Ministry of Water, Sanitation and Irrigation

Lake Victoria North 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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Prepared for:

Ministry of Water, Sanitation and Irrigation

Water Resources Authority

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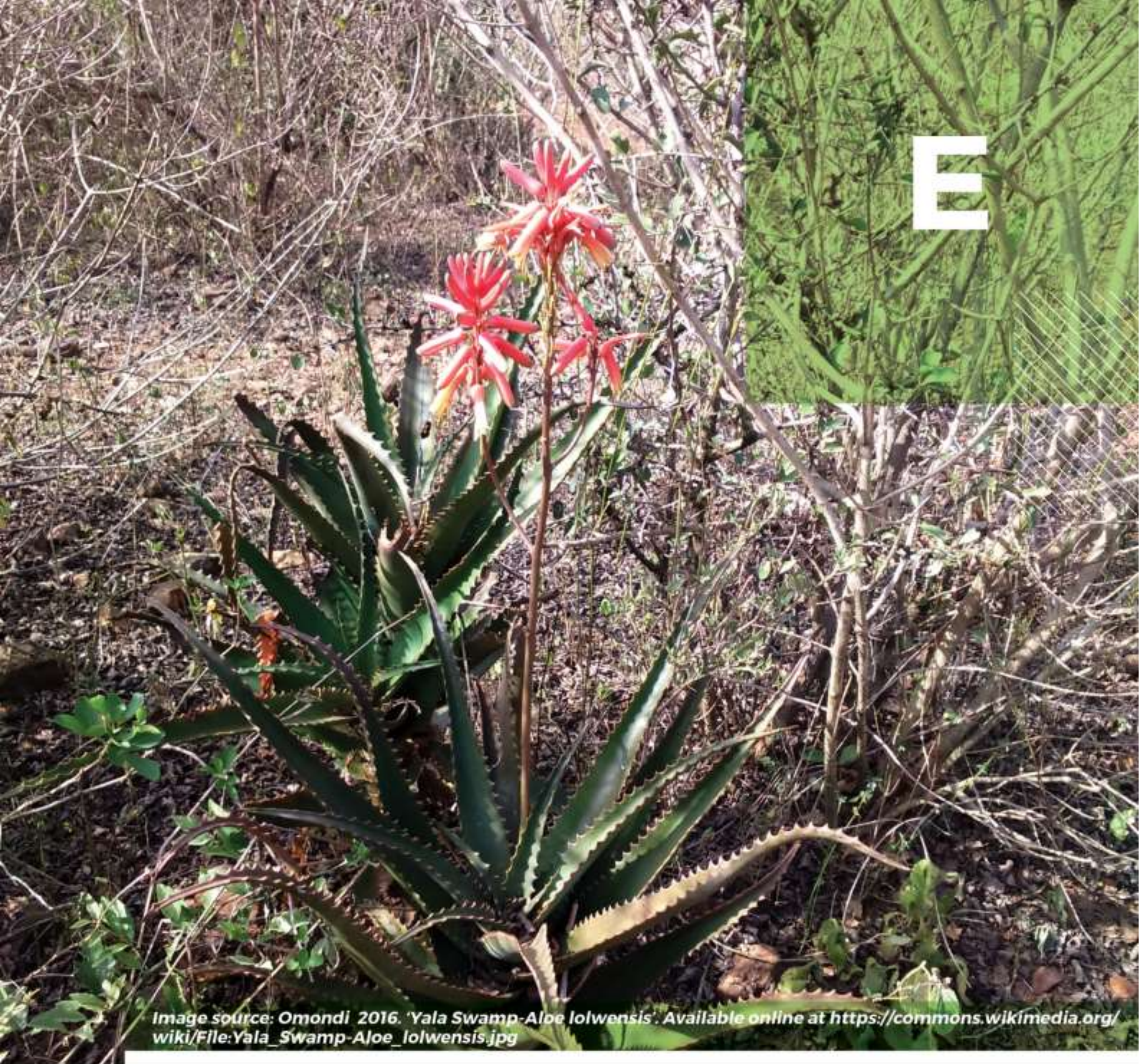

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Executive Summary

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

The Government of Kenya received financing from the World Bank toward the cost of implementing the Kenya Water Security and Climate Resilience Project Phase 1 (KWSCRP-1), to be implemented through the Ministry of Water, Sanitation and Irrigation. This Consultancy covers Sub-component 2.2 *Strengthening Water Resource Management and Planning* of the KWSCRP-1. The overall objective of this Consultancy is to strengthen WRA's capacity in terms of tools, skills and infrastructure to deliver on its mandate for water resource management and regulation in the country. A key set of deliverables under Sub-component 2.2 is the development of six Basin Plans for the six main river basins in Kenya. This document constitutes the Integrated Water Resources Management and Development Basin Plan for the Lake Victoria North (LVN) Basin. Integrated Water Resource 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 Plan for the LVN Basin is to provide a clear pathway for the sustainable utilisation and development of the water resources of the LVN 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 LVN Basin was developed, which reads as follows:

Becoming a model basin in collaborative catchment management, protection, conservation and control; equitably allocating good quality water for sustainable socio-economic development and preservation of ecosystems by 2040.

E2. Biophysical environment

The LVN Basin has an area of 18 500 km^2 and is located at the western part of the country, with Mount Elgon to the north, Uganda bordering to the west and Lake Victoria to the south-west. Although the LVN Basin only covers 3.2% of the country's total area, the catchment houses about 18% of the country's total population, resulting in this basin having the highest population density in the country. The major towns in the Basin are Eldoret, Kakamega, Kitale, Bungoma, Webuye, Kapenguria, Busia, Siaya, Mbale and Kapsabet.

The topography of the LVN Basin varies from 4 320 masl at Mount Elgon to 1 130 masl at Lake Victoria. The Basin is divided into 38 sub-basins, 1AA to 1FG. The Nzoia River is the largest river in the basin and drains 70% of the basin, followed by the Yala River which drains 18% of the basin. Both rivers drain into Lake Victoria. The Sio River flows across the Ugandan border before draining into Lake Victoria. The Nzoia River is a permanent river with seasonal variability and high flows during the two rainy seasons, which frequently cause the river to burst its banks and cause flooding of the lower plains. Surface water quality is degraded due to effluent discharges from major towns and urban areas, factories in Eldoret as well as due to irrigation return flows in some areas.

The LVN Basin faces the north-eastern side of Lake Victoria, which is the largest freshwater lake in Africa. The Lake is a shared water resource between Kenya, Tanzania, and Uganda. The major wetland areas in the LVN Basin are Kingwal, Yala, Sergoit, Saiwa and Sio-Siteko. These systems are being threatened by overexploitation of surface and groundwater resources, catchment degradation which result in increased sediment loads, land use changes, encroachment and pollution.

The climate of the LVN Basin is primarily influenced by the topography of the basin, the intertropical convergence zone (ITCZ), and the proximity to Lake Victoria. These factors contribute to the range and variability in precipitation and temperature regimes. Average annual maximum day temperatures vary from 18°C to 27°C across the basin, while the average annual minimum night temperatures vary from 4°C to 16°C. The central, northern, and southern parts of the basin receive higher rainfall, ranging from a mean annual precipitation (MAP) of about 1 700 mm to 1 900 mm, while the MAP reduces to about 1 000 mm in the southwestern, and north-eastern parts of the basin. Rainfall occurs throughout the year in the basin, however there are two periods of higher rainfall which occur during the year, namely the long rains between March and May, and the short rains from October to November. The rainfall of the basin varies depending on the location.

Under the influence of climate change there has been an increase in extreme climatic events in the LVN Basin. The climate change analysis, undertaken by this Consultancy, showed a general increase (between 4% and 5%) in mean annual rainfall across the basin by 2050. On average, the RCP 4.5 analysis predicted that the MAP across the LVN Basin would increase by 70 mm, from 1 536 mm to 1 606 mm, while day and night temperatures in the basin are expected to increase by up to 1.2°C and 1.4°C respectively by 2050. These projections are in line with current observed climate trends. The variability of future climate within the basin will necessitate adaptive resilience to significantly different scenarios within a season, inter-annually and by decadal. These challenges include increasing temperature and evaporation rates, increasing intensity of extreme events, unpredictable and irregular weather conditions, increased frequency of droughts, and a shift in seasons.

The LVN Basin is vulnerable to flood disasters, and the most vulnerable areas are Lower Yala, Lower Sio and Lower Nzoia (specifically Budalangi). Flooding is currently controlled on the Nzoia and Yala Rivers through the construction of dykes.

The LVN Basin forms part of the highest rainfall region in the country. The vegetation cover is mainly a mosaic of forest and evergreen vegetation, with mountain forest vegetation in the highlands. The forests in the basin comprise a critical part of the LVN hydrological ecosystem and have numerous economic, social, cultural and ecological values, as they provide essential goods and services. Human encroachment is threatening the forest reserves in the basin and there has been a significant loss of vegetation cover.

The Mount Elgon National Park is shared between the LVN Basin and the Rift Valley Basin. Other protected areas are the Kakamega Forest and Chapkitale National Reserves, and the Mount Elgon, Cherangani Hills and Mau Forest Complex water conservation forests.

Land use in the LVN Basin is dominated by agricultural use, with small urban and industrial areas. However, many areas are characterised by unsustainable land use.

E3. Socio-economic environment

The total population of the LVN Basin is almost 8.55 million, which is equivalent to a population density of 462 persons/km^2. This is the highest population density of all six river basins in the country. Most of the population in the LVN Basin live in rural settlements, with only 20% of the population located in urban areas. The population of the LVN Basin is expected to increase due to high projected growth rates, particularly for the urban sector.

The formal sector in the basin 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 informal sector employs 43% of the labour force and covers all small-scale activities that are semi-organised, unregulated and use basic technologies. The main economic activities in the basin are agriculture and fishing. The LVN Basin's location adjacent to Lake Victoria makes the production of fish a strategic opportunity. The sources of livelihood vary across the basin, from fishing in the coastal areas to subsistence agriculture and crop and livestock production in the pastoral and farming areas.

The country's most food insecure areas do not fall within the LVN Basin. The basin is a relatively wet area, with a low number of drought events and few poor-growing seasons. However, parts of the basin do suffer from food insecurity. For the market-dependent households, especially in the rural areas, food prices play a key role in food security.

At present, about 31% of the urban population in the basin receive piped water provided by Water Service Providers, while 16% are dependent on unimproved water sources. The remaining 53% are supplied from groundwater, which include protected and unimproved sources. In rural areas, 25% of the population abstract water directly from rivers, ponds and lakes and 70% use groundwater. The rural population in the basin also has a much lower percentage of piped water supply at only 5% compared to the urban population at 31%.

Approximately 2% of the households in the LVN Basin are connected to a formal sewerage system, all of which are in urban areas. On-site sanitation facilities like pit latrines and septic tanks are used by 94% of the population, while 4% of the population have no form of sanitation system and resort to unsanitary waste disposal.

It has been estimated that approximately 80% of all communicable diseases in Kenya are water related. 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. Many of the counties within the LVN Basin experience high rates of 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, limited 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 LVN 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 LVN Basin were identified and prioritised during a two-day workshop with key stakeholders under four main categories:

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

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

E5. Water availability and water quality

The total LVN Basin natural surface water runoff equals 5 622 MCM/a. More than 90% of the total basin runoff originates from the Nzoia, Yala and Sio rivers combined, i.e. 64% from the Nzoia (3 576 MCM/a) 20% from the Yala (1 139 MCM/a) and 9% from the Sio (522 MCM/a). The Malakasi River with a mean annual runoff (MAR) of 222 MCM/a (4% of the total basin runoff) drains into Uganda. The Malaba River, which also flows into Uganda, has a natural MAR of 162 MCM/a, equivalent to less than 3% of the basin runoff. The month of May generally has the highest runoff, with elevated flows from April to December. The lowest runoff occurs from January to March.

The annual groundwater recharge for the LVN Basin was estimated at 1 508 MCM/a, with a sustainable annual groundwater yield of 216 MCM/a. Good groundwater potential is found throughout the basin.

The projected sub-basin precipitation and temperature changes under climate change scenario RCP 4.5 were superimposed on the hydrological model of the LVN Basin to assess the potential impacts on runoff. The natural runoff in the basin is expected to decrease between 6% and 15% in most areas across the basin, with the largest decrease occurring in the Lusumu River sub-basin, a tributary of the Nzoia River. The total surface water runoff from the LVN Basin is projected to decrease to 5 177 MCM/a under RCP 4.5. It was found that the potential groundwater yield in the basin is expected to marginally increase by 0.5% to 217 MCM/a by 2050 under RCP 4.5.

The total current (2018) estimated water demand in the LVN Basin equates to 286 MCM/a as shown in Table E2. Most of the water is needed for domestic / industrial use in the major urban centres.

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

Sector	Volume (MCM/a)
Irrigation	**40**
- Small scale / Private	14
- Large-scale	26
Domestic and Industrial	**205**
Livestock	**29**
Other	**12**
Total	**286**

The 2018 water balance in the LVN Basin in terms of natural surface water runoff and sustainable groundwater yield, the ecological reserve and current water demands is summarised in Table E3. The current water demand constitutes about 5% of the total water resources available for use. It is important to realise that although the water balance might indicate that the total annual demand is less than the water resources available, supply deficits often occur during dry years and/or the dry season, when the demand exceeds availability of water in the rivers in specific locations.

Table E3: 2018 LVN basin water balance (MCM/a)

Water Source	Surface water	Groundwater	Total
Natural / Available water	5 622	216	5 838
Imported water	-	-	-
Ecological reserve	(792)		(792)
		Total	**5 046**
		Water demand (2018)	(286)
		Balance	**4 760**

The scenario evaluations which were undertaken as part of this Study concluded that the expected growth in urban centre water demands by 2040 will result in a significant reduction in supply reliability to the urban centres. A key priority for the development of water resources in the LVN Basin should therefore concern improved water supply to the main urban centres including Eldoret, through the provision of storage and/or intra-basin transfers. Furthermore, the full extent of planned small-scale and large-scale irrigation development in the Nzoia sub-basin should be feasible but will require the construction of a number of small dams as well as the Upper and Lower Nzoia dams and Moi's Bridge Dam to ensure a high reliability of supply. The areal extent of the irrigation scheme linked to the proposed Kibolo Dam should potentially be reduced, as some of the water in Moi's Bridge Dam needs to be reserved for supplying Eldoret. To ensure a reliable supply of water, the areal extent of the proposed large-scale irrigation schemes in the Yala and Sio sub-basins should be reduced, if these schemes are to operate as run-of-river schemes. Cost-benefit analyses have shown that careful consideration needs to be given to the types of crops cultivated in the proposed large-scale irrigation areas to ensure the financial viability of these schemes.

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 1 884 MCM/a as detailed in Table E4. 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 LVN 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 the basin will require the development of infrastructure for storage and regulation.

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

Sector	MCM/a
Irrigation	**1 100**
- Small scale / Private	542
- Large-scale	559
Domestic and Industrial	**673**
- Urban centres	124
- Basin-wide	549
Livestock	**95**
Other	**16**
Total	**1 884**

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

Currently the LVN Basin has 54 stream flow monitoring stations, although it is likely that historical data exists for many more stations. In 2018, 44 of these stations were known to be operational, and there were no lake monitoring stations. The majority of these are manually operated as rated sections. 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. Currently, the water quality monitoring programme operated by WRA faces the challenges of inadequately qualified and trained staff, as well as inadequate operational resources to facilitate regular sampling and laboratory analysis. In addition, because of inadequate equipment, the laboratories are only able to carry out limited analyses. Currently there are 19 groundwater level monitoring boreholes.

E6. Current water resources development and water allocations

The existing dams in the LVN Basin are Chebara (Moiben) (18 MCM), Ellegirini (2 MCM), Kipkarren (3 MCM), Twin Rivers (< 1), Kesses Dam (1 MCM) and various other small dams and pans (8.1 MCM). There are currently no large hydropower installations in the LVN Basin. There is one small hydropower station in Sosiani, about 25 km west of Eldoret Town along the Sosiani River, with an installed capacity of 400 kW.

Food crops constitute the majority of cultivated crops in the LVN Basin, followed by horticultural crops. The total crop area in the LVN Basin in 2010 was estimated as 776 800 ha, mainly consisting of rain-fed crops. Of this area, less than 5% is estimated to be irrigated at present (2018). Existing large-scale irrigation schemes include Dominion Farms (1 480 ha of rice) and Bunyala (700 ha of rice).

The total current (2018) groundwater use in the basin is estimated at 47 MCM/a.

Ongoing water resources development projects in the basin include the Lower Nzoia Irrigation Scheme, which involves developing 4 000 ha on the left bank of the lower Nzoia River (Phase 1) and a further 3 800 ha (Phase 2) on the right (northern) bank of the Lower Nzoia River. Water for irrigation will be abstracted directly from the Nzoia 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 LVN 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 none of the sub-basins in the LVN Basin are currently over-allocated, i.e. neither the Normal Flow component (available for domestic and industrial use) nor 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 should be noted that some sub-basins do not have any data captured against them in the Permit Database.

E7. Evaluation of scenarios

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

Scenario 1: Lack of funding / Business as usual with irrigation development

This scenario represents the “do nothing” case - a possible worst-case scenario. It assumes that there is <u>no</u> further investment in water resources infrastructure and development including large-scale irrigation, except Upper and Lower Nzoia irrigation schemes which were assumed to be limited to the areas currently under implementation. Yet, 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). As with Scenario 0, non-compliance with the Q95 Reserve due to inadequate monitoring and enforcement is assumed. Climate change impacts are incorporated in the water resources model.

Scenario 2: Limited development

The limited development scenario is the same as Scenario 1, except that limited funds are now available to implement some of the dams and planned transfer schemes as identified in various studies and plans and by stakeholders, for supplying future urban demands. The large-scale irrigation schemes are the same as Scenario 1. As some funds are now available, compliance with Q95 as the ecological reserve is assumed. However, as with 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: Full development

The full development scenario is the same as Scenario 2, except that more funds are now available to implement all the major irrigation schemes at maximum planned areas, i.e. Upper and Lower Nzoia schemes are also implemented at full areal extent. This scenario is evaluated with limited storage and full storage respectively, i.e. the potential benefits of implementing Moi's Bridge, Upper and Lower Nzoia dams are assessed. In essence this scenario evaluates the availability of water and the need for identified storage and transfer schemes to supply future demands, specifically the significant large-scale irrigation (including Upper and Lower Nzoia irrigation schemes) and the projected urban demands. It evaluates the trade-off between potential socio-economic benefits due to the water resources developments, and negative environmental and social impacts. As with Scenarios 1 and 2, vegetation loss at 10% across the catchment is still assumed due to the focus on large scale development in the basin.

Three sub-scenarios were defined under Scenario 3:

- Scenario 3A: Limited storage and Q95 as environmental flow requirement
- Scenario 3Bi: Full storage and Q95 as environmental flow requirement
- Scenario 3Bii: Full storage and EFlow holding flows as environmental flow requirement

Scenario 4: Sustainable development

This scenario represents a progressive approach towards a sustainable development future, i.e. balanced water resources development which limits environmental and social impacts yet provides meaningful socio-economic benefits linked to the development of water resources with a reliable supply of water. This scenario avoids any development in environmentally sensitive areas, assumes 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. 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. Compliance with Q95 as the ecological reserve is assumed.

The criteria which were adopted for the sustainable development of water resources in the LVN 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.Urban centres were modelled to abstract from rivers in addition to the stored water withdrawals
- 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 4:

- Scenario 4A: No reduction in large-scale irrigation areas
- Scenario 4Bi: A reduction in the areal extent of some of the large-scale irrigation schemes as well as a further reduction in future urban demands based on less conservative projections

  Scenario 4Bii: Relocating some of the proposed dams further downstream, to increase upstream catchment areas and runoff into the dams (Teremi and Siyoi dams) and assigning some of the water in the proposed Kibolo Dam towards meeting Eldoret's future water demands. As well as a further reduction in the areal extent of some of the large-scale irrigation schemes

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

- Supply deficits for current urban and rural domestic demands as well as small scale irrigation demands currently occur mainly due to shortfalls during the dry season.
- The expected growth in urban centre water demands by 2040 will result in a significant reduction in supply reliability to the urban centres. A key priority for the development of water resources in the LVN Basin should therefore concern improved water supply to the main urban centres including Eldoret and Kakamega, through the provision of storage and/or intra-basin transfers.
- Interventions towards improving water availability and assurance of supply to urban users should include a combination of new storage dams, new and/or upgrades to existing inter- and intra-basin transfers, water demand management measures, conjunctive use 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 which is projected to increase significantly, new or additional storage (dams and pans), as well as local groundwater development need to be promoted.
- The full extent of planned large-scale irrigation development in the Nzoia sub-basin (as per the NWMP) appear to be feasible but will require the construction of the Upper and Lower Nzoia dams to ensure a high reliability of supply.
- The areal extent of the irrigation scheme linked to the proposed Kibolo Dam should potentially be reduced, as some of the water in Moi's Bridge Dam needs to be reserved for supplying Eldoret.
- To ensure a reliable supply of water, the areal extent of the proposed large-scale irrigation schemes in the Yala and Sio sub-basins should be reduced, if these schemes are to operate as run-of-river schemes.
- Climate change is expected to result in increased rainfall and temperatures, however, the net impact will be less water availability and increased irrigation demands. This highlights the importance of providing storage and the need for water demand management.

- It is imperative that water demand management is implemented in all urban areas, while irrigation efficiencies should also be improved.
- The availability of water for use within the basin will be severely impacted by the introduction of variable minimum environmental flows as opposed to the current Q95 minimum constant flow. Careful consideration should be given to resource classification and how this will impact water resources availability.

E8. Proposed development pathway

The essence of the proposed water resources development plan for the LVN Basin, up to 2040, is to address the expected growth in urban water demands, to ensure a reliable water availability for the proposed large-scale irrigation development as well as the significant expansion of small-scale irrigation in the basin, to improve existing and future water resources availability for smaller towns and basin-wide domestic and livestock water demands and to unlock the significant potential for socio-economic development through the construction of large, multi-purpose water resources development projects in the basin. This will necessitate the construction of small-scale and large-scale storage and regulation infrastructure, the expansion of existing and the development of new intra- and inter-basin transfers, and increased groundwater abstraction. In addition; water demand management will be required for both small and large-scale irrigation and for urban centres.

E9. Water resources development investment plan

Meeting the above objectives will require the following interventions:

- The existing transfer from Moiben Dam to Eldoret and Iten needs to be expanded, while a new dam would have to be constructed on the Sosiani River or the Kipkarren River to supply Eldoret.
- To meet the future domestic and industrial demands of other urban areas (e.g. Kakamega, Kapenguria, Moi's bridge, Matunda, Lumakanda, Kimilili, Bungoma, Chwele, Yala, Siyaya, Mbale), towns and rural areas as well as livestock and small-scale irrigation water demands within the remainder of the LVN Basin, additional storage should be provided through the implementation of already identified dams, the construction of additional dams and pans, and through the construction of more boreholes, while more intra-basin transfers might also be required.
- The proposed Nandi Forest Multipurpose Dam Project needs to be implemented to make use of the abundant water resources in the upper Yala River - to augment the future urban water supply to Kisumu, to generate hydropower and to enable large-scale irrigation development along the lower Oroba River in Lake Victoria South Basin. The dam would also be able to provide for the expected increase in domestic and small-scale irrigation water demands in the middle and lower Yala sub-basin, and possibly to augment the supply to Kakamega through an intra-basin transfer.
- The Lower and Upper Nzoia Dam projects, as well as Moi's Bridge and Kibolo Dam should be implemented to increase supply reliability to future large-scale irrigation development. An added benefit of these projects relates to the generation of hydropower and flood control.
- Implementation and enforcement of environmental flows downstream of proposed dams and large-scale irrigation schemes to maintain the ecological health of the rivers.

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

Table E5. LVN 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				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
Intra-basin Transfers	Capacity		Water Supply	Hydropower	Flood Control	LS Irrigation	7	45																					
Moiben Dam to Eldoret Transfer Expansion	7.5 MCM	6.1	💧				7	45	3	3	23	23																	
Inter-basin Transfers							84	560																					
Nandi Forest Multipurpose Dam, Transfer to LVS and HP	220 MCM, 189 MCM/a, 50 MW	94	💧	💧		💧	84	560	Cost included in Lake Victoria South Basin Plan																				
Other Water Resources Developments							201	1343																					
Siyoi Dam	4 MCM	16	💧				5	36					5	18	18														
Kibolo Dam	40 MCM	27	💧			💧	21	140							11	11	47	47	47										
Teremi Dam	3 MCM	17	💧				5	30				5	15	15															
Moi's Bridge Dam	214 MCM	49	💧			💧	38	253	19	19	84	84	84																
Upper Nzoia Dam (Site 34B)	204 MCM; 16 MW	194		💧		💧	36	241						18	18	121	121												
Lower Nzoia Dam (Site 42A)	395 MCM; 25 MW	540		💧		💧	50	335																		50	168	168	
Dams and pans	117 MCM	-	💧				37	247	19	19	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
Groundwater development (Boreholes)	128 MCM/a	-	💧				9	61	5	5	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Large Scale Irrigation Schemes (excl. dams)							216	1438																					
Lower Sio	5 280 ha	-				💧	20	130									20	43	43	43									
Yala Swamp	3 680 ha	-				💧	14	91													7	7	30	30	30				
Upper Nzoia	24 000 ha	-				💧	71	473					35	35	118	118	118	118											
Lower Nzoia	10 470 ha	-				💧	31	206	31	34	34	34														34	34	34	
Moi's Bridge	15 840 ha	-				💧	47	312					23	23	104	104	104												
Kibolo	9 200 ha	-				💧	34	227																	17	17	76	76	76
								O&M Cost	0.0	0.0	3.9	7.9	10.8	12.0	18.4	27.4	37.5	43.1	45.8	47.3	47.7	48.1	49.2	50.4	51.6	52.8	60.2	67.5	69.8
								Total Annual Cost (USD Million)	**76**	**80**	**161**	**170**	**191**	**138**	**303**	**397**	**463**	**268**	**152**	**107**	**71**	**71**	**96**	**97**	**115**	**171**	**354**	**361**	**162**

E10. Integrated Water Resources Management and Development Plan for the LVN Basin

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

Table E6. Basin Plan – Key Strategic Areas and Objectives

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

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

Table E7 Summarised Basin Plan budget under the 10 key strategic areas

Key Strategic Areas and Themes		Budget (USD Million)				
		2020-2022	2022-2025	2025-2030	2030-2040	Total
KSA 1	**Catchment management** – Promote improved and sustainable catchment management – Sustainable water and land use and management practices – Natural resources management for protection & sustainable use – Rehabilitation of degraded environments	5.1	34.3	29.7	22.1	**91**
KSA 2	**Water resources protection** – Classification of water resources – Reserve determination – Determine Resource Quality Objectives – Conserve and protect ecological infrastructure	0.3	0.8	1.8	1.9	**5**
KSA 3	**Groundwater management and development** – Groundwater resource assessment, allocation and regulation – Groundwater development – Groundwater asset management – Conservation and protection of groundwater	10.0	29.3	18.7	28.0	**86**
KSA 4	**Water quality management** – Effective data collection, information generation, dissemination, knowledge management – Promote sound water quality management governance – Efficient and effective management of point and nonpoint sources of water pollution	3.8	27.7	80.9	107.7	**220**
KSA 5	**Climate change adaptation and preparedness** – Understand impacts of climate change on water resources at appropriate spatial scales – Climate change mitigation – Climate change adaptation	4.4	11.4	11.1	7.9	**35**

Key Strategic Areas and Themes		Budget (USD Million)				
		2020-2022	2022-2025	2025-2030	2030-2040	Total
KSA 6	**Flood and drought management** – Flood management – Drought management	6.9	32.8	4.0	6.8	**51**
KSA 7	**Hydromet monitoring** – Improved monitoring network – Improved information management	2.0	12.1	8.5	5.0	**28**
KSA 8	**Water resources development** – Surface water resource assessment, allocation and regulation – Water resources planning – Water storage and conveyance – Groundwater development – Hydropower development – Water for agriculture – Water based tourism and recreation – Non-conventional water resources – Water resources systems operation	130	681	1 841	928	**3 580**
KSA 9	**Strengthen Institutional frameworks** – Promote improved and sustainable catchment management – Guidelines, codes of practice and manuals	5.0	2.6	2.7	2.0	**12**
KSA 10	**Strengthen enabling environment to support institutions** – Develop institutional capacities to support improved IWRM&D	5.3	9.0	4.4	6.0	**25**
Total		**173**	**841**	**2 003**	**1 115**	**4 132**

E11. Roadmap for the Basin Plan

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

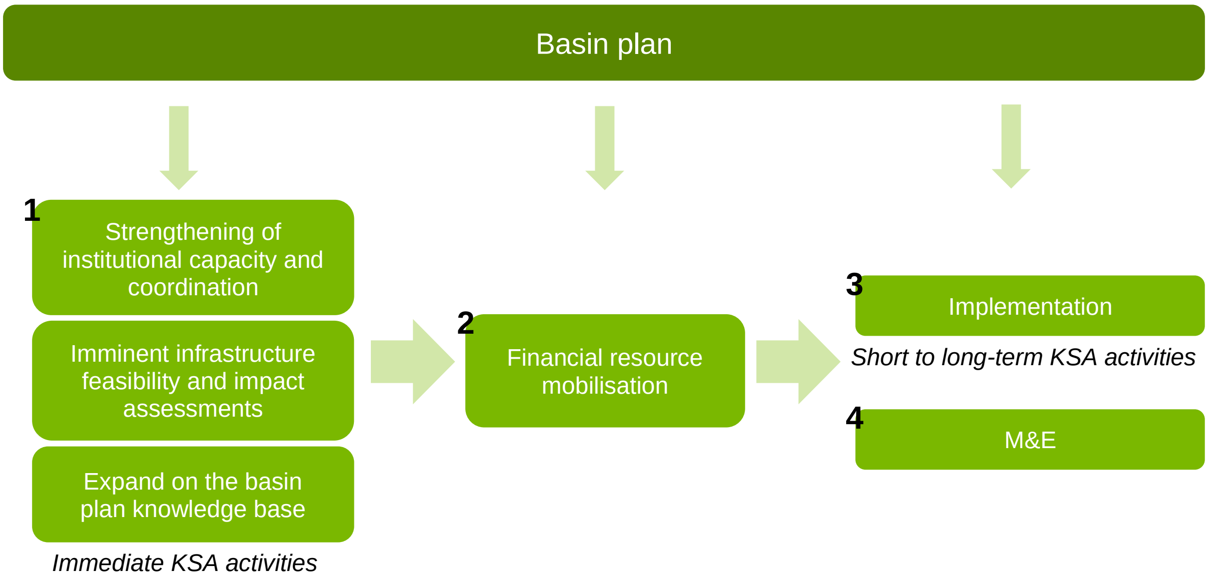

Figure E1: Roadmap for implementation of the basin plan

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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
BOD	Biochemical Oxygen Demand
BWRC	Basin Water Resource Committee
CAAC	Catchment Area Advisory Committee
CBA	Cost-benefit analysis
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
ERC	Energy Regulatory Commission
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	Headquarters
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
LVNWWDA	Lake Victoria North Water Works Development Agency
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
REA	Rural Electrification Agency
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
UPOPs	Unintentionally Produced Persistent Organic Pollutants
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

01

Image source: AG Africa 2016. 'kakamega-forest_morning-mist' Available online at https://africageographic.com/blog/exploring-the-diverse-kakamega-forest-in-kenya/

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 Plan 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 Lake Victoria North (LVN) Basin.

Figure 1-1: LVN Basin location map

1.2 Objectives of the Basin Plan for the LVN Basin

Integrated Water Resource 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 LVN Basin is to provide a clear pathway for the sustainable utilisation and development of the water resources of the LVN 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 LVN Basin Plan

The conceptual approach to the development of the basin plan for the LVN Basin is described schematically in Figure 1-2.

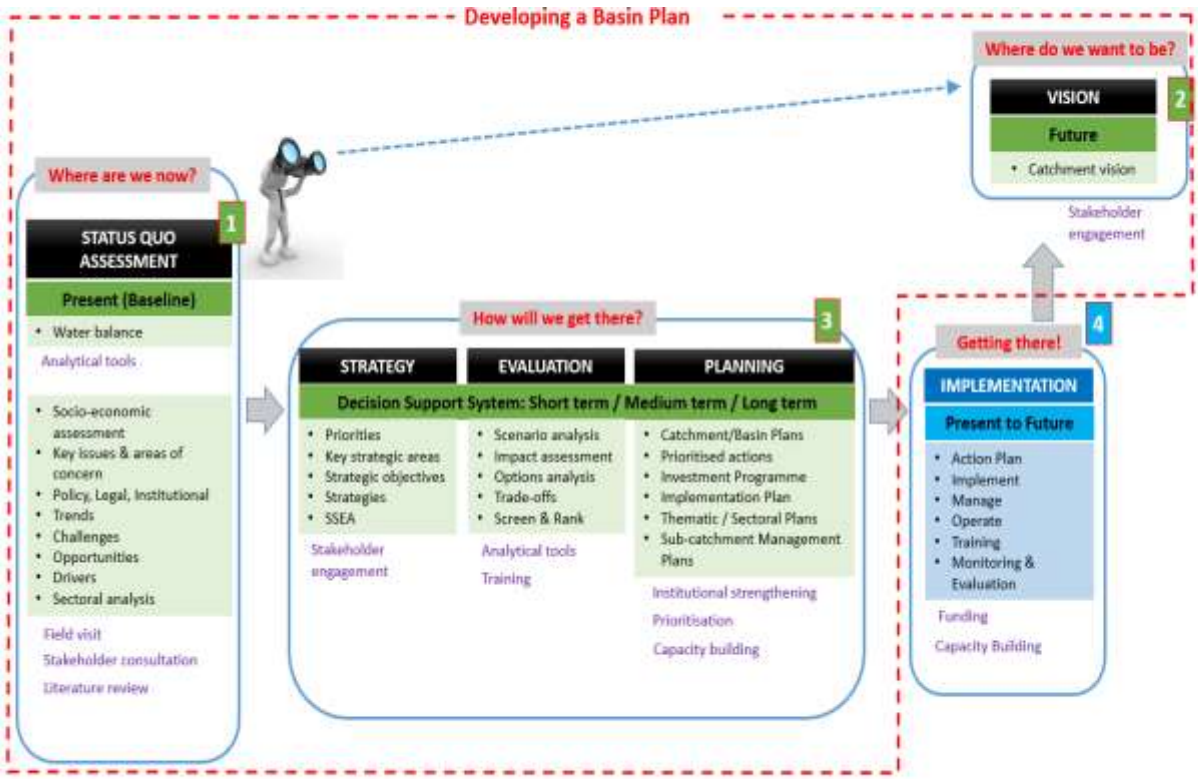


Figure 1-2: Conceptual approach to basin planning

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 LVN Basin.

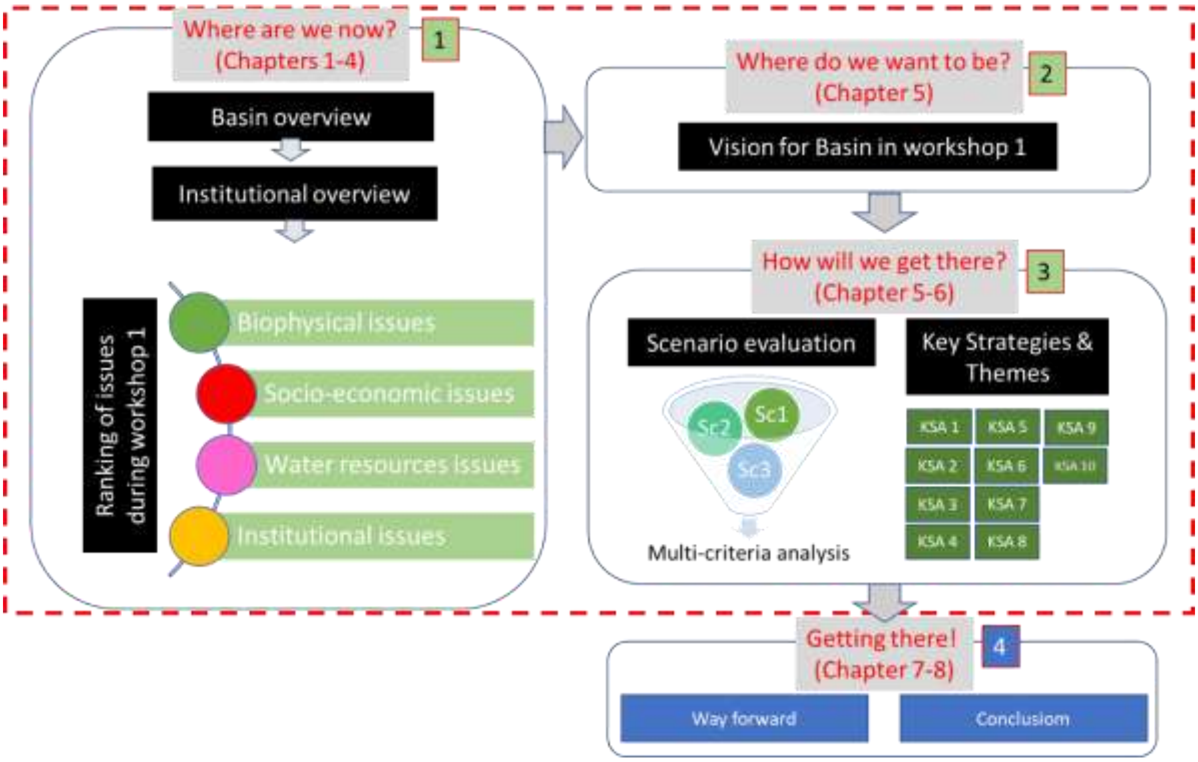


Figure 1-3: Key stages in development of LVN Basin Plan

1.4 Structure of the 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: 'Saiwa Swamp National Park Marshbuck Antelope'. Available online at https://ajkenyasafaris.com/things-todo/saiwa-swamp-national-park/703-sitatunga-or-marshbuck-tragelaphus-spekii-is-a-swamp-dwelling-antelope-female-singapore/

02

Basin Overview

2 Basin Overview

2.1 Introduction

The LVN Basin has an area of 18 500 km^2 [1] and is located at the western part of the country, with Mount Elgon to the north, Uganda bordering to the west and Lake Victoria to the south-west. Although the LVN Basin only covers 3.2% of the country's total area, the catchment houses about 18% of the country's total population, resulting in this basin having the highest population density in the country.

