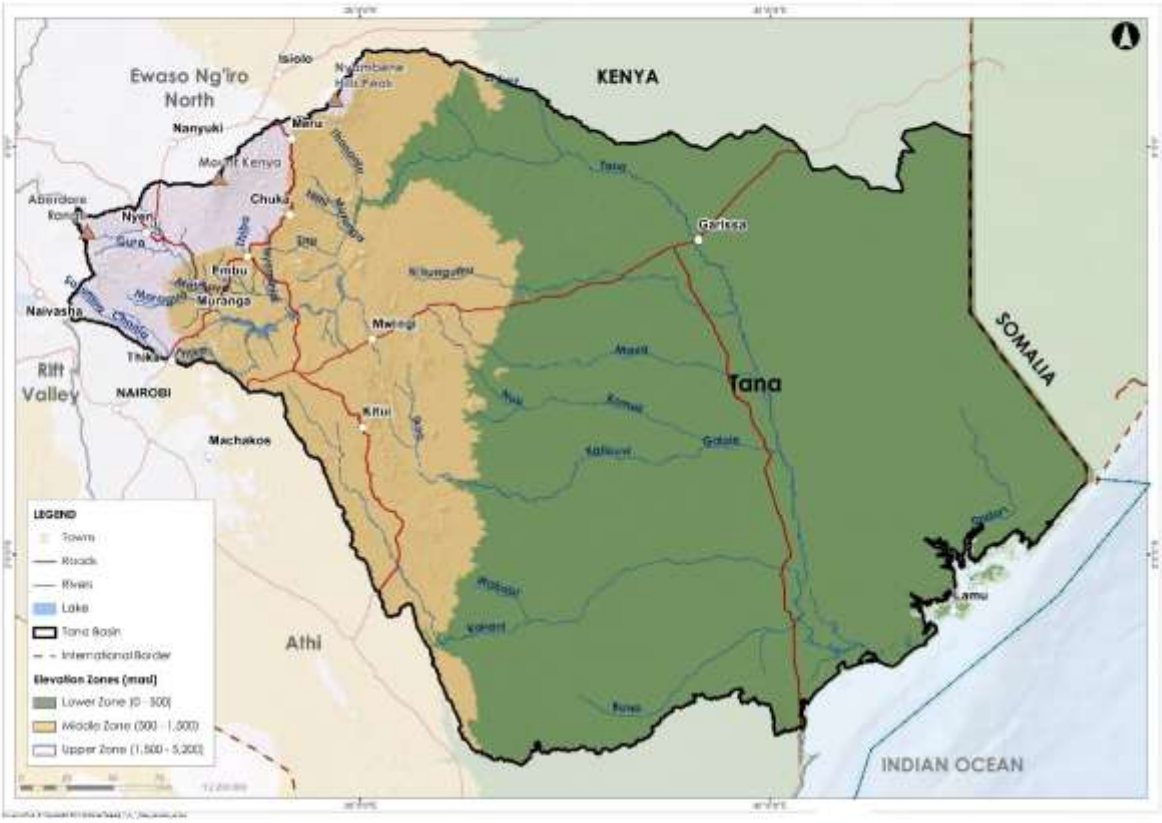


Figure 2-3: Elevation zones in the Tana Basin

Most of the Basin consists of plains, with mountains and hillslopes in the upper part of the Basin. There are also significant Badlands along the Tana River above Garissa town. The term 'badlands' describes an intensely dissected natural landscape with limited vegetation, which has been exposed to rapid fluvial erosion (Bryan & Yair, 1982). Extremely high drainage densities in this region serve as evidence of the dominance of overland flow. Most of the Basin consists of plains, with mountains and hillslopes in the upper part of the Basin. There are also significant Badlands along the Tana River above Garissa town. The term 'badlands' describes an intensely dissected natural landscape with limited vegetation, which has been exposed to rapid fluvial erosion (Bryan & Yair, 1982). Extremely high drainage densities in this region serve as evidence of the dominance of overland flow. Figure 2-5 displays the dominant landforms in the Tana Basin.

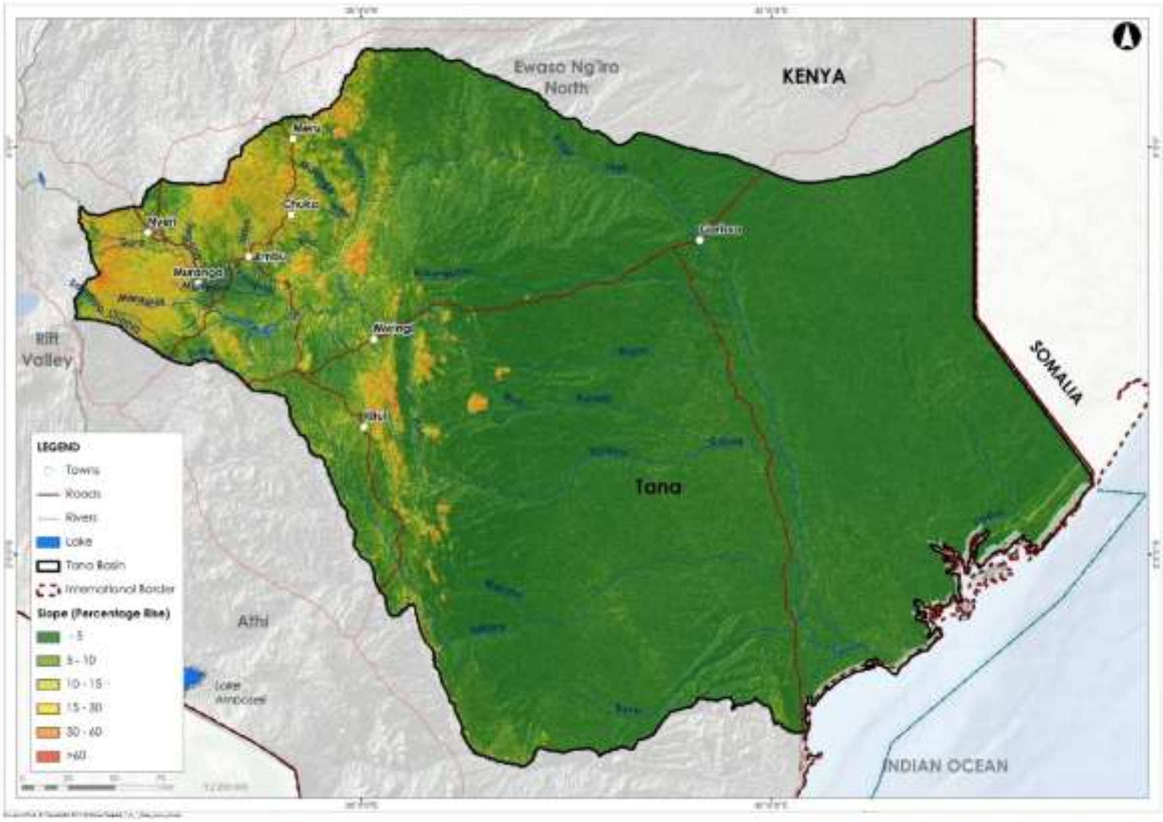


Figure 2-4: Slope categories in the Tana Basin

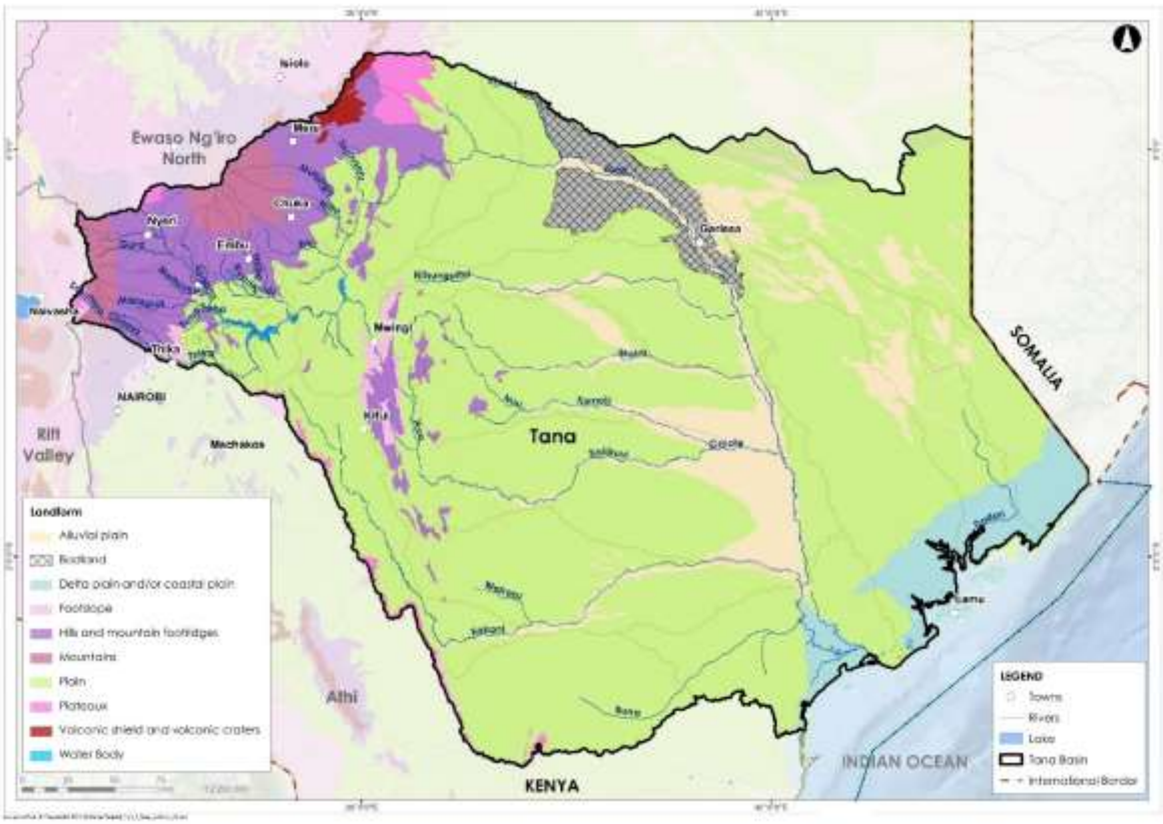


Figure 2-5: Landforms of the Tana Basin

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 Tana Basin due to its detailed soil mapping base. The soil types found in the Tana Basin are listed below. The main soil types in the lower Tana River catchment are Fluvisols along the Tana River and floodplains, Planosols, Solontez, Vertisols and Lixisols. The middle catchment is made up of mainly Ferralsols, Cambisols, Luvisols and Lixisols. The upper-most parts of the catchment surrounding Nyeri and Embu towns are made up of mainly dark-coloured Umbric Nitisols, which are rich in organic matter (Jones et al., 2013) was used as a reference for the soil types found across the Tana Basin due to its detailed soil mapping base. The soil types found in the Tana Basin are listed below. The main soil types in the lower Tana River catchment are Fluvisols along the Tana River and floodplains, Planosols, Solontez, Vertisols and Lixisols. The middle catchment is made up of mainly Ferralsols, Cambisols, Luvisols and Lixisols. The upper-most parts of the catchment surrounding Nyeri and Embu towns are made up of mainly dark-coloured Umbric Nitisols, which are rich in organic matter (Table 2-1). The soil classifications associated with Figure 2-6 are presented in Table 2-2.

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

Soil Type	Description
Fluvisols	Found in flood plains, lakes, deltas or marine deposits. High agricultural potential, but risk of flooding or waterlogging.
Planosols	Characterised by a subsurface layer of clay accumulation. Occur in low-lying areas that can support either grass or open forest vegetation.
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	Contain high levels of plant nutrients, but due to a high clay content are not suited to cultivation.
Lixisols	Low levels of plant nutrients and a high erodibility make agriculture possible only with frequent fertilizer applications, minimum tillage, and careful erosion control.
Ferralsols	Red and yellow weathered soils, resulting from an accumulation of metal oxides. Have a low fertility due to the residual metal oxides and the leaching of mineral nutrients. They require additions of lime and fertilizer if they are to be used for agriculture.
Cambisols	Young soils. Various characteristics depending on factors. One of the better agricultural soils due to good nutrient-holding capacity.
Luvisols	Slightly acidic with high clay content and high mineral nutrient content. Good water retention capacity. Productive soils if managed properly.
Umbric Nitisols	Have a high nutrient content and deep, permeable structure.

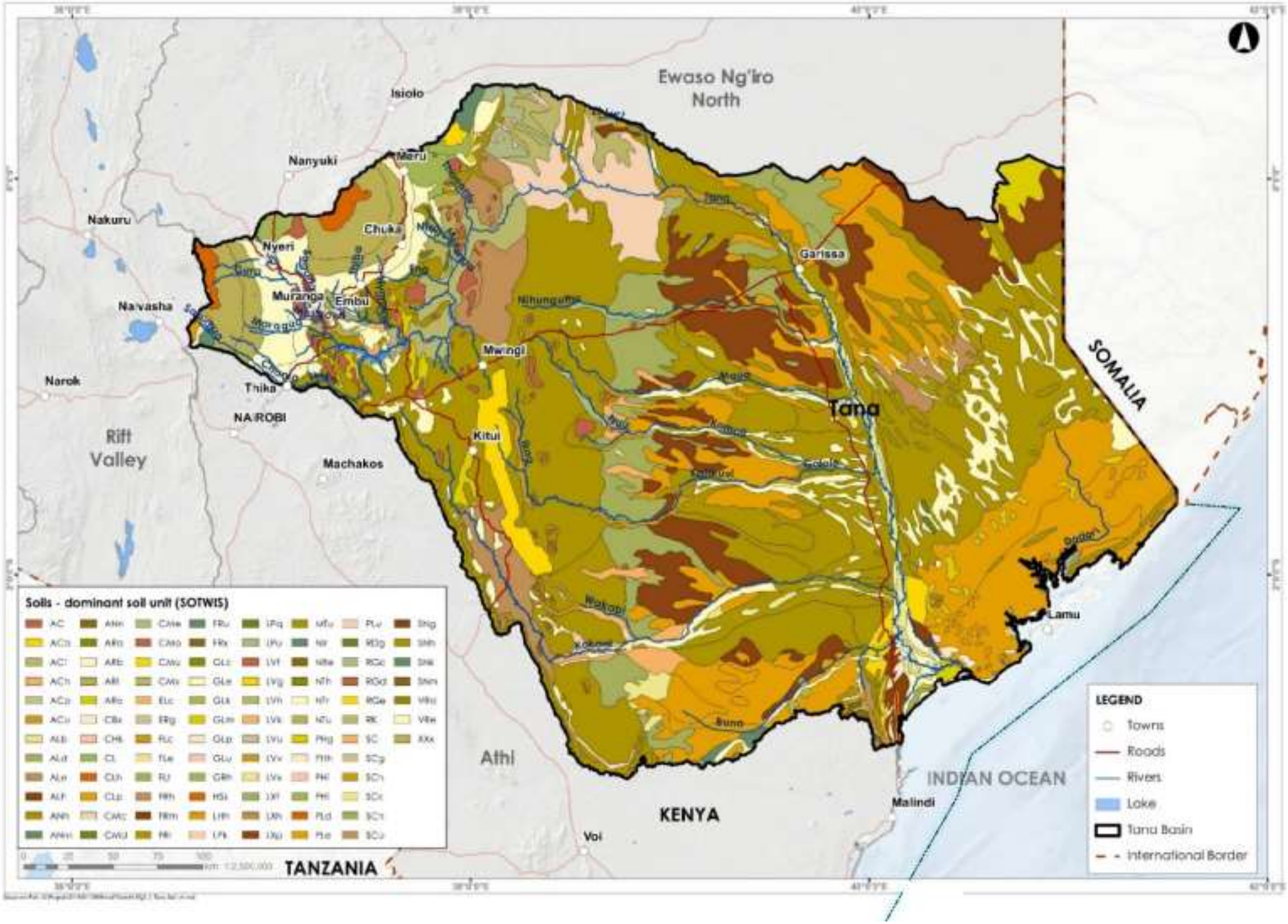


Figure 2-6: Soils in the Tana Basin

Table 2-2: Soil Classifications for the Tana Basin

Soil Index	Description	Soil Index	Description	Soil Index	Description	Soil Index	Description
AC	Acrisols	**CMd**	Dystric Cambisols	**LPk**	Rendzic Leptosols	**PLd**	Dystric Planosols
ACb	Cambic Acrisols	**CMe**	Eutric Cambisols	**LPq**	Lithic Leptosols	**PLe**	Eutric Planosols
ACf	Ferric Acrisols	**CMo**	Ferralic Cambisols	**LPu**	Umbric Leptosols	**PLu**	Umbric Planosols
ACh	Haplic Acrisols	**CMu**	Humic Cambisols	**LVf**	Ferric Luvisols	**RDg**	Dystric Regosol
ACp	Plinthis Acrisols	**CMx**	Chromic Cambisols	**LVg**	Gleyic Luvisols	**RGc**	Calcaric Regosols
ACu	Humic Acrisols	**ELc**	Rendzinas	**LVh**	Haplic Luvisols	**RGd**	Dystric Regosols
ALb	Cambic Alisols	**ERg**	Rendzinas	**LVk**	Calcic Luvisols	**RGe**	Eutric Regosols
ALd	Dystric Alisols	**FLe**	Eutric Fluvisols	**LVu**	Humic Luvisols	**RK**	Calcic Regosol
ALe	Eutric Alisols	**FLt**	Thionic Fluvisols	**LVv**	Vertic Luvisols	**SC**	Solonchaks
ALh	Haplic Alisols	**FRh**	Haplic Ferralsols	**LVx**	Chromic Luvisols	**SCg**	Gleyic Solonchaks
ANh	Haplic Andosols	**FRm**	Mollic Ferralsols	**LXf**	Ferric Lixisols	**SCh**	Haplic Solonchaks
ANm	Mollic Andosols	**FRr**	Rhodic Ferralsols	**LXh**	Haplic Lixisols	**SCk**	Calcic Solonchaks
ANn	Melanic Andosols	**FRu**	Humic Ferralsols	**LXp**	Plinthic Lixisols	**SCn**	Sodic Solonchaks
ARa	Albic Arenosols	**FRx**	Xanthic Ferralsols	**MTu**	Greyzems	**SCo**	Ferralic Solonchaks
ARb	Cambic Arenosols	**GLc**	Calcaric Gleysols	**NIr**	Nitisols	**SNg**	Gleyic Solonetz
ARl	Luvic Arenosols	**GLe**	Eutic Gleysols	**NRe**	Nitisols	**SNh**	Haplic Solonetz
ARo	Ferralic Arenosols	**GLk**	Calcic Gleysols	**NTh**	Haplic Nitisols	**SNk**	Calcic Solonetz
CBx	Carbic	**GLm**	Mollic Gleysols	**NTr**	Rhodic Nitisols	**SNm**	Mollic Solonetz
CHk	Calcic Chernozem	**GLp**	Plinthic Gleysols	**NTu**	Humic Nitisols	**VRd**	Dystric Vertisol
CL	Calcisols	**Glu**	Umbric Gleysols	**PHg**	Gleyic Phaeozems	**VRe**	Eutric Vertisol
CLh	Haplic Calcisols	**GRh**	Haplic Greyzems	**PHi**	Lithic Phaeozems	**XXx**	Xanthic Xerosols
CLp	Petric Calcisols	**HSs**	Terric Histosols	**PHh**	Haplic Phaeozems		
CMc	Calcaric Cambisols	**LHh**	Haplic Luvisol	**PHl**	Luvic Phaeozems		

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) (refer to **Annexure A1**). The outputs of the tool provided both potential soil loss (i.e. inherent erosion risk) and estimated soil loss (i.e. accounting for vegetation cover and land 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.

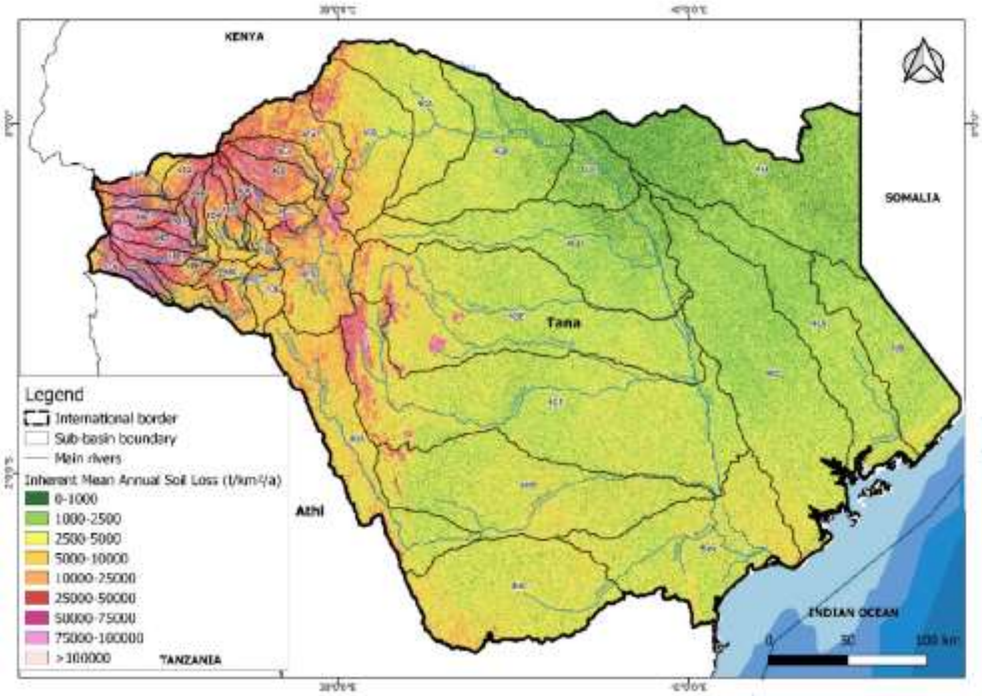


Figure 2-7: Tana Basin Inherent Soil Erosion Risk (C and P factor not included)

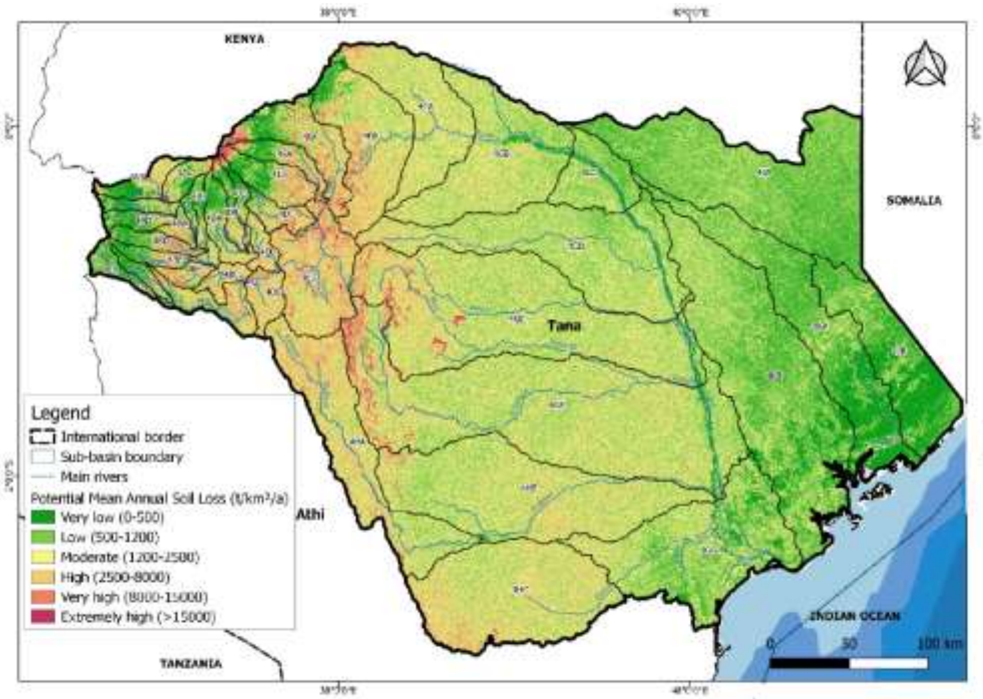


Figure 2-8: Tana Basin Potential Soil Erosion Risk

2.2.1.3 Geology and hydrogeology

Geology and groundwater characteristics

The geology of the Tana basin is presented in Figure 2-9. The Tana Basin is characterised by humid highlands feeding the perennial Tana River, which flows generally east and then south towards the coast, where it emerges into the Indian Ocean at Kipini, in Tana River County.

The upper part of the Tana Basin is underlain by Miocene, Pliocene and recent volcanic rocks which overlie Precambrian metamorphic Basement at depth. This zone hosts the vast majority of the Basin's population and most of its high-value agricultural land (Kiambu, Murang'a, Nyeri and Kirinyaga Counties; and the upper parts of Embu, Meru and Tharaka-Nithi Counties). The upper zone of the basin has relatively good aquifers (including the extreme northern part of the Nairobi Aquifer System), which are a valuable water supply for the domestic and commercial sectors. Groundwater may be facing localised over-abstraction in the upper Tana Basin. High concentrations of iron, fluoride and manganese have been found in groundwater in some areas in the upper basin.

As the river flows east to lower elevations, it crosses over metamorphic Basement rocks, which underlie the semi-arid counties of eastern Machakos, Kitui, and south eastern Isiolo, and the lower elevations of Embu, Tharaka-Nithi and Meru Counties. Metamorphic Basement hosts locally useful aquifers and supports sand dams and shallow wells in eastern Machakos and Kitui Counties. Alluvial aquifers are of local importance in the middle/lower zone, astride the Tana River.

Basement rocks give way to younger sediments as the river flows south east towards the Indian Ocean, flowing between Tana River and Garissa Counties; and the northern tip of Kilifi County. Lamu County lies north east of Kipini, and the coastal strip is underlain by young coastal sediments. The coastal zone is threatened by saltwater intrusion, which worsens with proximity to the coastline. Abstraction is limited in certain areas, while the coastal coral limestone and sand aquifers are often of local importance.

The Tana Aquifer Map (Water Resources Management Authority, 2015b) proposed the following breakdown of aquifer groups across the Tana Basin, presented in Table 2-3: Aquifer groups in the Tana Basin. The three zones are essentially climatic, with Zone I in the humid uplands and Zone III covering the arid lowlands. The main geological and hydrogeological characteristics of these three zones are summarised in Table 2-3.

Table 2-3: Aquifer groups in the Tana Basin: Upper, middle and lower aquifer regions in the Tana Basin (Water Resources Management Authority, 2015b)

Zone	Description
I	Upper Tana Region: the volcanic eastern and southern slopes of Mount Kenya, the Aberdares and Nyambene Hills (> 1 300 m masl). Recharge, transit and discharge zones of a regional aquifer system.
II	Middle Tana Region: Tharaka, Mbeere, Kitui, Mwingi, and parts of Machakos Districts (500 to 1 300 m masl). Semi-arid to arid, localised aquifer systems typically poor.
III	Lower Tana Region: (area < 500 m masl including coastal zone). Complex local and semi-regional aquifers systems.

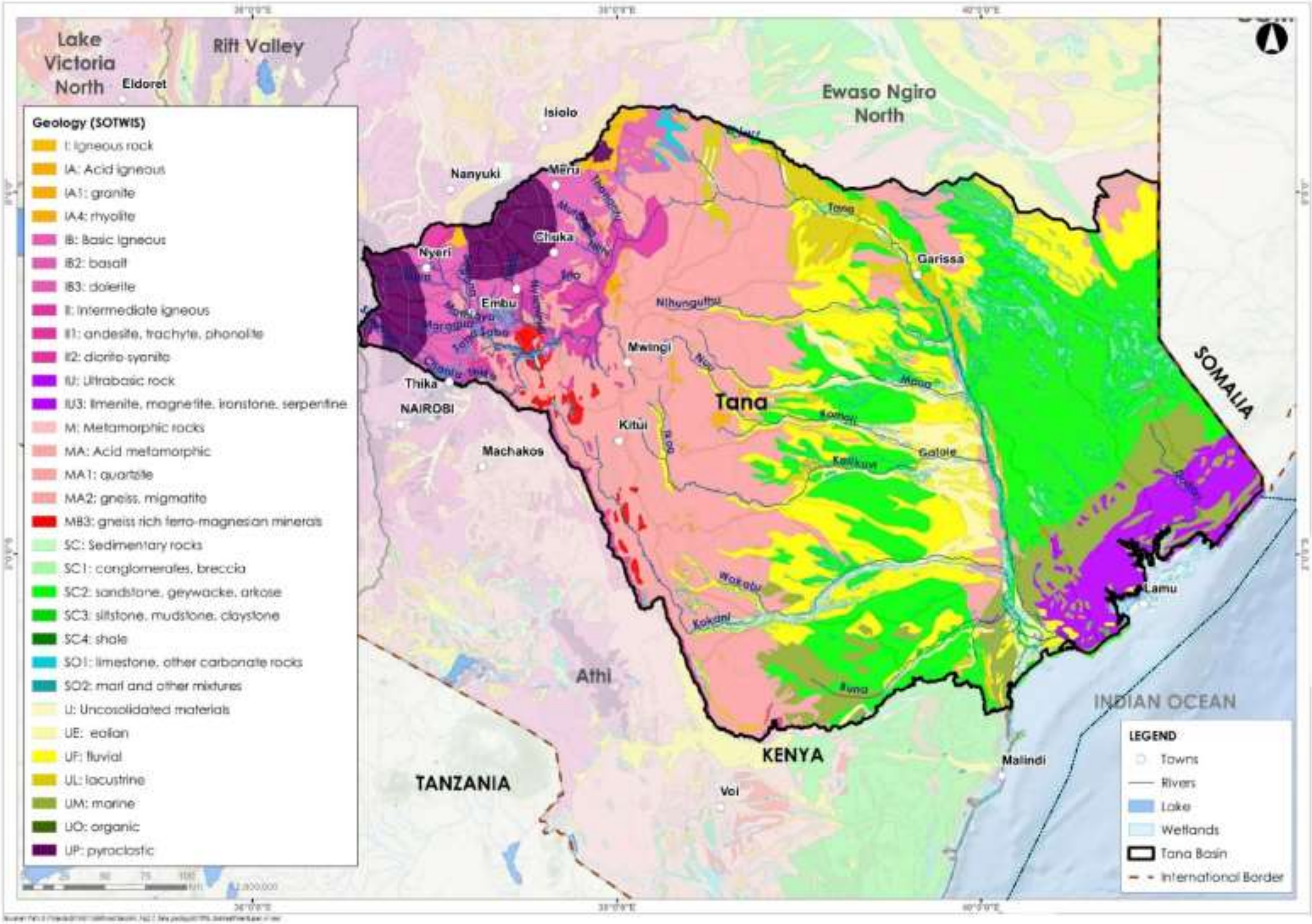


Figure 2-9: Geology of the Tana Basin

WRMA Aquifer classification

At present, the aquifer classification system in place in Kenya is described by Water Resources Management Authority, 2007. A new classification system was developed as part of this consultancy, and is proposed in section 6.4.30.

The Water Resources Management Authority (2007) classification system is partly demand-oriented and partly geo-political. There are five classes, as follows:

- 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 Authority.

Each is further defined in terms of its status, described as follows:

- **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 Tana Basin's aquifers under the current classification are summarised in Table 2-4 below.

Table 2-4: Current classification of aquifers in the Tana Basin

Name	Dominant lithology	Status
Major		
Mount Kenya volcanics	Weathered/fractured trachytes and basalts	Satisfactory
Southern Aberdare volcanics	Basalts	Alert
Minor		
Eastern Basement	Gneisses and schists	Alert
Hindi, Bele, Chomo	Calcareous sands	Alert
Kiongwe	Dune sands	Alert
Lake Kenyatta	Sands and corals	Alarm – pollution, over-abstraction
Lamu dunes	Dune sands	Alarm – sole source, salinisation
Tana Delta	Dune sands	Alert
Timboni-Gongoni	Shoreline sediments	Alarm
Poor		
Lamu Embayment	Poorly consolidated sands and sandstones	Satisfactory
Southern Merti Beds	Sands, gravels, sandstone and conglomerates.	Alert

2.2.1.4 Drainage

The Tana River is the main river in the basin and drains approximately 76% of the Tana Basin. It originates on the slopes of Mount Kenya and flows eastward until it reaches Garissa town, after which it flows southwards and pours into the Indian Ocean at the Tana Delta. The Tana Basin is divided into 39 sub-basins, 4AA to 4KB, displayed in Figure 2-10 The drainage network and sub-basins of the upper Tana Basin are displayed in more detail in Figure 2-11.

The upper part of the Tana Basin constitutes the headwaters of the Tana River and includes sub-basins 4AA, 4AB, 4AC, 4AD, 4BA, 4BB, 4BC, 4BD, 4BE, 4BF, 4BG, 4CB, 4CC, 4DA, 4DB, 4DC, 4DD, 4DE,4EA, 4EB, 4EC, 4ED. Upstream tributaries include the Chania, Thiba, Maragua and Thika rivers.

The remainder of the Tana Basin includes sub-basins linked to Tana River: 4FA, 4FB, 4GA, 4GB, 4GC, 4GD, 4GE, 4GF, 4HA, 4HB, 4HC and 4GG; as well as 4JB; 4JA, 4KA and 4KB; (Figure 2-10). Eastwards-draining, seasonal tributaries join the main stem of the Tana River downstream of Garissa and include Nihunguthu, Maua, Komoli, Galole and Kokani rivers. Smaller rivers in the north-eastern part of the basin drain to Somalia and the Indian Ocean. The Tana River discharges into the Indian Ocean at the Tana Delta.

2.2.1.5 Lakes and wetlands

The Tana River hosts Kenya’s largest and richest wetlands (Figure 2-12). As the River enters the Indian Ocean, before the coral reef drop off, the Tana River passes through a large floodplain of wetlands, riverine forests, woodlands, bushlands, fresh and brackish lakes, estuaries, mangroves and grasslands (Ministry of Environment and Mineral Resources, 2012), commonly referred to as the Tana Delta (Ministry of Environment and Mineral Resources, 2012), commonly referred to as the Tana Delta.

The upper part of the Tana Basin hosts wetlands along tributaries above the seven forks dam. These wetlands are under threat from expansion of agriculture.

The middle and lower Tana Basin hosts the Tana River Delta as well as other wetlands associated with the floodplain of Tana River. There ae also estuaries and mangroves associated with the coastal region of Tana Basin.

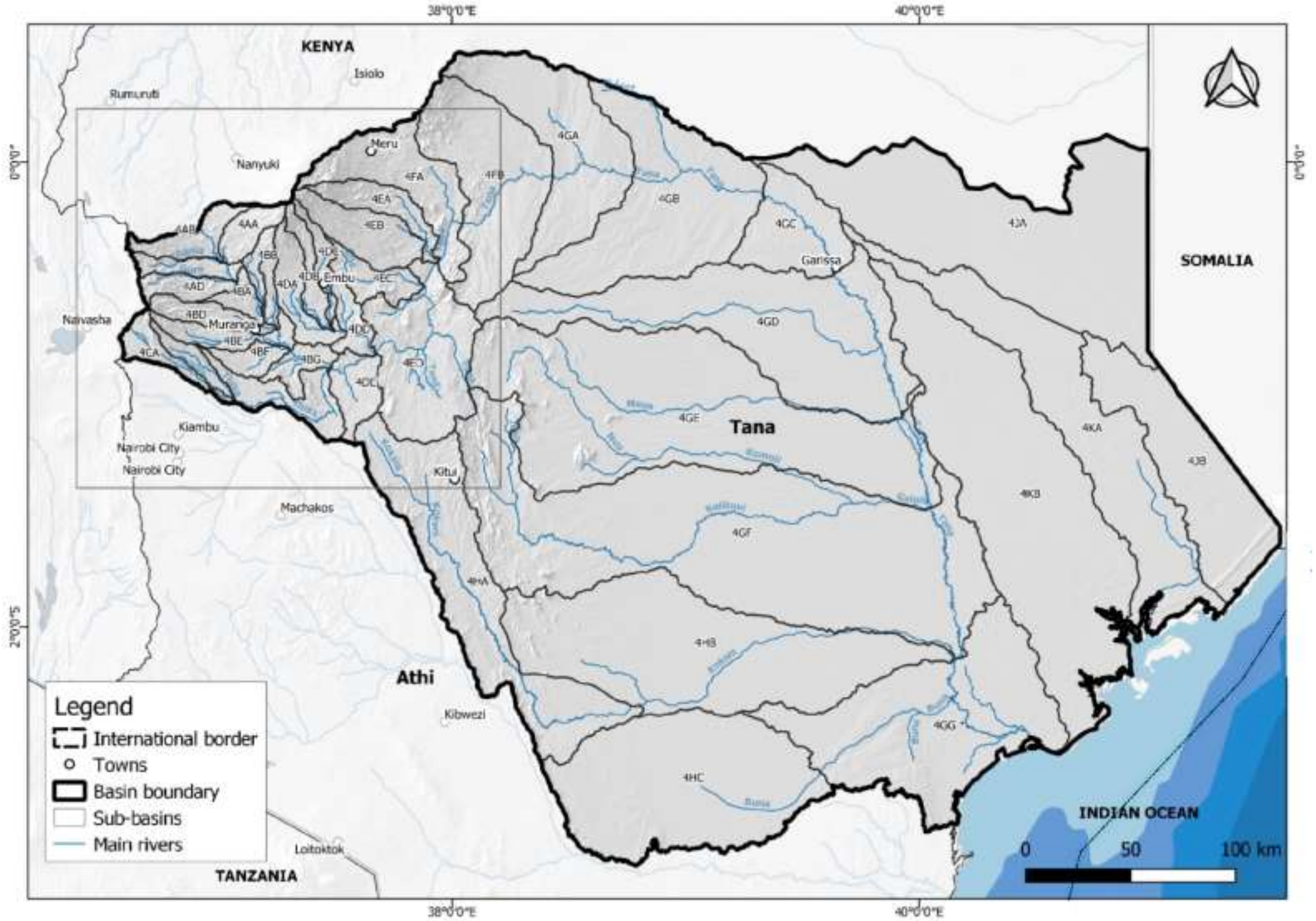


Figure 2-10: Drainage network and sub-basins of the Tana Basin

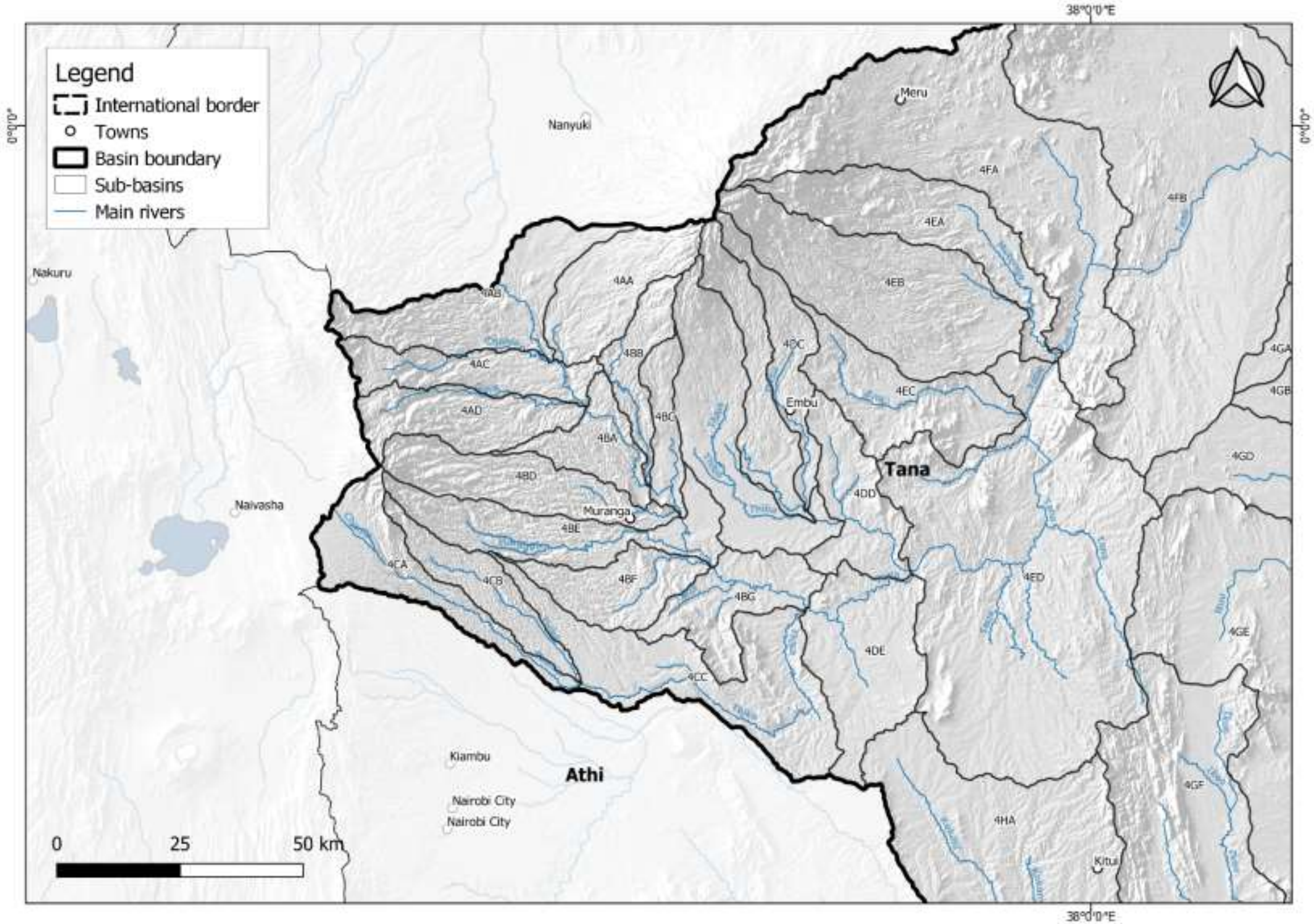


Figure 2-11: Drainage network and sub-basins of the upper Tana Basin

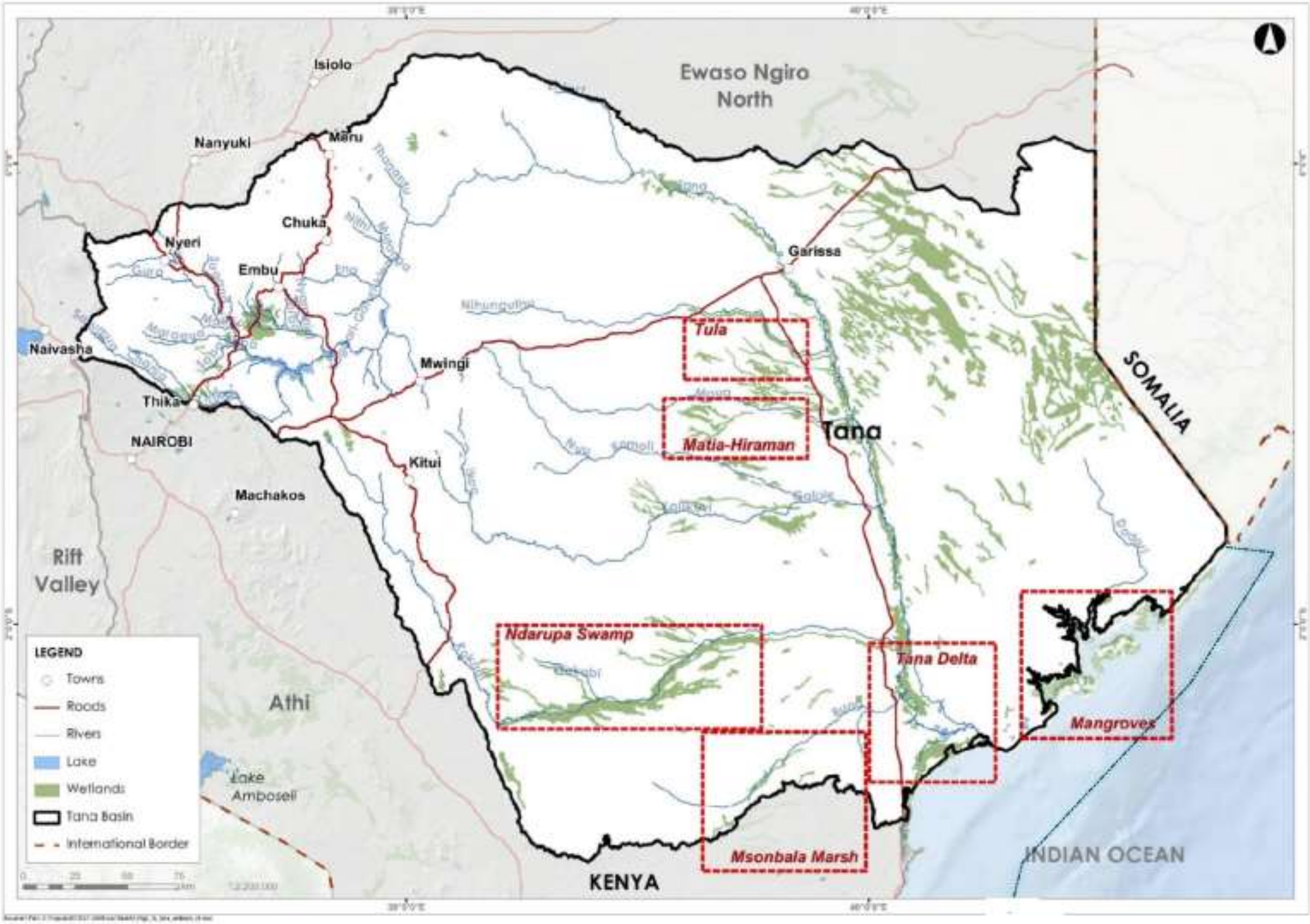


Figure 2-12: Major wetlands in the Tana Basin

2.2.2 Climate

2.2.2.1 Current climate

The Tana Basin is known for its hot and dry climate. The climate of the Tana Basin is brought about by the topography of the Basin, and the movements of two air masses over the Inter-Tropical Convergence Zone (ITCZ). The upper part of the Basin is classified as humid land, the coastal area as humid and semi-arid land and parts of the central area as arid and semi-arid. The mean annual precipitation across the basin varies from less than 450 mm in some areas in the north-east to as high as 1 900 mm along the watershed in the high-lying areas in the west and 1 000 mm along the coast. The mean annual precipitation across the basin is 673 mm. Average annual maximum day temperatures vary from 19°C to 35°C across the basin, while the average annual minimum night temperatures vary from 4°C to 23°C.

Figure 2-13 displays the mean annual precipitation and average temperatures across the basin.

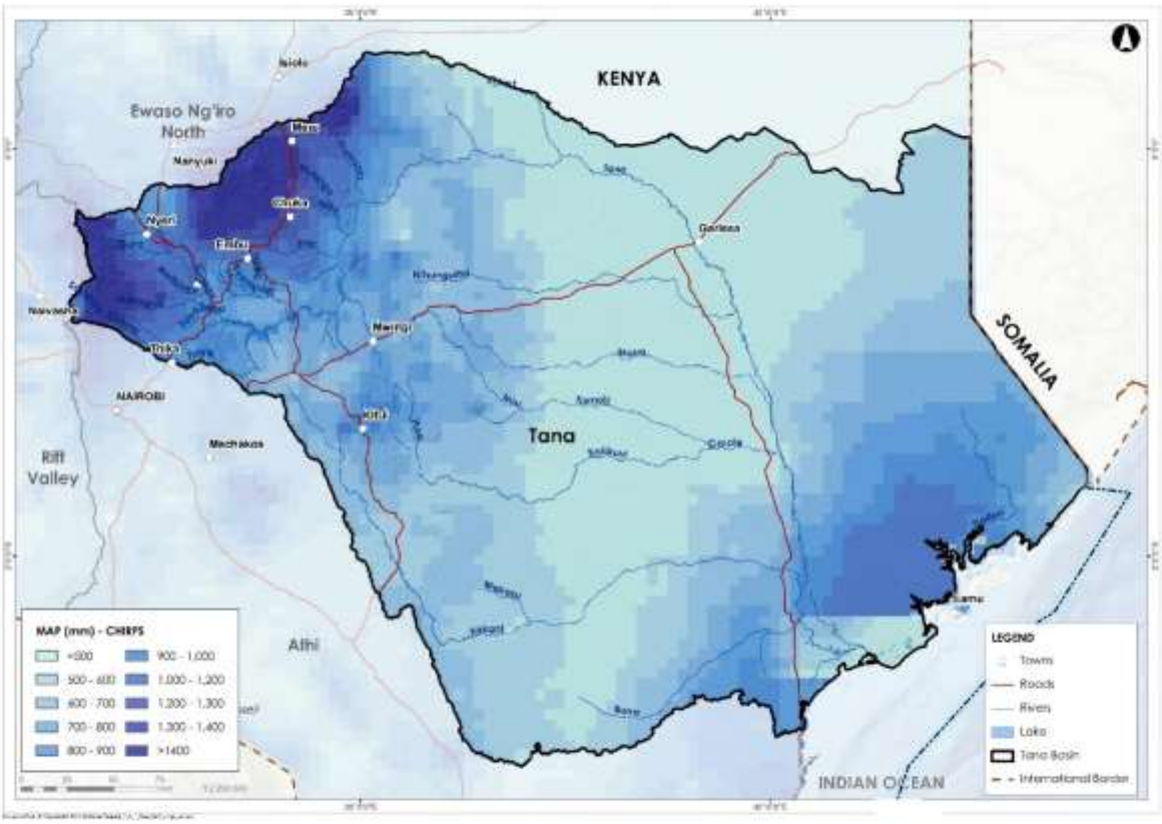


Figure 2-13: Mean annual precipitation across the Tana Basin

Two periods of rainfall occur during the year, namely the ‘long’ rains between March and May, and the ‘short’ rains from October to November. The variation of temperature and precipitation at Bura (lower basin) and Nyeri (upper basin) is shown in Figure 2-14.

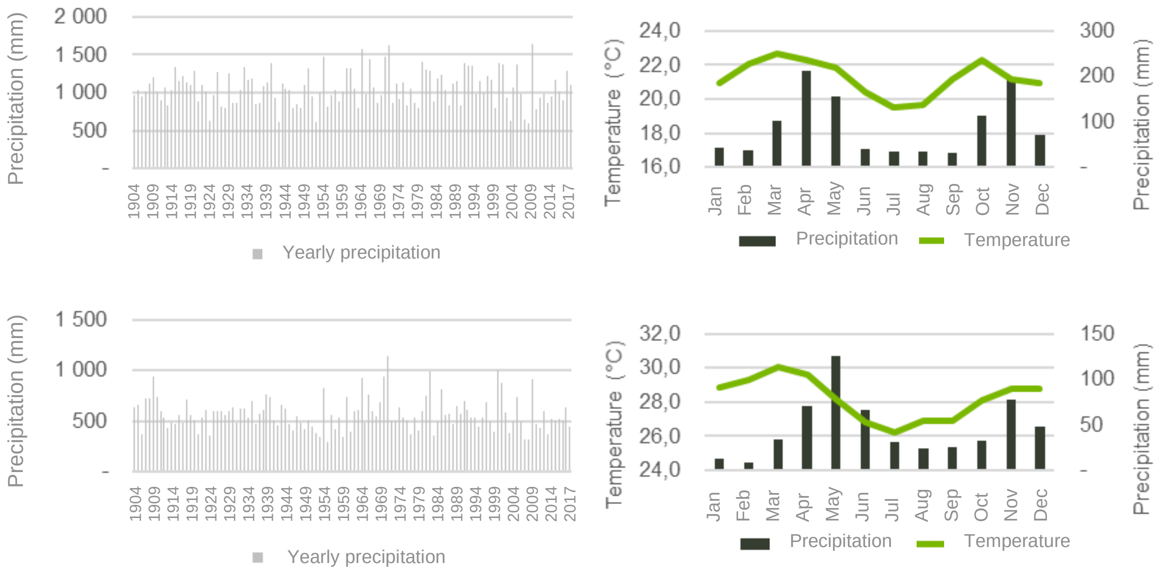
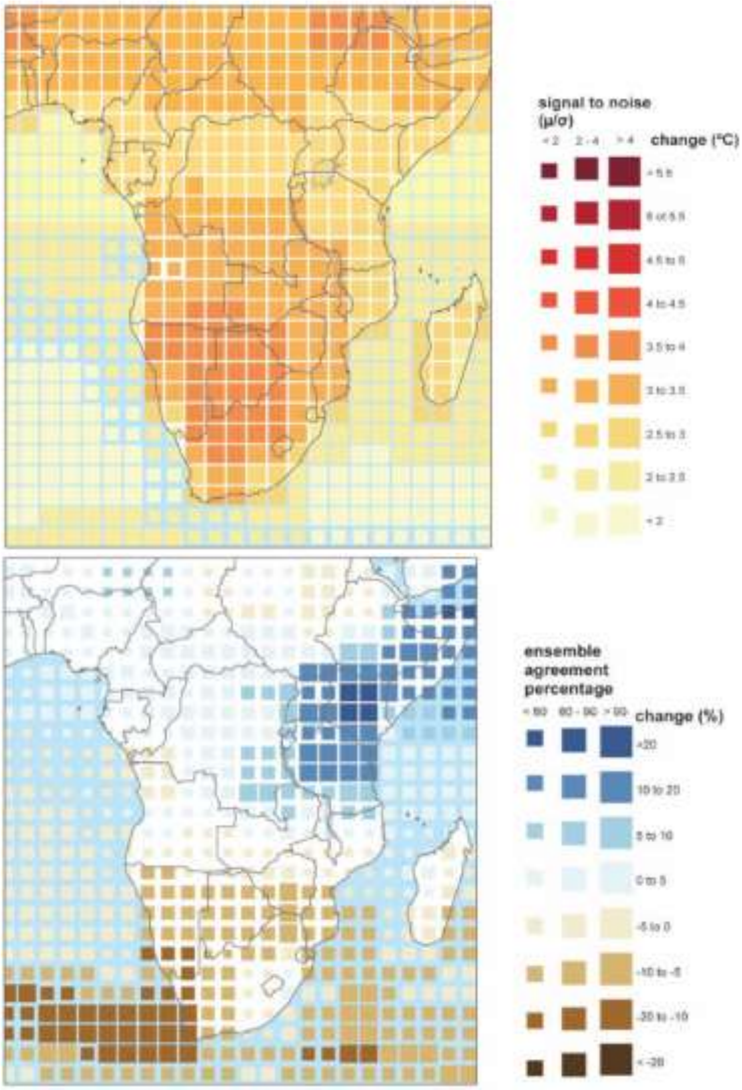


Figure 2-14: Variation of precipitation and max. temperature at Nyeri (upper basin) and Bura (lower basin) in Tana Basin

2.2.2.2 Future climate

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 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 generally expected to increase. This is likely to change the risk and vulnerability profiles of Kenya and its basins.



***** *From 1960-1990 baseline climate, percentage change in average annual precipitation, averaged over 21 CMIP3 models (Met Office, 2011). Climate: Observations, projections and impacts. Kenya. Exeter, UK: (Met Office, 2011). Climate: Observations, projections and impacts. Kenya. Exeter, UK: Met Office.*

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

Factors such as the topography, proximity to the equator, and air masses contribute to the range and variability in precipitation and temperature regimes and changes across the Tana Basin. To assist with the assessment of climate change impacts in the Tana Basin a more detailed analysis was therefore undertaken by analysing multiple climate projection datasets and assessing the expected climate impacts on more localised precipitation and flow in the Tana Basin sub-basins (refer to **Annexure A2**).

The climate analysis showed a general increase (between 0% and 10%) in mean annual precipitation (MAP) across the Tana Basin by 2050, with the average MAP across the basin increasing from 673 mm to 723 mm by 2050 under RCP 4.5. The climate analysis on precipitation, indicates a consistent increase in future precipitation in the sub-basins during the ‘short’ rainy season and during the months of January and February. During the ‘long’ rainy season the increase in precipitation is less pronounced. Furthermore, the eastern sub-basins also appear to be much wetter in future than the western sub-basins. During the dry season from June to October, an overall decreasing precipitation trend is observed.

Projected sub-basin precipitation and temperature changes under climate change scenario RCP 4.5 were superimposed on the hydrological model of the Tana Basin to assess the potential impacts on runoff. The climate analysis on flow indicates an increase in flow consistent to the rainfall patterns; increasing in the 'short' rainy season, remaining largely unchanged during the 'long' rainy season and decreasing during the dry season. The total surface water runoff from the Tana Basin is projected to increase with 4% by 2050. 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. This suggests that even though the average flow decreases during the dry season, the rivers will generally be able to sustain the low flows better during the dry season.

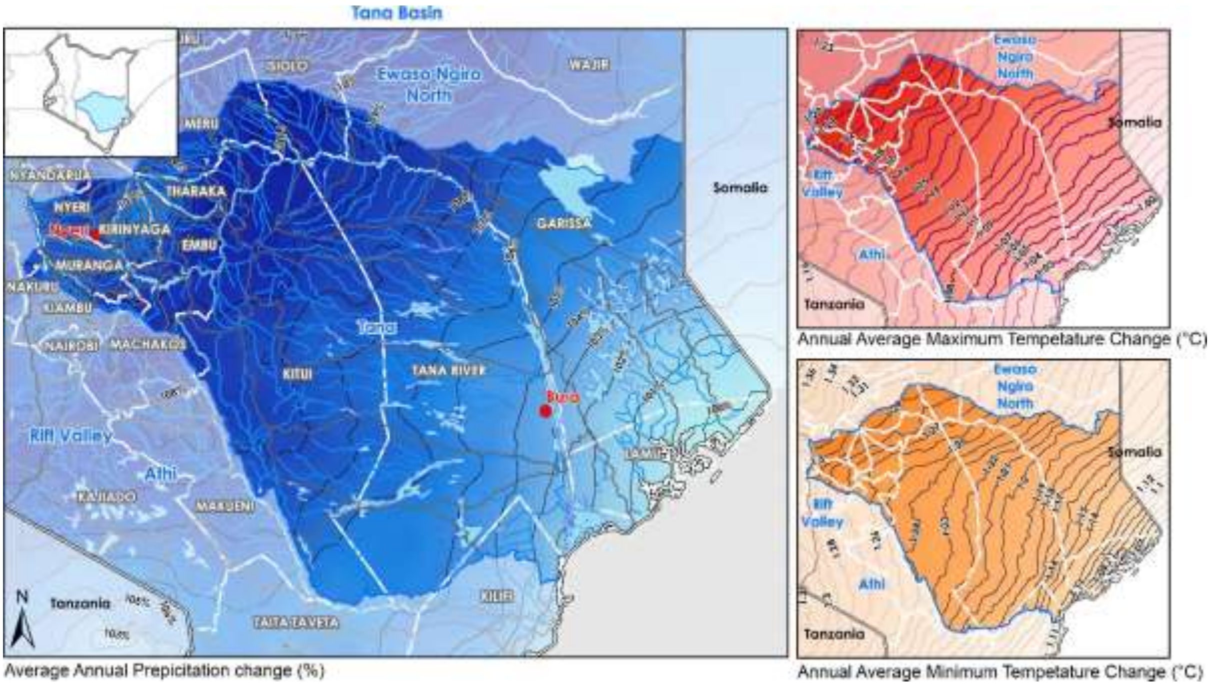


Figure 2-16: Change in annual precipitation, maximum and minimum temperature by 2050 (RCP 4.5)

The maximum projected temperature anomalies in the Tana Basin are presented in Figure 2-17.

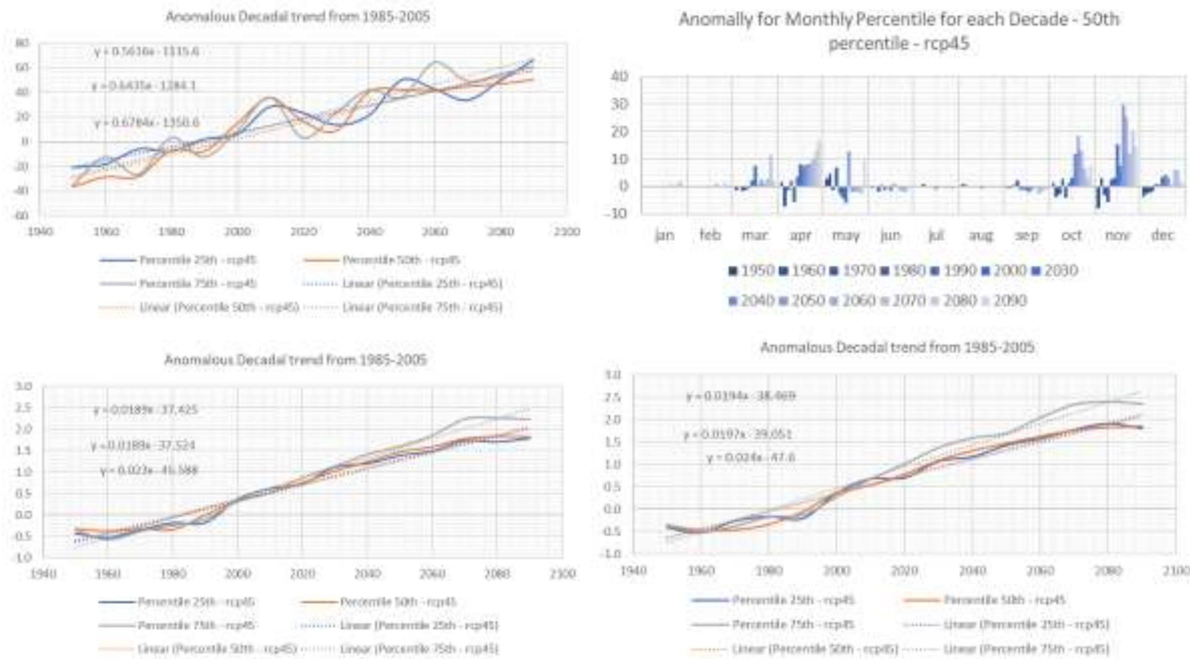


Figure 2-17: Projected Tmax anomalies in the Tana Basin by 2050 (RCP 4.5)

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

The upper Tana has a region of high-rainfall that is characterised by good vegetation cover, although this is also a region of agricultural land use therefore vegetation cover has seasonal fluctuations.

The lower and middle Tana is characterised by a semi-arid climate and reduced vegetation cover. This is a region of pastoralism with limited agriculture. There is improved vegetation cover in the protected forests in the coastal strip.