The water demand in the basin is expected to increase significantly in future due to the expected growth in population, urbanisation, as well as due to major irrigation schemes being planned. This heightens the need to address the current water-related issues experienced within the basin – not only the growing water demand, but also issues related to catchment degradation and water resources protection.

An overview map of the LVN Basin is shown in Figure 2-1.

Figure 2-1: Overview map of LVN Basin

There are ten counties within the LVN Basin, which are covered in their entirety or majority by the drainage basin (Figure 2-2). Some counties cross hydrological boundaries and therefore need to engage with multiple BWRCs and WRA offices. The counties within the LVN Basin include Trans Nzoia, Bungoma, Busia, Siaya, Vihiga, Kakamega, Nandi, Uasin Gishu, Elgeyo Marakwet and West Pokot counties. The geographical area of West Pokot county that lies within the basin is minor; thus, this county is not considered in this report.

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

Figure 2-2: Counties within the LVN Basin

The major towns in the Basin include Eldoret, Kakamega, Kitale, Bungoma, Kapenguria, Busia, Siaya, Mbale and Kapsabet. The LVN Basin receives the highest rainfall in the country, providing opportunities for irrigation and surface water resource development. Although surface water resources are available in the Basin, they are unevenly distributed, both spatially and temporally, and as a result, almost 70% of the population depends on groundwater supply from springs, wells and shallow boreholes.

2.2 Bio-physical

2.2.1 Physiography

2.2.1.1 Topography and landforms

The LVN Basin is located in the highlands of Kenya. As evident from Figure 2-3, the topography of the LVN Basin varies from 4 320 masl at Mount Elgon to 1 130 masl at Lake Victoria (Figure 2-3). The basin is divided into two topographic zones: the upper zone (2 600 to 1 500 masl) and the middle zone (1 500 to 500 masl). Major water towers include Mount Elgon and Cherangani Hills.

Figure 2-3: Elevation zones in the LVN Basin

The terrain slope categories within the LVN Basin are shown in Figure 2-4. Generally, most of the basin is gently sloping. However, steeper slopes are found on Mount Elgon on the Ugandan border and the Cherangani Hills on the north-eastern part of the Basin bordering the Rift Valley Basin, between Kapenguria and Iten.

Figure 2-4: Slope categories in the LVN Basin

The Nzoia River catchment makes up most of the land area of the LVN Basin. It originates on the steep slopes of the upper Basin. Mount Elgon is located on the north-western side of the upper basin, on the border with Uganda, and has an elevation of 4 320 masl. The Cherangani Hills are located on the north-eastern part of the Basin bordering the Rift Valley Basin, between Kapenguria and Iten. These two features are shown as 'mountains' and 'hills and mountain footridges' in Figure 2-5, which displays the dominant landforms in LVN Basin

The dominant landform in the Basin is 'plateau', as shown in Figure 2-5. The Nandi Escarpment cuts across the plateau in the centre of the Basin, diverting the Yala River to the south. The next most common landform is the plain in the east, and on the edge of Lake Victoria in the west.

The Sio River originates near Bungoma Town in the western portion of the Basin, draining the mountain slopes of Mount Elgon. Alluvial plains occur along the riverbed on the border with Uganda, where it exits Kenya and flows through Uganda, before draining into Lake Victoria on the Ugandan shoreline.

The Yala River is located in the south-eastern part of the Lake Victoria Basin, originating on the border with the Rift Valley Basin to the east, and draining into Lake Victoria in the west. The landforms in the catchment of this river are much less varied than the other rivers in the Basin, consisting only of footslopes, plateaus, escarpment and plain.

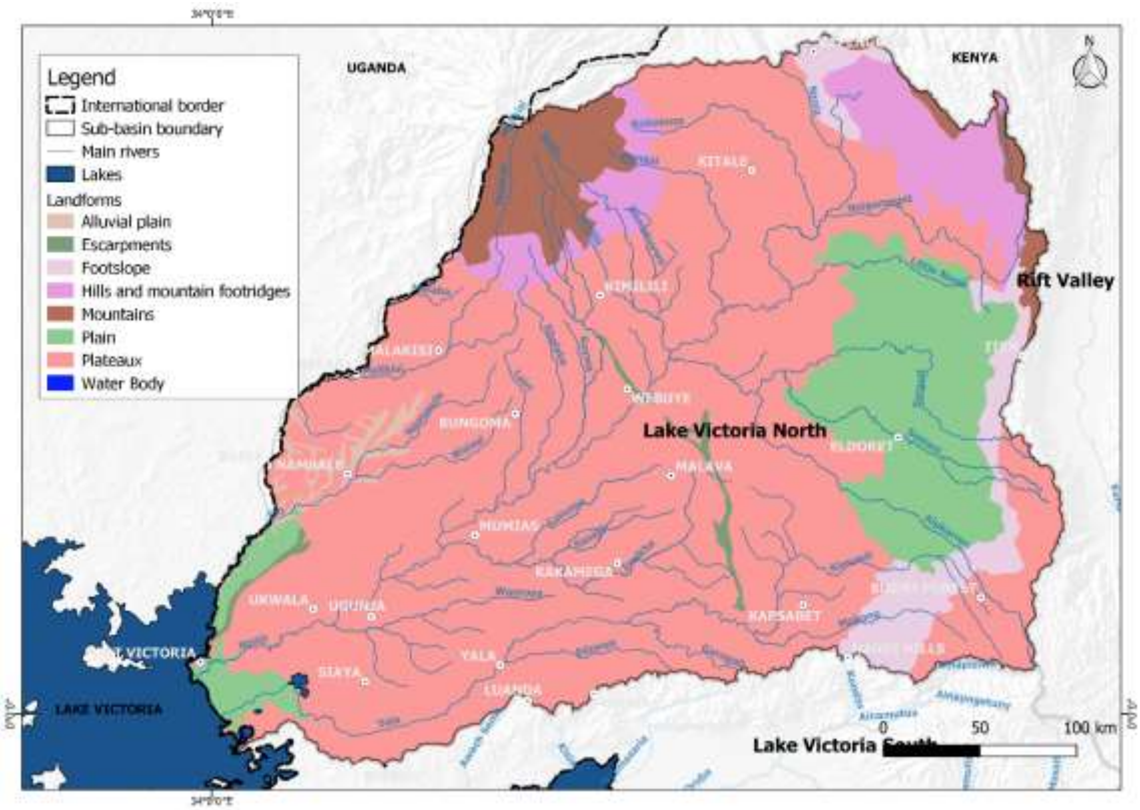


Figure 2-5: Landforms of the LVN Basin

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 LVN Basin due to its detailed soil mapping base. The main soil types found in the LVN Basin are listed in Table 2-1.

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

Soil Type	Description
Acrisols	Clay-rich sub-soil associated with humid, tropical climates.
Ferralsols	Low nutrient levels and nutrient retention. Sandy/silty texture. Commonly found under tropical rainforests. Sustains natural vegetation.
Nitisols	High clay content and iron rich. Support a wide range of crops, particularly coffee in East Africa. Fertiliser required for annual cropping.
Gleysols	Wetland soils which have undergone prolonged periods of intermittent or continuous saturation.

The soils in the upper parts of the LVN Basin are mainly Ferralsols, which are strongly weathered soils with low nutrient levels. These are interspersed with Nitisols which are deep red soils with some organic matter. The lower parts of the LVN Basin are mainly Acrisols which are acidic soils with clay-rich subsoils. The Basin is also scattered with Gleysols, which are soils saturated by groundwater for long periods. Figure 2-6 displays the soils of the LVN Basin and the classifications associated with are presented in Table 2-2.

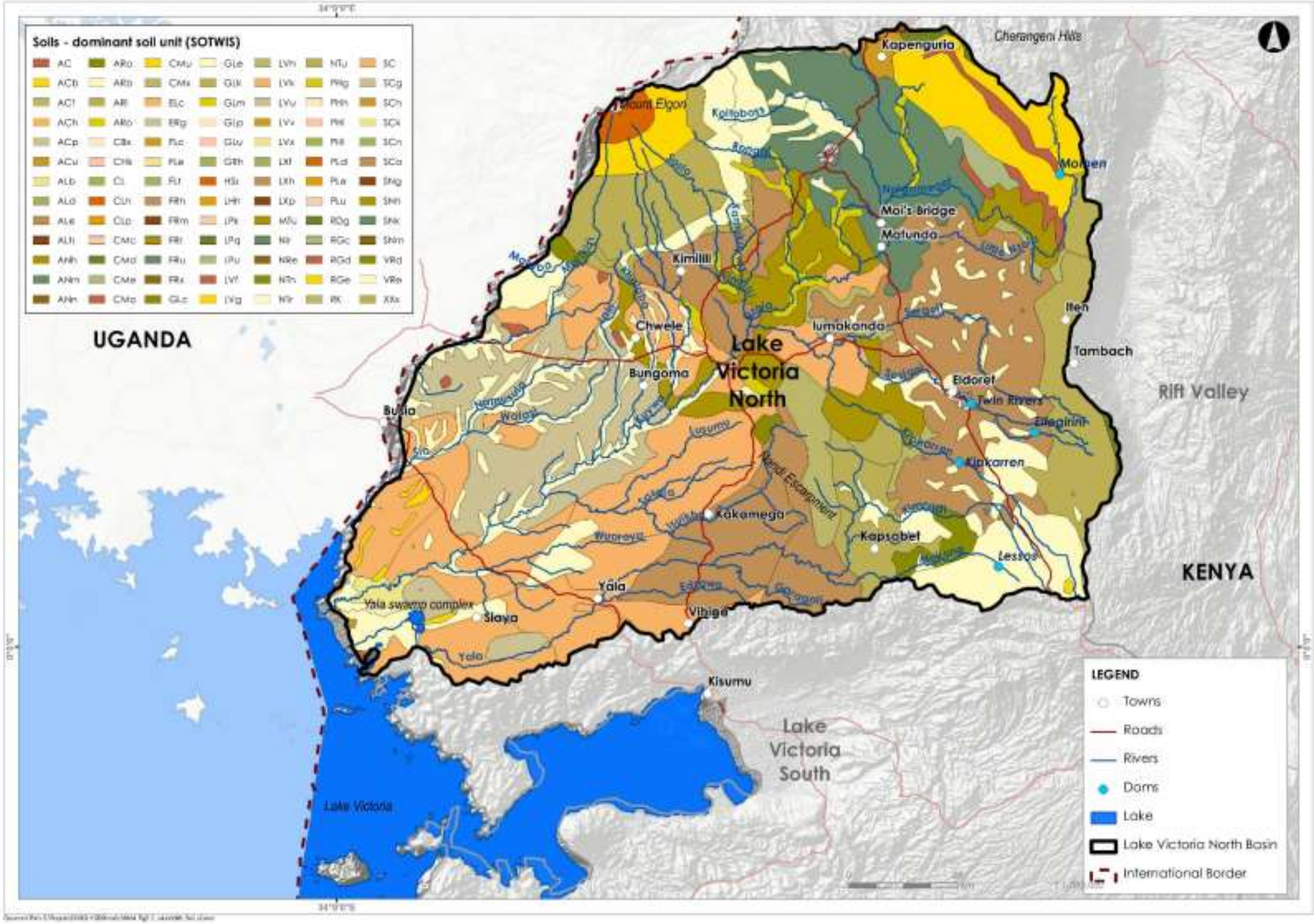


Figure 2-6: Soils in the LVN Basin

Table 2-2: Soil Classification for the LVN Basin

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

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 the footslopes of Mt Elgon below the forest has less vegetation cover which influences the higher erosion rates. The gazetted forests in the headwaters of Nzoia and Yala Rivers have very low rates of erosion.

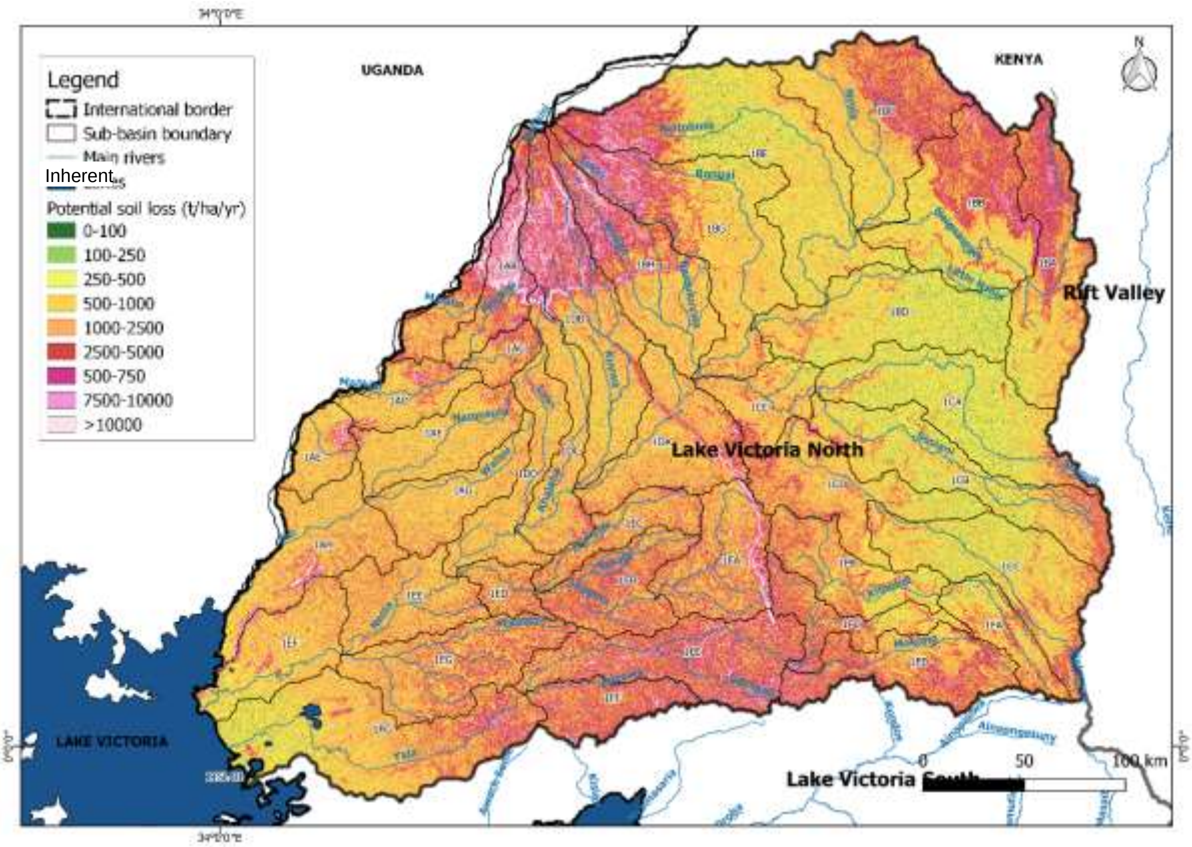


Figure 2-7: LVN Basin Inherent Soil Erosion Risk (C and P factor not included)

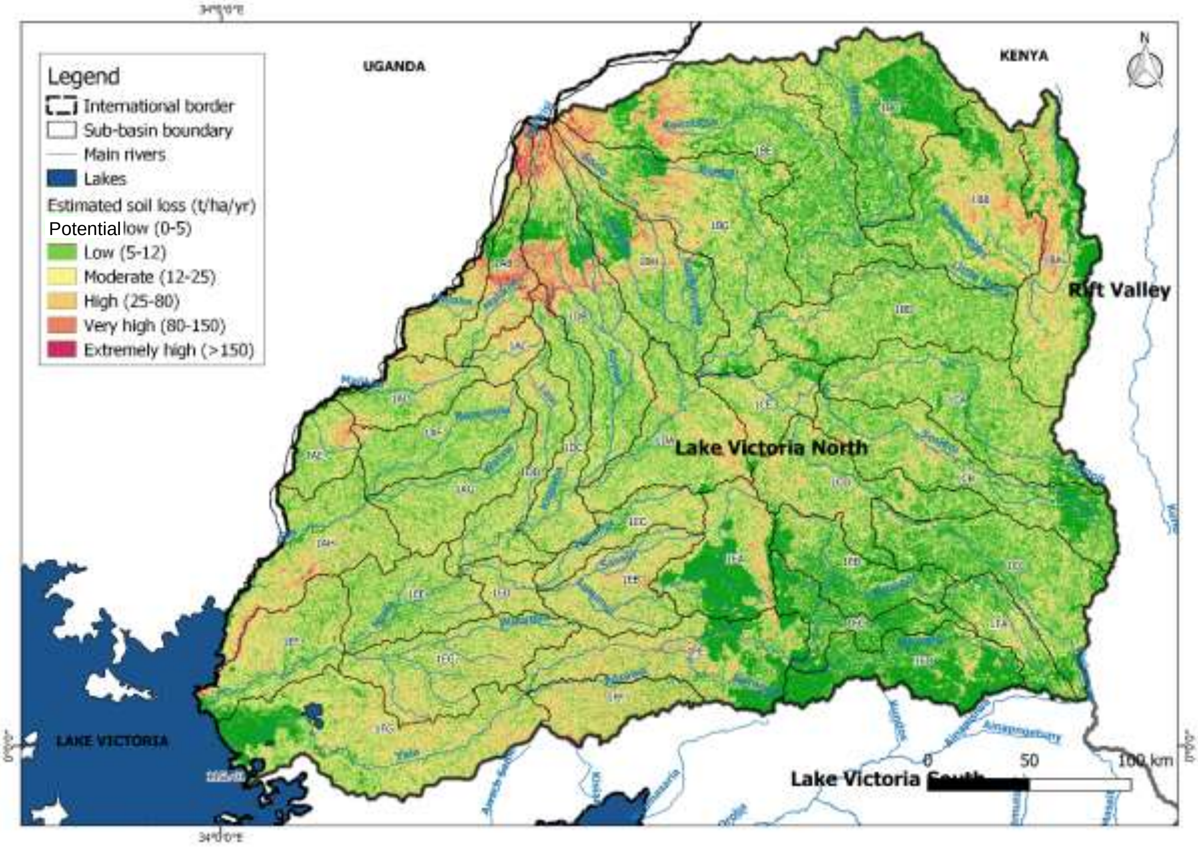


Figure 2-8: LVN Basin Potential Soil Erosion Risk

2.2.1.3 Geology and hydrogeology

Geology and groundwater characteristics

Overall, the geology of the LVN Basin is the Archaean-Paleoproterozoic granite-greenstone terrain, which is found in western Kenya around Lake Victoria. The Nyanzian rock group (basalts, endesites, dacites, rhyolites, pyroclastics and ashes) is overlain by the younger Kavirondian rock group (conglomerates, greywackes, sandstones, shales and mudstones). The structural geology is characterised by a series of east-west orientated folds, and faults and shear zones are common. The terrain is rich in base metal mineralisation as well as minable rock units such as granitoids and greenstone metavolcanics. Figure 2-9 displays the geology of the LVN Basin.

The major rock type in the Basin is metamorphic rocks. In the upper part of the Basin (north east and east of the prominent Nandi Fault) the underlying geology comprises Basement geology of the Mozambique Group. The lower parts (west and south west of the Nandi Fault) of the Basin are underlain by metasediments, the Nyanzian (basalts, endesites, dacites, rhyolites, pyroclastics and ashes) and Kavirondan groups (conglomerates, greywackes, sandstones, shales and mudstones). Where these are weathered, they constitute a useful aquifer system that provides water to numerous springs, shallow wells and a much smaller number of boreholes.

In the upper elevations of the Basin, younger (Oligocene-Miocene) volcanics overlie the metamorphic rocks. Two volcanic centres exist, the extrusive Mount Elgon volcano on the Kenya-Uganda border; and the *plateau* phonolites of Uasin Gishu, which were extruded from the western edge of the Rift Valley and flowed westwards. Both host moderate aquifers, locally useful for small-scale water supplies.

In the Eldoret area well over 120 boreholes have been constructed in the Miocene *plateau* lavas. Flow is westwards from the recharge zone underlying the western part of the Elgeyo Escarpment. Borehole depths vary immensely. To the south and east where the lava thickness is greatest, considerable borehole depth is required to encounter water. Beneath Eldoret itself, however, the depth to the Basement rarely exceeds 130 m. The groundwater system is a multi-part aquifer, with water bearing zones occurring in either Old Land Surfaces (OLS) between separate lava flows, in basal tuffs and grits, or in the OLS at the top of the metamorphic Basement, or all three. Of the 119 boreholes reviewed, 30% reported multiple aquifer strikes. The aquifer system is confined; flow is predominately inter-granular and because of this, test yields are low to moderate (between 0.1 and 13.6 m^3/hr, with a mean of 3.5 m^3/hr) (The Nature Conservancy, 2019). There does not appear to have been significant depletion in this aquifer; however, water quality is considered marginal at some locations (EC~3,000µS/cm).

Aquifers in the Mount Elgon area (in Trans Nzoia County) are variable in terms of yield, and boreholes constructed in the Elgon volcanics are often of poor quality (EC>3,000µS/cm). Yields of seven boreholes in volcanic material ranged from dry to 3.12 m^3/hr. This contrasts with boreholes constructed in metamorphic Basement (east and south east of the mountain) where yields from seven boreholes ranged from 12 to 32 m^3/hr, which is good by Kenyan Basement standards (Odida, 2015).

Siaya County is underlain by metamorphic rocks of volcanic and volcanoclastic origin. They are intensively jointed, fractured and faulted and are covered by weathering material. The relatively high annual rainfall in the more elevated parts of the County provides reliable and steady recharge into the weathered layer. Groundwater levels typically vary between 5 and 15 mbgl. This makes groundwater readily accessible *via* hand dug wells and shallow boreholes. Where major faults and fractures occur, high-yielding deep boreholes can be constructed (DHV Consultants, 1988).

Boreholes in Navakholo (Kakamega County) have unusually high yields for the LVN Basin, 146 m^3/day (Lake Victoria North Water Services Board, 2011). Navakholo is located on Kavirondian rocks, which accounts for the high yields.

Elsewhere in the Basin few aquifers have been described in published material that could be reviewed as part of this consultancy.

WRMA Aquifer classification

The WRMA aquifer classification system (Water Resources Management Authority, 2007) is partly demand-oriented and partly geo-political. As part of this consultancy, a new aquifer classification system is proposed in section 6.4.36.4.4, and uses the same classes and status as is described below.

There are five classes in the WRMA aquifer classification system (Water Resources Management Authority, 2007) 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 WRA

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

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

The Lake Victoria South Basin’s aquifers under the WRMA aquifer classification system are summarised in Table 2-3.

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

Name	Dominant lithology	Status
Strategic		
None		
Major		
Mount Elgon (springs)	Decomposed Tertiary volcanics; phonolites and agglomeratic tuffs	Alert (conflict potential)
Kavirondan System; Bungoma Town	Metamorphosed sediments – conglomerate, grits.	Alarm (water quality)
Kavirondan System; Busia Town		Alarm (water quality)
Kavirondan System; Butere-Mumias		Alarm (water quality
Kavirondan System; Samia aquifer [2]	Highly weathered Kavirondan sediments	Satisfactory
Mumias granitic aquifer [3]	Weathered, decomposed and fractured granite intrusions	Satisfactory
Webuye aquifer	Highly weathered decomposed sediments	Alert (growing town)
Minor		
Uasin Gishu Phonolites	Tertiary volcanics – weathered phonolites, agglomeratic tuffs	Satisfactory
Poor		
Basement [4]	Weathered/poorly weathered Pre-Cambrian metamorphics	Satisfactory
Colluvial	Erosion debris	None given
Nyanzian volcanics [5]	Basalts, rhyolites andesites, and rhyolitic tuffs over Basement	Satisfactory
Special		
None		

[2] Archaean (Kavirondan) sediments; grits and conglomerates; good intergranular and fracture-flow aquifer; yields of 5 to 10 m^3/hr; variable quality (Water Resources Management Authority, 2007).

[3] Weathered/decomposed/fractured granite intrusions; good intergranular and fracture-flow aquifer; yields of between 1.5 and 5 m^3/hr; generally good quality.

[4] Precambrian metamorphics (Mozambique Belt); gneisses, granites and schists; poor intergranular (saprolite) and fracture flow (competent rock) aquifers; yields of less than 5 m^3/hr; generally poor quality.

[4] Archaean basalts, rhyolites, andesites and rhyolitic tuffs over basement rock; poor intergranular and fracture-flow aquifer; yields of less than 5 m3/hr; poor quality in some places and high salinity reported in southern Samia and parts of Siaya.

[5] Archaean basalts, rhyolites, andesites and rhyolitic tuffs over basement rock; poor intergranular and fracture-flow aquifer; yields of less than 5 m^3/hr; poor quality in some places and high salinity reported in southern Samia and parts of Siaya.

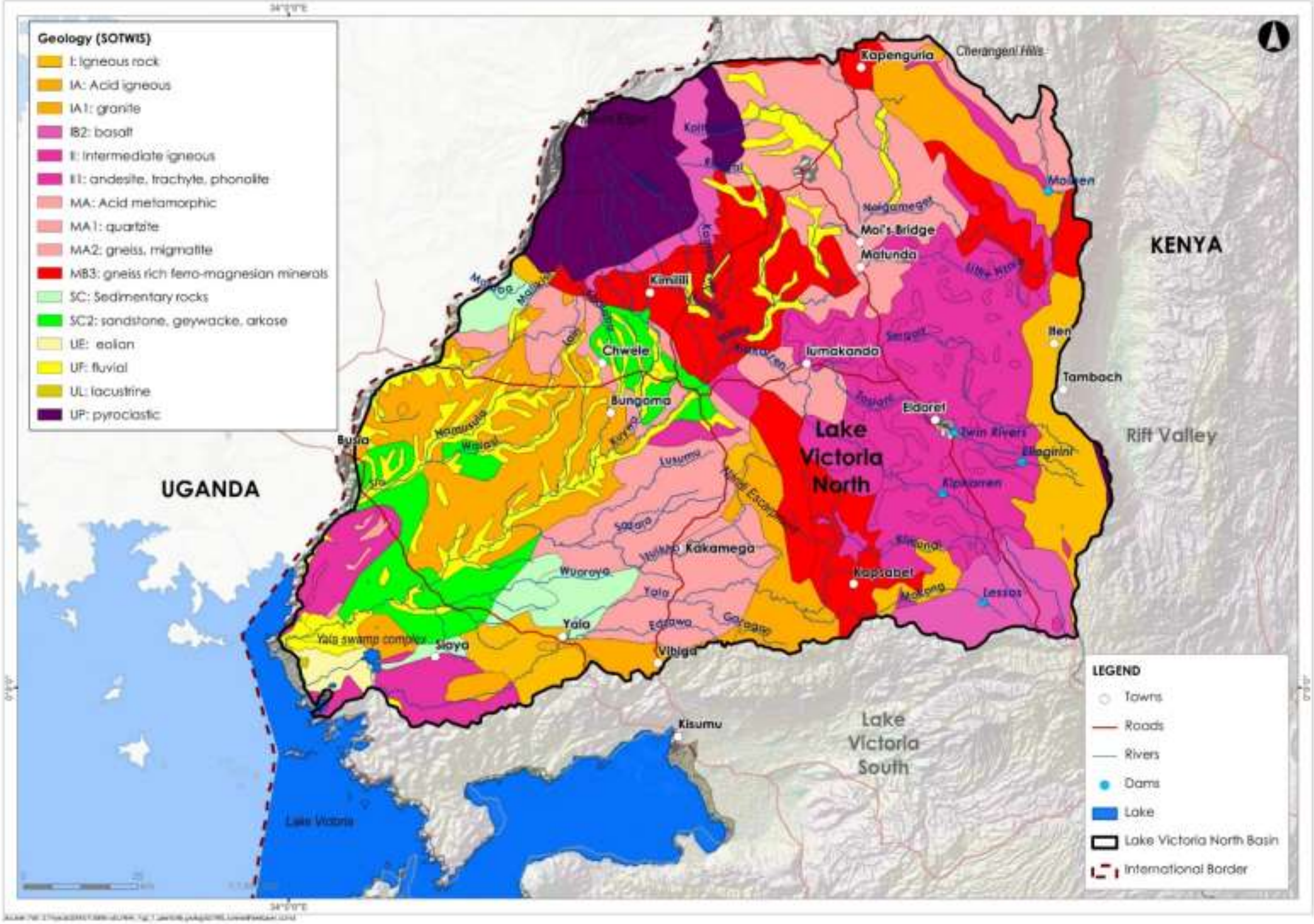


Figure 2-9: Geology in the LVN Basin

2.2.1.4 Drainage

The LVN Basin is divided into 38 sub-basins, 1AA to 1FG, as shown Figure 2-10. The Nzoia River is the largest river in the Basin and drains 70% of the catchment, followed by the Yala River which drains 18% of the catchment. Both rivers drain into Lake Victoria. The Sio River flows across the Ugandan border before draining into Lake Victoria. The Nzoia River is a permanent river with seasonal variability and high flows during rainy seasons between March and November, which frequently cause the river to burst its banks and cause flooding of the lower plains. Surface water quality is degraded due to effluent discharges from major towns, urban areas and factories and return flows from irrigation schemes. North of the Sio River, the Malakisi and Malaba Rivers originate on the slopes of Mount Elgon and cross the border into Uganda.

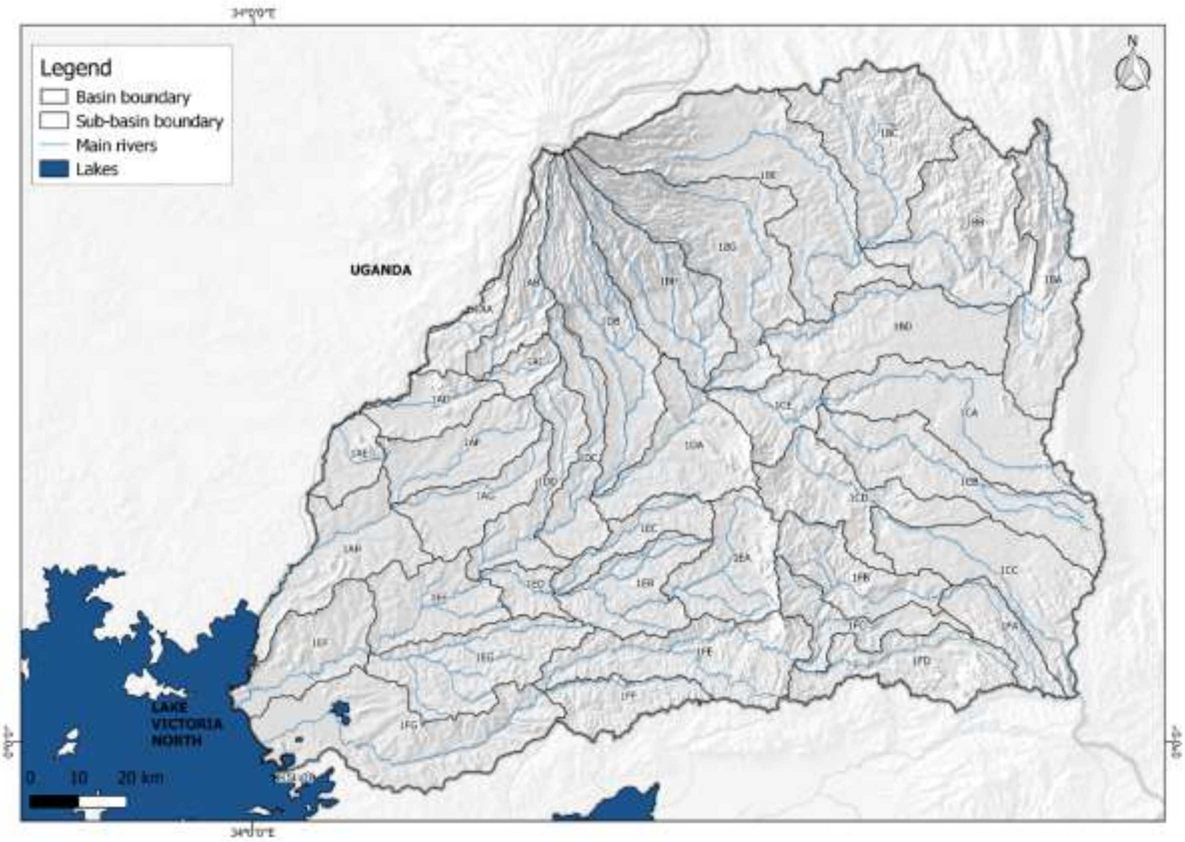


Figure 2-10: The drainage network and sub-basins of the LVN Basin

2.2.1.5 Lakes and wetlands

The LVN Basin faces the north-eastern side of Lake Victoria, which is the largest freshwater lake in Africa. The Lake is a shared water resource between Kenya, Tanzania, and Uganda. The major wetland areas in the LVN Basin are Kingwal, Yala, Sergoit, Saiwa and Sio-Siteko illustrated in Figure 2-11.

The Yala Swamp is located at the Yala River mouth and covers an area of 175 km^2. It is Kenya's largest freshwater wetland and is located on deltaic sediments of the Nzoia and Yala Rivers as they enter Lake Victoria (Ministry of Environment and Mineral Resources, 2012). The wetland contains three freshwater lakes: Kanyaboli, Sare and Namboyo. Vegetation is mainly papyrus, phramites and typha and it acts as a refuge for the threatened Sitatunga antelope. The associated lakes contain some critically endangered haplochromine fish species and the Swamp is an important bird habitat.

The Sio-Siteko wetland complex is a transboundary wetland that spans the Kenya-Uganda border. The wetland consists of interconnected secondary and tertiary subsystems that drain into Lake Victoria

(Ministry of Environment and Mineral Resources, 2012). The wetland complex has important ecosystem services, including storing and purifying water for Lake Victoria, being a source of food and livelihoods for surrounding communities and providing a rich fauna and flora diversity (Ministry of Environment and Mineral Resources, 2012).

The Kingwal Swamp is a high-altitude wetland located north of the Nandi hills. It is well known as a breeding site for the Sitatunga antelope (Ministry of Environment and Mineral Resources, 2012). It is also a habitat for crane bird population and the water berry tree which is used by communities.

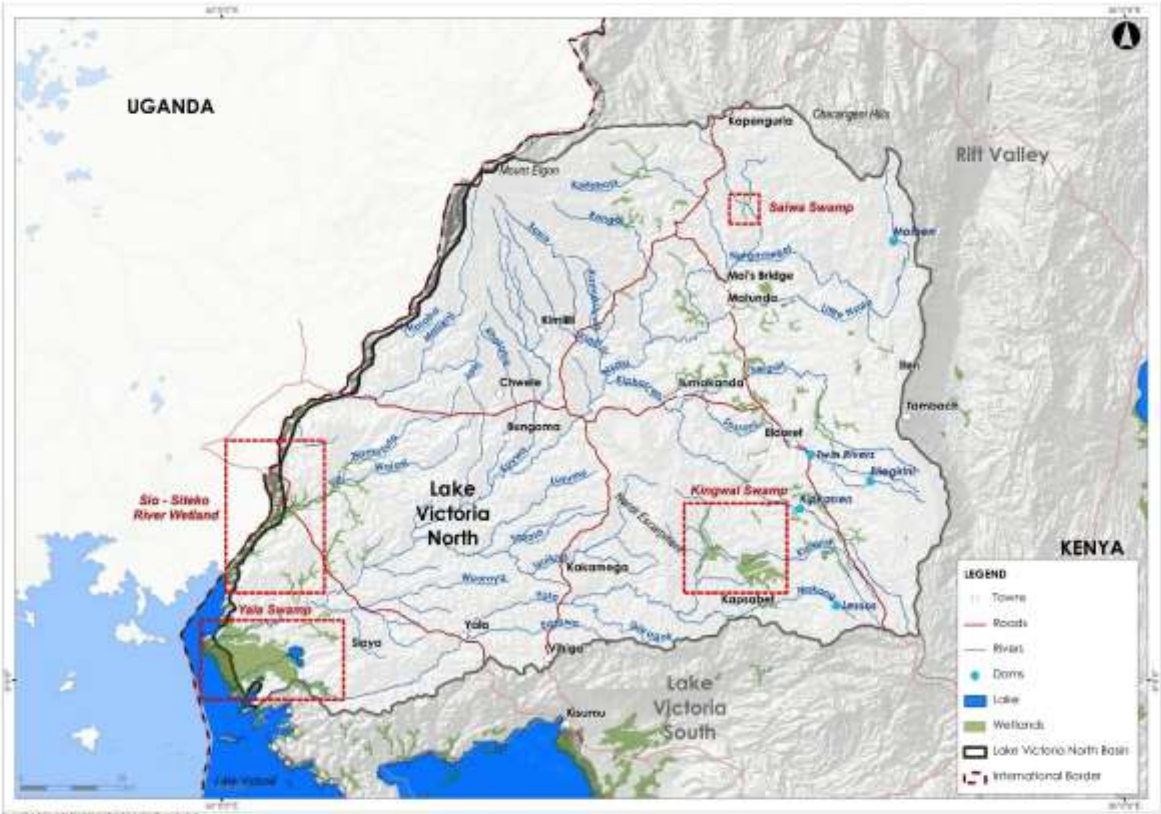


Figure 2-11: Major wetlands in the LVN Basin

2.2.2 Climate

2.2.2.1 Current climate

The climate of the LVN Basin is primarily influenced by the topography of the basin, the intertropical convergence zone (ITCZ), and its proximity to Lake Victoria (Water Resources Management Authority, 2015a). These factors contribute to the range and variability in precipitation and temperature regimes. Figure 2-12 displays the mean annual precipitation and average temperatures across the basin. Average annual maximum day temperatures vary from 18°C to 27°C across the basin, while the average annual minimum night temperatures vary from 4°C to 16°C. The central, northern, and southern parts of the basin receive higher rainfall, ranging from a mean annual precipitation (MAP) of about 1 700 mm to 1 900 mm, while the MAP reduces to about 1 000 mm in the southwestern, and north-eastern parts of the basin. The mean annual precipitation across the basin is 1 536 mm. Rainfall occurs throughout the year in the Basin, however there are two periods of higher rainfall which occur during the year, namely the long rains between March and May, and the short rains from September to November (similar to Uganda's rainy seasons). Rainfall is generally very limited between December and February. The rainfall of the Basin varies depending on the location.