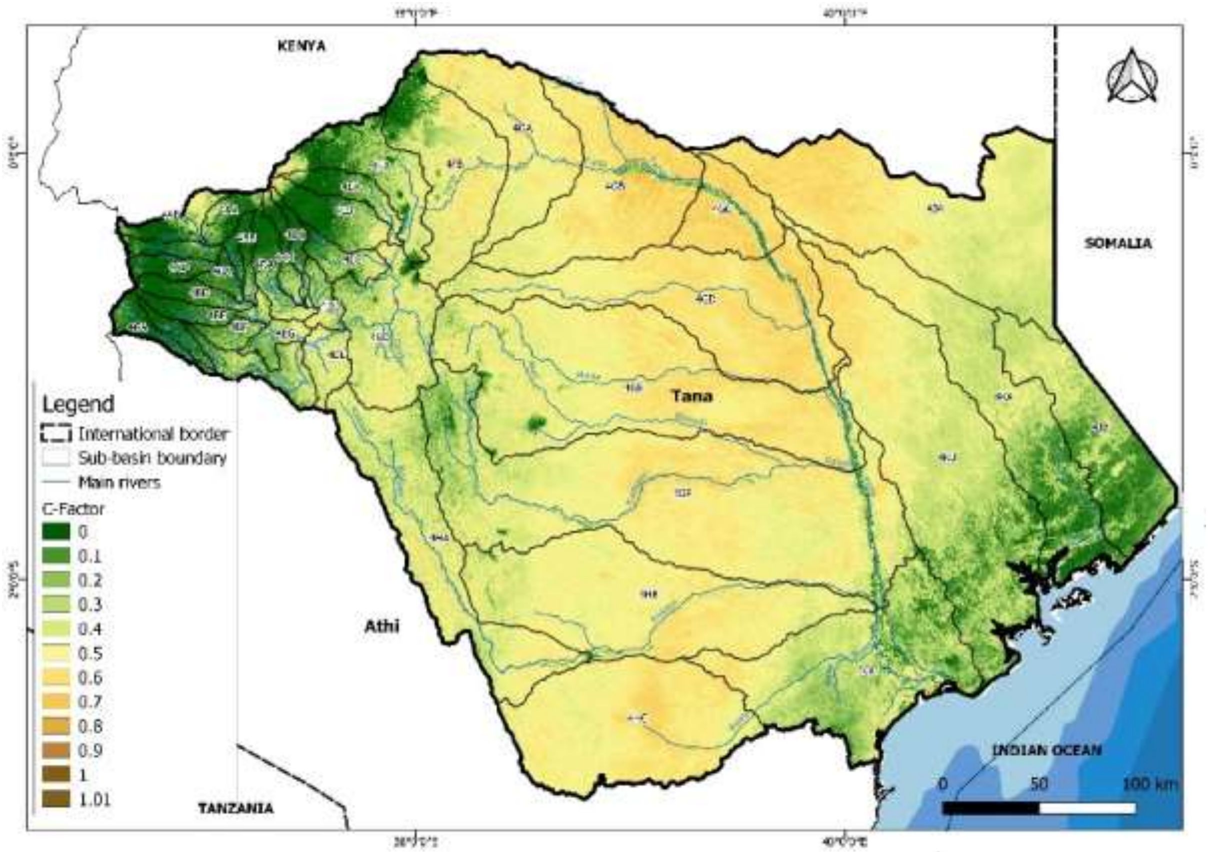


Figure 2-18: Vegetation cover in the Tana Basin

The vegetation cover in the Tana Basin is mainly savanna vegetation. The coastal areas are covered with mosaics of forests as well as tropical rainforest, swamp forest and mangrove areas. Table 2-5 lists some of the main forested hills in the Tana Basin.

Table 2-5: Major forests in the Tana Basin

Forest Mountain /Hill	Catchment	County
Aberdares	4AB, 4AC, 4AD, 4BD, 4BE, 4CA	Nyeri, Murang'a, Kiambu
Kikuyu Escarpment C	4CA	Kiambu
Nyeri Hill	4AB, 4AC	Nyeri
Muringato Nursery	4AB	Nyeri
Nyeri	4AB	Nyeri
Kiganjo	4AB	Nyeri
Mount Kenya	4AA, 4BB, 4DA, 4DC, 4EB, 4EC, 4EB, 4EA, 4FA	Nyeri, Kirinyaga, Tharaka-Nithi, Meru
Lusoi	4AB	Nyeri
Thunguru Hill	4EA	Meru
Upper Imenti	4EA	Meru
Lower Imenti	4EA	Meru
Kiega	4EA	Meru
Nyambeni A, B	4FB	Meru
Ngaia	4FB, 4GA	Meru
Thuuri	4FB	Tana
Kiagu	4FA	Tharaka Nithi
Njuguni	4EA	Tharaka Nithi
Munguni	4EA	Tharaka Nithi
Mutharanga	4EA, 4FA	Tharaka Nithi
Ntugi	4FA	Tharaka Nithi
Kijege	4FA	Tharaka Nithi
Kierera	4FA, 4EA	Tharaka Nithi
Kikingo	4FB	Tharaka Nithi
Maatha	4FB	Tharaka Nithi
Mutejwa	4FB	Tharaka Nithi
Gaikuyu	4ED	Kitui
Imba-Chakuyu	4GE	Kitui
Nuu	4GE	Kitui
Mutito	4GF	Kitui
Makongo_A	4GE, 4GF	Kitui
Endau	4GE	Kitui
Ngamba an East Ngamba	4GE	Kitui
Witu	4GG	Lamu

2.2.3.2 Biodiversity

Biodiversity in Tana Basin is linked to water resources and forest reserves or protected areas. The main biodiversity area is the Tana River Delta, which is known to include many endemic plants, primates, amphibians and reptiles (Ministry of Environment and Mineral Resources, 2012). The main biodiversity area is the Tana River Delta, which is known to include many endemic plants, primates, amphibians and reptiles (Ministry of Environment and Mineral Resources, 2012). The Delta provides a habitat for 320 plant taxa and hosts seven plants on the IUCN Red list (Ministry of Environment and Mineral Resources, 2012). It is a critical feeding and wintering ground for several migratory water birds such as waders, gulls and terns (Birdlife International, 2019; RAMSAR, 2020). The estuaries, mangroves and shorelines provide a habitat for a wide range of fish species and CITES (Convention on International Trade in Endangered Species of Wild Fauna & Flora) shark species have been recorded in the Delta area (Ministry of Environment and Mineral Resources, 2012). Figure 2-19 shows an example of an endemic bird of the Tana Basin.

Figure 2-19: Tana River Cisticola

2.2.3.3 Protected areas

There are 19 National Parks/Reserves in the Tana Basin, including the Kiunga Marine Reserve. The Tsavo East National Park falls partly within the Basin and is one of the largest protected areas in the country. Figure 2-20 shows the location of the main protected areas in the basin.

The Kenya Water Tower Agency (KWTA) is responsible for the management of areas considered to be water towers for downstream water supply. The Tana Basin has three gazetted Water Towers and 18 non-gazetted Water Towers.

Although the Tana River Delta is not a protected area, it is an important wetland ecosystem and is one of the most ecologically important wetlands in the country. The Delta is a Ramsar wetland and therefore Kenya Wildlife Services (KWS) has a mandate to protect the ecosystem, although this does not exclude sustainable human use. Table 2-6 presents the important and protected areas in the Tana Basin.

Table 2-6: The important and protected areas in the Tana Basin

County	Water Tower	Forest	Protected area	Wetland
Kiambu	Aberdares	Aberdares, Kikuyu, Escarpment_C		Various wetlands
Murang'a	Aberdares	Aberdares	Aberdare National Park	Various wetlands
Nyeri	Aberdares, Mount Kenya, Nyeri Hills (N), Karima Hills (N), TumuTumu Hills (N), Kiamachero (N)	Aberdares, Nyeri Hill, Muringato Nursery, Nyeri, Kiganjo, Mount Kenya, Lusoi	Aberdare National Park Mount Kenya National Reserve and Park	Various wetlands
Kirinyaga	Mount Kenya	Mount Kenya	Mount Kenya National Reserve and Park	Various wetlands
Embu	Mount Kenya, Kirimiri (N), Kiang'ombe Hills (N)	Mount Kenya	Mount Kenya National Reserve and Park Mwea National Reserve	Various wetlands
Tharaka-Nithi	Mount Kenya, Imenti (N)	Mount Kenya, Kiagu, Njuguni, Munguni, Mutharanga, Ntugi, Kijege, Kierera, Kikingo, Maatha, Mutejwa	Mount Kenya National Reserve and Park	
Meru	Mount Kenya, Ngaia Hills (N), Nyambene Hills	Mount Kenya, Thunguru Hill, Upper Imenti, Lower Imenti, Nyambeni A, B, Ngaia	Mount Kenya National Reserve and Park Meru National Park	Various wetlands
Machakos				
Kitui	Mumoni Hills (N), Kyawea (N), Kavonge/Museve Hills (N), Mutito Hills (N), Nuu Hills (N), Endau Hills (N), Mutha Hills (N), Mutuluni Hills (N)	Gaikuyu, Imba-Chakuyu, Nuu, Mutito, Makongo_A, Endau, Ngamba and East Ngamba	North Kitui National Reserve	Various wetlands, Ndarupa Swamp
Isiolo			Bisandi National Reserve	
Tana River		Nyambeni A, B, Thuuri	Kora National Park Tana River Primate National Reserve	Tana River Delta, Tula wetlands, Matia Haraman wetlands, Msonbala Marsh
Garissa			Rahole National Reserve Arawale National Reserve Boni National Reserve	Various wetlands
Lamu	Lk Kenyatta (N)	Witu	Dodori National Reserve	Lamu-Kiunga Mangroves

N: Non-gazetted water tower

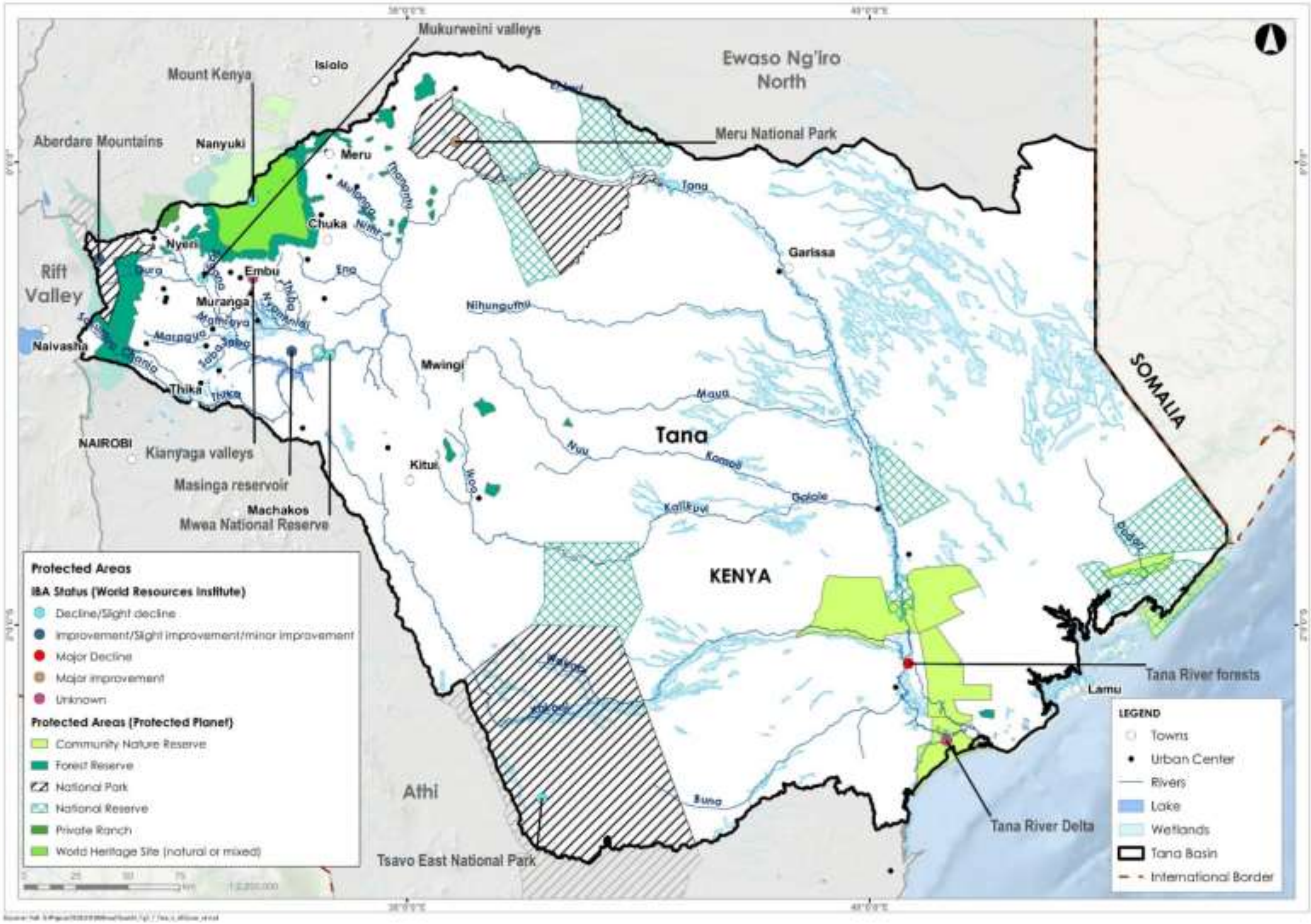


Figure 2-20: Protected areas across the Tana Basin

2.2.3.4 Land use

Land use in the Tana Basin includes forest, grassland/rangeland, agricultural use and urban areas. The Basin has a high population density and scattered urban and built-up areas in the upper sections of the basin with the dominant land use as rain-fed agriculture and rangeland. Figure 2-21 shows the major land cover types in the Tana Basin.

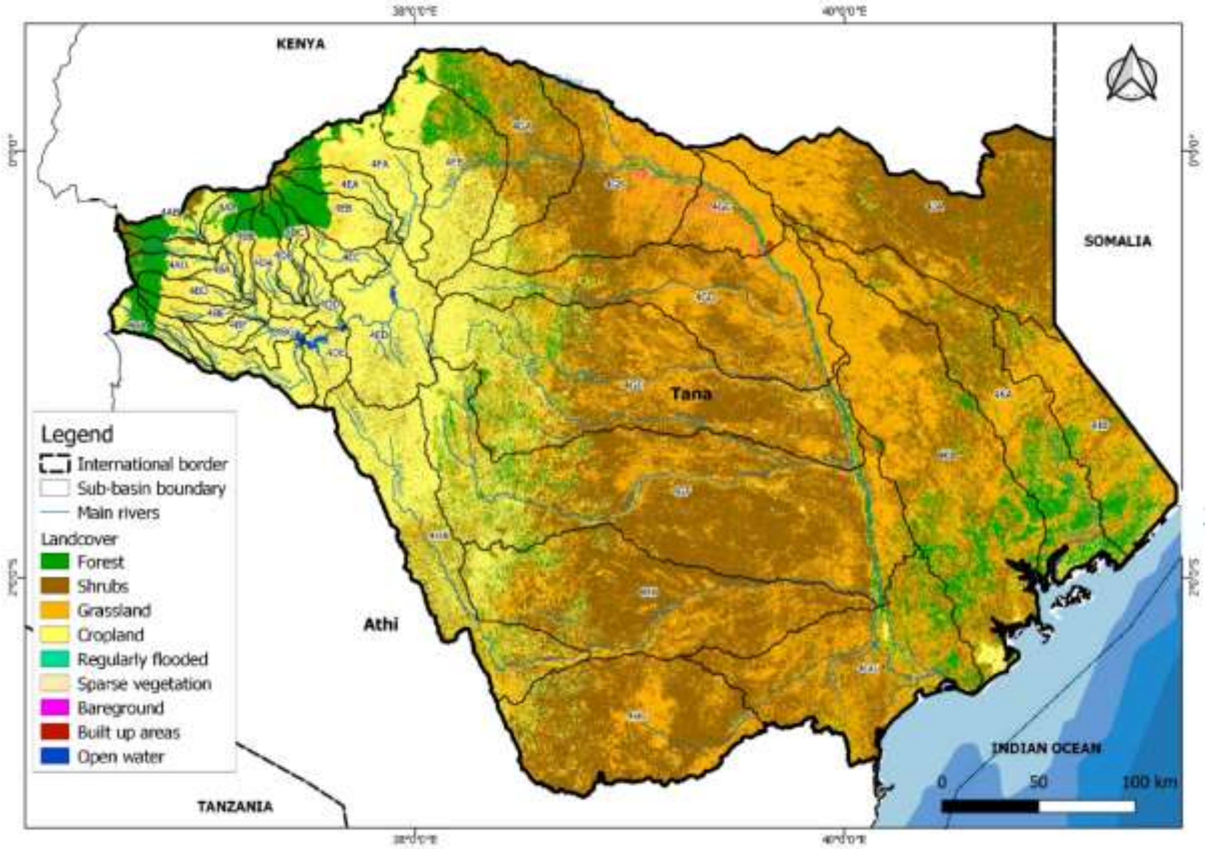


Figure 2-21: Tana Basin land cover map

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 Tana 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 Tana Basin, provided 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. Most of the basin has sustainable cropland use, except in the upper zone of the Basin (Figure 2-22). The highest level of unsustainable cropland use occurs in sub-basin 4BA, followed by 4BF and 4BD.

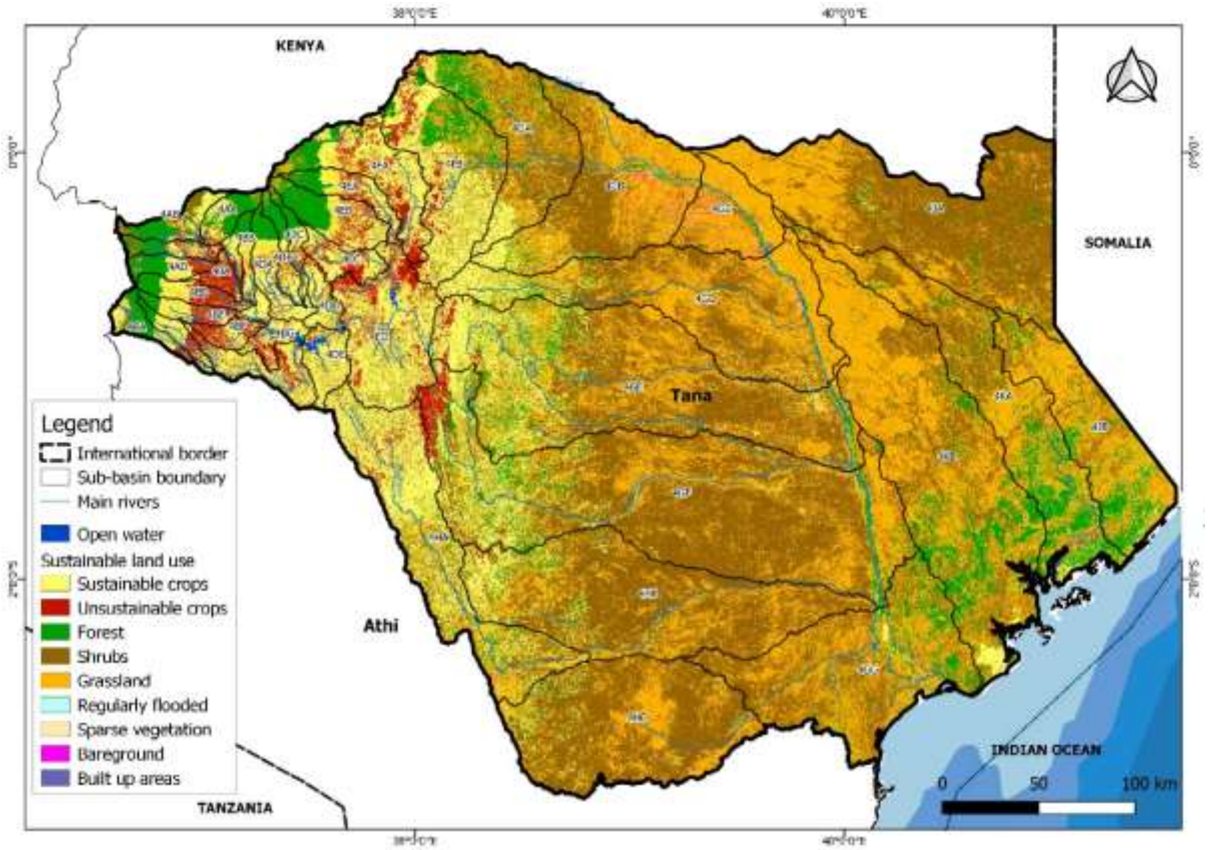


Figure 2-22: Sustainability of current land use in the Tana Basin

2.3 Socio-economics

Water plays a key role in the socio-economic environment in the Tana 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 Tana Basin in 2019 was estimated as 6.96 million, which is equivalent to a population density of 55 persons/km^2. Most of the population in the Tana Basin reside in rural settlements, with only 22% of the population currently found in urban areas.

Projections based on Census 2019 (Kenya National Bureau of Statistics, 2009) population data and United Nations population growth rates as estimated in the Kenya Vision 2030, indicate that the basin population will increase to 10.4 million by 2030 (Water Resources Management Authority, 2013). The rural population is projected to reduce from 4.7 million in 2010 to 4.0 million in 2030. The urban population is projected to increase from 1.0 million to 6.3 million by 2030 (Water Resources Management Authority, 2013).

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 Tana Basin is 0.9, which indicates that, on average, all adults have completed primary school education and very few completed secondary school education. This is an average value, individuals in a given area will differ.

2.3.2 Economy

2.3.2.1 Economic activity

There is limited economic activity in the Tana Basin and the average poverty rate in the Basin is at 40%. Key economic activities in the 14 counties within the Tana Basin are summarised in Table 2-7.

Table 2-7: Main economic activity of each county

County	Economic Activities	Reference
Nyeri	The Nyeri County is very agriculturally productive due to its high rainfall and fertile conditions, and cash crops such as tea and coffee are commonly grown in the area. The nearby Mount Kenya and Aberdare National Parks attract many tourists. Due to its large population, commerce thrives in the major urban centres.	(County Government of Nyeri, 2018)
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.	County Government of Kiambu, 2018
Murang'a	Murang'a County's economy is mainly dependent on agriculture. The major cash crops include tea, coffee, avocado, mangoes, macadamia and horticulture crops. Other economic activities in the county include quarry mining, bee keeping and small-scale fishing. The Murang'a County landscape includes a portion of the Aberdare Mountains to the west.	County Government of Murang'a, 2018
Kirinyaga	Kirinyaga County is located on the southern slopes of Mount Kenya. The county has six major rivers namely; Ragati, Sagana, Thiba, Nyamindi, Rwamuthambi and Rupingazi, all of which drain into the Tana River. Agriculture is Kirinyaga County's main economic activity. The forest areas of Mount Kenya attract many tourists to the county, and the trade and commerce industries are growing.	County Government of Kirinyaga, 2018
Embu	Agriculture is the main economic activity is the Embu County. Trading and commerce is also common in the area, and athletes do high altitude training on the foot slopes of Mount Kenya. Embu County is one of the five whose borders extend to the top of Mount Kenya.	County Government of Embu, 2019
Tharaka-Nithi	The terrain in Tharaka-Nithi County is mostly hilly. The major economic activities in Tharaka-Nithi county include coffee and tea, subsistence crops, subsistence dairy and livestock farming such as goats and sheep. In order to boost trade, the county has joined the Mount Kenya Trading and Economic bloc.	County Government of Tharaka Nithi, 2018
Meru	Meru County is on the eastern slopes of Mount Kenya, which form the headwaters of tributaries which drain into Tana and Ewaso Ng'iro Rivers. The main land use in the county is agriculture of crops and livestock. The main economic activities in Meru County are agriculture, wholesale and retail trade and tourist attractions such as National Parks.	County Government of Meru, 2018
Isiolo	The Merti Plateau extends down towards Lorian Swamp in Isiolo County. More than half of the county is severely arid with erratic and unreliable rainfall, limiting rainfed agriculture. The county's economy is therefore based on livestock production and pastoralism is the main economic activity. The Samburu and Shaba Game Reserves, Buffalo Springs, Lewa Downs and the Meru National Park are popular tourist destinations. Traditional jewellery making also contributes to the local tourism market.	County Government of Isiolo, 2018

County	Economic Activities	Reference
Garissa	Garissa County is within the ASAL region and is mostly flat without significant topographical features. The major physical features are the seasonal Laghas and the Tana River on the Tana Basin side. Most of the county practices pastoralism. The tourism industry is growing, and the main attractions are camel-riding and camping.	County Government of Garissa, 2018
Tana River	Tana River County is in the coastal region of Kenya. The topography in the Tana River County slopes down from the North-East towards the South-West coast. Farming and nomadic pastoralism are the main economic activities in Tana River County. Tourists are also attracted to the area due to the large ecological diversity of the Tana River Delta.	County Government of Tana River, 2018
Kitui	The landscape of Kitui County is generally flat and slopes gently down from west to east. In Kitui County, agriculture is the main economic activity, particularly subsistence farming. Wholesale and retail trade also contribute to the economy of the county.	County Government of Kitui, 2018
Machakos	Machakos County has both food crops and cash crops. The food crops include maize, beans, pigeon peas and cassava while cash crops include coffee, French beans, pineapples and sorghum. 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.	County Government of Machakos, 2018
Kilifi	Kilifi County has numerous opportunities in agriculture, particularly dairy and crop farming thanks to fertile soils and a good weather pattern. There exist several irrigation schemes in Kilifi. 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.	County Government of Kilifi, 2018
Lamu	Lamu County falls along the coastal regions of Kenya. The flat topography makes the county prone to flooding during the rainy seasons and periods of high tides. Lamu County consists of 65 islands forming the Lamu Archipelago. The main economic activities in Lamu County include fisheries, crop production, livestock production and tourism. Lamu Island is a rich heritage site including preserved Swahili architecture, which attracts many tourists to the area. The construction of a port at Lamu is currently ongoing which is planned to boost the county's economy.	County Government of Lamu, 2018

2.3.2.2 Employment and livelihoods

The formal sector is made up of both public and private enterprises which have been legally established or are listed with the registrar of companies. Most formal employment is in the urban centres although there is also formal employment in rural areas. The informal sector, also known as *jua kali*, employs 44% of the labour force in Tana Basin and covers all small-scale activities that are semi-organised, unregulated and use basic technologies. This sector provides employment for both rural and urban dwellers. Small-scale irrigation and pastoralism make up a large portion of the employment in the Tana 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 formal employment in the urban areas to subsistence agriculture and crop and livestock production in the pastoral and farming areas. The main livelihoods of the various counties are described below:

Table 2-8: Livelihood activity of each county

County	Livelihood Activities	Reference
Nyeri	Up to 22% of the population are employed in the formal economy and 37% are self-employed in areas such as agriculture or the Jua Kali and trade sectors. Unemployment is at 17.5% therefore the dependency ratio in the county is at 51%. There is a need to provide affordable credit to encourage more self-employment and establishing cottage industries to add value from farm produce.	(County Government of Nyeri, 2018)
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, supermarkets, 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
Murang'a	Up to 17% of the population are employed in the formal economy and 35% are self-employed in areas such as agriculture or the Jua Kali and trade sectors. Unemployment is at 17.7%. Most of wage earners earn their living from the agricultural and construction sectors.	County Government of Murang'a, 2018
Kirinyaga	Up to 14% of the population are employed in the formal economy and 39% are self-employed in areas such as agriculture or the Jua Kali and trade sectors. Unemployment is at 19.8%. Self-employment opportunities are expanding with the expansion of towns and market centres in the county due to rural urban migration.	County Government of Kirinyaga, 2018
Embu	Up to 17% of the population are employed in the formal economy and 43% are self-employed in areas such as agriculture or the Jua Kali and trade sectors. Unemployment is at 2.5% in Manyatta and Runyenjes and 5.9% in Mbeere North and Mbeere South. Self-employment opportunities are mainly in cash crop farming including tea, coffee miraa and dairy farming.	County Government of Embu, 2019
Tharaka-Nithi	Up to 14% of the population are employed in the formal economy and 37% are self-employed in areas such as agriculture or the Jua Kali and trade sectors. Unemployment is at 63%. Most people in the rural areas engage in livestock and crop farming, private businesses and other forms of income generation. The upper zones of the county have had a rise in tea, coffee, bananas, beans and maize; whilst the productivity of green grams, millet, sorghum and peas in high in the lower zone of the county.	County Government of Tharaka Nithi, 2018
Meru	Up to 10% of the population are employed in the formal economy and 10% are self-employed in areas such as agriculture or the Jua Kali and trade sectors. A significant issue in the county is the percentage of child labour in the active labour force, which is high at 35%. Unemployment is close to the national average of 7%.	County Government of Meru, 2018
Isiolo	Up to 18% of the population are employed in the formal economy and 50% are self-employed in areas such as agriculture or the Jua Kali and trade sectors. Unemployment is at 70%. There are high illiteracy levels, which accounts for the low levels of employment in the formal economy. Most people in rural areas engage in the livestock trade.	County Government of Isiolo, 2018
Garissa	Only 4% of the population are employed in the formal sector and up to 28% of the population is self-employed in areas such as milk vending, Jua Kali, miraa selling, hawking and livestock. Unemployment is at 28%.	County Government of Garissa, 2018
Tana River	Up to 11% of the population are employed in the formal economy and 43% are self-employed in areas such as agriculture or the Jua Kali and trade sectors. Unemployment is at 42.8%.	County Government of Tana River, 2018
Kitui	Up to 18% of the population are employed in the formal economy and 64% are self-employed in areas such as agriculture or the Jua Kali and trade sectors. Most of the self-employed are involved in farming.	County Government of Kitui, 2018

County	Livelihood Activities	Reference
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
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
Lamu	Up to 16% of the population are employed in the formal economy and 45% are self-employed in areas such as agriculture or the Jua Kali and trade sectors. Up to 46% of the labour force is illiterate which limits their involvement in the formal economy. Most of the unskilled labour force is involved in fishing, boat making, wood-carving and embroidery.	County Government of Lamu, 2018

2.3.3 Standard of living

2.3.3.1 Water supply and sanitation

The total storage volume of the existing dams in the Tana Basin is about 2 400 MCM, of which less than 1% is stored in small dams and pans (Water Resources Management Authority, 2013). There is currently an inter-basin transfer from Sasumua and Thika dams to Nairobi in the Athi Basin, with a total combined capacity of 181 MCM per annum (Water Resources Management Authority, 2013). It is estimated that there were about 1 600 boreholes in the Tana Basin in 2010 (Water Resources Management Authority, 2013), with a total abstraction volume in the order of 73 MCM per annum.

About 25% of the total population in the Basin is supplied directly from springs and boreholes. Almost half of the urban population receives piped water from a Water Service Provider (WSP), while 29% of the rural population receives piped water from a WSP (Water Resources Management Authority, 2013).

Most of the urban and rural populations make use of septic tanks and pit latrines for sanitation. There are currently no sewerage systems in place in the rural areas, and only 7% of the urban population has access to formal sewerage systems (Water Resources Management Authority, 2013).

The Water Act 2016 devolves water and sanitation services to the County Governments, who provides these services through Water Service Providers (WSPs). The Tana Water Works Development Agency and Coast Water Works Development Agency contract WSPs to provide potable water to the population in the Tana Basin. There are 12 urban WSPs and 18 rural WSPs operating across the Tana Basin.

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 owners a limited term on property, which can be extended upon expiry. Kenyan constitution limits tenure for non-citizens to a maximum of 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 landowner. 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 in Tana Basin are as follows:

Table 2-9: Land tenure of each county

County	Land tenure	Reference
Nyeri	Up to 85% of landowners have received title deeds. Most of the land in the county is owned by individuals as freehold and mainly where subsistence farming is practiced.	(County Government of Nyeri, 2018)
Kiambu	Officially 85% of landowners have received title deeds. Within the registered there is a large number of land parcels that has been subdivided and titles have not been registered.	County Government of Kiambu, 2018
Murang'a	Up to 14% of landowners have received title deeds. Most of the land use is agricultural therefore land holding is considered important. There is limited landlessness in the county.	County Government of Murang'a, 2018
Kirinyaga	Up to 67% of landowners have received title deeds, with 23% of the farmers in the lower zones of Mwea are farming on land owned by the National Irrigation Authority (NIA). Individuals own the land in the upper parts of the county while the lower parts are mostly owned by the NIA	County Government of Kirinyaga, 2018
Embu	Up to 29% of landowners have received title deeds. The Embu county is predominantly rural, with concentrations of people along the major permanent water sources where irrigation, farming and fishing are carried out. The lower parts, where there is less rainfall, have a more scattered settlement pattern.	County Government of Embu, 2019
Tharaka-Nithi	Up to 62.1% of landowners in the lower part of the county have received title deeds. Freehold land is the most common land tenure in the county, which is mainly put to agricultural use.	County Government of Tharaka Nithi, 2018
Meru	More than 60% of land in the county is registered as private land. There are incidences of landlessness in Meru town, Timau township, and Subuiga area.	County Government of Meru, 2018
Isiolo	Less than 1% of land in the county has title deeds, with more than 80% of the land being communally owned.	County Government of Isiolo, 2018
Garissa	The county is mainly communal land.	County Government of Garissa, 2018
Tana River	Up to 4.3% of land in the county has title deeds. Most of the land is communal.	County Government of Tana River, 2018
Kitui	Up to 25% of landowners in the county have received title deeds. Approximately 46% of the county is arable, with most people not owning title deeds to this land	County Government of Kitui, 2018
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
Lamu	Up to 42% of landowners in the county have received title deeds. The issue of land ownership is a thorny issue as most people who farm the land, do not own the land.	County Government of Lamu, 2018

2.4 Water resources

2.4.1 Surface water resources

2.4.1.1 Conceptual approach to surface water resources assessment

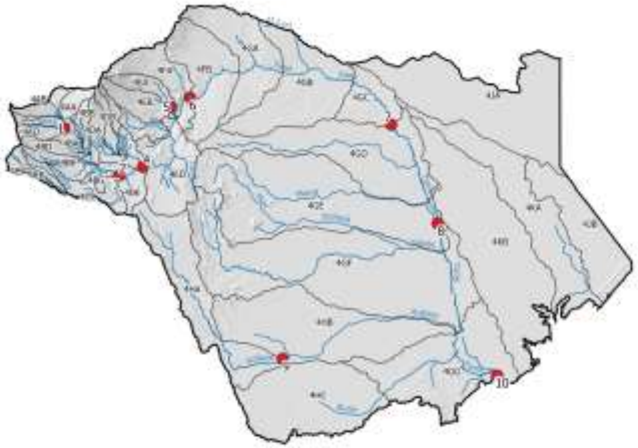
A surface water resources analysis for the Tana Basin was undertaken to quantify the available surface water within the basin under natural conditions in both space and time (see **Annexure A3**). This involved the development of a water resources systems model of the basin, including a rainfall-runoff model, which simulates water availability and demands and the movement of water through river networks and water infrastructure associated with different levels of water resources development. 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 Tana Basin are provided in "ISC Report C1-5: Tana Surface Water Resources Assessment".

2.4.1.2 Surface water resources potential

Figure 2-23 displays the simulated natural Mean Annual Runoff (MAR) at key locations across the Tana Basin. From Figure 2-23, the following observations can be made:

- The total Tana River natural runoff equals 7 082 MCM/a.
- More than 80% of the runoff in the Tana River originates upstream of the proposed High Grand Falls Dam site.
- About 40% of the runoff in the Tana River Basin originates upstream of Masinga Dam.
- The central part of the basin does not contribute any significant flow.
- There are significant losses along the lower Tana River and in the catchments joining the Tana River downstream of Garissa.



Node number	River name	MAR (MCM/a)
1	Upper Tana River	570
2	Tana R at Masinga Dam	1 890
3	Thika R u/s Masinga Dam	605
4	Thiba River	551
5	Nthi River	645
6	Tana at Grand Falls	6 130
7	Tana at Garissa	7 238
8	Tana at Hola	7 493
9	Upper Kokani R	440
10	Tana at Kipini	7 082

Figure 2-23: Natural mean annual runoff and seasonal flow patterns at key nodes

2.4.1.3 Seasonal flow variability

The rivers in the Tana Basin show a distinct seasonality in monthly flows with two peak flow seasons, the highest in April to May and a second, slightly lower peak in November to December. River flows are lowest in August and September.

To assess the extent to which the seasonal flows in the rivers vary, a Seasonal Index Map was developed (Figure 2-24), which expresses the average cumulative natural flow volume during the three driest consecutive months at each sub-basin outlet as a proportion of the total annual cumulative natural flow volume at the same location. From the map it is evident that most of the basin is characterised by very low flows during the dry season.

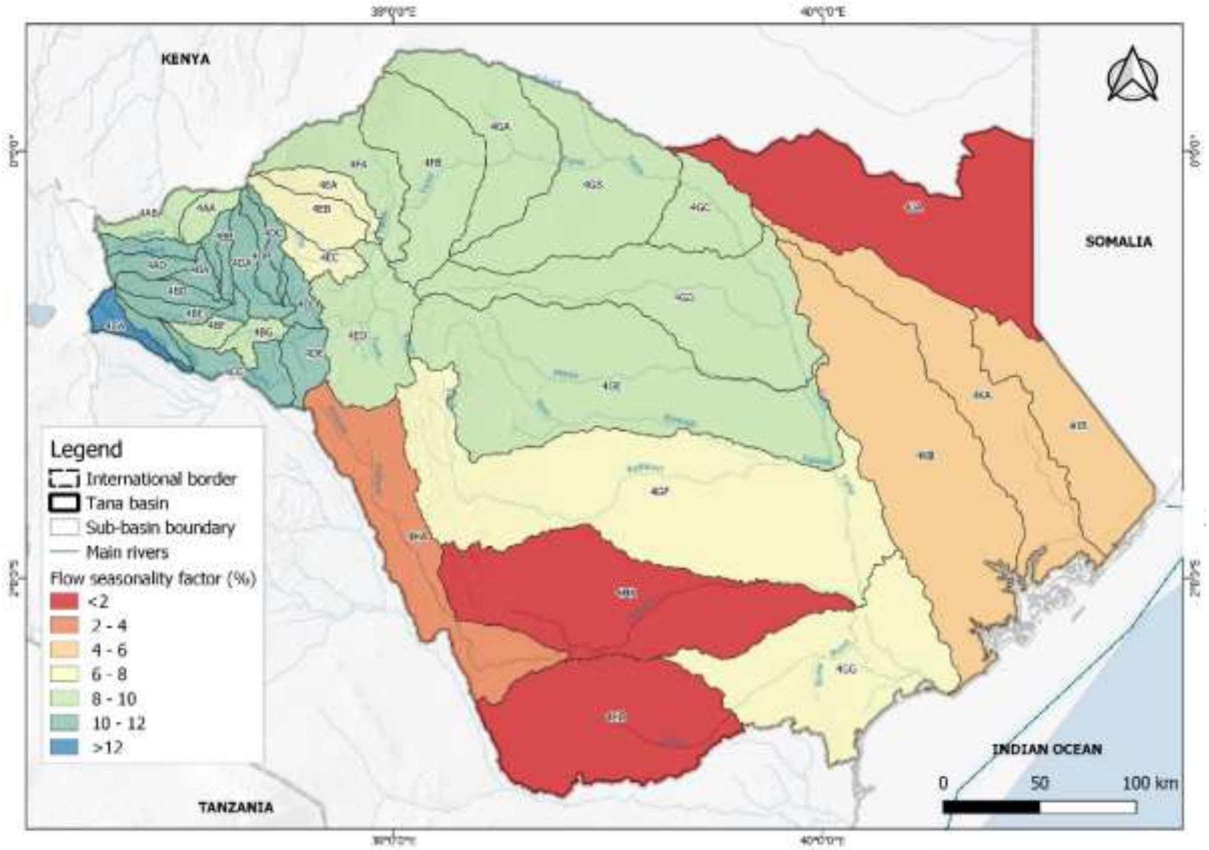


Figure 2-24: Flow seasonality Index per sub-basin

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 2-25 displays the annual variability of natural flow of the Tana River at Garissa. It highlights the inter-annual flow variability and declining trend in flow, which supports the need for the provision of more storage within the basin to improve resilience and assurance of supply. Especially as the Tana River is the main source of water supply to Nairobi, while also supplying almost 50% of Kenya’s electricity.

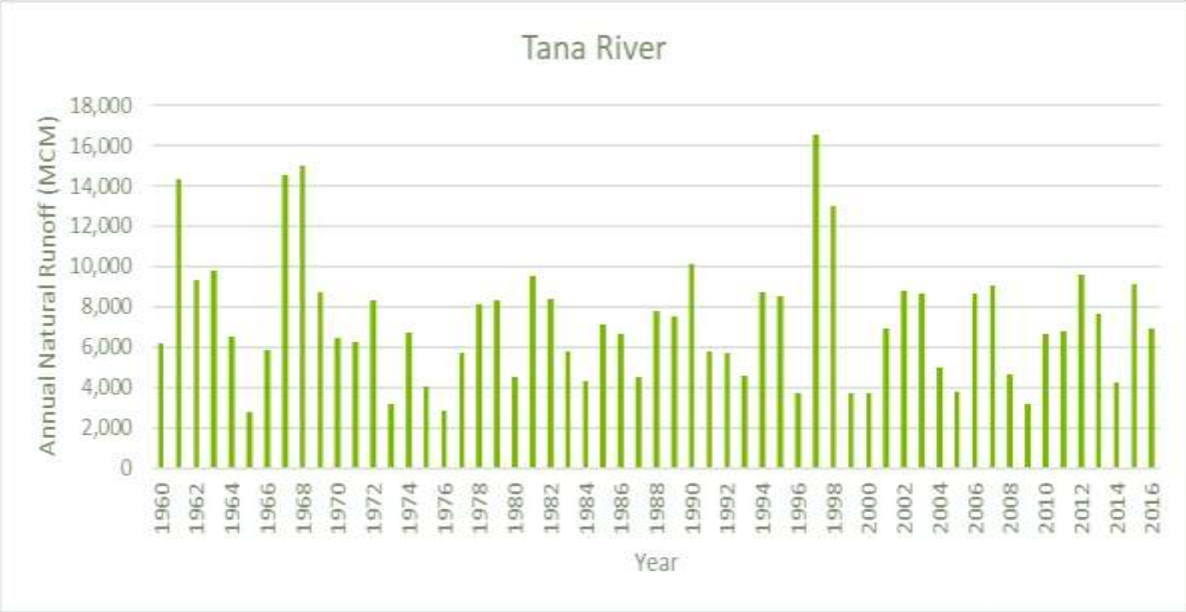


Figure 2-25: Annual flow variability in the Tana River at Garissa

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 2-26 shows calculated natural unit runoff values at sub-basin scale and highlights the significant variability across the basin from east to west in terms of absolute runoff.

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 2-27, the sub-basins in the north-western, upper region of the basin have high runoff coefficients between 15 and 30%. Further downstream and along the eastern and southern parts of the basin, runoff coefficients are generally less than 5%, which highlights the contrast between the upper and lower basin in terms of hydrological response. The average runoff coefficient across the basin equals 8.3%.

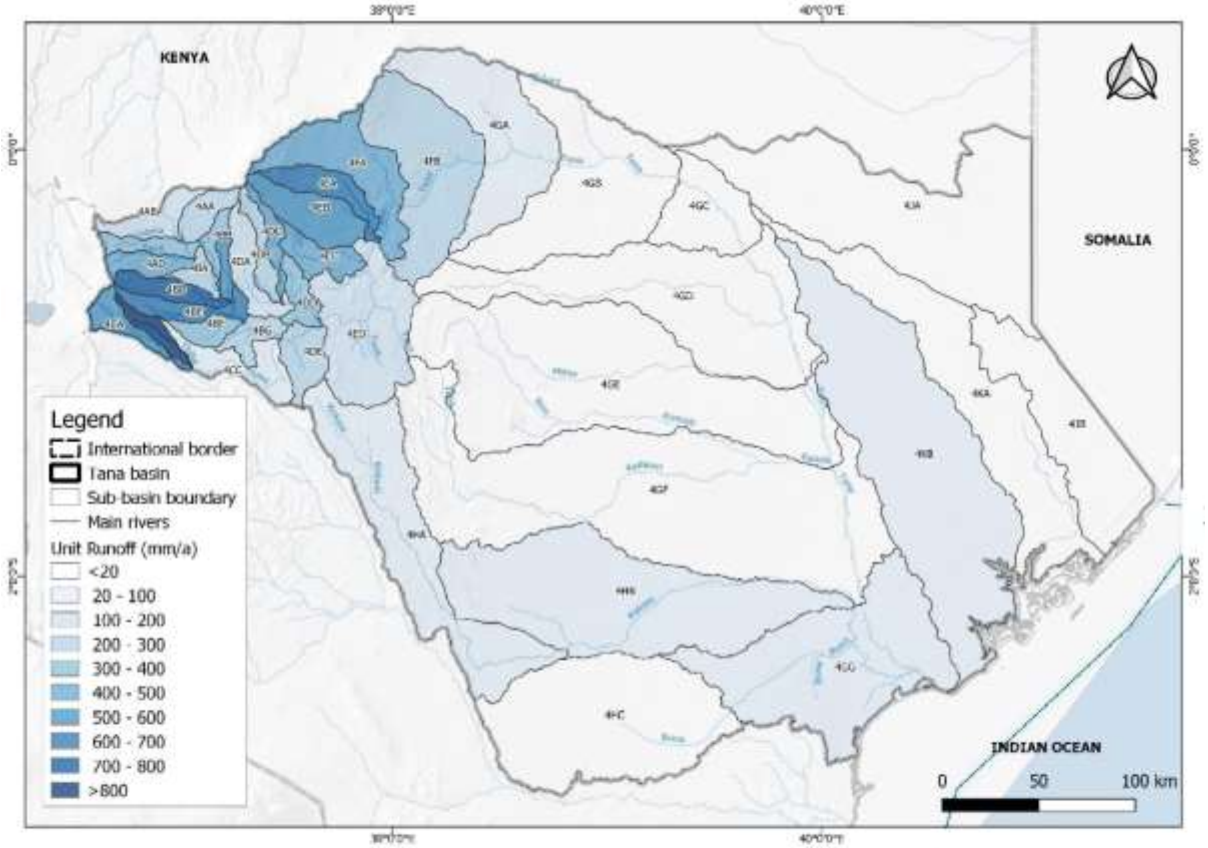


Figure 2-26: Unit runoff per sub-basin

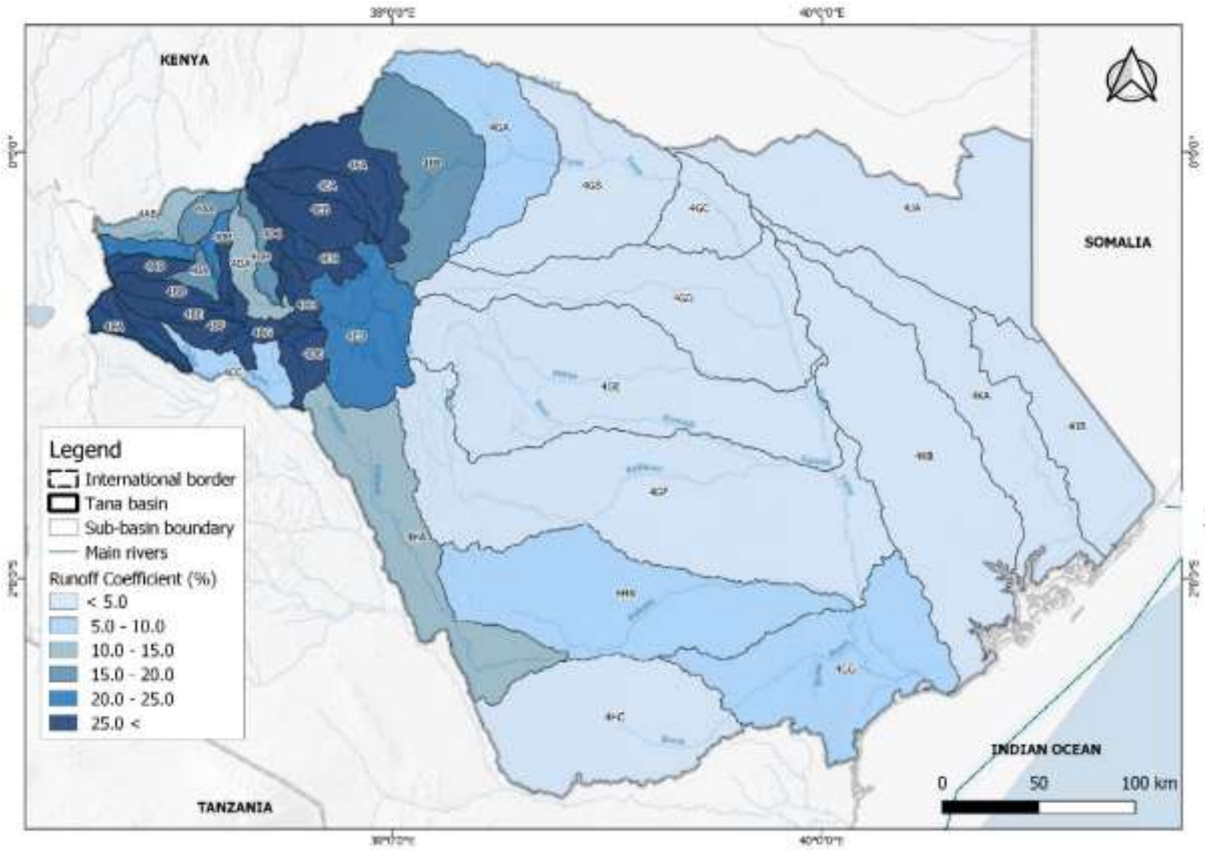


Figure 2-27: Runoff coefficient per sub-basin

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 Tana Basin. The RCP 4.5 analysis predicted that the Mean Annual Precipitation across the Tana Basin would increase from 673 mm to 723 mm by 2050, while day and night temperatures in the basin are expected to increase by up to 1.22°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 Tana Basin to assess the potential impacts on runoff. Figure 2-28 shows that the natural runoff in the basin is expected to increase in most sub-basins by between 2% and 6%, with some sub-basins as high as 8%. However, the natural runoff in sub-basins 4KA, 4KB and 4JB are expected to decrease. The total surface water runoff from the Tana Basin is projected to increase with 4% by 2050 under RCP 4.5 to 7 365 MCM/a.

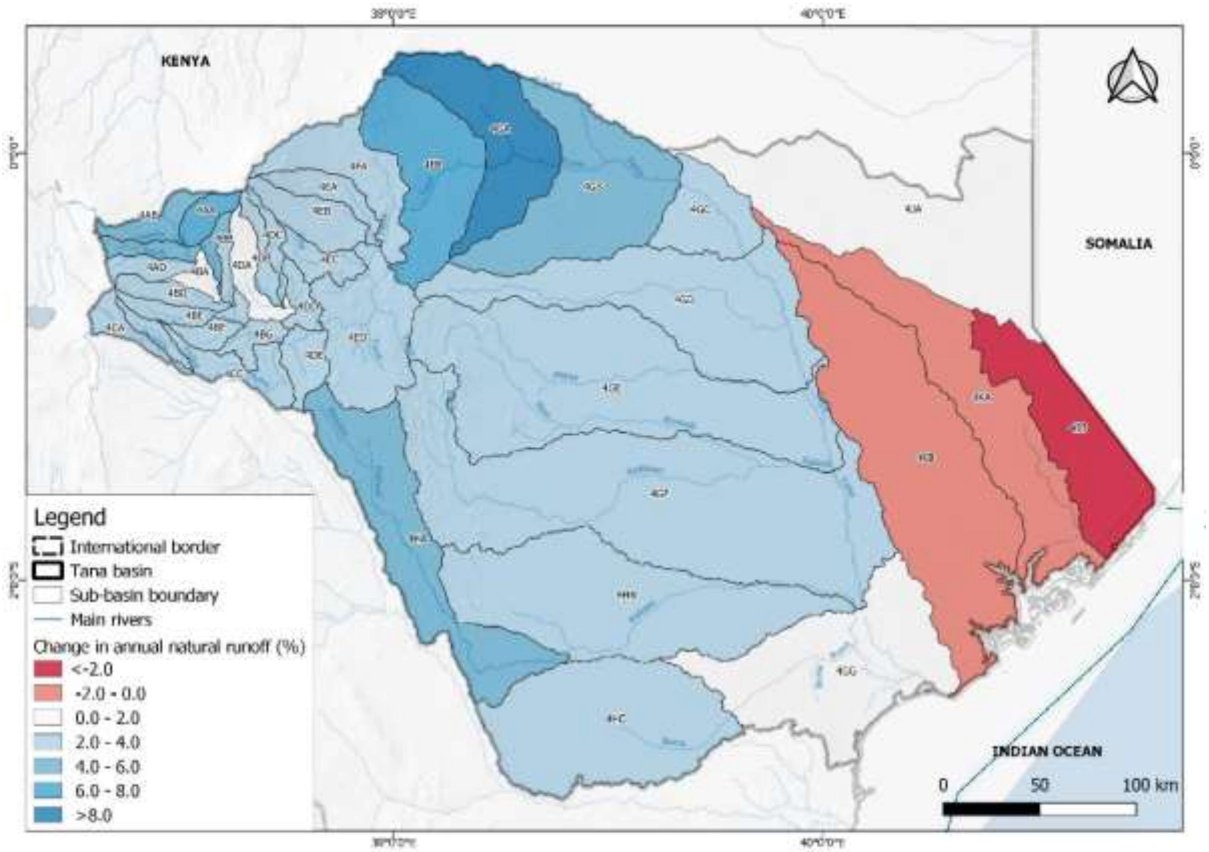


Figure 2-28: Climate change impacts on natural runoff in the Tana Basin 2050 (RCP 4.5)

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 Tana Basin was undertaken as part of this Consultancy (see **Annexure A4**). This entailed a GIS-based approach that used existing eridata 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 Tana Basin was estimated at 4 479 MCM/a, with a sustainable annual groundwater yield of 693 MCM/a. This is very similar to the Kenya National Water Master Plan (NWMP) 2030 sustainable groundwater yield estimate of 675 MCM/a for the Tana Basin (Water Resources Management Authority, 2013). 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 2-29 and Figure 2-30 display the annual recharge and potential groundwater availability in the Tana Basin. Good groundwater potential is found in the north-western part of the Tana basin, as well as the eastern part adjoining the coast.

Annexure B lists the groundwater potential per sub-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 Tana Basin to assess the potential impacts on recharge and groundwater potential. It was found that the recharge in the basin will increase by 7% to 4 792 MCM/a, while the potential groundwater yield is expected to increase by 7.5% to 745 MCM/a under RCP 4.5. This is different to the NWMP 2030 future sustainable groundwater yield which was projected to decrease in future (2030).

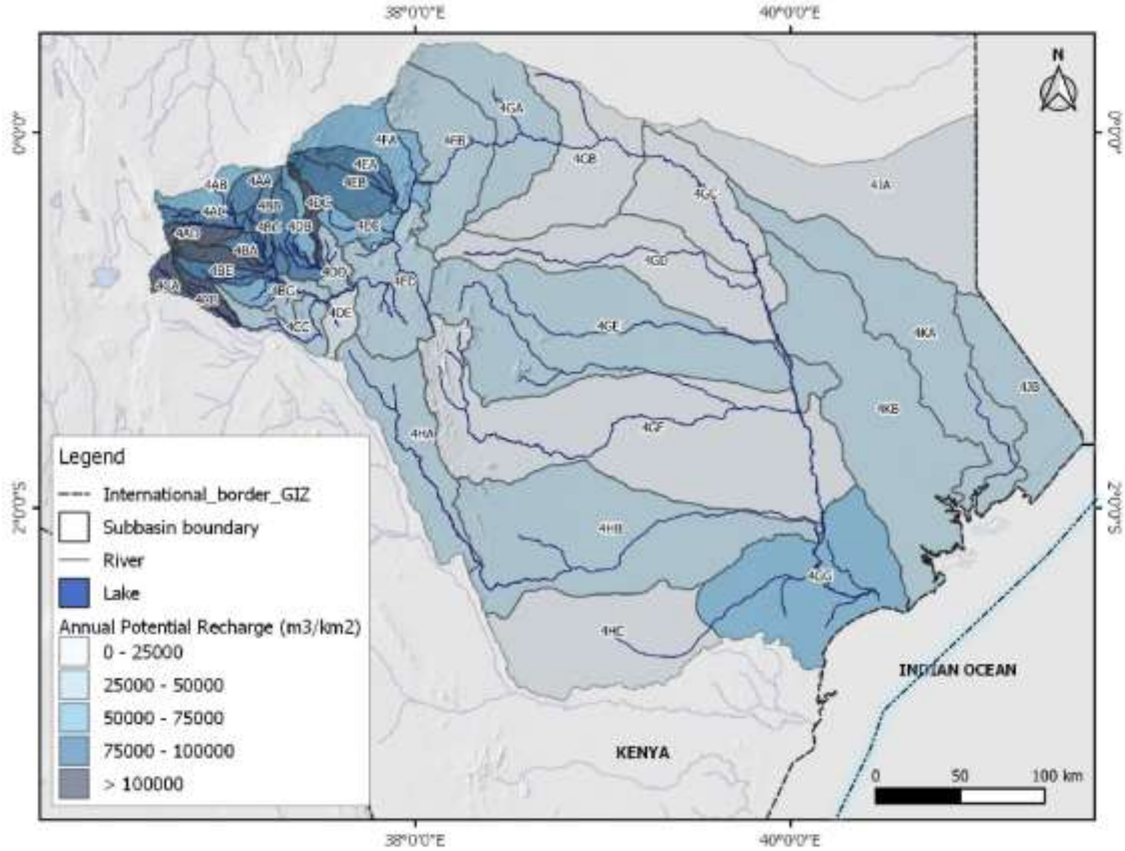


Figure 2-29: Estimated annual groundwater recharge in the Tana Basin

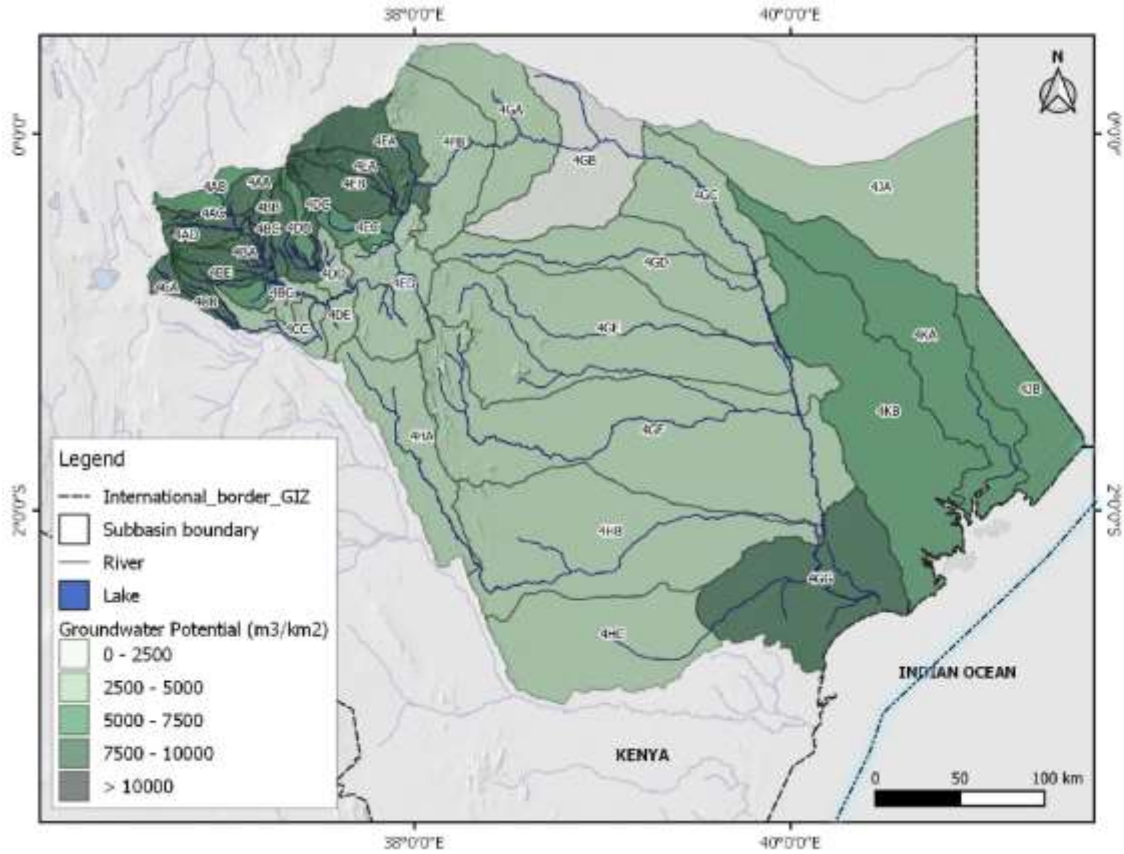


Figure 2-30: Estimated annual groundwater potential in the Tana Basin

2.4.3 Current water requirements

Currently, the main demand for water in the Tana Basin is for irrigation, followed by domestic and industrial demands as well as livestock water requirements. A significant volume of water is also exported (transferred) to the Athi Basin to augment Nairobi's water supply.

2.4.3.1 Irrigation water requirements

Irrigation area

To estimate current (2018) irrigation water requirements in the Tana 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 Kenya 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 current (2018) information provided by the NIA and the Department of Irrigation at the Ministry of Agriculture, Livestock and Fisheries on dominant crop types, cropping intensities, irrigation efficiencies. A 2018 FAO Kenya Irrigation inventory was also sourced.

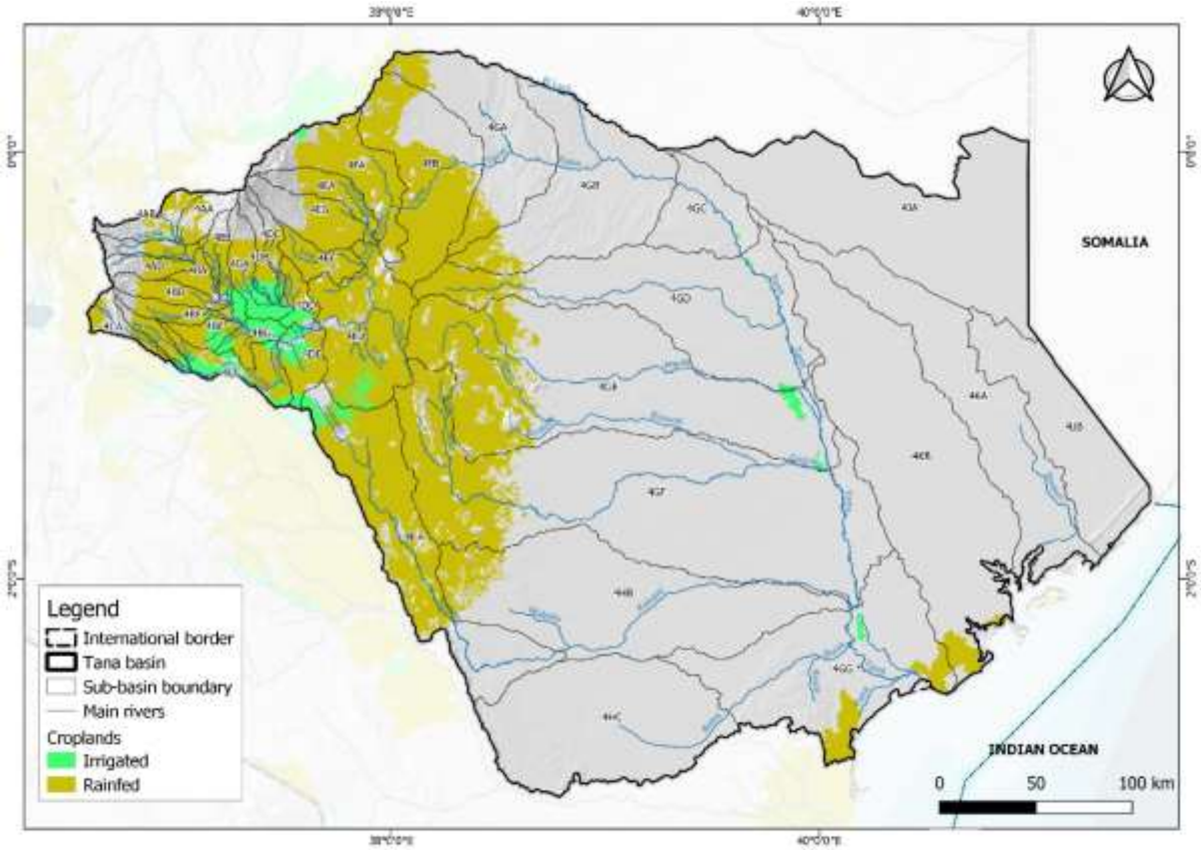


Figure 2-31: Irrigated crops in the Tana Basin (RCMRD Kenya Crop Mask, 2015)

An analysis and synthesis of the data and trends allowed present-day (2018) irrigated areas to be determined per sub-basin as summarised in Table 2-10. The total current (2018) irrigated area in the Tana Basin, including large-scale and small-scale as well as private irrigation, was estimated as 98 930 ha. This represents an increase of about 50% compared to the 2010 irrigation area of 64 425 ha as determined in the NWMP 2030.

Table 2-10: Irrigated areas per sub-basin (2018)

Sub-basin	Irrigated Area (ha)	Sub-basin	Irrigated Area (ha)	Sub-basin	Irrigated Area (ha)
4AA	1206	4CC	4970	4GB	578
4AB	1243	4DA	14133	4GC	223
4AC	838	4DB	9632	4GD	6070
4AD	1889	4DC	2723	4GE	1416
4BA	967	4DD	1014	4GF	2428
4BB	2189	4DE	494	4GG	3817
4BC	4536	4EA	2590	4HA	165
4BD	2464	4EB	4884	4HB	1195
4BE	2308	4EC	1366	4HC	903
4BF	659	4ED	2976	4JA	428
4BG	794	4FA	6850	4JB	176
4CA	1504	4FB	6200	4KA	386
4CB	1058	4GA	1608	4KB	47

Sub-basin	Irrigated Area (ha)	Sub-basin	Irrigated Area (ha)	Sub-basin	Irrigated Area (ha)
Total Irrigated Area		**98 930 ha**			

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 an average irrigation efficiency factor of 0.5 (Ministry of Agriculture, Livestock and Fisheries, personal communication, February 2019). 200% cropping intensities were assumed 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 current (2018) irrigation demand in the Tana Basin was calculated as 1 407 MCM/a, where the demand for small-scale irrigation is 880 MCM/a and the demand for large-scale irrigation is 527 MCM/a.

2.4.3.2 Domestic and Industrial water requirements

For the main urban centres in the Tana Basin, the latest water demand figures for domestic and industrial use were obtained from recent master plans or similar studies and projected to 2018 based on historical population growth factors.

For the remainder of the Tana Basin, water demands for urban domestic and industrial as well as rural domestic use were extracted per sub-basin from the NWMP 2030 and from the WRA Permit Database and compared. In cases where the PDB values were higher than the extrapolated NWMP 2030 estimates, the PDB values were used as representative of the current demand, and vice versa. The total domestic and industrial water demand in the Tana Basin supplied from surface water resources was estimated at 170 MCM/a. In addition, 46 MCM/a for domestic and industrial supply is abstracted from groundwater, which brings the total domestic and industrial demand in the Tana Basin to 217 MCM/a. Table 2-11 summarises information on current (2018) water demands for some of the major urban centres in the basin where such information was available.

Table 2-11: Current (2018) water demands of some of the major towns and urban areas

Urban centre	Demand	Water source
	MCM/a	
Nyeri	9.9	Chania River
Embu	5.0	Rupingazi River
Matuu	4.2	Thika River
Mwingi	1.3	Partly supplied by Kiambere Dam on the Tana River
Garissa and Madogo	6.2	Tana River
Kitui	9.1	Partly supplied from Masinga Dam on the Tana River
Lamu	3.3	Local sources
Total	**39**	

2.4.3.3 Livestock water requirements

The livestock water demands in the Tana Basin as per the WRA Permit Database, were compared to that of the NWMP 2030 and found to be significantly less. A conservative approach was therefore adopted by using the NWMP 2030 demand and extrapolating it to 48 MCM/a as the demand for 2018. Most of the livestock water demand is supplied from surface water.

2.4.3.4 Wildlife and fisheries

Water demands for fisheries and wildlife in the Tana Basin is negligible. Consequently, the water demand values as stated in the NWMP 2030 were accepted as correct and extrapolated to a 2018 demand of 14 MCM/a based on historical growth trends.

2.4.3.5 Total water requirements

The total current estimated water demand (2018) in the Tana Basin equates to 1 867 MCM/a as in Table 2-12. Most of the water is needed for irrigation use. Figure 2-32 shows the distribution of current water demands across the Tana Basin.

Table 2-12: Current (2018) water demand in the Tana Basin per main sector (MCM/a)

Sector	Total water demand (MCM/a)
Irrigation	**1 407**
– Small scale / Private	880
– Large-scale	527
Domestic and Industrial	**217**
– Urban centres	39
– Basin-wide	178
Livestock	**48**
Exports (to Nairobi)	**181**
Other	**14**
Total	**1 867**

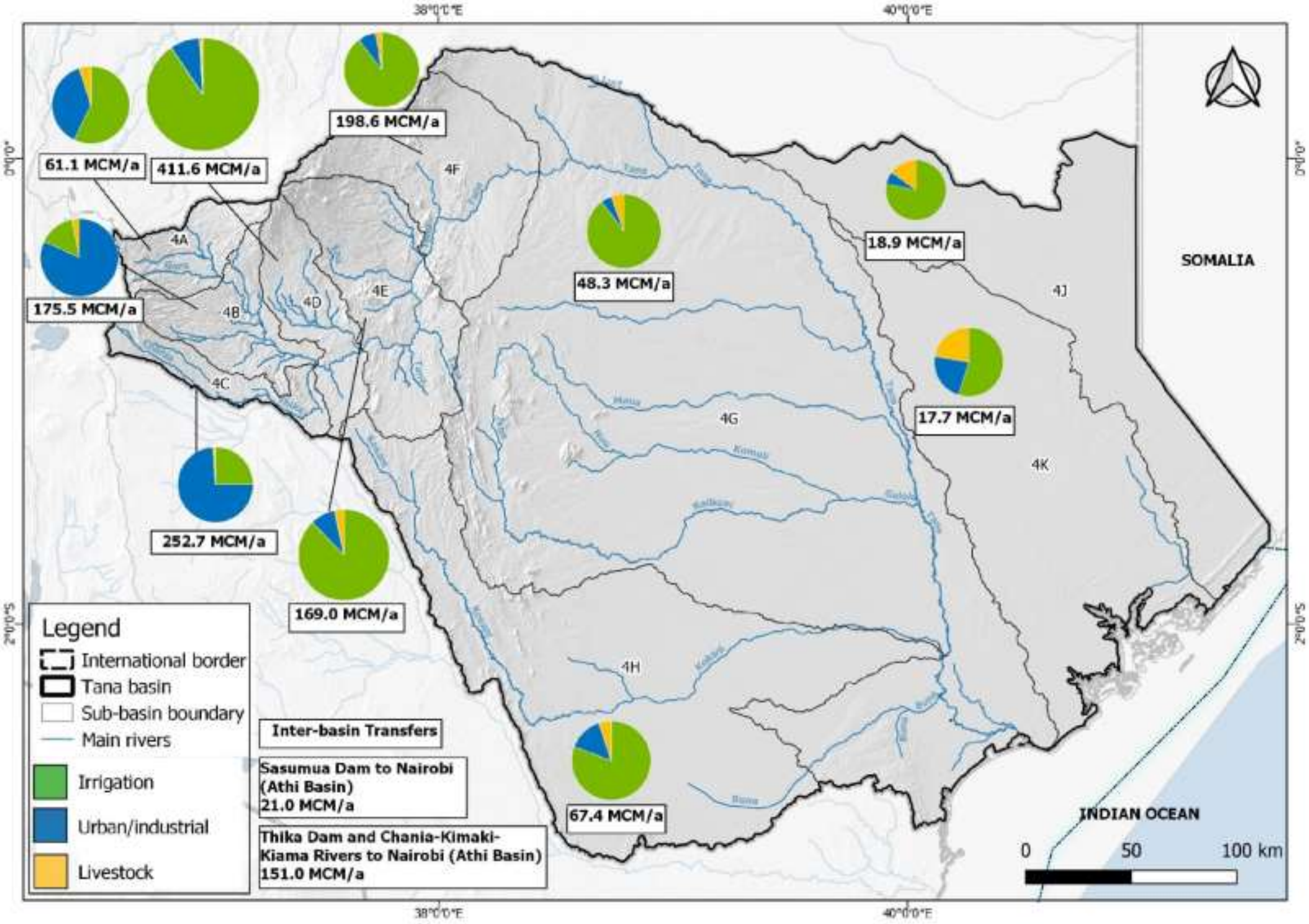


Figure 2-32: Present-day water requirements across the Tana Basin

2.4.4 Existing large-scale water resources development

The existing large-scale water resources developments in the Tana Basin are presented below. The existing water resource developments include storage, hydropower, water transfers, large-scale irrigation use and groundwater developments as well as ongoing water projects.

2.4.4.1 Storage

There are currently seven large dams in the Tana Basin. The dams are used for domestic water supply in the Tana Basin, for water supply to Nairobi and for hydropower generation. Key characteristics of the dams are presented in Table 2-13. Only dams with a storage capacity equal to or greater than 1 MCM were explicitly modelled in this Consultancy.

Table 2-13: Existing dams larger than 1 MCM: Key characteristics

Dam Name	Location	Purpose	Storage Capacity (MCM)	Dead storage volume (MCM)	Bottom Level (masl)	Full Supply Level (masl)	Minimum Operating Level (masl)
Sasumua Dam	0°45′43″S 36°40′54″E	Domestic water supply to Nairobi	16	3	2 485	2 515	2 490
Thika Dam	0°49′13″S 36°51′01″E	Domestic water supply to Nairobi	70	7	2 043	2 055	2 045
Masinga Dam on the Tana River (sub-basin 4ED)	00°53′21″S 37°35′40″E	Hydropower 40MW Domestic water supply to Kitui	1 560	280	1 048	1 055	1 049
Kamburu Dam (Commissioned 1974)	0.8291°S 37.6679°E	Hydropower 90MW	123	12	1 003	1 023	1 006
Gitaru Dam (commissioned 1999)	00°47′43″S 37°45′09″E	Hydropower 225MW	20	2	924	930	925
Kindaruma Dam (commissioned 1968)	00°48′38″S 37°48′46″E	Hydropower 44MW	16	0.8	780	790	782
Kiambere Dam (commissioned 1968)	00°48′38″S 37°48′46″E	Hydropower 168MW Domestic water supply to Mwingi	585	80	684	700	686

2.4.4.2 Hydropower

There are ten existing hydropower installations in the Tana River Basin. Five of these are situated in succession in the middle of the Tana basin, installed at major dams. The remaining five are smaller or run-of-river installations:

- Masinga power station at Masinga Dam on the Tana River with an installed capacity of 40 MW
- Kamburu power station at Kamburu Dam on the Tana River with an installed capacity of 90 MW
- Gitaru power station at Gitaru Dam on the Tana River with an installed capacity of 225 MW
- Kindaruma power station at Kindaruma Dam on Tana River with an installed capacity of 72 MW
- Kiambere power station at Masinga Dam on Tana River with an installed capacity of 168 MW
- Ndula small hydropower on the Thika River with an installed capacity of 2 MW
- MESCO small hydropower on the Maragua River with an installed capacity of 0.4 MW
- Sagana Falls power station on Sagana River near Nyeri with an installed capacity of 1.5 MW
- Tana hydroelectric power station on the Maragua River with an installed capacity 20 MW
- Wanji hydropower station with an installed capacity of 7.4 MW

2.4.4.3 Water transfers

The upper Tana River is the main source of water supply to Nairobi and its surrounding areas in the adjacent Athi Basin. Water is transferred from the Sasamua and Thika dams in the upper Tana basin as well as from rivers in the upper Tana basin as detailed below in Table 2-14.

Table 2-14: Inter-basin water transfers

Transfer Source	Town supplied	Transfer capacity (MCM/a)
Chania and Kiburu Rivers to Sasumua Dam. Sasumua Dam to Nairobi	Nairobi	21
Thika Dam	Nairobi	160
Chania, Kimaki, Kiama River diversions	Nairobi	
Maragua, Gikigie and Irati River Diversions (Northern Collector Tunnel Phase 1) *	Nairobi	189

* Currently under construction

In addition to the inter-basin transfers, water is also transferred inside the basin from Kiambere Dam to Mwingi Town (0.5 MCM/a capacity) and from Masinga Dam to the town of Kitui (3 MCM/a capacity).

2.4.4.4 Large-scale irrigation schemes

Information on existing large-scale irrigation schemes in the Tana Basin was obtained from the NWMP 2030 and validated with information provided by the NIA and the Department of Irrigation at the Ministry of Agriculture, Livestock and Fisheries. 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 Tana Basin has various existing large-scale irrigation schemes as summarised in Table 2-15.

The Mwea Irrigation Scheme is located in the upper Tana Basin in Kirinyaga County on the plains to the south of Mount Kenya and is one of the biggest schemes in Kenya for rice cultivation. In 2013, the scheme contributed almost 80% of Kenya's rice production.

The Bura and Hola irrigation schemes are located along the Tana River in Tana River County close to the town of Hola. They were originally used for cotton production and accounted for close to 40% of Kenya's cotton production in the 1980s. However, these schemes have since deteriorated due to minimal maintenance of pumps, financial constraints and inadequate technical capacity. Currently, maize is grown in these schemes.

Other schemes include: Muringa Banana Scheme in Tharaka Nithi County, Mitunguu Scheme in Meru County and Kibirigwi Scheme in Kirinyaga County as well as irrigation schemes along the lower Tana River close to the Delta.

Table 2-15: Existing large-scale irrigation schemes

Scheme	Irrigation area (ha)	Main crop type	Sub-basin	Water source
Mwea	10 117	Rice	4DA	Thiba and Nyamindi Rivers
Bura	6 070	Maize	4GD	Tana River
Hola	1 416	Maize	4GE	Tana River
Kibirigwi	420	Maize, Horticulture	4BC	Ragati River
Lower Tana / Delta	4 200	Rice, Sorghum	4GF / 4GG	Tana River
Muringa	2 631	Maize, Horticulture	4EB	Maara and Mutonga Rivers
Mitunguu	1 619	Maize	4FA	Thingithu River
Total	**26 500**			

2.4.4.5 Groundwater development and use

Most of the groundwater development in the Tana basin has occurred on a small-scale to serve rural communities and small centres across the Basin, often occurring in metamorphic Basement rock or associated alluvium. The use of groundwater for domestic water supply is higher in rural areas than urban areas in the Tana Basin. The greatest concentration of boreholes occurs in the humid upper part of the Tana Basin, particularly Murang'a County. Springs are also concentrated in the humid upland zones. Public water supply in the larger towns in the basin (including Garissa, Kitui, Meru, Mwingi, Thika and Kenol) is predominantly met by surface water, with groundwater supplementing these sources. The northern part of Garissa county (within the Tana Basin) is underlain by the Merti Aquifer and supports extensive pastoralism and small settlements that rely almost entirely on groundwater e.g. Wel Merer. Current groundwater use in the Tana 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 2-16. Groundwater supply for each sector was determined from information in the Permit Database and the NWMP 2030.

Table 2-16: Groundwater contribution to total water demand in the Tana 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 on various large dams in the Tana Basin is about to start, is currently underway, or has started but are currently on hold due to contractual and/or other issues. These dams include:

- Yatta Dam on the Thika River for domestic and irrigation supply;
- Thiba Dam on the Nyamindi River – mainly to be used for supplying Mwea Irrigation Scheme Extension;
- Karimenu II Dam on the Karimenu River from where water will be supplied to Kiambu and Nairobi counties
- Umaa Dam on the Nzeu River – to be used for domestic water supply.

In addition, the Government of Kenya has approved the construction of the High Grand Falls Dam at Kivuka along the Tana River. The dam, which forms part of the LAPSSET project, will be located on the borders Tharaka-Nithi, Kitui and Tana River counties. Furthermore, the Northern Collector Project (Phase 1), which is currently under construction, will divert flood water from the Maragua, Irati and Gikigie rivers in the upper Tana Basin into Thika Dam and will add up to 57 MCM/a to the Nairobi Water Supply.

2.4.5 Water balance

The 2018 water balance in the Tana Basin in terms of natural surface water runoff and sustainable groundwater yield, the ecological reserve and current (2018) water demands in the Tana Basin is summarised in Table 2-17. The current water demand constitutes about 25% of the total water resources available for use.

Table 2-17: Current (2018) Tana Basin water balance (MCM/a)

	Surface water	Groundwater	Total
Natural / Available water	7 082	693	7 775
Ecological reserve	(355)	-	(355)
		Total	7 420
		Water demand (2018)	(1 867)
		Balance	**5 553**

Due to climate change impacts, the natural surface water runoff is expected to increase to 7 365 MCM/a while the groundwater yield is projected to increase to 745 MCM/a by 2050.

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% (refer to **Annexure B1**).

Figure 2-33 displays the current surface, sub-basin water balances and shows that most of the sub-basins still have significant surface water resources available. There are some exceptions, however, where sub-basins have very low water availability due to low incremental runoff and/or excessive water requirements.

It is important to note that the sub-basin water 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. It is also 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).

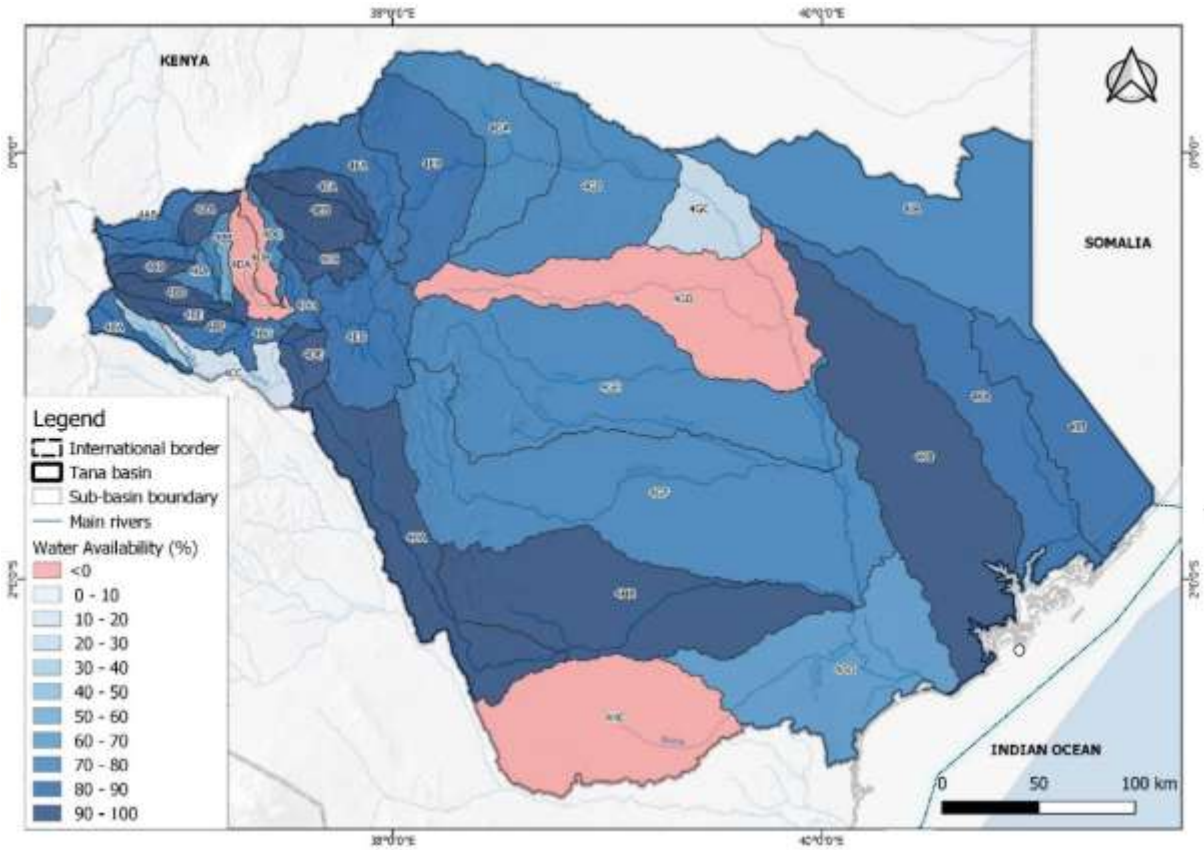


Figure 2-33: Surface water balance per sub-basin

The current estimated groundwater use in the Tana Basin equates to 64 MCM/a, which is about 11% of the estimated sustainable groundwater yield of 636 MCM/a. This leaves 563 MCM/a of groundwater available for potential use in the Tana 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, 2019b). Essentially, the Guideline prescribes a flow/reliability approach based on natural flow exceedance values, to estimate the volumes (Q) 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 surface water allocation status in the Tana 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 Tana 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.

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.

The current-day water availability and use in the Tana Basin is displayed in Figure 2-35

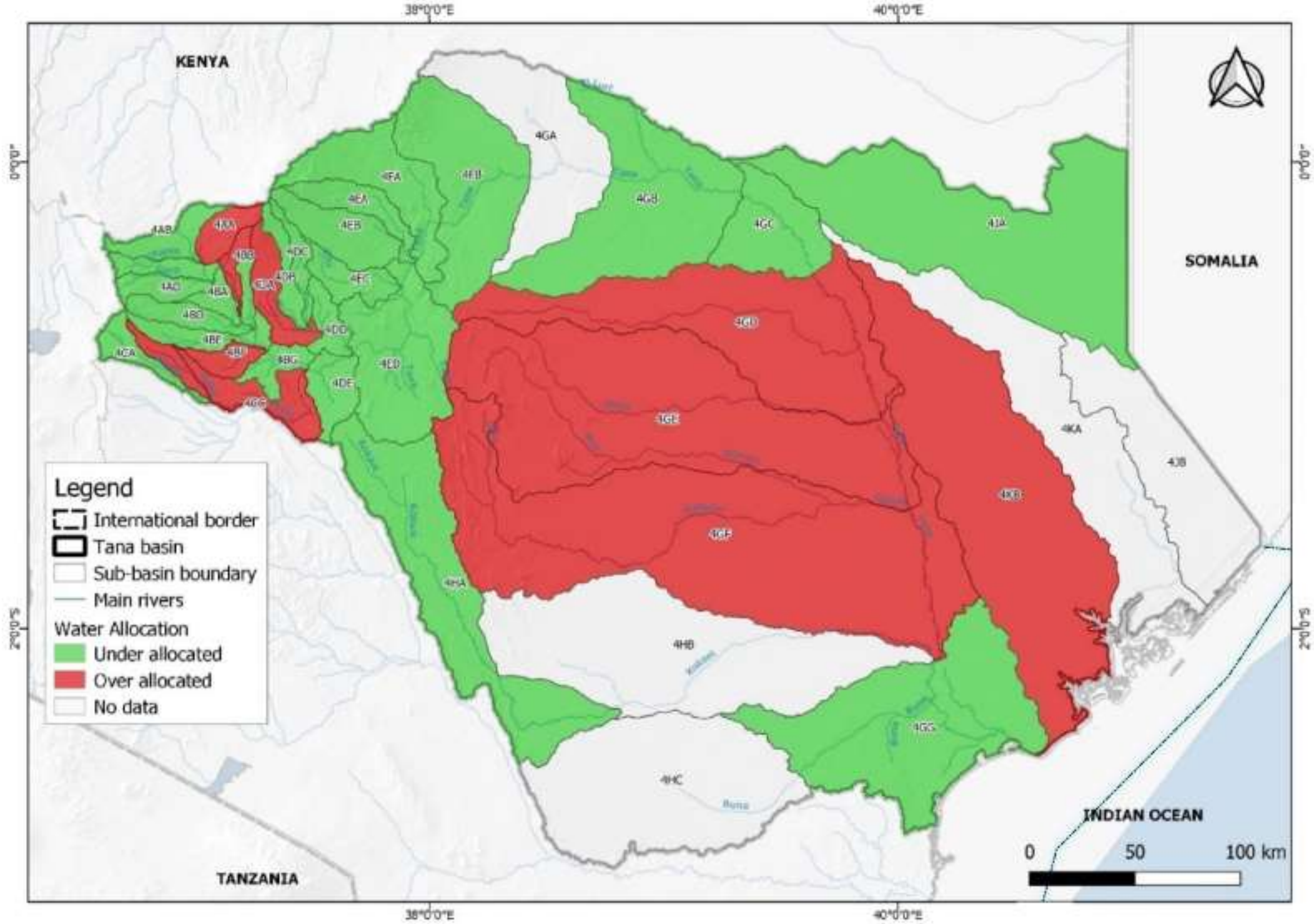


Figure 2-34: Surface water allocation status per sub-basin (2018)

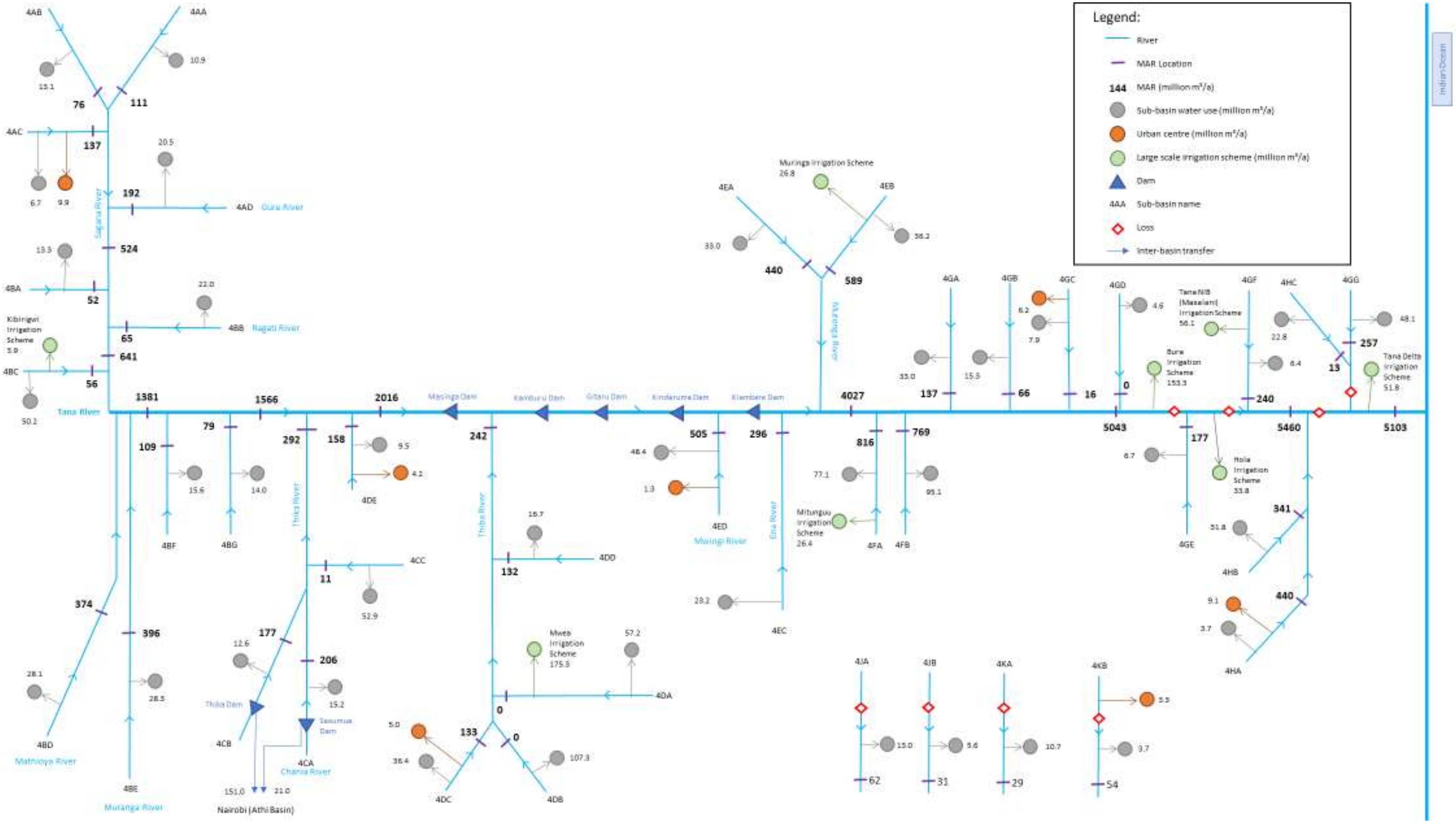


Figure 2-35: Current-day water availability and use in the Tana Basin

2.4.7 Water quality

Water quality in the Tana 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. The quality of water resources has deteriorated due to increased anthropogenic activities, with both point- and non-point sources of pollution being prevalent in the area. Unsustainable farming practices and poor management of croplands is evident in many parts of the basin. Major water pollution threats include municipal waste in the upper basin, industrial waste, sedimentation and agrochemicals. Water quality issues also stem from inadequate monitoring and compliance control, the use of fertilisers, poor waste disposal management and sedimentation of water bodies.

The most common pollutants in the Tana Basin include:

- Municipal/domestic sewage from urban settlements;
- Solid wastes from dump sites;
- Leachates from pit latrines, septic tanks and feedlots as well as acaricides from cattle dips;
- Nutrients and Pesticide Residues from agro-based industries;
- Sediment loads from degraded farmlands and from soil erosion in overgrazed lands and un-tarmacked roads at steep slopes;
- Pollutants in storm runoff from roads and urban centres, as well as oil and grease from oils spills, garages and petrol stations;
- Industrial effluents;
- Coffee farms/ washing stations and factories;
- Tea plantations and processing factories;
- Rice farms and Flower farms;
- Horticultural farms;
- Soil erosion from unpaved gravel roads;
- Acaricides from cattle dips;
- Quarrying, building stone mining and sand harvesting.

2.4.8 Existing hydro-meteorological 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

In 2018, the Tana Basin had 69 recorded stream flow monitoring stations. Of these, only 59 were known to be operational. It is highly likely that this number was much higher in the past. Table 2-18 provides details on the operational stream flow monitoring network in the Tana Basin. From the Table it is evident that the majority of currently operational stations are manually operated.

Table 2-18: Stream flow monitoring stations in Tana Basin (2018)

SRO	Operational			
	Telemetric	Automatic	Manual	Total
Garissa	0	1	1	**2**
Kerugoya	0	0	11	**11**
Kitui	0	0	0	**0**
Meru	1	1	19	**21**
Murang'a	0	9	16	**25**
Total	**1**	**11**	**47**	**59**

Most of the operational river gauging stations are rated sections. Most are read manually by gauge readers, with 12 automatic stations (1 of which is fitted with telemetry). Rating curves are updated yearly at the National office and distributed to the regional and sub-regional offices for use. However, challenges remain because many of the stations are also inaccessible during high flow conditions. Figure 2-36 displays the locations of operational stream flow gauging stations in the Tana Basin.

2.4.8.2 Monitoring of dam and lake levels

In 2018, there were no lake monitoring stations in the Tana Basin.

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 Tana basin. Figure 2-37 displays the spatial distribution of the operational meteorological stations in the Tana Basin for which information is available.

2.4.8.4 Water quality monitoring

Kenya's existing water quality monitoring network was designed to collect water quality data in key river systems to support the 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 2-19).

Table 2-19: Number of water quality monitoring stations in the Tana Basin (2018)

Tana Basin water quality stations	No. of current stations (2018)
Surface water	64
Effluent stations	10
Groundwater	27
Total	**101**

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 2-20.

Table 2-20: Surface water quality parameters 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-}.

2.4.8.5 Groundwater monitoring

There is a total of 41 groundwater monitoring points across the Basin; however, only 18 of these were operational in 2018 (seven Strategic, six Major, five Minor and none in Special aquifers). One borehole is a dedicated monitoring site (Water Resources Authority, 2018d). 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.

Of the existing monitored wells, most are manually dipped. Maintenance of monitoring wells is a serious concern. Similarly, to the surface water quality monitoring, inadequate equipment limits the parameters that are tested for groundwater. These parameters are listed in Table 2-21. It is not clear when the groundwater monitoring network was initiated in the Tana Basin or how far back the records go. However, the WRA started monitoring with mainly production boreholes where arrangements were made 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 has installed a few automatic level-loggers on dedicated solitary monitoring wells.

Table 2-21: Groundwater quality parameters analysed

Type of Water quality monitoring station	Parameters tested
Ground water quality monitoring stations	pH, DO, Temperature, TSS Conductivity, TDS, Nutients-NO^{2-}, NO^{3-}, PO_4^{3-}.

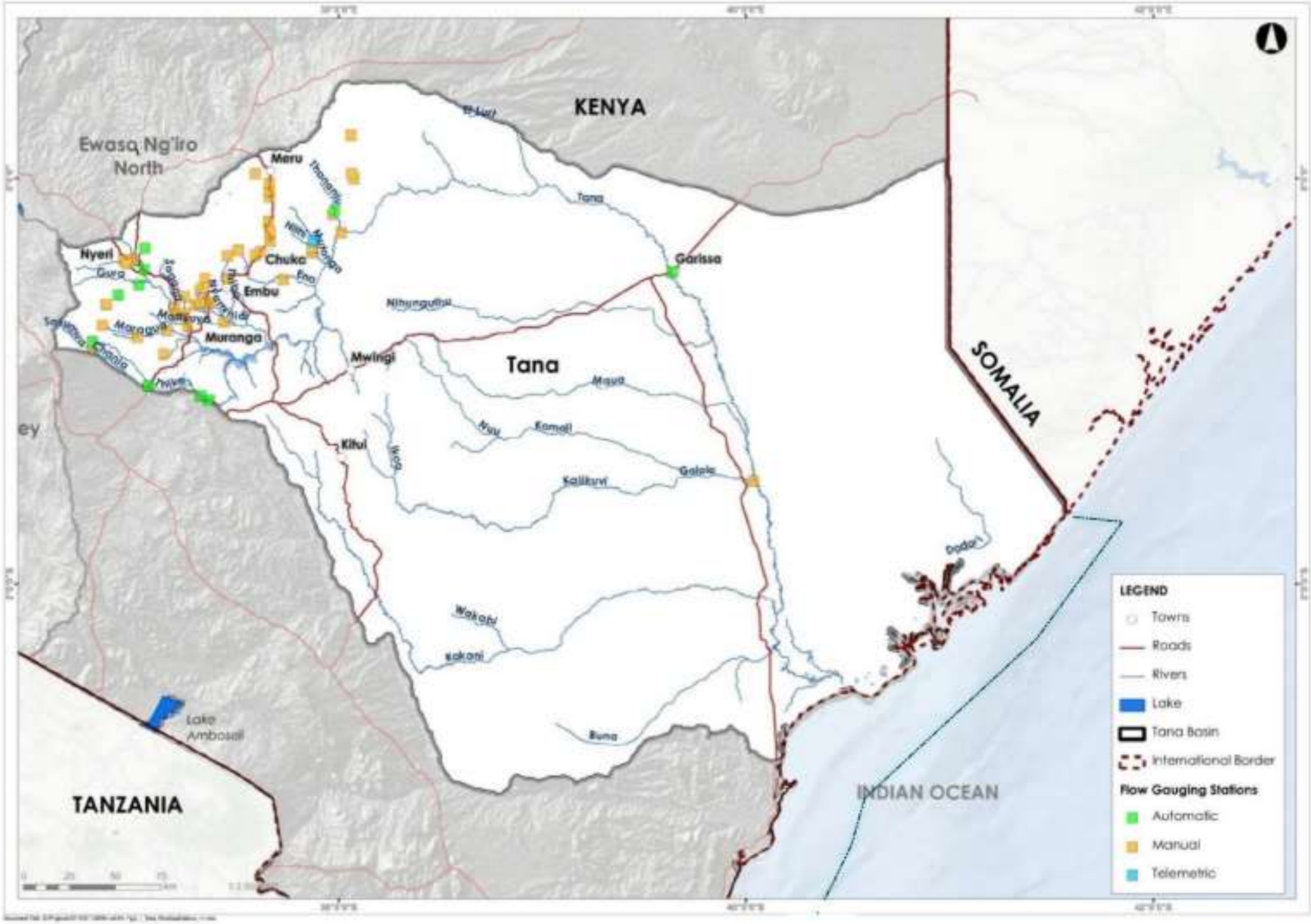


Figure 2-36: Locations of operational stream flow gauging stations in the Tana Basin (2018)

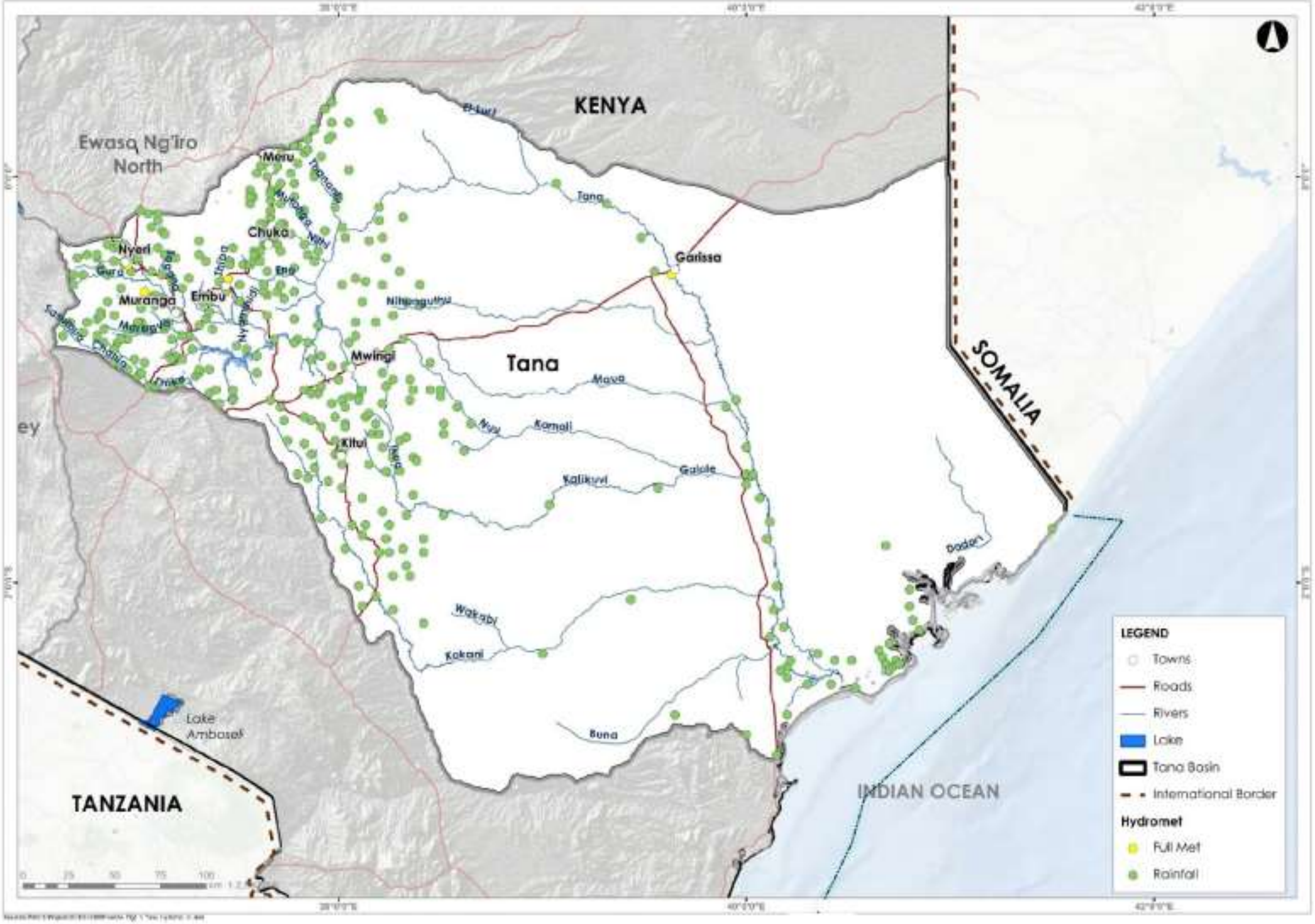


Figure 2-37: Locations of operational meteorological stations in the Tana Basin (2018)

Image source: USAID/Mariantonietta Peru 2018 'A cattle market in Garissa'. Available online at https://africanarguments.org/2018/06/27/lapsset-new-highway-long-neglected-garissa-kenya/

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.

To ensure that the implementation of the sub-plans, strategies, and actions emanating from this Basin Plan is guided by relevant legislative, policy and institutional principles, **Annexure C** provides an overview of the legal, institutional and policy framework relating to environmental and integrated water resources management. This framework needs to be understood if the Tana Basin Plan is to attain the goals of social acceptability, economic viability and technical sustainability in line with internationally accepted standards for good practice.

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 climate risks. Additionally, the World Economic Forum, through their Global Risks Reports, 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; and
- 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, Mount Kenya and Mount Elgon), and waste management and pollution control.

The Kenya National Water Resources Management Strategy provides the overarching policy framework for water resources management and development in Kenya, despite several 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 resources management, water services 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; and
- 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 Tana 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 Tana Basin and these are presented in Table 3-1.

Table 3-1: Guiding National Environmental Policy 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 (South African National Biodiversity Institute, 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 (Government of Kenya, 2007a). 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-potential 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 Petroleum and Energy Policy, (Government of Kenya, 2015) indicates that government will transform the Rural Electrification Agency into the National Electrification and Renewable Energy Authority 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 to improve the manner in which water (and other natural resources) are managed and sustainably developed.

The GoK *2002 Water Act (Act No. 8 of 2002)* came into effect in March 2003. It 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 several 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 GoK *2016 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 GoK 2016 Water Act 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 GoK 2016 Water Act that require resolution to clarify institutional matters. The ambiguity is regarding the dual and conflicting mandate of the BWRCs as an advisor to WRA on one hand and with executive powers for basin level water resources management on the other hand. In reality, operationalisation of the BWRCs is impossible if this ambiguity is not removed as it affects establishment of the committees and should be addressed urgently. 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) (Act No. 8 of 1999)* 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. In 2009, the Energy Regulatory Commission established a committee with responsibility for preparation of the Least Cost Power Development Plan 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 GoK 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 2010 Constitution, relate to socio-economic development and natural resources management and are critically important from a basin planning perspective. The key functions include, among others:

- Water Resources: the use of international waters and water resources, water protection, hydraulic engineering and the safety of dams;
- Environment: to be a nation that has a clean, secure and sustainable environment by 2030; protection of the environment and natural resources with a view to establishing a durable and sustainable system of development, including: fishing, hunting and gathering; protection of animals and wildlife;

- Socio-Economic: national economic policy and planning; national statistics and population data, the economy and society generally; education; national public works; public investment; as well as tourism policy and development;
- Agriculture and Irrigation: general principles of land planning and the coordination of planning within the counties, as well as implementing the agricultural policy;
- Energy: energy policy including electricity, gas and energy reticulation.

In the aftermath of the 2017 national elections, the National Government 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.

This list is by no means exhaustive but rather indicative. 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 listed, 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 resources 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 service providers. – Evaluate and recommend water and sewerage tariffs to the county water service providers and approve the imposition of such tariffs in line with consumer protection standards. – Set licence conditions and accredit water service 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.

Institution	Roles and responsibilities*
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)	– Finance the provision of water and sanitation services to disadvantaged groups and includes: o Community level initiatives for the sustainable management of water resources. o Development of water services in rural areas considered not to be commercially viable for provision of water services by licensees. o 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)	– Arbitrate 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.
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 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)	– Provide 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 provide 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 on 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 (IWRM), 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, regulation and oversight is achieved through the Regional Office (RO) and Sub-Regional Offices (SRO) of the Water Resources Authority (WRA) and the Water Resource Users Associations (WRUAs).

The Tana Basin is managed by five WRA SRO with the WRA RO located in Embu. The Basin has been delineated into 17 Catchment Management Units (CMU) based on hydrological and water resource considerations. Table 3-3 lists the sub-regions, the locations of the SROs as well as 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 Tana Basin

Sub-Region	WRA SRO	CMUs
Upper Tana	Murang'a	Sagana-Gura, Lower Sagana, Upper Thika and Lower Thika
Thiba	Kerugoya	Tana, Karaba, Ena and Thiba
Kathita - Mutonga	Meru	Mutonga, Kathita, Ura / Tharaka
Tiva - Tyaa	Kitui	Tiva and Lower Reservoirs
Lower Tana	Garissa	Lower Tana, Ijara / Lamu

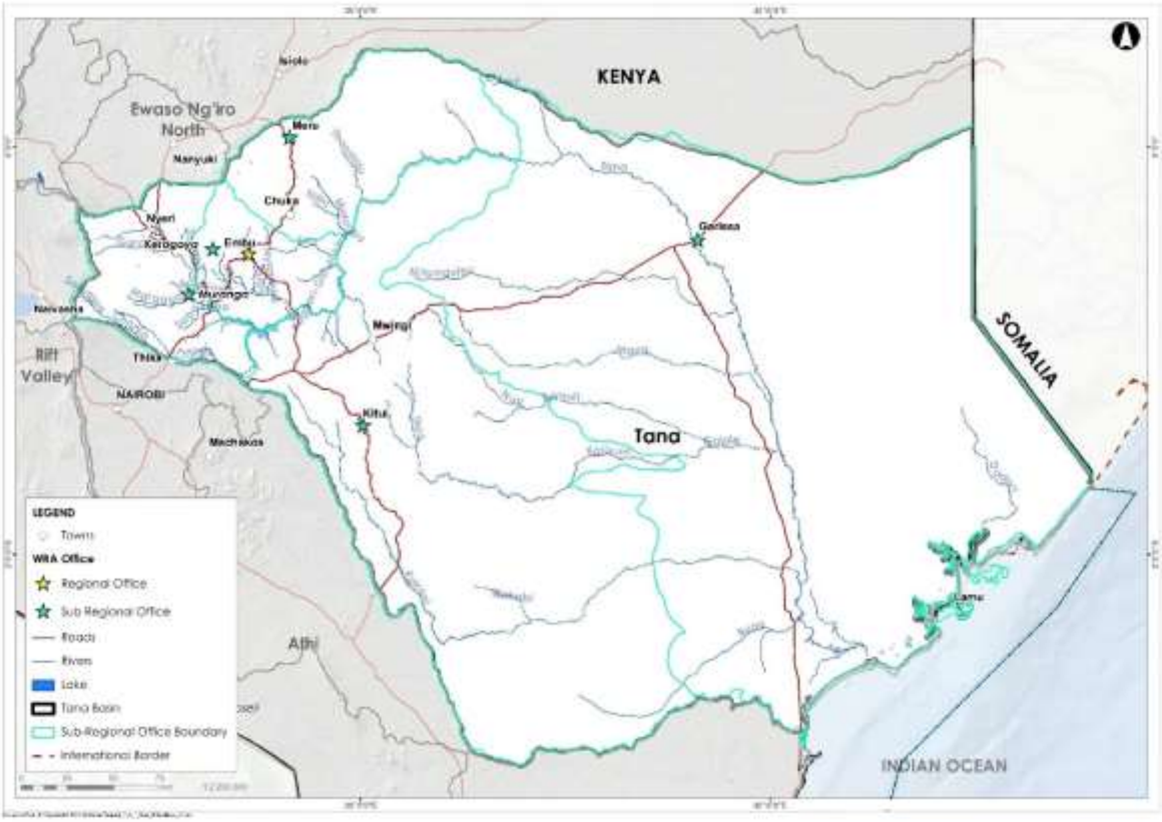


Figure 3-1: WRA Offices in the Tana Basin

Water users apply for water permits through the relevant WRA SRO, and the application is then sent to the RO or to the head office 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 Water Act 2016 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 services delivery as well as ensuring that water is used efficiently within their jurisdictions. To this end, the Water Act introduced Basin Water Resource Committees (BWRCs) as a replacement for the previous Catchment Area Advisory Committees (CAACs). At this juncture, during what is effectively a period of transition, the BWRCs function will be as per the Water Act, 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 resources 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 shall operate under the regulations made by the Authority Water Act 4 (a) including 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 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. The WRUAs 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. As provided for in the Water Act 2016 Section 29 (4), the BWRCs may contract WRUAs as agents to perform certain duties in water resources 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 issues such as insufficient financial resources. These challenges will require redress in order to support the implementation of this Basin Plan and realise the local level capacity building that can unlock the localised socio-economic development required to support Vision 2030. This is supported by the Water Act 2016 that states 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 county Governments are provided in Schedule Four of the Constitution. County Government 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, as well as 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.

There are 14 counties within the Tana Basin, 8 of which are fully enclosed within the basin (refer to Figure 2-2). Some counties cross hydrological boundaries and as such have to engage with multiple BWRCs and WRA offices. The counties within the Basin include Nyeri, Kiambu, Murang'a, Kirinyaga, Embu, Tharaka-Nithi, Meru, Isiolo, Garissa, Tana River, Kitui, Machakos, Kilifi and Lamu.

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 (Act No 1 of 2018) 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 water abstraction 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, they also 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 seen as 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. Further examples of these partnerships are that of 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 Tana 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 the multi-stakeholder initiative brings together the Government of Kenya, development partners, the private sector and civil society.

3.1.7.2 Stakeholder 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. 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 government agencies working in water resources management. 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. 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 Tana 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 Tana 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 (Tana, Athi, Lake Victoria South, Lake Victoria North, Rift Valley, Ewaso Ng'iro North). 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. NWMP 2030 information on surface water and groundwater resources availability and use in the Tana Basin have been compared with the water resources assessment results undertaken in this Consultancy (refer to the WRA report). The NWMP 2030 was used extensively to inform the development of the Tana Basin Plan.

3.2.3 Catchment management strategy

The Tana Catchment Management Strategy (CMS) (Water Resources Management Authority, 2015b) was completed in 2015 for the period 2015-2022 and provided a vision and framework for the management of water resources and related land resources in the basin. It outlines how the concept of integrated water resources management (IWRM) should be implemented at catchment level. The strategy provides an opportunity for water resources management institutions and stakeholders to formulate a coherent approach and focus for managing the water resources in a catchment. As such, the CMS is both a process and a framework for management, binding the Authority, the water users, other stakeholders and their representative structures in a social and/or legal union. The CMS timeframe was developed to harmonise with the NWMP 2030.

Table 3-4: Objectives of the Tana CMS

Strategy	Theme	Objective
Water resource protection	Water resource protection	– To improve water quality monitoring – To maintain the reserve flow – To classify water resources and set resource quality objectives – To develop and implement programs with county governments and other stakeholders on sanitation and solid waste management to support urban rivers' restoration – To ensure effluent dischargers comply with the permitting conditions – To enhance water resources protection capacity
	Catchment protection and conservation	– To restore and protect degraded water catchments. – To identify and recommend for gazettement of water conservation areas. – To collaborate with county governments in soil and water conservation efforts. – To build capacity of county governments in catchment protection and conservation
Resource augmentation adaptation and development	Flood and drought management	– To adopt best practices on Integrated Flood and Drought Management (IFDM) – To develop and operationalize a framework for collaboration with County Governments (CGs) and other Stakeholders on IFDM. – To enhance capacity on IFDM (CGs WRUAs, WRMA staff, monitoring, skills, use of Information Systems, Flood Control centres). – To mainstream Flood and Drought management in SCMPs. – To Enforce the Reserve flow requirement with respect to drought management.
	Climate change adaptation	– To enhance climate change induced disaster risk preparedness – To create awareness on the impact of climate change on water resources – To mainstream climate change adaptation measures in water resources management – To generate future water availability scenarios – Localise Regional Climate Models results for use at sub-catchment level
	Water resources infrastructure development	– To regulate water resources infrastructure development for safety and sustainability – To regulate the operations of the infrastructure to ensure downstream water commitments – To identify potential sites for water resources infrastructure development – To enforce codes of practice for surface water infrastructure development – To develop water resource infrastructure to maintain the reserve flow – To develop the codes of practice for surface water
	Rights based approach	– To ensure access to water resources for the vulnerable groups – To determine and maintain the reserve flow – To promote exchange of information and experiences

Strategy	Theme	Objective
	Livelihoods enhancement	– To build capacity in Livelihood activities of WRUAs, CBOs and Service Providers – To enhance the collaboration and Partnership with the CGs and other development partners to support LMGs – To build capacity for WRMA, WRUAs, CBOs and CGs on the management of LMGs
Implementation, information management and financing	Institutional strengthening	– To enhance capacity of RO, SROs and BWRC to effectively undertake WRM – To build capacity for the CGs on IWRM to effectively participate in water resources management – To enhance capacity of WRUAs to develop and implement SCMPs – To enhance collaboration with stakeholders for-catchment planning, research, coordination, resource mobilization, monitoring, reporting and information sharing
Monitoring and management		– To optimize water resources monitoring network – Enhance data management system (data collection, analysis, storage and dissemination) – To upgrade water resource information system

3.2.4 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 170 WRUAs out of a potential 240 WRUAs have been formed in the Tana 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 77 SCMPs have been developed in the Tana Basin.

3.2.5 County integrated development plans

County Integrated Development Plans (CIDPs) are prepared every five years by each county as a road map for development. The CIDP touches on all sectors devolved to County Governments. Catchment protection and water and sanitation services are functions featuring 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 aspects of each CIDP for the main counties situated in the Tana Basin are presented in Table 3-5.

Table 3-5: Key aspects of the CIDPs relevant to the Tana Basin

County	Water and Sanitation	Natural Resources	Agriculture
Nyeri CIDP (2018-2022)	Programmes include water supply and management. Flagship projects include Karemenu Mega Dam and Naromoru Mega Dam.	Programmes include environmental protection and conservation (i.e. reforestation).	Programmes include agricultural management (i.e. crop development, fish production management and extension programmes), agricultural training services, livestock production management, veterinary services and agriculture mechanization services. Flagship projects include establishing the Wambugu ATC Centre of Excellence.
Murang'a CIDP (2018-2022)	Programmes include water resources management (i.e. irrigation development, water supply infrastructure, sanitation and waste disposal, water storage).	Programmes include environmental management and protection (i.e. solid waste management, noise and air pollution control), natural resources conservation and management (i.e. forest conservation, water and catchment area protection) and climate change resilience.	Programmes include training and extension services, food and nutrition, livestock support services, veterinary disease and pest control, livestock breeding and fisheries support services. Flagship projects include the Dairy Development Programme and the Fruit Trees Development Programme.
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.
Kirinyaga CIDP (2018-2022)	Programmes include providing water supply services. Flagship projects include the Mwea Makima Water Project, Njukii-ini Water Project and Riagicheru Water Project.	Programmes include solid waste management.	Programmes include livestock resources management and development (i.e. livestock disease management and control, livestock extension and capacity building and aquaculture development), crop development and management.

County	Water and Sanitation	Natural Resources	Agriculture
Embu CIDP (2018-2017)	Programmes include provision of safe water and sanitation to various communities through bulk infrastructure, reticulation and borehole construction; protection of springs; rehabilitation of distribution network and purchase of water meters. New irrigation projects are also proposed. The flagship project is Kamumu dam. Mirundi Kirurumwe, Kianamu and Kathanje springs protection projects are ongoing.	Programmes include promotion of sustainable management and utilisation of natural resources through the preparation of environmental management plans for 2 sand harvesting societies and 2 quarrying societies and 1 mining societies annually and rehabilitation of disused quarries.	Programmes include livestock development and management, veterinary services management, crop development and management and food security schemes (e.g. fisheries development and management), irrigation development and management (i.e. water harvesting and irrigation schemes, irrigation schemes infrastructure development). Flagship programmes include developing new markets, improving access roads, expanding irrigation works and implementing post-harvest management systems. Ongoing projects include Karambari Earth Dam and ALLPRO shallow well improvement.
Tharaka-Nithi CIDP (2018-2022)	Programmes include domestic water supply, irrigation and drainage services. Flagship projects include the High Grand Falls Dam, the water and sanitation project in Chuka, Chogoria, Kathwana and Marimanti.	Programmes include afforestation, solid waste disposal and management, climate change, natural resources exploration and exploitation. Flagship projects include establishing a Geographical Information System Laboratory.	Programmes include crop production, livestock development, veterinary services and fisheries development. Flagship projects include establishing a Livestock Improvement Centre and the Integrated Aquaculture Irrigation Project.
Meru CIDP (2018-2022)	Programmes include rural, urban and irrigation water supply, urban and rural sanitation and hygiene, groundwater and surface water management. Flagship projects include the Maji Kwa Wote initiative and borehole drilling.	Programmes include rehabilitation of catchment riparian areas, forest ecosystem management, freshwater and wetland ecosystem access availability, waste management and pollution control. Flagship projects include efforts to rehabilitate riparian areas by planting bamboo.	Programmes include crop development, tree crop development, soil conservation, fertility management and water harvesting, inputs supply support, value addition/agro-processing, livestock production and management, veterinary services, fisheries development and agriculture mechanisation.
Isiolo CIDP (2018-2022)	Programmes include improving water supply and storage services and developing sanitation services and management.	Programmes include climate change mitigation and adaptation, solid waste management, environmental conservation (i.e. enhancing ecosystem productivity and sustainability) and environmental conservation (i.e. reducing desertification).	Programmes include the rehabilitation and expansion of irrigation schemes, providing increased agriculture mechanisation services, crop development and management, agribusiness and market development, livestock market development, training and extension services, veterinary services management, fisheries and cooperative development.

County	Water and Sanitation	Natural Resources	Agriculture
Garissa CIDP (2018-2022)	Programmes include increasing the area of land under irrigation (i.e. construction of mega pans for water storage and small holder schemes), development of water storage and groundwater source for multi-purpose water uses, catchment conservation and rehabilitation, expansion of water supply services, rehabilitation, maintenance and operation of water supplies, sewerage management, decentralised sewerage treatment, rehabilitation and maintenance of sewerage and sanitation facilities.	Programmes include environmental management systems, management, conservation and sustainable utilisation of forests, restoration of degraded sites and management of invasive species (i.e. *prosopis julifora*), promote sustainable exploitation of mineral resources, strengthening community conservancies and support of national reserves.	Programmes include crop production and management, livestock production and management, fisheries and cooperative development.
Tana River CIDP (2018-2022)	Programmes include water supply resources management (i.e. water resources conservation, water resources protection, rehabilitation of water supplies), water harvesting and storage, urban and rural water supply and water use efficiency. Flagship projects include the relocation and upgrading of the Hola Water Works, construction of the Bura-Chifri-Wayu water pipeline and the construction of the Bura-Hola water pipeline.	Programmes include renewable energy, forest management and development, wildlife management, solid waste management, environmental laws and policies (i.e. enforcement and surveillance), and climate change mitigation.	Programmes include food security, improved nutrition and sustainable agriculture (i.e. irrigation development, agribusiness development, extension and capacity building, nutrition and food safety), agricultural infrastructure development, livestock extension services, livestock marketing, drought mitigation, veterinary services and fisheries services.
Kitui CIDP (2018-2022)	Programmes include water resources development (e.g. drilling boreholes, the construction and extension of water pipelines, construction of dams and pans, water supplies maintenance and repairs), irrigation schemes development and maintenance,	Programmes include waste management, environmental management and awareness, tree growing and forest conservation, climate change adaption and mitigation, water catchment conservation and rehabilitation.	Programmes include crop development and food security, agribusiness development (i.e. agricultural extension services, livestock development, veterinary services and fisheries development. Flagship project include the Beekeeping and Honey Production Project and the Ndengu Revolution Project.
Machakos CIDP (2018-2022)	Programmes include water harvesting; improved assess to water through pans, major dams, weirs and boreholes; increased irrigation, improved sanitation and service delivery.	Programmes include enabling policy, catchment rehabilitation, tree planting, alternative energy sources, awareness on rainwater harvesting, rehabilitation of degraded rivers, solid waste management.	Programmes include enabling policy, mechanisation, 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
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.	Programmes include modernizing, promoting capacity building, improving production, livelihoods, dairy and beef cattle farming, fish production and marketing, land regularization and research and development.
Lamu CIDP (2018-2022)	Programmes include water sources protection, conservation and management (i.e. improving the water quality in aquifers), water supply (i.e. rainwater harvesting, establishing water kiosks, desalination), waste management and sanitation. Identified flagship projects include the Lamu-Garseni Water Supply Project, the construction of sewerage systems in Amu and Mokowe and constructing a desalination plan for Lamu Port.	Programmes include pollution control and regulation (i.e. noise and air pollution, surface, ground and sea water pollution control), natural resources conservation and management.	Programmes include extension advisory services, crop production and productivity (i.e. farm mechanisation, pest and disease control, climate change adaption), value addition, fisheries development services, veterinary services, livestock production and productivity. Flagship projects include the Mega Irrigation Project, the establishment of a cotton ginnery and a fruit processing factory plant.
Nyandarua CIDP (2018-2022)	Programmes include supplying potable water to county residents, sewerage and sanitation services, construction of small dams and pans, increasing water supply and storage capacity for irrigation.	Programmes include crop development, livestock development, veterinary services and fisheries development. Flagship projects include, construction of a potato processing plant and a sugar beet processing plant, bamboo farming, establishing a milk processing plant in Ol Kalou and providing countywide agricultural extension services.	Programmes include establishing a county Environmental Committee, solid waste management, wastewater management and creating public awareness on environmental issues.

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 Tana Basin who are responsible for development activities within their areas of jurisdiction, namely the Tana and Athi Rivers 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 Tana Delta Irrigation project is an ongoing TARDA project, which is expected to produce up to 24 000 tonnes of white rice under a double cropping program annually. The High Grand Falls Dam is another example of a TARDA project.

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.