Figure 2-12: Mean annual precipitation across LVN Basin

Annual and monthly average temperature and precipitation in the LVN Basin at Kitale (upper Basin) and Bungoma (middle Basin) are shown in Figure 2-13.The increasing trend in temperature since the 1960s is evident.

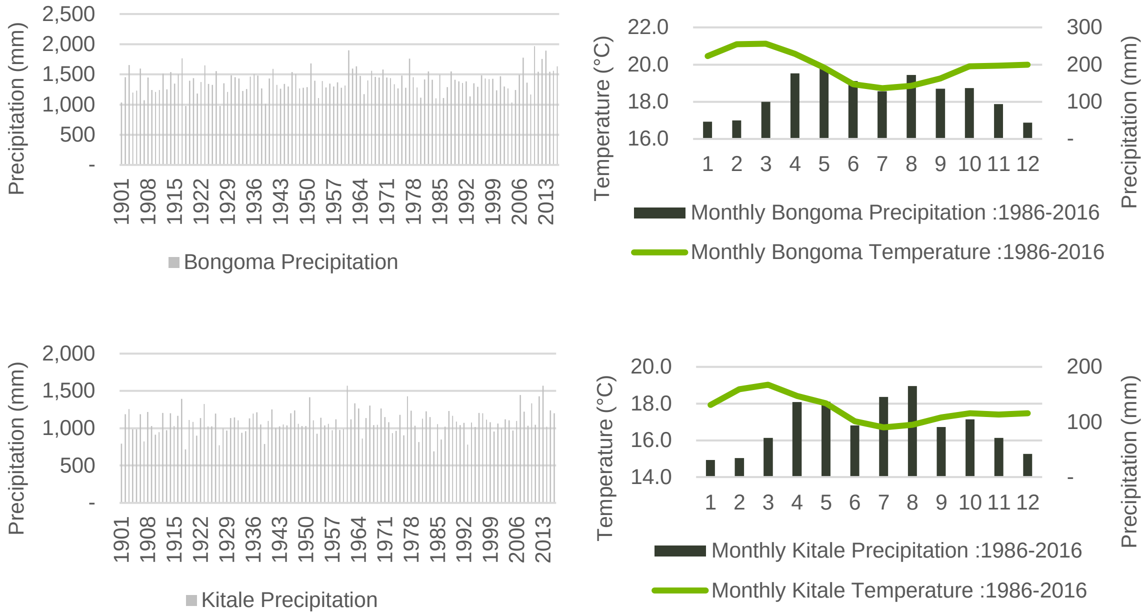


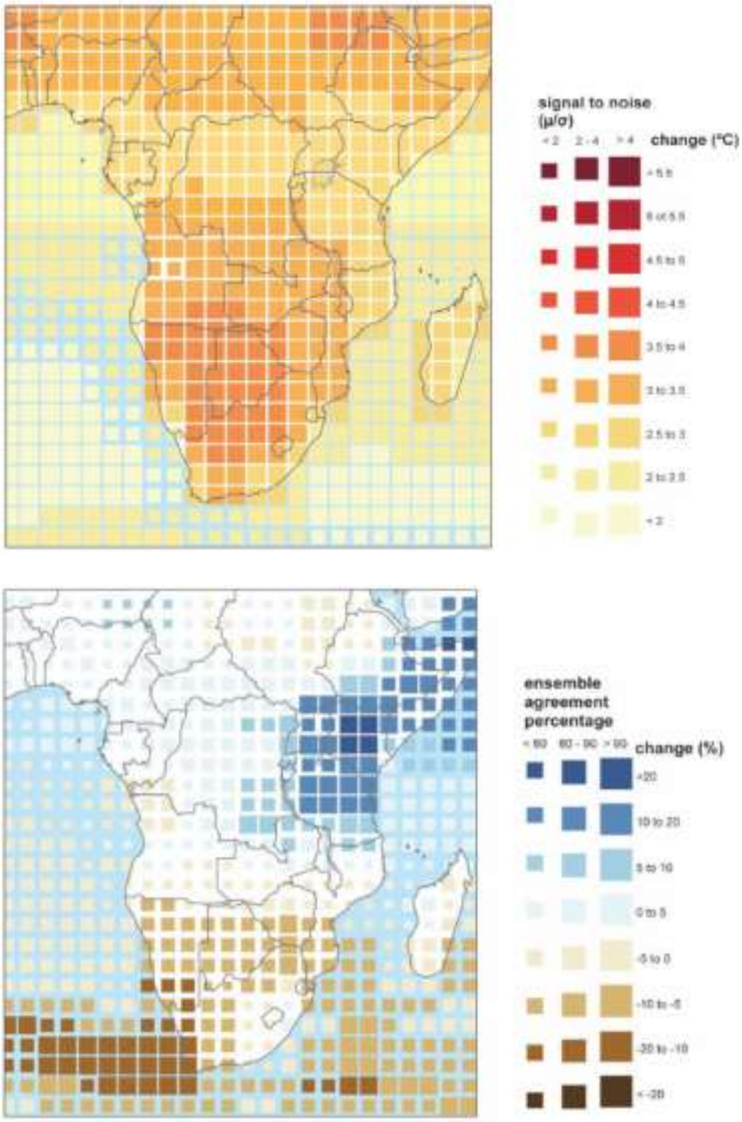
Figure 2-13: Baseline temperature and precipitation across LVN Basin

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 in order to ensure long term water security in Kenya. An effective response to climate change, combining both mitigation and adaptation strategies, will be imperative in achieving sustainable development and enhancing resilience.

Figure 2-14 shows the expected changes in precipitation and temperature across parts of Africa by 2100 and indicates that rainfall and temperature over Kenya are expected to increase. This is likely to change the risk and vulnerability profiles of Kenya and its basins.

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



*From 1960-1990 baseline climate, percentage change in average annual precipitation, averaged over 21 CMIP3 models.
Source: Met Office (2011).

Figure 2-14: Visualisation of GCM predictions of temp (top) and rainfall (bottom) for Africa by 2100.

To assist with the assessment of climate change impacts in the LVN Basin a more detailed analysis was undertaken by analysing multiple climate projection datasets and assessing the expected climate impacts on more localised precipitation and flow in the LVN Basin sub-basins (refer to **Annexure A2**).

The climate analysis showed a general increase (between 4% and 5%) in mean annual precipitation (MAP) across the LVN Basin by 2050, with the average MAP across the basin increasing from 1536 mm to 1 606 mm by 2050 under RCP 4.5. The day and night temperatures in the basin are expected to increase by up to 1.2°C and 1.4°C respectively by 2050. The climate analysis on precipitation, indicates a consistent increase in future precipitation in the sub-basins during the 'short' rainy season between September and November as well as during the dry months of January and February. There is also a significant increase in precipitation during the 'long' rainy season from March to May, however the precipitation decreases in May. During the dry season from June to August, an overall decreasing precipitation trend is observed. The climate analysis suggests that the precipitation during the rainy seasons will increase in intensities.

Projected sub-basin precipitation and temperature changes under climate change scenario RCP 4.5 were superimposed on the hydrological model of the LVN Basin to assess the potential impacts on runoff. The climate analysis on flow indicates an overall decrease in flow, this is due to high evapotranspiration and evaporation losses as a result of the temperature increase. The total surface water runoff from the LVN Basin is projected to decrease between 6% to 15% across the various sub-basins by 2050. Furthermore, it is expected that the lower flows in the river will decrease in magnitude, while the higher flows will only decrease slightly in comparison. This suggests that even though the average precipitation increases, the rivers will have lower flows due to the increased evaporation losses.

The climate change analysis which was undertaken as part of this Consultancy (refer to **Annexure A2**), showed a general increase (between 4% and 5%) in mean annual rainfall across the basin, while extreme temperatures are also expected to increase significantly. Figure 2-15 and Figure 2-16 show the expected changes in precipitation and temperature across the LVN Basin.

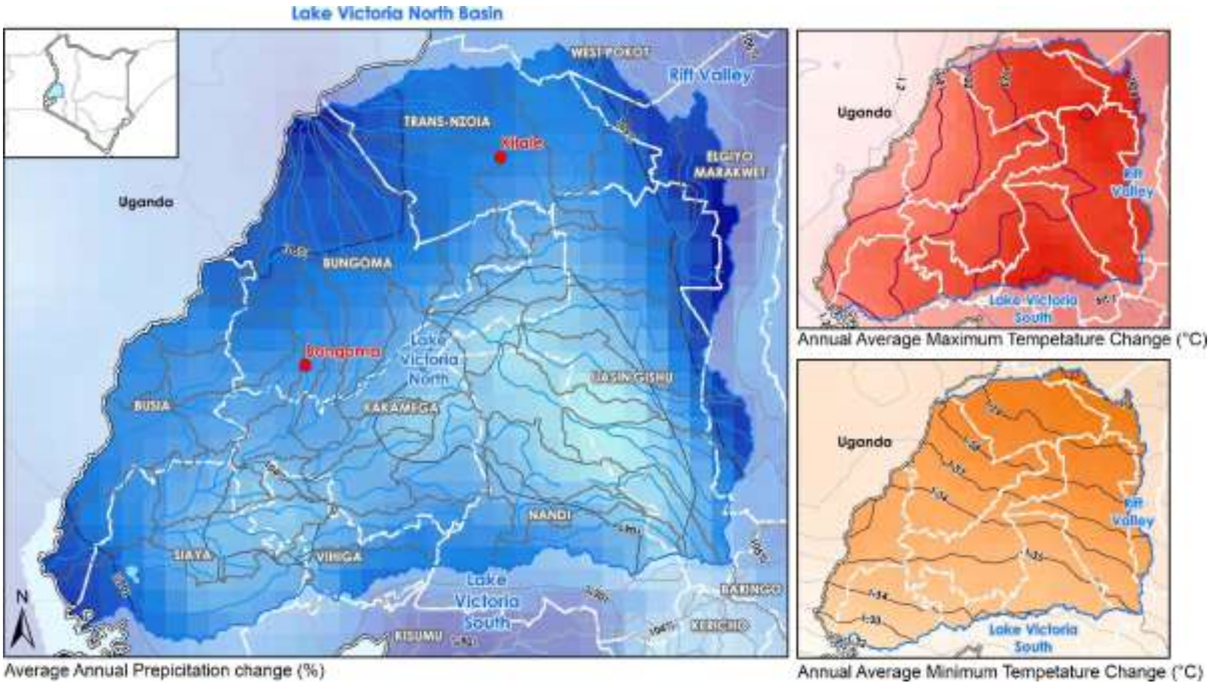


Figure 2-15: Projected Change in Mean Annual Precipitation in the LVN Basin by 2050 (RCP 4.5)

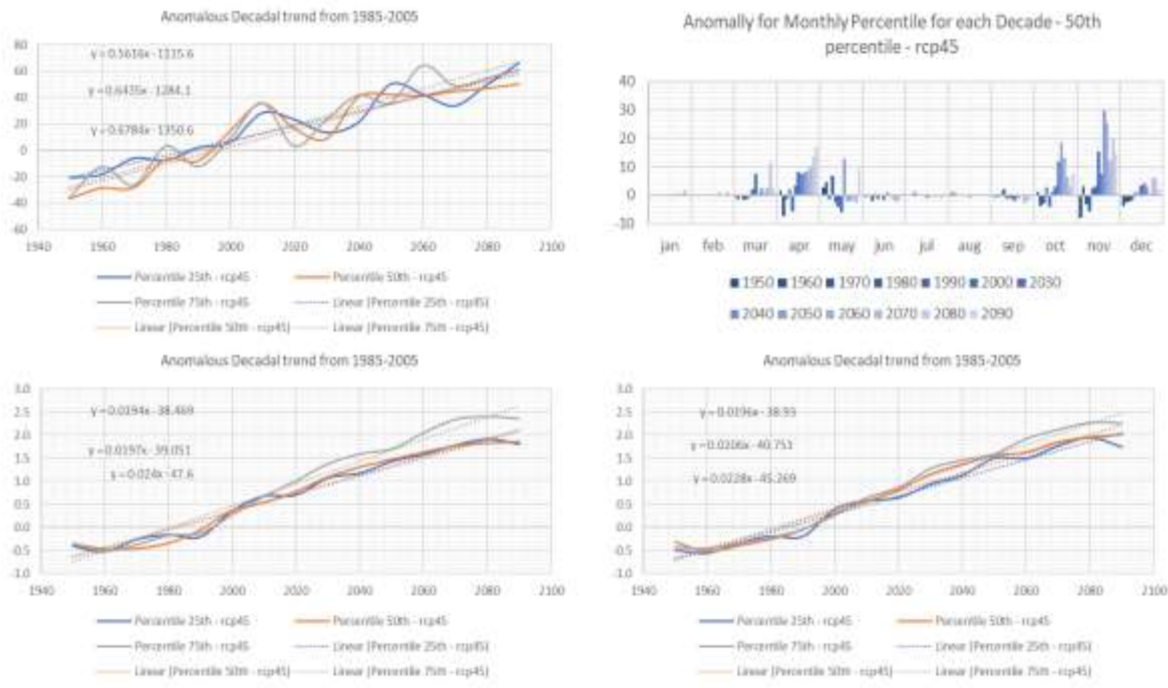


Figure 2-16: Project Tmax anomalies in the LVN Basin by 2050 (RCP 4.5)

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.

The LVN Basin forms part of the highest rainfall region in the country. The vegetation cover is mainly a mosaic of forest and evergreen vegetation, with mountain forest vegetation in the highlands.

Figure 2-17 shows the spatial variation of vegetation cover in the LVN Basin. (A high cover management factor indicates poor vegetation cover and vice versa).

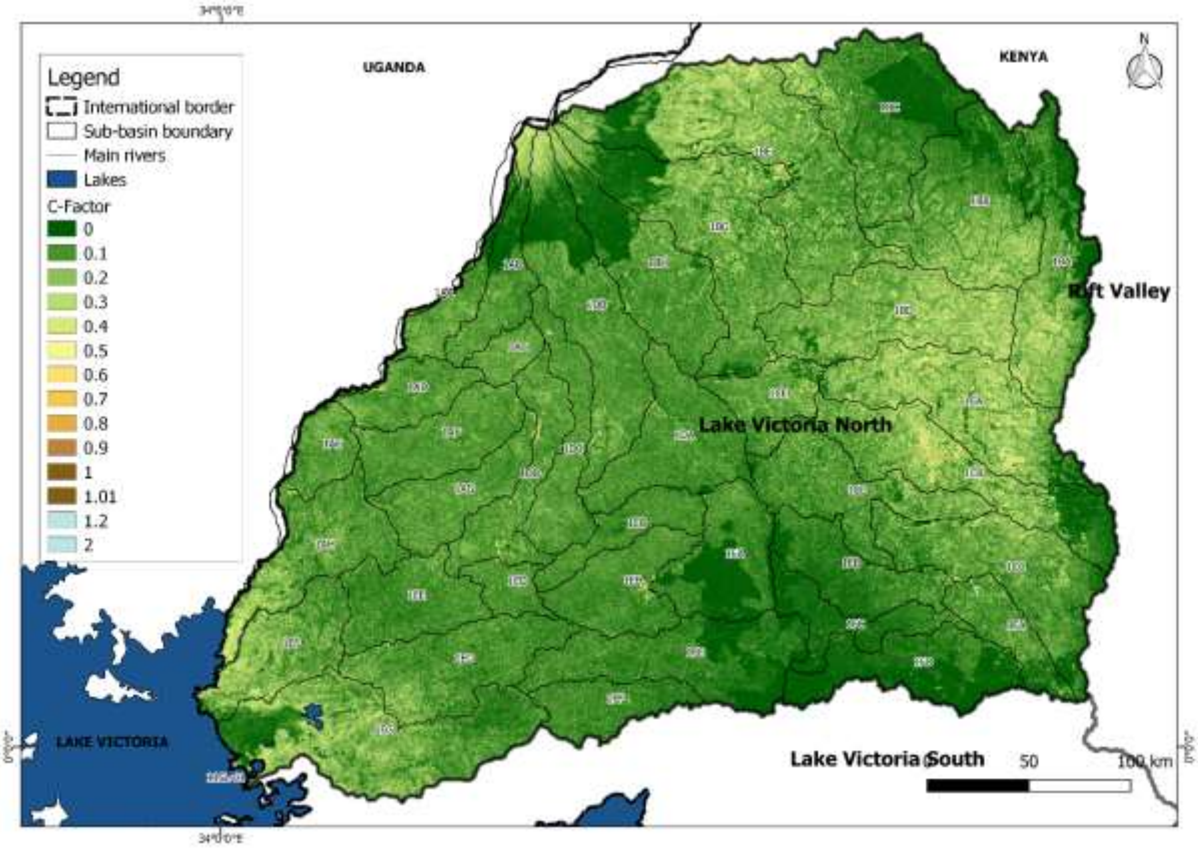


Figure 2-17: Vegetation cover in the LVN Basin

The Kenya Forest Service (KFS) is responsible for the conservation, sustainable development, management and utilisation of the country's forest resources. Catchment degradation and deforestation are a major challenge in the Basin. Forest recovery has been proposed for Mount Elgon, Cherangani Hills and Mau Forest complex as part of watershed conservation in the Basin (Water Resources Management Authority, 2015a). About 230 000 ha of forestation is proposed to achieve the target of Kenya Vision 2030.

2.2.3.2 Biodiversity

The major wetland areas in the LVN Basin are Kingwal, Yala, Sergoit, Saiwa and Sio-Siteko. Although the Yala Swamp is not a designated protected area, the ecosystem provides major ecological and hydrological functions and is a major source of livelihood for the surrounding communities. Its vegetation is dominated by papyrus, phragmites and typha. The Swamp houses many species, including the threatened Sitatunga antelope and birdlife and endangered fish species. The Sio-Siteko wetland system is shared between Kenya and Uganda. The wetland is an important ecosystem and source of livelihood for surrounding communities, and stores and purifies water flowing into Lake Victoria. Wetland degradation and encroachment is a significant issue in the Basin, especially in areas where wetlands are not protected.

Source: (Kenya Wildlife Service, n.d.)

Figure 2-18: Sitantunga antelope in the Saiwa Swamp National Park

2.2.3.3 Protected areas

The LVN Basin contains several environmentally protected areas (Figure 2-19) and is rich in freshwater and forest vegetation. The main Institution involved in environmental protection is the Ministry of Environment and Forestry; enacted through the Kenya Forest Services (KFS), Kenya Wildlife Services (KWS) and Kenya Water Towers Agency (KWTA). These departments have mandates for protecting Kenya's natural resources, ranging from forests, rivers and wetlands.

The KWS is responsible for the management of National Reserves in Kenya. The Mount Elgon National Park is shared between the LVN Basin and the Rift Valley Basin, with a total protected area of 169 km^2. Other protected areas are the Kakamega Forest (44 km^2) and Chapkitale (178 km^2) National Reserves, and the Mount Elgon, Cherangani Hills and Mau Forest Complex water conservation forests.

The KWTA is responsible for the management of areas considered to be water towers for downstream water supply. The LVN Basin has three important Water Towers: Mount Elgon, Cherangani and Mau Complex forest.

Table 2-4: The important and protected areas in the LVN Basin

County	Water Tower	Forest	Protected area	Wetland
Trans Nzoia	Mount Elgon Cherangani	Mount Elgon Forest Reserve Kitale Town Forest Reserve Sikhendu Forest Reserve (plantation) Kapolet Forest Reserve.	Mount Elgon National Park Saiwa Swamp National Park	
Bungoma	None	Mount Elgon Forest Reserve	Mount Elgon National Park	Wetlands occur
Busia	None	Natural forest on Samia and Budalang'i hills	None	Wetlands occur
Siaya	None	Hill top forests Got Abiero Ramogi Forests.	None	Yala swamp
Vihiga	None	Maragoli Hills	Maragoli Hills	Wetlands occur
Kakamega	None	Kakamega Forest Shinyalu and Lurambi natural forests Lugari commercial forest	Kakamega Forest National Reserve	Wetlands occur
Nandi	None	South Nandi forest (rain forest) North Nandi forest (rain forest)	None	King"wal swamp Kiprong swamp Kimondi swamp Birei swamp
Uasin Gishu	Mau Forest	Nabkoi forest Timborwa forest Sangalo forest Lorenge forest Kipkurere forest Kapsaret forest	None	Wetlands occur

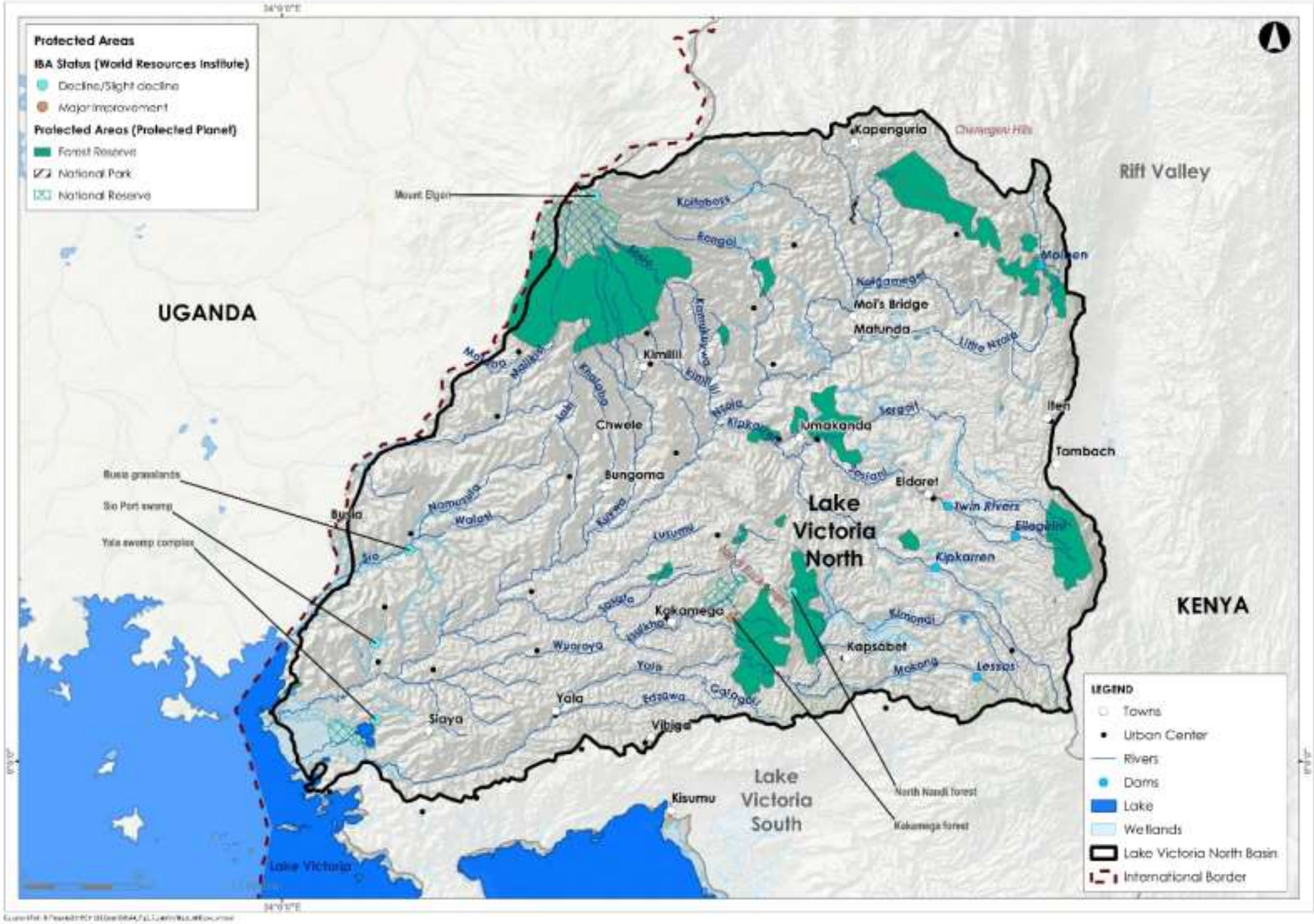


Figure 2-19: Protected areas across the LVN Basin

2.2.3.4 Land use

Land use in the LVN Basin is dominated by agricultural use, with small urban and industrial areas. The dominant land use in the LVN Basin is croplands. The total crop area in the LVN Basin in 2011 was estimated as 776 800 ha, mainly consisting of rain-fed crops (Water Resources Management Authority, 2013). The main food crops in the LVN Basin are maize, millet, bananas and cassava, while the cash crops consist of sugar cane, tea, wheat, ground nuts, maize and rice. In high potential areas, dairy farming is practiced together with traditional livestock keeping (Water Resources Management Authority, 2015a).

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

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 large parts of the basin have a soil capability of 1-3 (i.e. arable land) and that the tops of hills and mountains and steep slopes have a soil capability of 5-8 (i.e. non-arable land).

Overlaying the Land Capability map with the current land use in the basin, provides an indication of the level of sustainable land use in the basin under current conditions. From Figure 2-21, it is evident that the mountainous regions have unsustainable land uses, particularly around the lower slopes of Mount Elgon and on the boundary of the upper basin. The highest percentage of unsustainable crop land use occurs in sub-basin 1AB, followed by sub-basin 1FE.

Figure 2-20: LVN Basin land cover and use map

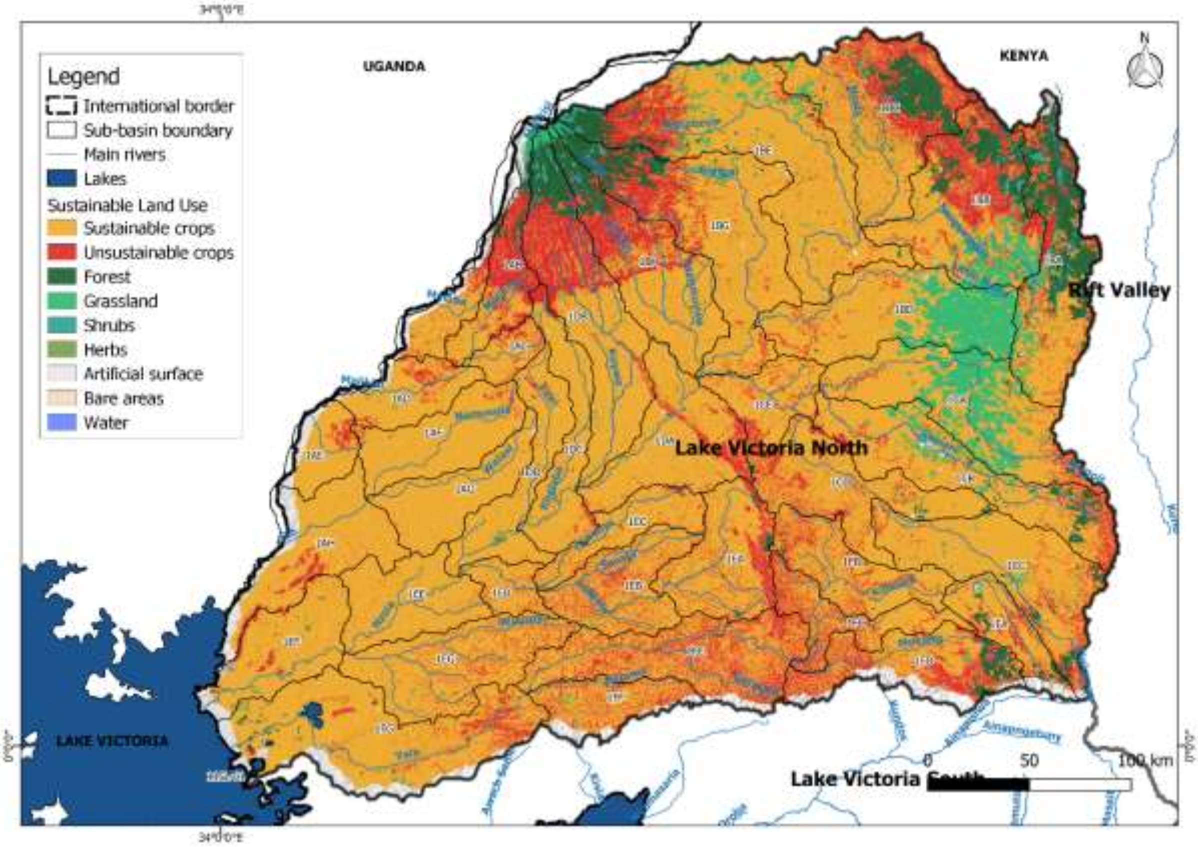


Figure 2-21: Sustainability of current land use in the LVN Basin

2.3 Socioeconomics

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

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 LVN Basin is 8.55 million, which is equivalent to a population density of 462 persons/km^2. This is the highest population density of all six river basins in the country.

Most of the population in the LVN Basin reside in rural settlements, with only 20% of the population located in urban areas. Only the Ewaso Ng'iro North Basin has a higher percentage of rural dwellers. The population of the LVN Basin is expected to increase due to high projected growth rates, particularly for the urban sector. The projected population is based on Census 2009 (Kenya National Bureau of Statistics, 2009) population data and United Nations population growth rates as estimated in the Kenya Vision 2030. The total population is projected to be 12.36 million in 2030. The rural population is projected to reduce from 5.43 million in 2010 to 4.65 million in 2030. The urban population is projected to increase from 1.53 million to 7.71 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 LVN Basin is 1.0, 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. Enrolment at primary and secondary schools is highest in Bungoma (119%, 63%), Vihaga (116%, 49%), Siaya (110%, 53%), and Kakamega (96%, 52%) counties. Busia (80%, 20%) and Elgeyo Marakwet (80%, 76%) counties have lower levels of school enrolment. (This information is not available for Nandi, Tranz-Nzoai, and Uasin Gishu counties).

2.3.2 Economy

2.3.2.1 Economic activity

The main economic activities in the Basin are agriculture and fishing. The LVN Basin's location adjacent to Lake Victoria makes the production of fish a strategic opportunity for the catchment. However, the fisheries sub-sector has been declining since 2014, with the total fish output decreasing by 12% from 2015 to 2016. Lake Victoria continues to account for over 80% of the total freshwater fish production in the country, however its output is decreasing partly due to the presence of water hyacinth and unsustainable fishing practises.

Industrial activity in the Basin is limited to the processing of locally produced raw materials from agriculture and fishing, for example: sugar and flour milling; paper, tobacco, coffee, dairy and chemical production; and fish processing factories. Industries are in the urban areas of Eldoret (Uasin Gishu County), Bungoma, Nzoia and Webuye (Bungoma County), Kakamega (Kakamega County), Kitale (Trans Nzoia County), Busia (Busia County), Siaya (Siaya County).

Limited gold mining taking place in the Basin, with potential existing for mining of other minerals. Sand mining and quarrying for building materials occurs throughout the Basin.

Tourism occurs at present, and there is significant potential for expansion of this sector in the Basin.

The LVN Basin includes ten counties, some of them only partly, as shown in Figure 2-2.The main economic activities per county are described in Table 2-5:

Table 2-5: Main economic activity of each county

County	Economic activity	Reference
Bungoma	This county falls wholly within the LVN basin. The main economic activity in Bungoma County is agriculture. Approximately 201 655 ha of food crops are under cultivation and 86 423 ha of cash crops. Most crops are rain-fed, but there are four operational irrigation schemes in the county, located at: Kamusinga, Chebukui, Kuywa and Stabicha.The beef and dairy industries are also growing in this county. - The Kenya-Uganda railway which passes through the region has also contributed significantly to the development of urban centres and retail business. The main industries in the county are sugar milling and paper production. Other industries are tobacco, coffee, dairy and chemical production. These industries all rely on locally produced raw materials. The main industrial centres are located in Nzoia and Webuye.	(County Government of Bungoma, 2018)

County	Economic activity	Reference
Busia	This county falls wholly within the LVN Basin. The main economic activities in Busia County are agriculture, fishing and trade. - Agriculture (crop cultivation and livestock rearing) and fisheries provide for 65% of the county's earnings, and most people in the county are employed directly or indirectly in this sector. It is estimated that 63 126 ha is under food crops (maize, beans, sweet potatoes, millet, cassava), and 11 948 ha is under cash crops (cotton, tobacco and sugar cane) in the county. Irrigation schemes in the county consist of small-scale irrigation schemes ranging between 70 and 200 ha in size, and large-scale schemes totalling 8 000 ha. The crops irrigated include vegetables, melons, tomatoes, maize, sorghum and rice. - Fishing in the lake region is one of the major economic activities in the county. Approximately 5 000 families living on the lake shore rely directly on fishing for their livelihood, and 3 000 families trade in lake resources. The estimated value of fish traded in Busia county is Kshs. 1.2 billion annually. The main commercial species caught are Tilapia, Omena and Nile Perch. Cage farming of fish is being encouraged in the lake to help increase fish stocks. - The county is the main point of entry between Kenya and Uganda, accounting for the bulk of trade between the two countries. The towns of Busia and Malaba benefit from the trade of livestock, agricultural products and manufactured goods. Other urban areas in the county are Port Victoria, Bumala, Nambale and Samia. - The relatively large population provides a potentially large labour force which, if utilised well, would allow the county to be a major contributor to Kenya's economy. There is not much industry in Busia county. There are two major sugar factories, and smaller industries such as flour mills and fish processing factories exist.	(County Government of Busia, 2018)
Kakamega	This county falls wholly within the LVN Basin. The major economic activity in Kakamega County is agriculture. - Food crops cover 114 054 ha (mainly maize) and cash crops (mainly sugar cane) cover 141 429 ha. The cultivation of tea is being promoted in Khwisero, Ikolomani and Shanyalu sub-counties. Rice production is being promoted in Matungu, Mumias and Buere sub-counties. - Fish farming projects are being implemented by the County Government of Kakamega, and the Department of Fisheries is implementing a fish Farming Programme. - The Kakamega Forest is a major tourist attraction, and opportunities exist for development of tourist facilities to tap into this resource. This applies particularly to avifauna, with international interest in at least 45 species of local birds, including some threatened species. - The county is home to a large sugar producing company, Mumias sugar. Other minor industries are bakeries, small scale milk cold rooms and the fish factory in Kakamega town. There are no industrial parks in the county, and it is proposed that one is established in the town centre of Kakamega.	(County Government of Kakamega, 2017)
Trans Nzoia	This county falls wholly within the LVN Basin The leading economic activity in the Trans Nzoia County is agriculture, and it is referred to as the "bread basket of Kenya" due to its large-scale maize farms. The county is considered to be one of the most food secure in Kenya. There are about 157 068 ha under food crops, 2 590 ha under horticultural crops and 4 173 ha under cash crops. - The food crops include maize, beans, potatoes, millet, bananas and wheat, while cash crops include sugar cane, coffee and tea. Horticultural crops grown are tomatoes, cabbages, kale, avocados, oranges, mangoes, and export crops like French beans, sugar snaps, snow peas, chillies and cut flowers. - Other economic activities include dairy farming, horticulture, fishing and commerce in the commercial hub of Kitale Town. The county hosts tourist attractions such as the Mount Elgon National Park, Kitale Nature Conservancy and Saiwa Swamp National Park.	(County Government of Trans Nzoia, 2018)

County	Economic activity	Reference
Uasin Gishu	The majority of this county falls within the LVN Basin, with a very small portion of the southern tip falling into the Lake Victoria South Basin. Uasin Gishu County houses the large town of Eldoret. - The economy is dominated by dairy farming and agriculture, the main crops being maize and wheat. Bananas, macadamias, avocados and coffee were introduced during the previous CIDP period to increase crop diversity in the county. Approximately 41% of the population lives below the poverty line. There is very little industry or mining in the county. - Tourism is an important growth area for the county, and tourism products such as the Chagaiya High Altitude Training camp, the Kesses dam tourist attraction site, and the River Sosiani Nature Park were developed in the previous CIDP period.	(County Government of Uasin Gishu, 2018)
Nandi	Approximately 70% of this county falls within LVN Basin, with the remaining 30% falling within the Lake Victoria South Basin. - Agriculture is the main economic activity in Nandi County, and many households keep cattle for both the production of beef and dairy products. Food crops (maize, beans, finger millet, sorghum, sweet potatoes and cassava) cover approximately 105 087 ha, while cash crops (tea, coffee and sugar cane) account of 28 294 ha. An area of 250 ha is currently under irrigation in the county, with a total potential of 2 500 ha. The Chemise Ward irrigation scheme of 1 500 ha. - Sports events such as golf tournaments and cross-country running competitions regularly bring a number of visitors to the county. The county also hosts both Kenyan and foreign athletes and cyclists who come to the region to do high altitude training. - The county has many tea processing factories, and a number of small industries such as timber lumbering, coffee, milk, honey processing. There is an initiative to establish a textile apparel unit in the county. - There are currently no industrial parks in the County, but there is an initiative to establish one in Chemase. The purpose would be to create employment, improve agro-processing and value. - A flagship water supply initiative is planned in Nandi County. The Keben water project, is planned in partnership with the national government, and will provide water to Nandi Hills and Kapsebet town and their environs.	(County Government of Nandi, 2018)
Siaya	Approximately 70% of this county falls within LVN Basin, with the remaining 30% falling within the Lake Victoria South Basin. The latest CIDP for this county is not available, so this information is based on the previous CIDP covering the period 2013-2017. In Siaya County, agriculture and fishing are the main economic activities, and cattle and poultry are also kept. There are several fisheries in the county that process fish from Lake Victoria. Main food crops include maize, sorghum, millet, beans, cowpeas, cassava, sweet potatoes, groundnuts and finger millets, and cover 150 300 ha. - Cash crops include cotton, rice, sugar cane and groundnuts, and cover an area of 2 500 ha. Vegetables and fruit are also grown. The reclamation of 450 ha of the Yala Swamp for rice production was a significant project that increased the area under cash crops. - There is very little industry in the county, with the only officially demarcated industrial area being in Siaya town. - The mining of gold has taken place in the county on a subsistence basis for some time in Bondo, Siava, Rarieda, Ugunia and Gem sub-counties. Granite and black sand are mined in the Yala valley and sand is harvested along the beaches of the Nzoia River. There is potential to mine other minerals, precious stones and rare earth elements such as fluorite. - Some tourism is taking place, but there is still considerable growth potential for tourism in the county.	(County Government of Siaya, 2018)

County	Economic activity	Reference
Vihiga	Approximately 60% of this county falls within LVN Basin, with the remaining 40% falling within the Lake Victoria South Basin. The main economic activity in Vihiga county is agriculture. Food crops take up 40 000 ha, consisting of maize, beans, cassava, sweet potatoes, vegetables, millet and sorghum. - The major cash crops include tea, coffee, bananas and horticulture, and cover 8 000 ha. There is some conventional livestock rearing taking place in the county, with the rearing of guinea fowl and bee keeping emerging as new enterprises. - The county has very limited industrial activity. There is one tea processing factory in the county, with tea production in the county estimated to be 10.6 million kg per annum. There are also milk cooling plants, with a total production of 28.5 million litres. - Some mining of soil (for brick making, pot making and house construction), sand and stone takes place in the county. Mining is practiced on a small scale in Luanda South, Isava / Lyaduywa, south Maragoli and Muhudu wards. Prospecting for gold and other minerals is underway at Kichutu in Viyalo, Chavakali and Shiru wards. - There is high potential for increasing the tourism industry.	(County Government of Vihiga, 2018)
Elgeyo Marakwet	Half of this county falls within the LVN Basin, with the remaining half falling within the Rift Valley Basin. The main economic activity in the county is agriculture, and more than 80% of households rely on the sector for their livelihoods. Major food crops are maize, beans, wheat, bananas, green grams (mung beans), groundnuts, sorghum, millet and cow peas, covering 48 490 ha. The major cash crops include potatoes, avocados, passion fruit, mangoes, tea, coffee and pyrethrum, and cover 15 610 ha. - The main type of livestock reared is cattle, which are farmed for beef and dairy, but no ranches exist. Some bee keeping takes place, and there is potential for growth for this form of agriculture. - Sand harvesting is a major source of revenue for the county, taking place along the Kerio River. Stone crushing quarries are under construction in Rokocho. There is potential for quarrying of building stones in the southern region, and there are large deposits of Murram (used in the construction of roads) in Sergoit, Kimani and surrounding areas. There is scope for oil drilling, with one borehole in Chepsigot and more pilot drilling planned. - The county has no major industries at present, but many small "cottage industries" exist as follows: timber lumbering, coffee, groundnut, green grams, mano, milk and honey value addition. There are four major market centres in the county, located at Iten, Kapsowar, Kapcherop and Kamwosor. Additionally, small markets dealing in fresh farm produce and livestock occur throughout the county. - There is high potential for increasing the tourism industry, which includes wildlife viewing, athletics, paragliding and cultural interest. The recent opening and restocking of the Rimoi game reserve is a substantial step in this direction.	(County Government of Elgeyo Marakwet, 2018)
West Pokot	A very small section of southern West Pokot County falls within the LVN Basin, with most of the county forming part of the Rift Valley Basin. Consequently, this county is not discussed further here.	(County Government of West Pokot, 2018)

Despite the above economic activities, the average poverty rate in the LVN Basin is at 46%, which is still significantly high. The County in the Basin with the highest poverty rate is Busia County, with a poverty rate of 60%. The next highest rate is 53%, for Elgeyo Marakwet County. Uasin Gishu County has the lowest poverty rate of 34% (Wiesmann et al., 2016).