3.2.7 Projects planned by Water Works Development Agencies

The Tana Water Works Development Agency (Tana WWDA), Coast Water Works Development Agency (CWWDA), Northern Water Works Development Agency (NWWDA), and Tanathi Water Works Development Agency (Tanathi WWDA) are operational in the Tana Basin.

These WSBs 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 counties, to major dam and water resource projects, including the proposed Rahole Canal, which will extract water from the Tana River in Tana River County, the Masinga Dam to Kitui Water Transfer, Yatta Dam and Yatta Canal, and Umaa Dam. The Tana WSB has financing from the African Development Bank towards the Kenya Towns Sustainable Water Supply and Sanitation Program.

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

The total storage volume of the existing dams in the Tana Basin is about 2 400 MCM, of which only 1% is stored in small dams and pans (Water Resources Management Authority, 2013). There is currently an inter-basin transfer from Sasumua and Thika dams to Nairobi in the Athi Basin, with a total combined capacity of 181 MCM per annum (Water Resources Management Authority, 2013). Further water resources development is essential to satisfy the growing future water demands.

According to the NWMP 2030 about 41% of the population in the Tana Basin receives drinking water from unimproved sources (unregistered water vendors and water taken from lakes and streams without proper treatment), while about 25% of the population get drinking water from springs, wells and boreholes. The total population that receives piped water from WSPs is 34%. There are 11 urban WSPs and 18 rural WSP, and together these WSPs provide a capacity of 240 358 m^3/day. Out of the 11 urban WSPs, four have records indicating more than 50% of non-revenue water (NRW).

The Tana Basin has a limited sewerage system coverage ratio of just 2%. About 87% of the population use on-site sanitation facilities such as septic tanks and about 11% do not have any treatment facilities, and resort to unsanitary waste disposal (Water Resources Management Authority, 2013).

Development in the water supply and sanitation sector in the Tana 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 50%), 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, financial constraints, water quality, low reliability of supply, and various institutional challenges. 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, mining and transport

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% 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 Resources 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 energy 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 sources based on life cycle least cost criteria to minimise stress on the water resources. The insufficient 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 hydropower.

Only 16% of the total population of Tana Basin has access to electricity. Paraffin is commonly used for lighting in households without access to electricity, and about 91% of the population use biomass (burning of firewood and charcoal) as a source of energy for cooking. 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 part of the basin is in the ASAL region, the rural-dwellers in this basin tend to be mainly semi-nomadic pastoralists and agro-pastoralists. The Tana Basin stakeholders will need to develop specific plans based on distributed generation and renewable energy to expand energy access to many users in this region.

The basin is richly endowed with solar energy. Considering that a major section of the basin is not connected to the national grid, the opportunity for exploiting renewable energy is very attractive.

Garissa County, through the Rural Electrification and Renewable Energy Corporation, has developed the largest grid connected solar power plant in East and Central Africa. The project is contributing about 2% to the national energy grid.

The geology of an area is of critical relevance to the occurrence of different minerals. In Garissa, mining activities include Gypsum mining and stone quarrying. Other mineral deposits in the basin include Coal, Iron ore, Copper, Gemstones, Limestone, Magnetite and Marble. Tana Riverbeds and banks are exploited for sand, while gypsum is mainly mined in Garissa county.

Although currently there is limited exploitation of minerals in the basin, there is potential for mining in the future, thus it is important that future water demands for the mining sector are accommodated in water resources planning.

Since 2009, the Government of Kenya has expressed plans to undertake a multipurpose transport and communication corridor known as the ‘Lamu Port-South Sudan-Ethiopia Transport (LAPSSET) Corridor. LAPSSET will consist of a standard gauge railway line, a port, a superhighway, a regional international airport, an ultra-modern tourist resort, an oil pipeline, and a fibre-optic cable constructed to link Lamu in Kenya to Juba and Addis Ababa. The proposed development of Lamu Port will result in an influx of people and industries and is envisaged to include an oil refinery. This will result in an increase in the demand for available water, and increased water pollution from both industrial and domestic wastes.

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 in this sector 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 subsistence farming 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 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. The irrigation potential in Kenya gas not been fully developed as yet. 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 Basins. 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.

Various Directorates under the Agriculture, Fisheries and Food Authority 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. Aquaculture in the Tana Basin are mainly small-scale fish farms in tanks, earthen raceways or ponds. Large-scale aquaculture occurs in Sagana and Kiganjo.

Water demands for agriculture in the Tana 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 about 1 million ha, mainly consisting of rain-fed crops, with only 99 000 ha of irrigated crops in 2018. The Tana Basin therefore has high potential for agricultural development.

3.2.8.4 Forestry, land use and catchment management

In 2010, the total forest area in the Tana Basin was about 446 000 ha. Forest reserves in the basin largely cover the areas surrounding the major water towers of the catchment, as well as groundwater recharge areas. Forest Reserves are located mainly the upper Tana and coastal region. The valuation of the forests in the basin and its contribution to the national economy is largely undocumented.

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 1 370 000 ha of forestation is proposed in the NWMP 2030 for Tana Basin up to 2030.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 1 370 000 ha of forestation is proposed in the NWMP 2030 for Tana 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.

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 Tana Basin.

The upper Tana Basin has important water towers which are under threat of farming encroachment. This area is also underlain by volcanic geology and steep slopes which means that the land is inherently prone to high levels of erosion. Farming on these steep slopes causes high levels of erosion and landslides. The lower Tana Basin is mainly rangelands and grasslands. These areas are primarily used to provide pasture for livestock farmers in the basin. Climate variability and overgrazing of the rangeland and grassland areas have increased the risk of vegetation loss and consequent soil erosion.

3.2.8.5 Biodiversity, protected areas and tourism

Biodiversity in the Tana Basin is linked to water resources and forest reserves or protected areas.

The major wetland in the Tana Basin is the Tana River Delta. The estuaries, mangroves and shorelines in the Delta provide a habitat for a wide range of plants and animals and is listed as an important RAMSAR site. The wetland ecosystems of the Tana Basin are environmentally sensitive areas under threat from human encroachment. 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.

Aside from the water towers and gazetted forests, which are managed by KWTA and KFS respectively, the Parks and Reserves Division of the 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 Tana Basin, 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 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 Tana Basin are increased deforestation, agricultural encroachment 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 insubstantial institutions arise from inadequate governance structures and inadequate capacity for law enforcement, and insubstantial 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 Tana 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 resources management in the basin result in biodiversity conservation.

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.

Image source: Erik (HASH) Hersman 2009. 'Lamu Island'. Available online at https://en.wikipedia.org/wiki/Lamu#/media/File:Lamu,_Lamu_Island,_Kenya.jpg

04

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 Tana 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 Tana 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 Tana 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.

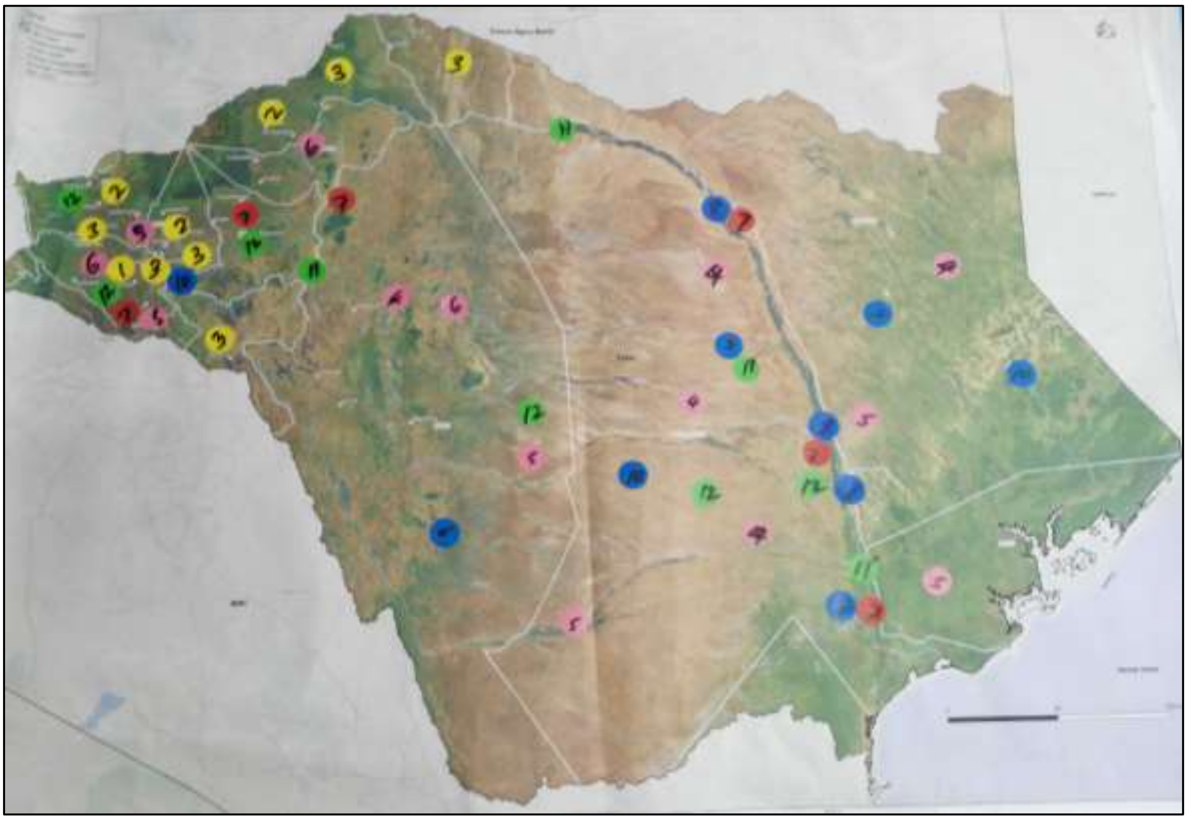


Figure 4-1: Example of outputs from the workshop for the Tana Basin

Issues were identified under the following main categories:

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

Figure 4-2 shows the relative frequency of the identified issues in the Tana Basin under the above categories.

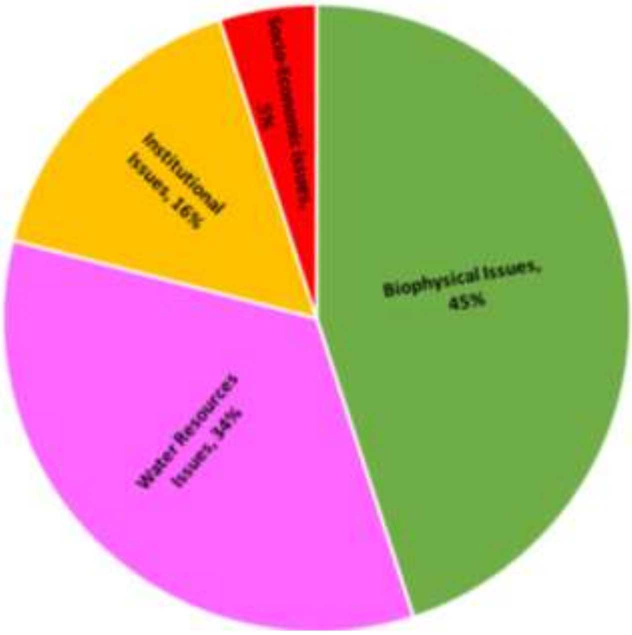


Figure 4-2: Frequency of identified key issues in the Tana Basin

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

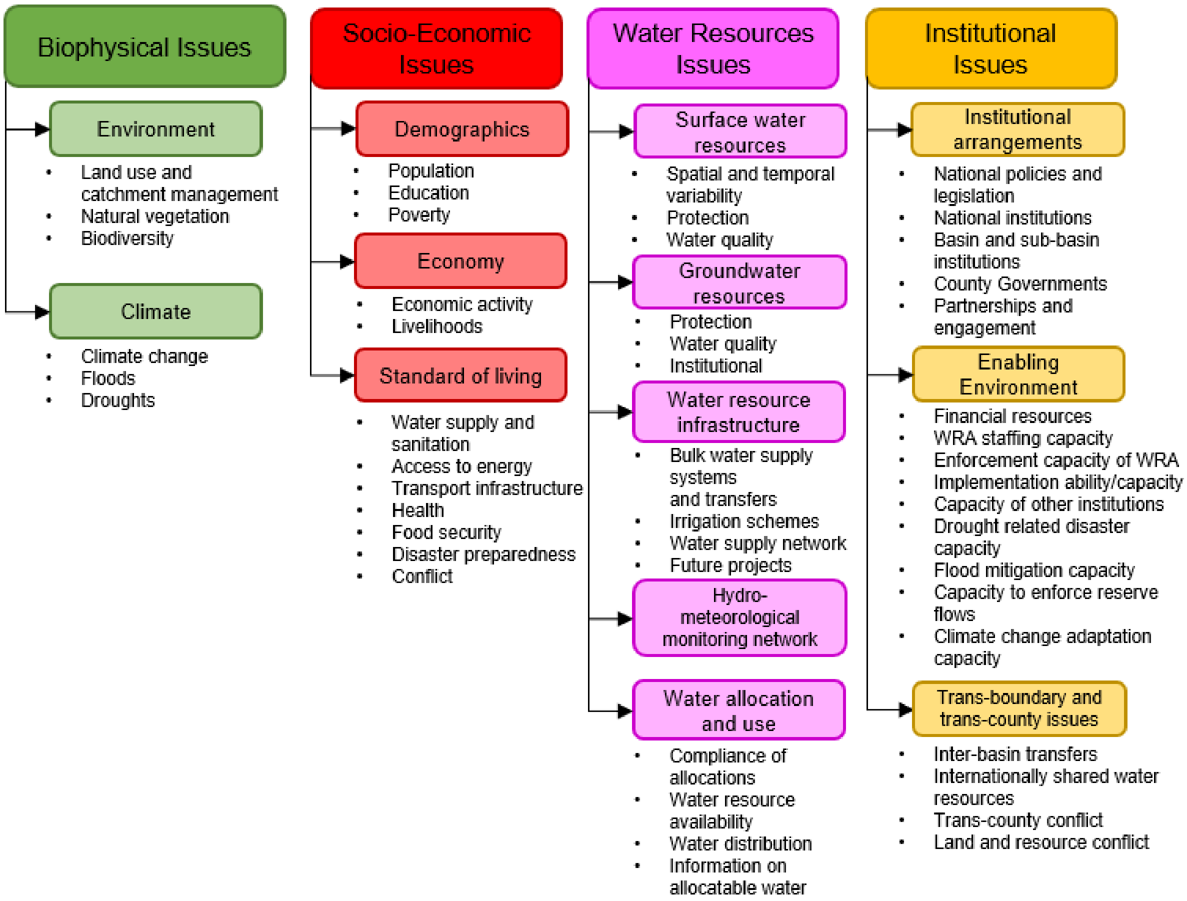


Figure 4-3: Key issues framework

4.3 Biophysical issues

https://jrsbiodiversity.org/three-freshwater-grants-east-africa-2018/hippo-group-in-tana-river-tana-delta-photo-by-p-usher/

Out of the four key issues identified, biophysical issues were ranked highest in the Tana Basin. Poor land use and catchment management issues were considered the most important to address, followed by environmental issues (loss of natural vegetation and biodiversity loss), and climate issues (droughts and floods).

4.3.1 Environment

The environment encompasses the land, vegetation and biodiversity of Tana Basin. Sustainable management of the land is necessary to maintain healthy vegetation and biodiversity. Issues arise through poor land use management and vegetation or biodiversity loss.

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. 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, agro-pastoralists 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. 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 Tana 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. 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).

Unsustainable agricultural practices and expansion

The predominant crop agriculture in Tana Basin is small-scale rain-fed farming in the highlands or close to seasonal water. With an increased population in these areas there has been an expansion of agriculture into sensitive ecosystems such as riparian areas, wetlands and into steep areas. 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:

- Cultivation on steep slopes, wetlands, riparian areas and quarries have led to landslides and soil erosion, therefore reduced productivity in Nyeri, Kirinyaga and Embu (County Government of Embu, 2019; County Government of Kirinyaga, 2018; County Government of Nyeri, 2018)
- Mukurwe-ini, Othaya and Tetu Sub-counties are prone to landslides due to poor farming methods in riparian areas in Nyeri County (County Government of Nyeri, 2018).
- There has been encroachment of springs in the Aberdare Range and Mount Kenya.
- In Nyeri County, poor farming methods have resulted in riparian areas being destroyed and rivers banks left bare, and landslides are now common in the hilly areas of Mukurwe-ini, Othaya and Tetu Sub Counties (County Government of Nyeri, 2018).

Poor rangeland management

There are many ranches and pastoralist areas in the rangelands of the basin. Rangelands are areas outside of towns and cultivated fields where animals graze. 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 natural resource management. This land use is under threat due to droughts increasing pressure on available pasture and limited water resources. Limited resources have meant that pastoralists move into sensitive areas such as riparian areas, seasonal rivers and forests for forage and water. Land degradation is also influenced by overgrazing as livestock may be forced to graze areas to a point where soil is exposed and vulnerable to wind and water erosion.

Examples of poor rangeland management:

- The pastoral areas of Tana River and Garissa Counties dry lands have become more and more unreliable for livestock keeping due to the slow but surely depletion of its rangelands caused by erratic rainfalls patterns and overgrazing livestock population (County Government of Lamu, 2018).

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 Environment and Management Authority, 2007). Sand harvesting can take the form of on-farm harvesting, seashore/lakeshore harvesting and riverbed harvesting. Sand harvesting may not be conducted on riverbanks due to the significant soil erosion risks, and catchment degradation risks associated.

Example of unsustainable sand harvesting:

- Sand harvesting and extraction of other building materials occurs in Embu county (County Government of Embu, 2019).
- Meru County has sand harvesting in river beds (County Government of Meru, 2018).
- Tharaka-Nithi County has unsustainable sand harvesting and quarrying (County Government of Tharaka Nithi, 2018).
- In Garissa county sand harvesting is done in seasonal rivers/streams (laghas) (County Government of Garissa, 2018).

Unsustainable mining

Mining and collection of stones and other minerals are 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 mining:

- Environmental degradation in Tana River County is caused by over exploitation of natural resources, where some mining practices do not follow the Environmental Management Plans as outlined in Environmental Impact Assessments and mining licenses (e.g. failing to backfill the mining pits). Quarrying, sand harvesting and gypsum harvesting take place across the county (County Government of Tana River, 2018).

Land use change

Land in the ASALs are 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.

Urban sprawl

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. Examples include the urban and peri-urban areas of Embu, Meru, Murang'a, Thika, Nyeri and Garissa.

4.3.1.2 Natural vegetation

The major contributors to the loss of natural vegetation in the Tana 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 basin’s natural vegetation.

According to the Global Forest Watch dataset there has been significant tree loss (tree cover considered to be vegetation above 5m) over the period 2001-2019 (Figure 4-4). The areas surrounding Mt Kenya and Aberdares have also had tree gain over the period 2001-2012.

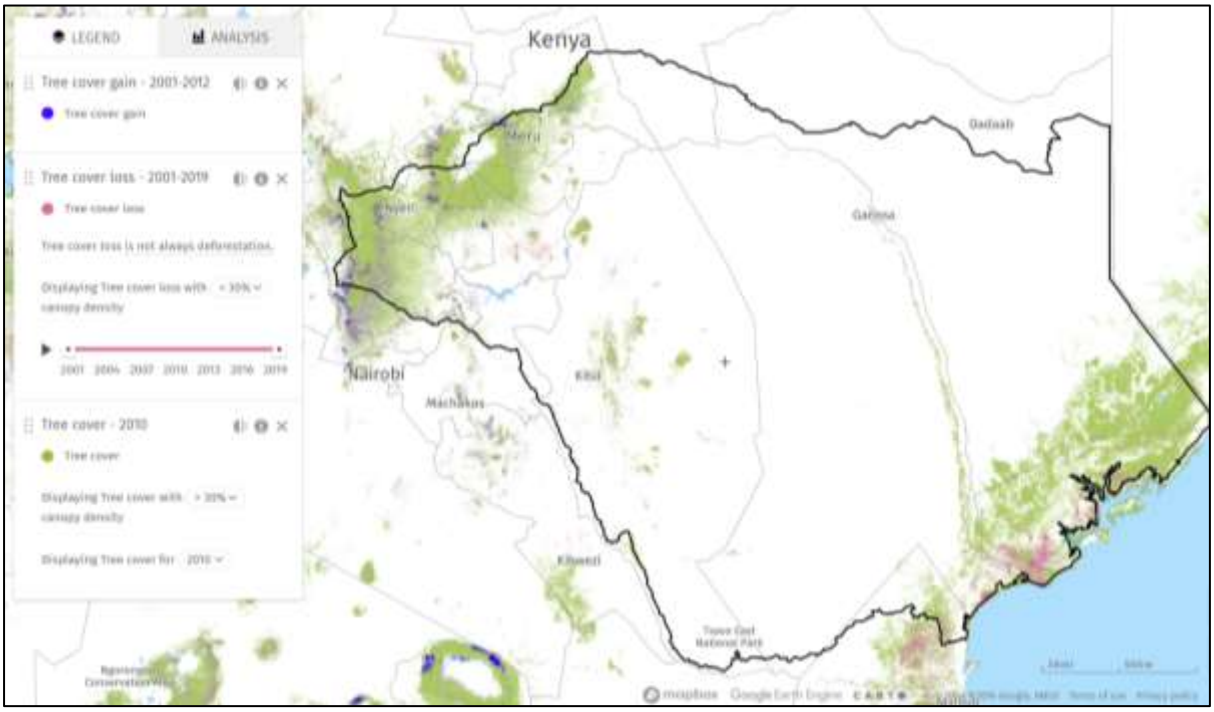


Figure 4-4: Tree loss and tree gain for Tana Basin according to Global Forest Watch

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 Tana 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. In order to achieve the targets of Kenya Vision 2030 about 1 370 000 ha of future forestation is proposed in the Basin (Water Resources Management Authority, 2013).

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

- Forests encroached by human developments for farming (County Government of Embu, 2019; County Government of Kirinyaga, 2018; County Government of Nyeri, 2018; County Government of Tana River, 2018; County Government of Tharaka Nithi, 2018)
- A challenge in Meru County is that most of the hills have been demarcated and allotments given to individuals (County Government of Meru, 2018).
- Deforestation due to illegal logging is occurring in Gatumbiro, Karima and Tumutumu Hill forest (County Government of Nyeri, 2018).

Encroachment of aquatic land

Wetlands and seasonal rivers (laghas) in Tana Basin are being encroached for farming and grazing. 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:

- Cultivation along riverbanks in Kirinyaga County (County Government of Kirinyaga, 2018).
- Wetlands in Meru County have suffered from encroachment and poor agricultural practices in farms adjacent to them (County Government of Meru, 2018). This emphasises the risk of floods.
- Forest destruction along riverine areas, mainly due to farming in Tana River County (County Government of Tana River, 2018).
- Lake Kenyatta and Lamu sand dunes are threatened by encroachment (County Government of Lamu, 2018; Water Resources Management Authority, 2015b).

Invasive alien species

The main threat from alien invasive plants is *Prosopis Juriflora* (commonly known as Mathenge). The tree spreads rapidly, outcompeting natural vegetation and reducing grazing areas. This contributes to rangeland degradation. Other invasive species are *Lantana camara, Solanum spp.* and *Opuntia spp.*, which become an issue when forest cover is cleared.

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 is also inadequate. The issues of biodiversity loss are addressed below.

Threatened ecosystems

The Tana 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:

- Logging in Mount Kenya forest (County Government of Embu, 2019).
- Illegal grazing on gazetted and non-gazetted hills (County Government of Tharaka Nithi, 2018).
- Tana River Delta encroachment (County Government of Tana River, 2018).

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:

- Drought increases human-wildlife conflict (County Government of Nyeri, 2018).

4.3.2 Climate

4.3.2.1 Climate change

Under the influence of climate change there has been an increase in extreme climatic events in the Tana Basin (County Government of Tana River, 2018). 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, increased streamflow (Omwoyo et al., 2017), and an increased risk of flooding and greater environmental degradation. Higher evaporative demand will also offset any benefits should rainfall possibly increase, also resulting in less effective rainfall (Omwoyo et al., 2017). These changes also have societal impacts through crop yields, as well as on the forestry industry which make proper sustained catchment management implementation even more essential. Most of the economic activities in Kenya are largely dependent on the climate (Government of Kenya, 2010b).

The sections below provide examples of potential issues linked to climate change in the Tana Basin. They specifically discuss the effects on people, the economy, infrastructure, and the rise of conflict.

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 and 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 physico-chemical parameters, micro-pollutants and biological parameters. Rising temperatures provide environments conducive for malaria vectors to thrive, therefore creating health issues. Average annual temperature in the Tana 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. The inconsistent rainfall makes locating water sources difficult for pastoralists and 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 Tana 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 Tana 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.

Examples of climate change impacts:

- Tana River county has observed intrusion of salt waters upstream, drying of ox-bow lakes, reduced crop productivity, loss of biodiversity, changing ecosystems and destruction of infrastructure (County Government of Tana River, 2018).
- Meru county has also experienced river flows dwindling over time, and during dry spells downstream users receive little or no water. This has resulted in resource conflicts and deaths. It is noted that the snow-capped mountains are becoming bare and the Moorland has been encroached by farmers who have constructed intakes (County Government of Meru, 2018).

4.3.2.2 Floods

The main areas susceptible to flooding in the Tana Basin include the middle to upper zones of Tana River, Kirinyaga and Kitui counties, as well as the lower slopes of Mount Kenya where flash floods and mudslides occur. Garissa and Tana River counties are characterised by long-duration flooding when the Tana River overflows its banks at Garissa Town, the middle Tana River reaches, and the Tana River Delta. Garissa Town also experiences local flooding due to inadequate urban drainage infrastructure. Occasional riparian and floodplain damage also occur along the Maua, Komoli, Kalikuvi, Kokani and Buna river tributaries of the Tana River. In general, there is inadequate capacity at local and regional level to manage flood-related disasters. The following sections provide examples of the issues caused by the inadequate preparedness for floods in the Basin.

People affected by floods

Floods have social consequences for people due to the disruption they cause on everyday activities. People are affected by floods in the event of displaced households. Pit latrines are easily destroyed or washed away in floods, resulting in sanitation issues as well as waterborne diseases, such as cholera and typhoid. Floods cause erosion and sedimentation, which reduces the water quality, causing health issues. Due to some farmlands located in floodplains, the crops are destroyed, which increases food insecurity.

It must be noted that similar to the farmlands, numerous communities reside in floodplain areas, which is why they are affected by seasonal floods. This is a major issue as these communities have been established in areas which are not safe to inhabit, and relocating communities has many issues and is often not regarded as an option.

Examples of people affected by floods:

- As a result of the changing in weather patterns, the risk of flooding is increased in Tana, especially in Tana Delta, Tana North and Tana river Sub county. (County Government of Tana River, 2018).
- The basin was affected by floods in the years of 2002, 2003 and 2010, and caused about 10 000 people to be internally displaced in areas such as Bura, Gubani, Masabubu and Tana Delta. (Huho et al., 2016).
- Tana also faces environmental threats which contribute to environmental degradation and ultimately deforestation floods. (County Government of Tana River, 2018).

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:

- Loss of livestock, crops, and decreased livestock production occurred due to flash floods in many of the counties including Tana River (Reliefweb, 2018a). In addition, the floods caused damage to road infrastructure in counties such as Tana River which often hinders the accessibility of markets. As a result, farmers are unable to sell their livestock, and crops which causes significant financial losses (Reliefweb, 2018a).

Damage to infrastructure

Floods can cause major damage to infrastructure depending on the severity of the flood.

Examples of damage to infrastructure due to floods:

- As a result of the long rains reported in June 2018, school infrastructure and sanitation facilities were damaged in the counties of Tana River and Garissa (UNICEF, 2018).

4.3.2.3 Droughts

Most of the Tana Basin is characterised by low rainfall and as a result the basin is affected by droughts almost every year. The extent and magnitude of the effects of droughts vary across the basin, with Chifiri, Hakoka, Kesi, Roka, Koticha Mlima and Koticha Odwani to be characterised as the water stressed areas. Prolonged droughts affect the recharge levels of the basin's water sources. Water use restriction levels are not clearly defined for the existing dams in the Basin, which cause operational issues during times of drought. These needs to be reframed. In addition, dam operating rules should be adhered to, and new ones should be developed to mitigate the impacts of droughts and floods.

The following sections provide examples of the issues caused by the inadequate preparedness for droughts in the Basin.

People affected by droughts

People, in both rural and urban areas are affected by droughts due to water scarcity and food insecurity as well as the livelihoods of those earning an income from the agricultural sector. 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. With an increase in droughts, leading to food insecurity and water scarcity, the percentage of the population suffering from malnutrition is likely to increase.

Examples of people affected by droughts:

- The Tana River County experiences yearly droughts in some parts, due to low rainfall (County Government of Tana River, 2018).
- In 1975, 1976, 1980, 1981, 1983, 2001, 2004, and 2009 the Tana River County experienced drought conditions, with the Central and North regions being mostly affected (Ngaina et al., 2014).
- In May 2019, the National Drought Management Authority reported that Tana River County is one of the ASAL counties experiencing drought alarming conditions as a result of prolonged dry spells (National Drought Management Authority, 2019a).
- Non-rechargeable levels of water sources in the Tana River contributes to prolonged drought in the county (County Government of Tana River, 2018).
- Tana River is also a county faced with environmental degradation effects (County Government of Tana River, 2018).
- Future projections for the climate of Tana River County, indicate that it will continue to be affected greatly by droughts. As a result, about 67% of the population will be food insecure and ultimately continue relying on food aid annually. (Kenya County Climate Risks Profiles Series).

Economic impacts of droughts

The agricultural sectors of all of the Counties in the Basin experience major losses due to droughts. Due to a large amount of the farmlands in the Basin being rain-fed agriculture, droughts result in low crop yields, poor quality of produce, and a change in varieties. Although crop prices increase to counter the lower crop yields, the agricultural sector usually experiences a reduction in sales, and therefore a reduction in income (County Government of Isiolo, 2018). Various areas in the Basin have been susceptible to losses in the agricultural sector due to droughts. 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. Pastoralists are often forced to migrate in search of water for their livestock.

Examples of economic impacts of droughts:

- Great losses of plants have been reported by farmers in the Tana River County due to a lack of enough rain to support production (National Drought Management Authority, 2019b).
- The prices of essential commodities were reported to be high in 2019, causing households to experience a deficit of food stocks (National Drought Management Authority, 2019b).
- The Tana River county experiences severe droughts, causing food security factors to be stressed as there is a reduction in harvests because of depressed rains (National Drought Management Authority, 2019b).
- Parts of the Tana Basin have been affected with severe vegetation deficits, which contributed to a decrease in livestock production, as was reported in May 2019 by the National Drought Management Authority in the National Early Drought Warning Bulletin (National Drought Management Authority, 2019b).

Conflict due to droughts

Droughts result in scarcity of water and as a result, wildlife and livestock travel in search of water. This gives rise to conflicts between various groups for reasons such as resource-based conflict, human-wildlife conflict, predation of livestock by wild animals, and transboundary conflict. Conflict due to water scarcity has been reported within the Tana Basin in the past (Water Resources Management Authority, 2015b). Conflict arises between locals and pastoralists when the migration of the pastoralists’ livestock increases competition for available resources (i.e. resource-based conflict). Crop farmers do not like livestock travelling across their land. The probability of humans coming into contact with wildlife increases during droughts as both humans and animals are in search of food and water (i.e. human-wildlife conflict). Livestock are preyed upon by wild animals, especially during a drought when food is scarce (i.e. conflict due to predation of livestock). Drought is the cause of many transboundary conflicts as it worsens water scarcity and thus results in County Government's prioritising water supply for their own residents (i.e. transboundary conflict).

Example of impacts of droughts:

- (National Drought Management Authority, 2019b)(National Drought Management Authority, 2019b)(National Drought Management Authority, 2019b)(National Drought Management Authority, 2019b)(National Drought Management Authority, 2019b)There has been reports of resource-based tensions and conflicts as a result of migrations of livestock among locals from Garissa towards Tana River and Tana Delta (National Drought Management Authority, 2019b).

4.4 Socio-economic issues

Socio-economic issues were deemed least important relative to other issue categories in the Tana Basin. Research regarding the demographics, economy and the standard of living provided information in the socio-economic issues.

4.4.1 Demographics

The demographic challenges in the Tana 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 Tana Basin is expected to experience significant population growth in the future, although water resources are limited and affected by climate change. This poses a challenge in terms of managing and servicing the growing population, especially in the growing urban centres.

Urbanisation

With water challenges in the Basin it is likely that there will be migration to urban centres. Currently most of the population reside in the rural areas. An increase in urban population will put pressure on existing resources. 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.

4.4.1.2 Education

The inadequate education can affect water resources management in terms of information sharing with the public as well as general understanding of water resources and the relevant laws and regulations put in place to protect water resources. The education challenges are discussed further below.

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.

Minimal understanding and awareness

There is minimal 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 provide an opportunity for better understanding of laws and regulations, and implementation and enforcement will also improve. There is minimal 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.

Inadequate education of water resources from a young age

Understanding brings awareness, which raises the concern of the limited 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.
- Technical and Vocational Training Centres 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.

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. 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 Tana 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 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

Economic development has a major influence on the development of water resources. With an increase in population expected there is a need to invest in infrastructure development. Furthermore, as discussed above, agriculture is the mainstay of Kenya's economy. 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 Tana Basin, discussed below, will influence the planning for water resources.

4.4.2.1 Economic activity

Plans for new infrastructure

With the projected increase in urbanisation in Tana Basin it is important to provide for a growing population in certain areas. LAPSSET will also significantly increase future water demands along the LAPSSET corridor and specifically in Lamu.

Example of new infrastructure:

- LAPSSET (Lamu Port, South Sudan, Ethiopia Transport Corridor) project is a mega infrastructure project bringing together Kenya, Ethiopia and South Sudan. It entails seven key infrastructure components, with plans for inter-regional highways, railway lines and oil pipelines from Lamu to Isiolo and from Isiolo to Juba (South Sudan) and Addis Ababa (Ethiopia), an international airport at Isiolo, and a resort city at Isiolo.

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.

4.4.2.2 Livelihoods

Those engaging in livelihood activities are usually reliant on natural resource supply in a catchment. With increasing population and demand, natural resources are being degraded therefore livelihood activities are not sustainable. This is an issue as it impacts people's self-reliance, and thus puts pressure on the economy. Sources of livelihoods in the Tana Basin vary from pastoralism to subsistence agriculture and crop/livestock farming. Threats to these activities include the following:

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

The Constitution of Kenya (2010) is based on the identification of sustainable access to safe water and basic sanitation, as well as a healthy environment as a human right. The people in the Tana Basin face various challenges in terms of their standard of living, which have been categorised into water supply and sanitation challenges, access to energy, transport infrastructure, food security and disaster preparedness. These are discussed further below.

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 41% of the population retrieve drinking water from unimproved water sources and 25% of the population get water from springs, wells and boreholes (Water Resources Management Authority, 2013).

The population growth is expected to be high. More than half of the urban population receives piped water from a WSP, whilst 29% of the rural population receives piped water from a WSP (Water Resources Management Authority, 2013). Most of the urban and rural populations make use of septic tanks and pit latrines for sanitation. There are currently no sewerage systems in place in the rural areas, and only 7% of the urban population has access to formal sewerage systems (Water Resources Management Authority, 2013).

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.

4.4.3.3 Transport infrastructure

Inadequate transport infrastructure contributes to food insecurity and limits future opportunities for development. Access roads above seasonal rivers (laghas) in the Tana 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. 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. Murang’a, Kirinyaga, Isiolo, Tana River, Kitui, Kiambu, Machakos counties are the main counties that have experienced malaria as a top disease, causing morbidity.

4.4.3.5 Food security

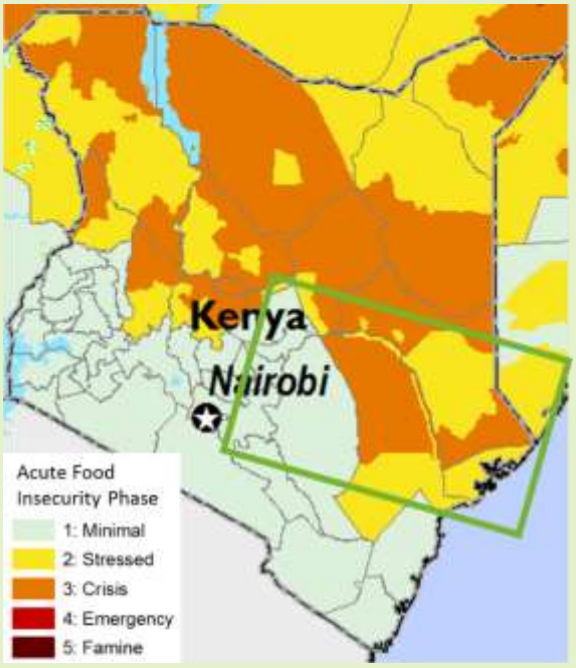
High population growth and low agricultural productivity in Kenya have led to agricultural production not meeting consumption. Low production is linked to the reliance on rain-fed agriculture, limited access to farming inputs, low uptake of new technology and influence of climate change. Populations in semi-arid counties are already facing food crises due to chronic drought. Tana River County is the most food-insecure area within the Tana Basin, with between 15 to 20% of households having poor or borderline food consumption. Tana River County is a drought-prone area with very high levels of poverty and low levels of education. Household in this area are highly dependent on markets to purchase food for consumption, and high food prices and poor market access increase food insecurity. Nyeri and Kirinyaga counties are food-secure, with less than 5% of households having poor or borderline food consumption. These counties lie within a high-potential agricultural zone, with more reliable rainfall and a well-developed road network which facilitates trade.

Short term food security outlook

Below-average rainfall in the long rainy season from March to May 2017 led to food shortages across most of the pastoral and agricultural areas in the Tana Basin.

Livestock productivity in the pastoral areas was below-average, limiting household income and increasing staple food prices. Crop production was good in the areas surrounding Embu, which received good rainfall, however crop production was poor in the Kitui and Tana River counties.

The short-term food security outlook shows that the Tana River, Isiolo, Garissa and Lamu counties were in a stressed to crisis food-insecurity phase during 2018, while the remaining counties remained in a minimal food-insecurity phase



Short-term food security outlook in Tana Basin

Food insecurity is closely linked to droughts in the dry regions of Tana Basin. 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.

Prolonged droughts

Changing rainfall patterns and prolonged droughts are an issue in most of the Basin where pastoralism is the main livelihood activity. Droughts reduce pastureland and limit water resources, creating significant food security issues.

Rain-fed agriculture

There are no major irrigation schemes in the Tana Basin. Most of the agricultural land in the basin is rain-fed agriculture and most of the land is rangeland.

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.

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 Tana 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

The majority of conflicts within the Tana 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.
- Illegal encroachment into the water towers and wetlands.
- 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, riparian users' access to the water resource.
- Resource use conflicts from pastoralist communities.
- Over-abstraction from rivers during the dry season.
- Water pollution by industries who do not comply with their license agreements.

4.5 Water resources availability, management and development issues

Water resources availability, management and development issues were ranked second (after Biophysical issues) in terms of priority in the Tana Basin. The main sub-issue was water quantity followed by water allocation and use.

4.5.1 Surface water resources

The Tana Basin has several water resources challenges, with insufficient water to meet demand in certain locations and during certain times of the year. Irrigation is the greatest demand in the Basin, which is expected to increase in the future. Sedimentation of seasonal rivers and pans is an issue as it limits already scarce water resources. The main surface water issues, regarding spatial and temporal distribution, protection as well as quality are discussed below.

4.5.1.1 Spatial and temporal variability

The spatial variability of water resources in Tana 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 Tana River region and middle Basin has a high demand for water, which surpasses the current water supply capacity in some areas. Some areas have high irrigation demands, and in other areas the demand is mostly for domestic and livestock. Many of the rivers in the lower Basin are seasonal, which results in an inconsistent supply of water.

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:

- In Kitui County, the access to piped water is worse in urban areas (36.1% of the population) than in rural areas (41.1%). The percentage of the county population that must walk more than 30 minutes to collect water is 57.6%, above the national average of 11.6% (County Government of Kitui, 2018).

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 the Tana Basin are discussed below:

Illegal abstraction

There is concern that in the high lying headwater regions water is being over abstracted, leaving limited water resources for downstream users.

Inadequate water for development

There is a concern associated with inadequate water resources for proposed projects to be developed.

Inadequate resource quality objectives

The resource quality objective for the water resources in the Tana 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 objective. The degradation of the water resources in the Tana Basin due to pollution emanates, among many other things, from the inadequate resource quality objectives. However, there are urgent plans to develop guidelines for the establishment of resource quality objectives and classification for all the basins.

4.5.1.3 Water quality

Water quality issues in the Tana Basin are not centred around urban quality issues, but rather agricultural pollution in the Upper Tana and sedimentation of surface water resources.

Sedimentation

Sedimentation negatively affects the water quality of the rivers and limits surface water storage. Extreme rainfall events have recently increased flash floods and sedimentation in the lower Basin. Poor land use management, rangeland management and deforestation also contribute to the high sediment loads in rivers. Stormwater from urban areas gets washed into rivers, carrying the sediments from the roads and pavements.

The most common sedimentation issues in the Basin are:

- Sediment loads from degraded farmlands
- Soil erosion from overgrazed lands and un-tarmacked roads

Dumping of solid waste

The dumping of solid waste contributes to surface water pollution. Issues are usually linked with informal settlements. In urban centres such as Amu and Shella there are established solid waste management systems but other areas in the Basin do not have the same level of service. This solid waste lands up in the stormwater, which ends up in rivers and dams.

Sanitation

Many urban centres usually have unplanned informal settlements, often with high population densities. These areas 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.

Inadequate sewerage treatment

Similar to the inadequate connections to proper sewerage systems, there are inadequate wastewater treatment facilities, which makes efforts to alleviate water quality deterioration difficult to implement.

Non-point sources

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

Example of water quality issues:

- In the lower parts of Mwea Constituency (Kirinyaga County) the main sources of water are from the rivers Thiba and Nyamindi, and the water is contaminated due to the use of fertilizers and pesticides (County Government of Kirinyaga, 2018).
- In Tharaka-Nithi County, water quality has deteriorated due to deforestation, which in turn effects the quality of fish and the quality of tourism (County Government of Tharaka Nithi, 2018).

4.5.2 Groundwater resources

The major issues surrounding groundwater resources in the Tana basin are summarised below. A more extensive discussion around groundwater issues is presented in section 0.

4.5.2.1 Protection

The Water Act 2016 defines protection of groundwater under Section 22/23 and groundwater use is managed through Section 47 and 104. However, the unsustainable use of groundwater is still a cause for concern in the Tana Basin. Groundwater issues have resulted from inadequate protection of groundwater, which is discussed further below.

Groundwater protection programs

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), 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.

Unsustainable groundwater use

Groundwater is under stress from over-abstraction in the Tana. This is increased by inadequate enforcement and management. Both Makuyu (Muranga County) and Warazo Lusoi (Nyeri County) have been identified as areas of possible groundwater over-abstraction (Knoop et al., 2012). Concerns have been expressed about the concentration of boreholes in the Kenol-Kabati area; Kenol Town is a rapidly urbanising centre in the southern part of Muranga County, formerly served largely by boreholes (Wamuchira, 2009). Some Basement aquifers may have also suffered localised depletion.

Saltwater intrusion

Saltwater intrusion has occurred in the Shela sand dune aquifer, Lamu. This may be due to over-abstraction or that only a small part of the aquifer is exploited. A simple numerical model will be developed for the Shela aquifer during 2019, after which it will be possible to draw up a coherent management plan. There may be grounds for concern about over-abstraction in the Lake Kenyatta coral and sand aquifer. The aquifer lies close to sea level, and there is a potential risk of saltwater intrusion.

Transboundary aquifers

There are two transboundary aquifers in the Tana Basin. 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", 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 groundwater resources. 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

Natural contaminants in the Tana Basin include fluoride, iron and manganese, as well as elevated total dissolved solids (TDS). There is widespread natural fluoride in the NAS and some other volcanic and Basement aquifers, as well as elevated natural iron and manganese in much of the basement aquifers. There are currently no Groundwater Quality Management Plans for areas with a high level of risk to groundwater quality issues. Basement groundwaters often contain water with elevated TDS, particularly in Arid and Semi-Arid Lands (ASALs) of the Basin.

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, 2019b) 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 Co-ordination (Water Quality) Regulations (2006) pre-date water legislation the Water Act in 2002, and effluent regulations in the Water Resources Management (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 (cf. t*he 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

Groundwater data quality is patchy, and in 2018 there was only one dedicated monitoring site in the Tana Basin (Water Resources Authority, 2018d). Most groundwater level data is collected from boreholes that are used as production boreholes. All too often, the data shows dynamic as well as static water levels. This restricts the utility of water level data to determine long-term trends. Abstraction monitoring is also 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. 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).

Unclassified groundwater applications in the PDB

The PDB of the WRA has had challenges, including numerous duplicate or out-of-date entries. When it comes to water permit classification, a decision must be made whether dedicated monitoring boreholes (or piezometers) require a Water Permit. 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). Furthermore, clarity is also required whether true exploratory boreholes require a Water Permit after completion, if they are not to be commissioned as production boreholes. Finally, the function and application of the Form WRMA 0A3 (Notification Approval for Construction of Work and Use of Water) needs clarification.

4.5.3 Water resources infrastructure

Tana Basin has limited water resources although there are dams for storage of water there are high demands, there is also a significant inter-basin transfer to Athi Basin. 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 Tana Basin is inadequate storage for various uses. The design of dams and other infrastructure is important to maintain the capacity designed for. There has been evidence that some irrigation dams as well other infrastructure is undersized for floods, which raises the question of whether floods were considered during the design of the infrastructure.

4.5.3.2 Irrigation schemes

There are major irrigation schemes in Tana Basin, although a large portion of agriculture is rain-fed. There are proposed irrigation schemes, which should help relieve the problem of food insecurity and unlock the significant irrigation potential in the basin.

4.5.3.3 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.

4.5.3.4 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.

Priority areas for groundwater resource development

There is currently inadequate information regarding the groundwater potential across the Tana 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 Tana Basin is inadequate, and the network is not being effectively operated. Inconsistent collection, recording and analysis of data, and as well as vandalism of monitoring stations, are a serious problem in the basin (Water Resources Management Authority, 2015a).

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.

4.5.5 Water allocation and use

One of the key challenges across most of the Tana Basin is limited water resource availability. 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.

4.5.5.2 Water resource availability

One of the key challenges across most of the Tana Basin is limited water resource availability. The discrepancy in water availability verses water demand creates challenges in allocation of water.

4.5.5.3 Water distribution

The water supplied in the Tana Basin is distributed unevenly in terms of both spatial and temporal contexts. The areas beyond the jurisdiction of the 11 urban WSPs either have no water infrastructure or receive water through community water projects. These areas rely on a variety of unimproved water sources ranging from rock catchments, springs and wells. Most of these are unprotected and are at risk of contamination. 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.

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.

4.6 Institutional issues

General institutional issues ranked third in terms of priority in the Tana Basin. with Institutional issues as the priority sub-issue.

4.6.1 Institutional arrangements

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

During the workshop on institutional issues, stakeholders noted that basin wide, issues of overlapping mandates, unclear policies and conflicting sectoral laws was a challenge. This is noted in the Physical Planning Act, and Agricultural/Land Acts, which holds a different definition to the Water Act regulations as to what constitutes riparian area. 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. Subsequently concerns were raised that there are some laws that do not align with the newly promulgated Water Act. Furthermore, minimal coordination between National Government and county government of the basin was also highlighted as a key challenge.

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 a 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

Poor water quality is one of the pressing challenges affecting the integrity of water resources in the basin. In 2014 only 17 major effluent dischargers were registered for the basin of while only 6 complied with the Effluent Discharge Control Plan (EDCP) however, none of them were issued with the effluent discharge permit. The lack of dischargers awarded ED permits reflects a decline in compliance to effluent discharge regulations and implies that the quality of effluent discharged is declining, hence the deteriorating water quality in Tana basin. Furthermore, it signifies that there has been poor oversight and pollution control from the WRA which could be attributed to inadequate resources such as technical skills, monitoring equipment and financial resources to enforce effluent discharge regulation. Given the widespread water quality challenges affecting the basin, strengthening the capacity of the WRA to enforce effluent discharge regulations, conduct water quality testing and compliance checks is pertinent for reversing the trend of non-compliance amongst effluent dischargers.

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

There are currently 170 existing WRUAs in the Tana Basin (as of 2019), as well as a further 70 WRUAs which have been proposed by the WRA. The establishment of the remaining WRUAs is crucial for ensuring good governance of local water resources. To date the establishment of these institutions has been slow mainly due to minimal financial and human resources. The challenges of limited financial resources and inadequate human resources also extends to existing WRUAs. This has rendered some institutions hallow and dysfunctional. Given the powers and functions of WRUAs as well as the powers and functions that can be delegated to WRUAs as per the Water Act, the strengthening of these institutions is crucial for upholding the NWA. Therefore, WRUAs need to be adequately financed through sustainable revenue streams. In addition, they need to be adequately staffed with legal, technical, professional and para technical human resources.

The unclear role of the BWRCs

BWRCs replaced the former CAACs which previously played a regulatory function at a regional level and maintained certain levels of autonomy. In terms of the Water Act 2016, BWRCs have not been assigned regulatory powers and are committees of the WRA. The placement of BWRCs under the WRA creates a confusion at a regional level about who is responsible for conducting certain water resources management activities between the BWRCs and WRA sub regional offices. Clarity regarding the mandate BWRCs is important for ensuring that the governance of water resources at a regional level is undertaken adequately, in addition it is critical for ensuring that BWRCs are allocated with sufficient resources in order to perform their functions.

Expansive area of jurisdiction

The Tana basin is divided into 17 CMUs based on common catchment characteristics, managed by five SROs. Due to the manner in which CMU's are designated, this forces some WRA SROs to oversee large areas with limited resources. This is apparent in the Kitui SRO and Garissa SRO which oversees the middle and lower Tana on a staff complement of 24 people combined. Issues of understaffing, inadequate vehicles, insufficient monitoring infrastructure and limited financial resources affecting these offices make it difficult for the WRA to effectively manage the entire area.

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.

Inadequate coordination

Counties are given mandate to independently plan their land; however, this has created siloed planning and has led to loss of coordination regarding the management of natural resources such as wildlife and water. Given the boundless nature of water, there is need for policy action to ensure integration of planning and decision-making at a trans-county level.

The Tana basin has several institutions with differing mandates and regulatory responsibilities operating within the jurisdictions of county government. County Executive Committees draw membership from Government platforms, and these intergovernmental platforms at a county level should be enhanced in order to ensure improved coordination and alignment in the execution of activities in the county government's area of jurisdiction.

4.6.1.5 Partnerships and engagement

Inadequate partnerships

Initial discussions with WRA indicate that there are a few partnerships in place, 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. The few partnerships operating the basin such as the Upper Tana Nairobi Water Fund, which is a collaboration between government, big business, utilities, conservation groups, researchers, and farmers is still fledgling. The partnership aims to increase farm productivity upstream while improving the water supply and cutting the costs of hydropower and clean water for users downstream.

Inadequate coordination between stakeholders

Basin wide there is inadequate coordination between the various institutions operating in the Tana basin. The inadequate coordination and subsequent misalignment between the institutions can largely be attributed to the fact that there are currently no effective platforms at a basin level, that facilitate for improved planning and coordination, where stakeholders from the various institutions are represented. The inadequate coordination has led to siloed planning, limited data sharing and duplication of activities.

Low public awareness of WRA's mandate

Generally, there is low public awareness of WRA in the Tana 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 Tana 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 WRA RO and SRO are under-capacitated with inadequate office space and equipment to effectively undertake tasks. The Meru and Garissa sub-regions require the construction of new office blocks, furthermore office equipment such as desks, computers, printers and laptops need to be upgraded. 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. In 2016 only 52 surface water monitoring station were collecting data 4 times a year and there were only 12 operational groundwater monitoring stations collecting data. 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

The Tana basin has a total of 7 vehicles of which 2 are in Embu RO and each of the SRO have one vehicle. The inadequate number of vehicles negatively affects day to day activities, data collection, monitoring and compliance activities in the basin. Unquestionably, more vehicles are needed at the WRA regional and sub-regional offices to improve the capacity of the WRA to cover more area and improve their and overall effectiveness and efficiency.

Inadequate laboratory facilities

The basin does not have enough laboratory facilities to carry out water quality testing and monitoring. Presently not all SRO have laboratory facilities and rely on other laboratory testing facilities which often either have aging equipment or inadequate supplies and materials. For example, the WRA laboratory facilities in Murang'a SRO are not equipped to analyse certain parameters regarding water quality such as Total Suspended Solids (TSS). Overall, there is a need to upgrade existing laboratory facilities as well as construct new facilities at SROs in order to improve operational efficiency of the WRA.

4.6.2.2 WRA staffing capacity

Understaffing in the Tana basin is affecting the operational efficiency of the WRA. In 2017, the staff complement of basin amounted to 100 people with the Embu RO 27 people, Meru SRO 13 people, Kerugoya SRO 14 people, Murang'a SRO 22 people, Kitui SRO15 people and Garissa SRO with 9 people. Given the expansive area of jurisdiction served by the Kitui and Garissa SRO, the WRA needs to urgently recruit personnel to increase staff complement in these areas. Overall the WRA needs to increase staff complement on technical areas such as water quality testing and monitoring including professional areas. In addition, the WRA needs to conduct training, upskilling and reskilling of the current staff complement. This should cover all the important aspects necessary for effective operation such as basic legislative and policy frameworks, good governance practices and advocacy; resource use conflict management, resource mobilisation and management, project management; and participatory resource mapping and management (Zeleke et al., 2019).

4.6.2.3 Enforcement capacity of WRA

The result of the inadequate staff is the inadequate capacity to conduct compliance and enforcement activities in the basin. Weak oversight and inadequate enforcement capacity at a basin level have led to water use irregularities such as illegal abstractions and over abstraction. Illegal abstractions are most common in the Upper Tana region. Given the deteriorating water quality levels due to limited oversight, effluent dischargers and the projected negative impacts climate change will have on water recourse, there is a need to increate compliance and enforcement capacity in the basin.

Currently, the WRA legal department is taking the lead on enforcement issues however the function is centralised and operating from HQ and serves all the six regional offices based on demand and occurrence of legal enforcement matters. As a result, there is also an inadequate number of enforcement teams on the ground. In addition, the WRA has approximately 17 trained legal prosecutors drawn from various departments such as water rights.

4.6.2.4 Implementation ability/capacity

Despite the development of the catchment management strategy for the basin there is no clear indication on progress in implementing strategic action of the strategy. This implies that there is limited ability to implement strategic plans in the basin as result improved focus in strengthening the capacity of the WRA to implement strategic plans is required. The implementation of long-term plans requires adequate financial and capacitated human resources, given the inadequacy of these resources in the basin, it becomes a struggle for the WRA to improve implementation of strategic actions identified in long-term plans. Therefore, specific bottlenecks regarding human and financial resources affecting the implementation of long-term plans needs to be assessed and corrective measures should be undertaken to address bottlenecks.

4.6.2.5 Capacity of other institutions

There are capacity challenges in some of the offices of the other institutions, including KFS, NEMA, KWTA and County Governments. This in turn affects the quality of outcomes that are implemented jointly with WRA. There is need for increased training and capacity as well as investment in all areas that need enhancement such as funding, equipment, human resources etc.

4.6.2.6 Capacity in WRA to deal with drought related disasters

There are areas of the Tana basin that are prone to long dry spells which exacerbate water scarcity, increase competition and eventuality of conflict. The Kitui county, Tana county and Garissa county are just some of the areas most affected by drought. Despite the severe impacts of droughts, the basin does not have a comprehensive / holistic drought management plan. The Garissa and Thika river are the only rivers with gauging stations which measure water levels to determine when water use restrictions should be applied by the WRA RO in times of droughts. The gauge stations have two steps of water level warnings, namely Alert and Alarm levels (Water Resources Management Authority, 2013). Once river water level reaches the warning level, WRMA Tana Regional Office carries out water use restriction by regulating water intake (Water Resources Management Authority, 2013).

The Tana basin has eight existing dams for hydropower and domestic water supply purposes, however a drought disaster management program has been developed and there is no clear programme of how water use restrictions in these dams will be carried out (Water Resources Management Authority, 2013). The inadequate drought disaster management programme and plan is likely due to inadequate technical expertise in drought planning.

4.6.2.7 Capacity in WRA with regards to flood mitigation

There is currently no systematic flood management taking place in the Tana basin, in addition there are no flood control measures (structural and non-structural) for some of the areas, i.e. Garissa, that experience severe floods. The mapping of flood prone areas in the basin has not been undertaken and there is no clear indication whether the WRA has a flood forecasting system (Water Resources Management Authority, 2013).

4.6.2.8 Capacity to enforce reserve flows

The WRA offices in the Tana basin are understaffed, inadequate compliance and enforcement capacity and struggle with over abstraction. The WRA therefore struggles to enforce reserve flows. The WRA has undertaken only minimal reserve determination of all water resources of the basin in order to be able to monitor abstractions and ensure that the issuance of water use permits is in line with the reserve.

4.6.2.9 Capacity of WRA with regards to climate change adaptation strategies

The Government of Kenya has developed various climate change tools to steer climate change response including and not limited to the National Climate Change Action Plan (Government of Kenya, 2013b), NDC submitted to UNFCCC in 2016 and the National Adaptation Plan (Government of Kenya, 2016). 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. WRA does not have a department or desk to specifically address climate change issues, rather climate change is blended into programme and project activities on a case by case basis.

4.6.3 Transboundary and trans-county issues

The upper Tana basin transfers water resources to the Athi Basin. There are potential conflicts between the two Basins if water resources are not managed and developed cooperatively. There are also conflicts between counties due to disparities in water use between upstream and downstream users.

4.6.3.1 Inter-basin transfers

The Tana basin provides approximately 80% of the Athi basin's water via an inter-basin transfer from the Thika and Sasumua dams to Nairobi. Therefore, any future developments within the Tana Basin could potentially impact on the quantity, quality and seasonality of flows transferred to Nairobi as a result need to be carefully monitored. There is also an intrabasin transfer from Masinga and Kiambere dams to support domestic water use at a transfer volume of 4 MCM/year. Developments undertaken upstream of the Masinga dam need to be carefully monitored for potential impacts on water quality and quantity.

4.6.3.2 Internationally shared water resources

The basin does have internationally shared rivers and aquifers.

4.6.3.3 Trans-county conflict

Intra basin trans-county conflicts and inter basin trans-county conflicts are mainly over arable land and water resources. Intra-basin cross-county tensions have been reported between farmers and pastoralist of the Kitui and Tana river counties. Intra-county conflicts exist between the upstream and downstream users of the Thiba River. The conflicts arise from the belief that upstream users are over abstracting. There has been a lot of tension between Murang'a county and Nairobi county in the Athi basin 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 Murang'a county (at the start of the tunnel) before commencing construction of the tunnel to Nairobi from Kitui county and Tana river county. There are also conflicts in Meru county and Isiolo county in the Ewaso Ng'iro North basin.

4.6.3.4 Land and resource conflict

Gaining access to arable land for grazing and farming within proximity of adequate water resources has resulted in conflicts in some areas. Conflicts have been reported between herders and subsistence farmers along the Thua river and around the Mutha area have been reported.

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Image source: J.M. Ledgard 2012 'Kenya's Secert Water Way'. Available online at https://www.1843magazine.com/content/places/jm-ledgard/secret-river

Vision and Scenario Evaluation

5 Vision and Scenario Evaluation

5.1 Introduction

In light of an improved understanding of the current situation in the Tana Basin as described in Sections 2 to 4, this Section presents the Vision for the Tana 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 Tana Basin

The Vision for the Tana Basin, which was developed in conjunction with stakeholders, reads as follows:

To be the Leading Basin in Sustainable Water Conservation, Protection, Regulation, Management and Use for Socio-Economic Development and Ecosystem Services for All by 2040

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 stepwise conceptual approach towards the evaluation of water management interventions.