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. However, there is also a small degree of formal employment in rural areas e.g. for large-scale irrigation and tourism.

The informal sector, also known as *jua kali*, employs 43% of the labour force in the LVN 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.

Livelihoods refers to a person's means of securing the basic necessities of life (i.e. food, water, shelter and clothing). Engaging in livelihood activities involves acquiring knowledge, skills, social network, raw materials, and other resources to meet individual or collective needs on a sustainable basis. Investing in livelihood activities reduces the costs associated with the provision of aid and protection; and builds self-reliance. The sources of livelihood vary across the basin, from fishing in the coastal areas to subsistence agriculture and crop and livestock production in the pastoral and farming areas. The livelihoods of the various counties are described in Table 2-6 below.

Table 2-6: Livelihood activity of each county

County	Livelihood activity	Reference
Bungoma county	Most of the wage earners in Bungoma county are employed in the agricultural sector. As previously mentioned, the industries in the county are sugar milling, paper production, tobacco, coffee, dairy and chemical production, and the main industrial centres are located in Nzoia and Webuye. The county has high levels of unemployment, especially amongst the youth. Most of the labour force, especially the unemployed, are unskilled. Low incomes and high levels of poverty have been identified as main development issues in the county. The poverty rate of the County was estimated to be 47% (Wiesmann et al., 2016).	(County Government of Bungoma, 2018)
Busia county	Approximately 49% of the population is earning a wage, most of these jobs being in the agricultural sector. The labour force is largely unskilled, and the establishment of vocational training institutions is seen as a need. The county has a high unemployment rate of 67%, and the creation of employment opportunities is a continued challenge. The poverty rate of the County was estimated to be 60% (Wiesmann et al., 2016).	(County Government of Busia, 2018)
Kakamega county	Approximately 80% of wage earners in the county are employed in the agricultural sector, mainly in the rural areas. Other sectors employing wage earners are environmental protection, water, housing, energy, infrastructure and information communication technology (ICT) sectors. Many of these jobs are seasonal and temporary, for example casual employment on farms during planting or harvesting seasons. The poverty rate of the County was estimated to be 49% (Wiesmann et al., 2016).	(County Government of Kakamega, 2017)
Trans Nzoia county	Most people in the county are involved in farming: combining the rearing of animals with the growing of crops. The main crops grown are maize, bananas, wheat, coffee and tea, with horticultural crops and fruit becoming more common. Livestock is mainly used for meat and milk production. The number of wage earners in the county is estimated to be 450 952, most of which are located in the rural areas. Most of these (65%) are self-employed. Approximately 23% of the total wage earners are employed in the formal sector, 44% in the informal sector, and 33% in the small-scale agriculture sector. One of the major goals of the CIDP is to create employment for at least 20% of the population through industrialisation programmes. The poverty rate of the County was estimated to be 41% (Wiesmann et al., 2016).	(County Government of Trans Nzoia, 2018)
Uasin Gishu county	Information on the percentage of the population who are earning wages is not available, but there is a need for additional employment opportunities, particularly among the youth. Land issues have led to 'land grabbing' problems. The poverty rate of the County was estimated to be 34%	(County Government of Uasin Gishu, 2018)

County	Livelihood activity	Reference
	(Wiesmann et al., 2016).	
Nandi county	Approximately 54% of the population are wage earning. A small portion of these people work in the formal sector, while the majority are self-employed, in the informal sector, and agricultural activities including small-scale agriculture and pastoralism. Average farm size is reducing because of the rapid increase in population and the demand for land. This fragmentation of land is likely to have an adverse effect on overall food production and land productivity. The poverty rate of the County was estimated to be 40% (Wiesmann et al., 2016).	(County Government of Nandi, 2018)
Siaya county	The population is largely rural and over 70% is engaged in agriculture, which is the main source of income in the county. The poverty rate of the County was estimated to be 38% (Wiesmann et al., 2016).	(County Government of Siaya, 2018)
Vihiga county	Agriculture provides 70% of employment opportunities. Most wage earners are in the agriculture and rural development sector. There have been diminishing opportunities for formal employment in the county, resulting in an increase in levels of unemployment, particularly amongst the youth. This in turn has resulted in high dependency ratios, and the fact that those who are employed have limited ability to save and invest. The poverty rate of the County was estimated to be 39% (Wiesmann et al., 2016).	(County Government of Vihiga, 2018)
Elgeyo Marakwet county	Only 54% of the population of the county are engaged in wage employment. Most of these people (98%) are engaged in the informal sector and agricultural activities, including small-scale agriculture and pastoralism. High unemployment rates exist amongst the youth of the county. The poverty rate of the County was estimated to be 53% (Wiesmann et al., 2016).	(County Government of Elgeyo Marakwet, 2018)

2.3.3 Standard of living

2.3.3.1 Water supply and sanitation

There are currently five large dams in the LVN Basin (with storage in excess of 1 MCM) supplying mainly urban and domestic demands, as well as many small dams and pan. The total storage volume in the basin is estimated at about 32 MCM.

There is currently one bulk water supply intra-basin transfer from Moiben Dam to Eldoret/Iten and to Tambach (in the Rift Valley Basin), with a total transfer capacity of 8 MCM per annum. Groundwater supplies make up approximately 41 MCM per annum from 1,776 boreholes, and mainly supply domestic needs (Water Resources Management Authority, 2013).

Based on 2009 Census data, the total population in the LVN Basin in 2009 was approximately 7 million, of which 1.5 million live in urban areas (concentrated in Eldoret and surrounding areas) and 5.5 million live in rural areas. Water Service Providers (WSPs) mainly supply the urban population, while the rural population is served by small community-based water supply schemes.

At present, about 31% of the urban population in the basin receive piped water provided by WSPs, while 16% are dependent on unimproved water sources (3% from water vendors and 13% as direct use from rivers, ponds and lakes). The remaining 53% are supplied from groundwater, which include protected and unimproved sources. In rural areas, 25% of the population abstract water directly from rivers, ponds and lakes, 70% use groundwater and 0% are supplied by water vendors. The rural population in the basin also has a much lower percentage of piped water supply at only 5% compared to the urban population at 31% (Water Resources Management Authority, 2013). In total, about 66% of water users in the LVN Basin are supplied directly from springs and boreholes, while only 11% of the population receive piped water via a Water Services Provider (WSP) (Table 2-7).

Table 2-7: Existing access (%) to water supply infrastructure in the Basin

Type	Piped supply by WSP (%)	Spring / Borehole	Water Vendor	Stream/ Lake
Urban	31	53	3	13
Rural	5	70	0	25
Total	11	66	1	22

Source: 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). There are six urban WSPs and three rural WSPs in the Basin, and together these WSPs provide a capacity of 113,106 m^3/day. The non-revenue water (NRW) of these WSPs ranges from 25% to 64% (average of 48%), which largely contributes to the low number of people receiving piped water.

Approximately 2% of the households in the LVN Basin are connected to a formal sewerage system, all of which are in urban areas. On-site sanitation facilities like pit latrines and septic tanks are used by 94% of the population, while 4% of the population have no form of sanitation system and resort to unsanitary waste disposal.

Most of the urban and rural populations make use of septic tanks and pit latrines for sanitation. There are currently no formal sewerage systems in the rural areas, and only 7% of the urban population has access to a formal sewerage system (Table 2-8).

Table 2-8: Existing access (%) to sanitation infrastructure in the Basin

Type	Sewerage System (%)	Septic tank/ Pit latrine (%)	Bush (%)
Urban	7	92	1
Rural	0	95	5
Total	2	94	4

Source: Water Resources Management Authority, 2013

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 land owner. This system dates from the Crown lands Ordinance of 1902 which declared that all waste and unoccupied land in the protectorate was crown land.
- **Foreign access to land in Kenya:** a person who is not a citizen of Kenya may hold the land as part of a leasehold tenure and this lease should not extend before 99 years.

The land tenure trends for the counties in LVN Basin are described in Table 2-9:

Table 2-9: Land tenure of each county

County	Land Tenure	Reference
Bungoma	Only 35% of land parcels in the county have title deeds, and 66% of households live on ancestral lands with no official documents of ownership.	(County Government of Bungoma, 2018)
Busia	This county consists mostly of ancestral land (92%), and 72% of this land has been demarcated with title deeds issued. The County Government is focusing on the demarcation and issuing of title deeds. As the population of the county increases, land currently being used for forestry and agriculture is under pressure, and this trend is expected to continue.	(County Government of Busia, 2018)
Elgeyo Marakwet	The proportion of parcels with title deeds in the county has increased from 29% to 50%. Most of these are in the highlands, where private ownership of agricultural land has been the norm. The process of adjudication is still taking place in the Kerio Valley, which consists mainly of community land. Delays have been caused by security incidents and intra and extra clan issues.	(County Government of Elgeyo Marakwet, 2018)
Kakamega	Approximately 95% of land in the county is categorized as private land, with the remaining land being public land or registered as leasehold or freehold interest. Land with title deeds is estimated at 39%. This low percentage is attributed to the lengthy land adjudication process and land tenure system. Most of the population of the county have access to land, although in many cases it is small, and many people live on their ancestral land.	(County Government of Kakamega, 2017)
Nandi	Approximately 80% of landowners have title deeds. Those without titles are mainly in urban centres other than Kapsabet, Koilot, Ndalt and Nandi Hills, company farms and individuals squatting on public lands. Title deeds are not collected from the Registry because of financial constraints of landowners, and intervention and assistance may be required to rectify this.	(County Government of Nandi, 2018)
Siaya	Most of the land in the county is private land, with the remainder being public or communal land. As at 2012, 259 124 farmers had been issued with title deeds, although many of these title deeds need to be updated with the current occupiers of the land. There is little landlessness in the county, but the trend of leasing or selling land for commercial endeavours has the potential to cause this. The high population densities in Uganja, Gem and Ugenya and limited land for agriculture make these areas vulnerable.	(County Government of Siaya, 2018)
Trans Nzoia	The percentage of landowners with title deeds improved to 40% in 2017, from 30% at the beginning of the previous CIDP period of 2013-2017. Landlessness in the county takes the form of squatter and informal settlements which have formed on public land.	(County Government of Trans Nzoia, 2018)
Uasin Gishu	Most of the land in this county does not have formal titles, which has led to 'land-grabbing' taking place. This CIDP aims to issue 2 500 title deeds by 2022.	(County Government of Uasin Gishu, 2018)
Vihiga	Only 28% of land has title deeds, while the rest of the county is ancestral land. An estimated 3% of households are landless, leading to the invasion of the Maragoli hills and Kibili Forests for settlements. Additionally, people have moved to adjoining counties.	(County Government of Vihiga, 2018)

2.4 Water resources

2.4.1 Surface water resources

2.4.1.1 Conceptual approach to surface water resources assessment

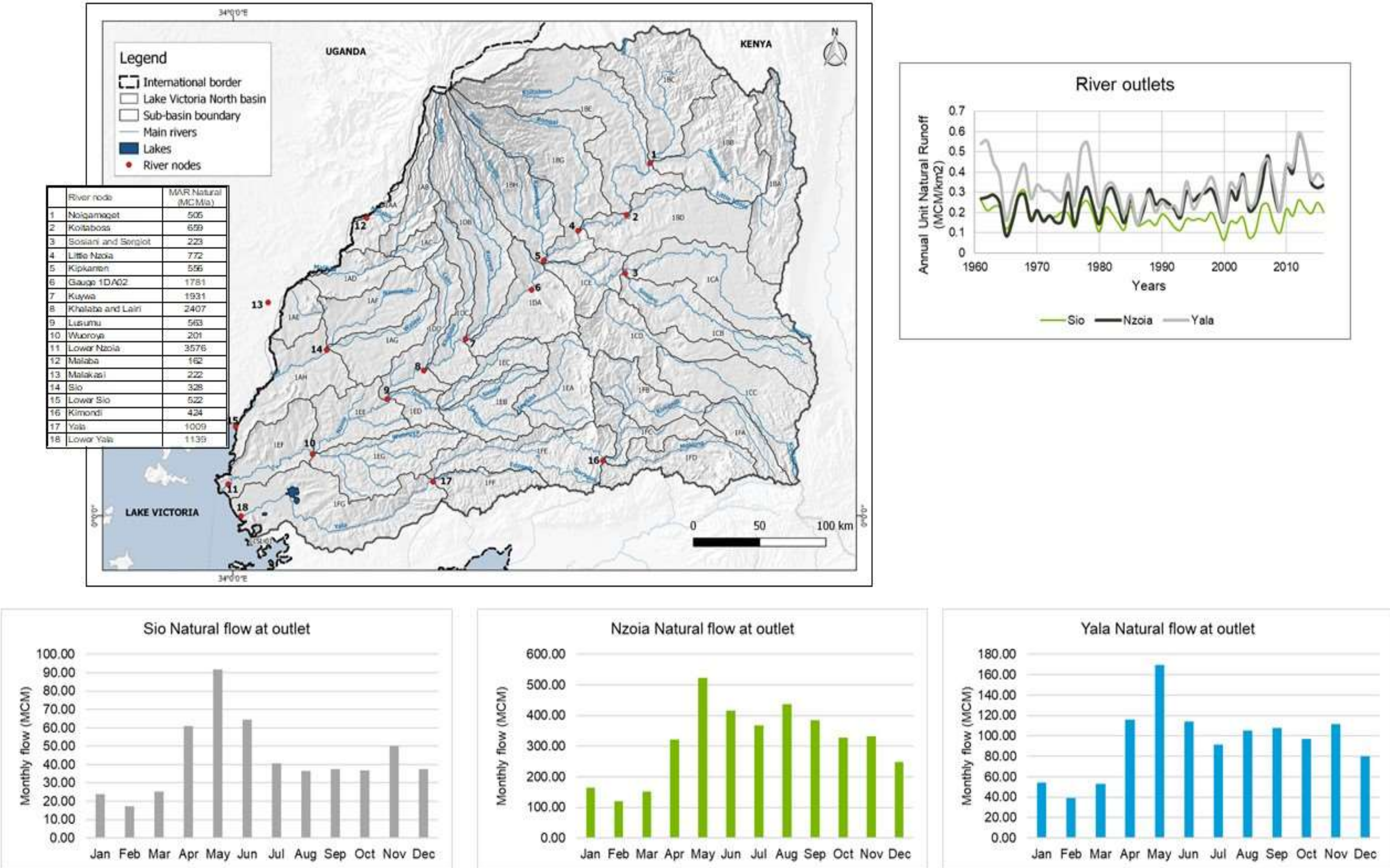
A surface water resources analysis for the LVN Basin was undertaken to quantify the available surface water within the basin under natural conditions in both space and time (refer to **Annexure A3**). This involved the development of a water resources systems model of the basin, including a rainfall-runoff model. Based on the availability of historical rainfall data, a simulation period from 1960 to 2017 was used for the model simulations, conducted at a daily time-step. MIKE HYDRO Basin, which incorporates the NAM rainfall-runoff model, was used as the water resources systems model. The water resources modelling task involved several 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 LVN Basin are provided in "ISC Report C1-2: Lake Victoria North Surface Water Resources Assessment".

2.4.1.2 Surface water resources potential

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

- The total basin natural runoff equals 5 622 MCM/a.
- More than 90% of the total basin runoff originates from the Nzoia, Yala and Sio rivers combined, i.e. 64% from the Nzoia (3 576 MCM/a) 20% from the Yala (1 139 MCM/a) and 9% from the Sio (522 MCM/a).
- The Malakasi River with a natural discharge of 222 MCM/a (4% of the total basin runoff) drains into Uganda.
- The Malaba River, which also flows into Uganda, has a natural mean annual runoff of 162 MCM/a, equivalent to less than 3% of the basin runoff.
- The month of May generally has the highest runoff, with elevated flows from April to December.
- The lowest runoff occurs from January to March.



	River node	MAR Natural (MCM/a)
1	Noigameget	505
2	Koitaboss	659
3	Sosiani and Sergiot	223
4	Little Nzoia	772
5	Kipkaren	556
6	Gauge 1DA02	1781
7	Kuywa	1931
8	Khalaba and Lairi	2407
9	Lusumu	563
10	Wuoroya	201
11	Lower Nzoia	3576
12	Malaba	162
13	Malakasi	222
14	Sio	328
15	Lower Sio	522
16	Kimondi	424
17	Yala	1009
18	Lower Yala	1139

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

2.4.1.3 Seasonal flow variability

All the rivers in the basin generally have high flows between April and December. However, January to March are characterised by lower flows. To assess the extent to which the seasonal flows in the rivers vary, a Seasonal Index Map was developed (Figure 2-23), which expresses the cumulative natural flow volume during the three driest consecutive months, as a proportion of the total annual natural flow volume per sub-basin. From the map it is evident that large parts of the basin are characterised by low flows during the dry season.

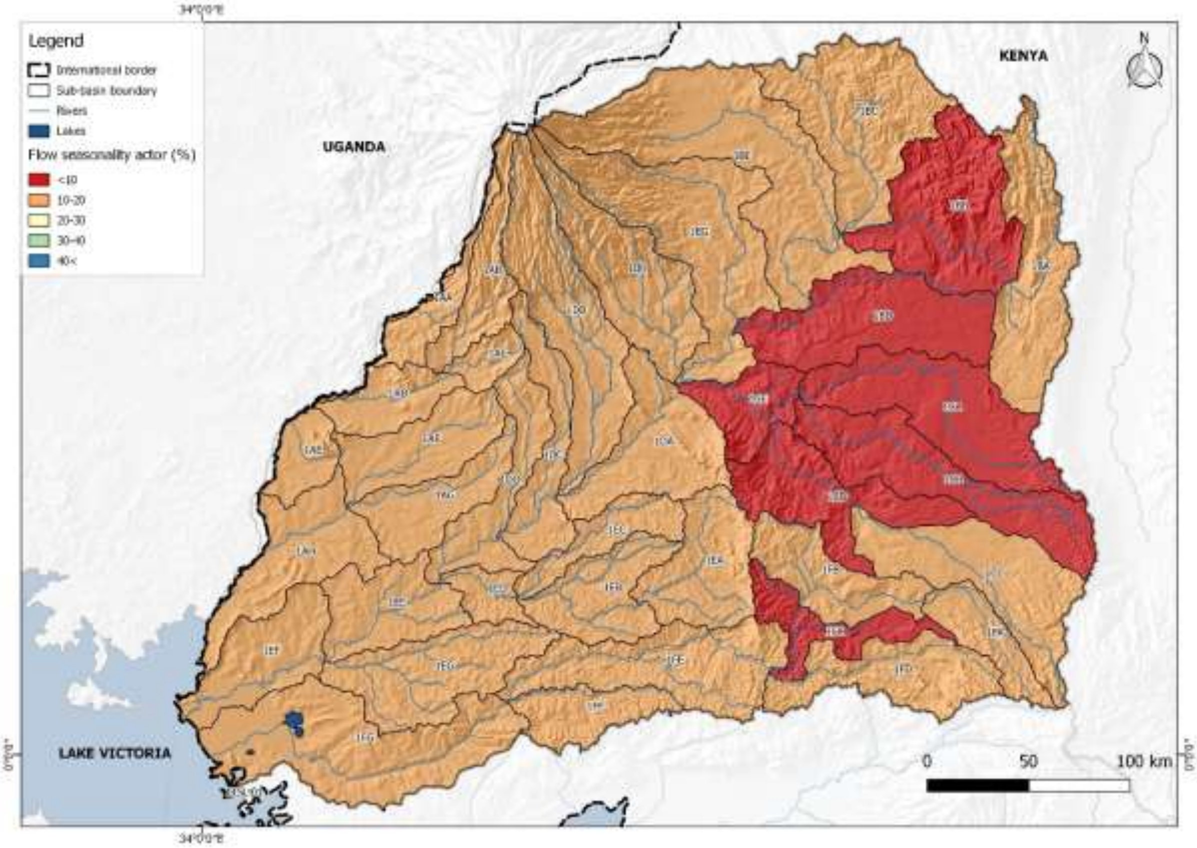


Figure 2-23: Flow seasonality Index per sub-basin

2.4.1.4 Annual flow variability

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

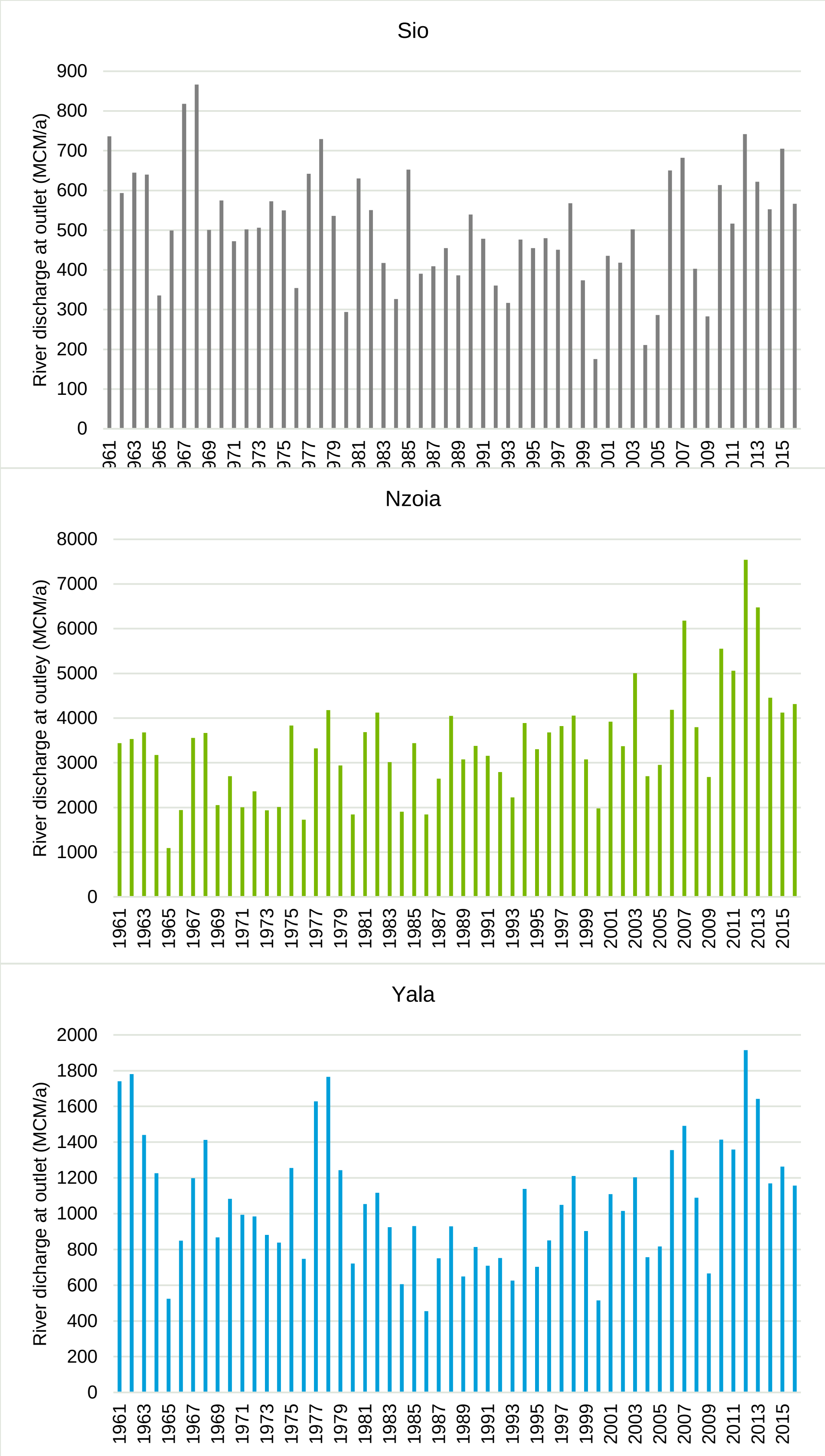


Figure 2-24: Annual flow variability in the three main rivers in the LVN Basin

2.4.1.5 Unit runoff

Unit runoff is defined as the depth of runoff (mm) from a catchment area and as such allows for direct comparison between geographically distinct areas. Figure 2-25 shows calculated natural unit runoff values at sub-basin scale in the LVN Basin and highlights the relatively high unit runoff in the central part of the LVN Basin as well as the progressively lower unit runoff values towards the upper part of the basin. The sub-basins on the border of Lake Victoria, again display lower unit runoff values.

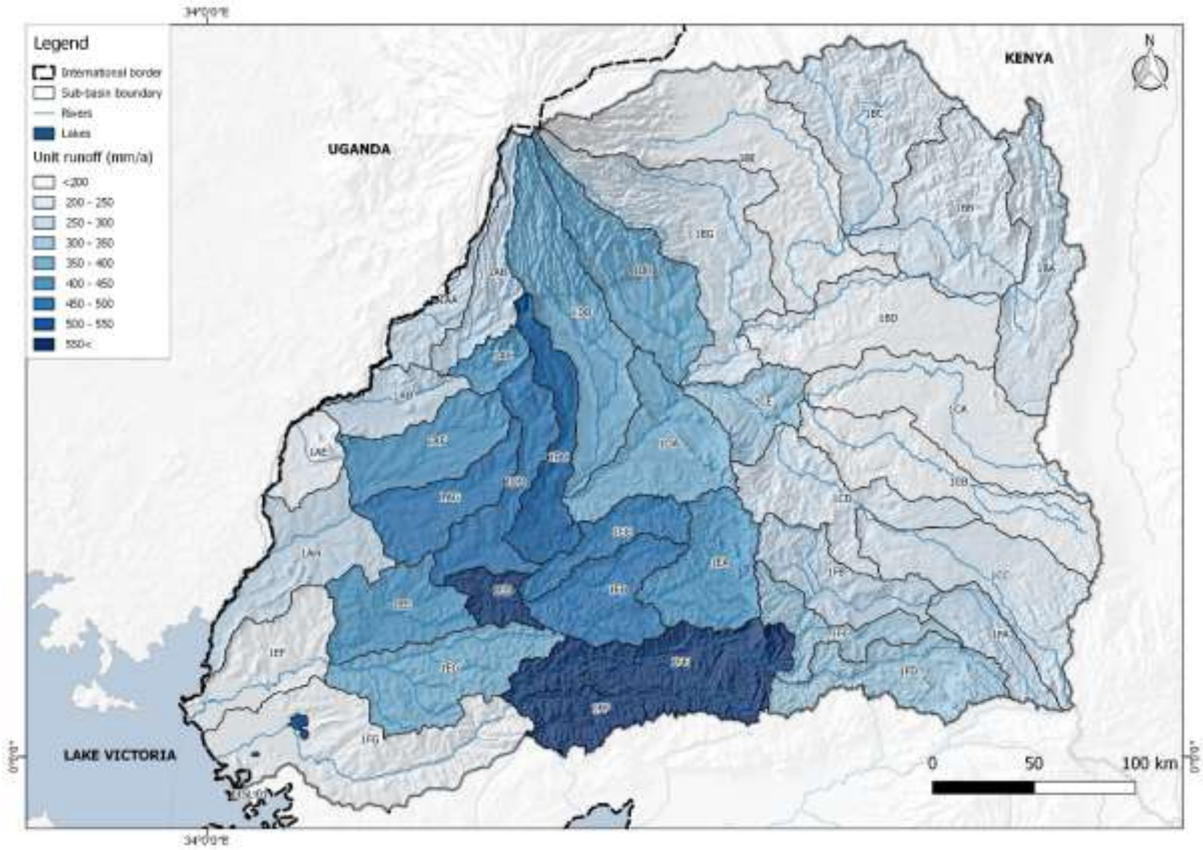


Figure 2-25: Unit runoff per sub-basin

2.4.1.6 Runoff coefficient

The runoff coefficient is a coefficient relating the amount of runoff from a catchment to the amount of precipitation received. It is typically a function of soils, topography, vegetation and rainfall intensity. A high runoff coefficient indicates lower interception, lower infiltration and higher runoff associated with steeper areas, while a lower runoff coefficient is associated with higher permeability, denser vegetation and more gentle topography. As shown in Figure 2-26, most of the sub-basins in the LVN basin have runoff coefficients above 10%, with some of the sub-basins in the central part of the basin characterised by runoff coefficients as high as 30%. The average runoff coefficient across the basin equals 20%.

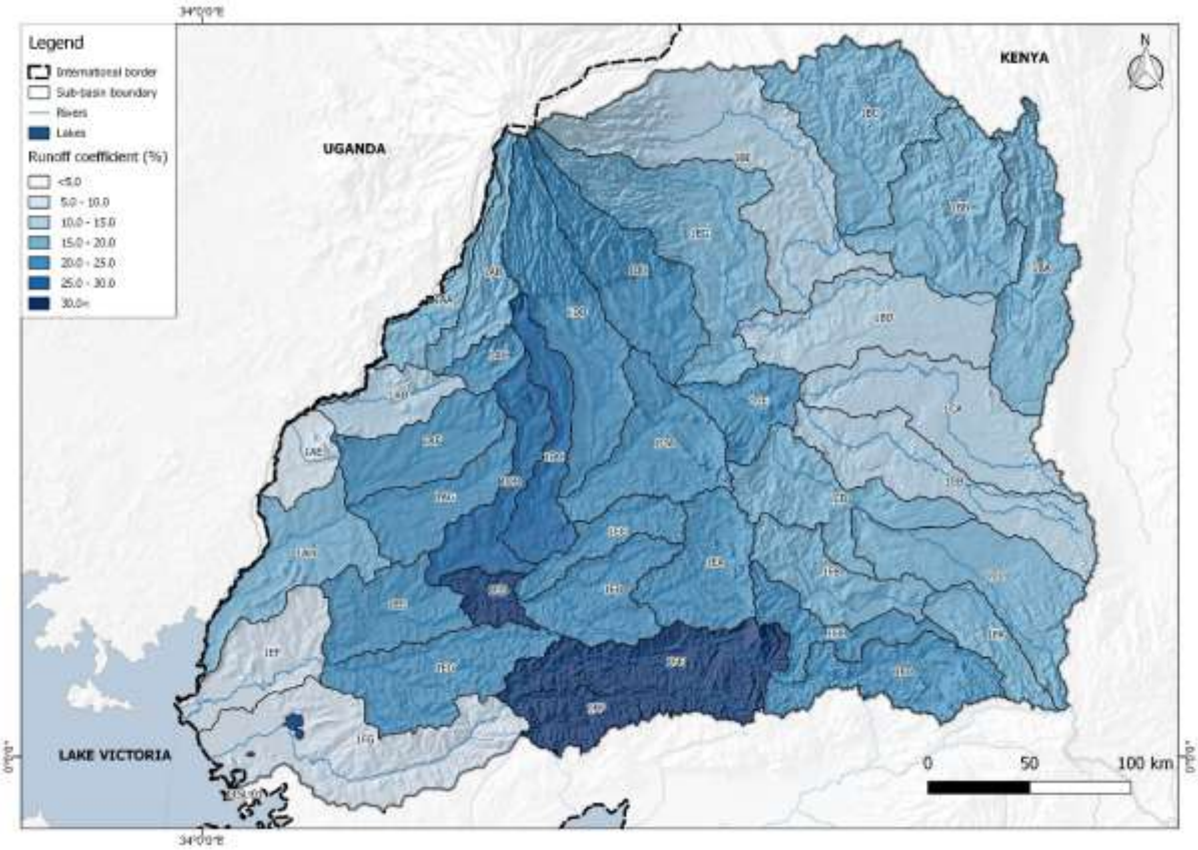


Figure 2-26: Runoff coefficient per sub-basin

2.4.1.7 Impacts of climate change on surface water resources

The climate change analysis which was undertaken as part of this Consultancy (refer to **Annexure A2**), showed that projected future precipitation totals are varied across the LVN Basin. On average, the RCP 4.5 analysis predicted that the Mean Annual Precipitation across the LVN Basin would increase on average by 70 mm, from 1 536 mm to 1606 mm, while day and night temperatures in the basin are expected to increase by up to 1.2°C and 1.4°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 LVN Basin to assess the potential impacts on runoff. Figure 2-27 shows that the natural runoff in the basin is expected to decrease between 6% and 15% in most areas across the basin, with the largest decrease occurring in the Yala swamp sub-basin (1FG). The total surface water runoff from the LVN Basin is projected to decrease with almost 8% to 5 177 MCM/a under RCP 4.5. Even though rainfall is projected to increase, the expected increase in temperature and associated evapotranspiration due to the dense vegetation in the basin, will thus result in a net reduction in surface water runoff from the basin.