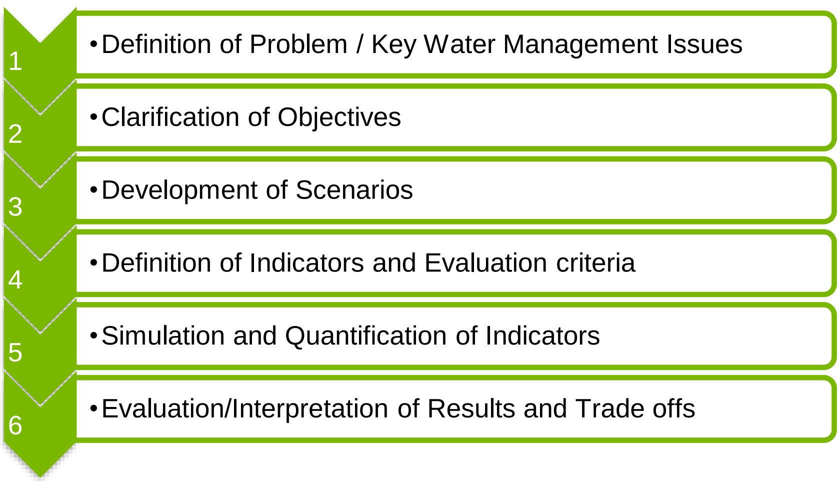


Figure 5-1: Scenario Evaluation (adapted from Kusek & Rist, 2004 and World Bank, 2008)

The key aim of the Tana Basin Plan was 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 adopted by this Study is illustrated schematically in Figure 5-2 below. The interventions and drivers are the key variables which constitute 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.**

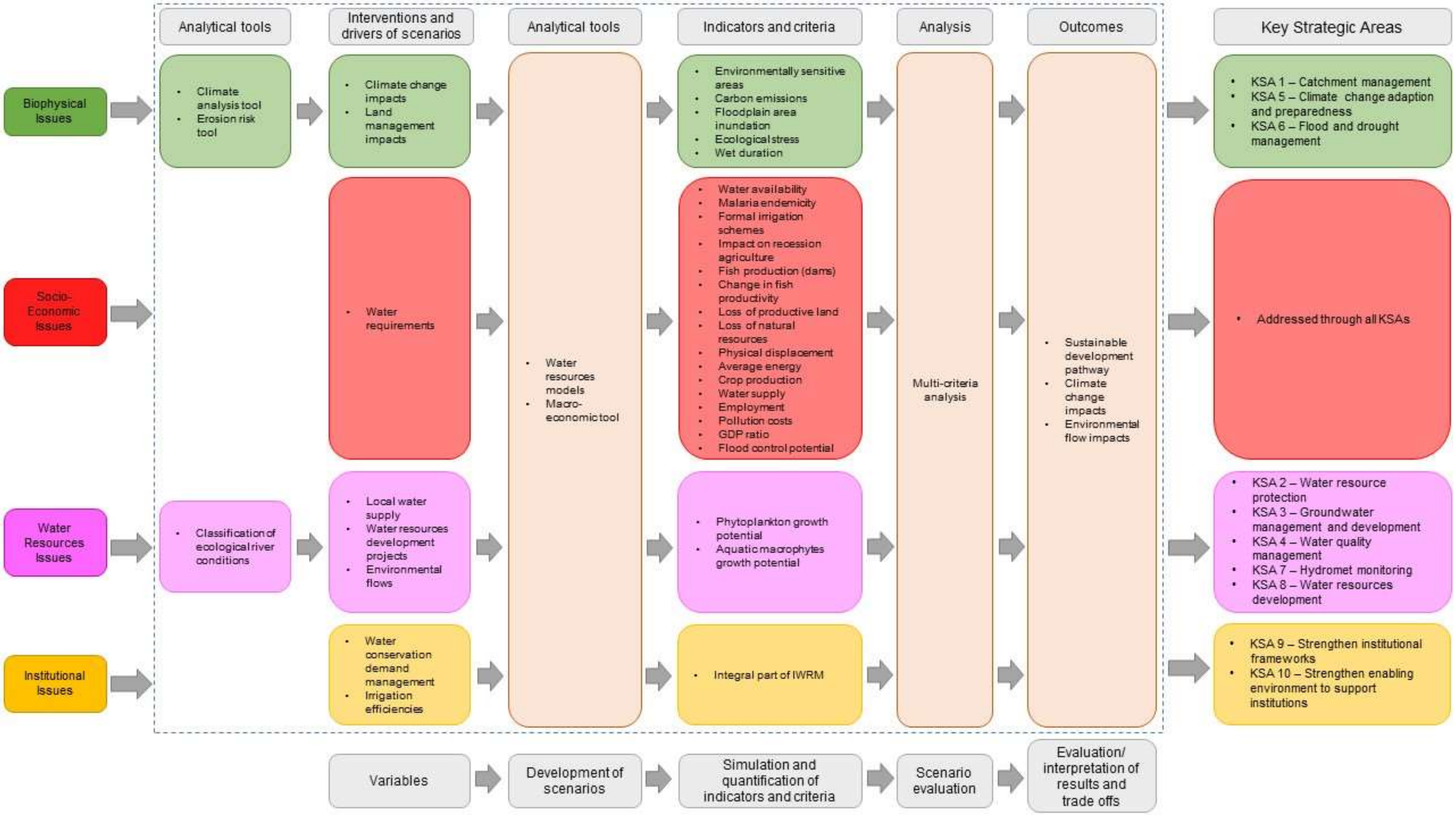


Figure 5-2: Approach to scenario development and evaluation

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 Tana 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 Tana Basin relates to the expected growth in future water requirements. To estimate future (2040) water requirements in the Tana Basin, the following approach was used:

Irrigation water requirements

To estimate future (2040) small-scale irrigation areas in the Tana 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 Tana 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 Tana 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 Tana 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 Tana 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 Tana 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 Tana 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 and large-scale irrigation schemes as listed in Table 5-1, Table 5-2,and Table 5-3 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**
Yatta	4CC	Kiambu Machakos	35	Water Supply (Matuu Town and Machakos County)
Thiba	4DA	Kirinyaga Embu	11	Large scale irrigation: Mwea Extension by 10 000 ha
High Grand Falls	4FB	Kitui Tharaka-Nithi	5 700	Water supply (Garissa, Lamu Port (LAPSSET), Masalani, Hola, Madogo) Large scale irrigation Hydropower (700 MW) Flood control
Umaa	4GF	Kitui	1	Water Supply (Kitui Town)
Kora	4GA	Tana River Isiolo	537	Large-scale Irrigation (25 000 ha)
Mutuni	4HA	Kitui	17	Water Supply (Kitui)
Kitimui	4HA	Kitui Machakos	8	Water Supply (Kitui)
Karura	4ED	Embu	-	Hydropower (67 MW)
Kindaruma HP upgrade	4ED	Embu	Existing dam	Hydropower (+32 MW)
Thuchi	4EB	Embu	23	Large-scale Irrigation (Kaagari Gaturi – 6 600 ha) Water supply (Embu Town and Embu County)
Karimenu 2	4CA	Kiambu	14	Water Supply (Nairobi/Kiambu counties)
Maragua4	4BE	Murang'a	33	Water Supply (Nairobi); Transfer to Athi Basin
Ndiara	4CA	Kiambu	12	Water Supply (Nairobi); Transfer to Athi Basin
Chania-B	4CA	Kiambu	49	Water Supply (Nairobi); Transfer to Athi Basin
Thika 3A	4CA	Kiambu	7.5	Water Supply (Nairobi); Transfer to Athi Basin

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

Transfers				
Scheme	**Counties**	**Proposed transfer capacity**	**Average transfer volume**	**Purpose**
Masinga Dam to Kitui (Upgrade existing)	Garissa Lamu	30 MCM/a	23 MCM/a	Water Supply (Kitui)
Kiambere Dam to Mwingi (Upgrade existing)	Machakos Kitui	7 MCM/a	2 MCM/a	Water Supply (Mwingi)
Upper Tana to Athi: NCT Phase II, Maragua 4	Kiambu Murang'a Nairobi	Total: 270 MCM/a	Total: 105 MCM/a	Water Supply (Nairobi)
High Grand Falls Dam to Lamu	Kiambu Murang'a	102 MCM/a (Final capacity depending on Lamu future water demand)	102 MCM/a	Water Supply (Lamu Port – LAPSSET)

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

Large-scale irrigation				
Scheme	**County**	**Proposed Area (ha)**	**Crop type**	**Source**
Kaagari Gaturi	Embu	6 600	Fruit trees	Thuchi Dam
Mitunguu	Embu	2 000	Maize	Thingithu River
Mwea Irrigation extension	Kirinyaga	Extend to 14 000	Rice	Thiba Dam
Usueni – Wikithuki Irrigation Development Project	Kitui	5 800	Maize	Tana River
D/S High Grand Falls	Tana River	106 000 (total)		Lower Tana River (High Grand Falls and Kora dams)
Masalani Irrigation Project		30 000	Sorghum	
Hola Irrigation extension		Extend to 6 400	Maize	
Bura Irrigation extension		Extend to 6 500	Maize	
Kora Irrigation Project		25 000	Maize	
Tana Delta Irrigation Project		Sugar: 20 000 Rice: 10 000	Sugarcane, rice	
Rahole Irrigation Scheme		8 000	Maize, rice, bananas	

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 Tana 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 5-4 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 Tana 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 Tana 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:
  - The implementation of Ndiara, Chania B and Thika 3 A dams in the upper Tana Basin, as further augmentation of transfer to the Athi basin, does not have to take place before 2040
  - Mutuni and Kitimui dams not included as options for water supply to Kitui
  - Future areas of irrigation schemes reduced:
    - Mwea: New total area 10 100 ha
    - Kaagari-Gaturi: New area 3 300 ha
    - Mitunguu: Area 1 600 ha (no expansion)
- 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 5-4: Scenario definition

Category	Type	Scenario						
		0	1	2A	2B	3A	3B	3C
Water resources development	Large dams	Gitaru	Gitaru	Gitaru	Gitaru	Gitaru	Gitaru	Gitaru
		Kamburu	Kamburu	Kamburu	Kamburu	Kamburu	Kamburu	Kamburu
		Kiambere	Kiambere	Kiambere	Kiambere	Kiambere	Kiambere	Kiambere
		Kindaruma	Kindaruma	Kindaruma	Kindaruma	Kindaruma	Kindaruma	Kindaruma
		Masinga	Masinga	Masinga	Masinga	Masinga	Masinga	Masinga
		Sasumua	Sasumua	Sasumua	Sasumua	Sasumua	Sasumua	Sasumua
		Thika	Thika	Thika	Thika	Thika	Thika	Thika
			Yatta	Yatta	Yatta	Yatta	Yatta	Yatta
			Thiba	Thiba	Thiba	Thiba	Thiba	Thiba
			Karimenu 2	Karimenu 2	Karimenu 2	Karimenu 2	Karimenu 2	Karimenu 2
			Umaa	Umaa	Umaa	Umaa	Umaa	Umaa
				High Grand Falls	High Grand Falls	High Grand Falls	High Grand Falls	High Grand Falls
				Maragua4	Maragua4	Maragua4	Maragua4	Maragua4
				Ndiara	Ndiara	Ndiara	Ndiara	
				Chania-B	Chania-B	Chania-B	Chania-B	
				Thika 3A	Thika 3A	Thika 3A	Thika 3A	
				Kora	Kora	Kora	Kora	Kora
				Mutuni	Mutuni	Mutuni	Mutuni	
				Kitimui	Kitimui	Kitimui	Kitimui	
				Thuchi	Thuchi	Thuchi	Thuchi	Thuchi
	Hydropower	Sagana Falls (1.5MW)	Sagana Falls (1.5MW)	Sagana Falls (1.5MW)	Sagana Falls (1.5MW)	Sagana Falls (1.5MW)	Sagana Falls (1.5MW)	Sagana Falls (1.5MW)
		Mesco (0.38MW)	Mesco (0.38MW)	Mesco (0.38MW)	Mesco (0.38MW)	Mesco (0.38MW)	Mesco (0.38MW)	Mesco (0.38MW)
		Wanji (7.4MW)	Wanji (7.4MW)	Wanji (7.4MW)	Wanji (7.4MW)	Wanji (7.4MW)	Wanji (7.4MW)	Wanji (7.4MW)
		Tana (20MW)	Tana (20MW)	Tana (20MW)	Tana (20MW)	Tana (20MW)	Tana (20MW)	Tana (20MW)
		Ndula (2MW)	Ndula (2MW)	Ndula (2MW)	Ndula (2MW)	Ndula (2MW)	Ndula (2MW)	Ndula (2MW)
		Gitaru (225MW)	Gitaru (225MW)	Gitaru (225MW)	Gitaru (225MW)	Gitaru (225MW)	Gitaru (225MW)	Gitaru (225MW)
		Kamburu (90MW)	Kamburu (90MW)	Kamburu (90MW)	Kamburu (90MW)	Kamburu (90MW)	Kamburu (90MW)	Kamburu (90MW)
		Kiambere (168MW)	Kiambere (168MW)	Kiambere (168MW)	Kiambere (168MW)	Kiambere (168MW)	Kiambere (168MW)	Kiambere (168MW)
		Kindaruma (72MW)	Kindaruma (72MW)	Kindaruma (104MW)	Kindaruma (104MW)	Kindaruma (104MW)	Kindaruma (104MW)	Kindaruma (104MW)
		Masinga (40MW)	Masinga (40MW)	Masinga (40MW)	Masinga (40MW)	Masinga (40MW)	Masinga (40MW)	Masinga (40MW)
				High Grand Falls (700MW)	High Grand Falls (700MW)	High Grand Falls (700MW)	High Grand Falls (700MW)	High Grand Falls (700MW)
				Karura (67MW)	Karura (67MW)	Karura (67MW)	Karura (67MW)	Karura (67MW)

Category	Type	Scenario						
		0	1	2A	2B	3A	3B	3C
Water resources development	Inter-basin transfers to Athi Basin	Thika Dam	Thika Dam	Thika Dam	Thika Dam	Thika Dam	Thika Dam	Thika Dam
		Sasumua Dam	Sasumua Dam	Sasumua Dam	Sasumua Dam	Sasumua Dam	Sasumua Dam	Sasumua Dam
		NCT Phase 1	NCT Phase 1	NCT Phase 1	NCT Phase 1	NCT Phase 1	NCT Phase 1	NCT Phase 1
				NCT Phase 2	NCT Phase 2	NCT Phase 2	NCT Phase 2	NCT Phase 2
				Maragua 4 Dam	Maragua 4 Dam	Maragua 4 Dam	Maragua 4 Dam	Maragua 4 Dam
	Intra-basin transfers	Masinga to Kitui	Masinga to Kitui	Masinga to Kitui	Masinga to Kitui	Masinga to Kitui	Masinga to Kitui	Masinga to Kitui
		Kiambere to Mwingi	Kiambere to Mwingi	Kiambere to Mwingi	Kiambere to Mwingi	Kiambere to Mwingi	Kiambere to Mwingi	Kiambere to Mwingi
				Masinga to Kitui Ext.	Masinga to Kitui Ext.	Masinga to Kitui Ext.	Masinga to Kitui Ext.	Masinga to Kitui Ext.
				Kiambere to Mwingi Ext.	Kiambere to Mwingi Ext.	Kiambere to Mwingi Ext.	Kiambere to Mwingi Ext.	Kiambere to Mwingi Ext.
				High Grand Falls to Lamu	High Grand Falls to Lamu	High Grand Falls to Lamu	High Grand Falls to Lamu	High Grand Falls to Lamu
	Small scale irrigation (ha)	72 430	79 922	79 922	79 922	79 922	79 922	79 922
	Large scale irrigation (ha)	Bura (6 000 ha)	Bura (6 000 ha)	Bura (6 000 ha)	Bura (6 000 ha)	Bura (6 000 ha)	Bura (6 000 ha)	Bura (6 400 ha)
		Hola (1 400 ha)	Hola (1 400 ha)	Hola Expansion (6 400 ha)	Hola Expansion (6 400 ha)	Hola Expansion (6 400 ha)	Hola Expansion (6 400 ha)	Hola Expansion (6 400 ha)
		Mwea (10 100 ha)	Mwea (10 100 ha)	Mwea Expansion (14 000 ha)	Mwea Expansion (14 000 ha)	Mwea Expansion (14 000 ha)	Mwea Expansion (14 000 ha)	Mwea (10 100 ha)
		Tana NIA (2 400 ha)	Tana NIA (2 400 ha)	Tana NIA (2 400 ha)	Tana NIA (2 400 ha)	Tana NIA (2 400 ha)	Tana NIA (2 400 ha)	Tana NIA (2 400 ha)
		Kibirgwi (400 ha)	Kibirgwi (400 ha)	Kibirgwi (400 ha)	Kibirgwi (400 ha)	Kibirgwi (400 ha)	Kibirgwi (400 ha)	Kibirgwi (400 ha)
		Muringa Banana Ph1&2 (2 600 ha)	Muringa Banana Ph1&2 (2 600 ha)	Muringa Banana Ph1&2 (2 600 ha)	Muringa Banana Ph1&2 (2 600 ha)	Muringa Banana Ph1&2 (2 600 ha)	Muringa Banana Ph1&2 (2 600 ha)	Muringa Banana Ph1&2 (2 600 ha)
		Tana Delta irrigation Project (2 000 ha)	Tana Delta irrigation Project (2 000 ha)	Tana Delta irrigation Project (30 000 ha)	Tana Delta irrigation Project (30 000 ha)	Tana Delta irrigation Project (30 000 ha)	Tana Delta irrigation Project (30 000 ha)	Tana Delta irrigation Project (30 000 ha)
		Mitunguu (1 600 ha)	Mitunguu (1 600 ha)	Mitunguu expansion (2 000 ha)	Mitunguu expansion (2 000 ha)	Mitunguu expansion (2 000 ha)	Mitunguu expansion (2 000 ha)	Mitunguu (1 600 ha)
				Kora Dam Irrigation (25 000 ha)	Kora Dam Irrigation (25 000 ha)	Kora Dam Irrigation (25 000 ha)	Kora Dam Irrigation (25 000 ha)	Kora Dam Irrigation (25 000 ha)
				Kaagari Gaturi (6 600 ha)	Kaagari Gaturi (6 600 ha)	Kaagari Gaturi (6 600 ha)	Kaagari Gaturi (6 600 ha)	Kaagari Gaturi (3 300 ha)
				Usueni – Wikithuki irrigation development project (5 800 ha)	Usueni – Wikithuki irrigation development project (5 800 ha)	Usueni – Wikithuki irrigation development project (5 800 ha)	Usueni – Wikithuki irrigation development project (5 800 ha)	Usueni – Wikithuki irrigation development project (5 800 ha)
				Rahole irrigation Scheme (near Garissa) (8 000 ha)	Rahole irrigation Scheme (near Garissa) (8 000 ha)	Rahole irrigation Scheme (near Garissa) (8 000 ha)	Rahole irrigation Scheme (near Garissa) (8 000 ha)	Rahole irrigation Scheme (near Garissa) (8 000 ha)

Category	Type	Scenario						
		0	1	2A	2B	3A	3B	3C
				Masalani (NIA) (30 000 ha)	Masalani (NIA) (30 000 ha)	Masalani (NIA) (30 000 ha)	Masalani (NIA) (30 000 ha)	Masalani (NIA) (30 000 ha)
	Small dams/pans (MCM)	27	27	27	27	27	27	159
	Groundwater use (MCM/a)	64	64	64	64	64	64	333
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)	30	30	29	29	28	28	28
Climate	Climate change	No	Yes	Yes	No	Yes	Yes	Yes
Water demand (MCM/a)	- Irrigation	1 408	1 554	4 371	4 275	3 355	3 355	3 161
	- Domestic/Industrial	217	940	940	940	878	878	752
	- Other	61	119	119	119	119	119	119
	- Export	181	232	337	337	337	337	337
	Total	1 867	2 845	5 767	5 671	4 689	4 689	4 370

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 5-5 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 5-5: 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 5-6 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 5-6: 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 5-7 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 5-8 indicates the evaluation criteria as calculated for each scenario of the Tana 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 5-9 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 5-7: 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 5-8: 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	0.4	325	325	325	325	319
		Carbon emissions dams	tons	n/a	8587	388805	388805	388805	388805	299161
		Carbon emissions LIR	tons	n/a	858	1054708	1054708	1054708	1054708	1013057
	Downstream areas	Floodplain area inundated	% change from baseline	n/a	7.3	-6.9	-9.3	-6.7	20.7	-8.5
		Ecological stress	Index (-5 to 0)	n/a	-3.8	-4.1	-4.2	-4.1	-3.8	-4.1
		Wet duration	% change from baseline	n/a	-96.6	-97.1	-97.2	-97.1	-96.2	-97.0
	Water quality	Phytoplankton growth potential	Average growth potential %	64.7	57.7	76.8	78.0	76.8	69.9	78.4
		Aquatic macrophytes growth potential	Index (-5 to 0)	-0.8	-1.0	-1.2	-1.2	-1.2	-0.9	-1.1
SOCIAL	Water availability	Change in availability of water for riparian users	% change from baseline	n/a	6.2	-3.6	-3.8	-2.8	17.8	-5.6
	Community health and safety	Malaria endemicity	Malaria endemicity (km^2)	25	26	113	113	113	113	107
	Food security and livelihoods	Formal irrigation schemes	Area (km^2)	265	265	1372	1372	1372	1372	1295
		Impact on recession agriculture	% change from baseline	n/a	7.3	-6.9	-9.3	-6.7	20.7	-8.5
		Fish production (dams/lakes)	tons/annum	626	672	1713	1700	1719	1486	1747
		Change in fish productivity	% change from baseline	n/a	-96.6	-97.1	-97.2	-97.1	-96.2	-97.0
		Loss of productive land	Area (km^2)	n/a	3	117	117	117	117	101
		Loss of natural resources	Area (km^2)	n/a	0.4	325	325	325	325	319
	Displacement	Physical displacement	Number people	n/a	5338	57602	57602	57602	57602	34596
ECONOMIC	Energy	Avg energy	GWh/annum	1722	1678	3465	3338	3479	3520	3446
	Food production	Crop production (formal irrigation)	Million ton/annum	0.2	0.2	1.6	1.5	1.7	1.1	1.7
		Fish production (dams/lakes)	tons/annum	626	672	1713	1700	1719	1486	1747
	Water supply	Urban water supply	Ratio	0.72	0.57	0.77	0.76	0.79	0.52	0.81
		Domestic water supply	Ratio	0.80	0.76	0.76	0.75	0.76	0.69	0.80
		Formal irrigation water supply	Ratio	0.76	0.72	0.71	0.71	0.75	0.48	0.80
		Small-scale irrigation water supply	Ratio	0.69	0.66	0.65	0.64	0.65	0.51	0.80
	Employment	Employment formal irrigation	Jobs/annum	31926	53000	274440	274440	343050	343050	323790
		Employment hydropower	Jobs/annum	3302	3355	6930	6675	8698	8800	8615
	Pollution costs	Pollution cost index related to dams and formal irrigation schemes	Ratio of baseline	1.0	1.0	1.2	1.2	1.2	1.1	1.2
	Sediment	Sediment potential index	Ratio of baseline	1.00	1.00	0.95	0.95	0.94	0.94	0.94
	Primary GDP	GDP index	Ratio of baseline	1.0	2.8	3.7	3.7	4.4	4.3	5.5
	Flood control	Flood control potential	Ratio	0.33	0.34	1.18	1.18	1.18	1.18	1.16

Table 5-9: 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 5-10.

- Scenario 3C ranks above Scenarios 1, 2A and 3A from an Economic and Social perspective. This is mainly due to a more reliable supply of water as a result of improved irrigation efficiencies, a reduction in urban demands through water demand management and the development of small dams and pans for water supply.
- Scenario 3C scores higher than Scenarios 2A and 3A from an Environmental perspective due to less development in environmentally sensitive areas through a reduction in some irrigation scheme footprints and fewer dams implemented.
- Scenario 1 scores the highest from an Environmental perspective due to the limited environmental impacts from large dam and irrigation scheme footprint areas. Although the implementation of Q95 as a minimum release under Scenarios 2A and 3A should lead to a slight improvement to the aquatic environment, this is not enough to outscore Scenario 1 Environmentally – also because application of Q95 as a constant minimum flow does not significantly improve the aquatic habitat.
- The business as usual scenario (Scenario 1) scores lowest under Economic, mainly due to the impacts of increased water demands without investment in storage and regulation infrastructure, no implementation of additional large-scale irrigation and no expansion of hydropower capacity under Scenario 1.

Table 5-10: Scenario scores and ranking for the business as usual, full development and sustainable development scenarios

	ECON	ENV	SOC
SC1	0.444	0.699	0.473
SC2A	0.466	0.446	0.489
SC3A	0.491	0.455	0.513
SC3C	0.512	0.468	0.527
SC1	4	1	4
SC2A	3	4	3
SC3A	2	3	2
SC3C	1	2	1

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

- The supply deficits for current urban and rural domestic as well as irrigation water requirements in the Tana Basin typically vary between 20% and 40%, mainly due to shortfalls during the dry season and/or during droughts.
- Within the Tana Basin, projections for growth in urban and rural domestic, livestock and irrigation water requirements by 2040, will necessitate significant interventions for the development of water resources to ensure water availability at an acceptable assurance of supply. This will demand a combination of new storage dams, intra-basin transfers, water demand management measures, conjunctive use depending on groundwater availability and quality, as well as consideration of measures for rainwater harvesting.
- 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.
- Groundwater abstractions need to be monitored to ensure the sustainable yields are adhered to.
- It is recommended that water demand management is implemented in all urban areas, while irrigation efficiencies should also be improved.
- Even taking into consideration the existing and planned inter-basin transfers from the upper Tana Basin to the Athi Basin, which is a priority, there is still significant water resources available for development in the Tana Basin.
- The planned 700 MW hydropower installation at High Grand Falls Dam, the construction of Karura (67 MW) and the installation of an additional 32 MW at Kindaruma Dam, will increase the hydropower generated in the Tana Basin by almost 100%.
- Existing and planned hydropower installations along the upper and middle Tana River, including the proposed High Grand Falls Dam, should be operated and optimised in order to maximise energy output towards meeting the future energy requirements of Kenya. This will demand integrated, basin wide operating rules taking into consideration inter-basin transfers in the upper Tana Basin, hydropower optimisation, flood control and irrigation requirements along the lower Tana River as well as water requirements in urban centres supplied from the existing and planned large dams.
- The proposed High Grand Falls Dam will be able to support extensive irrigation along the lower Tana River at a high assurance of supply, generate hydropower, provide flood control, and supply various towns along the lower Tana River including Lamu Port (via a transfer), where significant growth in water demand, linked to the LAPSSET development, is expected.

- The addition of Kora Dam, downstream of High Grand Falls Dam, will facilitate the re-regulation of releases (mainly hydropower) from High Grand Falls Dam. This will allow the expansion of irrigation and improve irrigation efficiencies without having a negative impact on the operation of High Grand Falls in terms of hydropower and flood control as priority functions.
- The Northern Collector Tunnel Phase 1 scheme will increase the average transfer volume to the Athi Basin by about 50 MCM/a. The completion of the Maragua 4 Dam and related infrastructure as well as the Northern Collector Tunnel Phase 2 Transfer, representing Phases 3 and 4 of the bulk water upgrade as recommended in the Master Plan for Nairobi and Satellite Towns (Ministry of Water and Irrigation & Athi Water Services Board, 2012), will increase the transfer volume to the Athi Basin by another 92 MCM/a on average. The implementation of Ndiara, Chania B and Thika 3 A dams in the upper Tana Basin, as further augmentation of transfer to the Athi basin, does not have to take place before 2040.
- The new Umaa Dam in conjunction with an extension of the current transfer capacity from Masinga Dam, should be able to meet the expected growth in the urban water requirements of Kitui Town up to 2040. The construction of Kitimui and Mutuni dams, as water sources for supplying Kitui Town, could therefore be delayed.
- Almost 80% of the planned large-scale irrigation development in the upper Tana Basin is feasible. This will, however, require the construction of large and small dams to ensure a high reliability of supply e.g. Thiba and Thuchi dams.
- The maximum area of large-scale irrigation along the lower Tana River, which will be supported by High Grand Falls and Kora dams at a high assurance of supply, is in the order of 106 000 ha.
- In order to reduce the loss in storage in existing and proposed large dams in the basin due to sedimentation, catchment management measures and programmes should be implemented in the upstream catchments where erosion risk has been identified as high.

Additional considerations need to be made to ensure the chosen pathway is sustainable in all three dimensions:

- The deterioration of the basin in the business as usual scenario (Scenario 1), due to continuous deforestation and overgrazing, is not explicit in the analysis, with Scenario 1 ranking highest from an Environmental perspective. This is due to the nature of the analysis and the fact there is only one criterion which assesses catchment management intervention impacts/benefits. Nevertheless, it is imperative that catchment management interventions linked to reforestation, improved land-use management and reduced overgrazing are integrated into the sustainable development pathway.
- The sustainable development pathway aims to limit or avoid any development in environmentally sensitive areas. However, the results of this analysis should be supported by Environmental Impact Assessments (EIAs) and Environmental Management Plans (EMPs) for each scheme before implementation. This was accommodated to some extent through qualitative indicators as part of individual scheme analyses (refer to Section 6.9.6).
- The financial viability of schemes was not explicitly addressed in the scenario analysis and evaluation. Individual scheme evaluations (refer to Section 6.9.6), however, included cost-benefit analyses which is essential for identifying the most sustainable and economically beneficial schemes.

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 5-11.

- Scenario 2A (with climate change), ranks above Scenario 2B (without climate change) from an Economic, Social and Environmental perspective. This is mainly due to the increased rainfall - especially in the upper basin - under the climate change scenario and the additional water which is available as surface water and groundwater. Even though there is increased evapotranspiration and some impacts on seasonality of flows due to climate change, the net benefit is still positive.

Table 5-11: Scenario scores and ranking for the climate change comparison

	ECON	ENV	SOC
SC2A	0.584	0.500	0.615
SC2B	0.548	0.418	0.566
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 Tana Basin, 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 5-12.

- The impact of the EFlows from an Economic perspective is evident as 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 significantly 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 5-12: Scenario scores and ranking for the environmental flow comparison

	ECON	ENV	SOC
SC3A	0.566	0.395	0.573
SC3B	0.554	0.505	0.593
SC3A	1	2	2
SC3B	2	1	1

Although the EFlow scenario ranked higher than the Q95 scenario in two 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. Furthermore, environmental flood releases, which will ensure the health of the Tana River Delta, should be incorporated in the operating rules of Kora and High Grand Falls dams.

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 Tana Basin Plan is to provide a clear way forward for the integrated management and development of the water resources of the Tana 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 Tana Basin and to unlock the value of water as it relates to socio-economic development, ten Key Strategic Areas (KSAs) were formulated for the Tana 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 support effective institutions	Improved regulatory responses to strengthen catchment-based water resources management

The ten KSAs are discussed in detail in the following sections in terms of 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 (Figure 6-1). The utilisation and management of land and water resources should thus be done in an integrated manner to ensure the sustainability of both.

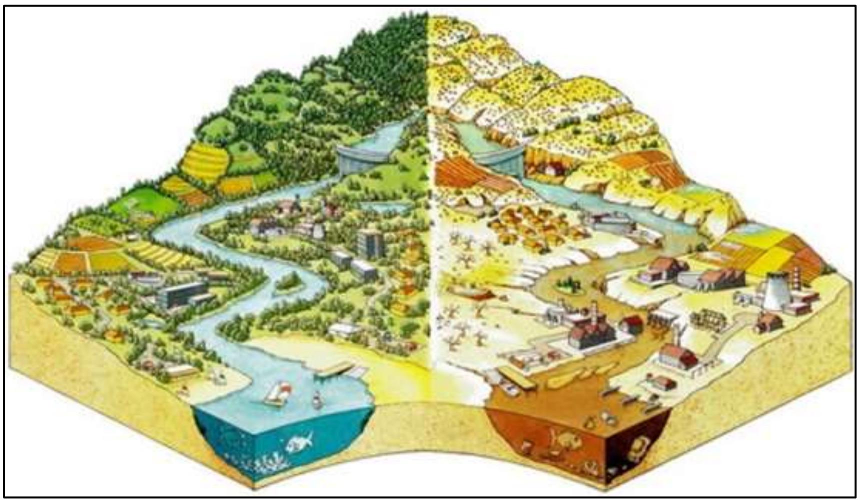


Figure 6-1: Illustration of good (left) and poor (right) state of both land and water resources in a catchment

Land degradation is not just the physical degradation of the soil, but the disturbance of the biophysical environment through human activity. The interconnected links of land degradation are illustrated in Figure 6-2. Land degradation 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.

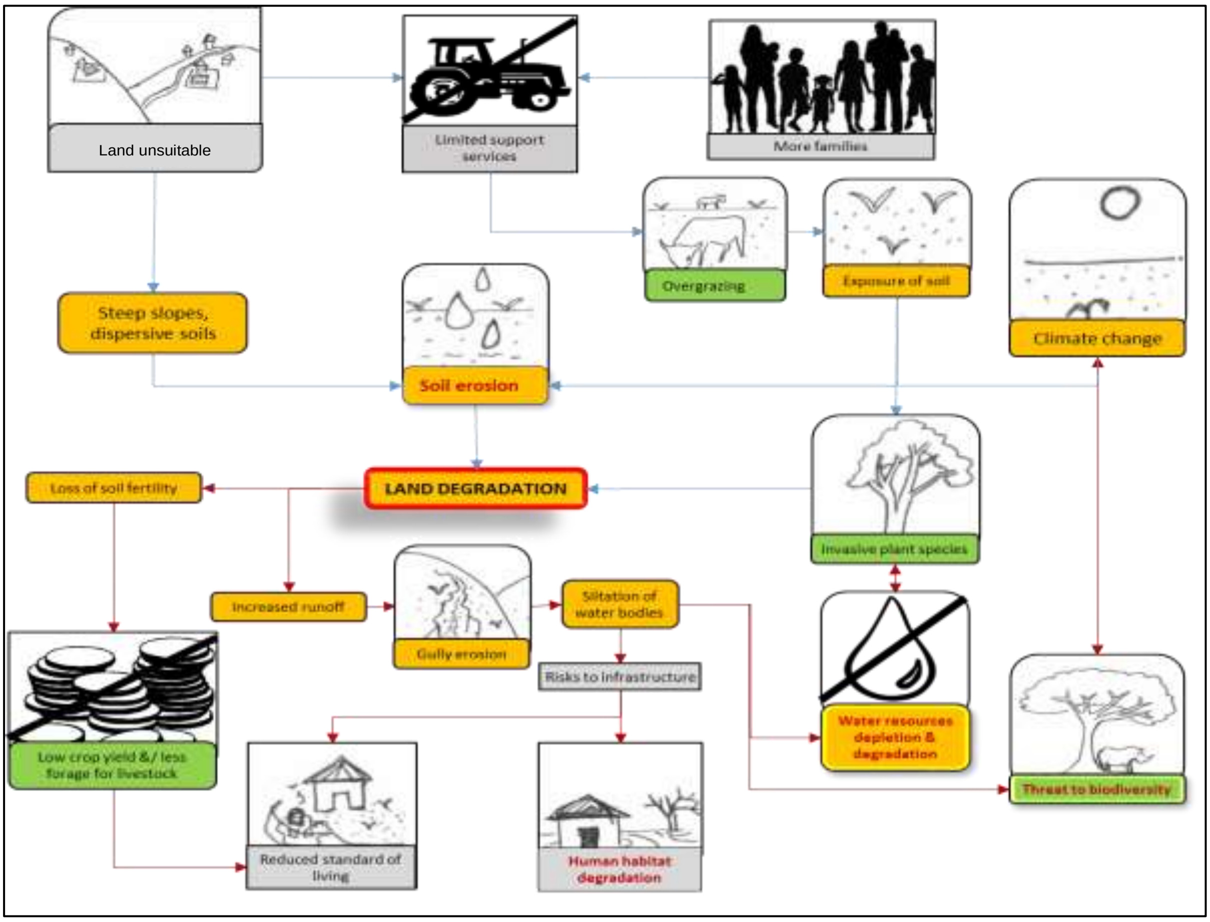


Figure 6-2: Example of the interconnected links of land degradation

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.

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.

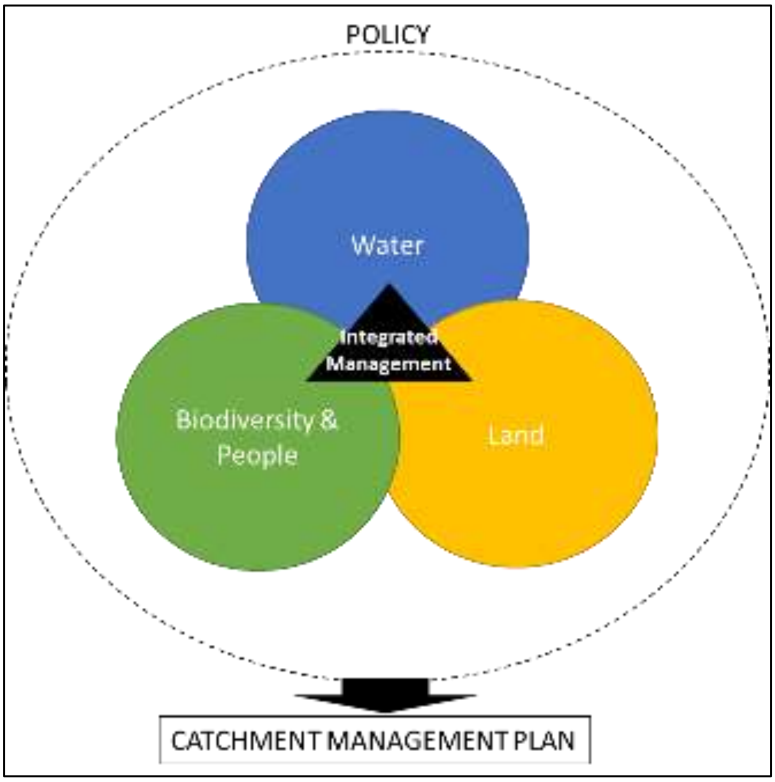


Figure 6-3: Interaction of different management strategies for catchment management

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 resources 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. 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.

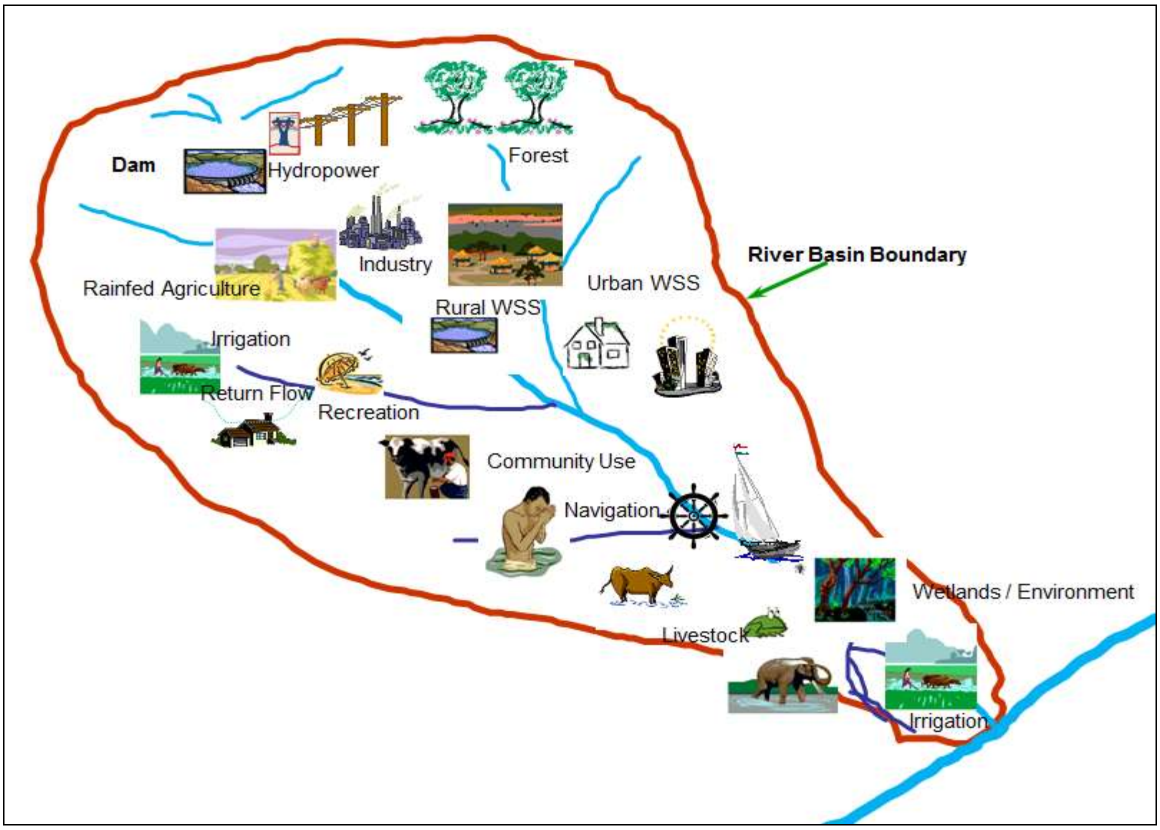


Figure 6-4: Illustration of water and land use activities within a catchment

Several difficulties arise in this concept. Firstly, people are not settled according to catchment boundaries. Secondly more than one Tribal Authority or District Council may fall into catchment, and conversely one Tribal Authority or District Council's administrative area may cover more than one catchment area.

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.

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 Tana 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 work together to achieve sustainable management of the Basin.

6.2.3.1 Water resource-based issues

The Tana Basin is managed by five WRA Sub-regional offices, which manage 17 Catchment Management Units (CMUs) based on hydrological, water resources and land use considerations. Some of the WRA offices in the Tana 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 Tana Basin for the period 2015-2022 (Water Resources Management Authority, 2015b). Section 8 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. The SCMP is an IWRM tool for water resources management to support sub-catchment management. The Tana Basin has 170 existing WRUAs out of a potential 240 WRUAs needed to cover the whole basin. The 70 WRUAs gap of 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 operating at local level in the Tana Basin

Upper Tana		
	**WRA SR / SRO / CMUs**	Upper Tana/ Murang'a/Sagana-Gura, Lower Sagana, Upper Thika and Lower Thika
	Issues	– Increased catchment degradation – Encroachment into wetland areas and riparian lands – Poor solid waste disposal – Quarrying – Mining – Sand harvesting – Under investment in catchment conservation – Seven Forks dams is threatened by siltation as a result of catchment degradation
Lower Tana		
	**WRA SR / SRO / CMUs**	Thiba/Kerugoya/Tana, Karaba, Ena and Thiba; Kathita – Mutonga/Meru/Mutonga, Kathita Kathita, Ura and Tharaka-Nithi; Tiva – Tyaa/Kitui/Tiva and Lower Reservoirs; Lower Tana/Garissa/Lower Tana, Ijara and Lamu
	Issues	– Increased catchment degradation – Encroachment into wetland areas and riparian lands – Poor solid waste disposal – Quarrying – Mining – Sand harvesting – Encroachment of the Lamu sand dunes – Under investment in catchment conservation – Lake Kenyatta, and the Lamu sand dunes are threatened by encroachment.

6.2.3.2 Land/Agriculture-based issues

Various Directorates under the Agriculture, Fisheries and Food Authority 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 a 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: Agricultural institutions operating at local level in the Tana Basin and relevant issues

Upper Tana		
	**AFFA/extension services**	Nyeri, Kiambu, Murang'a, Kirinyaga, Embu
	Pastoralists	None
	Issues	**Nyeri** – Cultivation on steep slopes, wetlands, riparian areas and quarries have led to landslides and soil erosion, therefore reduced productivity **Kirinyaga** – Cultivation along riverbanks **Embu** – Deforestation, especially farming areas – Farming on steep slopes led to soil erosion

Lower Tana		
	**AFFA/extension services**	Meru, Tharaka-Nithi, Isiolo, Garissa, Tana River, Kitui, Machakos, Lamu
	Pastoralists	Isiolo, Garissa, Tana River
	Issues	**Meru** – Cultivation of riparian land and drainage of marshy land **Tharaka-Nithi** – Forests encroached by human developments for farming – Farming on hillside causes soil erosion – Illegal grazing on gazetted and non-gazetted hills **Isiolo/Garissa** – Overgrazing and overstocking leading to land degradation **Tana River** – Forest destruction along riverine areas, mainly due to farming – Loss of rangelands – Soil erosion on farm lands – Invasive *Prosopis juliflora* threatens livestock keeping on grazing land **Lamu** – Garissa and Tana River counties have become less reliable for livestock keeping due to erratic rainfall and overgrazing. This puts pressure on Lamu county due to competing resources

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 provides for groundwater recharge. There are 18 gazetted, 24 non-gazetted, water towers in Kenya. In the Tana Basin the gazetted water towers include Mount Kenya, Aberdares Range and Nyambene Hills.

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 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 Tana 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 operating at local level in the Tana Basin and relevant issues

Upper Tana		
	**Water Towers (KWTA)**	Mount Kenya, Aberdares Range and Nyambene Hills
	National Parks (KWS)	Aberdare National Park, Mount Kenya National Reserve and Park, Mwea National Reserve.
	Issues	– Land prone to landslides due to poor farming methods in riparian areas – Uncontrolled logging is causing biodiversity loss in forests
Lower Tana		
	**Water Towers (KWTA)**	Mount Kenya
	National Parks (KWS)	Mount Kenya National Reserve and Park, Meru National Park, North Kitui National Reserve, Bisandi National Reserve, Kora National Park, Tana River Primate National Reserve, Rahole National Reserve, Arawale National Reserve, Boni National Reserve, Dodori National Reserve
	Issues	– Logging in Mount Kenya forest – Forests encroached by human developments for farming or exploiting forest resources – Illegal grazing on gazetted and non-gazetted hills – Cultivation of riparian land and drainage of marshy land – Encroachment of swamps and wetlands creating risks of floods – Forest destruction along riverine areas, mainly due to farming, destroying habitats along riverbanks – LAPSSET requires strategic environmental assessments – Severe droughts resulted in drying up of Lakes along coastal areas

6.2.3.4 Governance-based issues

County Integrated Development Plans (CIDPs) 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 inadequate coordination and poor resource use due to the independent nature of County planning.

The main topographical feature of Nyeri County is Mount Kenya to the east and the Aberdare Range to the west (County Government of Nyeri, 2018). South of the county is characterised by steep ridges, valleys and hills. The county is very agriculturally productive due to its high rainfall and fertile conditions, and cash crops such as tea and coffee are commonly grown in the area. Murang'a county lies along the slopes of the Aberdares ranges, with drivers which drain into the Tana River (County Government of Murang'a, 2018). The county is underlain by porous, volcanic geology, which although fertile, has a high erosion risk. The predominant agriculture is mainly tea and coffee, although the dissected topography causes gully erosion and landslides. Kirinyaga county is defined by Mount Kenya to the North and is characterised by valleys extending from the peak (County Government of Kirinyaga, 2018). Snow melt from the mountain flows in natural streams to join Thiba River downstream. Agriculture is the main economic activity in the county. Embu county is characterised by Mount Kenya to the north-west and the Mwea plains to the south (County Government of Embu, 2019). The Thuci, Tana, Kii, Rupingazi, Thiba and Ena Rivers extend across the county. There are some major hydroelectric dams which occur on the Tana River, within the county. Agriculture is the main economic activity.

Meru county is characterised by Mount Kenya to the west and Nyambene ranges to the north. Rivers drain off these mountain ranges to meet the Tana River downstream. The main economic activity is agriculture. Tharaka-Nithi county is characterised by Mount Kenya to the west and Tana River to the east. Tributaries that flow off the mountain are Mutonga, Thingithu, Kahita, Thanantu, Thangatha, Kithinu and Ura rivers. The major economic activities in Tharaka-Nithi county include coffee and tea, subsistence crops, subsistence dairy and livestock farming such as goats and sheep. The southern extent of Isiolo county occurs in Tana Basin (County Government of Isiolo, 2018). Most of the flat low-lying county has erratic rainfall, which limits rainfed agriculture therefore the economy is based on livestock production and pastoralism. Pastoralism is also the main economy in the flat and low-lying Garissa county. The main drainage features in the county are the seasonal "laghas". These "laghas" are also present in Tana River county, which flow in a west-east direction from Kitui and Makueni counties into Tana River (County Government of Tana River, 2018). The main feature in Tana River county is the Tana River which extends along the north and south-east borders. Farming and nomadic pastoralism are the main economic activities in the county. The Yatta Plateau extends from the western part of Kitui count and stretches to the south between Athi River and Tiva River (County Government of Kitui, 2018). Agriculture is the main economic activity, particularly subsistence farming. The northern border of Machakos county is defined by Tana River. Thika River extends through the county from Kiambu county to join Tana River as well as other smaller tributaries of Tana River. Machakos County has both food crops and cash crops.

Table 6-5: Governance operating at local level in the Tana Basin and relevant issues

Upper Tana		
	**Counties**	Nyeri, Kiambu, Murang'a, Kirinyaga, Embu
	Issues	**Nyeri** – Cultivation on steep slopes – Mukurwe-ini, Othaya and Tetu Sub-counties prone to landslides due to poor farming methods in riparian areas – Inadequate solid and liquid waste management in urban/peri-urban areas – Uncontrolled logging is causing biodiversity loss in forests – Loss of tree cover causing floods – Drought leading to loss of biodiversity, drying up of water bodies, water pollution, human wildlife conflict, increased trekking distance to water points and community conflict **Murang'a** – Overexploitation of forests – Unsustainable extraction of non-renewable resources – No solid waste management in the county **Kirinyaga** – Deforestation and illegal logging – Poor solid waste disposal – Cultivation along riverbanks – Pollution from industries and farmers – Dumping of waste – Stormwater pollution from residential areas and car washes along riverbanks – Increased flooding in lower Mwea **Embu** – Deforestation, especially farming areas – Logging in Mount Kenya forest – Wetland encroachment – Farming on steep slopes led to soil erosion – Sand harvesting and extraction of other building materials

Lower Tana		
	**Counties**	Meru, Tharaka-Nithi, Isiolo, Garissa, Tana River, Kitui, Machakos, Lamu
	Issues	**Meru** – Sand mining in river beds – Deforestation, forest fires and extinction of some tree species – Cultivation of riparian land and drainage of marshy land – Water levels of springs, swamps and lakes in decline – Land degradation (soil erosion, soil infertility) – Eucalyptus in riparian and wetland areas reducing water levels – Encroachment of swamps and wetlands creating risks of floods **Tharaka-Nithi** – Forests encroached by human developments for farming or exploiting forest resources – Farming on hillside causes soil erosion – Illegal grazing on gazetted and non-gazetted hills – Charcoal burning – Sand harvesting and quarrying – Water pollution **Isiolo** – Charcoal burning and deforestation of the limited vegetation – Soil erosion caused by strong winds – Overgrazing and overstocking leading to land degradation – Dust creates health problems – Unsustainable sand mining **Garissa** – Refugee settlements have contributed to logging and over-grazing – Charcoal burning and deforestation – Frequent floods in rainy season contributes to environmental degradation **Tana River** – Forest destruction along riverine areas, mainly due to farming – Loss of rangelands – Soil erosion on farm lands – Deforestation causing floods – Invasive *Prosopis juliflora* threatens livestock keeping on grazing land – Tana River has reduced water levels – Poor solid waste management **Lamu** – Garissa and Tana River counties have become less reliable for livestock keeping due to erratic rainfall and overgrazing. This puts pressure on Lamu county due to competing resources. – Increased human population has put more pressure on natural resources – LAPSSET requires strategic environmental assessments – Encroachment of catchment areas and wetlands (i.e. Shella sand dunes) through human development – Most of Lamu county is flat and prone to flooding – Severe droughts resulted in drying up of Lakes – Only Amu and Shella have waste disposal sites

6.2.4 Strategy

In previous Sections 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).

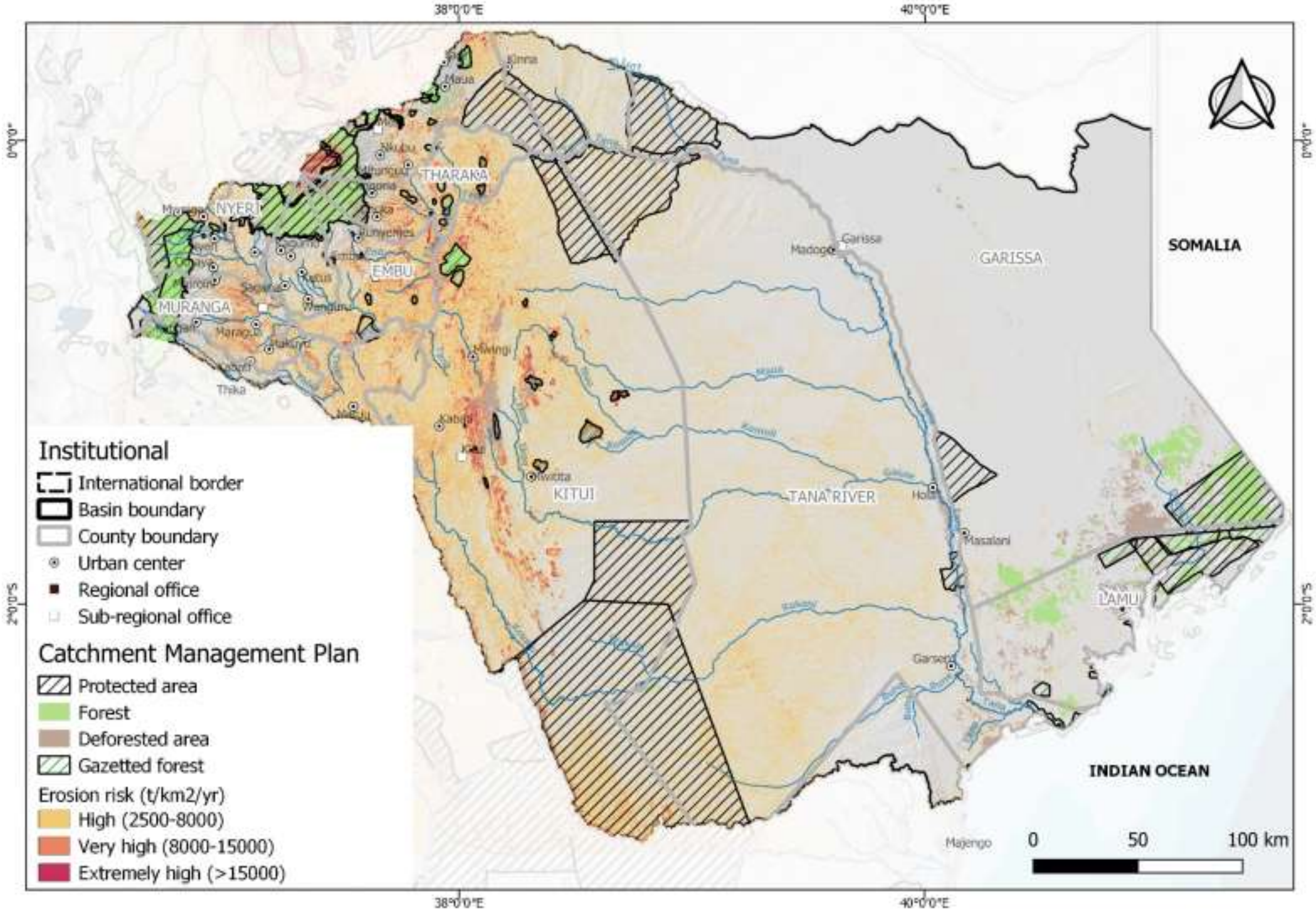


Figure 6-5: Catchment management considerations in Tana Basin

In order to comprehensively and systematically address the range of catchment management issues identified in the Tana Basin, Table 6-6 sets out 4 Strategic Themes and 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.

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 Tana 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 sub-catchment 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	
Water conservation and management is considered a priority in the Tana Basin due to water scarcity. Water is important in the Basin both for urban use as well as for agricultural/rangeland 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 Lower Tana basin has meant that pastoralists move further into National Parks to find water, which increases human/wildlife conflict. Water resources 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 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.		

1	Key Strategic Area:	Catchment Management

- **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 ASAL regions of the Tana 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 Tana 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.

The steeper regions of upper Tana Basin which do not have a dense vegetation cover are more prone to high levels of erosion than the lower plains. Although forest cover provides protection from soil erosion, these areas are increasingly being encroached by communities. Improved erosion and runoff control measures and sediment trapping will also improve resilience to flash floods and erosion. In the lower plains of Tana 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, riverbank 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.

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/Riverbank 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/riverbanks 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 riverbanks 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

1	Key Strategic Area:	Catchment Management

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 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**, 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.

- **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.

1	Key Strategic Area:	Catchment Management

– **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.

1.3	Theme:	Natural resources management for the protection and sustainable use of natural resources
1.3.1	Improved wetlands and lake management	

According to the Tana Basin CMS (Water Resources Management Authority, 2015b), wetlands are under threat from human encroachment for settlement, expansion of crop production and livestock grazing.

The Tana Delta is a Ramsar wetland and needs to be protected from further environmental degradation. In Tana River County there is encroachment of the riparian areas for farming (County Government of Tana River, 2018). This encroachment has increased the risks of floods. Water levels of springs, swamps and lakes have also been in decline along the coastal region.

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

Refer to KSA 2

2. 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 and should have fire protection. 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.
- 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/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. Programs 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	Key Strategic Area:	Catchment Management
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 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 Buy back 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 using alien trees (i.e. eucalyptus in Meru County). 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	Key Strategic Area:	Catchment Management
1.3.5	Removal of alien invasive species	

Community knowledge base on how to sustainably manage invasive and alien species should be strengthened. This is because there is knowledge but not strong understanding 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.

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.

1	Key Strategic Area:	Catchment Management
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; Energy efficient stoves and ovens; Heat retention cooker; Solar turtle		
1.3.8	Improved sand mine management	
Collaborate with county governments in developing and implementing a sand harvesting policy and enforce a Sand Conservation and Utilisation Act. In addition, initiate a study to identify alternative sources of building materials other than sand, and initiate cross-boundary sand management in the basin.		
1.4	**Theme:**	**Rehabilitation of degraded environments**
1.4.1	Rehabilitation and Restoration Plan	
Develop a restoration and rehabilitation programme. Refer to 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 Tana Basin CMS (Water Resources Management Authority, 2015b) forests are under threat of encroachment. 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 Water Act 2016 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 WRA. 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: 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 Resources 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.

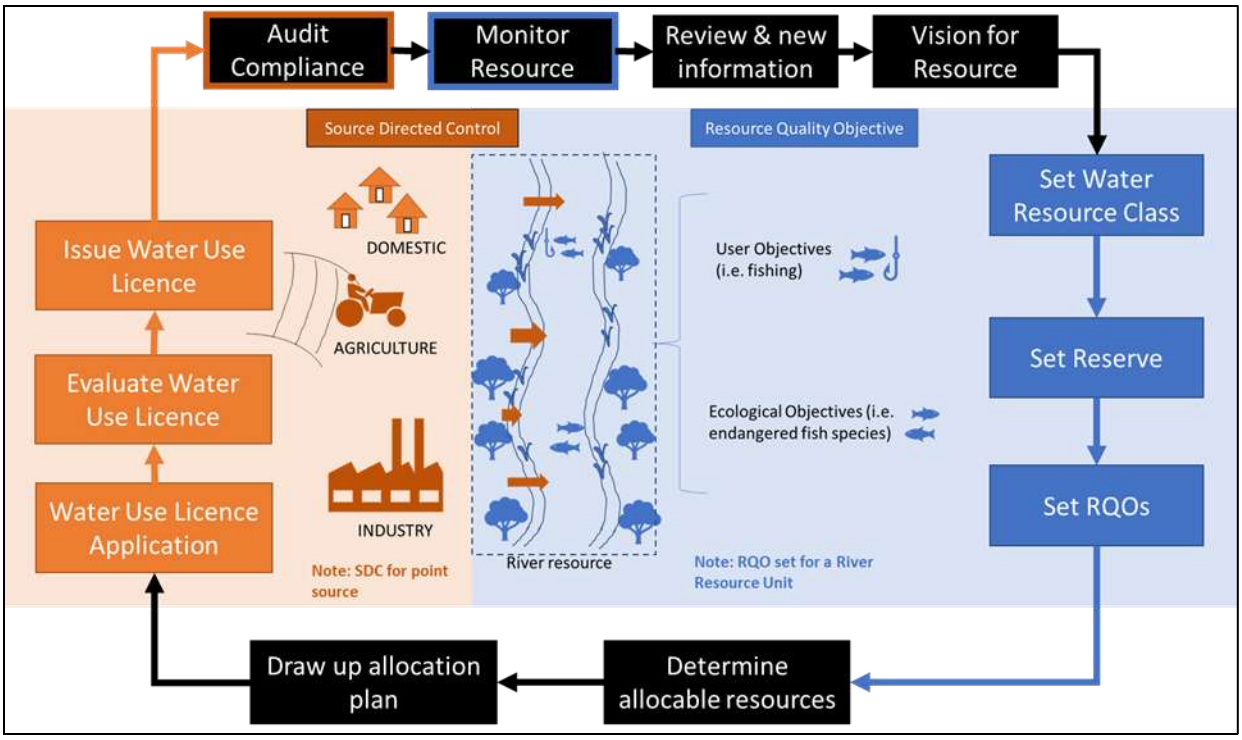


Figure 6-7: Water resources management cycle

Classifying water resources and determining Resource quality objectives follow aligned steps as shown in *based **on** Department of Water Affairs, 2007, 2011

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.

*based on Department of Water Affairs, 2007, 2011

Figure 6-8: Procedure to determine water resource classes and resource quality objectives in South Africa

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.

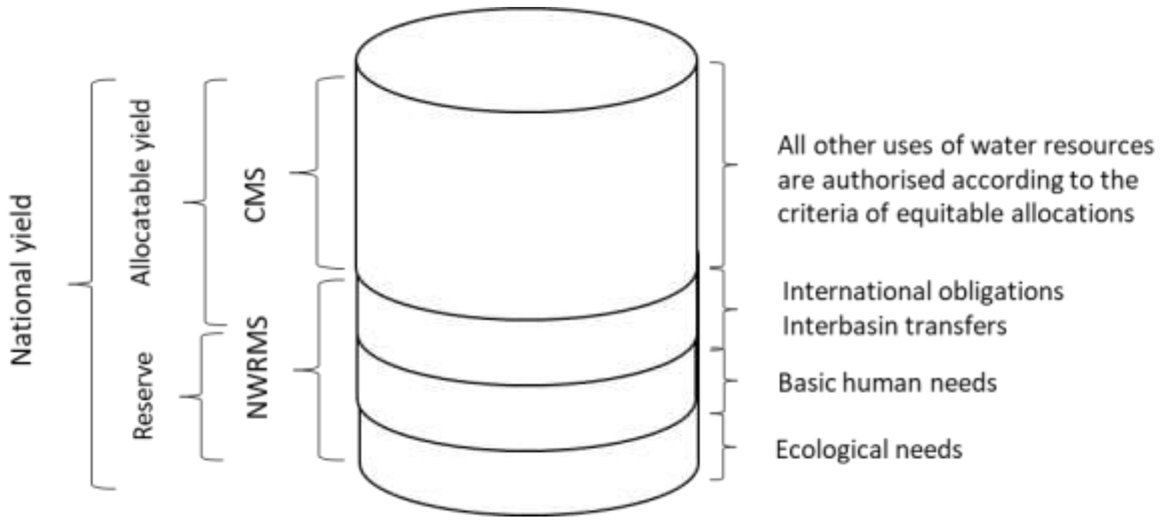


Figure 6-9: Water resources demand categories diagram (Water Resources Management Authority, 2010)

6.3.3 Water resources protection in the Tana Basin

6.3.3.1 Water resource protection under the Water Act

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 Sub-Catchment Management Plans (SCMPs), which are local level action plans. The Tana Basin has 79 existing WRUAs out of a potential 258 WRUAs needed to cover the whole basin. The 179 WRUAs gap of 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 Tana Basin as well as water towers are summarised below. The table also lists water towers 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 Tana Basin

Basin	Counties	WRA Sub-Region	WRA SRO	CMU	Water Towers (KWTA)
Upper Tana	Nyeri, Kiambu, Murang'a, Kirinyaga, Embu	Upper Tana	Murang'a	Sagana-Gura, Upper Thika and Lower Thika	Mount Kenya, Aberdares Range and Nyambene Hills
Lower Tana	Meru, Tharaka-Nithi, Isiolo, Garissa, Tana River, Kitui, Machakos, Lamu	Thiba	Kerugoya	Tana, Karaba, Ena and Thiba	Mount Kenya
		Kathita Mutonga	Meru	Mutonga, Kathita, Ura and Tharaka-Nithi	
		Tiva mTyaa	Kitui	Tiva and Lower Reservoirs	
		Lower Tana	Garissa	Lower Tana, Ijara and Lamu	

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 water resources protection issues and challenges in the Tana Basin, Table 6-8 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.

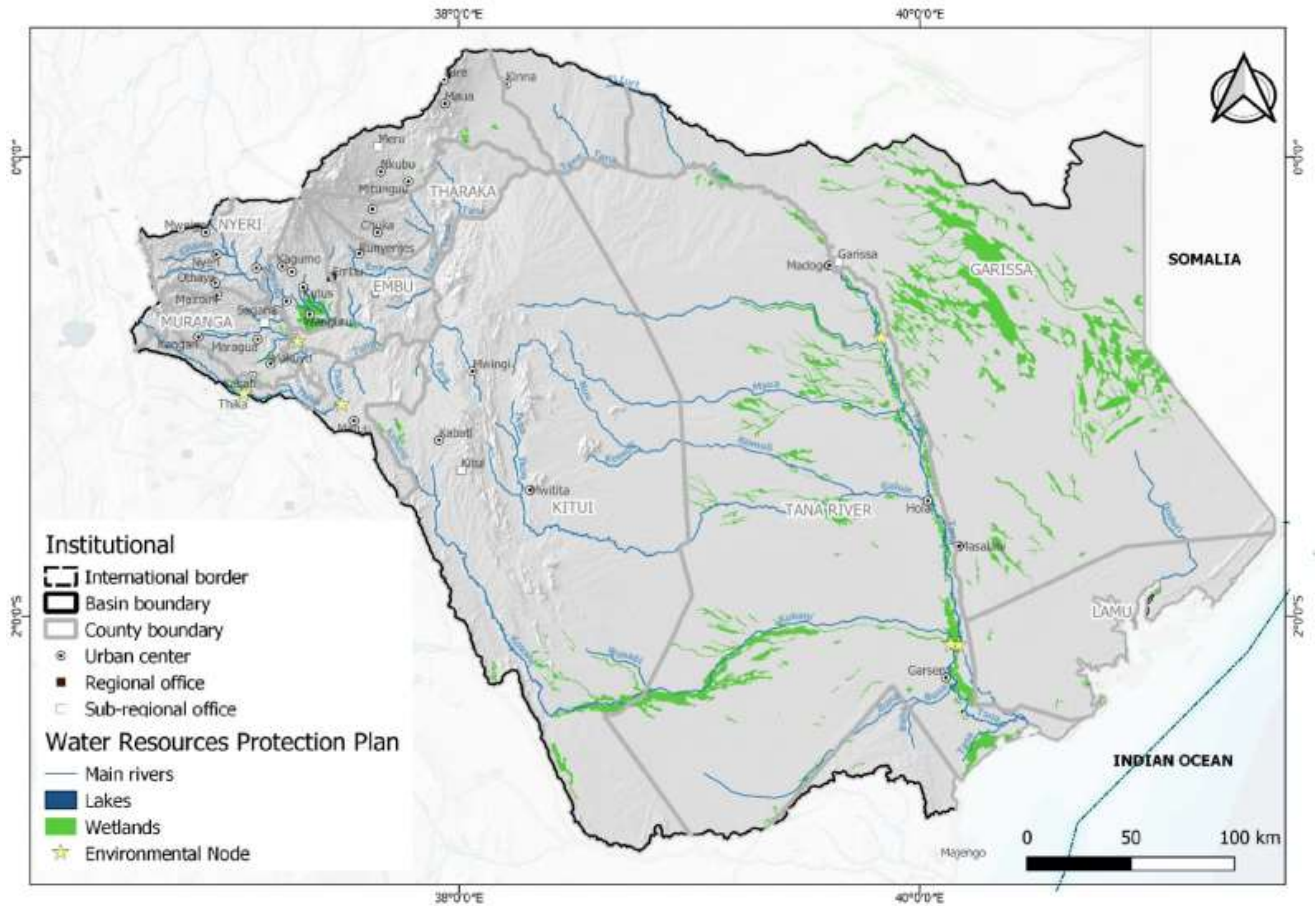


Figure 6-10: Water resources protection considerations in Tana Basin

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 Tana Basin.		
2.1.2	Determine Class of water resources	
Determining the Class of a water resource is the first step in the Water Resources 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 Tana 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 Resources Management cycle which is an adaptive management approach focused on goal-setting. Once the ecological 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 ecological 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 Tana 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 critical in supporting key ecological systems which underpin human wellbeing by providing essential ecosystem goods and services. A strategic social and environmental assessment is therefore an important component of the Classification of Tana Basins water resources. The Classification of water resources 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		

2	Key Strategic Area:	Water Resources Protection
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 (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 (Ministry of Water and Irrigation, 2012) addresses groundwater protection in S. 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 Tana 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

In the humid upper part of the Tana Basin (south eastern Aberdares and southern and eastern Mount Kenya), surface water is widely available and heavily exploited for water supply, including a significant out of Basin transfer to Nairobi (Athi Basin). Many of these surface water resources are near full exploitation, and attention is shifting to groundwater development.

Elsewhere, localised and often poor aquifers serve rural communities and small centres across the Basin, often occurring in metamorphic basement rock or associated alluvium. These are small-scale but nevertheless important in terms of local water supply. This illustrates the importance of groundwater to human livelihoods and development in the Tana Basin.

Groundwater is accessed via springs (both protected and unprotected), shallow wells and drilled boreholes. The greatest concentration of boreholes occurs in the humid upper part of the Tana Basin, particularly Murang'a County. Springs are also concentrated in the humid upland zones.

The Upper Tana Natural Resources Management Project (UTaNRMP) acknowledges the importance of protected and unprotected springs in water supply in the six counties that the Project supports (Murang'a, Nyeri, Kirinyaga, Embu Tharaka-Nithi and Meru). These all lie in the humid upper part of the Basin. Over the life of the project, it is anticipated that up to 60 000 households will benefit from improved springs, boreholes and wells (UTaNRMP, 2014b). In its Baseline Survey Report, UTaNRMP describes numerous protected and unprotected springs in the target counties (UTaNRMP, 2014a) .

There are some strategically important springs in the lowlands; the 2012 Tana River Delta Strategic Environmental Assessment Scoping Report (Odhengo et al., 2012) cites the following as strategically important springs in the drier parts of the Tana Basin:

- Springs in the Kiang'ombe/Kiambere Hills, Mbeere District
- Tamani Springs, Meru North
- Springs in the Mutitu Hills, Kitui District
- Springs in the Nuu Hills, Mwingi District
- Springs in the Endau Hills, Kitui District.

Within the Tana Basin there is limited conjunctive use for public water supply:

- Garissa Town, and several settlements on the banks of the Tana River, exploit a combination of surface and groundwater resources.
- Kitui (Kitui Water & Sewerage Company) relies principally on surface water from the Masinga reservoir. However, supply is supplemented by groundwater from eight boreholes in the vicinity of Kitui Town.
- Meru (Kathita Kiirua Water Supply) is partly supplied by the Muruiya Springs.
- Meru and Maua (Meru and Maua Water Company) relies partly on the Gatobora springs to supplement surface water from the Kathita River.
- Mwingi (Kitui County; Kiambere-Mwingi Water and Sewerage Company) relies principally on surface water from the Kiambere reservoir which may be supplemented by groundwater.
- Thika (Thika Water and Sewerage Company) is predominantly supplied from surface water sources. However, some supplementary groundwater sources have been developed.
- Kenol Town is an unplanned example of conjunctive use, where the utility water supplier is in direct competition with private sector groundwater suppliers and vendors.

Private sector conjunctive use in the basin includes numerous irrigated floricultural and commercial vegetable farms in the humid uplands. These farms use the whole range of water sources including groundwater, surface water, rainwater harvested from greenhouse roofs, and in many cases, re-cycling of hydroponic or treated water. Kakuzi Ltd (Makuyu) is an example of conjunctive use, although skewed heavily in favour of surface water. Penta Tancom Ltd/Penta Flowers Ltd (Thika) is another example.

Conjunctive groundwater use for domestic water supply is rapidly changing in the Tana basin. Examples of the potential future conjunctive use for public water supply exist:

- It appears likely that Garissa water supply will expand its reliance on groundwater for municipality supply, and this may ultimately supplant surface water entirely.
- Many of the CIDPs describe past or planned borehole projects that in cases will supplement and in cases may supplant surface water sources. These projects blur the lines between WSP supplies and small-scale community water supplies. Ultimately the economics of scale will probably lead to the incorporation of community water supply systems into more formal management entities.
- In the face of increasing populations and declining surface water resources in the humid upper parts of the Tana Basin, it is very likely that more and more of the WSPs in these areas will turn to groundwater resources as supplementary water sources. This is likely to stress some of these upland aquifers, so borehole densities and abstraction rates in these areas should be monitored periodically.

6.4.3 Groundwater resource potential

The annual groundwater recharge for the Tana Basin was estimated at 4 479 MCM/a, with a sustainable annual groundwater yield of 693 MCM/a. This is very similar to the Kenya National Water Master Plan (NWMP) 2030 sustainable groundwater yield estimate of 675 MCM/a for the Tana Basin (Water Resources Management Authority, 2013). 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 were superimposed on the groundwater model of the Tana Basin to assess the potential impacts on recharge and groundwater potential. It was found that the recharge in the basin will increase by 7% to 4 792 MCM/a, while the potential groundwater yield is expected to increase by 7.5% to 745 MCM/a under RCP 4.5. This is different to the NWMP 2030 future sustainable groundwater yield which was projected to decrease in future (2030).

Annexure B lists the groundwater potential per sub-basin.

6.4.4 Proposed aquifer classification

The current classification system of aquifers in the Tana Basin (refer to section 2.2.1.3) 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.

The proposed aquifer classification system for the Tana Basin is included in “ISC Report D2-2: Groundwater Monitoring and Management Guideline”.

Table 6-9: Proposed classification of aquifers in the Tana Basin

Name	Geology/lithology	Area (km^2)	Depth range (m)	Yield potential (m^3/day)	Dominant flow type(s)	Typical EC (µS/cm)	Status
MAJOR							
Southern Aberdare Volcanics	The geology is dominated by Miocene Simbara Basalts Series. The series is quite thick, reaching up to 900 m at its thickest. Its lithology comprises porphyritic basalts and basaltic agglomerates, but also includes flow-brecciated lavas, or 'autobreccia'. The porphyries include phenocrysts of augite, olivine and plagioclase in a groundmass of the same minerals.	3 250	First aquifer <50; Second aquifer <100 Deep aquifer proved at >500	>86 <240 <860	Intergranular and fracture	<1 500	Alert
Mt Kenya Volcanics South	The uppermost units consist of ash accumulations, bedded deposits containing abundant lava and pumice inclusions of all sizes, with fragments of feldspars, nepheline and dark minerals, in a fine-grained matrix. These are underlain by micro porphyritic dark grey basalts, with sparse phenocrysts of deep green olivine. Older lavas consist of extensive flows of porphyritic phonolites that lie directly on Basement System gneisses. The phonolites are associated with bands of brecciated phonolite and phonolitic agglomerates and include *kenyte*, a glassy variety of porphyritic phonolite	7 499	Multi-layered; at least two aquifers <120	First aquifer<240 Second aquifer>240	Intergranular and fracture	<1 500	Satisfactory
MINOR							
Eastern Basement	Banded biotite/muscovite/hornblende gneisses; hornblende schists, granitoid gneisses. The gneisses and schists are of semi-pelitic and pelitic origin. Bands of crystalline limestone and calc-silicate gneisses occur; high-grade metamorphism has resulted to migmatization in places, with amphibolite schlieren.	27 823	50-100	<86	Intergranular and fracture	>1 000	Alert
Lamu dunes	Shallow aquifer with freshwater zone <20m deep; consists of medium to fine sand, intercalated with horizons of broken shells (coquina)	15	<15	<86	Intergranular	<1 000	Alarm

Name	Geology/lithology	Area (km^2)	Depth range (m)	Yield potential (m^3/day)	Dominant flow type(s)	Typical EC (µS/cm)	Status
Timboni-Gongoni	Shallow aquifer (freshwater zone <10m deep); Holocene shoreline sediment series made up of medium to coarse sand, with limited gravels and clay	24	<10	<86	Intergranular	<1 000	Alarm
Hindi, Bele, Chomo	Shallow aquifers (freshwater zone<20m deep); medium to fine calcareous sands. Other lithologies include lagoonal clayey sands, fossil dune sands, raised coral reefs and coquinas.	30	<20	Hindi <86; Bele >240 Chomo>240	Intergranular	<1 000	Alert
Lake Kenyatta	Fossilised coral limestone, with sand lenses and cavities overlaid by recent unconsolidated sands and sandy clays	22	<20	<86	Intergranular	<1 000	Alarm
Kiongwe	Very fine, fine and medium grained Holocene shoreline dune sands	55	<10	<86	Intergranular	<1 000	Alert
Tana Delta	Very fine, fine and medium grained Holocene shoreline dune sands	65	<10	<86	Intergranular	<1 000	Alert
POOR							
Southern Merti Beds	These Pliocene sediments are a southern extension of the Merti Beds. The beds comprise coarse-textured continental fluvial to marine deposits, essentially sands, gravels, sandstone and conglomerates.	20 582	140-180	<86	Intergranular	>3 000	Alert
Lamu Embayment	The aquifer is made up of poorly consolidated sands and sandstones with kaolinitic clays.	46 226	>150	<86	Intergranular	>6 000	Satisfactory

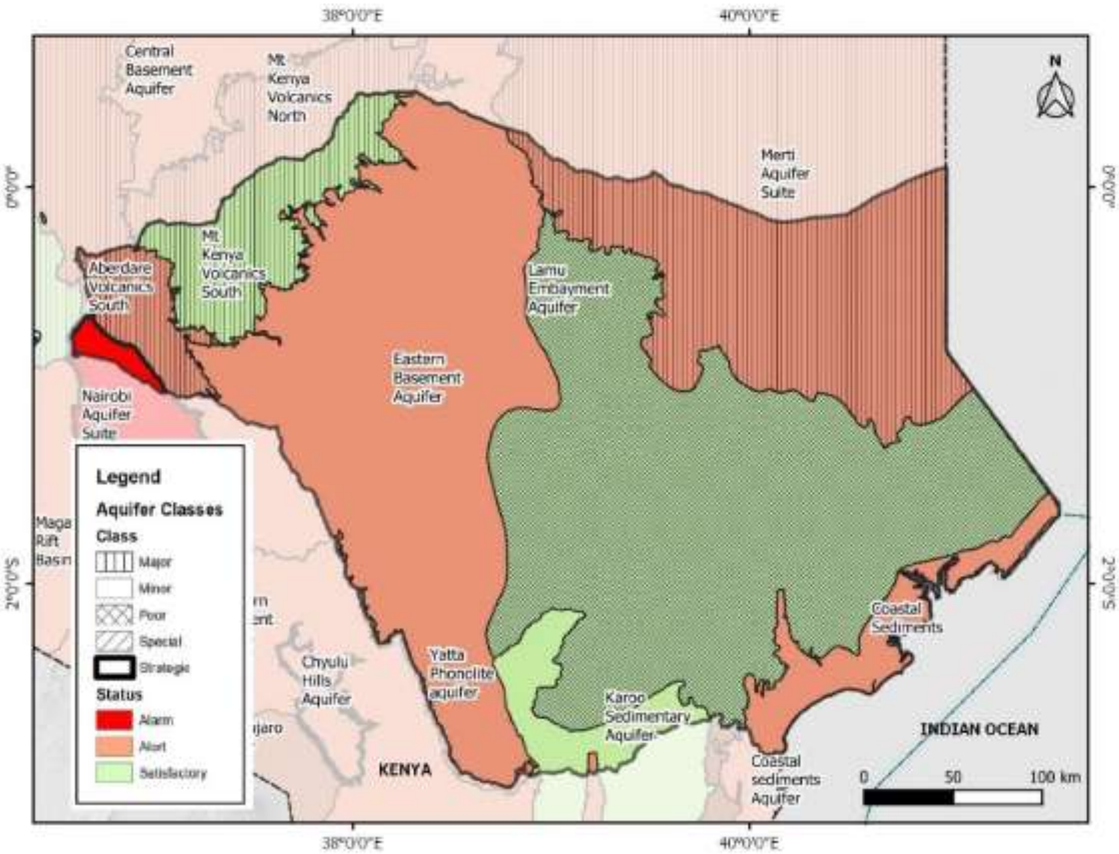


Figure 6-11: Proposed aquifer classification of the Tana Basin

6.4.5 Key groundwater issues and challenges in the Tana 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. The vulnerability of the Tana Basin is largely unknown as few aquifers have been studied at the appropriate level of detail.

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 Tana Basin include fluoride, iron and manganese, as well as elevated total dissolved solids (TDS). There is widespread natural fluoride in the NAS and some other volcanic and Basement aquifers, as well as elevated natural iron and manganese in much of the basement aquifers. Basement groundwaters often contain water with elevated TDS, particularly in Arid and Semi-Arid Lands (ASALs) of the Basin. High TDS values are most pronounced in ASAL lands, where evaporation comfortably exceeds mean annual rainfall. Where evaporation comfortably exceeds rainfall, salts are concentrated in the soil horizons that are then flushed into the aquifer during recharge events (Water Resources Authority, 2019d).

Generally, the extent and significance of groundwater pollution in the Tana Basin is relatively unknown. However, given high population densities in the humid parts of the Tana Basin and reported experiences in this and other Basins, shallow groundwater pollution is likely to be more widespread than currently reported. Various studies are outlined below and provide information on the state of water quality and pollution in certain parts of the basin.

Swarzenski & Mundorff, (1977) and many subsequent studies, including Blandenier (2015), Water Resources Management Authority (2009) and GIBB Africa Ltd (2004), have presented groundwater chemistry data for the then North-Eastern Province, which illustrates the salinity gradient that increases from north to south through central Garissa County, towards the coast. Basic data is presented in Table 6-10, and shows that groundwaters in the Masalani-Ijara hinterland are too saline for any practical uses.

Table 6-10: Garissa County groundwater chemistry summary from north to south, Tana Basin only (Swarzenski & Mundorff, 1977)

Location	EC	TDS	Na	Cl	SO_4	F	Hardness
Unit	µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L [1]
(Kenya Bureau of Standards, 2007)	—	1 000	200	250	400	1.5	300
Wel Merer	1 740	1 260	373	197	35	2.0	80
Fafi	10 910	7 034	2 587	3 546	255	2.69	390
Kolbio	33 000	25 900		12 900	2.430	3.3	985
Ijara West	15 500	15 450	3 927	5 900	3 910	3.2	4 320
Galma Galla	20 888	12 800		5 500	2 130	1.1	985
Witu [2]		1 080		225			0.5

[1] mg/L as $CaCO_3$

[2] From National Water Resources Database (NWRD) 2005; groundwater from a Pleistocene sand and coral aquifer.

Murigi (2004) assessed water quality in surface waters, shallow wells, and shallow and deep boreholes in the Makuyu area (Murang'a County). This study found that fluoride was generally acceptable, with a single exception (a 120 m deep borehole at Makuyu Secondary School), at 2.5 mg/L (the Standard is 1.5 mg/L). Iron and manganese ranged from 0.1 to 1.15 mg/L and 0.005 to 1.01 mg/L respectively, both of which exceed the Kenya Standard for Drinking Water at the upper end of the range 0.3 and 0.5 mg/L respectively (Kenya Bureau of Standards, 2007). Other trace metals tested (titanium, copper, zinc, strontium, yttrium and zirconium) were all at acceptable concentrations. Surface waters and some shallow wells and boreholes were found to be contaminated by bacteria. However, deep boreholes were not contaminated. Njoroge et al. (2014) present the same trace metal data.

Giorgio et al. (2006) studied traditional wells in the eastern, urbanised Pleistocene limestone part of Lamu Island. It reported that electrical conductivities ranged from <200 to >5 000 µS/cm. Nitrate concentrations in Stone Town were found to range from 5 to 106 mg/L, suggesting some wastewater pollution. Shela wellfield conductivities were typically <500 µS/cm in 1985, rising to between 690 and >2 050 µS/cm in 2008 (Kuria, 2008). Production wells in the Shela wellfield closer to the sea (to the south) had salinized more than the northern part of the wellfield. (Okello et al., 2014) state that water level elevations in the Shela wellfield ranges from 1.2 to 1.6 mamsl, rising to 2.5 to 4 mamsl at the western end of the dunes.

Muthangya & Samoei (2012) measured basic water quality parameters in shallow wells and boreholes in the Mui Basin, Kitui County (the time of year of sampling was not indicated). Electrical conductivity ranged from 1 600 to 2 017 µS/cm in shallow wells, and 2 000 to 3 700 µS/cm in boreholes.

Groundwater quality was assessed across Garissa County as part of a water resources assessment (County Government of Garissa, 2018). This included the part of the County that lies in the Ewaso Ng'iro North Basin. However, logistic and security constraints limited sampling to the northern part of the county, and excluded Balambala, Fafi, Ijara and Hulugho sub-counties, all of which lie in the Tana

Basin. Shallow groundwater resources exist in the Tana alluvium; this typically extends 200 to 400 m from the riverbank and is about 20 m thick. It can be a good source of high quality, large volume groundwater. Yields range from 10 to 60 m^3/d, with ECs typically <1 000 µS/cm. At the GAWASCO Ziwani BH compound where three boreholes are located, EC (in a combined sample from three boreholes) was 187 µS/cm, TDS was 126.5 mg/L and pH 7.09.

Kitheka (2016) measured total dissolved solids (TDS) in shallow Kitui County groundwaters drawn from sand rivers and from scoop holes and shallow wells in sand dams in wet and dry seasons. Wet season TDS ranged from 77.8 to 272 mg/L, while in dry seasons it ranged from 227 to 3 320 mg/L. Dry season TDS often comfortably exceeded the Kenya Standard (1 000 mg/L).

Karegi et al. (2018) examined groundwaters from 10 boreholes in Mbeere Sub-County (Embu County) that ranged from 23 to 120 meters in depth. Most samples were acceptable as potable waters, though isolated occurrences of excessive chloride (two samples greater than the KEBS Standard of 250 mg/L; up to 844 mg/L), iron (one sample at 1.0 mg/L), fluoride (two samples >1.5 mg/L, up to 2.1 mg/L), and nitrate (none exceeding 50 mg/L, but three samples >35 mg/L). The relatively high nitrate concentrations may indicate pollution from septic tanks, pit latrines or diffuse sources.

Mbura (2018) repeatedly tested eight hand-pumped shallow well waters in the southern part of Tharaka-Nithi County over wet (December) and dry (August) seasons. The area is underlain by metamorphic Basement and is semi-arid, with mean annual rainfall of just over 600 mm/yr. The study found elevated concentrations of total dissolved solids (TDS) in both wet and dry seasons, typically being higher in the dry season, with mean values 1346 mg/L (dry season) and 1049 mg/L (wet season). The KEBS Standard for TDS is 1 000mg/L. Fluoride concentrations showed a similar seasonal disparity, in many cases significantly exceeding the Standard, with ranged of 0.9 to 13.3 mg/L (dry season) and 1.0 to 6.5 mg/L (wet season). Hardness comfortably exceeded the Standard (300 mg/L as $CaCO_3$) in both seasons, with values of 665 mg/L in the dry season and 735 mg/L in the wet season as $CaCO_3$.

6.4.5.3 Other issues and challenges

Regulatory

Surface water and groundwater are effectively treated as different water resources, resulting in compromised planning, integration and resource allocations. The recent Water Allocation Plan Guideline (Water Resources Authority, 2019b) should help resolve this, as it defines both surface water and groundwater as resources.

Unclear NEMA and WRA mandates regarding 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 Co-ordination (Water Quality) Regulations, 2006), pre-dates water legislation (Water Act in 2002, and effluent regulations in the Water Resources Management (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

The current state of groundwater monitoring in the Tana basin is presented in section 2.4.8.3. The state of groundwater monitoring is however changing; an additional 14 shallow dedicated monitoring boreholes are being constructed in the Basin in 2018-19, to be installed in the Lamu sand dunes aquifer. These monitoring sites are to be fitted with water level loggers and telemetry. The most recent CMS

(Water Resources Management Authority, 2015b) proposes the establishment of an additional six groundwater monitoring sites, five of which are in the lower Tana Basin, an area which had no operational sites in 2015 (the site at Lake Kenyatta was not operating). These proposed sites are at Dujis (Garissa County); Kiunga, Hindi and Lamu (Lamu); and Kipini (Tana River).

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, and general and faecal coliforms (Water Resources Management Authority, 2015b). The list excludes total nitrogen and total phosphorus, which would be of value in surface water pollution monitoring.

The capacity to improve abstraction monitoring will be boosted by the adoption and implementation of formal guidelines for groundwater abstraction surveys, using electromagnetic flow meters (Water Resources Authority, 2018c).

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 a number of 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.

Over-abstraction in the Tana Basin

Over-abstraction across the Tana Basin is patchy and restricted to 'hotspots'. The National Groundwater Balance Report (Water Resources Authority, 2019d) shows that the areas within the Tana Basin where abstraction approaches recharge are limited to the high population density, humid uplands (sub-catchments 4A to 4E). However, nowhere does abstraction exceed recharge at present.

- In the NAS (not everywhere); the extent of depletion could be mapped reasonably easily, due to the borehole density. There is some limited scope for Managed Aquifer Recharge (MAR) (National Water Conservation & Pipeline Corporation, 2006; Water Resources Management Authority, 2009), and few substitute water sources (surface water sources from new dams in-catchment).

While only a small surface area within the Tana Basin is underlain by the NAS (862 km^2), there is a dense borehole distribution according to the PDB.

- Both Makuyu (Murang'a County) and Warazo Lusoi (Nyeri County) have been identified as areas of possible groundwater over-abstraction (Knoop et al., 2012).
- Concerns have been expressed about the concentration of boreholes in the Kenol-Kabati area; Kenol Town is a rapidly urbanising centre in the southern part of Murang'a County, formerly served largely by boreholes (Wamuchira, 2009). A groundwater abstraction survey would determine whether there is a high enough density of boreholes and level of abstraction that merits concern. Note that the water utility, Murang'a South Water and Sanitation Company (MUSWASCO) has plans to improve surface water-sourced treated water to Kenol (Murang'a South Water and Sanitation Company, 2016). A proposal for a non-revenue water reduction project highlights the competition that "*many*" commercial, borehole-based suppliers and vendors represent to the financial sustainability of the utility (Murang'a South Water and Sanitation Company, 2017).
- Kuria (2008) noted over-abstraction in the Lamu Sand Dunes aquifer.
- The level of over-abstraction at the local level from other aquifers in the Tana Basin is unknown. Some Basement aquifers may have suffered localised depletion.

Saltwater intrusion

Coastal aquifers in the Tana Basin have a high risk of sea water intrusion where there is over abstraction. Seawater intrusion risk has been identified in the Lamu Shela dunes aquifer in the Tana Basin (Kuria et al., 2010).

Saltwater intrusion has occurred in the Shela sand dune aquifer, Lamu. This may be due to over-abstraction or that only a small part of the aquifer is exploited. The 30 wellfields cover an area of about 2.6 km^2, yet produce an average of 1 736 m^3/d (Water Services Regulatory Board, 2018). Kuria (2008) documents rising electrical conductivity in these groundwaters between 1985 and 2008. A simple numerical model will be developed for the Shela aquifer during 2019, after which it will be possible to draw up a coherent management plan. The dune system is already a protected GCA, however this protection is only nominal, covering an area of 958 ha (Declaration of Monuments; Lamu Water Catchment Area, 2002). Protection has been ineffective, and the WRMA issued a Stop Order in 2008, preventing any activity within the protected area and demolishing a number of structures within it. The area that the WRA currently proposes establishing as a GCA covers 1971 ha, with the actual catchment area requiring protection calculated to be approximately 1650 ha (Water Resources Management Authority, 2009).

There may be grounds for concern about over-abstraction in the Lake Kenyatta coral and sand aquifer, for which there are 29 document sets in the PDB (of which 26 are either Authorisations or Permits, and amount to 1 411 m^3/d). The aquifer lies close to sea level (land elevations are rarely >15 mamsl), and there is a potential risk of saltwater intrusion. The aquifer is typically 20 m thick, and the fresh-saltwater interface occurs at depths of 20 to 40 mbgl; static water levels fluctuate seasonally but are typically <1 to three mamsl. Properly sited and constructed boreholes are capable of yields of 20 to 30 m^3/hr for modest drawdowns (<1 m). Studies in the late 1980s and early 1990s suggest that the aquifer covers an area of at least 10 km^2 (Gicheruh, 1993; Groundwater Survey (Kenya) Ltd, 1987). Aquifer recharge is largely bank recharge from the seasonal Lake Kenyatta, which has run close to dry in recent years, and dried up completely in 1956 (National Environment Secretariat, 1985). The hydraulic gradient is very flat, so the possibility of saltwater intrusion certainly exists.

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 models or partial models are available across the country (NAS, Msambweni aquifer, Chyulu Hills aquifer and Baricho palaeochannel aquifer), but none in the Tana Basin. The Lamu sand dune aquifer is planned to be modelled during 2019. Interesting small-scale models of bankside sand dam recharge have been generated, but these are of very small scale and are not very relevant at the Basin scale (e.g. Borst & de Haas, 2006).

Elsewhere there are no models. 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 Tana Basin, both shared with neighbouring basins 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. This combines the Karoo Suite, Shimba Hills, Kambe Limestone and Shale, and Coastal Sediment aquifers; only the very northern tip of this aquifer lies within the Tana Basin, in southern Tana River and northern Kilifi Counties. Most of AF31 lies in the Athi Basin.
- AF38 – Merti aquifer (Nijsten et al., 2018); a total of 12 000 km^2, shared with Somalia. The southern part of this aquifer lies in the Tana Basin, with the balance in the Ewaso Ng'iro North Basin. The boundaries of this aquifer system are ill-defined; however, we believe that TWAP under-estimates the true extent of it, unless the definition restricts the aquifer to areas where groundwaters are 1 000 mg/L as TDS or less. The broadly potable area is estimated at 22 900 km^2 (GIBB Africa Ltd, 2004).

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 GW Policy (Ministry of Water and Irrigation, 2013), lists the following activities required to improve transboundary GW 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 GW resources.

Climate change

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 Tana Basin aquifers are uncertain, although a slight increase in mean annual recharge is likely. Sea level rise will affect coastal aquifers and sediments in hydraulic continuity with the sea.

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 GW 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, 2018c, 2018b, 2018a). 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 (Government of Kenya, 2007b) - 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 Tana 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 Tana 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 Tana 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 GW 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).		
3.1.4	Groundwater allocation	
National Resource Quality Objectives should be developed. In relation to a groundwater resource, the resource quality objective 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, Groundwater 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 objective s 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, 2019b) discusses the determination of water balances and accommodates both surface water and groundwater. Current groundwater potential by sub-basin in the Tana 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.		

3	Key Strategic Area:	Groundwater management

- 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 GW 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 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 Tana 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. 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 ASAL Basement aquifers in the Tana Basin, particularly in Kitui County. (Asala, 2017) describes the application of GIS and remote sensing in determining areas where recharge could be augmented, using Machakos County as a case study.

Managed aquifer recharge (MAR)

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 WRM Rules (Government of Kenya, 2007b). 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 Authority, 2018c). 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 several 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 may occur in the Tana Basin but has yet to be described.

Unintentional aquifer recharge

The extent to which unintentional recharge occurs in the Tana Basin is unknown.

Managed Aquifer Recharge potential in the Tana Basin

In the Ngunga catchment, Kitui County, MAR could occur via sand dams in seasonal streams in areas underlain by siliceous metamorphic Basement (National Water Conservation & Pipeline Corporation, 2006)

MAR to the Shela dunes aquifer (Lamu county) is likely possible, provided that a recharge water source can be located. An interim measure could be to channel any rainfall runoff into infiltration basins in the shallow valley between the southern and northern wells. However, long-term plans to supply the new Lamu Port from Tana River surface water sources (Ministry of Environment Water and Natural Resources, 2013), which includes water for Lamu Island, may reduce the viability of a MAR scheme at Shela. As a wastewater treatment project for Lamu Island is also planned (Coast Water Services Board, 2018), tertiary treated wastewater could also be a source of recharge water (assuming socio-cultural objections can be over-ridden). A variant of this would be using soil aquifer treatment and recharge, as used in Israel’s Dan Region Reclamation Project, where treated, recharged water is used for agricultural purposes (Kanarek & Michail, 1996). The Wastewater Master Plan assumes the re-cycling of treated wastewater for agricultural purposes after conventional treatment. The Oda wellfield (Northern Basement aquifer) has an uncertain potential for MAR (National Water Conservation & Pipeline Corporation, 2006).

3	Key Strategic Area:	Groundwater management
3.2.2	Local groundwater development: Reconciliation of water demands and groundwater availability and implementation of groundwater schemes	
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 Tana 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: Reconciliation of water demands and groundwater availability and implementation of groundwater schemes	
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 regional water supply schemes.		
3.2.4	Conjunctive use: Reconciliation of water demands and groundwater availability	
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: – Vehicles/heavy plant; at present, WRA GW does not own or operate its own vehicles or GW 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 GW computers and printers, laptops/notebooks, PDAs, licensed software, storage facilities etc.) – Laboratory infrastructure: it is not expected that GW sections would have laboratories tied exclusively to GW, but laboratory facilities must be expanded to include the capacity to measure GW-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, GW 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: o Rental cost (per day or per week, as relevant) o Rental requirements (items rented must be insured by the renter and proof of insurance provided to the WRA) o Any other condition of rental o 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		

3	Key Strategic Area:	Groundwater management

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 always fit for purpose, 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.

3.4	Theme:	Conservation and protection of groundwater
3.4.1	Groundwater source protection	

- **GW 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 Tana Basin groundwater.
- **Saltwater intrusion prevention:** As above for saltwater intrusion prevention; assess significance of Tana 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 Tana 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 Tana 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 Tana Basin’s polluted aquifers**: Use the Guidelines for Groundwater Quality Surveys in Kenya (WRA, 2018d) 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. The 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
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

To develop and successfully implement a Water Quality Management Plan for the Tana 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 Tana 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 Tana 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 Environmental Protection Agency 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.

- **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 Environmental Protection Agency 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
- Wastewater
- 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 wastewater 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 Tana Basin

Water resources in the Tana basin exhibits symptoms of deterioration due to rapid urbanisation, inadequate sewerage infrastructure and wastewater treatment, increasing use of agrochemicals 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.

The most common pollutant sources in the Tana Basin are typically:

- Industrial effluents from cities and towns
- Municipal/Domestic sewage from urban settlements
- Solid wastes from dump sites
- Nutrients and pesticide residues, from agro-based industries
- Coffee farms/ washing stations and factories
- Tea plantations and processing factories
- Rice farms
- Flower farms
- Horticultural farms
- Sediment loads from degraded farmlands
- Soil erosion and sediment loads from overgrazed lands
- Soil erosion from unpaved gravel roads
- Storm runoff from roads and urban centres
- Oil and grease from oils spills, garages and petrol stations, and vehicle workshops
- Leachates from pit latrines, septic tanks and feedlots
- Acaricides from cattle dips

The actual sources of pollution within the Tana Basin under the headings of Upper, Middle and Lower Tana River are indicated in Table 6-15 below.

Table 6-15: Major sources of pollution in the Tana Basin

Basin	Sources of Pollution	
Upper Tana	Municipal wastes and untreated sewage	Towns of Thika, Murang'a, Sagana, Nyeri, Kerugoya, Karatina, Mwea
	Agro chemicals	Farms along the rivers Sagana, Chania, Thiba, Nairobi
	Mining activities	None
	Industrial waste discharges	Towns of Thika, Murang'a, Kerugoya, Nyeri
	Soil erosion and sediment	Evident on riparian reserves, and hill slopes and unpaved roads in the smaller towns and rural areas
	Salinity	Some Groundwater sources

Basin	Sources of Pollution	
Middle Tana	Municipal wastes and untreated sewage	Towns of Meru, Embu, Maua, Runyenjes
	Agro chemicals	Horticultural and flower farms near the towns of Meru, Runyenjes and Embu
	Mining activities	Sand harvesting in most areas
	Industrial waste discharges	Towns of Meru, Embu, Maua
	Soil erosion and sediment	Evident on riparian reserves, and hill slopes and unpaved roads in the smaller towns and rural areas
	Salinity	
Lower Tana	Municipal wastes and untreated sewage	Towns of Garissa, Garsen, Hola, Bura, Lamu
	Agro chemicals	From farms along Lower Tana river at Garsen, Hola and Bura
	Mining activities	Coal mines at Kitui, Gypsum at Garissa
	Industrial waste discharges	From towns of Garissa, Hola, Lamu and Garsen
	Soil erosion and sediment	Evident on riparian reserves, and hill slopes and unpaved roads in the smaller towns and rural areas
	Salinity	Some Ground water sources and sea water intrusion along the coastline

6.5.4.1 Surface water

Surface Waters in the Tana Basin have been divided into Upper Tana, Middle Tana and Lower or Coastal Tana. With 4 SROs based at Murang'a, Meru, Kitui and Garissa with a Regional Office at Embu. Upper Tana has one SRO at Murang'a, Middle Tana, two SROs at Meru and Kitui and Lower Tana one SRO at Garissa. Figure 6-12 shows the water quality characteristics of water bodies within the Tana Basin.

Upper Tana

The upper reaches of the Tana Basin fall within the Counties of Murang'a, Nyeri, Kirinyaga. Meru, Tharaka-Nithi, Machakos and upper parts of Embu, the following are some of the rivers that drain the upper reaches of the Tana River System; Chania, Nairobi, Sagana, Maragua, Gura, Thika, Ragati, Sabasaba, Rwamuthambi, Mathioya, Mugitio, Thegu, Karimiru, Kimakia and Kayawe, Ena and Rutui.

The increase in population growth and the pressure exerted on land and water resources, has led to severe land degradation and pollution of the rivers from anthropogenic activities and domestic effluent from urban settlements. These rivers have also been polluted by effluent from agro-based industries such as tea, coffee rice and horticulture. Industrial effluents from factories in towns such as Thika also contribute to the pollution of these rivers.

The rivers appear brown and are laden with silt and sediment from the farms and contain nutrients from the fertilizers used on the farms as well as pesticide residues. All these rivers show high levels of colour and turbidity, bacterial contamination, diminished dissolved oxygen levels and moderately high levels of BOD and COD. In their current state the rivers forming Upper Tana, were in the past few decades, suitable for domestic purposes. Currently these rivers are now unsuitable for domestic uses in their raw state.

Out of the 58 Surface Water monitoring stations in Tana Basin, about 32 are in the Upper Tana, 22 in Middle and four in the Lower Tana.

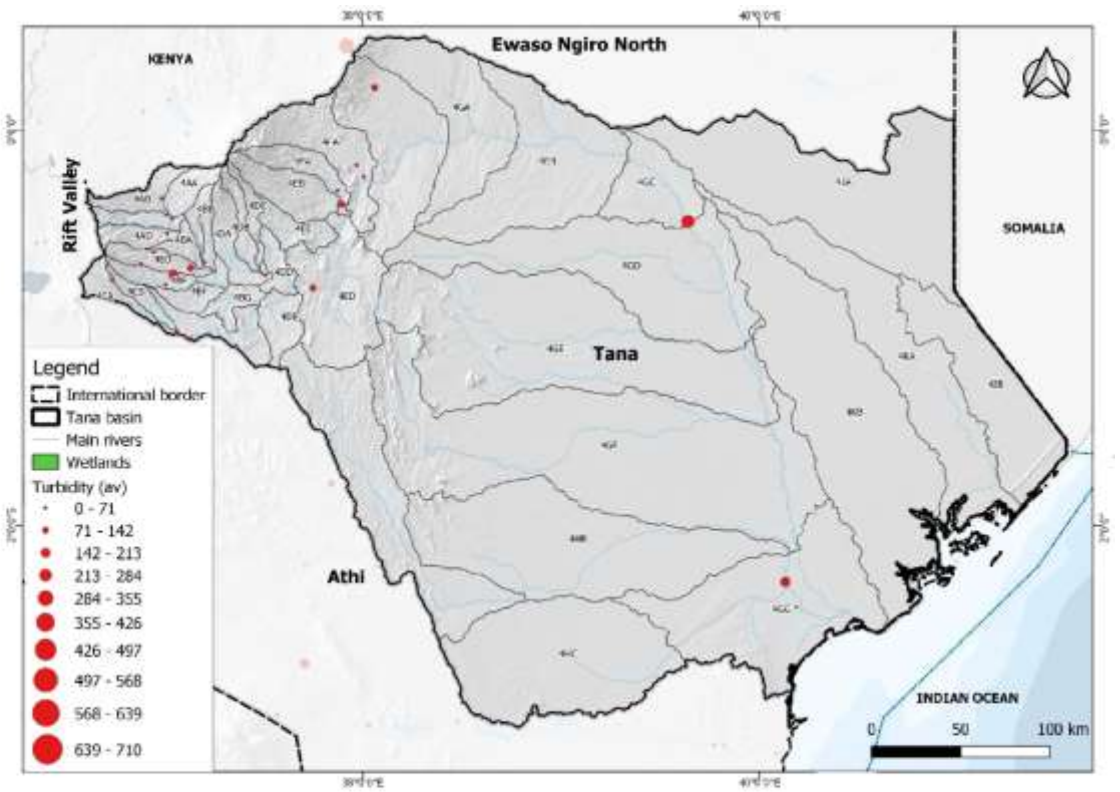
Middle Tana

Middle Tana, also referred to as the Kathita-Mutonga system comprise of the following rivers: Thingithu, Kithinu, Tungu, Kathita, Ruguti, Mara, Rujiweru, Kinyantha, Gaciuma, Thiiba, Rwamuthambi, Nyamindi, Mutonga, Thananthu, and Rupingazi. Activities on the catchments include, small and large scale intensive farming and livestock rearing. Crops grown include tea, coffee and rice at Mwea. On the drier areas, pastoralism is practiced. Some quarrying is also undertaken which results in increased sediment runoff. The Middle Tana is prone to incidences of gross pollution from such agro-activities. The other pollution threat is bacterial contamination from treated or untreated domestic sewage emanating from urban and rural settlements.

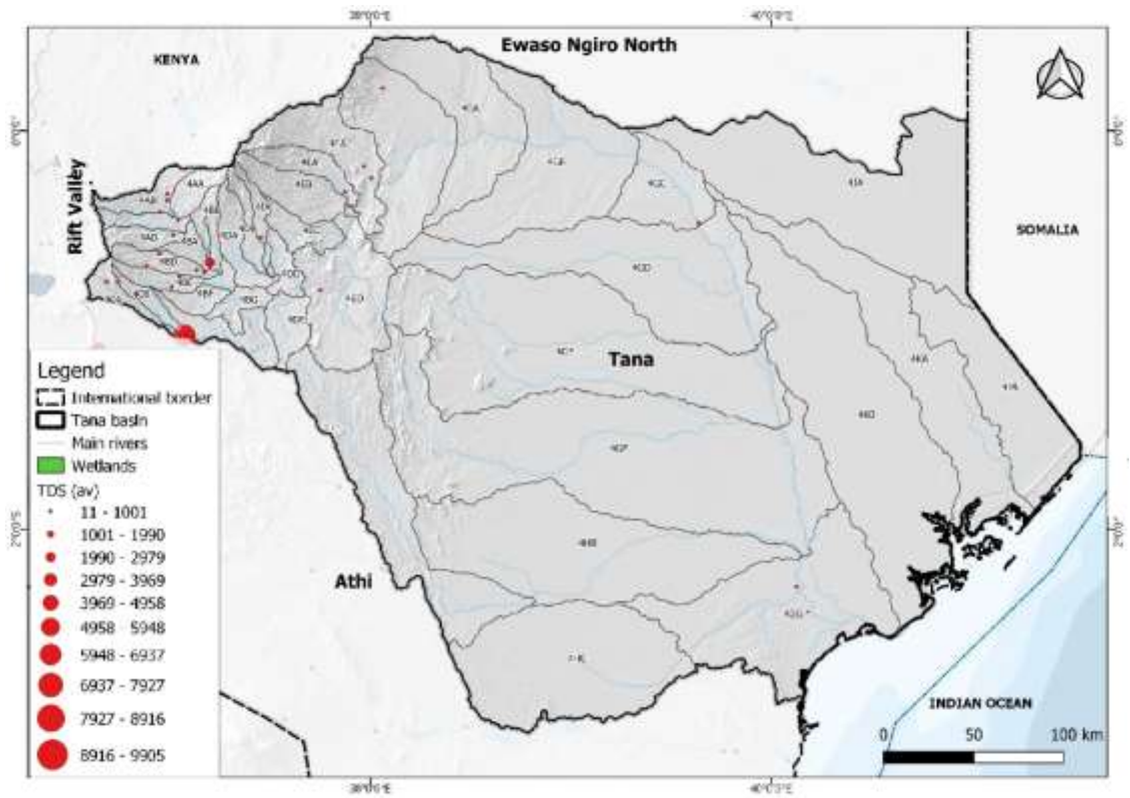
These rivers have also been polluted by effluent from agro-based industries such as tea, coffee and horticulture. Industrial effluents derived from factories in towns such as Meru, Kerugoya, Embu, and Runyenjes contaminates receiving rivers. These rivers appear brown and are laden with silt and sediment from the farms and carry nutrients from the fertilizers used on the farms and pesticide residues. Downstream of towns the rivers are contaminated with pathogenic bacteria. All the rivers show high levels of colour and turbidity, bacterial contamination, diminished dissolved oxygen levels and moderately high levels of BOD and COD.

Lower Tana

No tributaries join the Tana downstream of Garissa, except for massive runoff from Kitui County during the rains. There are monitoring stations at Garissa, Garsen and Hola. The most critical water quality issue at these stations is sediment and turbidity giving the water a dark brown colour. The water is contaminated with high bacterial counts emanating from the urban and rural settlements upstream along the river.



a.



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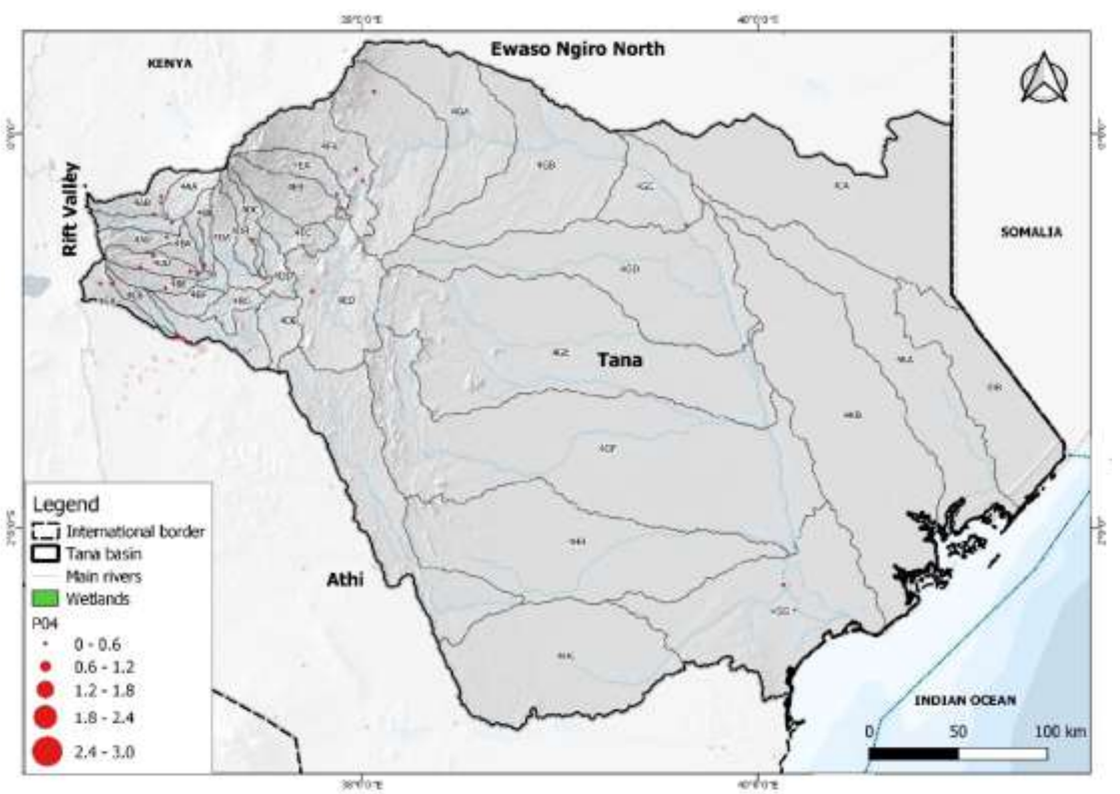

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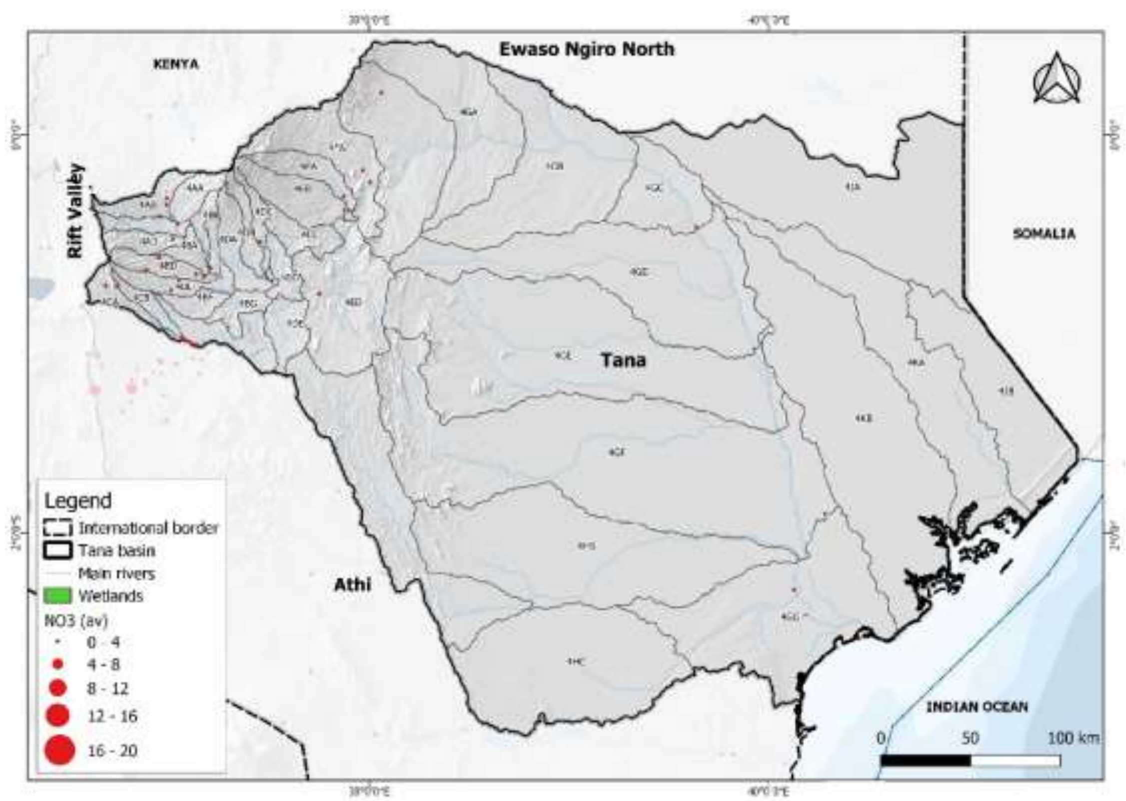

d.

Figure 6-12: Surface water quality monitoring stations in Tana Basin with turbidity (a), TDS (b), PO_4 (c) and NO_3 (d)

** Note data limitations meant that water quality maps for other parameters could not be developed*

6.5.4.2 Groundwater

A comprehensive overview of groundwater quality is provided in section 6.4.5.2. However, given that surface and groundwater in a given location are often in hydraulic continuity, it is necessary to provide a context for a link between the two.

Where surface waters are polluted, bank-side recharge to alluvial aquifers may lead to localised groundwater pollution. Catchments that drain agriculturally-rich areas (such as the Upper Tana Basin) are capable of the long-distance transport of potentially harmful pollutants. The current status of pollution by POPs in the Tana Basin is not known. At-risk aquifers would include all riverside alluvial aquifers, such as those in Tana Basin. Polluted surface waters from the humid, highly populated parts of the basin inevitably find their way downstream. Rivers such as the Thika River suffer from heavy metal contamination from industrial pollution (Asiago, 2018; Kimani et al., 2016). Other rivers and streams are also likely to suffer from wastewater pollution, particularly from urban centres, which can contaminate alluvial aquifers during bank-side recharge. Lake Kenyatta aquifer is vulnerable to pollution, due to the high transmissivity of the coral limestone aquifer. Coral limestone aquifers show a greater risk of pollution contamination in other parts of Kenya (Tole, 1997).

Pollutants (human wastewater) have been demonstrated in Mombasa, Eldoret and Kisumu. Similar patterns may exist in shallow aquifers beneath informal settlements in the larger towns in the southwestern part of the Tana Basin. Pollution by pharmaceuticals is likely but not certain. Abila et al., (2012) examined 96 water samples from shallow wells in the eight main residential areas in Kitui Town during May to July 2011. These wells ranged from five to 25 m in depth. In all eight zones, significant bacterial concentrations were observed. Bacterial presence and concentration was associated with proximity to septic tanks or toilets, with mean distances between wells and sanitation facilities ranging from six to 23.5 meters across the eight zones.

There is no doubt whatsoever that streams draining the Nairobi area are polluted (e.g. Njuguna et al., 2017). Recent studies show that recharge to the Nairobi Aquifer Suite 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. This may apply to the small part of the Tana Basin underlain by the NAS (covering 862 km^2).

K'oreje et al. (2016) found pharmaceutical compounds in wastewaters and surface waters in Nairobi, albeit at low concentrations; similar groundwater pollution in the Tana Basin is likely, particularly in aquifers beneath high density informal settlements. These are the only studies of their type carried out in Kenya that have been reviewed as part of this study. The study of pharmaceutical pollution in groundwaters is a comparatively recent phenomenon, even in developed countries, but the presence and persistence of pharmaceutical products and other organic compounds in groundwaters has been widely reported (Lapworth et al., 2012; McEneff et al., 2015).

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 resources management institutions have the capacity and systems in place to efficiently manage water quality.

The water quality vision for the Tana 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 Tana Basin should be focused on managing the pollution problems in urban centres and maintaining the fitness for use.

In order to comprehensively and systematically address the water quality issues and challenges in the Tana Basin, Table 6-16 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 6-16: Strategic Framework - Water Quality Management

4	**Key Strategic Area:**	**Water Quality Management (SW and GW)**
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 Tana Basin. 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 upgrading the 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. Several 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 Tana 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 WQ 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 Tana 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 Tana 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 Tana 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	Key Strategic Area:	Water Quality Management (SW and GW)
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 Tana Basin should be enforced. This database should also serve as the approved database for all reporting and assessment of water quality data in the Tana 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 Tana Basin, identify key water quality concerns, their causes and consequences, and recommend management actions to mitigate negative impacts.

4.2 Theme: Promote sound water quality management governance in the Tana Basin

With so many institutions involved in different aspects of water quality management in the Tana 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 Tana 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 regarding 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 several 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 Tana Basin. WRA should advocate alignment of strategies to serve a common purpose of rehabilitating urban rivers and streams in the Tana 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 Tana Basin.

Participate in river clean-up campaigns of rivers. 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 Tana 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 Tana 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

4	Key Strategic Area:	Water Quality Management (SW and GW)

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 are 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 have a huge negative impact on urban water quality due to indiscriminate disposal of liquid and solid household wastes. Agricultural also has 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.

Several 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 Tana 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 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 (SW and GW)
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 CIDPs and to develop relevant county legislation.

The National Climate Change Action Plan (NCCAP) 2013-2017 (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. 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, three of which (nos. 1 to 3) align very strongly with the planning and management of water resources.

Table 6-17: 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 National Adaptation Plan (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 Tana 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 Tana 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 potential. 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 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 an 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 (Government of Kenya, 2018).

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.

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 under the future likely impacts of climate change will increase 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 6-18. Aspects which relate to water resources management and planning are highlighted.

Table 6-18: Potential climate change impacts (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 such as 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 and supports 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.

Social impacts	
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 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 must travel long distances to **search for wate**r.
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 and more frequent coastal flooding, changing patterns of shoreline erosion, **increased salinity of coastal aquifer**s, 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 properties of the soil.
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.

Environmental impacts	
Deforestation and forest degradation	**Deforestation and forest degradation** in Kenya is 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 Tana 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 Tana Basin, **Table 6-19** sets out 3 Strategic Themes and provides specific strategies under each theme. These themes are focused on understanding and mitigating the impacts and cross sectoral ramifications of the changing climate in the Tana Basin.

Table 6-19: Strategic Framework - Climate Change Adaptation

5	**Key Strategic Area:**	**Climate Change Adaptation and Preparedness**
5.1	**Theme:**	**Understand impacts of climate change on water resources at appropriate spatial scales**
5.1.1	Quantify climate change impacts (rainfall & temperature) on surface water and groundwater resources and demands in the Tana 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 Tana 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	
Make use of efficient energy technologies and techniques at household level.		
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. 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	
Increase resilience through diversification of agroforestry's 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.

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.

6.7.2 Characteristics of floods and droughts in the Tana Basin

6.7.2.1 Frequency and extent of floods in the Tana Basin

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 1997/78, Kenya experienced 8 individual years with widespread flooding (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 flood-related human deaths and a further 5600 human deaths due to cholera, malaria and Rift Valley Fever, 2.3 million livestock lost, and 100 000 km roads and 13 major bridges destroyed (Gathura, 2015).
- During the period 1998-2012, widespread flooding and landslides across Kenya were absent for only two of the years and during a number of these events the *Tana River, Meru, Murang'a, and Isiolo* counties 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. The *Tana River, Isiolo, Murang'a and Garissa counties* in the Tana Basin were impacted to varying degrees (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. Tana Basin counties that were impacted were *Garissa, Tana River, Kirinyaga, Isiolo, Machakos and Kilifi* (International Federation of Red Cross, 2016a).

- Widespread flooding and occasional landslides during April and May 2016 displaced 49 000 people and caused 100 deaths. Tana Basin counties, *Garissa, Embu, Murang'a and Tana River*, were severely impacted (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. *Garissa* county was severely impacted (Davies, 2017).
- Widespread flooding and various landslides during March-May 2018 impacted more than 800 000 people across Kenya, including in various Tana Basin counties: *Kilifi, Tana River, Garissa, Isiolo, Kitui and Murang'a.* 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 were lost, while about 100 schools were flooded (OCHA, 2018).

6.7.2.2 Flood-prone areas in the Tana Basin

The chronic flood-prone areas in the Tana Basin are as follows (Government of Kenya, 2009; Water Resources Management Authority, 2015b):

- Flash-floods and mudslides: *Middle to upper zones of Tana River, Kirinyaga and Kitui counties* as well as the lower slopes of Mount Kenya - due to poor cultivation practices on steep slopes. It should be noted that, in these rural areas, flash-floods and mudslides are a primary cause of loss of life and destruction of cultivated lands, transport infrastructure, water supply infrastructure and riparian homesteads.
- Long-duration flooding (1 – 4 months): *Garissa and Tana River counties* - caused by the Tana River overflowing its banks in both urban and agricultural areas. Garissa Town, the Middle Tana River reaches, and the Tana River Delta are regarded as the most long-duration flood-prone locations in the Tana Basin.
- Short-to-medium duration flooding (1 – 5 days): Intermittently in *Garissa Town* due to inadequate urban drainage infrastructure, and occasional riparian and floodplain damage along the Maua, Komoli, Kalikuvi, Kokani and Buna River tributaries of the Tana River.

6.7.2.3 Frequency and extent of droughts in the Tana Basin

During the past two decades Kenya has experienced five widespread multi-year droughts with devastating socio-economic and environmental consequences. The table below provides an outline of these five droughts. Given that the climate over most of the Tana Basin is categorised as arid and semi-arid, most of the counties of the Tana Basin were either severely or partially impacted by these droughts. The north-western and western region of the Basin was the exception.

Table 6-20: Widespread Kenyan droughts during the past two decades (Huho et al., 2016; Reliefweb, 2018b).

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 Drought-prone areas in the Tana Basin

The climate over 80% of the Tana Basin area is arid or semi-arid (the only exceptions are the eastern and southern slopes of Mount Kenya and the eastern slopes of the Aberdares Range and Nyambene Hills). Under these precarious climate conditions, it follows that, if consecutive rainfall seasons should fail, such as occurred during the years indicated above, emergency drought conditions would eventually develop in most the Basin’s 14 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 Tana Basin, that have been compiled during the recent past.

6.7.4.1 National Water Master Plan 2030, Volume III Part F – Tana Catchment Area

The Water Master Plan for the Tana 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 the flood disaster management plan for the Tana Basin distinguished between “structural” and “non-structural” measures, as follows:

- Implementation of flood control measures for Garissa Town and its peri-urban regions: construction of a new dike, reinforcing or heightening of existing dikes, widening of high-water river channel by realignment of existing dikes, widening of low-water channel by excavation, flood discharge control by upstream multi-purpose dams, flood discharge control by retarding basins and river improvement works.
- Preparation of flood hazard maps and evacuation plans covering all of Garissa Town and its peri-urban regions, as well as the Lower Tana River: The maps and evacuation plans were to be developed by the WRMA Tana Regional Office, who would also have the responsibility for dissemination of flood warnings.
- Establishment of a CBDM System in the Lower Part of Tana River downstream of Garissa: The components of the CBDM System should be the following: (i) preparation of communities to operate the CBDM and establishment of a flow of monitoring, information dissemination and evacuation drills in cooperation with the WRMA Tana Regional Office, Lower Tana Sub-Regional Office, and the local government offices; (ii) construction of evacuation centres and evacuation routes by community involvement; (iii) voluntary monitoring by communities using simple rain gauge and water level gauge readings; (iv) community involvement in flood prevention activities and (v) construction of small-scale structural measures such as small revetments and culverts.
- Improvement of multi-purpose dam discharge warnings regarding Kiambere Dam, which is the upstream dam nearest to Garissa Town: (i) stipulating that TARDA, the owner of the dam, would be responsible for issuing warnings about dam releases; (ii) improving existing dissemination methods the affected communities and general public; (iii) providing dam release information to the WRMA Tana Regional Office, which is the implementing organisation on river administration at catchment level.

Drought disaster management plan

The proposed components of a drought disaster management plan for the Tana Basin were as follows:

- Preparation of drought-related operating rules for eight existing reservoirs and eleven proposed reservoirs.
- Establishment of a Basin Drought Conciliation Council for the Tana River system, with legal status to avoid water conflict during droughts. The Council’s membership would comprise WRMA regional staff, county staff and representatives of WRUAs.

- Setting of drought-based restrictions placed on water supplies to the different water-user sectors. To understand clearly the timing of necessary actions for water use restriction, three steps of reference based on reservoir water level would be set for the respective reservoirs, as follows: (i) Normal: At this reservoir water level, the Basin Drought Conciliation Council meets to devise actions that would be taken should the reservoir water level become lower. (ii) Alert: The reservoir water level which triggers water use restrictions. (iii) Alarm: The reservoir water level at which releases from the reservoir are drastically curtailed.
- Establishment of a drought early warning system, based on existing KMD short-term, monthly and seasonal rainfall forecasts and utilised to further inform decisions about when to commence with timely water restrictions, and to help prepare communities regarding drought damage or to raise awareness about the importance of increased water conservation.