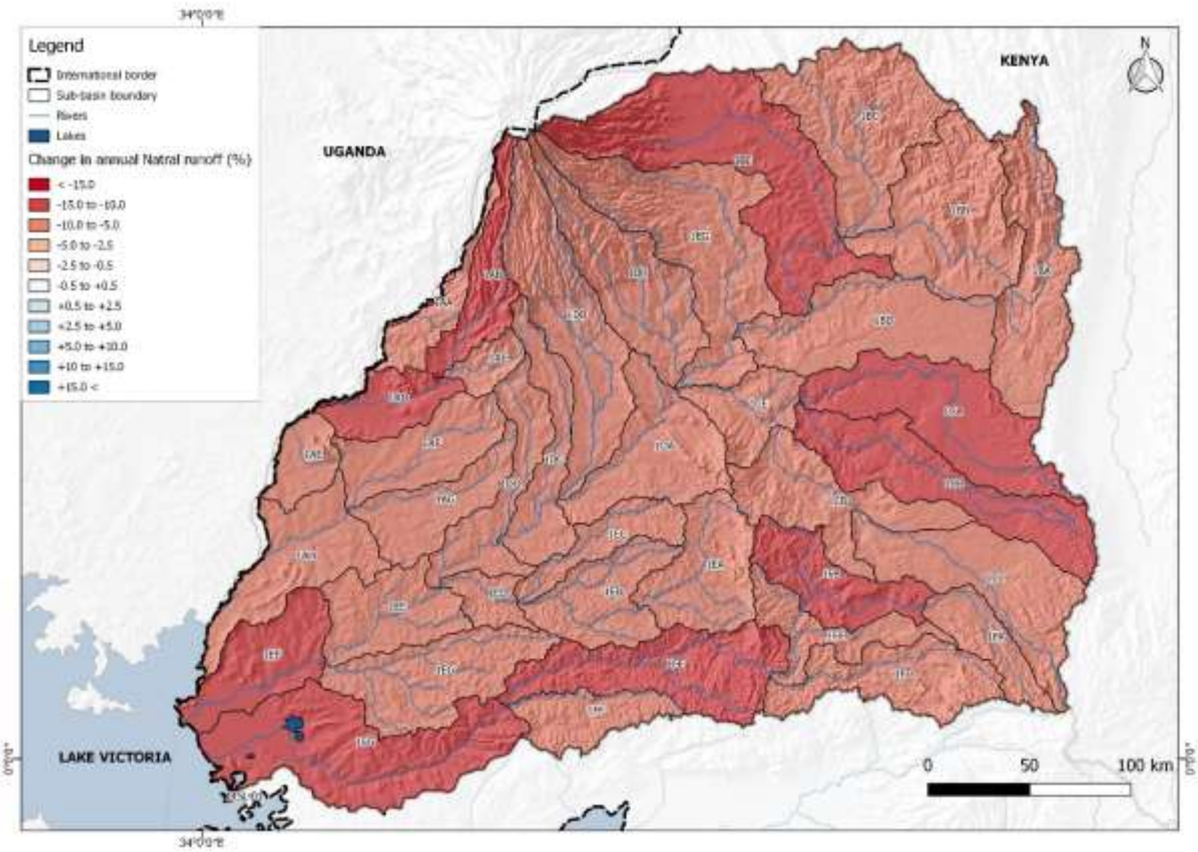


Figure 2-27: Climate change impacts on natural runoff in the LVN Basin 2050 (RCP 4.5)

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 LVN Basin was undertaken as part of this Consultancy (see **Annexure A4**). This entailed a GIS-based approach that used existing data at a national scale. Datasets were derived from macro and secondary geology, topography, rainfall and estimates of recharge, which were categorised and weighted to quantify groundwater availability / potential. While this approach allows for assessments at any scale, it provides generic data sets best suited for rapid and regional-scale groundwater resource assessments and does not replace the need for detailed resource assessments for areas with high groundwater competition or water quality concerns like saline aquifer intrusion, for example. The adopted approach takes local rainfall-groundwater recharge relationships and local lithological and structural permeabilities into account, and therefore is not applicable for deep-seated aquifers located far from their recharge source. It aims to capture most 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 LVN Basin was estimated at 1,508 MCM/a, with a sustainable annual groundwater yield of 216 MCM/a. This is significantly higher than the NWMP 2030 sustainable groundwater yield estimate of 116 MCM/a for the LVN Basin. However, whereas the NWMP 2030 assumed sustainable yield as a percentage of recharge (10%), the groundwater assessment which was conducted as part of this Consultancy estimated sustainable yield based on regional and secondary permeability and topography. Figure 2-28 and Figure 2-29 display the recharge and potential groundwater availability in the LVN Basin. High groundwater potential is found throughout the basin.

Annexure B lists the groundwater potential per sub-basin.

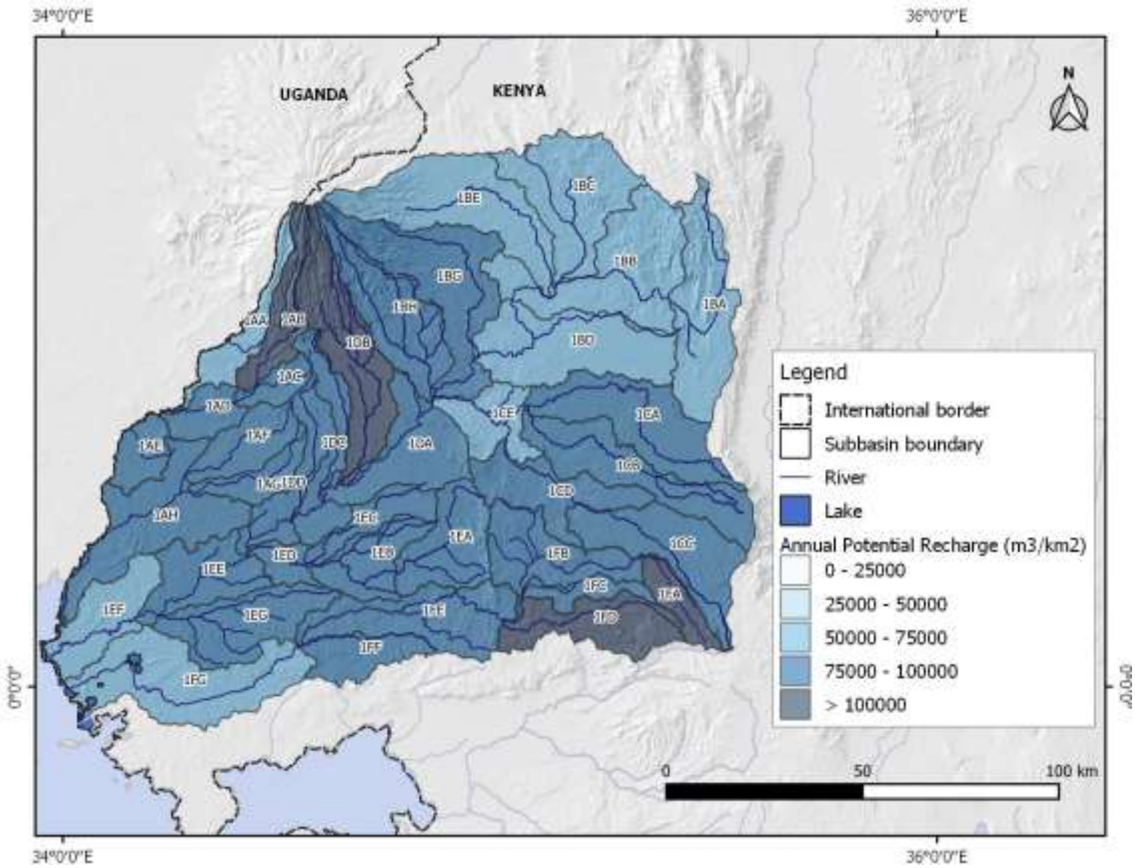


Figure 2-28: Estimated annual groundwater recharge in the LVN Basin

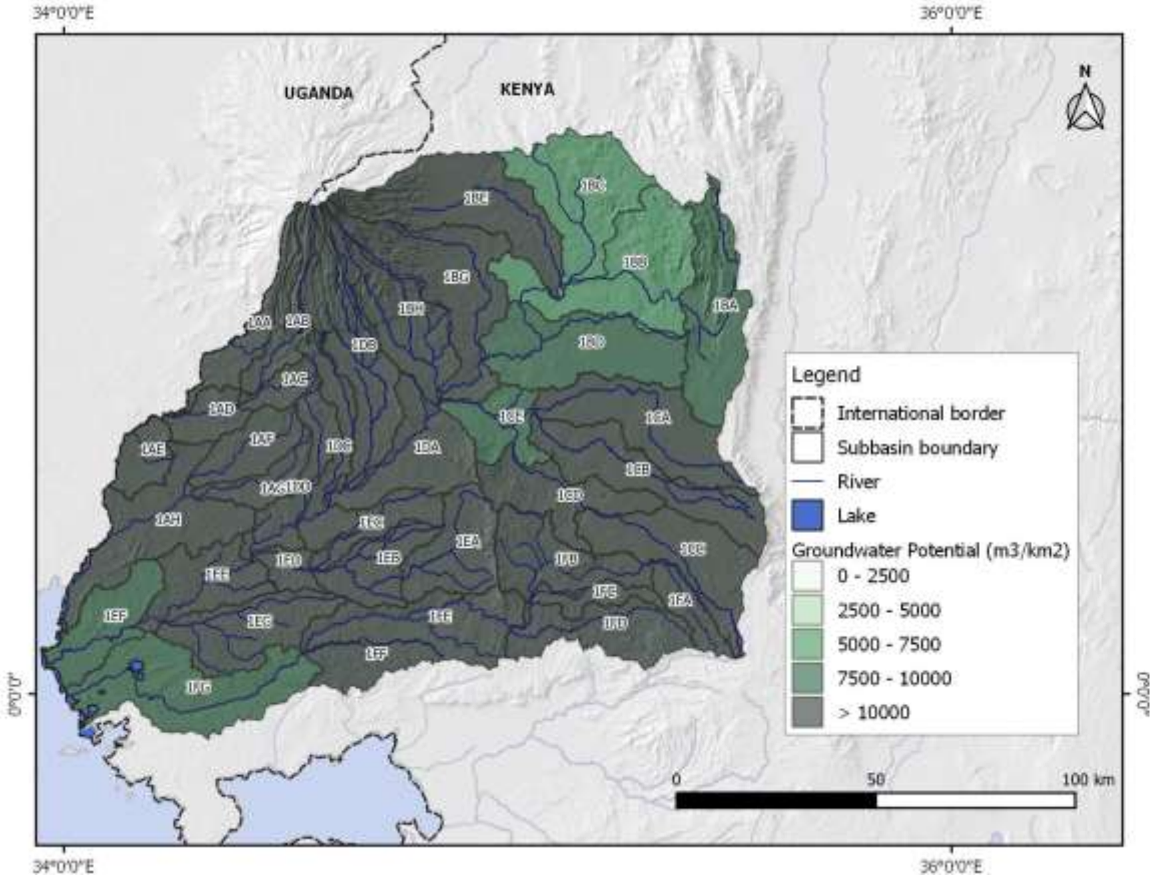


Figure 2-29: Estimated sustainable groundwater yield in the LVN Basin

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 A**) were superimposed on the groundwater model of the LVN Basin to assess the potential impacts on recharge and groundwater potential. It was found that the recharge in the basin will increase marginally by 0.3% to 1 530 MCM/a, while the potential groundwater yield is expected to marginally increase by 0.5% to 217 MCM/a under RCP 4.5.

2.4.3 Current water requirements

Currently, the main demand for water in the LVN Basin consists of urban domestic and industrial water requirements.

2.4.3.1 Irrigation water requirements

Irrigation area

Food crops constitute most of the cultivated crops in the LVN Basin, followed by horticultural crops. The total crop area in the LVN Basin in 2010 was estimated as 776 800 ha, mainly consisting of rain-fed crops (Water Resources Management Authority, 2013). Of this area, less than 5% is estimated to be irrigated at present. This includes small-scale and private irrigation as well as large-scale irrigation.

To estimate current (2018) irrigation water requirements in the LVN 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 250 m 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.

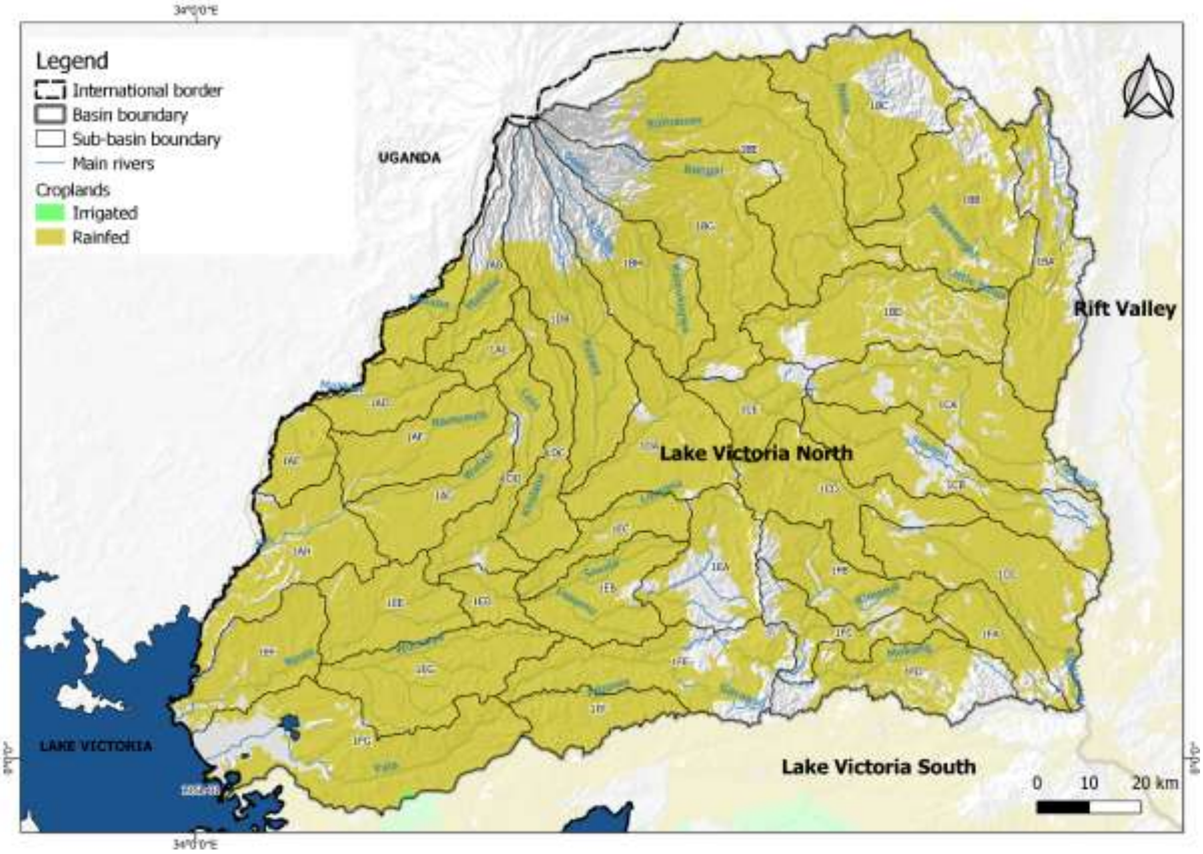


Figure 2-30: Rainfed and Irrigated crops in the LVN Basin (RCMRD Kenya Crop Mask, 2015)

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

An analysis and synthesis of the data and trends allowed present-day (2018) large-scale, small-scale and private irrigated areas to be determined per sub-basin as summarised in Table 2-10. The total current (2018) irrigated area in the LVN Basin is estimated as 3 629 ha. This represents an increase of about 93% compared to the 2010 irrigation area of 1 876 ha as determined in the NWMP 2030 and confirms the increase in irrigation in the basin.

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

Sub-basin	Area (ha)	Sub-basin	Area (ha)	Sub-basin	Area (ha)	Sub-basin	Area (ha)
1AA	28	1CE	11	1BC	95	1EF	700
1AB	6	1DA	20	1BD	24	1EG	106
1AC	2	1DB	14	1BE	41	1FA	10
1AD	47	1DC	9	1BG	31	1FB	43
1AE	44	1DD	9	1BH	14	1FC	33
1AF	50	1EA	20	1CA	38	1FD	53
1AG	41	1EB	12	1CB	67	1FE	39
1AH	142	1EC	8	1CC	50	1FF	2
1BA	119	1ED	2	1CD	50	1FG	1 514
1BB	87	1EE	109				

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 large scale irrigation schemes as well as for small-scale horticulture, maize, rice and sorghum, while a 60% cropping intensity was used for vegetables, beans, green grams and cow peas (Ministry of Agriculture, Livestock and Fisheries, personal communication, February 2019).

The total current irrigation demand in the LVN Basin was calculated as 40 MCM/a and includes 26 MCM/a for large scale irrigation and 14 MCM/a for small-scale and private irrigation. It equates to an average irrigation demand of 11 022 m³/ha per annum and is almost double the 2010 estimated demand of 18 MCM/a for irrigation as per the NWMP 2030. This demand is predominantly supplied from surface water, although groundwater provides some supply for small-scale irrigation.

2.4.3.2 Domestic and Industrial water requirements

For some of the urban centres in the basin, the latest water demand figures for domestic and industrial use were obtained from recent development and master plans or similar studies. Water demands for urban domestic and industrial as well as rural domestic use were also extracted per sub-basin from the NWMP 2030 and from the WRA Permit Database and compared. Where the Permit Database values were higher than the NWMP 2030 estimates extrapolated to 2018, the permit Database values were used as representative of the current demand and vice versa. The total domestic and industrial water demand in the basin was estimated at 205 MCM/a. This is slightly more than the NWMP 2030 estimate (2010) of 175 MCM/a as should be expected.

2.4.3.3 Livestock water requirements

The livestock water demands in the LVN Basin, as per the WRA Permit Database, were compared to that of the NWMP 2030 and found to be significantly less. Due to the livestock water demand in the LVN Basin being almost negligible when compared to the urban-rural and irrigation demands, a conservative approach was adopted for this Study by extrapolating the NWMP 2030 estimate to 29 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 constitute less than 1% of water demand in the basin. Consequently, the wildlife and fisheries water demand values as stated in the NWMP 2030 were accepted as correct and extrapolated to a 2018 demand of 12 MCM/a.

2.4.3.5 Total water requirements

The total current water requirement (2018) in the LVN Basin equates to 286 MCM/a. Currently, the main demand for water in the LVN Basin is constituted by domestic and industrial water requirements, followed by irrigation and livestock as summarised in Table 2-11. Figure 2-31 shows the distribution of current water demands across the LVN Basin. Current water requirements per sub-basin and main user category in the Lake Victoria North Basin are summarised in **Annexure B1.**

Table 2-11: Current (2018) water requirements in the LVN Basin per main sector

Sector	Volume (MCM/a)
Irrigation	**40**
- Small scale / Private	14
- Large-scale	26
Domestic and Industrial	**205**
Livestock	**29**
Other	**12**
Total	**286**

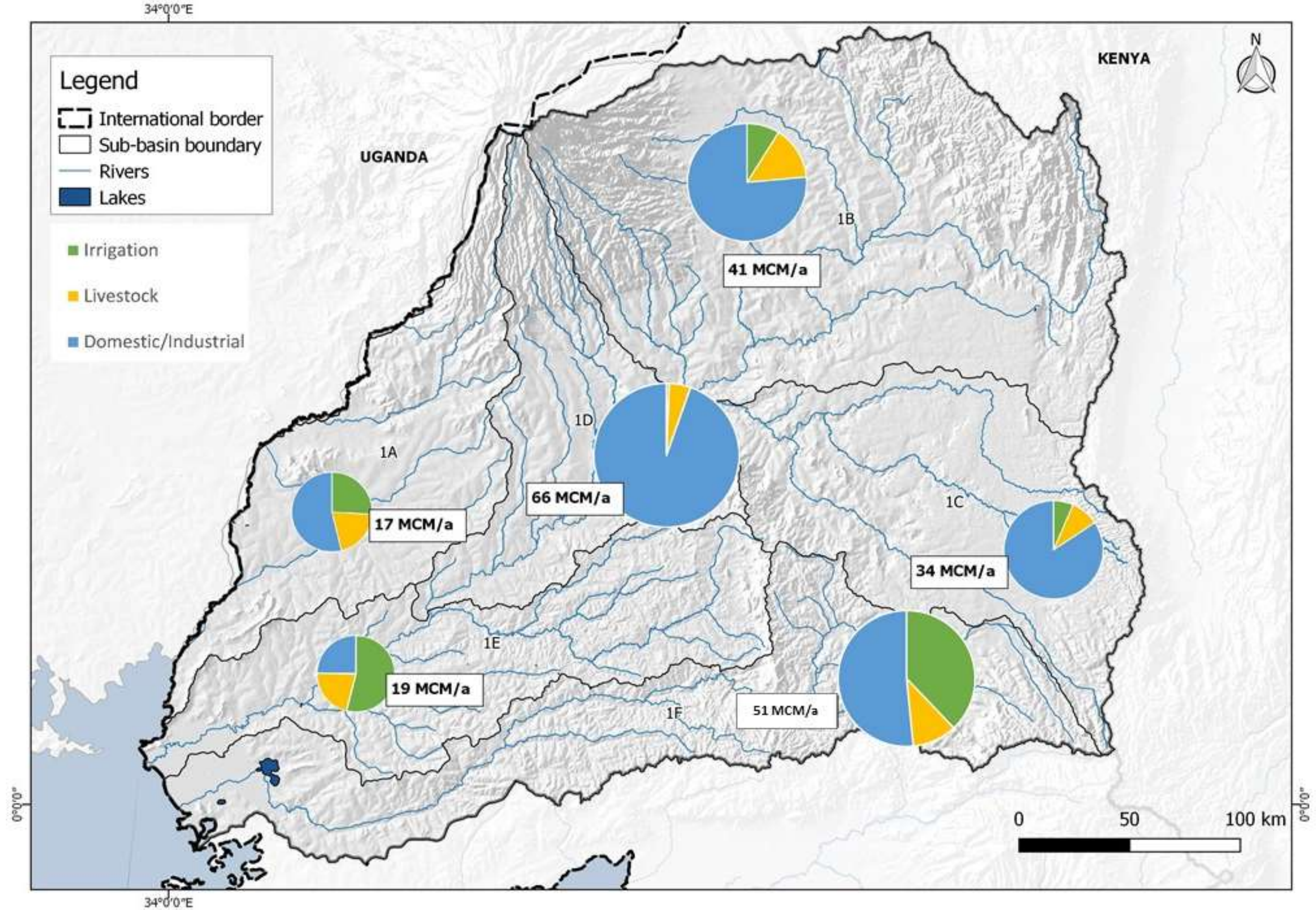


Figure 2-31: Present-day (2018) water requirements across the LVN Basin

2.4.4 Existing large-scale water resources infrastructure

The existing water resources developments in the LVN Basin include several dams and transfers, which mainly supply domestic demands.

2.4.4.1 Storage

The total storage volume of the existing large dams in the LVN Basin is approximately 32 MCM, of which about 25% is stored in about 270 small dams and pans across the basin (Water Resources Management Authority, 2013). The existing dams in the LVN Basin, as well as their storage capacities and uses are listed in Table 2-12. Only dams with a storage capacity equal to or greater than 1 MCM were explicitly modelled in this Consultancy.

Table 2-12: Existing major dams in the LVN Basin

Dam Name	Storage Capacity (MCM)	Purpose
Chebara (Moiben)	18	Domestic supply and Transfer (Eldoret / Iten / Tambach Towns)
Ellegirini	2	Domestic supply (Eldoret Town)
Kipkarren	3	Domestic supply (Eldoret Town)
Twin Rivers	< 1	Domestic supply (Eldoret Town)
Kesses Dam	1	Kesses and Lessos Towns
Small dams and pans	8	Domestic, livestock, irrigation

2.4.4.2 Hydropower

There are currently no large hydropower installations in the LVN Basin. There is one small hydropower station in Sosiani, about 25 km west of Eldoret Town along the Sosiani River. The Sosiani Hydropower Station was constructed in 1955 with an installed capacity of 400 kW. It is currently owned and operated by KenGen.

2.4.4.3 Water transfers

Existing intra-basin transfers in the LVN Basin were incorporated in the present-day MIKE Hydro Basin model and are listed below. The details of these transfers are presented in Table 2-13. In addition to the transfer to Eldoret, a limited volume of water is also transferred to Tambach Town in the adjacent Rift Valley Basin.

Table 2-13: Existing intra-basin water transfers

Transfer Source	Town supplied	Daily transfer volume (m3/day)
Intra-basin		
Chebara (Moiben) Dam	Eldoret and Iten	28 000

2.4.4.4 Large scale irrigation schemes

Information on existing large-scale irrigation schemes in the basin was obtained from the NWMP, 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. Information on existing large-scale irrigation schemes in the LVN Basin is summarised in Table 2-14.

Table 2-14: Existing large-scale irrigation schemes

Large-scale Irrigation Scheme	Irrigation area (ha)	Main crop type
Dominion Farms	1 480	Rice
Bunyala	700	Rice
Total	**2 180**	

Other irrigation in the basin has been classified as small-scale and private and are accommodated under the basin-wide demands.

2.4.4.5 Groundwater development and use

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

According to the NWMP 2030, there are currently 1 776 boreholes in the LVN Basin. The total current (2018) groundwater use in the basin was estimated at 47 MCM/a.

A review of the LVN Basin County Integrated Development Plans shows the commitment of counties to construct or rehabilitate boreholes and shallow wells, and to protect springs or rehabilitate protected springs for urban and rural water supply.

Kakamega County: The Kakamega water utility (KACWASCO) plans to revive six boreholes by 2021 (Kakamega County Water and Sanitation Company, 2017). The water utility also serves Busia, Mumias, Butere and Nambale Towns. Navakholo Town in Kakamega County relies exclusively on two high-capacity boreholes for water supply, yielding 58 m^3/hr (C-9232) and 29 m^3/hr (C-9243) which are unusually high yields for the LVN Basin (Lake Victoria North Water Services Board, 2011).

Vihiga County: Notable achievements between 2013 and 2018 was the construction/rehabilitation of 136 springs; rehabilitation of 15 shallow wells with hand pumps; construction of four shallow wells equipped with hand pumps, and drilling and equipping of nine boreholes (County Government of Vihiga, 2018). The objectives for 2018 to 2023 is for 25 boreholes and 30 shallow wells to be constructed, and 200 springs to be protected (County Government of Vihiga, 2018).

Busia County: Between 2013 and 2018, 100 solar boreholes were constructed, and 120 hand pumps, 70 shallow wells and 35 springs were rehabilitated (County Government of Busia, 2018).

Bungoma County: Between 2013 and 2018, 33 boreholes were constructed and 555 springs were protected (County Government of Bungoma, 2018). The objectives for 2018 to 2023 is for 90 strategic boreholes to be constructed, 50 boreholes to be upgraded to solar, and at least 700 springs to be rehabilitated or protected (County Government of Bungoma, 2018).

Trans Nzoia: In Trans Nzoia County, there are over 300 shallow wells, over 132 springs, and over 150 boreholes (of which 34 were drilled by the County) (County Government of Trans Nzoia, 2018). The CIDP plans to drill 1 000 boreholes and shallow wells over the life of the CID and protect 250 springs.

Nandi: The CIDP states that there are 3 038 shallow wells, 67 protected springs, 1 358 unprotected springs and 30 boreholes across the county (County Government of Nandi, 2018).

Uasin Gishu: In Uasin Gishu, at least 36 springs are proposed for protection in the next CIDP period, and 164 boreholes are to be constructed (County Government of Uasin Gishu, 2018).

Siaya: in Siaya County, the driest in the Basin, there were reported to be 170 boreholes, 106 protected springs and 815 protected shallow wells in 2013 (County Government of Siaya, 2018).

The percentage of the total water demand in each sector that is supplied from groundwater is shown below. Groundwater supply for each sector was determined from information in the Permit Database and the NWMP 2030.

Table 2-15: Groundwater contribution to meeting water demand in the LVN Basin (%) per sector

Use	Domestic (basin-wide)	Domestic (urban centres)	Livestock	Large-scale Irrigation	Small-scale Irrigation	Industrial	Other
% met by groundwater	22%	21%	9%	0%	3%	5%	0%

2.4.4.6 Ongoing major water projects

Ongoing water resources development projects in the basin include the Lower Nzoia Irrigation Scheme, which involves developing 4 000 ha on the left bank of the lower Nzoia River (Phase 1) and a further 3 800 ha (Phase 2) on the right (northern) bank of the Lower Nzoia River. Water for irrigation will be abstracted directly from the Nzoia River.

2.4.5 Water balance

The 2018 water balance in the LVN Basin in terms of natural surface water runoff and sustainable groundwater yield, water imports, the ecological reserve and current (2018) water demands in the LVN Basin is summarised in Table 2-16. The current water demand constitutes about 6% of the total water resources available for use.

Table 2-16: 2018 LVN Basin water balance per main sector (MCM/a)

Water Source	Surface water	Groundwater	Total
Natural / Available water	5 622	216	5 838
Imported/Exported water	-	-	-
Ecological reserve	(792)		(792)
		Total	**5 046**
		Water demand (2018)	**(286)**
		Balance	**4 760**

Due to climate change impacts, the natural surface water runoff is expected to decrease to 5 177 MCM/a, while the groundwater yield is projected to remain the same at 217 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 2-32 displays the current surface, sub-basin water balances and shows that all the sub-basins still have significant volumes of surface water available.

Figure 2-33 schematically displays the current surface water runoff at key locations in the LVN Basin. It shows that the current mean annual runoff of the Sio, Nzoia, and Yala Rivers where they discharge into the Indian Ocean is 508 MCM/a, 3 400 MCM/a, and 1 059 MCM/a respectively.

It is important to realise that although the sub-basin water balances might indicate that the total annual demand in a sub-basin is less than the water resources available in the sub-basin, supply deficits often occur during dry years and/or the dry season, when the demand exceeds availability of water in the rivers. Supply reliability and water deficits are evaluated as part of the scenario analysis (refer to Section 6).

The current estimated groundwater use in the LVN Basin equates to 47 MCM/a, which is about 22% of the estimated sustainable groundwater yield of 216 MCM/a. This leaves about 170 MCM/a of groundwater available for potential use in the LVN Basin.

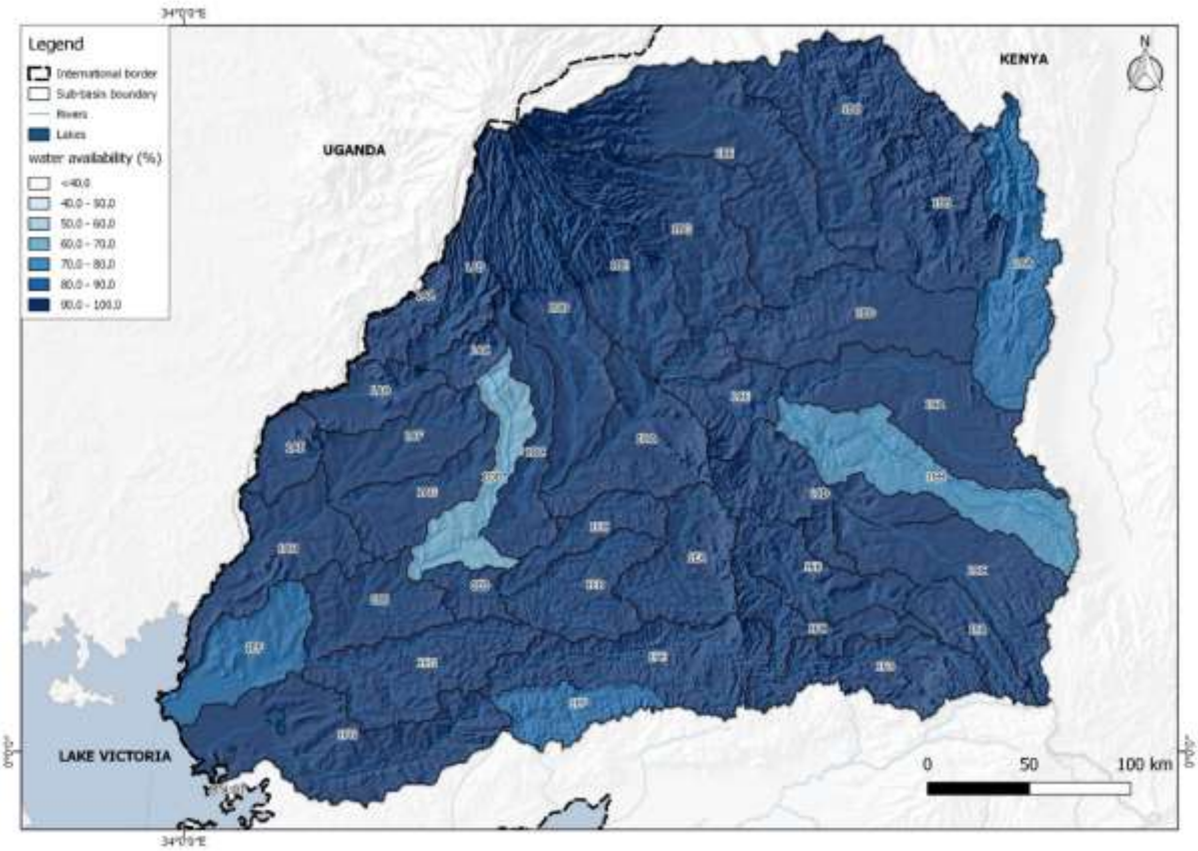


Figure 2-32: Water balance per sub-basin

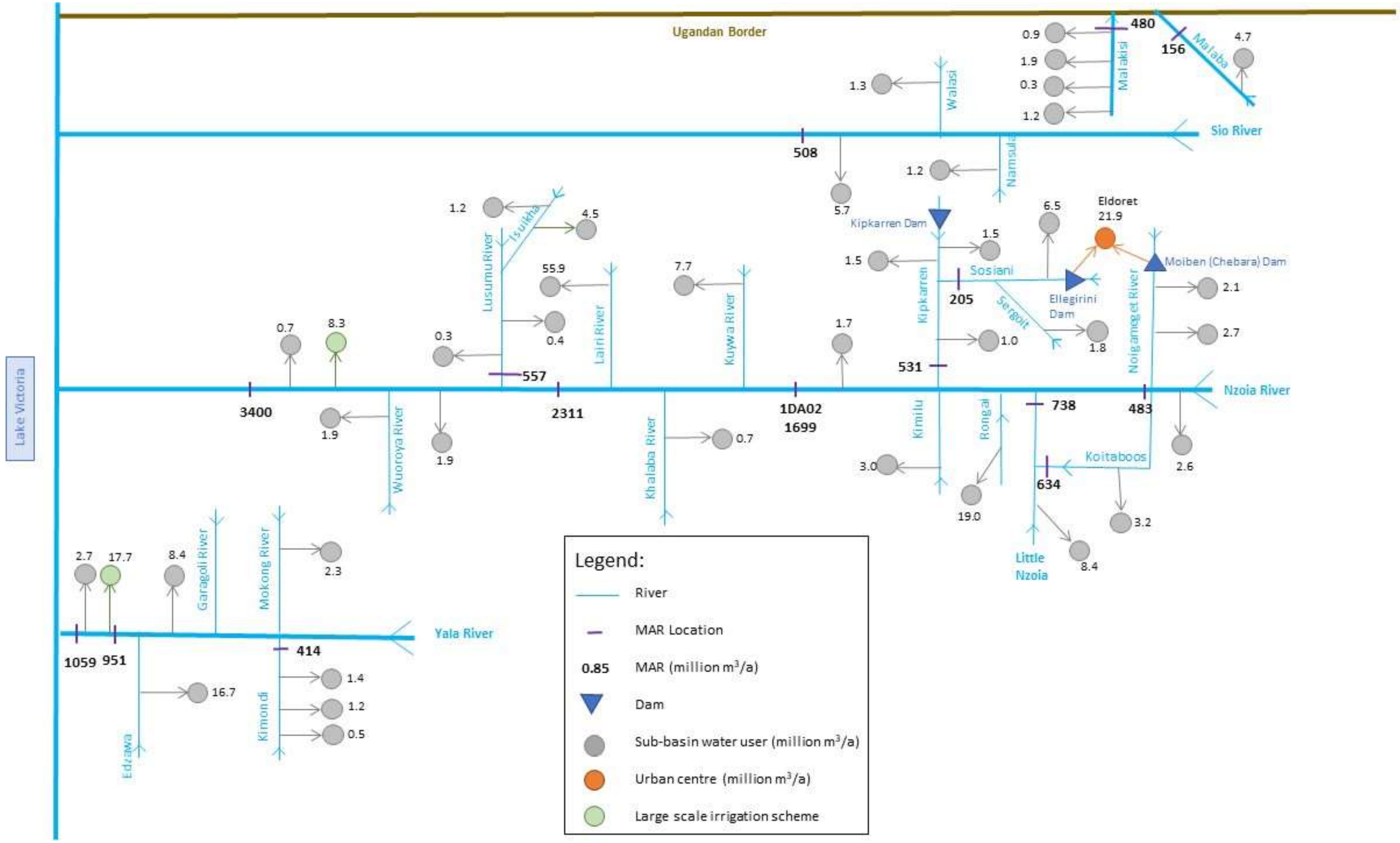


Figure 2-33: Current-day water availability and use in the LVN Basin

2.4.6 Surface water allocations

The WRA uses the permitting system as a tool to regulate the use of water resources in Kenya and enhance equitable use of water resources. This water allocation is based on order of priority; reserve, domestic, agricultural, and finally industrial. Water permits have a five-year validity period, with renewal subject to the conditions attached for compliance. These permits, as captured in the Permit Database, reflect the current allocation of water to different user categories. The volume of water which is available for allocation in any catchment, is determined in accordance with the Guidelines for Water Allocation (Water Resources Management Authority, 2010) superseded by Draft 2018 Water Allocation Guideline (Water Resources Authority, 2019a). Essentially, the Guideline prescribes a flow/reliability approach based on natural flow exceedance values, to estimate the volumes (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 LVN 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 LVN 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. Sub-basins indicated with “no data” represent sub-basins with no permit-based allocation records in the Permit Database.

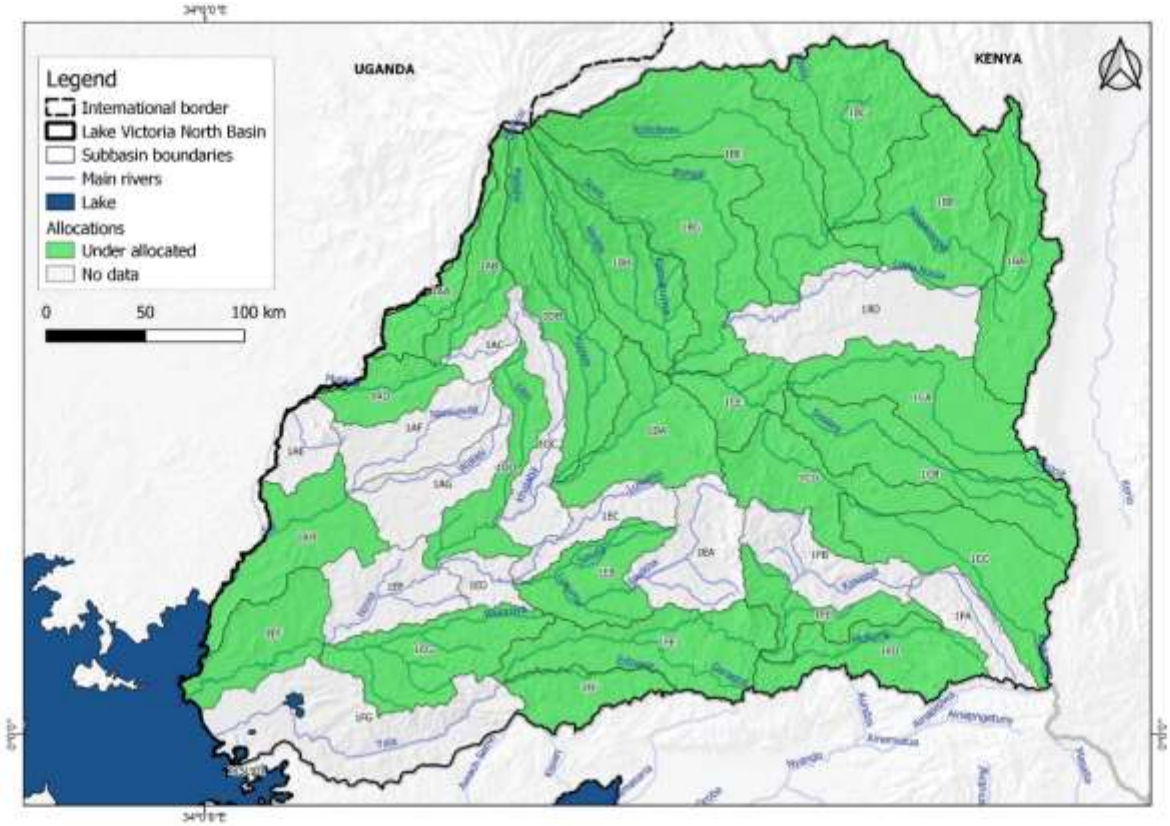


Figure 2-34: Water allocation status per sub-basin (2018)

2.4.7 Water quality

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

The most common pollutants in LVN Basin are:

- Industrial Effluents from major towns
- Municipal/Domestic sewage from urban settlements
- Solid wastes from dump sites
- Nutrients and Pesticide Residues, from Agro-based industries
- Flower farms
- Horticultural farms
- Sediment loads from degraded farmlands
- Soil erosion from overgrazed lands
- Soil erosion from gravel and unpaved roads
- Storm runoff from roads and urban centres
- Oil and grease from oils spills, garages and Petrol stations
- Leachates from Pit latrines, Septic tanks and feedlots
- Acaricides from Cattle dips
- Artisanal Mine wastes

2.4.8 Existing hydrometeorological monitoring network

As part of this consultancy, the current hydrometeorological network was reviewed, and a proposed hydrometeorological monitoring design network is discussed in section 6.8.3. The sections 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 measurement

In 2018, the LVN Basin has 54 daily water level monitoring stations. Of these, only 44 were known to be operational. It is highly likely that this number was much higher in the past. Table 2-17 provides details on the operational stream flow monitoring network in the LVN Basin, where the majority of these are manually operated.

Table 2-17: Current stream flow monitoring stations in LVN Basin

SRO	Operational			
	Telemetric	Automatic	Manual	Total
Eldoret	0	1	20	21
Kitale	0	0	12	12
Siaya	3	2	6	11
Total	**3**	**3**	**38**	**44**

Figure 2-35 displays the currently operational river gauging stations in the LVN Basin. Most of the operational river gauging stations are rated sections. Most are read manually by gauge readers, with 6 automatic stations (3 of which are 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.

2.4.8.2 Monitoring of dam and lake levels

In 2018, there were no operational lake monitoring stations in the LVN 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 LVN basin. Figure 2-36 displays the spatial distribution of the operational meteorological stations in the LVN Basin for which information is available.

2.4.8.4 Water quality monitoring

Kenya's existing surface water quality monitoring network was designed to collect water quality data in key river systems to support assessment and management of water quality in the country. The current practice in WRA is to monitor certain water quality parameters at most operational river gauging stations. This is done by sub-regional WRA staff at unknown intervals. In addition, effluent samples are supposed to be taken at potential point source pollution locations across the basin. n 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 2-18).

Table 2-18: Number of water quality monitoring stations in the LVN Basin (2018)

LVN Basin water quality stations	No. of current stations (2018)
Surface water	37
Effluent stations	25
Groundwater	21
Total	**83**

Currently, the water quality monitoring programme operated by WRA faces the challenges of inadequately qualified and trained staff and inadequate operational resources to facilitate regular sampling and laboratory analysis. In addition, because of inadequate equipment currently, the laboratories are only able to carry out analysis on a handful of parameters as listed in Table 2-19. Note that some stations may not sample all of the parameters listed below

Table 2-19: Parameters currently analysed

Type of Water quality monitoring station	Parameters tested
Effluent discharge points	Flow, pH, DO, Temperature, BOD, COD, Conductivity, TDS, Nutrients- NO2-, NO3-, PO43-, TSS
Surface water quality monitoring stations	Flow, pH, DO, Temperature, TSS Conductivity, TDS, Nutrients- NO2-, NO3-, PO43-.
Ground water quality monitoring stations	pH, DO, Temperature, TSS Conductivity, TDS, Nutients-NO2-, NO3-, PO43-.

2.4.8.5 Groundwater monitoring

There are a total of 19 groundwater level monitoring points across the Basin (0 Strategic, 6 Major, 7 Minor and 6 Special), all of which are operational (Water Resources Authority, 2018d). In the 2014 reporting period there were 13 operational monitoring boreholes (Water Resources Management Authority (2015b). 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 2-19.

It is not clear when the groundwater monitoring network was initiated in the LVN 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.

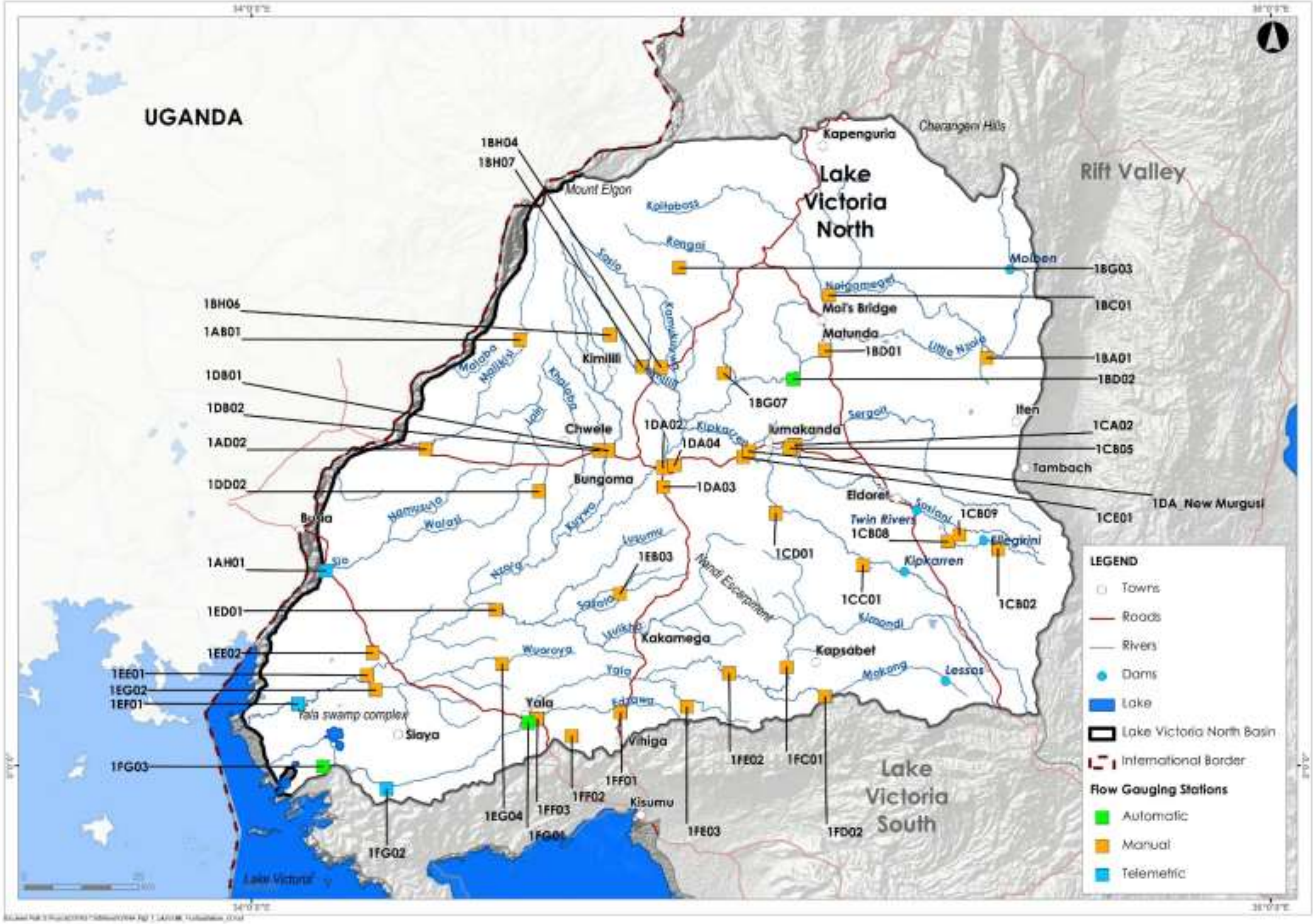


Figure 2-35: Locations of operational stream flow gauging stations in the LVN Basin

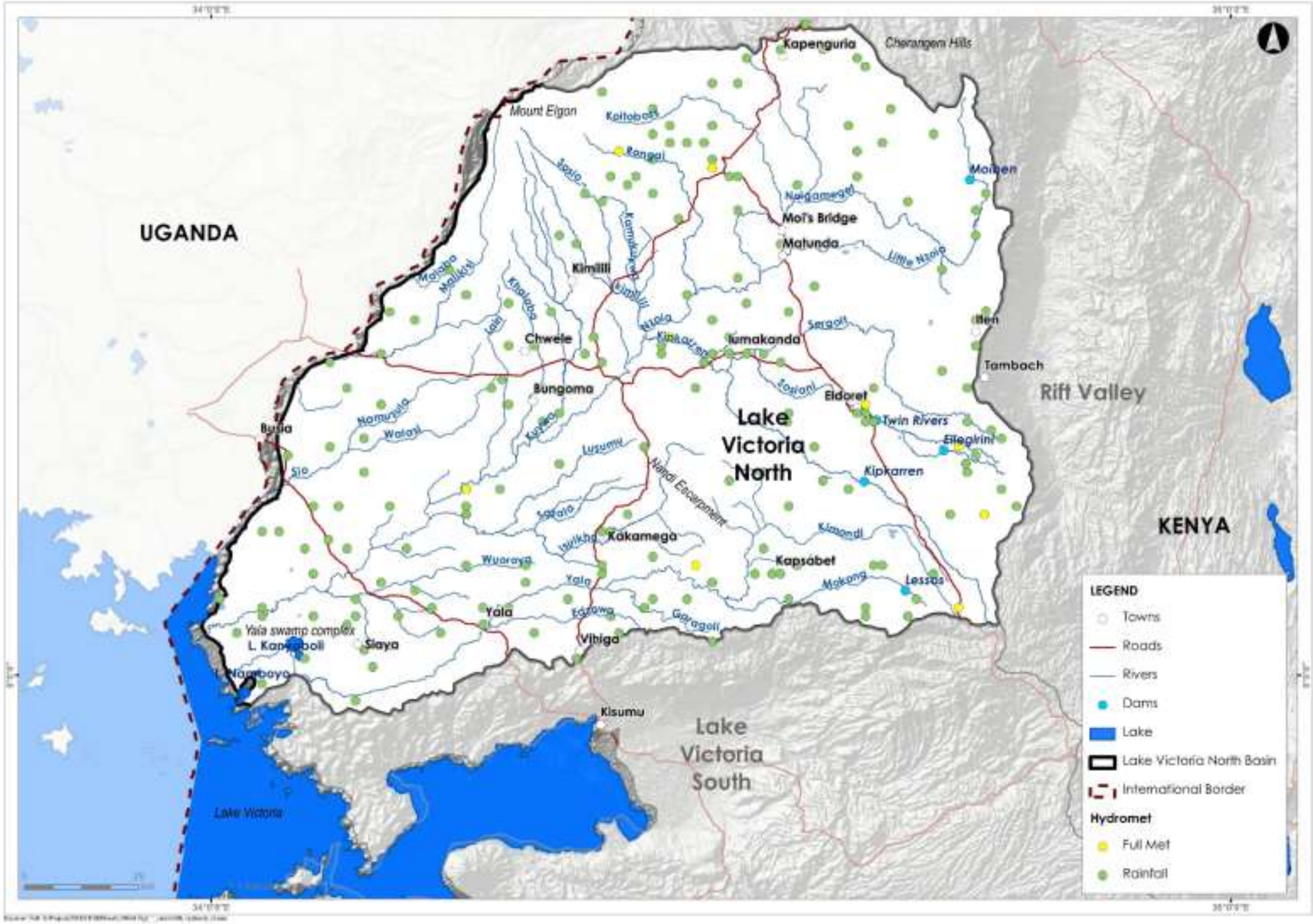


Figure 2-36: Locations of operational meteorological stations in the LVN Basin

Image source: Burgstede Photography 2005 'Mount Elgon'. Available online at http://www.burgstede.com/Travel/Kenia,%20Tanzania%20(2004)/09%20-%20Mount%20Elgon/index.html

03

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. The recognition of the link between water and land is also of importance. This recognition provides the basis for improved integration in the planning, management and sustainable development of natural resources. In this regard, institutional arrangements from national to county level are imperative for leading efforts in socio-economic development at national scale and for implementing national government policies on natural resource and environmental conservation at a local scale.

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

3.1.2 National policies

3.1.2.1 Water

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

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

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

In addition to these 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 resource 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' introduced key shifts in policy such as the separation of functions (including water resource management, water service delivery, policy, regulation, financing), the devolution of decision making to regional and local levels, the commercialisation of water (i.e. water to be treated as an economic and social good) and stakeholder participation through community and private sector participation.

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

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

3.1.2.2 Environment and natural resources

In conjunction with the 'Sessional paper no. 1 of 1999 on national policy on water resources management policy and development' (Government of Kenya, 1999), 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 several 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 LVN 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 several important principles to take into consideration in undertaking planning in the LVN Basin and these are presented below.

Table 3-1: Guiding NEP principles for basin planning

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

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

A key issue to distil from the ‘Sessional paper no. 1 of 1999 on national policy on water resources management policy and development’ and NEP concerns the recognition of the value and benefits that are accrued from ecological infrastructure. This refers to the naturally functioning ecosystems that deliver valuable services to people, such as water and climate regulation, soil formation and disaster risk reduction (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. The transformation of smallholder agriculture from that of subsistence to an innovative, commercially oriented and modern agricultural sector has been identified as a fundamental component for achieving agricultural growth. It is realised that this transformation will be achieved through transforming key institutions in agriculture, livestock, forestry and wildlife to promote agricultural growth; increasing productivity of crops, livestock and tree cover; introducing land-use policies for better use of high- and medium-potential lands; developing more irrigable areas in Arid or Semi-Arid Lands (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 (REA) into the National Electrification and Renewable Energy Authority (NERA) to be the lead agency for development of energy resources that includes both geothermal energy and hydropower. Hydropower provides a significant portion of the energy mix, with the intention to further improve current systems whist developing new opportunities.

3.1.3 Legislation

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

In March 2003 the GoK **Water Act** *(Act No. 8 of 2002)* came into effect. This Water Act 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 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 **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 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. Some ambiguities in the GoK 2016 Water Act that require resolution in order 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 MoWSI 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.

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

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

3.1.4 National institutions

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

In the aftermath of the 2017 national elections, the national government in Kenya has undergone some changes in configuration to support a more effective and efficient Government. Whilst many Ministries 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 tabulated, in Table 3-2.

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

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

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

* The roles and responsibilities provided are not comprehensive – only some of the key functions are listed.

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

3.1.5 Basin and sub-basin institutions

Noting the requirements of Integrated Water Resources Management, institutions have been established at basin and sub-basin levels to improve the day-to-day management of water resources as well as to improve the regulation and oversight required to ensure that water is efficiently used in accordance with water use permits.

Under the auspices of the 2016 Water Act, this is achieved through the Regional and Sub-Regional Offices of the Water Resources Authority (WRA) and the Water Resource Users Associations (WRUAs).

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

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

Sub-Region	WRA SRO	CMUs
Kipkaren – Upper Yala	Eldoret	Kipkaren, Upper Yala
Elgon – Cherangani	Kitale	Upper Nzoia, Middle Nzoia, Sio-Malaba-Malakisi, Mount Elgon
Lower Nzoia - Yala	Siaya	Lower Nzoia, Lower Yala

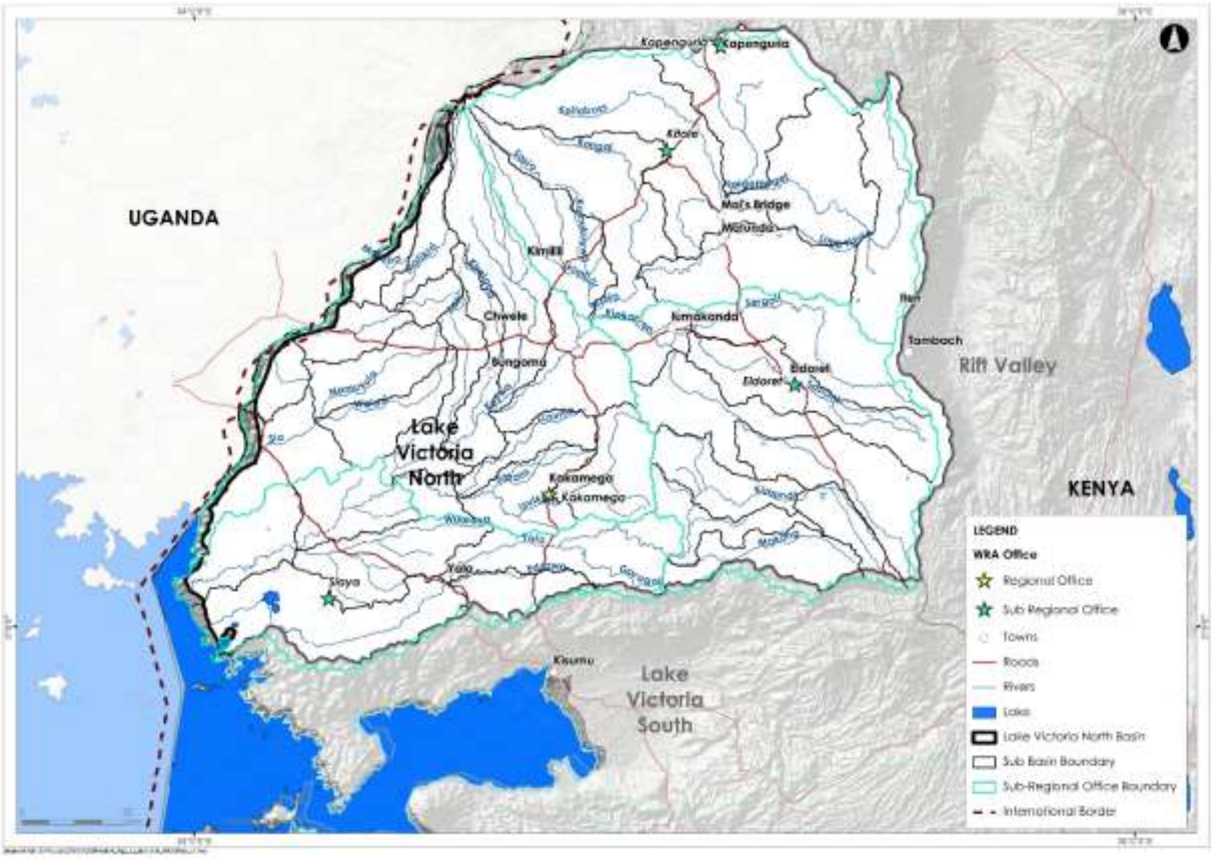


Figure 3-1: WRA Offices and sub-regions in the LVN Basin

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

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

Regional and Sub-Regional Offices will be essential to separate staff and functions that are managerial in nature, and as such, supportive of the BWRCs. The BWRCs 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 Water Resource User Associations (WRUAs) has been essential in ensuring a focus on the operational management functions within a sub-basin. The WRUAs are community-based, voluntary associations made up of water users and riparian owners interested in proper management of their water resources and were established to enable the collaborative management of water resources and to provide essential support in the resolution of conflicts concerning the use of water resources. As provided for in the Water Act 2016 Section 29 (4), BWRCs may contract WRUAs as agents to perform certain duties in water resource management. To date, WRUAs have performed important local functions, but have faced an array of challenges that have served to hinder their effectiveness. Many of these are enabling factors such as capacity in terms of having sufficient skills and training, but also includes such issues as insufficient financial resources. These challenges will require redress in order to support the implementation of this Basin Plan and realise the local level capacitation that can unlock the localised socio-economic development required to support Vision 2030. This is supported by the 2016 Water Act that provides in Section 29 (3) that "*basin area water resources management strategy shall facilitate the establishment and operation of water resources user associations*".

3.1.6 County governments

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

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

The county governments face considerable challenges as a relatively new level of government, and these include capacity and financial resources. The latter is being assisted through the *Division of Revenue Act (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 abstractive water use and waste discharges) and exposed to the associated risks. Therefore, whilst there is a need for the private sector and civil society to engage in water resources management to manage their own risks, in so doing they provide critical support to the wider water sector.

The nature of these partnerships will vary depending on their relationship with the water sector and the various interfaces that these actors have. For example, the partnership between WRA and the Kenya Meteorological Department (KMD) at national level is 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. Another example is that with international Non-Governmental Organisations (NGOs) such as World Wildlife Fund (WWF) and International Union for Conservation of Nature (IUCN), amongst others. These provide useful capacity as well as enable (and often fund) studies and research that sometimes serve to unlock challenges.

As the implementation of the LVN 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.

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 regarding stakeholder engagement and there is a sense that in Kenya this is the case. The benefits that can be realised through catchment forum processes have not always been maximised and ongoing work is needed to find more appropriate forum structures and functional modalities that ensure that the maximum benefits from stakeholder engagement are 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 to effective engagement is the overlap of mandates of the various national and county 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 (refer to Annexure A: Analytical Tools). This process however must involve adequate stakeholder consultations including county governments and various actors in the basin who need to be included in the planning for such engagement to work (refer to **Annexure D**).

3.2 Existing Development Plans and Sectoral Perspectives

3.2.1 Introduction

To ensure that this Basin Plan is representative and aligned with current plans and strategies related to water resources planning and management in the LVN 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 LVN Basin are also presented in this Section.

3.2.2 National Water Master Plan 2030

The NWMP 2030 was completed in 2013 and covers all six river basins in Kenya. For each basin, the NWMP 2030 provides information related to water resources, water demands, high level water allocations, economic evaluations of proposed interventions and implementation programmes. In addition, the NWMP 2030 presents development plans related to water supply, sanitation, irrigation, hydropower and water resources. The NWMP 2030 information on surface water and groundwater resources availability and use in the LVN Basin have been compared with the water resources assessment results undertaken in this Consultancy (refer to Section 2.4). Furthermore, the NWMP 2030 was used extensively to inform the development of the LVN Basin Plan, specifically the sub-plans as outlined in section 6.

3.2.3 Catchment management strategy

The LVN Catchment Management Strategy (CMS) (Water Resources Management Authority, 2015a) was completed in 2015 for the period 2015-2022. The strategy provides an opportunity for water resources management institutions and stakeholders to formulate a coherent approach and focus for managing water resources. 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 LVN CMS

Strategy	Theme	Objective
Water resource protection	Water resource protection	- To ensure effluent all dischargers comply with permitting requirements - To maintain the RQOs - To improve water quality assessments - To collaborate with County Governments and other stakeholders on sanitation and solid waste management
	Catchment protection and conservation	- To restore degraded water catchments - To protect water catchments - To enhance collaboration with County Governments and other stakeholders in catchment restoration - To enhance capacity in catchment protection and conservation

Strategy	Theme	Objective
Resource augmentation adaptation and development	Flood and drought management	- To develop and implement a framework for collaboration with County Governments and other Stakeholders on Integrated Flood Drought Management. - To enhance capacity on Integrated Flood Drought Management including monitoring skills, use of information systems and flood control centres - To mainstream Flood and Drought Management in SCMPs
	Climate change adaptation	- To strengthen monitoring systems for enhanced data collection - To enhance capacity and create awareness on climate change effects - To develop scenarios to support decision making to generate future water availability scenarios
	Water resources infrastructure development	- To regulate water resources infrastructure development - To regulate the operations of the infrastructure - To identify potential sites for water resources infrastructure development
	Rights based approach	- To ensure access to water resources for the vulnerable groups - To maintain the reserve for all water bodies
	Livelihoods enhancement	- To build capacity of WRMA and other stakeholders to implement livelihood activities - To implement livelihood enhancement projects
Implementation, information management and financing	Institutional strengthening	- To enhance capacity of WRMA and CAAC to effectively undertake WRM - To build capacity for the County Governments to effectively participate in integrated water resources management - To enhance capacity of WRUAs to undertake WRM activities - To enhance collaboration with stakeholders on IWRM issues
Monitoring and management		- To optimize water resources monitoring network - To enhance data management system - To upgrade water resource information system - To establish an effective monitoring and evaluation system of the CMS implementation

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 94 WRUAs out of a potential 106 WRUAs have been formed in the LVN 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 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 NWMP 2030 and the basin area plan, it is directly held in the custody of the WRUAs who oversee 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 will be used as a reference document in the preparation of the SCMPs. To date, only 34 SCMPs have been developed in the LVN Basin.

3.2.5 County Integrated Development Plans

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

The key aspects of each CIDP for the main counties situated in the LVN Basin are presented in Table 3-5 (refer to Figure 2-2Figure 2-23 in Section 2.1. for a map of the counties).

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

County	Water and sanitation	Natural resources	Agriculture
Bungoma CIDP (2018-2022)	Sector priorities are to increase access to safe water supply and improved sanitation in urban and rural areas; and to improve water resource management and regulation; to increase utilisation of existing water, and to increase the provision of water for production facilities (industry).	Sector priorities are to increase agricultural production and productivity; increase access to critical farm inputs (including access to water and irrigation), improve agricultural markets and value addition; and strengthen institutional capacity.	The main areas in the county that have environmental concerns include Mount Elgon forest, Chetambe hills, Sang'alo hills, riparian areas, food basket zones in Tongaren, schools and institutional spaces and quarrying areas. Sector priorities include restoring and maintaining ecosystems; promoting the sustainable use of Environment and Natural Resources (ENR); increasing wetland coverage and reducing degradation; maintaining the meteorological information systems; climate change management; and maintaining the recommended forest coverage.
Busia CIDP (2018-2022)	A major programme objective of the CIDP is to increase the clean water supply for industrial and domestic use in urban and rural areas. The total volume of water produced per day, the total volume of storage, and the number of water connections will increase in the planning period. Existing water supply systems will be better maintained to reduce down time. The Programme of Preventative and Promotive Health Services aims to reduce the burden of disease, injuries and mortality. As part of this programme, the number of health facilities connected to the water supply grid and the number of households with upgraded sanitation will be increased across the county.	Agriculture will be modernised by the development of Agriculture and Extension Policy; development of Land Use Policy; increasing investment in irrigation agriculture, crops and livestock diversification and the maintenance of indigenous genetic seed banks. Rain fed agriculture areas with growth potential were identified as Teso South, Teso North and Nambale. Areas of irrigated agriculture and livestock were identified as Samia, the Bunyala Matayos "Blue economy" and Bunyala.	The natural environment in the county is heavily degraded through deforestation, encroachment in riparian areas, and sand harvesting. Conservation of the natural environment is an important theme in the CIDP. The strategies to achieve this are to: develop a county environmental management and safety framework policy; strengthen the county environment committee; manage liquid and solid waste; protect all degraded areas; implement afforestation, soil conservation, riverine protection (including riparian zones, wetlands and riverine basins) and control pollution and mitigate the effects of pollution.

County	Water and sanitation	Natural resources	Agriculture
Kakamega CIDP (2018-2022)	Programmes include increasing the percentage of the population with access to clean, safe, piped water from 12.4% to 40% by 2022. This will include rehabilitating and/or augmenting urban water supply schemes in Tindinyo, Mumias, Lumakanda, Malava, Soy, Navakholo and Matunda. Additionally, boreholes will be drilled, and rainwater harvesting, and storage will be promoted. Programmes to improve sanitation include the safe disposal of sludge and production of organic manure, and the safe disposal of faecal matter and wastewater through increased access to sewerage services. To this end, the stalled Maraba Sewerage plant will be completed, the existing Sewerage Plant at Shirere will be expanded, and new Sewerage plants will be constructed at Mumias, Matunda, Moi's Bridge, Butere and Malava. An alternative financing mechanism for the Water Sector is proposed in order to ensure sustained financing for the sector.	Programmes include: improving agricultural extension services as well as research and training; promotion of climate smart agricultural practices; livestock development; increasing area of land under irrigation; increasing fish productivity and production; and increasing crop production and productivity;	There is significant potential for tourism in the county, especially because of the international interest in the birds of the Kakamega Forest. Programmes include environmental conservation and pollution control to ensure a clean, safe, healthy environment; climate change management; conservation of forest resources, water catchment protection and sustainable utilisation of natural resources; and tourism development (improving tourist infrastructure).
Trans Nzoia CIDP (2018-2022)	Programmes include rehabilitation and expansion of water supply systems including: Kiptogot-Kolongolo water project, Sosio-Teldet water project, Kitale water supply and sanitation project, sustainable management of water resources, mapping of surface and groundwater sources, rehabilitation of dams and pans, increase water supply and sanitation infrastructure, provide more irrigation water, increased boreholes	Programmes include land, soil and water conservation, promotion of climate smart agriculture, capacity building, increasing agricultural productivity and profitability, livestock productivity improvement including livestock disease control, promotion of fisheries, promotion of crop diversification, and the establishment of model farms and an Agricultural Training Centre.	

County	Water and sanitation	Natural resources	Agriculture
Uasin Gishu CIDP (2018-2022)	Acute water shortages have occurred in the county, particularly in Eldoret, where water rationing was implemented. The CIDP aims to provide clean accessible and adequate water within a reasonable distance (shorter than the current distances of 1.5 km in rural areas and 0.5 km in urban areas), and to rehabilitate, maintain and extend sewer lines, so that more households can be reached. Programmes include increased access to water supply, diversification of water sources, rehabilitation of dams. Flagship projects are: Kipkabus water project (Ainabkoi Olare ward – 2019 completion date), Moi's Bridge water supply project (Soy ward – 2019 completion date).	Investing in increased agricultural production and productivity will ensure food security and improved nutritional status for the residents of the county. Programmes to achieve this include increasing livestock, crop and fish production and by adding value to agricultural products. Extension services will be improved, post-harvest management will be supported through provision of adequate storage facilities and driers, farm inputs (e.g. seeds, fertilizers and artificial insemination) will be subsidised, especially for small scale farmers, livestock disease will be controlled, irrigation and greenhouse farming will be initiated, agriculture will be mechanized, and fish farming will be promoted.	One of the goals of the CIDP is to attain a sustainable environment through protection, restoration, conservation and management of the environment. Programmes include, catchment protection and conservation, forest resource conservation and management, riparian zone conservation, promotion of green energy and solid waste management. Climate change effects will be dealt with by building resilience, enhancing adaptation and developing mitigation strategies. Tourism facilities and attractions will be developed to increase the number of tourists visiting the county.
Nandi CIDP (2018-2022)	**:** The access to water supply is on average up to 0.5 km away, and the county intends to reduce this distance to 0.1 km away over the five-year period. The percentage of the county population connected to water supply will be increased from 30% to 60% by 2022, and another 650 households will be connected to the sewer network by 2022. Programmes to achieve these goals are described as follows: All water projects that have become dysfunctional will be revived and rehabilitated, and existing dams will be rehabilitated. The County Government will collaborate with communities and NGOs to drill boreholes to be managed by community groups. The Kapsabet wastewater treatment plant will be rehabilitated and expanded, and a new treatment works will be constructed in Nandi Hills at Mokong river. Existing community-based water projects will be rehabilitated, revived and expanded. Flagship programmes (in which the county will partner with the National Government) include: the **Keben water project**, which will provide water to Nandi Hills and Kapsabet town and their environs.	Agriculture is a vital source of income for households and the county; and is a priority for economic empowerment in the county. The goal for the sector is to increase food and nutritional security, commercialisation of agriculture, and effective and efficient marketing systems in the sector. This will be achieved through crop and livestock development, increased access to irrigation, soil and water conservation, and increased agricultural extension and training. Flagship projects planned for implementation throughout the county include the installation of a milk processing plant, a maize milling plant, a coffee milling plant, soil fertility management, poultry hatcheries and artificial insemination services and milk coolers. A category B slaughterhouse will be constructed at Kapsabet, heifer development and a seed multiplication centre will be established at Kaimosi and Kimwani, and the Kaimosi ATC will be revamped, and a seedling nursery, animal feed mill and a Farm Demonstration Unit will be established there.	The county intends to create policies to protect the environment. Environmentally sensitive areas will be mapped, and development of these areas will be prohibited. Degraded wetlands and riverbanks will be restored. Communities will be sensitised and made aware of these areas. Public open spaces that have been 'land grabbed' will be repossessed and developed. Sustainable liquid and solid waste disposal systems will be promoted. All buildings will meet energy efficient criteria (solar heating systems and roof water harvesting), and other forms of green energy will be encouraged. Climate change considerations will be included in all county policies and plans

County	Water and sanitation	Natural resources	Agriculture
	Kabiyet / Kaiboi water project in Mosop sub county, which will provide potable water to major centres and community water kiosks and tanks. **Mosoriot water project** in Chesumei and Emgwen sub counties, which will provide water to major centres and community water kiosks and tanks **Nandi County Spatial Plan** will apply to the whole county to provide a basis for investment and the provision of infrastructure **EU Water Tower Programme** applies to the whole county to restore degrades landscapes **Nandi Hills water project** will provide water to Nandi Hills town and its surrounds.		
Siaya CIDP (2013-2017)	The water supply in the county is inadequate, supplying only 42% of the population. The CIDP intended to expand the water supply system, introduce campaigns to educate people about safe water and sanitation practices, and to intensify environmental conservation. Climate change mitigation and adaption measures would be adopted, guided by the National Climate Response Strategy. Sanitation is also a problem in the county, with only 6% of households having access to piped water, and only 75% having latrines. No sewage systems existed in the urban centres at the start of the CIDP planning period. A major project to construct a water and sewer system in Bondo and Siaya Towns was planned for the CIDP. Waste management in urban centres needs to be improved with the introduction of a proper solid waste disposal system. A flagship project is upgrading of the Sidindi Malanga Water Supply. The Siaya Town Sewage System project is ongoing, and proposals have been made to establish sewage systems in major towns in the county.	Programmes to improve and grow agriculture include expanding the extension services, increasing the land under irrigation, increasing the quality and quantity of farm produce, improving storage of farm produce, enhancing livestock disease control, improving access to markets, making fish stocks more sustainable, improving storage of harvested fish, making credit more available to farmers. Flagship projects applying to the whole county include subsidising farm inputs and implementing the multi strategic food reserve. Flagship projects located in Siaya are: a mechanisation project, and the modernisation of the Siaya Agricultural Training College.	Considerable environmental degradation has taken place in the county, particularly in Lake Victoria and the Yala swamp, which is the third largest wetland in Kenya. Water levels have reduced, and soil erosion is taking place, resulting in the silting up of wetlands, dams and water pans. Additionally, riverbanks, arable farmland and forests have been destroyed. This has resulted in the decline in agricultural and fisheries production in the county. The CIDP aims to promote environmental conservation and embrace measures to green the economy

County	Water and sanitation	Natural resources	Agriculture
Vihiga CIDP (2018-2022)	The percentage of the population with access to safe and adequate water is 64%, with the average time to access a safe water source being 15 minutes. The major water schemes in the county are Mbale, Maseno, Kaimosi, Hamisi, Vihiga, Vokoli and Kaptech water supplies. Some of these are operational, while others are under rehabilitation. Approximately 85% of the residents of the county use improved sanitation. No sewage system exists at present, but the county plans to establish sewage systems to major urban areas. Programmes include improving access to clean and safe water and sanitation services by investing in water infrastructure, sanitation and environmental management conservation programmes. Additionally, solid waste collection, management and disposal will be improved throughout the county. Significant water projects are the Majengo Gisambai Water Project which will serve 8 000 people by 2020, and the completion of the South West Bunyore Water Project, which will supply water to 9 000 people by 2020. A notable sanitation project is the rehabilitation of Kaimosi Sewerage Works which will serve 4 000 people by 2019.	Programmes to improve agriculture include improving crop, livestock and fish production and productivity through increased support services, farmer inputs, marketing and value addition and post-harvest management; and the development of co-operatives. Flagship projects are the upgrading of Mwitoko fish Farm in Luanda; banana value chain development and commercialisation; and county subsidies for farm inputs such as fertiliser and certified seeds.	Natural resources in the county have been degraded, resulting in low farm yields and food insecurity, deforestation and water pollution. Programmes to improve this are the Sustainable Land Management and Agro-Diversity initiative, which will educate farmers within 5 km of forests in the Shiru and Muhudu wards, the establishment of an Agricultural Training Centre, reduction of farm input costs, and making affordable credit available to small scale farmers.
Elgeyo Marakwet CIDP (2018-2022)	The county has four gazetted water supply systems namely: Kaptarakwa, Kapkoi, Chepkorio, and Chepsigot. Others are community managed. The average walking distance to the nearest water source is 2.5 km. There are no sewage systems in the county at present. The average percentage of households with latrines is 87%, and those with septic tanks is 2%. Programmes include increased access to clean and safe water, improved liquid and solid waste management systems, promotion of public awareness of water conservation and efficient water use, construction of dams and pans, de-silting of dams, strengthening Water and Sanitation Providers, establishment of sewerage systems, spring protection.	Programmes include crop development, agricultural extension and training services, sustainable land management, irrigation, livestock development, trade and industry development, cooperative development, veterinary services, tourism development, and trade and industry development.	Programmes include sustainable land management and conservation of the environment, wetland conservation, conservation of water catchment areas, mainstreaming of climate change actions, tourism development, Rimoi National Reserve development, and culture and heritage preservation, promotion of alternative energy sources, and improved solid waste management

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. Two regional Development Authorities have jurisdiction over parts of the LVN Basin:

The **Kerio Valley Development Authority** is responsible for regional development in the Kerio Valley, which falls mainly withing the Rift Valley Basin. It includes the town of Eldoret and a small portion of the Elgeyo-Marakwet County in the north-eastern part of the LVN Basin. Since their main area of responsibility falls within the Rift Valley Basin, it is not covered further in this report.