6.7.4.2 Tana and Athi Rivers Development Authority (TARDA) Strategic Plan 2014 – 2018 (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 is outlined in the extract presented in Figure 6-22 below.

Table 6-21: TARDA strategy for flood and drought mitigation for Athi and Tana River Basins

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

6.7.4.3 Tana Catchment Area Catchment Management Strategy 2015 – 2022 (Water Resources Management Authority, 2015b)

In the Tana CMS, five levels of structural/non-structural flood and drought interventions are envisaged: regional, sub-regional, County Governments, WRUAs and local communities. Table 6-22 presents a generic summary of the proposed interventions.

Table 6-22: Levels of flood and drought management envisaged for the Tana 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 and 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.

The goal and objectives of the flood and drought management component of the CMS were as follows:

Goal:

Develop and implement Integrated Flood and Drought Management Plans in collaboration with Stakeholders.

Objectives:

- To adopt best practices in Integrated Flood and Drought Management (IFDM):
  - Establish three community-based Flood and five Drought Management Committees, including WRUAs, other relevant stakeholders and dam operators.
  - Develop three flood and five drought hazard maps.
  - Establish three flood evacuation centres and six evacuation routes.
- To develop and operationalise a framework for collaboration with County Governments and other Stakeholders regarding IFDM:
  - Collaborate with the County Governments and other Stakeholders to undertake structural measures for floods (e.g., check dams, culverts, raised roads, river training, pans, dams).
  - Promote rainwater harvesting in 10 Catchment Management Units (CMUs).
  - Review 60 existing SCMPs to include Flood and Drought Management (FDM).
  - Develop 80 new SCMPs to include Flood and Drought Management.
- To enhance capacity in Integrated Flood and Drought Management, including monitoring skills, use of information systems and flood control centres:
  - Mainstream existing school and community awareness campaigns and education programmes on flood and drought management (evacuation drills, flood-fighting techniques, production of educational materials, exchange visits).
  - Promote efficient use of water and storage in 12 WRUAs.
  - Develop and implement three Integrated Flood Management Plans and five Integrated Drought Management Plans.
- To mainstream Flood and Drought Management in Sub-Catchment Management Plans:
  - Identify areas of collaboration with County Governments and other stakeholders.
  - Develop and operationalise the collaboration frameworks with County Governments and other stakeholders.
  - Enhance capacity in IFDM (CGs, WRUAs, WRMA staff) with respect to monitoring skills and establishment of information systems and Flood and Drought Operation Control Centres.
- To enforce the Reserve flow requirements with respect to drought management:
  - Carry out three training needs assessment for WRMA, WRUAs and County Governments.
  - Prepare and Implement three training plans.
  - Upgrade existing monitoring networks (5 river gauging stations and 13 rainfall stations) and equipment for real-time data transmission.
  - Upgrade field equipment (5 Acoustic Doppler Velocity Meters).
  - Upscale three Integrated Flood Early Warning Systems and five Integrated Drought Early Warning Systems.
  - Establish six operational Flood and Drought Forecasting Centres.
  - Implement a Reserve Flow Requirement Enforcement Plan for drought situations in 5 CMUs.

Some of the Strategic Actions were to be completed between 2015 and 2020, while the rest were continuous and long-term.

6.7.5 Key achievements, challenges and constraints

In the documents discussed in Section 6, as well as in various relevant documents available on the GoK web-site, a range of achievements, challenges and constraints regarding flood and drought disaster management are identified. Although various of these items are aimed at the national level, they nevertheless have importance at the Basin, county and sub-county levels. These achievements, challenges and constraints are outlined in the following sub-Sections.

6.7.5.1 Achievements

- Protective revetments have been constructed along the Lower Tana River over a length of 3.0 km.
- Three water level warnings for the Tana River, namely, *Alert, Alarm* and *Flood*, been determined for the Garissa and Garsen streamflow gauging stations (based on experience). Once the river water level reaches a warning level, the WRA Tana Regional Office disseminates information to the public along the downstream reaches through relevant local governments at county and district level.
- Integrated Flood and Drought Management Plans for the complete Tana Basin were completed in 2015 as part of the CMS.
- The National Hydro-Meteorological Network Design Project for the Republic of Kenya, currently underway, has designed a provisional network of 55 meteorological and 86 river gauging stations (telemetric or automatic or manual) for the Tana Basin.
- 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).
- The Cabinet approved the National Drought Emergency Fund (NDEF) Regulations in May 2018. The Regulations guide the operations of the National Drought Emergency Fund which is to be established for improving the effectiveness and efficiency of drought risk management systems in Kenya as well as to provide a common basket of emergency funds for drought risk management. The establishment of the NDEF reflects a wider Government policy shift towards drought risk management rather than crisis management. NDMA has, since 2014, been piloting the use of a dedicated Fund in drought risk management through the European Union-funded Drought Contingency Fund (DCF). The DCF business process was successfully employed during the 2016-2017 drought, thereby mitigating losses both of lives and livelihoods.
- The Department of Agriculture has been rolling out a subsidised crop insurance policy to maize farmers in various counties. Campaigns are ongoing by the Department to advise farmers to construct water-harvesting structures on their farms in order to benefit from good rainfall periods.

6.7.5.2 Challenges

- The WRA Tana Regional Office has not yet implemented a drought disaster management operation based on three water level warnings and related discharges, namely Normal, Alert, and Alarm levels, at suitable river gauging stations as a reference level. The above three triggers should indicate that water use restrictions by regulating water intakes were required.
- Sourcing financing for implementation of the flood and drought management components of the Tana Basin CMS: In 2014 the cost of this work was estimated as about USD 10 million.
- 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.

- 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 potential 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 the Tana 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 and oversee their implementation as emergency response interventions. It has been a serious constraint that the Tana 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 Department for International Development (DFID) found that coordination between national and local actors in humanitarian resource mobilisation was generally incoherent (Development Initiatives, 2017). 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 in different Ministries.

  Furthermore, the mandate of NDMA also overlaps with the mandates of NDOC and NDMU. *The National Disaster Management Authority Bill* (2019) 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.

  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 6-13).

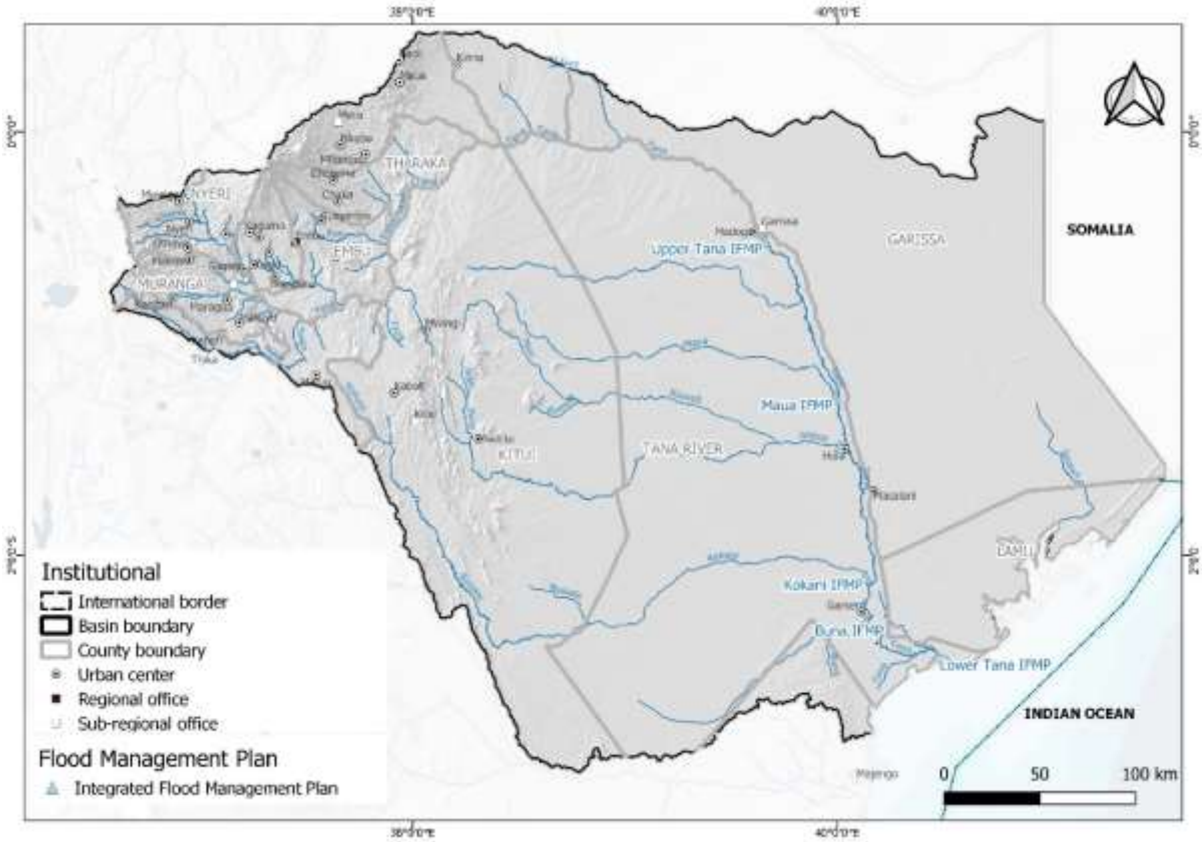

Figure 6-13: Flood management plan for Tana Basin

In order to comprehensively and systematically address the flood and drought issues and challenges in the Tana Basin, the table below sets out two Strategic Themes with specific Strategies under each Theme. The Themes address Flood and Drought Management.

Table 6-23: Strategic Framework – Flood and drought management

Key Strategic Area 6		**Flood and drought management**
6.1	**Theme:**	**Flood management**
6.1.1	Undertake flood risk assessment	
The chronic flood-prone areas in the Tana Basin are as follows: – Flash-floods and mudslides: *Middle to upper zones of Tana River, Kirinyaga and Kitui counties* as well as the lower slopes of Mount Kenya - due to poor cultivation practices on steep slopes. It should be noted that, in these rural areas, flash-floods and mudslides are a primary cause of loss of life and destruction of cultivated lands, transport infrastructure, water supply infrastructure and riparian homesteads. – Long-duration flooding (1 – 4 months): *Garissa and Tana River counties* - caused by the Tana River overflowing its banks in both urban and agricultural areas. Garissa Town, the Middle Tana River reaches, and the Tana River Delta are regarded as the most long-duration flood-prone locations in the Tana Basin. – Short-to-medium duration flooding (1 – 5 days): Intermittently in *Garissa Town* due to inadequate urban drainage infrastructure, and occasional riparian and floodplain damage along the Maua, Komoli, Kalikuvi, Kokani and Buna River tributaries of the Tana River. High-level assessments will be undertaken of the flood exposure of each village and town in the above counties in terms of proximity to river channels, flood-plains and low-lying land, as well as vulnerable transport, access and escape routes and river crossings. Stormwater drainage in the larger urban areas will also be assessed. 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 historical information about the frequency of high-water levels and long-duration inundations. The above information will be systematised in a Flood Risk Register for the Tana Basin, which will provide a starting point for the Integrated Flood Management Plans discussed below.		

Key Strategic Area 6	**Flood and drought management**

6.1.2 Formalise institutional roles and partnership collaborations.

The existing government institutions and agencies and other stakeholders with partnership roles in flood management are as follows[2]:

- 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 a Tana Basin Flood Response Forum (FRF) be established that integrates all flood-relevant resource mobilisations and related interventions in the Tana Basin by the various collaboration partnerships listed above. The Tana 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 Tana Basin FRF must be systematised through the development of appropriate standard operating procedures (SOPs)[3].

6.1.3 Develop flood response protocol

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 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 protocol 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 flood-prone sub-catchments in the Tana Basin, namely the Upper Tana River upstream of and including Garissa Town; the Lower Tana River downstream of Garissa, including the Tana River Delta and each of the Maua, Komoli, Kalikuvi, Kokani and Buna River tributaries of the Tana River. The IFMPs will be structured around the following topics:

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[2] 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.

[3] 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 implementing 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 (Development Initiatives, 2017).

Key Strategic Area 6	**Flood and drought management**

- 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 above flood-prone catchment IFMPs that cover the Tana Basin, will be reviewed by the *Tana Basin FRF* and, through negotiation with representatives of each of the affected stakeholder sectors 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 Tana 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 flood-plains in each of the above flood-prone catchments in the Tana River Basin. Wherever feasible, *community-based* flood early warning and flood preparedness approaches will be followed.

The *Tana Basin FRF* will provide a platform for coordinating the resourcing and for 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 Tana 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 aim is to expand organisational capacity in the Tana 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 *Tana Basin Flood Response Forum (FRF)* introduced in Sub-Section 6.1.2.
- ***Institutional technical skills*:** The aim is to strategically expand institutional technical skills relevant to flood 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 Tana 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 existing government institutions and agencies and other stakeholders with partnership roles in drought management are as follows[4]:

[4] 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

- 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 *Tana Basin Drought Response Forum (DRF)* be established that integrates all drought-relevant resource mobilisations and related interventions in the Tana Basin by the various collaboration partnerships listed above. The *Tana 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 Tana Basin counties' offices. Furthermore, the activities of the *Tana 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 Tana Basin Drought Response must address five primary drought response needs, i.e. drought monitoring, drought early warning, drought severity assessment, mitigation interventions and recovery interventions.

Currently, drought monitoring, drought early warning and severity assessment are conducted by the NDMA, who issues regular Drought Early Warning Bulletins, 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 Tana Basin must be reviewed and deliberated by the collaboration partnership participants in the *Tana Basin Drought Response*. In the case of an adverse severity assessment, the *Tana Basin Drought Response* 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 Tana Basin.

6.2.4	Strengthen existing drought early warning systems

The NDMA currently issues regular Drought Early Warning Bulletins for ASAL counties. Given that about 80% of the Tana Basin area can be classified as arid and semi-arid (the only exceptions are the eastern and southern slopes of Mount Kenya and the eastern slopes of the Aberdares Range and Nyambene Hills), most of the counties are included in the NDMA Bulletins.

SOP responses based on the Bulletins' early warning findings and alerts must be an integrating force in the above *Tana Basin Drought Response*. The sub-county scale of the Bulletins' reporting ensures that such responses can

Key Strategic Area 6	Flood and drought management
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 three drought-prone counties in the Tana Basin. The Famine Early Warning Systems Network (FEWS NET), which produces monthly reports and maps detailing current and projected food insecurity in several regions in the world, has a Regional Office in Kenya and FEWS NET outputs will support the deliberations by the participants in the *Tana Basin Drought Response*.	
6.2.5 Capacity development	
Capacity for drought management in the Tana 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 Tana Basin's 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 Tana 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 *Tana Basin Drought Response* introduced in Sub-Section 7.2.1. – ***Institutional technical skills***: The approach here 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 Tana 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 Tana Basin

An overview of the existing hydrometeorological monitoring network in the Tana Basin is provided in Section 2.4.8. The current network needs to be expanded and 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.

Most of the operational river gauging stations in the Tana 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. However, challenges remain because many of the stations are also inaccessible during high flow conditions. Flow measurement for checking and updating rating curves are typically done with an acoustic doppler velocimetry (ADV) or an acoustic doppler current profiler (ACDP) during high flow periods and on the main branch of the Tana River. 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 Basin, little accurate information is known about operational status, station types, parameters collected, operators, and even confirmed coordinates of meteorological stations.

Due to the low rainfall in parts of the Tana Basin, and a heavy reliance on the existing surface water sources, monitoring and protection of water sources in the basin is of utmost importance. To address this problem, intensified monitoring and enforcement of the water permit conditions and effluent discharge guidelines will be required as a start. Currently, the water quality monitoring programme operated by WRA faces challenges of inadequately qualified and trained staff and inadequate operational resources to facilitate regular sampling and laboratory analysis. There is a fairly well equipped with AAS Water Quality Testing Laboratory at Embu. It is well equipped with other basic laboratories equipment, but it only has one officer instead of an optimal number of five. Currently it can analyse both physico-chemical parameters and heavy metals on samples. However Upper and Middle Tana areas being farming areas for wheat, rice, tea and coffee, on which pesticides are applied, the Embu and Murang'a laboratories need a GLC or HPLC for the analysis of pesticide residues.

Furthermore, the mandates and roles and responsibilities of the different institutions involved in water quality management in the Tana 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 Tana Basin, there is currently a total of 41 operational groundwater monitoring points. 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. 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 is the design of a hydrometeorological network for the Tana 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 designing a stream flow monitoring network for the Tana Basin entailed an assessment of the existing and historical network in the Tana Basin against specific criteria. The result is a stream flow monitoring network design for the Tana Basin consisting of 72 stations. The non-operational stations will be refurbished, with 1 automatic station being downgraded to manual. In addition, 16 stations will be upgraded from manual to automatic, 4 stations will be upgraded from manual to telemetric, and 2 automatic stations will be upgraded from automatic to telemetric. In addition, 3 new stations will be constructed: 2 automatic and 1 telemetric station.

Table 6-24: Proposed streamflow monitoring network for the Tana Basin

Sub-Regional Office	Total Number of surface water Stations			
	Telemetric	Automatic	Manual	TOTAL
Garissa	3	2	0	**5**
Kerugoya	1	3	10	**14**
Kitui	0	0	0	**0**
Meru	3	8	14	**25**
Murang'a	2	15	11	**28**
TOTAL	**9**	**28**	**35**	**72**

The maps in Figure 6-14 to Figure 6-18 display the locations of the proposed surface water (flow) monitoring stations and meteorological stations per SRO area.

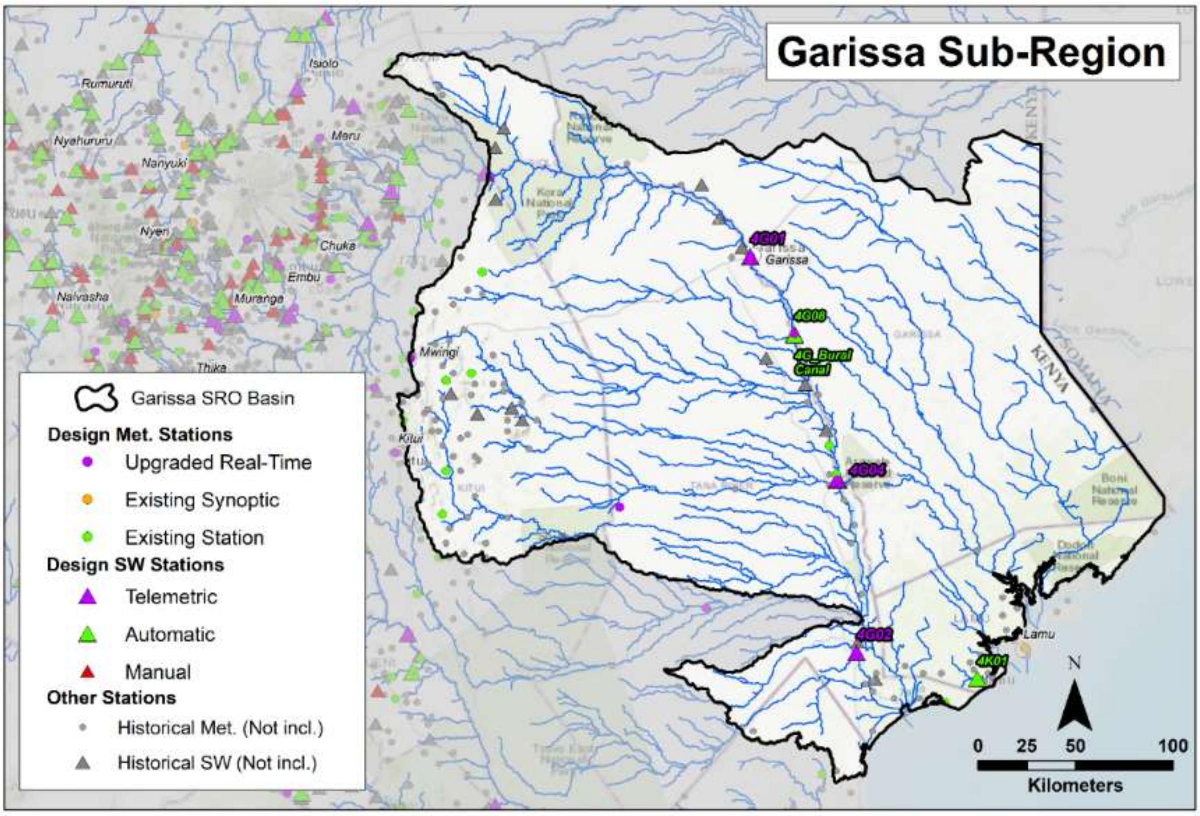

Figure 6-14: Garissa sub-region: Proposed flow and Hydromet monitoring network

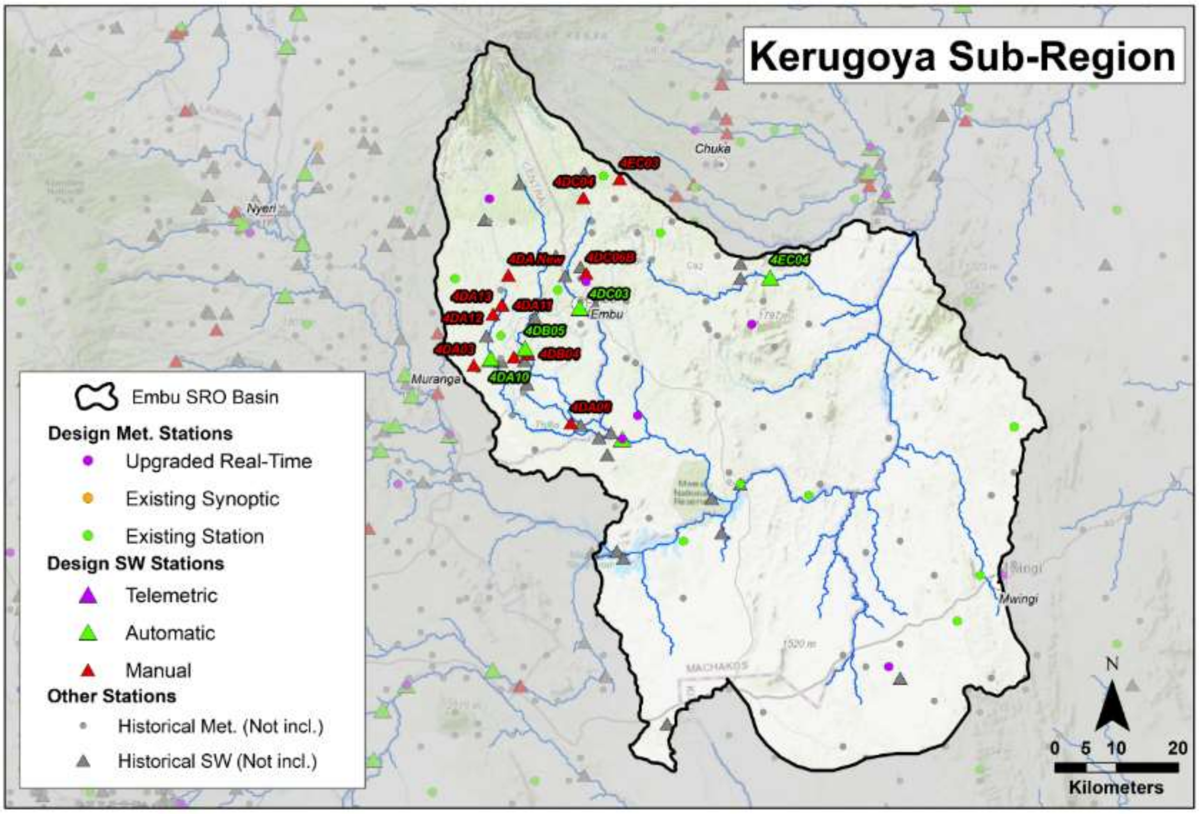

Figure 6-15: Kerugoya sub-region: Proposed flow and Hydromet monitoring network

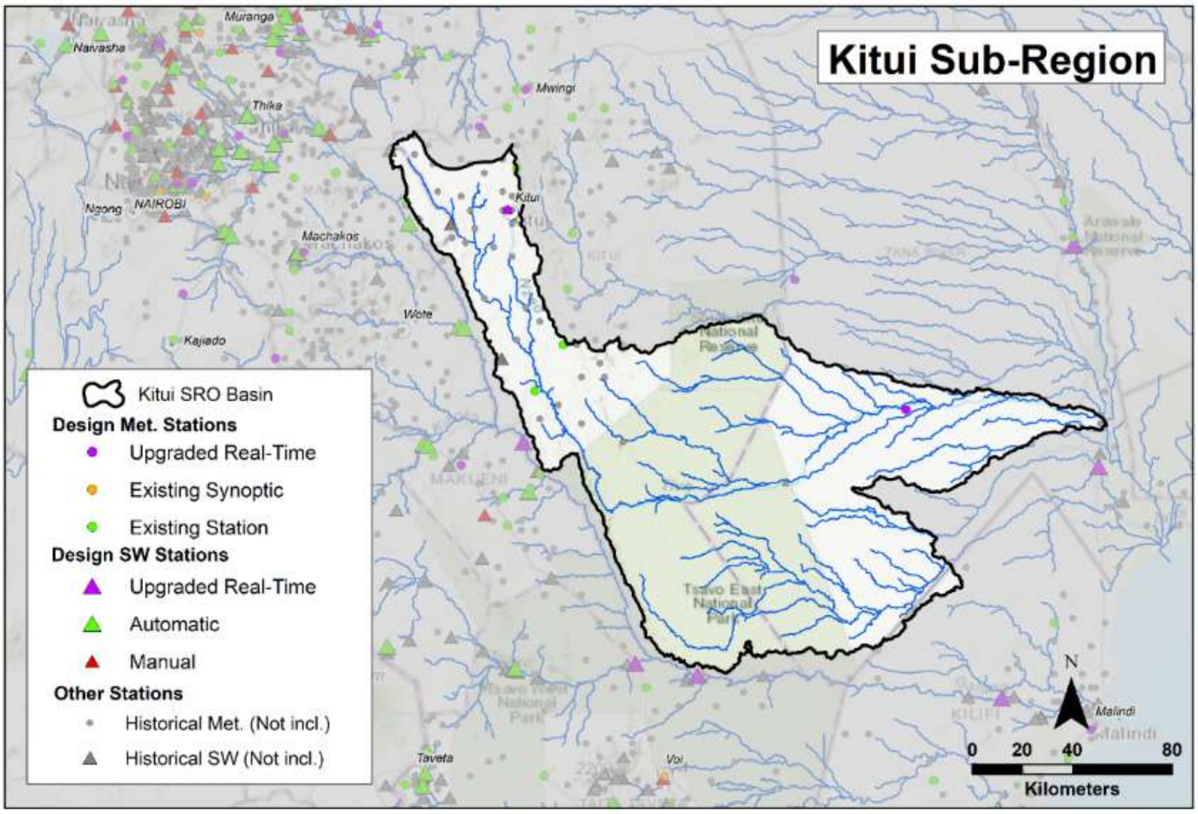

Figure 6-16: Kitui sub-region: Proposed flow and Hydromet monitoring network

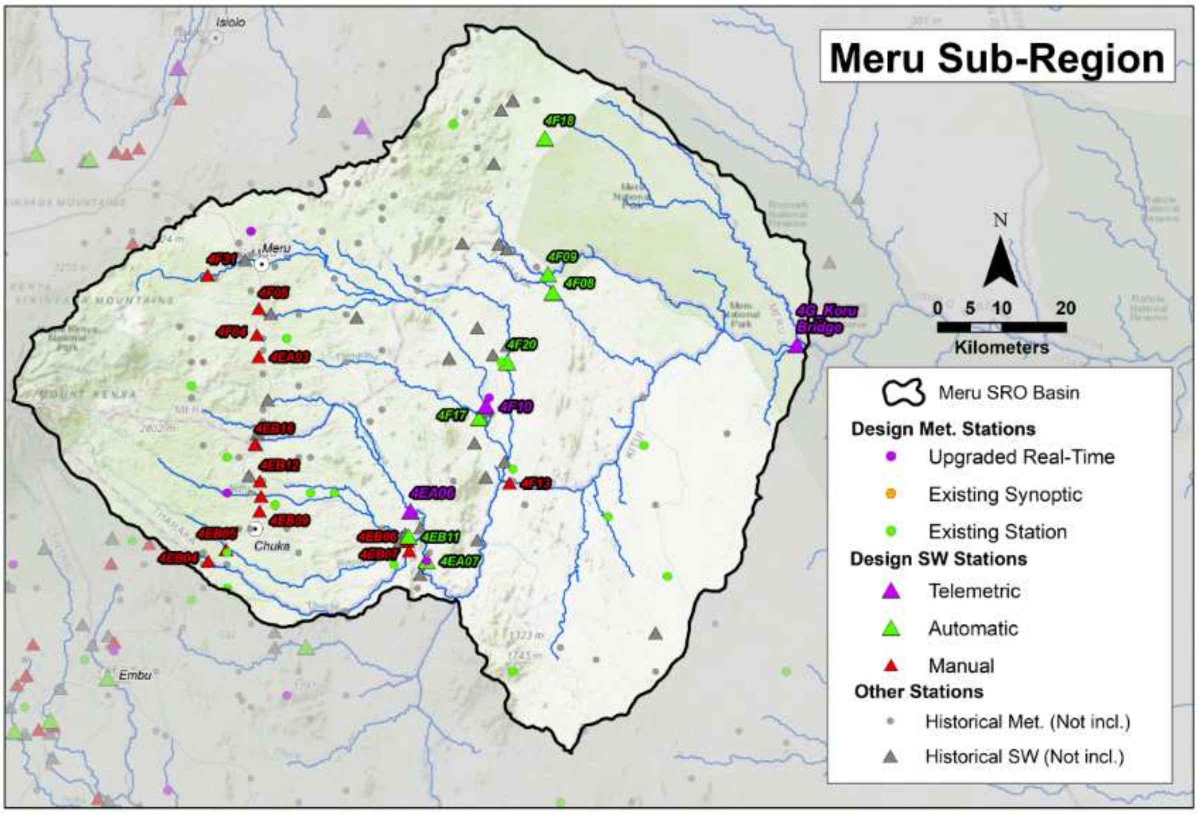

Figure 6-17: Meru sub-region: Proposed flow and Hydromet monitoring network

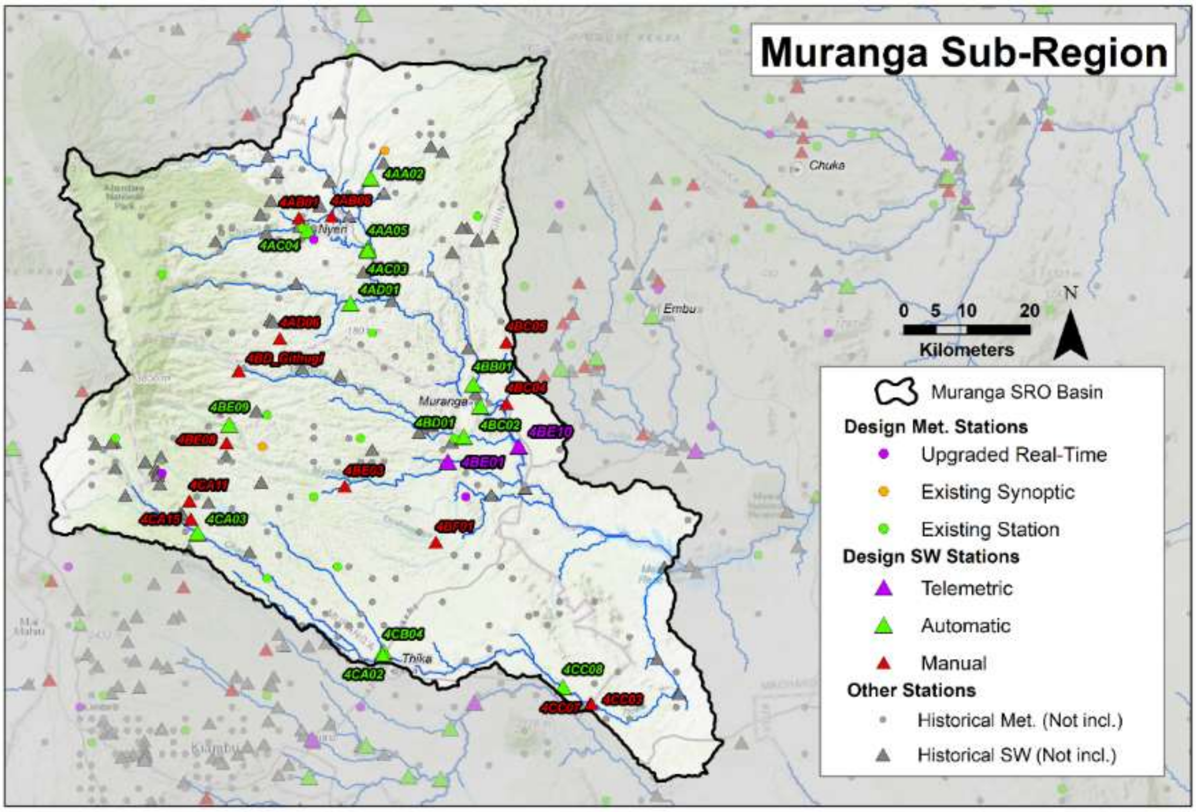

Figure 6-18: Murang'a sub-region: Proposed flow and Hydromet monitoring network

6.8.3.2 Monitoring of dam and lake levels

One new telemetric surface water monitoring station is proposed for Lake Kenyatta in Garissa County (Figure 6-14).

6.8.3.3 Meteorological monitoring

The approach towards the design of a meteorological network for the Tana Basin entailed an assessment of the historical meteorological network in the Basin against specific criteria. The result is a meteorological network design for the Tana basin consisting of 65 stations, of which 10 are telemetric. Figure 6-14 to Figure 6-18 also display the proposed meteorological network for the Tana 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 Tana 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.

Table 6-25: Proposed water quality monitoring network for Tana Basin

Tana Basin	Current stations (2018)	Proposed stations to be retained	Proposed stations to be discontinued	Proposed new stations	Total
Surface water	64	50	14	5	55
Effluent stations	10	10	0	7	17
Ground water	27	27	0	0	27
Total	**101**	**87**	**14**	**12**	**99**

Out of the total proposed stations, a number of them were proposed to be first priority (Table 6-26). 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 6-26: Proposed baseline and first priority stations for Tana basin

Tana Basin	Proposed baseline monitoring stations	Proposed first priority stations
Surface water	8	18
Effluent stations	-	6
Ground water	-	5
Total	**8**	**29**

Surface Water quality monitoring stations

The proposed surface water station water quality network for the Tana 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 Tana 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. Figure 6-19 to Figure 6-24 display the locations of the proposed surface water quality stations per WRA sub-region.

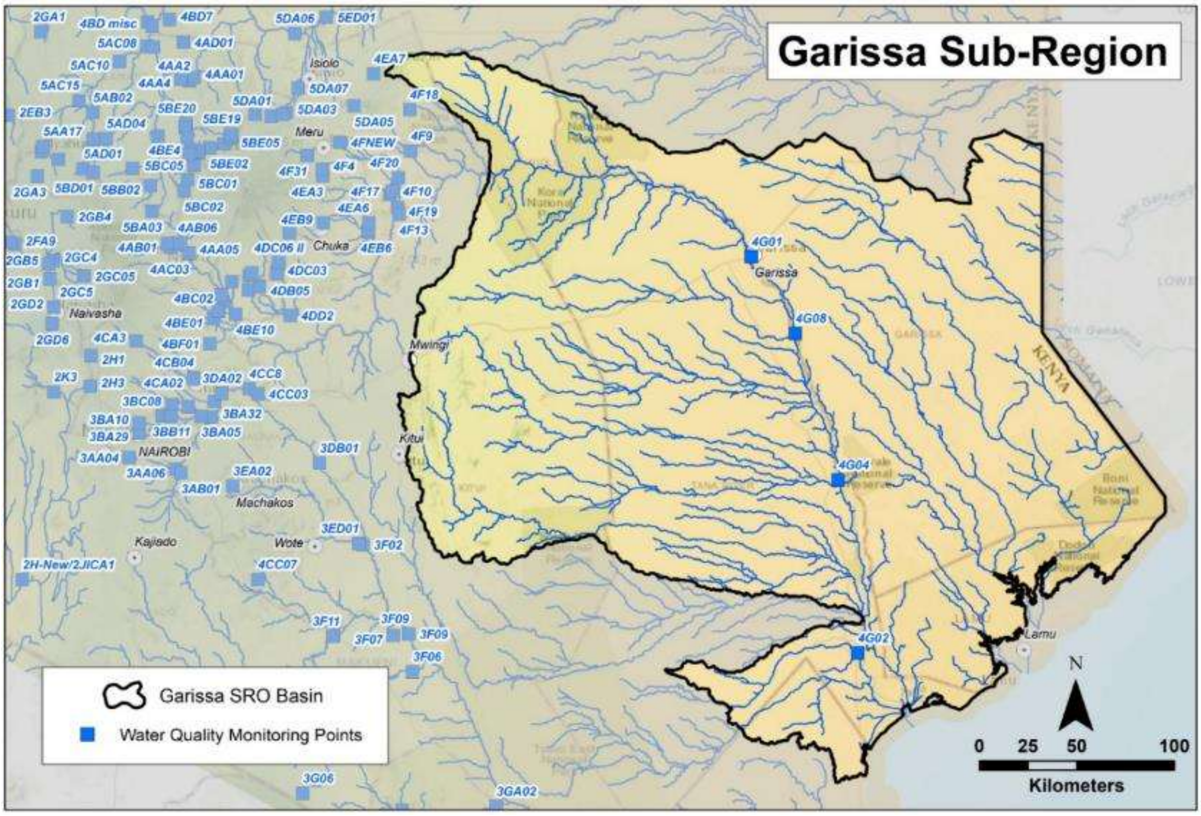

Figure 6-19: Garissa sub-region: Proposed surface water quality monitoring points

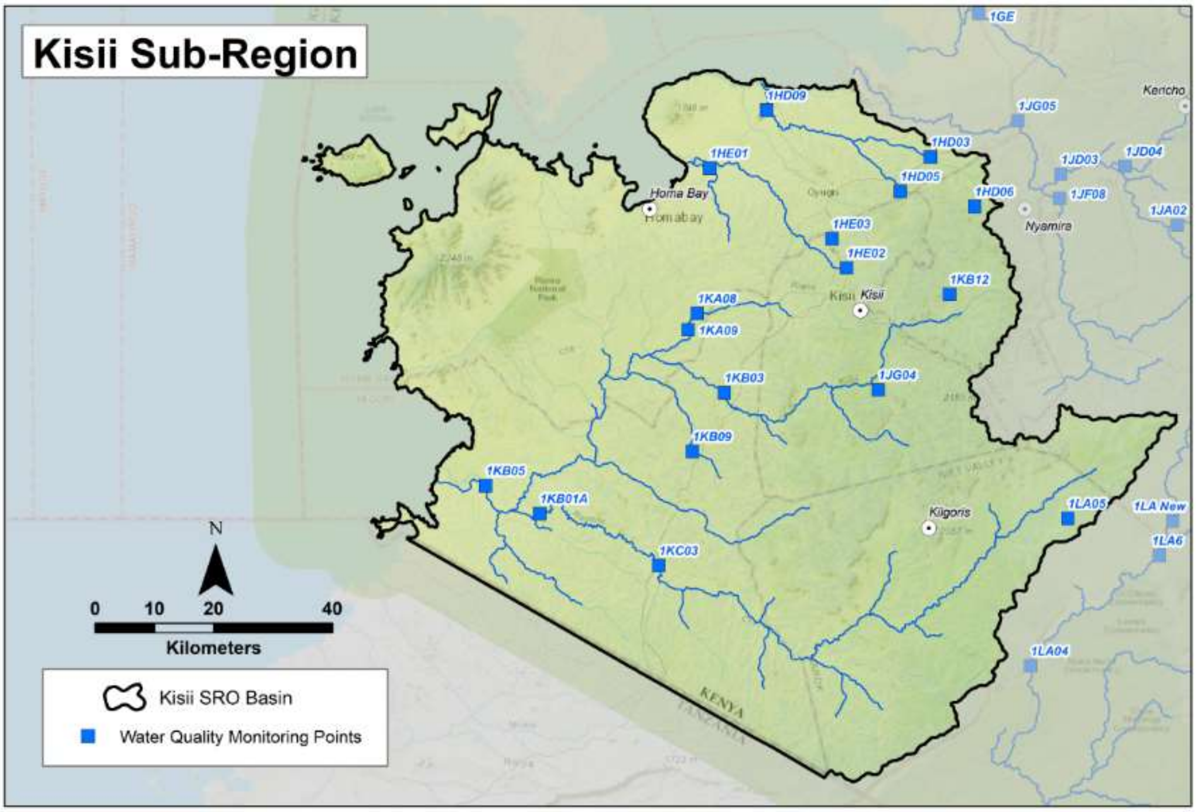

Figure 6-20: Kisii sub-region: Proposed surface water quality monitoring points

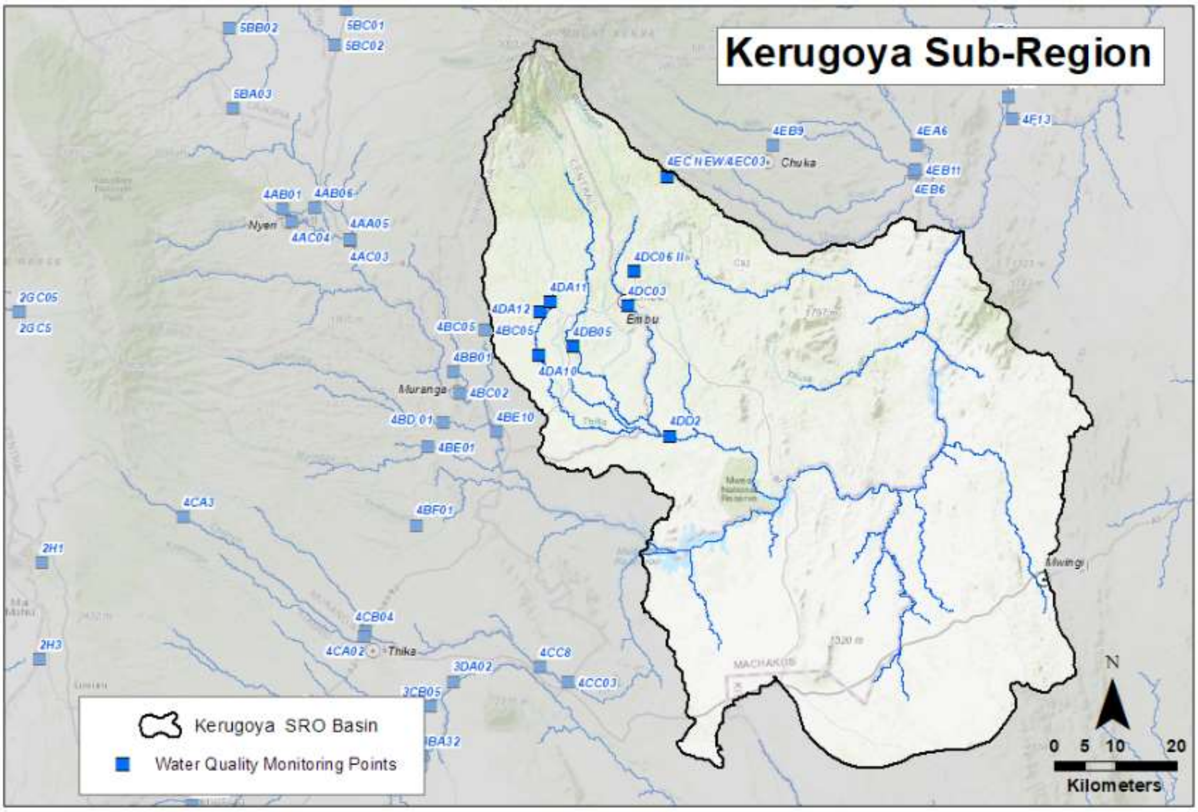

Figure 6-21: Kerugoya sub-region: Proposed surface water quality monitoring points

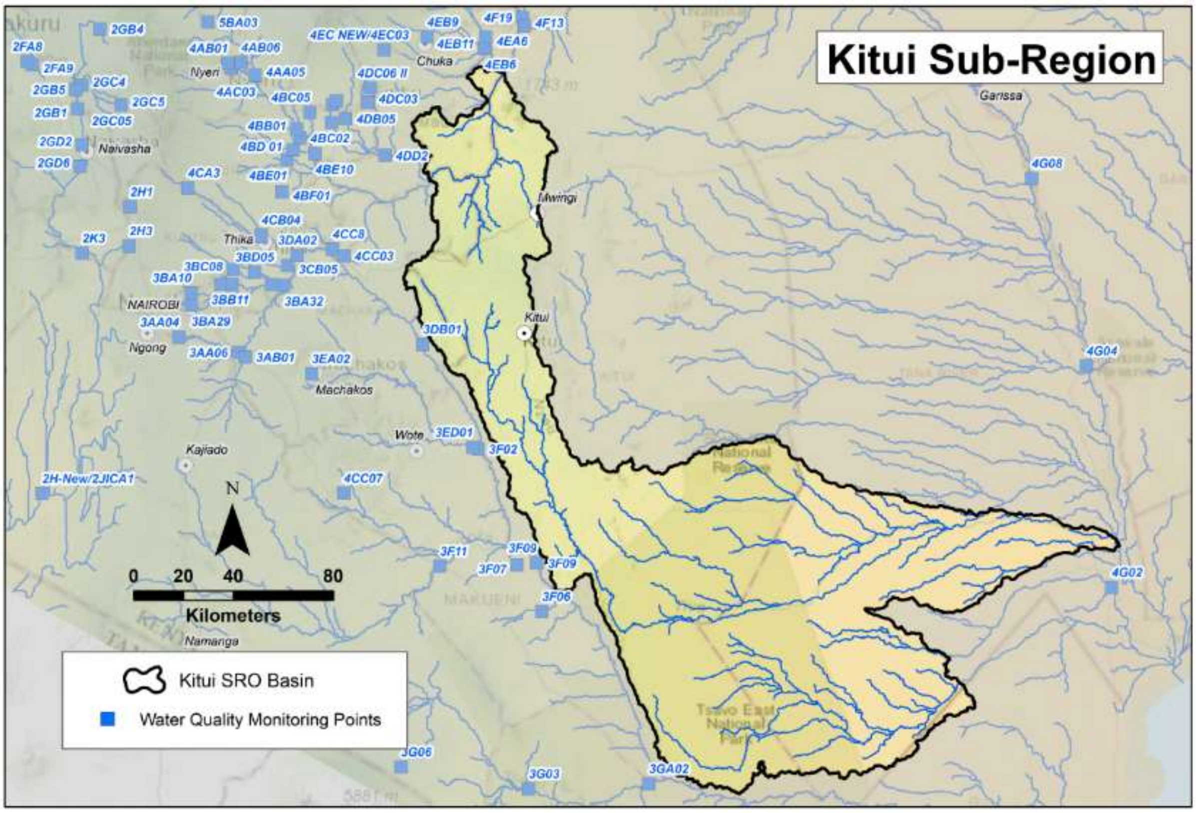

Figure 6-22: Kitui sub-region: Proposed surface water quality monitoring points

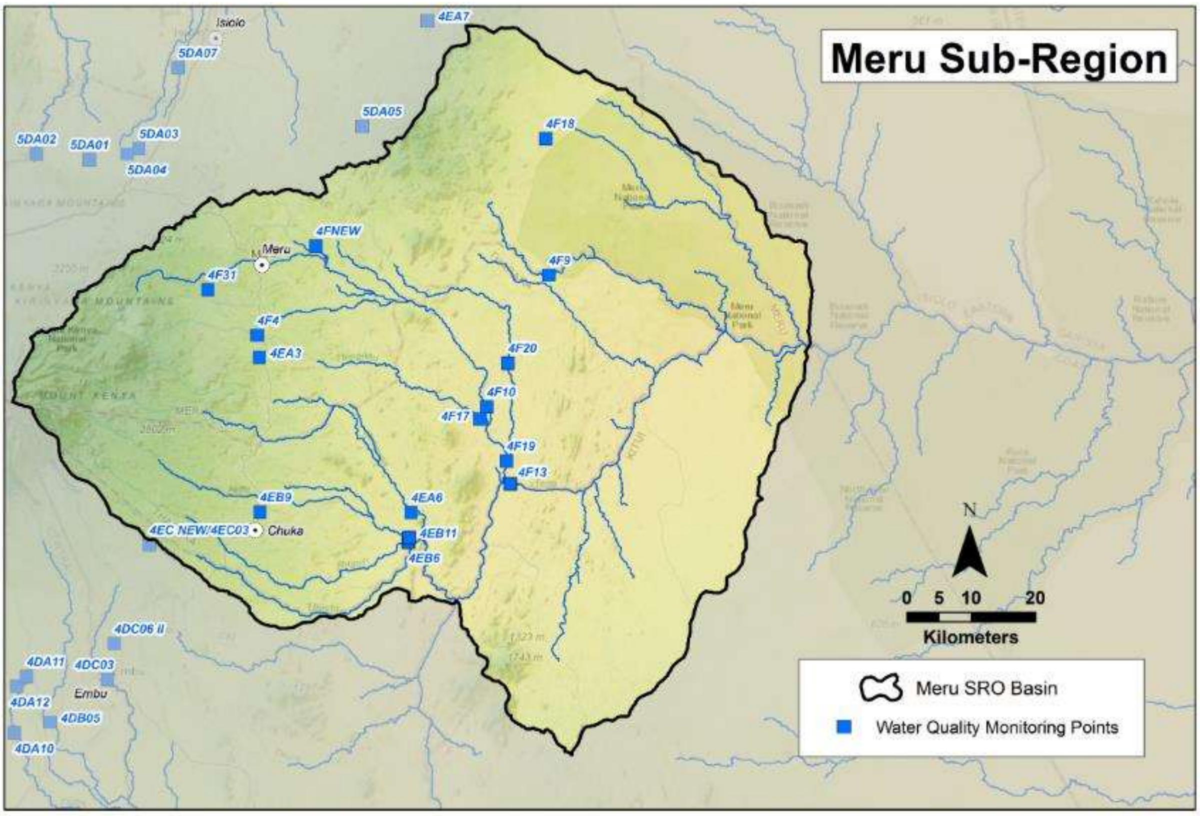

Figure 6-23: Meru sub-region: Proposed surface water quality monitoring points

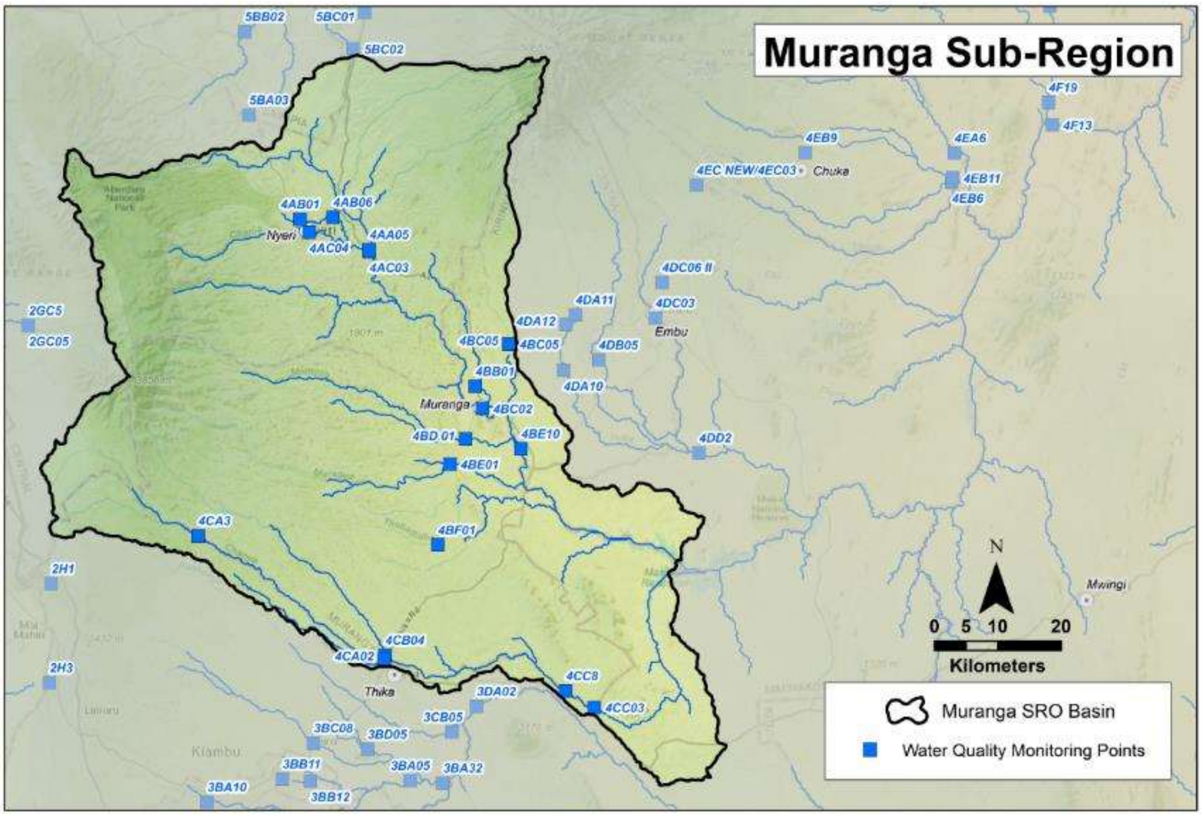

Figure 6-24: Murang'a sub-region: Proposed surface water quality monitoring points

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 past polluting history of the source. Most of the sources within the Tana 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 GW will show low concentrations of dissolved salts during the wet season and high concentrations during the dry season when recharge is minimal. Major WQ changes could occur because of over-abstraction.

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 do not have 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 Groundwater monitoring

An additional 14 shallow dedicated monitoring boreholes are being constructed in the Basin in 2018-19, to be installed in the Lamu sand dunes aquifer. These monitoring sites are to be fitted with water level loggers and telemetry.

The most recent CMS (Water Resources Management Authority, 2015b) proposes the establishment of an additional six groundwater monitoring sites, five of which are in the lower Tana Basin where in 2015 there were none in operation (the site at Lake Kenyatta was not operating). These proposed sites are at Dujis (Garissa County); Kiunga, Hindi and Lamu (Lamu); and Kipini (Tana River).

6.8.3.6 Flood Early Warning System

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 6-27). 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 6-27). 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 6-27: 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 Garsen, Hola, Garissa flood prone area in the Tana Basin was proposed for a FEWS design. The proposed FEWS is shown in Figure 6-25 and comprises 4 telemetric stream flow gauging stations and 16 full telemetric meteorological Automatic Weather Stations for the Tana River flood prone areas. Details of the proposed stream flow and meteorological telemetric monitoring stations to inform the FEWS are listed in the tables below and shown on the map below.

Table 6-28: Tana FEWS – Proposed telemetric stream flow gauging stations

ID	River	WRA SRO	Lat	Long	Operational Status	Existing Station Type	ISC Design Station Type
4G_Koru Bridge	Saka Tana	Meru	-0.076	38.415	Non-operational	None	Telemetric
4G01	Tana Garissa	Garissa	-0.464	39.637	Operational	Automatic	Telemetric
4G02	Tana Garsen	Garissa	-2.289	40.127	Non-operational	Manual	Telemetric
4G04	Tana Hola	Garissa	-1.492	40.036	Operational	Manual	Telemetric

Table 6-29: Tana FEWS – Proposed telemetric meteorological stations

ID	Station Name	Lat	Long	Existing Station Type	County
9037142	Kiang'Ombe County Forest - Meru	-0.567	37.700	Manual	Embu
9037165	Kangeta Full Primary School	-0.700	37.533	Manual	Embu
9037202	Embu Meteorological Station	-0.505	37.458	Synoptic	Embu
9036288	Wambugu F.T.C (Nyeri Met Stn)	-0.433	36.967	Synoptic	Garissa
9039000	Garissa Meteorological Station	-0.483	39.633	Synoptic	Garissa
9037115	Kerugoya Castle Forest Station	-0.383	37.317	Manual	Kirinyaga
9038008	Mwingi Agricultural Station	-0.933	38.067	Manual	Kitui
9137152	Nzawa Primary School	-1.067	37.900	Manual	Kitui
9138014	Kitui Water Dam	-1.367	38.000	Manual	Kitui
8937065	Meru Meteorological Station	0.150	37.650	Synoptic	Meru

ID	Station Name	Lat	Long	Existing Station Type	County
9036233	Kimakia Forest Station	-0.767	36.750	Manual	Murang’a
9037207	Kawaharura Forest Guard Post	-0.800	37.183	Manual	Murang’a
9139002	Waldena A.P.'S Post	-1.617	39.033	Manual	Tana River
9239004	Assa Sub-Location	-2.083	39.433	Manual	Tana River
9037123	Chogoria Forest Station	-0.283	37.617	Manual	Tharaka-Nithi
9037160	Marimanti W.D.D. Met. Site	-0.150	37.983	Manual	Tharaka-Nithi

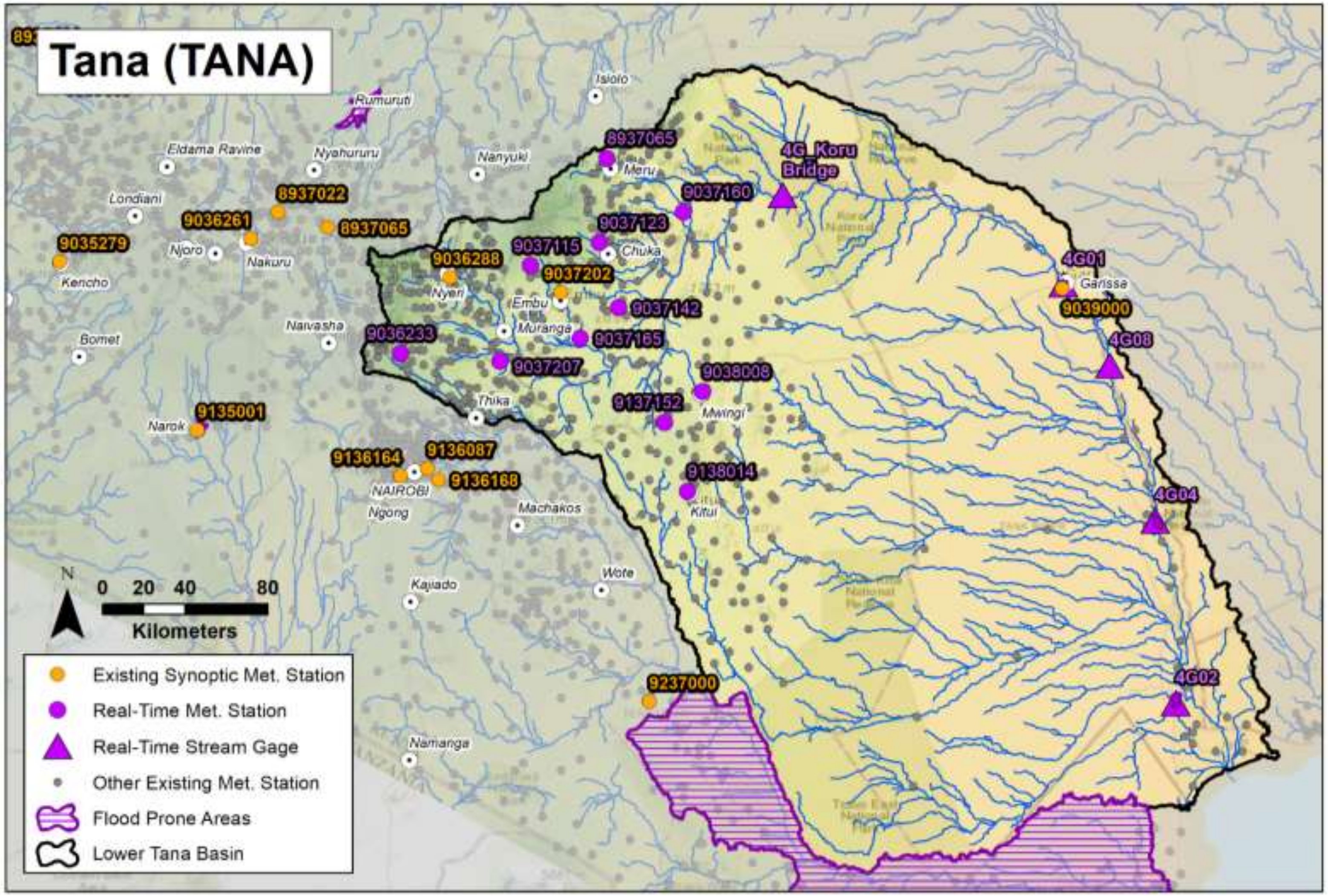

Figure 6-25: Proposed Tana flood early warning hydromet network

6.8.4 Strategy

In order to comprehensively and systematically address the hydrometeorological monitoring issues and challenges in the Tana Basin, Table 6-30 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 6-30: 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 Tana 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 consider 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 Tana 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 Tana 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 Tana 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 Tana 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 regarding 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 Tana 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 regarding 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 regarding 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 regarding 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 Tana 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 Tana 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 upper part of the Tana Basin is classified as humid with a mean annual precipitation as high as 1 900 mm in the western, high-lying areas. The central and coastal part of the basin is arid and semi-arid with the mean annual precipitation below 500 mm in some areas. Due to the topographical and climate variability across the basin, surface water distribution in the basin varies greatly (both temporally and spatially) and many areas, especially in the middle and lower part of the basin, often lack sufficient access to water.

Existing large-scale water resources developments in the Tana Basin include seven large dams. Two of these dams (Sasamua and Thika) are in the upper tributaries of the Tana River and supply about 181 MCM/a of water to Nairobi via an inter-basin transfer. The other five dams are located along the main Tana River in the upper basin and constitute the so-called Seven Forks Hydro Scheme, which involves a cascading system to produce hydropower. The dams include Masinga, Kamburu, Gitaru, Kindaruma and Kiambere. The installed hydropower capacity at these five dams total 595 MW. To provide adequate flow during the dry periods, water is stored at the upstream Masinga Dam and released during the dry season. In addition to these hydropower installations, there are five smaller run-of-river installations in the upper part of the basin with a total installed capacity of about 31 MW.

Eight large-scale irrigation schemes exist in the basin with a total area of about 26 000 ha. These schemes include Mwea, Kibirigwi, Muringa and Mitunguu in the upper basin, as well as Bura, Hola, Tana River and Tana Delta schemes along the lower Tana River.

Construction on various large dams in the Tana Basin is about to start, is currently underway, or has started but are currently on hold due to contractual and/or other issues. These dams include Yatta Dam on the Thika River for domestic and irrigation supply, Thiba Dam on the Nyamindi River – mainly to be used for supplying Mwea Irrigation Scheme Extension, Karimenu II Dam on the Karimenu River from where water will be supplied to Kiambu and Nairobi counties, and Umaa Dam on the Nzeu River – to be used for domestic water supply. In addition, the Government of Kenya has approved the construction of the High Grand Falls Dam at Kivuka along the Tana River. The dam, which forms part of the LAPSSET project, will be located on the borders Tharaka-Nithi, Kitui and Tana River counties.