The **Lake Basin Development Authority's** area of jurisdiction covers approximately 39 000 km^2, including the LVN and Lake Victoria South Basins. The mandate of the Lake Basin Development Authority is to spearhead development, undertake overall integrated planning, co-ordination and implementation of programs and projects in the basin. It was established in 1979 by an Act of Parliament and falls under the Ministry of East African Community and Regional Development.

Three of the five water towers in the country fall within the area under the jurisdiction of the Lake Basin Development Authority, namely: the Mau complex, Cherangany Hills and Mount Elgon. The rivers feeding Lake Victoria originate from these water towers, and three of these fall within the Lake Victoria Basin (Sio, Nzoia and Yala rivers). The Lake Basin Development Authority implements an integrated land and water management system. They have partnered with County Governments, Youth and Women's groups to promote the commercialisation of tree seedlings production, bamboo commercialisation and value addition as part of a wider programme for climate change mitigations mainly in the catchment and riverine areas of the Basin. The Lake Development Authority plans to produce 20 million seedlings, undertake catchment management and ecosystems studies as part of these catchment restoration activities.

Two major projects taking place under the auspices of the Lake Basin Development Authority are the Magwagwa and Nandi Multipurpose Dams, the latter falling within the LVN Basin. Capacity building and technology transfer are also provided in the areas of agriculture and livestock development; dairy development; apiculture development; coffee farming within the region, and aquaculture development.

3.2.7 Projects planned by Water Works Development Agencies

One Water Works Development Agency (WWDA) operates in the LVN Basin. The LVN Water Works Development Agency (LVNWWDA) covers the following counties: Bungoma, Kakamega, Vihiga, Busia, Uasin Gishu, Trans Nzoia and Nandi. Five Urban Water Service Providers have been appointed to provide of water and sanitation services directly to the various urban areas within its coverage. The Water Service Providers include:

- Eldoret Water and Sanitation Company: serving Eldoret town and its environs.
- Nzoia Water Services Company: serving the towns of Kitale, Webuye, Kimilili and Bungoma.
- Western Water Services Company: serving the towns of Kakamega, Busia, Mumias, Butere and Nambale.
- Amatsi Water Services Company: serving Luanda, Majengo, Chavakali, Kaimosi, Maseno University and Mbale.
- Kapsabet Nandi Water and Sanitation Company: serving Kapsabet town and its environs

The LVNWWDA has ongoing and proposed projects that vary from rehabilitation of water supply schemes, extension of service lines, construction of storage tanks and drilling and equipping of boreholes in all the counties, to major dam and water resource projects. Some of these projects are listed below:

- **Greater Vihiga Gravity Water Supply System**. This proposed gravity system would mainly the area of coverage of Amatsi Water Services Company Limited (AWASCO) including Maseno, Mbale, Kaimosi, Sosiani and Vihiga Water supplies which currently serves about 30,912 people and its targeted to improve service to the schemes and serve about 60% of the total households in the schemes' service areas.
- The **Kapcherop Water Supply Project** will supply the Sengwers, indigenous people of Kapcherop as an extension to the Kapcherop Kapsowar Water Supply project which was recently completed under the first phase of the Water and Sanitation Improvement Project (WaSSIP I).
- KOICA and LVNWWDA to develop **major water supply in Bungoma**.
- **Kiminini Kona Community Water Supply**
- **Chesikaki – Cheptais – Sirisia Water Supply**
- **Moi's Bridge – Matunda Water Supply System** under rehabilitation

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

3.2.8 Sectoral perspectives

3.2.8.1 Water supply and sanitation

There are currently three large dams in the LVN Basin, as well as many small dams and pans, with a total storage volume of about 32 MCM, as shown in Table 4.1. These supply mainly urban and domestic demands and livestock watering. The location of the existing major reservoirs is shown in

Table 3-6. There is very little irrigation demand in the basin at present.

There is currently one bulk water supply intra-basin transfer from Chebara (Moiben) Dam to Eldoret and Tambach towns, with a total transfer capacity of 8 MCM per annum (22 000 m^3/d). There are currently no transfers into the Basin from other Basins, or out of the Basin to other Basins. One future inter basin transfer is planned from the proposed Nandi Forest Dam on the Yala River to the Oboro River in Lake Victoria South Basin.

Table 3-6: Existing bulk water storage in LVN Basin

Relative Size	Storage schemes	Volume (MCM)	Purpose
Large dams > 1MCM	Moiben	18	Domestic supply
	Ellegirini	2	Domestic supply
	Kipkarren	3	Domestic supply
Smaller dams and pans	Lessos	1	Domestic supply
	Twin Rivers	Small	Domestic supply
	Small dams & pans	8	Domestic & livestock supply
Total		**32**	**-**

Further development of bulk water resources is essential to satisfy the growing future water demands. This should be supplemented by the development of small dams for scattered water demands as well as groundwater resource development to augment surface water in certain areas.

About 23% of the population in the LVN Basin currently receives drinking water from unimproved sources (unregistered water vendors and water taken from lakes and streams without proper treatment), while 66% receive water directly from boreholes and springs. Approximately 11% of the households in the LVN Basin receive piped water, the majority of these being urban households (Table 3-7).

Table 3-7: Existing access (%) to water supply infrastructure in LVN Basin

Type	Piped supply by WSP	Spring/ Borehole	Water Vendor	Stream/ Lake
Urban	31	53	3	13
Rural	5	70	0	25
Total	11	66	1	22

Source: (Water Resources Management Authority, 2013)

The LVN Water Works Development Agency contracts Water Services Providers (WSPs) to provide the population with potable water. There are eight urban WSPs, namely Eldoret WSC, Nzoia WSC, Western WSC, Amatsi WSC, Kapsabet Nandi WSC, Sibo WSC, Kapenguria WSC and Item Tambach Water Project. There are also three rural WSPs, namely Uasin Gishu District, Lugari District and Trans Nzoia District. Together these WSPs provide a capacity of 113,106 m3/day. The non-revenue water (NRW) of these WSPs ranges from 25% to 64% (average of 48%).

Water users apply for water permits through the relevant WRA SRO, and the application is then sent to the RO for processing. Class A to C permits are handled at RO level, while Class D permits are handled at Head Office. An Abstraction and Pollution Survey Report must be submitted by the water user (conducted by a qualified professional consultant) with the application. The water permits are recorded in the Water Permit Database at the RO.

Approximately 2% of households are connected to a formal sewerage system, all of these being located in urban areas. Pit latrines and septic tanks are used by 94% of the population, while 2% of the population have no form of sanitation system (Table 3-8).

Table 3-8: Existing access (%) to sanitation infrastructure in LVN Basin

Type	Sewerage System	Septic tank/ Pit latrine	Bush
Urban	7	92	1
Rural	0	95	5
Total	2	94	4

Source: (Water Resources Management Authority, 2013)

Development in the water supply and sanitation sector in the basin is hampered by insufficient institutional, human resources, financial and technological capacity. Some of the specific aspects relate to poor performance of many utilities, high levels of non-revenue water (NRW) in many utilities (above 40%), poor governance practices, non-viable utilities, inadequate enforcement of water resources regulations, a lack of clear mandates for actors in the storage sub-sector. Challenges under the water supply sector include water scarcity, assurance of supply, population growth, urbanisation and industrialisation, financial constraints, water quality, low reliability of supply, and various institutional challenges. 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 one percent consists of solar and other forms of energy. Hydroelectric power in Kenya currently accounts for about 49% of installed capacity, which is about 761 MW. However, the Government of Kenya is strongly pushing for a shift to other alternative resources of electricity generation and by 2030 it is expected that hydro power will only account for 5% of total capacity at 1 039 MW.

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

About 9% of the population in the LVN Basin has access to electricity. Paraffin is commonly used for lighting in households without access to electricity, and about 95% of the population use biomass (burning of firewood and charcoal) as a source of energy for cooking. There is one small hydropower scheme in the catchment on the Sosiani River, with an installed capacity of 400 kW. Although hydropower generation is currently low in the catchment, there is potential for future development of hydropower dams on the Nzoia and Yala rivers.

Connection of users to the main electricity grid in the LVN is generally very poor except in large towns. The rest of the basin has no access to modern energy services or employs off-grid energy systems like solar, wind and hydro.

The LVN Basin will need to develop specific plans based on distributed generation and renewable energy to expand energy access to many users in this region. Considering that a major section of the Basin is not connected to the national grid, the opportunity for exploiting renewable energy is very attractive. This would involve using mini-grid hydro, mini-grid wind, stand-alone diesel, stand-alone PV or a hybrid combination of these technologies. The use of run of the river micro-hydro systems is also a potential possibility.

- Limited gold mining taking place in the LVN Basin at the following locations:
  - Kakamega County - Ikolomani goldmines
  - Siaya County in Bondo, Siaya, Rarieda, Unguja and Gem sub-counties
  - Nandi county - Chemase in Tinderet Sub-County
- There is potential to mine other minerals, precious stones and rare earth elements, for example graphite (Cheang'any hills), asbestos, vermiculite and fluorite.
- Sand mining and quarrying for building materials such as granite, murram and ballast, occurs throughout the Basin. Sand harvesting is common along riverbanks and areas with sandy soils, such as the riverbanks of the Nzoia, Malakisi, Sirisia, Kundos, Kipkaren and Mokong Rivers.
- All these activities need to be regulated to ensure safe and sustainable practices.
- Prospecting for gold and other minerals is underway in Vihaga county at Kichutu in Viyalo, Chavakali and Shiru wards. The CIDP recognises this potential for more mining activity in the county, and intends to promote this by involving development partners to invest in modern mining technology and establish mining plants
- Future water demands for the mining sector need to be accommodated in water resources planning.

3.2.8.3 Agriculture

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

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

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

Freshwater fishing in Lake Victoria is the largest in Kenya and accounts for 78.7% of the total freshwater fisheries production (Water Resources Management Authority, 2013). 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 limited knowledge and skills and inadequate supplies of quality feed and seed fish. Small-scale rural enterprises produce mainly Tilapia at a subsistence level.

The LVN Basin is classified as humid land (Water Resources Management Authority, 2013). Water demands for agriculture in the Basin include commercial farming (mainly horticulture, floriculture and wheat farming), livestock keeping, small-holder subsistence farming 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 776 811 ha, mainly consisting of rain-fed crops, with only 1 876 ha of irrigated crops. This irrigated area is made up of 19% large-scale, 71% small-scale and 10% private irrigation schemes (Water Resources Management Authority, 2013).

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

3.2.8.4 Forestry, land use and catchment management

Poor land use planning and management have detrimental effects on the water resources of a basin. Human encroachment of riparian land and forest areas, as well as unsustainable agricultural, pastoral and livelihood activities that are incompatible with the capacity of the land are some of the major land use issues in the LVN Basin. The valuation of the forests in the basin and its contribution to the national economy is largely undocumented. Human encroachment, illegal logging, overgrazing, fires, pests and diseases among others are threatening the forest reserves leading to a significant loss of vegetation cover. In 2010, the total forest area in the LVN Basin was about 107,000 ha. However, according to satellite imagery, the forested area had decreased by about 30% since 1990 (Water Resources Management Authority, 2013). 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 230 000 ha of forestation is proposed in the NWMP 2030 for LVN Basin up to 2030.

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

In the LVN Basin, forest reserves largely cover the area surrounding the major water tower of the catchment as well as groundwater recharge areas. These reserves include: Mount Elgon Park, Cherangani Hills, and the Mau Forest Complex. Other forest reserves are the Kakamega and Nandi forest reserves. The Kikuyu Escarpment, Chyulu Hills and Ngong Hills forest reserves are important groundwater recharge areas in the catchment.

3.2.8.5 Biodiversity, protected areas and tourism

The LVN Basin contains important wildlife habitats and tourism/recreation assets. It includes one national park namely, Mount Elgon National Park. Lake Victoria is a major tourist attraction, with many people visiting the lake to fish, and to enjoy its natural beauty. Other tourist attractions are the Kakamega Forest (renowned for the occurrence of the rare bird species, for example: The Great Blue Turaco), Saiwa Game Reserve and the 'Crying Stone' located in Kakamega County. The LVN Basin has developed infrastructure for tourism, including holiday resorts, camping areas and transport infrastructure.

Aside from the Water Towers and gazetted forests, which are managed by KWTA and KFS respectively, the Parks and Reserves division of the Kenya Wildlife Service (KWS) manages the National Parks, National Reserves, and National Sanctuaries 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 LVN 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 obliges states to develop appropriate domestic measures for effective management of biodiversity in relation to access to genetic resources, benefit-sharing and compliance. Biodiversity in wetlands and sections of the river flowing through protected areas also receive protection by KWS.

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

The LVN Basin ecosystems, as with most river basins in Kenya, do not have specific plans or strategies that target biodiversity and ecosystem conservation. However, efforts made for natural resource management, basin rehabilitation, and integrated water resource management in the basin result in biodiversity conservation. The wetland ecosystems of the LVN Basin are environmentally sensitive areas under threat from human encroachment. Lake Victoria is an international lake in the LVN Basin which straddles the Kenya-Uganda border. 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.

04

Image source: Western Kenya 2014. 'The bank of River Nzoia at Rwambwa Bridge'. Available online at https://www.flickr.com/photos/wkcddfmp/16987735225com.

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 LVN 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 LVN 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 LVN 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.

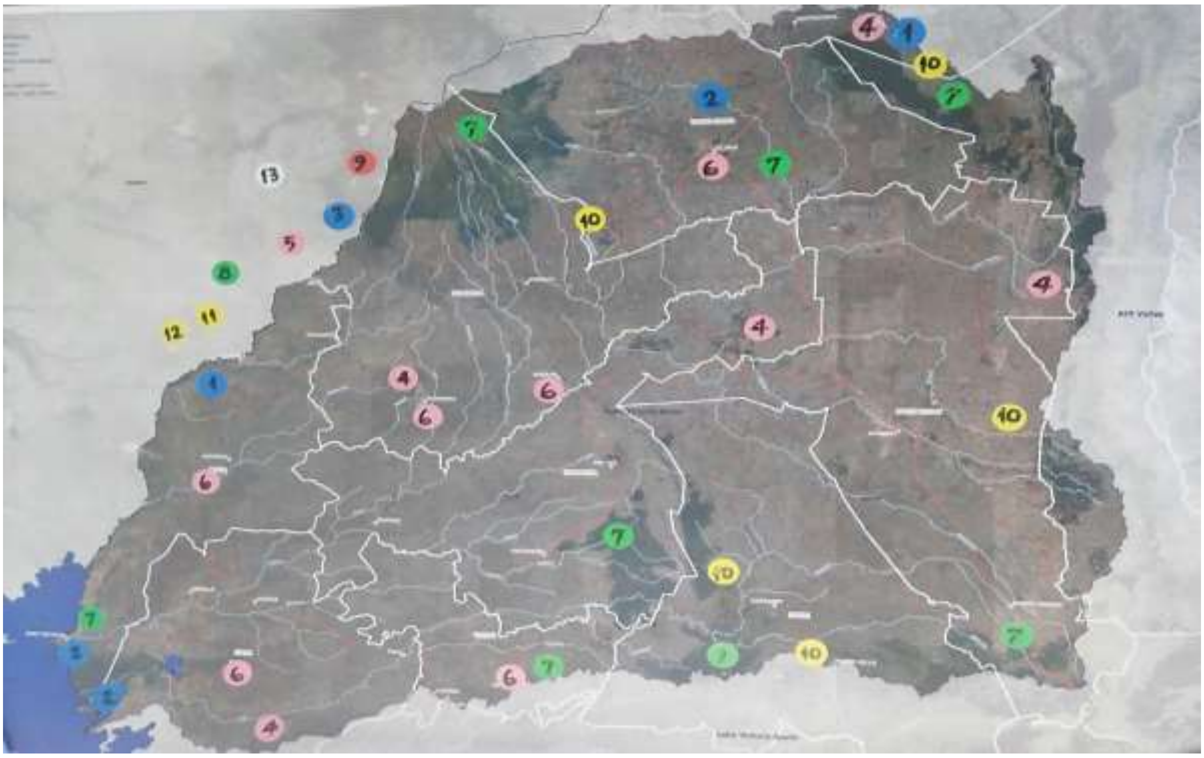


Figure 4-1: Example of output from the workshop for the LVN Basin

During the workshop key stakeholders (listed in **Annexure D**) were spilt into nine groups, each group was asked to identify issues under the following main categories:

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

The outputs from the session were collated and Figure 4-2 shows the relative frequency of identified issues in the basin under the above categories.

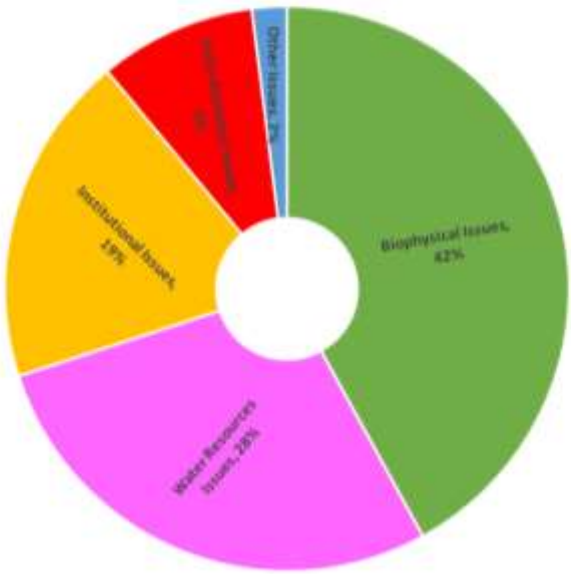


Figure 4-2: Frequency of identified key issues in the LVN Basin

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.

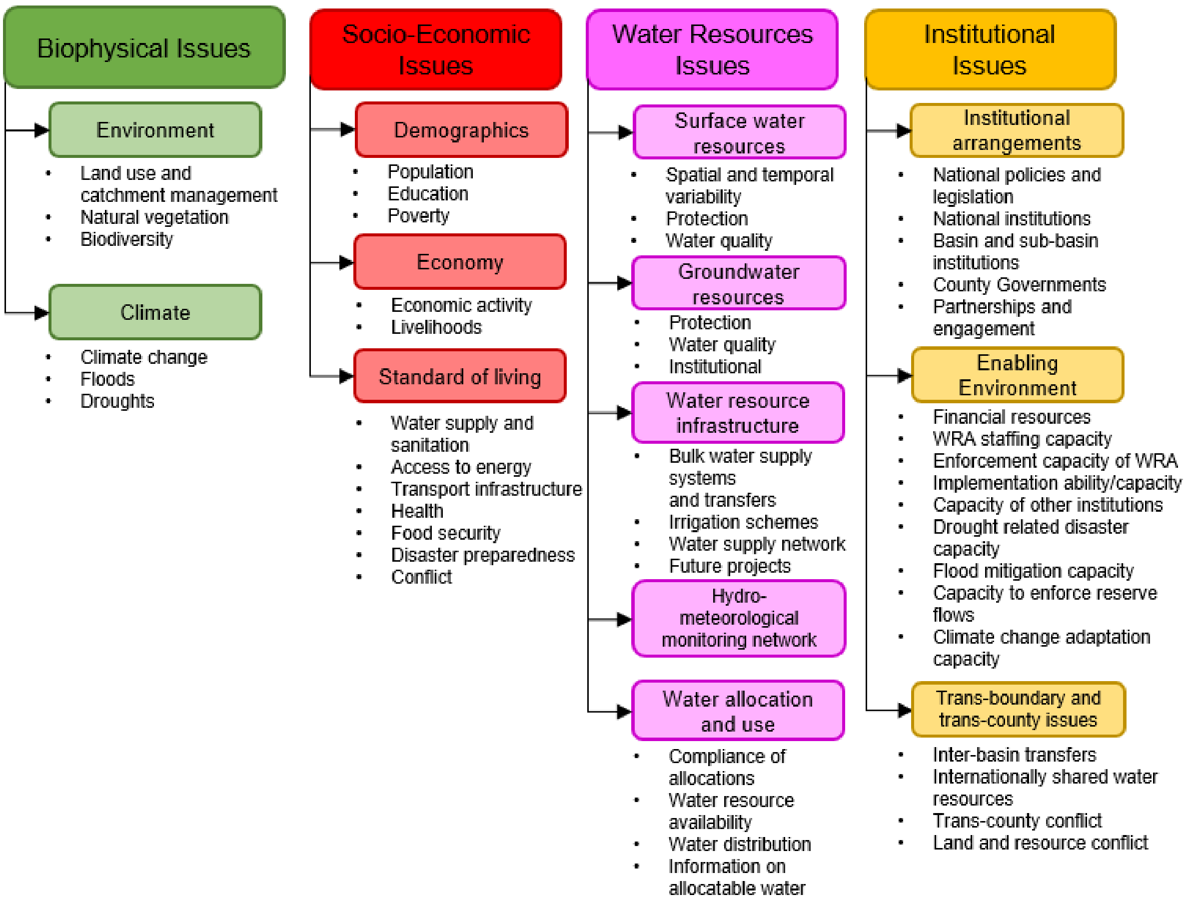


Figure 4-3: Key issues framework

4.3 Biophysical issues

Out of the four key issues identified, biophysical issues were ranked highest in the LVN Basin. According to the first workshop results the main biophysical issue in the LVN Basin is poor land use and watershed planning and management.

Image source: www.sheldrickwildlifetrust.org/news/updates/anti-poaching-initiative-in-the-mau-forest-reaps-rewards-for-wildlife

4.3.1 Environment

The environment encompasses the land, vegetation and biodiversity of LVN 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 (Government of Kenya, 2007a). About 16% of Kenya's land is potentially arable. This is dominated by commercial agriculture (cropland 31%, grazing land 30% and forests 22%), urban centres, game parks, markets, homesteads and infrastructure (Government of Kenya, 2010a). The remaining 84% of Kenya's land that is non-arable is 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. Human encroachment of riparian areas, springs, wetlands and forest areas, as well as unsustainable agricultural, pastoral and livelihood activities that are incompatible with the capacity of the land are some of the major land use issues in the LVN Basin.

Agricultural systems can either be rainfed or irrigated agriculture. Most of Kenya is dependent on rainfed agriculture, with the performance being dependent on the agro-climatic zones. In the humid, high-altitude areas such as the LVN Basin, predictability of a good crop is high (Government of Kenya, 2010a). However, the population density has increased and land has been subdivided to a degree that it has become uneconomical for farm enterprises (Government of Kenya, 2010a).

Unsustainable agricultural practices and expansion

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

Examples of unsustainable agricultural/pastoral practices and expansion:

- Poor land management in Busia county leading to environmental degradation, for example soil erosion and flooding in the southern part of Teso North, Teso South and Bunyala sub-counties (County Government of Busia, 2018).
- In Elgeyo-Marakwet, encroachment by farmers into wetlands and riparian reserves has resulted in serious environmental degradation in the following areas: Embobut, Embo mon, Arror, Moiben, Chepkaitit, Embolot, Enou, Emsoo, Kessup, Torok, Sabor and Kimarer. Wetlands that have been encroached on include Kaptalamwa in Lelan Ward, Kararia in Kapyego Ward, Chesawa and Katepseron in Embobut-Embolot Ward (County Government of Elgeyo Marakwet, 2018)
- Similar encroachment by farmers into wetlands and riparian reserves in Nandi county has also resulted in serious environmental degradation, particularly soil erosion. Overgrazing has further contributed to soil erosion, particularly in the rainy season. Landslides occur often in the rainy season along the escarpment, particularly in Chorondo and Uson in Tindiret sub-county, causing loss of life and damage to property (County Government of Nandi, 2018).
- Poor land use practices in Kakamega county have caused environmental degradation such as soil erosion, water pollution from sedimentation, eutrophication, loss of riparian areas, landsides, and frequent flash floods (County Government of Kakamega, 2017).
- Poor farming and fishing methods in Siaya county have led to environmental degradation such as the destruction of riverbanks, wetlands and arable farmland. As a result, agricultural and fisheries production have declined over the years, further worsening the economic status of the county population (County Government of Siaya, 2018)
- In Trans Nzoia, land degradation due to poor agricultural practices and encroachment on fragile ecosystems has led to gully erosion in Kapkoi and Tuwan stream (County Government of Trans Nzoia, 2018).
- Poor farming practices have been a major contribution to environmental degradation in Vihiga county, leading to low farm yields and food insecurity, as well as increase landslides and reducing wetlands (County Government of Vihiga, 2018).

Mudslides and landslide

Landslides and mudslides accompany heavy rains or follow droughts. Although they are caused by weather patterns, they are exacerbated by poor catchment management and decreasing vegetation cover. Landslides and mudslides can have devastating impacts on communities, and further degrade and damage catchments.

Examples of unsustainable agricultural/pastoral practices and expansion:

- In Trans Nzoia County, landslides have been experienced in Milimani in Cherang'any, and Kimondo in Mount Elgon. Encroachment on Mount Elgon and Cherang'any hills, deforestation, poor agricultural practices and changing weather patterns have all contributed to the occurrence of landslides (County Government of Trans Nzoia, 2018).
- Landslides occur in the Shinyalu and Kuvasali areas of Kakamega County, as a result of floods and changes in land use (County Government of Kakamega, 2017).

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 river bed 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:

- Rivers with sand mining:
  - Kerio River in Elgeyo Marakwet (County Government of Elgeyo Marakwet, 2018)
  - Major Rivers in Kakamega county, including Yala, Isiukhu, Nzoia, Firatsi, Sasala and Lusumu (County Government of Kakamega, 2017)
  - Nzoia River in Trans Nzoia county (County Government of Trans Nzoia, 2018)
- Counties with sand mining issues:
  - Sand harvesting occurs in Bungoma county. It is common along riverbanks and areas with sandy soils such as Malakisi and Sirisaia (County Government of Bungoma, 2018).
  - Sand harvesting along riverbanks occurs in Busia County (County Government of Busia, 2018).
  - Sand harvesting, mainly for construction purposes, is undertaken in Kakamega county (County Government of Kakamega, 2017).
  - Sand harvesting in Nandi County usually occurs in Aldai and Tinderet sub-counties (County Government of Nandi, 2018).
  - Sand harvesting occurs in Trans Nzoia county in Machewa, Saboti, Keiyo and Chepchoina wards (County Government of Trans Nzoia, 2018).
  - Sand harvesting takes place in Vihiga county (County Government of Vihiga, 2018)

Unsustainable mining

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

Example of unsustainable mining:

- Mining is one of the major contributors to environmental degradation in Vihaga county (County Government of Vihiga, 2018)
- Gold mining has taken place in Nandi county at Chemase in Tinderet sub-county since 2009. The company undertaking these mining operations has been accused of poor management of the environment (County Government of Nandi, 2018)
- Gold mining is carried out in Rosterman in Lurambi, Ikolomani, Khwisero, Shinyalu and Butere in Kakamega county. Negative effects result from these activities, for example: acid mine drainage, air and noise pollution, collapse of mining pits, caving of overburden, and heavy metals pollution (County Government of Kakamega, 2017).
- Poor mining techniques are used in Elgeyo Marakwet county (County Government of Elgeyo Marakwet, 2018)

Land use change

Change in land use can have several effects, depending on the type of change that occurs. Deforestation occurs when trees are cut down and cleared so that fields can be planted. Wetlands and swamps are sometimes filled in or drained so that fields can be planted. Farmland can be turned to settlements, which may increase surface runoff due to the change in land cover. Urban areas will produce waste, which may increase pollution if not handled properly.

Fragmentation and urban sprawl

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

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

4.3.1.2 Natural vegetation

The major contributors to the loss of natural vegetation in the LVN 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 LVN 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 Nandi Hills have also had tree gain over the period 2001-2012.

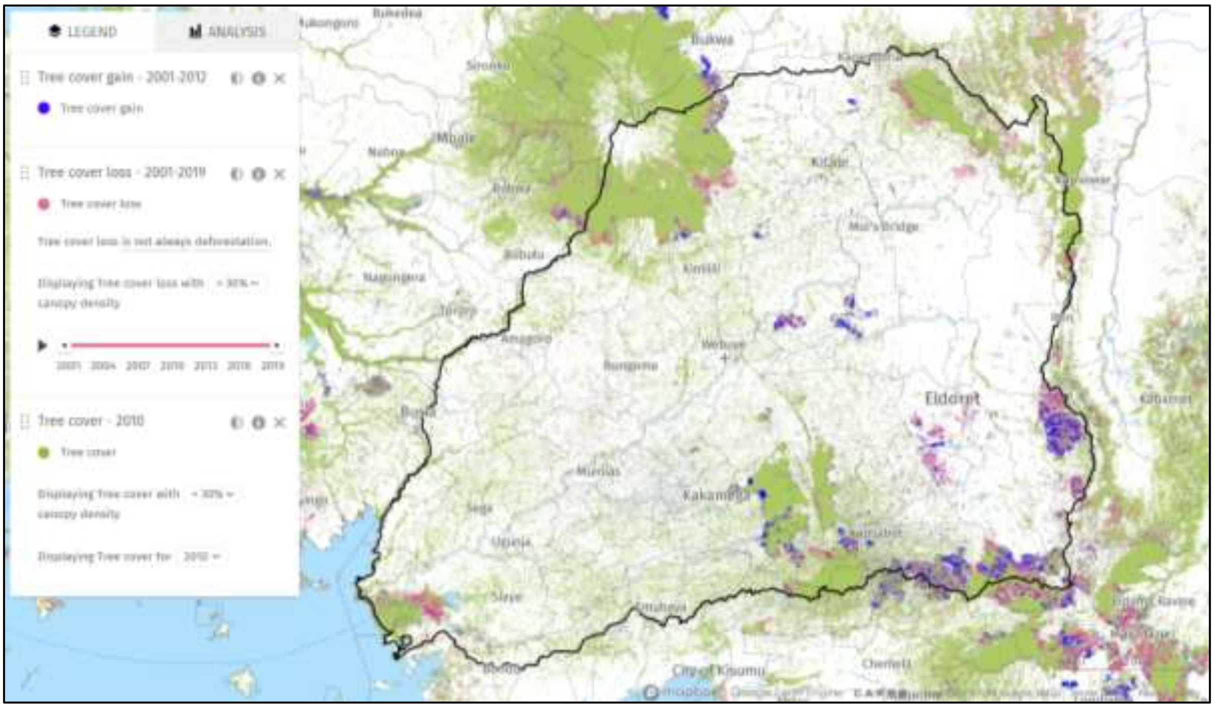


Figure 4-4: Tree loss and tree gain for LVN Basin according to Global Forest Watch

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 LVN Basin forest reserves have been threatened by human encroachment and there is a need to protect them. The total forest area in the LVN Basin in 2010 was about 107 000 ha, and according to satellite imagery, the forested area had decreased by about 30% since 1990 (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

- The high population in Bungoma county has led to encroachment on wetlands, riverbanks and protected forests for farming and settlement purposes. This has resulted in poor quality and quantity of water resources, increased intensity of flash floods, riverbank erosion and sedimentation. Some water catchment and riparian areas that need conservation are Kongit, Chesito, Kaptama, Kaptalelio, Chemoge Kaborom and Kaboywo. (County Government of Bungoma, 2018)
- In Busia county, the natural environment is heavily degraded through deforestation especially on the hills (County Government of Busia, 2018).
- Occupation of gazetted forest areas such as Embobut, Kipkabus and Chebara takes place in Elgeyo-Marakwet county. This leads to deforestation, illegal logging charcoal burning and forest fires along the escarpment and Kerio valley. The destruction of the water catchment areas has led to reduced water flow and escalating resource based conflicts among the downstream communities (County Government of Elgeyo Marakwet, 2018)
- Rivers in Kakamega county are drying up because of deforestation in the catchment areas. Many of these trees are used to create charcoal and make bricks as people try to earn an income and escape poverty (County Government of Kakamega, 2017).
- High levels of deforestation occur in Nandi county in the following areas: Nandi escarpment, Legemet, Ndalat, Kabiyet and Tabolwa hills (County Government of Nandi, 2018)
- Deforestation has occurred in Uasin-Gishu county because people rely on trees for fuel (County Government of Uasin Gishu, 2018).
- Trans Nzoia experiences high levels of deforestation. Landslides have occurred in Milimani in Cherang'any and Kimondo in Mount Elgon due to a combination of deforestation, poor agricultural practices, changing weather patterns, and encroachment for settlement and cultivation (County Government of Trans Nzoia, 2018).
- Deforestation in Siaya county has led to the destruction of tree cover, resulting in a decline in agricultural and fisheries production over the years (County Government of Siaya, 2018)

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

Examples of forest conservation efforts:

- During the period 2013-2017, the Elgeyo-Marakwet county government planted 1 100 000 tree seedlings in the Cheragany hills, escarpments and the Kerio Valley. Bamboo seedlings were also planted in wetlands, springs and water catchment areas that include: Lelan Wetland, Emsoo Dam Wetland, Kap Ali Spring in Iten Town, and Lolgarini dam in Kabiemit. The Elgeyo Marakwet charcoal act, 2017 was introduced to regulate the production of charcoal and reduce deforestation in the county. The latest CIDP includes plans to establish more tree nurseries and continue tree planting efforts (County Government of Elgeyo Marakwet, 2018).
- Tree planting by institutions and individuals will be promoted by the Nandi county government by establishing tree nurseries under a PPP arrangement (County Government of Nandi, 2018).

- Bungoma county has ongoing projects to promote environmental sustainability by planting trees along riparian zones, establishing woodlots to protect water catchment areas, and to establish a county tree nursery (County Government of Bungoma, 2018).
- Busia county plans to promote environmental protection through the planting of trees and the development of designs with environmental consideration measures (County Government of Busia, 2018).
- The tree cover in Kakamega county was increased by planning over 430 000 trees in public institutions, hill tops and riverbanks from 2013-2017. There are plans to plant more trees to increase tree cover in natural forests such as Kakamega, Malava, Kisere and Buyangu as well as planted forests such as Lugari, Likuyani and Navakholo (County Government of Kakamega, 2017)
- Siaya county has limited forest cover, with only two gazetted forests: Got Abiero and Ramogi Forests. Protection and planting of trees is being carried out in the county in collaboration with the local community. The banning of charcoal burning is being considered in Siaya county (County Government of Siaya, 2018).
- The forests in Trans Nzoia county occur mainly on the two water towers (Mount Elgon and Cherangany hills). These are degraded, and the county government and other stakeholders plan to embark on aggressive rehabilitation and restoration of these water towers. Woodlots will be established, and laws will be enacted to curb deforestation (County Government of Trans Nzoia, 2018).
- Usain-Gishu county will develop appropriate strategies to increase the forest cover from 7.55% to 8% by 2022. One area that will be targeted is the Sisioan River, where trees will be planted in the catchment (County Government of Uasin Gishu, 2018)
- Tree seedlings (13 000) were planted in Vihiga county at Emabungo hills, water catchment areas, public institutions and Maragoli hills (County Government of Vihiga, 2018)

Encroachment of aquatic land

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

Examples of encroachment of aquatic land (wetlands):

- High population pressure in Bungoma county has led to encroachment on wetlands, riverbanks and protected forests for farming and settlement purposes. (County Government of Bungoma, 2018).
- Farmland in Busia county is in short supply, forcing farmers to encroach on fragile areas like riverine catchments and wetlands for food production (County Government of Busia, 2018).
- Elgeyo county has a shortage of arable land, which has led to farming being practiced in wetlands and riparian reserves, resulting in serious environmental degradation. The following wetlands are most affected: Kaptalamwa in Lelan Ward, Kararia in Kapyego Ward, Chesawa and Katepseron in Embobut-Embolot Ward.

- Farmers in Nandi county have encroached into wetlands and riparian areas, including the Kingwal swamp, which is a tourist attraction. Settlements have also encroached on wetlands in some cases. Other destructive activities taking place are the unsustainable harvesting of aquatic plants and reeds, extensive planting of eucalyptus trees, overgrazing and brickmaking and harvesting activities. Other wetland areas affected are: Kibirong, Mutwot, Chepkunyuk, Kamatargui, Birei and Kapkong'ony (County Government of Nandi, 2018).
- The shores of Lake Victoria have been negatively affected by encroachment in Siaya county. The Yala Swamp is prone to overexploitation as the surrounding communities rely on the wetland for their livelihood. Large areas of the swamp have been converted for agricultural use (County Government of Siaya, 2018).
- Wetland encroachment has occurred in Uasin-Gishu county (County Government of Uasin Gishu, 2018)
- In Vihaga county, encroachment of wetlands by the growing population has led to declining water volumes in existing water sources. Planting of unsuitable species of trees close to wetlands and riparian land has led to wetlands reducing in size, resulting in water pollution leading to incidences of waterborne diseases (County Government of Vihiga, 2018).

Invasive alien species

Planting of alien species such as eucalyptus has led to the degradation of wetlands and riparian areas. Invasive alien weeds such as Elephant grass have spread from agricultural lands.