Most of the water currently consumed in the Tana Basin is for irrigation, followed by domestic and industrial use. Water is mainly sourced directly from rivers and small dams and pans - except for the Thika and Sasamua dams in the upper basin from where water is transferred to Nairobi. Supply reliability in most parts of the basin is medium to high due to the generally good availability of surface and groundwater. However, frequent shortages are experienced during the dry season due to lack of storage, often exacerbated by the late start of the wet season. Non-consumptive use in the basin relates to the generation of hydropower, with close to 40% of Kenya's energy needs being supplied from the hydropower installations along the Tana River.

The total current water requirement (2018) in the basin equates to 1 867 MCM/a.

Table 6-31: Current (2018) water demand in the Tana Basin per main sector (MCM/a)

Sector	Total water demand (MCM/a)
Irrigation	**1 407**
– Small scale / Private	880
– Large-scale	527
Domestic and Industrial	**217**
– Urban centres	39
– Basin-wide	178
Livestock	**48**
Exports	**181**
Other	**14**
Total	**1 867**

6.9.3 Water resources development potential

The current (2018) total water demand in the Tana Basin (1 867 MCM/a) constitutes about 25% of the total water resources available for use.

The results of the surface water resources analysis which was undertaken for this Consultancy, estimated the total natural surface runoff in the Tana Basin as 7 082 MCM/a, equivalent to an average runoff coefficient of 8%. The current surface water demand in the Basin was estimated at 1 803 MCM/a, which is about 25% of the surface water available - taking into consideration the ecological reserve (Q95), calculated as 355 MCM/a.

The current groundwater use in the Tana Basin was estimated at 64 MCM/a, which is about 9% of the estimated sustainable groundwater yield (693 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

A key consideration when estimating future water requirements in the Tana Basin relates to the significant irrigation potential in the basin and specifically along the lower Tana River. Similarly, future water demand for domestic and industrial use was based on a conservative, exponential population growth assumption based on recent trends in the basin, while also taking into consideration that less than 40% of the population in the basin is currently supplied by WSPs.

The scenario analyses undertaken as part of this Consultancy considered the proposed developments and projected (to 2040) growth in water demands across the basin. The analysis highlighted the water use benefits of improving irrigation efficiencies for both small-scale and large-scale irrigation in the Tana Basin. Similarly, water demand management should be implemented in all urban areas to improve water use efficiencies. The future water requirements as presented below therefore incorporate a 20% reduction in major urban water requirements, as well as improved irrigation efficiencies and a reduction in some of the proposed large-scale irrigation areas. Another important development initiative in the Tana Basin, with a direct impact on future water requirements, especially at Lamu Port, is the Lamu Port and Southern Sudan Ethiopia Transport Corridor Project (LAPSSET) Project.

The sustainable development scenario for the Tana Basin estimated the total future (2040) water requirement from the Basin at 4 370 MCM/a as detailed below. This represents a significant increase compared to the 2018 water demand in the basin, mainly as a result of new large-scale irrigation (130 000 ha), an expansion of small scale irrigation, increased transfers to the Athi Basin, ensuring that the LAPSSET developments in Lamu has sufficient water and for improving water supply to an increased number of urban and rural users.

Table 6-32: Future (2040) water demands in the Tana Basin

Sector	Total water demand (MCM/a)
Irrigation	**3 161**
– Small scale / Private	765
– Large-scale	2 396
Domestic and Industrial	**753**
– Urban centres	234
– Basin-wide	519
Livestock	**98**
Exports	**337**
Other	**21**
Total	**4 370**

Annexure B2 summarises future (2040) water demands per sub-basin and per main user category.

6.9.5 Proposed water resources developments

6.9.5.1 Overview

The essence of the proposed water resources development plan for the Tana Basin, up to 2040, is to unlock the significant irrigation potential in the basin, especially along the lower Tana River; to ensure a reliable supply of water to meet the expected growth in urban water demands, including the significant growth which is foreseen in Lamu Port associated with LAPSSET; to increase hydropower production in the basin; to implement the identified schemes which will export water to the Athi Basin; to improve existing and future water resources availability for smaller towns and basin-wide domestic, livestock and small-scale irrigation water demands; and to unlock socio-economic development through multi-purpose water resources development projects in the basin, including flood control. This will necessitate the construction of small-scale and large-scale storage, transfer and regulation infrastructure and increased groundwater abstraction. In addition, water demand management should be implemented for both small and large-scale irrigation and for urban centres.

The following specific interventions are proposed:

- Construction of High Grand Falls Multipurpose Dam. The dam, which forms part of the LAPSSET Project, will support extensive irrigation along the lower Tana River at a high assurance of supply, generate hydropower, provide flood control, and supply various towns along the lower Tana River including Lamu Port (via a transfer) where significant growth in water demand is expected linked to the LAPSSET development. In conjunction with the construction of High Grand Falls Dam, rehabilitation and expansion of existing as well as the implementation of new large-scale irrigation schemes along the lower Tana River should be initiated.

- Kora Dam, downstream of High Grand Falls Dam, to re-regulate hydropower releases from High Grand Falls Dam. This dam will allow further expansion of large-scale irrigation along the lower Tana River as part of future phases.
- Completion of the Northern Collector Tunnel Phase 1 and implementation of the Maragua 4 Dam and the Northern Collector Tunnel Phase 2 Transfer Schemes to increase the transfer capacity to the Athi Basin for meeting future water demands in the Greater Nairobi area.
- Construction of Thiba and Thuchi dams in the upper basin to improve the reliability of supply to existing irrigation schemes and to allow expansion of the Mwea and Kaagari-Gaturi irrigation projects.
- Rehabilitation of the Usueni-Wikithuki Irrigation project along the upper Tana River.
- Completion of Umaa Dam on the Nzeu River to supply Kitui Town.
- Completion of Karimenu 2 Dam on the Karimenu River to supply Kiambu and Nairobi counties.
- Increasing the capacities of the current intra-basin transfers from Masinga and Kiambere dams to Kitui and Mwingi towns.
- Finalise implementation of Yatta Dam on the Thika River to improve water supply to Matuu Town and assurance of supply for the users along the Yatta Canal.
- 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.
- Implementation and enforcement of the Q95 flow downstream of proposed dams and large-scale irrigation schemes to maintain the ecological health of the rivers. In addition, it is important that seasonal flood releases are made from High Grand Falls Dam to mimic the natural floods along the lower Tana River up to the Delta.
- Installation of 700 MW hydropower at High Grand Falls Dam, installation of an additional 32 MW at Kindaruma Dam and the implementation of Karura Scheme (67 MW) between Kindaruma and Kiambere dams on the main Tana River.

Table 6-33 summarises the proposed water resources developments and interventions in the Tana Basin with a planning horizon of 2040, while Figure 6-26 displays the locations of the existing and proposed large-scale water resources developments.

Table 6-33: Water resources development plan for the Tana Basin

Item	2018	2040	Comment
Storage: Large dams (MCM)	2 397	8 776	- 7 existing large dams - 4 new dams to supply growing urban centres and/or for irrigation supply - 2 new dams as part of transfer to Nairobi - 2 new multipurpose dam for large scale irrigation, urban water supply, hydropower and flood control
Storage: Small dams / pans (MCM)	27	186	To supply towns and local domestic and livestock demands and improve assurance of supply for small-scale and private irrigation
Groundwater use (MCM/a)	64	396	As conjunctive use with surface water storage, or as the only water source in areas where surface water is not available.
Irrigation area (ha)	98 930	211 500	The increase in irrigation area is mainly due to new proposed large-scale schemes along lower Tana River
Hydropower (MW)	626	1 350	Hydropower to be installed at HGF, Karura and Kindaruma

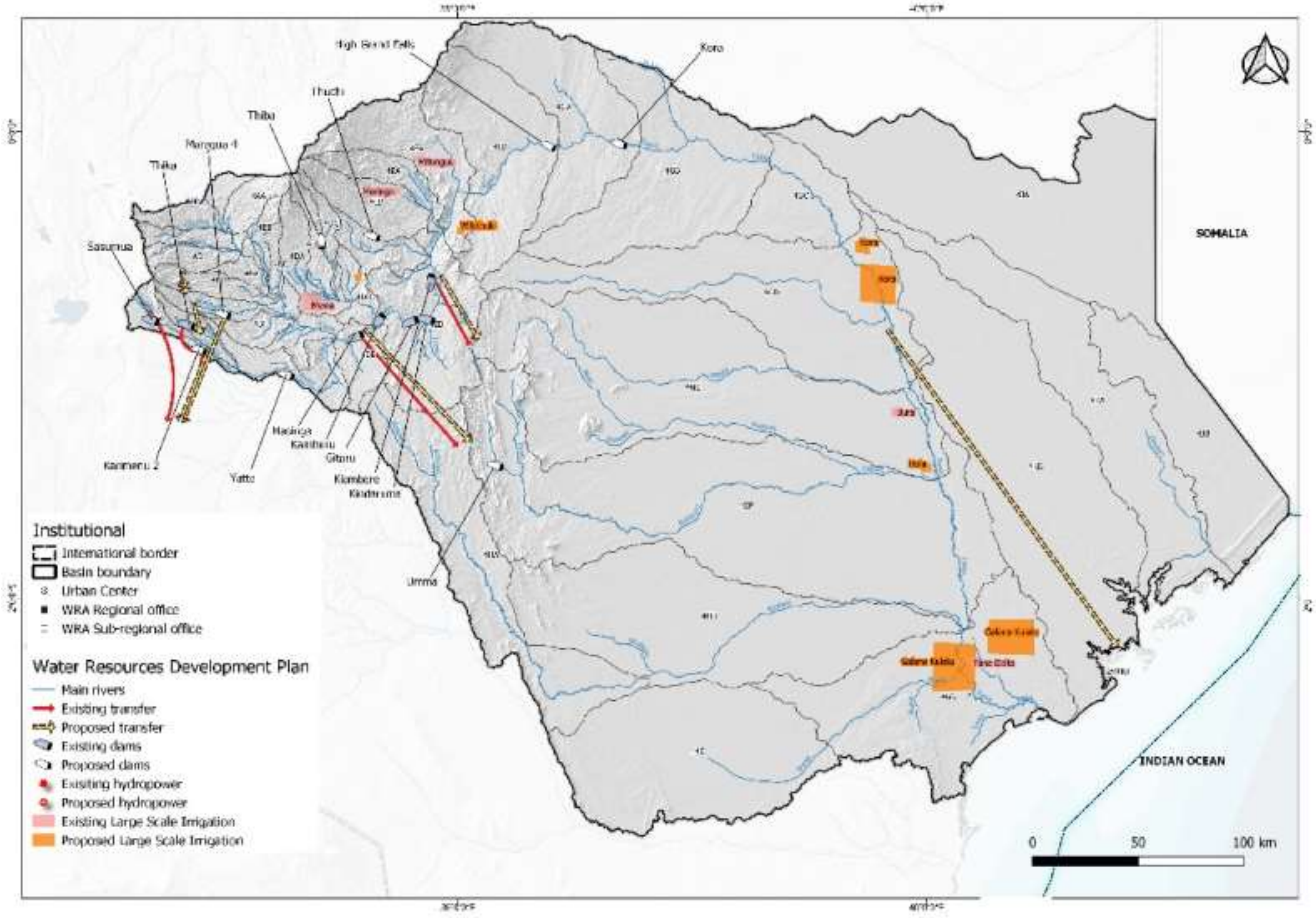

Figure 6-26: Proposed water resources developments in the Tana Basin

6.9.5.2 High Grand Falls Multipurpose Dam Project and Kora Dam

The High Grand Falls Multipurpose Dam project is the largest project undertaken by the Government of Kenya after the Standard Gauge Railway, and forms part of LAPSSET. Once completed, the dam will contribute significantly to the regional and national economy of Kenya. The 120 m high dam will create a storage area of 165 km^2 at full supply level and will have storage capacity of 5.7 BCM. The dam, which will be situated at Kivuka along the Tana River, about 60 km downstream of Kiambere Dam, will serve many purposes:

- As many of the upstream tributaries of the Tana River which originate along the steep slopes of Mount Kenya are unregulated, flooding is a significant risk along the lower Tana River. The primary purpose of High Grand Falls Dam therefore, will be to provide flood control along the lower Tana River where there are various flood prone areas.
- An initial 500 MW followed by a further 200 MW of hydropower will be installed at the dam. This is envisaged to triple the currently generated firm power in the Tana Basin, while the dam will also be used for peak power generation.
- Another key objective of the dam relates to the regulation of flow to improve the assurance of supply for the development of large-scale irrigation along the lower Tana River. At present, the unpredictability of flow in the lower Tana Basin along with a significant reduction in river flow during the dry season and during drought years, frequently results in supply shortfalls for irrigation and prohibits the development of further large-scale irrigation, even though there is huge potential for irrigation development. The construction of High Grand Falls Dam will support existing and new irrigation development along the lower Tana River at a high assurance of supply, and will allow increased water resources development in the upper part of the Tana Basin without impacting users downstream due to the significant storage provided at High Grand Falls. Analyses undertaken as part of this consultancy have shown that up to 106 000 ha of large-scale irrigation can be supported along the lower Tana River at a high assurance of supply from High Grand Falls Dam.
- The dam will improve the reliability of supply for domestic and industrial water requirements at various towns along the lower Tana River e.g. Garissa, Madogo, Hola and Massalani. Furthermore, water from the dam will be supplied to Lamu Port where significant growth in water demand is expected linked to the LAPSSET development.

The high-level analyses which have been undertaken as part of this Consultancy prioritised hydropower generation and flood control at High Grand Falls Dam, with irrigation supply as a secondary benefit. In addition to the Q95 minimum release, allowance was also made for two artificial flood releases from High Grand Falls Dam, one at the start of June and the other at the start of December, to mimic the natural floods occurring along the lower Tana River. A continuous release of 660 m3/s for a week per event was assessed, which equates to about 400 MCM each (Government of Kenya, 2011).

The operation of High Grand Falls Dam will be dictated by its primary purpose which is flood control and hydropower generation. As such, the construction of the much smaller Kora Dam (540 MCM) at Usueni on the Tana River about 65 km downstream of High Grand Falls Dam will facilitate the re-regulation of releases (hydropower and flood control) from High Grand Falls Dam. This will improve irrigation efficiencies and further expansion of irrigation without having a negative impact on the operation of High Grand Falls Dam. The construction of Kora Dam should be delayed until High Grand Falls Dam is at full hydropower generation capacity, until all the planned large-scale irrigation development along the lower Tana River have been implemented and until a comprehensive integrated operating rule / optimisation study has been undertaken for the Tana River System.

6.9.5.3 LAPSSET and water supply to Lamu Port

Since 2009, the Government of Kenya has expressed plans to undertake a multipurpose transport and communication corridor known as the ‘Lamu Port-South Sudan-Ethiopia Transport (LAPSSET) Corridor. LAPSSET will consist of a standard gauge railway line, a port, a super highway, a regional international airport, an ultra-modern tourist resort, an oil pipeline, and a fibre-optic cable constructed to link Lamu to Juba and Addis Ababa. The proposed development of Lamu Port will result in an influx of people and industries, including an oil refinery which has a large water demand. The port is expected to require a daily supply of water of up to 300 000 m^3/day (110 MCM/a) by 2040 (JPC & BAC/GKA JV, 2011) and this value was used in the analyses undertaken as part of this Consultancy. It is envisaged that this water will be supplied from the High Grand Falls Dam via the Tana River. To achieve this, a new weir at Nanigi on the Tana River, about 55 km downstream of Garissa is proposed, from where a pipeline or a canal of approximately 200 km will supply water to Lamu Port.

6.9.5.4 Inter-basin transfers

The water resources in the upper Tana Basin are critical for meeting current and future water demands of the greater Nairobi area in the adjacent Athi Basin via inter-basin transfers. From the existing Thika Dam on the Thika River and the Sasamua Dam on the Chania River in the upper Tana Basin, up to 181 MCM/a is currently supplied to Nairobi. The Northern Collector Project (Phase 1), which is currently under construction, will divert flood water from the Maragua, Irati and Gikigie rivers into Thika Dam and will add up to 51 MCM/a to the Nairobi Water Supply.

Furthermore, the completion of Maragua 4 Dam and related infrastructure as well as the Northern Collector Tunnel Phase 2 Transfer, the latter two representing Phases 3 and 4 of the bulk water upgrade as recommended in the Master Plan for Nairobi and Satellite Towns (Ministry of Water and Irrigation & Athi Water Services Board, 2012), will increase the transfer volume to the Athi Basin by about 105 MCM/a on average. In conjunction with the proposed Munyu Dam and other interventions in the upper Athi Basin, refer to the Athi Basin Plan (Water Resources Authority, 2019a), these Tana transfer schemes should be able to meet Nairobi’s 2040 water demand at a high assurance of supply.

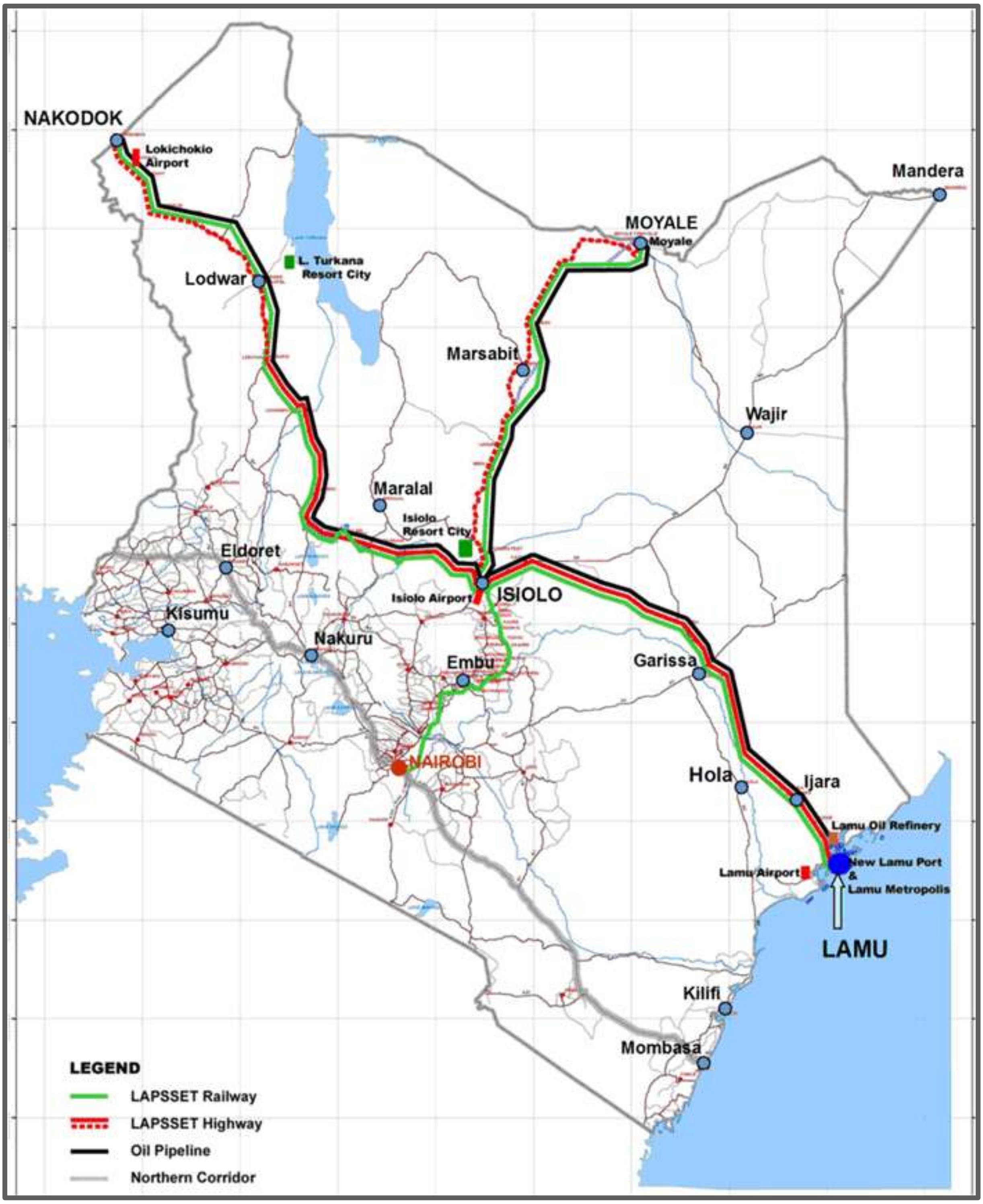

Figure 6-27: Proposed LAPSSET development

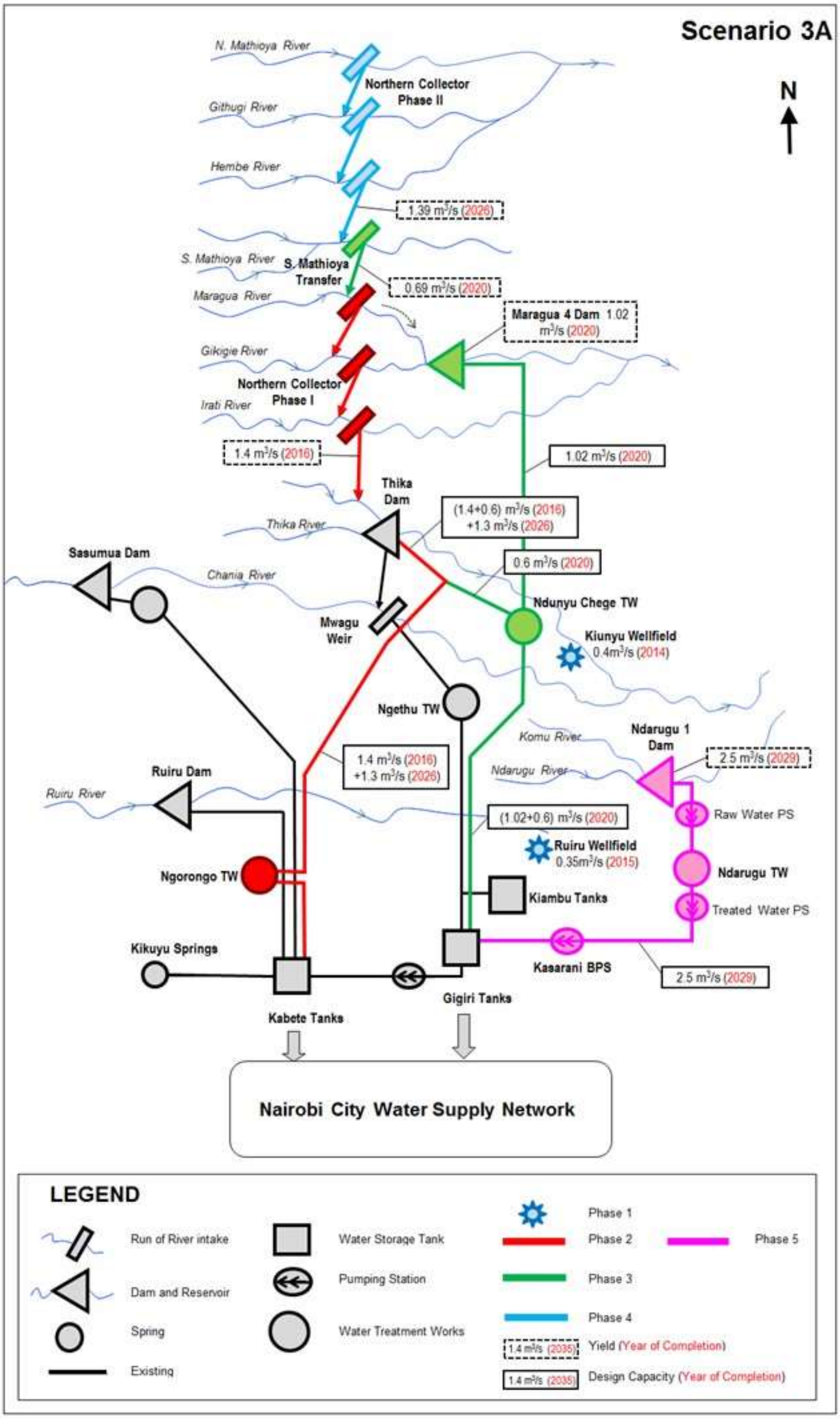

Figure 6-28: Scenario 3a for upgrading of bulk water supply system for Nairobi City (Ministry of Water and Irrigation & Athi Water Services Board, 2012)

6.9.5.5 Large-scale Irrigation development

Proposed irrigation developments in the upper Tana Basin up to 2040 include extension to the Mwea Irrigation scheme in Kirinyaga County by about 4 000 ha through the construction of Thiba Dam with a capacity of 15 MCM on the Nyamindi River. However, analyses have shown that the expansion of the scheme should be re-assessed, and that Thiba Dam should rather be used to improve the reliability of supply to the existing scheme instead of expanding the area under irrigation. Furthermore, the cost-benefit analysis indicated that careful consideration needs to be given to crop type to ensure the financial viability of the scheme. Similarly, the rehabilitation of the Usueni-Wikithuki Irrigation Scheme (5 800 ha) in Kitui County, supplied from the Tana River, seems sensitive to crop type and price and it is recommended that a more detailed feasibility study be undertaken before a final decision is made regarding the implementation of the scheme. Rehabilitation / expansion of the Kaagari Gaturi scheme to an area of 3 300 ha through the construction of Thuci Dam on the Thuci River in Embu County seems feasible.

There is significant irrigation potential in the lower Tana Basin adjacent to the Tana River, from about 60 km upstream of Garissa Town, all the way downstream to the Tana Delta. Various schemes along this stretch of river have been implemented since the 1960s and some of them are still in operation. The current large-scale irrigation in the lower Tana basin include Bura, Hola, Tana River and Tana Delta irrigation schemes, with a total area of about 11 200 ha. However, in general the schemes are not delivering optimal crop yields due to issues surrounding water availability in the Tana River and various other operational issues.

The High Grand Falls Dam will allow an improvement in the assurance of supply to the existing irrigation schemes and will make water available for significant expansion of irrigation along the lower Tana River. Although some small-scale irrigation development is foreseen downstream of High Grand Falls Dam, the focus of this analysis has been large-scale irrigation development. The proposed large-scale irrigation development will entail three stages:

The first stage will include the Bura East and West and Hola scheme extensions/improvements (cotton), and the Tana Delta Irrigation Projects (sugar and rice) (Government of Kenya, 2011). In the Tana delta two large-scale irrigation schemes are planned: Tana Delta Irrigation Project and Tana Delta Irrigated Sugar Project (Temper, 2013). In total 20 000 ha is to be converted to irrigated sugar cane plantations, and 10 000 ha will be used to grow rice.

In the second stage, the irrigation potential will be increased by the construction of a barrage at Nanigi and canals to divert the water to both banks. Construction of the Nanigi barrage is financially attractive because it will facilitate gravity supply, thereby reducing currently high pumping costs. The Masalani irrigation scheme is assumed to be constructed during this stage (Government of Kenya, 2011). It is envisaged that various crops will be grown in Masalani.

For the final stage, the re-regulating reservoir at Kora (Usueni) will be constructed to extend the irrigated area along the lower Tana River by up to 25 000 ha.

Table 6-34: Proposed large scale irrigation developments in the Tana Basin

Scheme name	County	Area
Kaagari Gaturi	Embu	3 300 ha
Usueni Wikithuki	Kitui	5 800 ha
Rahole	Tana River	8 000 ha
Bura	Tana River	Expand by 400 ha
Hola	Tana River	Expand by 5 000 ha
Tana Delta	Tana River	Expand by 28 000 ha
Masalani	Tana River	30 000 ha
Kora	Tana River	25 000 ha

6.9.5.6 Hydropower development

The planned 700 MW hydropower installation at High Grand Falls Dam, the construction of Karura (67 MW) and the installation of an additional 32 MW at Kindaruma Dam, will significantly increase the hydropower generated in the Tana Basin. The installation of hydropower at High Grand Falls Dam will be done in two phases of 500 MW and 200 MW.

6.9.5.7 Water supply to urban centres

Construction is starting soon on Umaa Dam which will supply Kitui Town. However, in order to meet the full expected growth in water demand up to 2040 at Kitui, it is proposed that the capacity of the existing transfer pipeline from Masinga Dam to Kitui be increased in future from the existing 3 MCM/a to 23 MCM/a.

Yatta Dam, which will be constructed soon, will be able to improve the reliability of future supply to Matuu Town, while analyses have shown that the proposed Tuchi Dam would be able meet Embu Town’s future water requirements.

In order to meet the expected growth in water demand at Mwingi, it is proposed that the capacity of the existing Kiambere Dam – Mwingi transfer be increased from 0.5 MCM/a to 2 MCM/a.

Finally, High Grand Falls Dam will improve the reliability of supply for domestic and industrial water requirements for various towns along the lower Tana River including Garissa, Madogo, Hola and Massalani. Water from the dam will also be supplied to Lamu Port at a capacity of 102 MCM/a (via a transfer from Nanigi Barrage), where significant growth in water demand is expected linked to the LAPSSET development.

6.9.5.8 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), especially as part of regional water supply schemes. Numerous aquifers have good potential, particularly for localised, small-scale groundwater abstraction, but need to carefully be managed as they are prone to contamination.

6.9.5.9 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 significant 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 surface water storage volume (as dams and pans) in the Tana Basin, which will be required to meet 2040 demands, amount to 159 MCM, while the total volume of additional groundwater development which will be required was estimated at 333 MCM/a.

Table 6-35 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.

Table 6-35: Additional storage requirements and groundwater development to meet 2040 demands

Sub-basin	Groundwater (MCM/a)	Surface Water Storage (MCM)	Sub-basin	Groundwater (MCM/a)	Surface Water Storage (MCM)
4AA	4.7	0.9	4EB	15.2	3.3
4AB	4.7	2.1	4EC	4.1	1.1
4AC	4.3	1.5	4ED	8.9	3.6
4AD	4.0	1.8	4FA	16.2	8.0
4BA	2.2	3.5	4FB	20.1	3.5
4BB	1.1	4.7	4GA	19.1	2.9
4BC	0.9	12.1	4GB	13.2	2.0
4BD	5.7	1.6	4GC	27.8	0.0
4BE	5.9	1.3	4GD	4.8	0.0
4BF	1.1	7.1	4GE	15.1	0.0
4BG	1.5	0.5	4GF	3.6	0.0
4CA	6.7	0.4	4GG	37.7	0.0
4CB	3.4	0.1	4HA	2.5	0.0
4CC	2.5	0.	4HB	24.6	0.0
4DA	9.1	26.9	4HC	16.4	0.0
4DB	0.1	44.7	4JA	11.6	0.0
4DC	1.4	25.4	4JB	5.3	0.0
4DD	1.6	0.3	4KA	9.6	0.0
4DE	1.0	0.1	4KB	8.2	0.0
4EA	7.5	0.6			

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 implementation include the transfer schemes from the upper Tana River to Nairobi which form part of the upgrading of the bulk water supply system for Nairobi. Similarly, upgrades to the capacities of the existing transfer pipelines from Masinga Dam to Kitui as well as from Kiambere Dam to Mwingi were treated as confirmed and these schemes were therefore not evaluated as part of the assessment of individual 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 6-36 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 6-36: Scheme multi-criteria analysis - Decision matrix

			Current Ranking	1	4	8	2	5	3	7	6
				Kindaruma Scheme	Yatta Scheme	Thiba Scheme	High Grand Falls Scheme	Umaa Scheme	Karura Scheme	Thuchi Scheme	Usueni-Wikithuki Scheme
				Kindaruma Dam (16MCM - Existing) *Hydropower upgrade (32MW)*	*Yatta Dam (35MCM)* *Matuu & Rural supply*	*Thiba Dam (11MCM)* *Mwea Irrigation (10,100ha - Existing)*	*High Grand Falls Dam (5,700MCM) & hydropower (700MW)* *Kora Dam (537MCM)* *Garissa, Lamu Port (LAPSSET) & Rural supply* *Masalani Irrigation (30,000ha)* *Hola Irrigation extension (6,600ha)* *Bura Irrigation (6,100ha - Existing)* *Kora Irrigation (25,000ha)* *Tana Delta Irrigation extension (30,000ha)* *Rahole Irrigation (8,000ha)* *Flood control*	*Umaa Dam (1MCM)* *Kitui supply*	*Hydropower (run-of-river; 67MW)*	*Thuchi Dam (23MCM)* *Embu & Rural supply* *Kaagari Gaturi Irrigation (6,600ha)*	*Usueni-Wikithuki Irrigation Irrigation (5,800ha)*
ENVIRONMENT	Footprint areas	Environmentally sensitive areas	Area (km^2)	0	0	0	314	0	0	0	4
		Carbon emissions dams	tons	0	3133	0	281981	843	0	8593	0
		Carbon emissions LIR	tons	0	0	0	910058	0	0	36825	66174
	Downstream areas	Floodplain area inundated	% change from baseline	-53	-32	-30	-14	100	-28	-12	-8
		Ecological stress	Index (-5 to 0)	-3	-5	-5	-4	-5	-3	-3	-3
		Wet duration	% change from baseline	-97	-98	-96	-96	-96	-97	-97	-97
	Water quality	Phytoplankton growth potential	Average growth potential %	0	18	59	62	0	0	76	0
		Aquatic macrophytes growth potential	Index (-5 to 0)	0	0	-5	0	0	0	-5	0
SOCIAL	Water availability	Riparian users	% change from baseline	1	-29	0	-19	0	-43	-35	-14
	Community health and safety	Malaria endemicity	Malaria endemicity (km^2)	0	0	7	83	0	0	2	3
	Food security and livelihoods	Formal irrigation schemes	Area (km^2)	0	0	100	1057	0	0	33	58
		Impact on recession agriculture	% change from baseline	-53	-32	-30	-14	100	-28	-12	-8
		Fish production (dams/lakes)	Tons/annum	0	32	9	981	2	0	52	0
		Change in fish productivity	% change from baseline	-97	-98	-96	-96	-96	-97	-97	-97
		Loss of productive land	Area (km^2)	0	1	2	87	0	0	7	4
		Loss of natural resources	Area (km^2)	0	0	0	314	0	0	0	4
	Displacement	Physical displacement	Number people	0	515	4525	19272	8	0	4927	4607
ECONOMIC	Energy	Avg energy	GWh/annum	51	0	0	1747	0	195	0	0
	Food production	Crop production (formal irrigation)	Ton/annum	0	0	0	1508113	0	0	26446	9338
		Fish production (dams/lakes)	Ton/annum	0	32	9	981	2	0	52	0
	Employment	Employment formal irrigation	Number people	0	0	25000	264368	0	0	8250	14500
		Employment hydropower	Number people	127	0	0	4368	0	487	0	0
	Sediment	Volume of dam silted	Index (-5 to 0)	0	-5	-5	-1	-5	0	-5	0
	Financial	BCR	Ratio	2.79	1.67	0.22	1.21	1.56	1.05	1.13	0.15
	Flood control	Flood control potential	Ratio (Dam capacity/MAR)	0.0	0.1	1.9	0.8	0.0	0.0	0.4	0.0
	Water productivity	Water productivity formal irrigation	Million USD/MCM	0.00	0.00	0.03	0.07	0.00	0.00	0.24	0.04
		Water productivity hydropower	Million USD/MCM	0.03	0.00	0.00	0.04	0.00	0.01	0.00	0.00
QUALITATIVE	Preparedness for implementation		5 Ready for implementation, 0 Not	3	4	3	3	4	2	3	4
	Public perception/buy-in		5 Full public support, -5 Very contentious	3	-1	4	4	4	3	3	3
	Scale of impact		5 Basin wide and beyond, 1 Very local	3	3	2	4	1	3	1	2
	Transboundary and trans-county implications		5 Beneficial, -5 Detrimental	2	3	0	4	0	2	0	0
	Potential downstream / environmental impact		5 Beneficial, -5 Detrimental	-1	2	-1	-3	-1	0	-1	-1
	Fatal flaw		0 None, -5 Flawed	0	0	0	-1	0	0	0	0

The outcome of the multi-criteria analysis provided a ranking of future schemes as shown in Table 6-37.

Table 6-37: Ranked water resources development schemes

1	**Kindaruma Scheme**	Kindaruma Dam (16MCM - Existing)
		Hydropower upgrade (32MW)
2	**High Grand Falls Scheme**	High Grand Falls Dam (5,700MCM) & hydropower (700MW)
		Kora Dam (537MCM)
		Garissa, Lamu Port (LAPSSET) & Rural supply
		Masalani Irrigation (30,000ha)
		Hola Irrigation extension (6,600ha)
		Bura Irrigation (6,100ha - Existing)
		Kora Irrigation (25,000ha)
		Tana Delta Irrigation extension (30,000ha)
		Rahole Irrigation (8,000ha)
		Flood control
3	**Karura Scheme**	Hydropower (run-of-river; 67MW)
4	**Yatta Scheme**	Yatta Dam (35MCM)
		Matuu & Rural supply
5	**Umaa Scheme**	Umaa Dam (1MCM)
		Kitui supply
6	**Usueni-Wikithuki Scheme**	Usueni-Wikithuki Irrigation Irrigation (5,800ha)
7	**Thuchi Scheme**	Thuchi Dam (23MCM)
		Embu & Rural supply
		Kaagari Gaturi Irrigation (6,600ha)
8	**Thiba Scheme**	Thiba Dam (11MCM)
		Mwea Irrigation (10,100ha - Existing)

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 6-38) was developed which provides information on the timing / phasing of schemes and associated capital, operations and maintenance expenditure from 2020 to 2040.

Table 6-38: Tana Basin Water Resources Development Investment Plan

Proposed Infrastructure Development - Water Resources, Hydropower & Large-Scale Irrigation							Expenditure (USD Million)																						
Scheme	Storage / Transfer Volume	1:10 yield (MCM/a)	Purpose: Water Supply	Purpose: Hydropower	Purpose: Flood Control	Purpose: LS Irrigation	Feasibility ESIA / Design	Capital	Phasing (Year) 2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Multi-purpose Dam Projects							**315**	**2100**																					
High Grand Falls Project (incl. HP)	5700 MCM, 700 MW	4000	●	●	●	●	315	2100	158	158	525	525	525	525															
Inter-basin Transfers							**88**	**585**																					
Maragua 4 / S Mathiyoua diversio	105 MCM/a	-	●				49	329	Cost included in Athi Basin Plan																				
NCT Phase II		-	●				38	256	Cost included in Athi Basin Plan																				
Intra-basin Transfers							**90**	**601**																					
Masinga Dam to Kitui	23 MCM/a	-	●				5	34												5	17	17							
Kiambere Dam to Mwingi	2 MCM/a	-	●				3	17				3	9	9															
Nanigi Barrage to Lamu	102 MCM/a	-	●				83	550								83	275	275											
Hydropower							**34**	**225**																					
Kindaruma upgrade	+32 MW	-		●			1	6					1	6															
Karura	67 MW	-		●			33	219									33	110	110										
Dams - water supply (urban & irrigation)							**24**	**161**																					
Umaa	1 MCM	0.2	●				2	14	9	7																			
Karimenu 2	14 MCM	4.5	●				9	59	39	29																			
Yatta	35 MCM	15	●				13	88	57	44																			
Dams - large scale irrigation							**94**	**629**																					
Kora	537 MCM	see HGF				●	74	492																		37	37	246	246
Thiba	11 MCM	4.2				●	9	59	38	30																			
Thuci	23 MCM	10	●			●	12	78								12	78												
Small dams / pans & Boreholes							**79**	**527**																					
Dams and pans	159 MCM	-	●				55	367	28	28	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
Groundwater (Boreholes)	333 MCM/a	-	●				24	160	20	20	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Large Scale Irrigation Schemes (cost excl. associated dams)							**292**	**1945**																					
Kaagari Gaturi	3 300 ha	-				●	10	65									10	33	33										
Usueni Wikithuki	5 800 ha	-				●	17	114							17	57	57												
Rahole	8 000 ha	-				●	24	158							24	79	79												
Bura	Expand by 400 ha	-				●	1	6							1	3	3												
Hola	Expand by 5 000 ha	-				●	12	79							12	39	39												
Tana Delta	Expand by 28 000 ha	-				●	66	440								66	110	110	110	110									
Masalani	30 000 ha	-				●	89	591														89	197	197	197				
Kora	25 000 ha	-				●	74	493																		74	164	164	164
								O&M Cost	3	6	19	33	47	61	62	67	84	98	105	108	109	110	116	121	127	128	132	143	154
								Total Annual Cost (USD Million)	**351**	**320**	**571**	**588**	**609**	**628**	**142**	**433**	**795**	**652**	**383**	**250**	**153**	**243**	**340**	**345**	**351**	**265**	**361**	**581**	**591**

6.9.7 Strategy

In order to comprehensively and systematically address the water resources development challenges in the Tana Basin, Table 6-39 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 6-39: 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 regarding 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 consider the reserve and resource quality objectives.		
8.2	**Theme:**	**Water Resources Planning**
8.2.1	Updated planning for bulk water resources development	
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. Lamu Port Master Planning should be undertaken.		
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 Lamu 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. The proposed large dams (greater than 1 MCM capacity) include High Grand Falls, Umaa, Yatta, Kora, Thiba and Thuchi.		
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.		
8.3.3	Inter-basin transfers to Athi Basin	
Proposed inter-basin transfers include Maragua 4 Dam and NCTP II.		
8.3.4	Intra-basin transfers	
Proposed intra-basin transfers include Masinga Dam to Kitui, Kiambere Dam to Mwingi and Nanigi to Lamu		

8. Key Strategic Area		Water resources development
8.3.5	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		
8.3.6	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.		
8.4	**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	
Hydropower generation in the basin is critical for the national economy. Three large-scale hydropower development schemes are proposed: Karura dam, Kindaruma dam and High Grand Falls dam.		
8.5.2	Small scale hydropower development	
Hydropower is an important source of energy for economic and social development, on both a large and small scale. For development, the potential for small-scale hydropower plants should be assessed across the basin, especially in the upper Tana Basin.		
8.6	**Theme:**	**Water for agriculture**
8.6.1	Large scale irrigation development: Develop new / expand existing irrigation schemes. Limit to max sustainable areas	
Extensive large-scale irrigation development is possible in the Basin, but will require storage. Eight large-scale irrigation projects are proposed, both new irrigation and the upgrading of existing schemes.		
8.6.2	Promote water conservation in irrigation	
As part of the sustainable scenario proposed in this basin plan, increased irrigation efficiency and reduced water demand for large-scale irrigation accounts largely for more sustainable water use. Water use efficiency can be increased through the rehabilitation or improvement of irrigation technologies and techniques, and through the use of smart metering.		
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	
The new large dams to be developed within the basin will provide opportunities for aquaculture and this should be promoted.		
8.6.4	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	
Desalination of sea water for Lamu Port does not seem feasible at this stage and a transfer from High Grand Falls Dam via the Nanigi barrage will be able to meet demands up to 2040 at a lower cost.		
8.8.2	Rainwater harvesting	

8. Key Strategic Area		Water resources development
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	
Reuse is not considered to be an option for water supply in the basin at this stage.		
8.8.4	Water Conservation and Demand Management	
WCDM should be implemented as an immediate option to reduce water demand in urban areas.		
8.9	**Theme:**	**Water resources systems operation**
8.9.1	Optimise system operating rules	
The operation of the proposed large dams should be optimised.		
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 Basin to inform decision with regard to curtailment of water use and the need for/phasing of new augmentation schemes.		
8.9.3	Maintenance of piped network	
Maintenance of piped network should be conducted to improve (reduce) NRW.		

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 Tana Basin, there 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 important, 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 Tana 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 Tana 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 WRA, aligned to the Water Act 2016, are important and will have impact on the institutional roles and responsibilities within the Tana 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 Tana 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 Tana 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 like 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 Tana 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 resources 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.

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 Tana 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 Strategy

The Institutional Strengthening Plan for the Tana Basin is aligned with the overall vision for the basin and focusses on ensuring that the basin becomes *the leading Basin in Sustainable Water Conservation, Protection, Regulation, Management and Use for Socio-Economic Development and Ecosystem Services for All by 2040.* The aim of the Plan is focused upon the incremental strengthening of the institutional frameworks to enable improved water resource governance within the Tana 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. This Plan is 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 2 Key Strategic Areas and Strategic Themes to achieve this objective and provides specific strategies under each theme.

Table 6-40: Strategic Framework – Institutional Strengthening

<table>
<tr><td>9</td><td>Key Strategic Area:</td><td>Strengthen the Institutional Frameworks</td></tr>
<tr><td>9.1</td><td>Theme:</td><td>Promote improved and sustainable catchment management</td></tr>
<tr><td>9.1.1</td><td colspan="2">Strengthen WRA's regulatory role</td></tr>
<tr><td colspan="3">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.
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 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.</td></tr>
<tr><td>9.1.2</td><td colspan="2">Strengthen BWRCs</td></tr>
<tr><td colspan="3">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 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 resources management, but also a range of skills to enable sound governance.</td></tr>
<tr><td>9.1.3</td><td colspan="2">Strengthen County Governments engagements in WRM in the basin</td></tr>
<tr><td colspan="3">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 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 of information and knowledge exchange need to be established to provide the necessary information required for decision making.</td></tr>
</table>

9	Key Strategic Area:	Strengthen the Institutional Frameworks
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 resources 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 or practice and manuals**	
9.2.1	Develop policies	
Develop policies 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.		
9.2.2	Develop guidelines to support specific water resources management activities	
Develop technical guidelines 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.		
9.2.3	Develop Codes of Practice	
Develop codes of practice 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.		
9.2.4	Develop manuals	
Develop manuals 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 6-41: Strategic Framework – Enabling environment to support effective water resources planning and management

10	Key Strategic Area:	Strengthen the enabling environment to support institutions
10.1	**Theme:**	**Development of institutional capacities to support improved water resources management and development.**
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 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.		
10.1.3	Strengthen partnerships	
The importance of inter-sectoral engagement in water resources 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	Key Strategic Area:	Strengthen the enabling environment to support institutions
10.1.4	Strengthen stakeholder engagement	
The importance of stakeholder engagement cannot be over emphasised. The improvement in the development of water resources 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 resources 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 Tana 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 resources 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.		

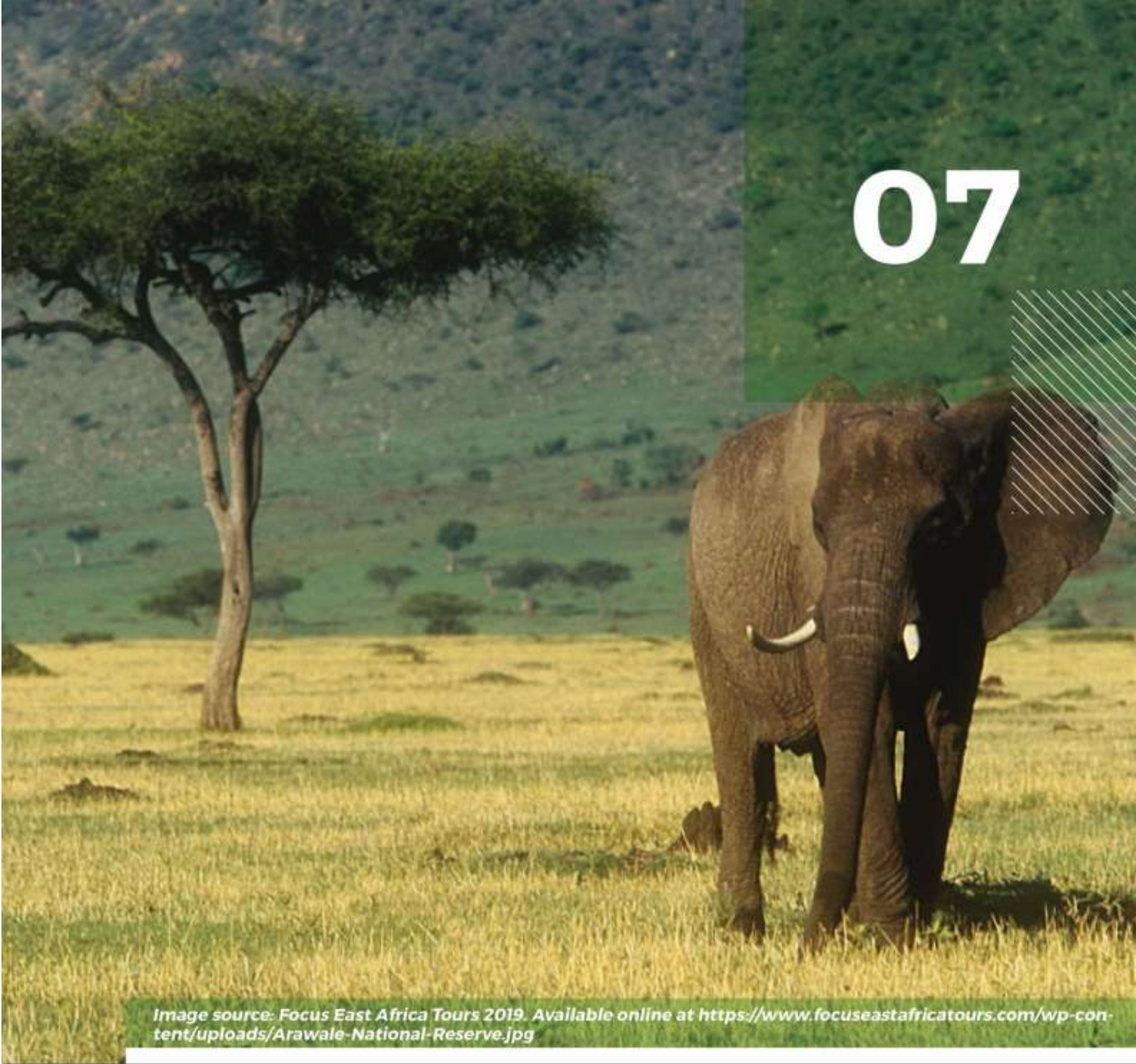

Image source: Focus East Africa Tours 2019. Available online at https://www.focuseastafricatours.com/wp-content/uploads/Arawale-National-Reserve.jpg

07

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 Tana Basin relate to large-scale water resources and related infrastructure which will support socio-economic development in the Tana Basin through improving 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 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. These water requirements refer not only to those in the Tana Basin, but include the existing and anticipated additional volume of water to be transferred from the Tana Basin to the upper Athi Basin

The essence of the proposed water resources development plan for the Tana Basin, up to 2040, is to unlock the significant irrigation potential in the basin, especially along the lower Tana River; to ensure a reliable supply of water to meet the expected growth in urban water demands, including the significant growth which is foreseen in Lamu Port associated with LAPSSET; to increase hydropower production in the basin; to implement the identified schemes which will export water to the Athi Basin; to improve existing and future water resources availability for smaller towns and basin-wide domestic, livestock and small-scale irrigation water demands; and to unlock socio-economic development through multi-purpose water resources development projects in the basin, including flood control. This will necessitate the construction of small-scale and large-scale storage, transfer and regulation infrastructure and increased groundwater abstraction. In addition, water demand management should be implemented for both small and large-scale irrigation and for urban centres. It is also recommended that a hydro-census be undertaken in the Tana Basin to confirm surface and groundwater use and supply sources and to improve the understanding of water quality issues across the basin.

In order to comprehensively and systematically address the range of water resources related issues and challenges in the Tana Basin and unlock the value of water as it relates to socio-economic development, ten key strategic areas were formulated for the Tana 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 Tana Basin Plan provide various synergies with the SDGs. Furthermore, it is important to note that the successful implementation of the Tana 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 Tana 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.

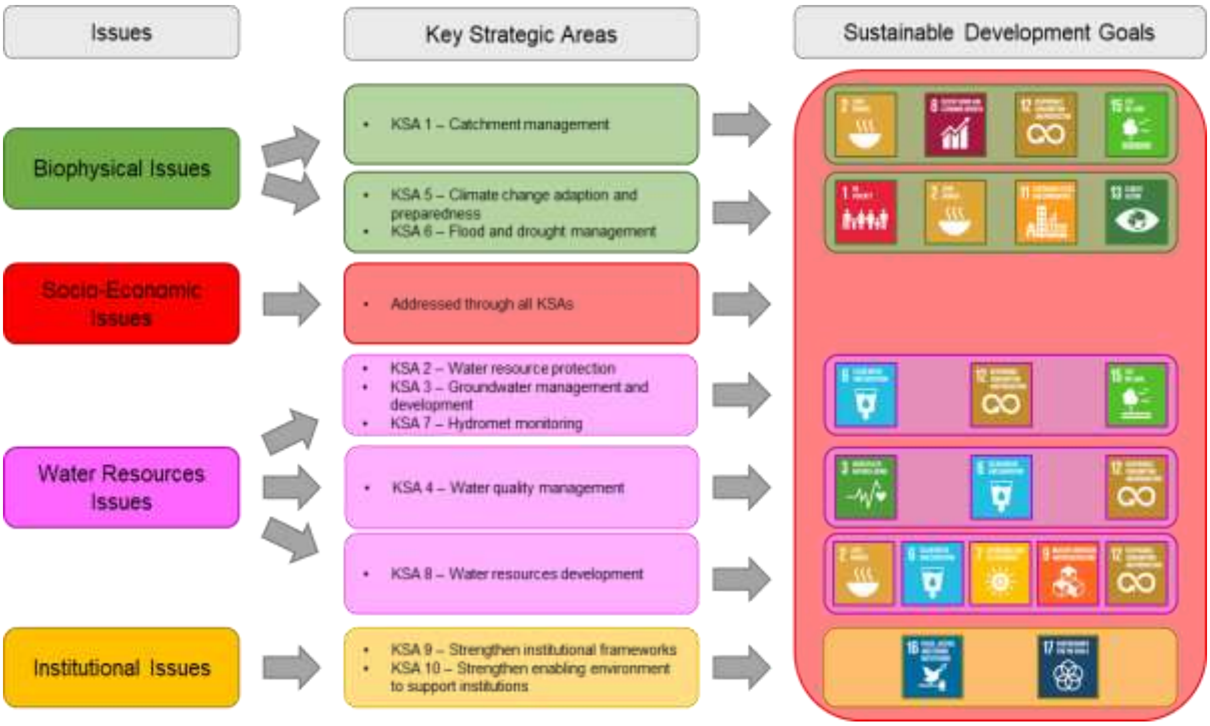

Figure 7-1: Integration of the SDGs into the Tana Basin Plan

7.3.2 Linkages with other plans

This Tana Basin Plan provides a vision and framework for the development and management of the water and related land resources of the Tana Basin. Essentially it reinforces the Tana CMS (2015-2022), supplements the NWMP 2030 and acts as a source of information for the development of Sub-catchment Management Plans (SCMPs), which Water User Associations (WRUAs) will implement. Whereas the Basin Plan contextualises the SCMPs, the SCMPs remain the resource mobilisation tools that WRUAs will use to source implementation funds and other resources. County governments are also involved in implementation activities, and as such will be required to review the Basin Plan and SCMPs to ensure that the County Integrated Development Plans (CIDPs) are linked and synchronised with the overall basin planning initiatives. Relevant Regional Development Authorities (TARDA and CDA) as well as the Water Works Development Agencies (Coastal WWDA, Tana WWDA, Tanathi WWDA) also need to review their proposed and existing projects to align with the investment plan as presented in 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 Tana 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.

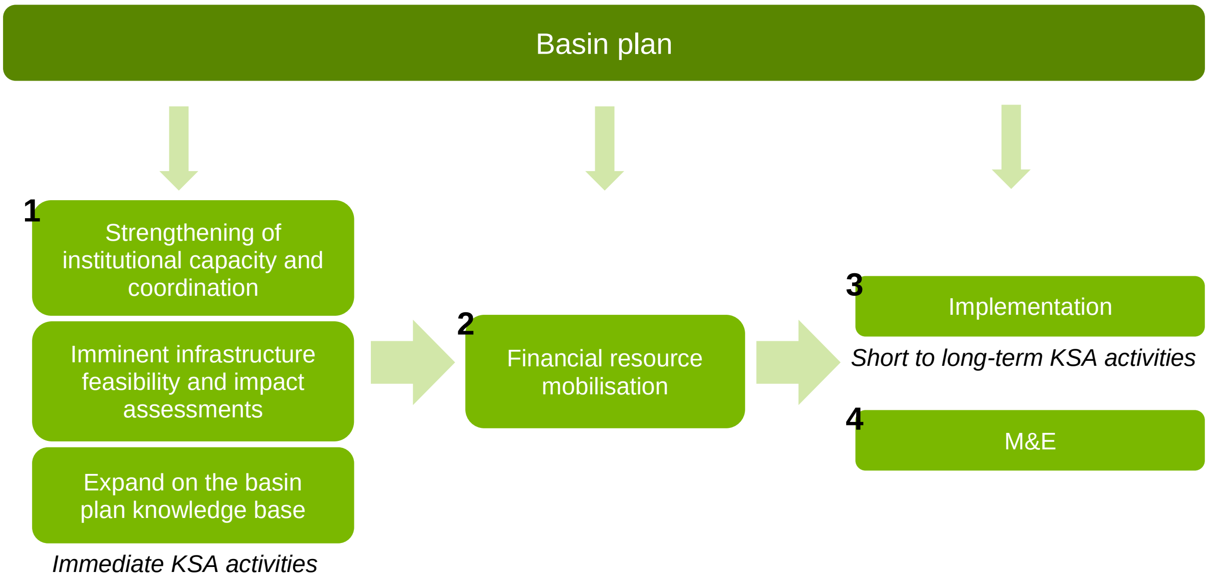

Figure 7-2: Roadmap for implementation of the Basin Plan

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 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 (refer to Table 7-1).

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 Tana basin, feasibility studies should begin immediately with the large dams that scored the highest ranking in the scenario analysis. These include High Grand Falls, Umaa, Yatta and Thiba dams. In addition, relevant studies and designs should immediately begin for the development of groundwater and small dams and pans. 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 are a good tool to leverage external financial support and develop informed policies. Therefore, this should form the basis of all basin plan activities moving forward.

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 the three areas describes during the previous section. 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 and developing strong knowledge bases, finances will be more easily mobilised for future activities. These immediate activities are also relatively cheap in comparison to the total budget of each KSA, as is shown in Table 7-2.

Table 7-2: Immediate implementation activities linked to institutional strengthening

KSA	Priority activities (immediate)	% of total KSA budget
KSA 1 Catchment Management		**7 %**
– 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 Tana Basin (conducted prior to Reserve and resource quality objective determination) – Determine the Reserve for prioritised water resources in the Tana Basin (note Reserve required for resource quality objectives) – Determine the Resource Quality Objectives for prioritised water resources in the Tana Basin		

KSA	Priority activities (immediate)	% of total KSA budget
KSA 3 Groundwater management		**15 %**
	– Implement aquifer mapping and groundwater modelling across the Tana 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 – Implement groundwater abstraction schemes in accordance with groundwater development planning	
KSA 4 Water quality management		**2 %**
	– Implement national water quality monitoring programme in the Tana 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 Tana 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 Tana Basin. – Embed water quality management activities related to domestic water use, crop and livestock production in SCMPs	
KSA 5 Climate change adaptation and preparedness		**14 %**
	– Quantify climate change impacts (rainfall & temperature) on surface water and groundwater resources and demands in the Tana 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		**15 %**
	– Government institutions/agencies and other stakeholders with partnership roles in flood management will form the Tana Basin Flood Response Forum (FRF) under the auspices of the KMD to integrate all flood-relevant resource mobilisations and related interventions in the Tana Basin. – Establish a Secretariat for the Tana Basin FRF with accommodation in the WRA Regional Office. – Develop appropriate SOPs for the Tana Basin FRF. – Organisational alignment/ collaboration: The Tana Basin Flood Response Forum (FRF) will expand organisational capacity in the Tana 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 Tana 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.	

<table>
<tr><th>KSA</th><th>Priority activities (immediate)</th><th>% of total KSA budget</th></tr>
<tr><td colspan="2">KSA 7 Hydrometeorological Monitoring</td><td>4 %</td></tr>
<tr><td colspan="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.</td></tr>
<tr><td colspan="2">KSA 8 Water Resources Development</td><td>6 %</td></tr>
<tr><td colspan="3">– 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</td></tr>
<tr><td colspan="2">KSA 9 Strengthen the Institutional Frameworks</td><td>39 %</td></tr>
<tr><td colspan="3">– 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</td></tr>
</table>

KSA	Priority activities (immediate)	% of total KSA budget
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.

Section 7.4.1 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. Section 7.4.1 also outlined the important role that good scientific studies and feasibility and impact assessments play for leveraging financing.

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 facilities, 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 7.4.2), 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 Tana 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 7.4.4)
- 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 individual activities are provided (summarised in 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 Tana 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	8.7	42.7	38.2	28.4	**118**
	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					
KSA 2	Water resources protection	0.3	0.8	1.8	1.9	**5**
	Classification of water resources					
	Reserve determination					
	Determine Resource Quality Objectives					
	Conserve and protect ecological infrastructure					
KSA 3	Groundwater management and development	31.1	67.6	58.1	57.2	**214**
	Groundwater resource assessment, allocation and regulation					
	Groundwater development					
	Groundwater asset management					
	Conservation and protection of groundwater					
KSA 4	Water quality management	4.1	31.6	91.5	121.9	**249**
	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					
KSA 5	Climate change adaptation and preparedness	4.9	13.0	12.4	8.6	**39**
	Understand impacts of climate change on water resources at appropriate spatial scales					
	Climate change mitigation					
	Climate change adaptation					

Key Strategic Areas and Themes		Budget (USD Million)				
		2020-2022	2022-2025	2025-2030	2030-2040	Total
KSA 6	Flood and drought management	8.2	40.4	2.1	3.6	**54**
	Flood management					
	Drought management					
KSA 7	Hydromet monitoring	1.0	13.1	8.5	6.0	**29**
	Improved monitoring network					
	Improved information management					
KSA 8	Water resources development	396	2 479	2 144	1 979	**6 997**
	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					
KSA 9	Strengthen Institutional frameworks	4.9	2.6	2.9	2.0	**12**
	Promote improved and sustainable catchment management					
	Guidelines, codes of practice and manuals					
KSA 10	Strengthen enabling environment to support institutions	5.3	9.0	4.4	6.0	**25**
	Develop institutional capacities to support improved IWRM&D					
Total		**463**	**2 699**	**2 363**	**2 215**	**7 743**

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

08

Image source: Mount Kenya Fitness Fanatics 2015. 'Nyeri town taken from the Nyeri Hills'. Available online at http://mountkenyafitness.blogspot.com/2015/04/35-beautiful-pictures-shot-in-nyeri.html

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)(Global Water Partnership, 2006)(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 Tana 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 to ensure successful implementation. However, 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 Tana 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 Tana 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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