4.3.1.3 Biodiversity

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

Threatened ecosystems

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

Examples of threatened ecosystems:

- The Mt. Elgon area, riverbanks, forest, Cherang'any hills, National parks and wetlands are biodiversity rich areas in Trans-Nzoia county that are under threat from encroachment, pachinch, invasive species, pests and diseases, wild fires, overharvesting and pollution. (County Government of Trans Nzoia, 2018).
- Threatened tree species in Busia county include Mvuli, Abbisia Gummisera, Albisia Amara around Samia and Bunyala Hills, Dombea and Olea Africana. Indigenous herb species are threatened by the application of herbicides, chemical fertilisers and weed control. Examples of these herb species include commallina bengatensis, spider weed, indigenous amaranthas and the local herb knows as sinyolonyolo (County Government of Busia, 2018).
- Elgoyo-Marakwet county plans to establish botanical gardens to preserve tree species which are used for medicinal purposes because of over harvesting (County Government of Elgeyo Marakwet, 2018).
- Kakamega Forest is a remnant of tropical rainforest and is rich in endemic species. It is globally recognised as an area of importance for avifauna and is an important tourist attraction (County Government of Kakamega, 2017)

- As mentioned previously, the Kingwal swamp in Nandi county is threatened by encroachment and unsustainable harvesting (County Government of Nandi, 2018).
- The Lake Kanyaboli ecosystem is degraded and requires rehabilitation and conservation (County Government of Siaya, 2018)
- The Saiwa Swamp ia a major tourist attraction in Trans-Nzoia County, and is home to the Sitatunga, a swamp-swelling antelope. Saiwa National Park is a protected area, but still faces the threats of deforestation, degradation and the clearing of bulrushes, and land encroachment (County Government of Trans Nzoia, 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:

- There has been human encroachment into wildlife habitat in Siaya county (County Government of Siaya, 2018).
- The habitat of the Sitatunga antelope is threatened by the degradation of Saiwa swamp through clearing of bulrushes and encroachment in Trans Nzoia county. This antelope is very rare and is an important tourist attraction (County Government of Trans Nzoia, 2018).
- The Sitantunga antelope is also found in the Kingwal Swamp in Nandi county. The county government plans to fence and protect the swamp in order to protect and conserve the species and promote tourism (County Government of Nandi, 2018)
- Wildlife, especially large herds of elephant, in the Rimoi game reserve is the main tourist attraction in Elgoyo-Marakwet county. The highly endangered pangolin occurs here (County Government of Elgeyo Marakwet, 2018).
- Forty-five of the species on the list of birds occurring in Kenya are only found in the Kakamega Forest, and nine of the species occur nowhere else in Kenya. Three species are threatened, namely Turner’s Eremomela (Eremomela turneri), Grey Parrot (Psittacus erithacus erithacus) and Chapin’ Flycatcher (Muscicapa lendu) (County Government of Kakamega, 2017).

4.3.2 Climate

The LVN basin has a tropical humid climate, with two rainy seasons from March to May (long rains) and October to November (short rains). The remaining months form the two dry seasons. The catchment is classified as humid land, and the mean annual precipitation (MAP) across the catchment is 1 420 mm. The average annual day temperatures vary from 16°C in the upper catchment to 28°C in the lower catchment, while the average annual night temperatures vary from 4°C in the upper catchment to 16°C in the lower catchment.

Image source: www.businessdailyafrica.com/datahub/Cash-crunch-in-race-to-deal-with-floods-aftermath-/3815418-4636560-luof7cz/index

4.3.2.1 Climate change

Climate change appears to be taking effect in Kenya. Expected impacts include increased temperature, increased intensity and frequency of extreme climate events as well as unpredictable weather patterns. The effects of climate change are addressed below.

Increasing intensity of extreme events

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

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

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

Increasing temperature and evaporation rates

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

Unpredictable and irregular weather conditions

Kenya's weather patterns have started changing and are becoming more unpredictable. As most farmlands in the LVN Basin are rain-fed, the inconsistent rainfall makes farming difficult. The unpredictability also makes long-term planning difficult and creates uncertainty in prioritisation of short-term adaptation strategies. According to the CMS (Water Resources Management Authority, 2015a) the climate in the LVN 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 acceleration in soil erosion following a dry spell.

Increased frequency of droughts

An increased severity of droughts that is expected in the LVN Basin (Water Resources Management Authority, 2015a) 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:

- Busia county has experienced flooding in the southern part of Teso North, Teso South and Banyala sub-counties (County Government of Busia, 2018).
- Elgeyo Marakwet county has experienced a general reduction in water levels in all rivers and water storage bodies in the county. Lake Kapnarok in the Kerio Valley has silted, and the lake waters have significantly reduced. Reduced flows have been experienced over the years in all rivers in the county, especially during the dry season from January to March (County Government of Elgeyo Marakwet, 2018).
- Flooding has been experienced in Kakamega county due to climatic changes, leading to displacement of people. Farming on the lowlands has been reduced due to regular destruction of crops during heavy rains, further affecting the already low food production in the county (County Government of Kakamega, 2017).
- Prolonged drought has been experienced in Trans-Nzoia county over the past few years, affecting agricultural activities, livestock and water sources. Flooding has affected areas such as Namanjalala every year (County Government of Trans Nzoia, 2018).
- Vihaga county has experienced climate change as varying high temperatures and erratic rainfall patterns (County Government of Vihiga, 2018).

4.3.2.2 Floods

The LVN Basin is vulnerable to flood disasters, and the most vulnerable areas are Lower Yala, Lower Sio and Lower Nzoia (specifically Budalangi). Flooding is currently controlled on the Nzoia and Yala Rivers through the construction of dykes. Recent historical floods include:

- The collapse of dykes in Budalangi in November 2006, displacing over 10 000 people.
- Heavy rains in October to November 2008, causing the River Nzoia to overflow its banks.

The Western Kenya Community Driven Development and Flood Mitigation Project (WKCDD&FMP) has been completed and is a key contributor to flood control and management in the LVN Basin. Their planning includes the construction of flood control dams and dykes, the development of Flood Early Warning Systems (FEWSs) and community-based disaster management systems.

Although the LVN Basin is not generally a drought-prone catchment, a recent Strategic Drought Mitigation Study undertaken for the LVN Water Services Board (WSB) focused on drought tendencies in the LVN, Lake Victoria South and the Rift Valley Basins. Some areas in the LVN Basin that experience drought include the Lower Sio, Nzoia and Yala sub-basins. There are currently fewer agencies involved in drought management compared to floods. Pre-emptive water use restrictions on the reservoirs supplying the LVN Basin have not been implemented, resulting in water rationing being applied in Eldoret in recent years (Ndanyi, 2017). There is also minimal enforcement of Reserve flows in the catchment.

Some of the proposed flood and drought management plans include flood control by dams, dykes and river improvement in the Nzoia River Basin; the operation of a FEWS in the Nzoia River Basin; preparation of integrated flood management plans in the Nzoia and Yala River Basins; and the implementation of Water Use Restriction Rules for reservoirs in the LVN Basin.

Figure 4-5: Flooding from the Yala River in the LVN Basin (Ndonga, 2018)

People affected by floods

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

Examples of people affected by floods:

- Frequent flooding in the lower lands of the Kakamega County affects food production and security due to the destruction of crops (County Government of Kakamega, 2017).
- People in the Busia County, along the Nzoia River are also severely affected as dikes burst during flood events. These areas were particularly affected by floods that occurred in 2006 and 2007, after which, the long-term food security of communities was affected (Earth Observatory, 2007).
- In 2008, heavy rain caused the Nzoia River's banks burst causing flooding of the surrounding areas.

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 experience a loss of income with reduced crop yields, additional expenses to repair equipment and possible re-cultivation of the land. Livestock farmers may incur loss due to floods causing livestock diseases and deaths. 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:

Agricultural activities are affected by floods due to the destruction of croplands in areas such as the Busia County (Earth Observatory, 2007).

Conflict

Communities that are vulnerable to flooding are generally those living on less secure pieces of land or those who do not have the resources to build stronger houses. Displacement of communities causes conflict as communities compete for more secure land.

Example of conflict caused by floods:

- Soil erosion caused by frequent flooding has reduced soil fertility in some areas of the Kakamega County causing conflict over competition for natural resources (County Government of Kakamega, 2017).
- Floods occurring in the Namanjalala area during the long rains have also caused conflict in the past (County Government of Trans Nzoia, 2018).

Damage to infrastructure

Depending on the magnitude and frequency, floods have the potential to deteriorate, and cause major damage to infrastructure. As a result, maintenance costs are often incurred (County Government of Kakamega, 2017).

Examples of damage to infrastructure caused by floods:

Floods have caused damage to irrigation infrastructure, critical infrastructure, and property in the Busia District in the past, particularly during the 2006, and 2007 floods (Earth Observatory, 2007).

4.3.2.3 Droughts

Although droughts in the LVN Basin are not as severe as in other parts of the country, below-average rainfall causes decreased agricultural production, deterioration of water quality, and lower lake levels. Areas within the Basin that experience frequent droughts include Lower Sio, Nzoia and Yala (Water Resources Management Authority, 2015a). 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 main issues associated with droughts are described below.

People affected by droughts

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

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

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

Example of people affected by droughts:

People have been displaced by frequent droughts in the Trans Nzoia County, and now there are high poverty levels amongst the women who were displaced (County Government of Trans Nzoia, 2018)

Economic impacts of droughts

The agricultural and livestock sectors experience major losses due to droughts. Due to a large amount of the farmlands in the LVN Basin being rain-fed agriculture, droughts result in low crop yields. Although crop prices increase to counter the lower crop yields, the agricultural sector usually experiences a reduction in sales.

The livestock sector experiences several issues because of droughts. The lack of water for cattle results in decreased milk production. Water scarcity also contributes to livestock diseases and deaths. There is concern that pastoralists and crop farmers may leave the agricultural sector in the hope of finding new work opportunities in the urban centres.

Example of economic impacts of droughts:

Hydropower generation becomes less efficient during droughts due to limited water availability (UNEP-DHI et al., 2016)

Conflict due to droughts

Droughts result in scarcity of water for both wildlife and people. This gives rise to conflicts between various groups. Conflict arises between locals and pastoralists when the migration of the pastoralists' livestock increases competition for available resources. The probability of humans encountering wildlife also increases during droughts as both humans and animals are in search of food and water. Drought is the cause of many trans-county conflicts as it worsens water scarcity.

Examples of conflict due to droughts:

Droughts in the dry season cause conflict along the boundary lines of Trans Nzoia and West Pokot Counties due to cattle rustling, as well as crop and animal diseases (County Government of Trans Nzoia, 2018)

4.4 Socio-economic issues

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

Agriculture, as the mainstay of Kenya's economy, is critical to the growth of the national economy. Following independence, the agricultural sector recorded a high growth rate and during this time small-scale agriculture grew rapidly as land and technology was made available (Government of Kenya, 2010a). Agricultural extension and research were also well supported by the government. Since then there has been a gradual decline, followed by growth when the Government identified the agriculture sector as a priority.

The Economic Recovery Strategy for Wealth and Employment Creation (Government of Kenya, 2003) emphasised economic growth and creation of wealth and employment as a means of eradicating poverty and achieving food security. The development of the agricultural sector was considered a top priority in reducing poverty because it is the most important economic activity for the poor in rural areas. In 2008, Kenya Vision 2030 was launched as the new long-term development blueprint for the country. This plan intends to convert smallholder agriculture from subsistence to an innovative, commercially oriented and modern sector. This has promoted livelihoods through agriculture as an important priority for Kenya.

The LVN Basin is expected to exhibit high population growth as well as urbanisation. The main socio-economic challenges in the basin are described below.

4.4.1 Demographics

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

4.4.1.1 Population

Increased population growth

The LVN Basin is expected to experience high population growth. This poses a challenge in terms of managing and servicing the growing population, especially in the growing urban centres.

Urbanisation

Urbanisation is a trend in the LVN Basin resulting from rural poverty, land pressures, and lack of jobs in rural areas (GEF et al., 2016). 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 storm water runoff will increase. Industrial areas increase along with the growth of an urban area, which will result in increased industrial effluent.

Example of population growth and urbanisation issues:

The sewerage infrastructure in Eldoret is insufficient for the current population, which is a major issue as the population is expected to increase.

4.4.1.2 Education

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.

Inadequate understanding and awareness

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

Inadequate of education of water resources from a young age

Understanding brings awareness, which raises the concern of the inadequate 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.
> - Technical and Vocational Training Centres (TVETs) are aimed at equipping trainees with practical skills and entrepreneurial skills to enable opportunities and improve livelihoods. These facilities need to have sustainable water and land management strategies integrated into them.

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. LVN Basin has a poverty rate of 38%, with Busia counties having a rate of 60% (Wiesmann et al., 2016). As previously stated, the total population is projected to be 12.36 million in 2030 (Water Resources Management Authority, 2013). The rural population is expected to remain stable, but the urban population is expected to increase by almost 300% by 2050. The challenges with poverty are that it creates a financial handicap, which restricts an individual’s financial capacity. This affects the individual’s ability to pay for services, making them reliant on incentivised programmes. The challenges faced in the LVN 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.

Inadequate finances

Poverty affects the financial capacity of individuals to pay for services. This means that certain areas of the LVN 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


Image source: www.businessdailyafrica.com/news/counties/Land-rates-up-five-times-for-Nandi-tea-firms/4003142-5031108-dqt0cs/index

As discussed above, agriculture is the mainstay of the LVN Basin's economy with trade forming another important economic activity. Economic development has a major influence on the development of water resources. Water scarcity has a direct impact on rain-fed and irrigated agriculture as well as livestock and an indirect impact on food processing industries. The economic activity occurring in the LVN Basin, discussed below, will influence the planning for water resources.

4.4.2.1 Economic activity

Plans for new urban development

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

Examples of new urban developments:

- Construct a Tier 1 marketplace at Chepkube, Bungoma Town to provide a suitable working environment for traders. Construct an industrial park along the Webuye-Malaba Road to promote industrial development and employment creation (County Government of Bungoma, 2018).
- To promote investment, three industrial / business parks and six economic zones will be established in Busia county (County Government of Busia, 2018)
- Elgoyo-Marakwet county plans to develop a cable car system and champion the adoption of premium part initiatives to promote tourism. Incubation centres will be established in four vocational training centres in Chesongoch, Chebara, Iten and Chepkorio. All CTCs will be equipped with modern tools and equipment (County Government of Elgeyo Marakwet, 2018)
- Bukhungu Stadium in Kakamega will be upgraded to international standards. County Polytechnic Centres of Excellence will be constructed to increase access to quality vocational education and training. The Kakmega County Youth Service will create employment opportunities for youth and economically empower them (County Government of Kakamega, 2017).
- Formal markets will be constructed in Kapsabet and Nandi hills. The Chemase Industrial Park will be created (County Government of Nandi, 2018).
- Completion of the Trans Nzoia county Teaching and Referral Hospital, the rehabilitation of Kitale county hospital, and the upgrading of all sub-county hospitals to Tier 3 (Cherang'any, Kapsara, Kwanza, Endebess, Saboti, Maunda, Mount Elgon) (County Government of Trans Nzoia, 2018).
- Markets in numerous towns in Uasin Gishu county will be upgraded by the addition of modern kiosks, perimeter walls or ablution facilities (County Government of Uasin Gishu, 2018)
- Market infrastructure will be developed in Sabatia, Emuhaya, Hamisi, Vihaga and Luanda (County Government of Vihiga, 2018).

Plans for new transport infrastructure

There are several proposed projects across the basin which aim to improve the transport infrastructure by upgrading roads and building new bridges and roads (according to various CIDPs). It is important to account for these developments to ensure that the catchment is protected during construction and operation of the new routes.

Examples of new transport infrastructure:

- A flagship project for 2018-2022 in Bongoma county is to use the Public Private Partnership model to upgrade major county roads to bitumen standards (County Government of Bungoma, 2018).

- Elgeyo-Marakwet county plans to upgrade 181 km of roads in the Kerio valley and 20 km town roads in Iten, Kapsowar, Kapcherop, Chepkorio, Flax, Kapyego and Tot. These upgrades will be externally funded (County Government of Elgeyo Marakwet, 2018).
- Two hundred km of rural and urban bitumen road will be constructed in Kakamega county as part of specific county Vision 2030 flagship projects. Additionally, a complete modern Bus Park will be constructed at Triangle in Mumias Township to improve urban transport and organise urban traffic (County Government of Kakamega, 2017).
- An ultra-modern bus terminus is planned for Kitale to improve traffic flow in the town (County Government of Trans Nzoia, 2018).
- Road traffic through Eldoret Town will be improved by the construction of Cheplaskei-Kapseret-Maili Tisa by-pass road (County Government of Uasin Gishu, 2018).

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.

Flower farming

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

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 LVN Basin vary from fishing in Lake Victoria to subsistence agriculture and crop/livestock farming in the farming areas. 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

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 LVN 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.

Image source: www.flickr.com/photos/usaidkenya/sets/72157653183130708/

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. Achieving the goal of increasing access to potable water across the Basin has the following challenges:

About 11% of the total population in the LVN Basin receive piped water provided by the WSPs, whilst 23% are dependent on unimproved sources (i.e. vendors and direct access) and the rest from groundwater sources (Water Resources Management Authority, 2013).

Formal sewerage systems have been developed in limited parts of the LVN Basin, and most of the population (92%) still makes use of septic tanks and pit latrines for sanitation purposes. There is an uneven distribution of water in terms of urban and rural areas, with the former generally having better access to water and sanitation facilities. However, water systems in the urban areas are often degraded and/or inadequate. Water and sanitation issues in informal settlements are prevalent due to inadequate access to safe water, improper drainage systems, and inadequate access roads and social amenities.

4.4.3.2 Access to energy

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

Example of access to energy issues:

Most households in Bungoma, Busia, Elgeyo Marakwet, Kakamega, Nandi, Trans Nzoia and Vihiga counties rely on paraffin for lighting and biofuels (wood, shrubs / grass, dung or charcoal) for cooking.

4.4.3.3 Transport infrastructure

Inadequate transport infrastructure contributes to food insecurity and limits future opportunities for development. Several roads in the LVN 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

Approximately 80% of communicable diseases are water, sanitation and hygiene related (Wiesmann et al., 2016). More than 90% of the water and sanitation related disease outbreaks occur in rural households. Water quality issues are caused by industrial effluent, solid waste dumping, sanitation issues, salinisation of groundwater, among others. Health issues are encountered when a person is malnourished, which is a result of food insecurity. Floods often result in the contamination of boreholes, raising concern for waterborne diseases.

Example of health issues:

The water-borne diseases of malaria and diarrhoea are among the main causes of death in the following counties in the Basin: Bungoma, Elgeyo-Marakwet, Kakamega, Nandi, Siaya and Vihiga. In Busia and Trans Nzoia counties, malaria is prevalent.

- Bungoma county (County Government of Bungoma, 2018)
  - The top cases of morbidity are malaria, anaemia, pneumonia, diarrhoea and peptic ulcers.
- Busia county (County Government of Busia, 2018)
  - The top cases for morbidity are malaria, road traffic accidents (RTA), respiratory diseases and skin diseases.
- Elgeyo Marakwet county (County Government of Elgeyo Marakwet, 2018)
  - The top cases for morbidity are respiratory infections, skin diseases, diarrhoea, pneumonia and malaria.
- Kakamega county (County Government of Kakamega, 2017)
  - The top cases for morbidity are malaria/fever, diarrhoea, stomach-ache, respiratory diseases and flu.
- Nandi county (County Government of Nandi, 2018)
  - The top cases for morbidity are respiratory tract infections, malaria, skin infections, diarrhoea and pneumonia.
- Siaya county (County Government of Siaya, 2018)
  - The top cases for morbidity are malaria, respiratory tract infections and diarrhoea.
- Trans Nzoia county (County Government of Trans Nzoia, 2018)
  - The top cases for morbidity are malaria, respiratory tract infections, skin diseases, urinary tract infection and pneumonia.
- Uasin Gishu county (County Government of Uasin Gishu, 2018)
  - This information is not available.
- Vihiga county (County Government of Vihiga, 2018)
  - The top cases for morbidity are malaria, HIV/AIDS related illness, respiratory infections, diabetes, cancer, diarrhoea and skin diseases.

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. There are various levels of food insecurity across the LVN Basin.

The country's most food insecure areas do not fall within the LVN Basin. The Basin is a relatively wet area, with a low number of drought events and few poor-growing seasons. However, parts of the Basin do suffer from food insecurity. For the market-dependent households, especially in the rural areas, food prices play a key role in food security. Markets in the high potential farming zones are fairly integrated and within close proximity to buyers. In areas where crop production only takes place during the rainy season, the seasonality of food supply necessitates the purchase of food from markets which are often inaccessible and highly priced.

Food shortages are experienced in Busia and Siaya Counties due to lack of access to food supplies, and poor nutritional diversity is also an issue in Busia County. Busia County is characterised by low education levels, low livestock ownership, and a large reliance on agricultural labour. It has a Poverty Gap of 60%, which is the highest in the Basin. Siaya County is characterised by small agricultural plots and a high percentage of households headed by women or the elderly. Stunted growth due to malnutrition of children under five years old is serious in Trans Nzoia, Uasin Gishu and Nandi Counties. The percentage of households with poor/borderline food consumption is 5 to 10% in Bungoma, Kakamega and Uasin Gishu Counties, 15 to 20% in Nandi, Siaya and Trans Nzoia Counties, and 20 to 25% in Busia County.

Food security in the counties is summarised according to basic nutrition levels of children. National stunting level (height for age) is 26%, wasting (weight for height) at 4%, underweight 11%. The overall Poverty Gap for Kenya as a country is 45% (Wiesmann et al., 2016).

Food insecurity is most prominent in Busia and Siaya Counties, mainly due to high levels of poverty and very high unemployment rates, followed by Trans Nzoia, Uasin Gishu and Nandi Counties. Uasin Gishu county is the main contributor to food security in Kenya and has the lowest poverty levels in the Basin. The lack of irrigation systems and reliance on rain for crop production results in low crop yields and leads to food insecurity. These are factors contributing to food insecurity, which are discussed further below:

Example of food security issues:

- Bungoma county (County Government of Bungoma, 2018)
  - Children under five years have stunting levels at 24%, wasting at 2% and underweight at 9%. The Poverty Gap for this County is 47% (Wiesmann et al., 2016).
- Busia county (County Government of Busia, 2018)
  - Children under five years have stunting levels at 27%, and 31% are malnourished. The Poverty Gap for this County is 60% (Wiesmann et al., 2016).
- Elgeyo Marakwet county (County Government of Elgeyo Marakwet, 2018)
  - Children under five have stunting levels at 30%, wasting at 4% and underweight at 13%. Seasonal food insecurity is experienced by about 55% of the population because they rely on rain-fed agricultural production combined with poor storage and distribution systems. The Poverty Gap for this County is 53% (Wiesmann et al., 2016).
- Kakamega county (County Government of Kakamega, 2017)
  - Stunting levels, wasting levels, and the percentage of children under five years who are underweight were not reported. The Poverty Gap for this County is 49% (Wiesmann et al., 2016).
- Nandi county (County Government of Nandi, 2018)
  - Children under five years have stunting levels at 30%, wasting at 4% and underweight at 11%. The Poverty Gap for this County is 40% (Wiesmann et al., 2016).
- Siaya county (County Government of Siaya, 2018)
  - Children under five have stunting levels at 23% and 13% are underweight. Wasting levels were not reported. The Poverty Gap for this County is 38% (Wiesmann et al., 2016).
- Trans Nzoia county (County Government of Trans Nzoia, 2018)
  - Children under five have stunting levels at 29.2%, wasting at 4.7% and underweight at 15.3%. As mentioned in Section 2.3.3., this county is one of the most food secure in Kenya. The Poverty Gap for this County is 41% (Wiesmann et al., 2016).
- Uasin Gishu county (County Government of Uasin Gishu, 2018)
  - Stunting levels, wasting levels, and the percentage of children under five years who are underweight were not reported. This county is the main contributor to food security in Kenya. The Poverty Gap for this County is 34% (Wiesmann et al., 2016).
- Vihiga county (County Government of Vihiga, 2018)
  - Children under five have stunting levels at 14.6%, wasting at 2.6% and underweight at 3.8%. The Poverty Gap for this County is 39% (Wiesmann et al., 2016).

Rain-fed agriculture

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

Food price fluctuations

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

High cost of living

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

4.4.3.6 Disaster preparedness

In areas where natural resources are degraded or where no disaster planning has taken place, communities are more vulnerable to the effects of the disasters. Fires can damage and destroy houses, forests, crops and grazing land. Floods can cause personal danger to communities and can also wash away good farming soil if there is no village-level emergency planning in place. Floods can cut off access to clean water supply and contribute to the spread of illnesses such as cholera. In the LVN 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.

4.5 Water resources availability, management and development issues

The middle LVN Basin has the most issues relating to inadequate infrastructure, while most water quality issues were identified in the lower LVN Basin.

4.5.1 Surface water resources

The quantity of surface water in the LVN Basin is an issue as the resource is not efficiently protected resulting in water shortages and inefficient water use. The quality of surface water is threatened by various types of pollution. The main issues regarding surface water quantity and quality are described below.

4.5.1.1 Spatial and temporal variability

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

Water security

The LVN Basin includes major towns such as Eldoret, Kitale and Kakamega and is the most densely populated area in Kenya, with an average catchment population density of 379 persons per km^2 (Water Resources Management Authority, 2013). High water demand is expected in the future that will be led by domestic and industrial water supply, as well as irrigation water uses.

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.

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 LVN Basin are discussed below:

Inefficient water use

The non-revenue water (NRW) is high for several of the WSPs in the basin. The average water supply amount per person is 230 L/person/day inclusive of NRW (Water Resources Management Authority, 2013). WSPs have enough capacity for the current service population, but the NRW rate is quite high (Water Resources Management Authority, 2013). Five out of seven urban WSPs have records of more than 50% of NRW.

Inadequate RQOs

There is currently limited Resource Quality Objectives (RQOs) for the water resources in the Lake Victoria North Basin. The RQOs 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 RQO. The degradation of the water resources in the Lake Victoria North Basin due to pollution emanates, among many other things, from the lack of RQOs. However, there are urgent plans to develop guidelines for the establishment of RQOs and River Classification for all the Basins.

4.5.1.3 Water quality

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

Dumping of solid waste

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

Sanitation

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

Inadequate sewerage treatment

Similar to the poor connections to proper sewerage systems, there is a lack of 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.

Sedimentation

Sedimentation negatively affects the water quality of the rivers. Agricultural activities are a major contributor to sediment loads in rivers. Also, stormwater from urban areas gets washed into rivers, carrying the sediments from the roads and pavements. Deforestation is another major contributor to increased sediment loads. Sediment loads are generally higher in the rainy seasons and lower in the dry seasons. As a result of the sediment load, the water quality is reduced, which has impacted the fisheries and tourism sector.

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

4.5.2 Groundwater resources

Most of the water supply in LVN Basin comes from surface water sources, given its abundance of rainfall and available surface water from Lake Victoria. It’s largest town, Eldoret, is only reliant on surface water. However, groundwater does play a key role in small-scale water supply for private domestic use. While groundwater provides 1% of the public water supply, it does provide 77% of the private domestic supply in the basin. This could result in over-abstraction of groundwater in the basin. The quality of groundwater is a major concern as the quality is often affected by inadequate sanitation systems. The main issues regarding groundwater quantity and quality are described below.

4.5.2.1 Protection

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

The unsustainable use of groundwater (particularly groundwater pollution from anthropogenic activities) is a concern for the LVN Basin. Groundwater issues have resulted from inadequate protection of groundwater, which is discussed further below.

Groundwater protection programs

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

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

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

Groundwater recharge areas

No groundwater models of the LVN Basin have been developed, and there is often a poor level of understanding of aquifers. There is a need to select Priority Aquifers for modelling, then prioritise these and develop models; this inevitably requires the establishment of a water resources monitoring network in advance of generating a model, which would involve any or all of the following:

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

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

Groundwater contamination

The significance of small-scale water sources (e.g. hand pumped boreholes, shallow wells and springs) in water supply in the LVN Basin, particularly rural water supply, is very clear on the ground. However, this is difficult to capture as the water permit process is typically skewed to capture data from larger, more significant water users.

It is apparent that reliance on these small-scale water resources and aquifers in the LVN basin is increasing. However, high population (such as in the LVN Basin) is resulting in the aquifers supplying these sources becoming contaminated by pit latrines and occasionally septic tanks. It is therefore important to address local groundwater recharge zones.

Transboundary aquifers

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

- Mount Elgon aquifer – Combination of trachytes and metamorphic Basement (ILEC et al., 2015); total area 4 900 km^2, shared with Uganda.

A transboundary aquifer policy needs to be developed; the National GW Policy (Ministry of Water and Irrigation, 2013), lists the following activities required to improve transboundary GW management ("Issue 9"):

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

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

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

4.5.2.2 Institutional

Regulations

There is poor planning and water allocation when it comes to considering surface water and groundwater allocation. The two remain divided, and effectively treated as different water resources. The recent Water Allocation Plan Guideline (Water Resources Authority, 2019a) should help to resolve this, as it treats both resources in a given area in its approach to WAPs. There is confused NEMA and WRA mandates with regards to wastewater management and licensing (both bodies seek 'polluter payments' from water users/polluters). NEMA legislation (Act of 1999 and effluent regulations in the Environmental Management and Co-ordination (Water Quality) Regulations, 2006) pre-date water legislation (Water Act in 2002, and effluent regulations in the Water Resources Management (Amendment) Rules). Communication of mandates between counties and the WRA are also uncertain, with counties 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 (cf. *the Natural Resources (Benefit Sharing) Bill*, 2014 and *the Natural Resources (Benefit Sharing) Bill*, 2018). Both Bills specifically include water resources. Mandates between different state actors are trans-sectoral.

Inadequate monitoring

Groundwater monitoring has improved significantly in the past decade, with a total of 19 operational groundwater monitoring points across the Basin (Water Resources Authority, 2018d). In the 2014 reporting period (Water Resources Management Authority, 2016) there were 13 operational monitoring boreholes. 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.

Private sector or NGO players do operate their own monitoring networks, such as that operated by Base Titanium Ltd in the South Coast (covering both water levels and water chemistry). Field water quality data collection is also improving, with a broader range of measurements planned in order that RQOs can be determined. Parameters planned cover the following: electrical conductivity, turbidity, temperature, pH, total suspended solids, dissolved oxygen, total nitrogen and total phosphorus. Abstraction monitoring is done on an ad hoc basis at best - groundwater users are required to submit abstraction data monthly or quarterly as evidence to support their water charge payments, but these are rarely checked in the field by the WRA. The capacity to improve abstraction monitoring will be boosted by the adoption of formal guidelines for groundwater abstraction surveys, using electromagnetic flow meters (Water Resources Authority, 2018c).

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.

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

4.5.3 Water resources infrastructure

The key issues regarding water resources infrastructure in the LVN Basin are described below.

4.5.3.1 Bulk water supply systems and transfers

The main issue of bulk water supply systems in the LVN Basin is inadequate storage for various uses. There is also a concern that the current infrastructure will not meet the growing demands. The design of dams and other infrastructure is important to maintain the capacity designed for. There has been evidence that some dams as well other infrastructure 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 a few major irrigation schemes in LVN Basin, but most of the agriculture is rain-fed. The lack of major irrigation schemes is a concern for the basin. There are proposed irrigation schemes, which should help relieve the problem of food insecurity.

4.5.3.3 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 a limited information regarding the groundwater potential across the LVN Basin, and priority areas have not been identified for groundwater resource development.

4.5.4 Hydrometeorological monitoring network

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

4.5.5 Water allocation and use

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

4.5.5.1 Compliance of allocations

Managing and enforcing water allocations and use is one of the major challenges in the basin, and there is currently inadequate capacity and time in WRA to enforce compliance and to collect, record and analyse water resource monitoring data. There is also inadequate monitoring of actual water use for large water users and illegal abstractions taking place which are not monitored and removed.

4.5.5.2 Water resource availability

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

Groundwater is used as a supplementary resource to surface water and is currently exploited without adequate knowledge of groundwater potential.

4.5.5.3 Information on allocable water

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

4.5.5.4 Water allocation

The fair allocation of water resources is affected by the social standing in society.

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

4.6 Institutional issues

4.6.1 Institutional arrangements

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

4.6.1.1 National policies and legislation

Promulgation of the Constitution of Kenya 2010

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

Conflicting policies, regulations and mandates

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

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

There is need to carry out a mapping and analysis of key institutions in the national and County Governments, civil and private sectors and their overlapping mandates while identifying opportunities of synergy. A detailed stakeholder analysis is to be undertaken at the beginning of the Strategic Environmental Assessment (SEA) process. This will include a governance and institutional assessment of the various institutions and how these are envisaged to change in the proposed basin plan. A range of institutions and organisations are directly involved in forest management and conservation of forests in the basin. Many of the forests in the basin forests are found on protected areas whose management is vested in the KFS. There are also closed canopy forests gazetted as national parks and national reserves managed by KWS. Moreover, a significant forest area is found in trust land and vested in the respective County Governments.

Revenue collection and resource mobilisation challenges

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

Non-compliance to effluent discharge regulations

For the 2011/12 and 2013/14 period the WRA reported that in June 2013 the LVN had the lowest number of registered major effluent dischargers at 15 (Water Resources Management Authority, 2016). The major discharges complied with the Effluent Discharge Control Plan (EDCP) and were subsequently issued with an effluent discharge permit. However, in June 2014 the 15 registered major effluent dischargers had their ED permits cancelled. It is not clear whether the revocation of ED licenses and discontinuation of effluent discharged into the lake was as a result of non-compliance.

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 are some initiatives that have brought WRUAs and CFAs together on how to manage the river sub-basin as a system. The Centre for International Research on Forest has been working in the Mount Elgon region, and has successfully brought together WRUAs and CFAs to manage the Chebombai sub basin.

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 (2019) 94 established WRUAs out of the potential 106 WRUAs, translating into 12 WRUAs that need to be established. However, there are disparities in levels of development and maturity of the established WRUAs. Among the well-established WRUAs is the Kuywa Water Resources Users Association (KUWRUA) with robust institutional structures and technical capacity in comparison with other WRUAs in the region (Liambila, 2017). The institutional elements and technical capacity for existing WRUAs and those that are yet to be established needs to be bolstered to improve the operational capability of the institutions. Limited financial resources also affect the operational excellence of WRUAs. This is also compounded by the fact that several of the WRUAs in the basin do not have long term financial strategies or resource mobilisation plans as a result struggle to sustain themselves (Openji, 2017).

The unclear role of the BWRCs

There are conflicting mandates for the BWRCs in the Water Act (2016) where they have both advisory and management functions. ISC has an understanding that the BWRCs will remain advisory for the foreseeable future with a long-term plan of making the BWRCs have an executive role. There is a need to develop tools to support the operationalisation of the BWRCs, when they are finally established, and to ring-fence WRA staff at the ROs who will provide both technical and secretariat services to the BWRCs. The actual responsibility and how the BWRCs will work with WRA at the regional offices will only be clear once the mandates are agreed upon.

Expansive area of jurisdiction

The total area of LVN Basin is 18 374 km^2, corresponding to 3.2% of the country's total land area (Water Resources Management Authority, 2013). The regional office is in Kakamega with sub-regional offices in Eldoret, Kitale and Siaya. LVN covers 8 counties namely Trans Nzoia, Kakamega, Bungoma, Siaya, Vihiga, Nandi, Ursin Gishu and Busia. This is clearly a very expansive basin and WRA's 4 offices in the basin poses a challenge in terms of capacity to effectively serve all the 8 counties. Most stakeholders have been voicing the need to have more representation of WRA in every County to increase WRA's effectiveness. This situation is further worsened by WRA's inadequate human resources, financing, vehicles, laboratory facilities and data.

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 established in the Forests Act 2005 and the Forest Conservation and Management Act No.34 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.

County Governments have been actively pursuing ground water development with some counties acquiring borehole drilling rigs to support their ground water development plans. Some of the boreholes drilled have not followed formal registration with WRA posing a serious challenge to ground water monitoring and revenue collection for WRA.

Limited coordination

Limited coordination and isolated planning by the various stakeholders operating in the counties is prevalent. These practices are also reflected in the NWMP 2030. The Master plan proposes the development of major dams in the upper reaches of the Nzoia River. The area has rich water and water conservation forest such as Mount Elgon, Cherangany Hills and other gazetted forests. These dams might have significant negative impact on water and forest conservation. The development of these dams will likely occur at the expense of the forest despite Vision 2030 advocating for improved efforts towards forest recovery and afforestation.

Additionally, isolated planning is another major challenge to water conservation. Since 2013, Kenya has had a devolved system of governance and one of the components of this is the counties planning their own land independently of each other. In the case of 'moving resources' like wildlife and water, this has led to loss of coordination and poor resource use. There is need for policy action to ensure integration of planning and decision making at all levels. Some counties have established environment management committees and WRA is a member of some of these committees, such as West Pokot and Elgeyo Marakwet where the County Environment Committees and WRA meet regularly. For the other counties, WRA is not a member of the committees.

4.6.1.5 Partnerships and engagement

Limited partnerships

The partnerships operating in the basin predominately operate at a nation-wide level with key strategic partners with seemingly less partnerships at a localised level. Limited partnerships at a localised level is concerning since it is as this sphere where focused collective action can take place. Increased efforts at improving coordination and formation of partnerships amongst sub-catchments stakeholders is incremental going forward.

Limited coordination between stakeholders

Generally, there is currently a limited of coordination between the WRA, WRUAs, County Governments and other stakeholders which leads to poor urban and rural planning and uncontrolled development which has a negative impact on regulation of use and management of water resources.

One of the challenges facing WRA towards integrated river basin management has been limited coordination amongst the various WRUAs working within a large basin. Some of the larger river basins such as the Nzoia could have as many as 100 WRUAs operating within the same basin (Liambila, 2017). Thus, there is need for coordination of the activities that each of them carries out to ensure synergy and harmonisation of initiatives. The LVN basin forum aimed at ensuring coordination amongst WRUAs was set to be established in 2016 however there is no clear indication on the functionality and effectiveness of the platform.

Low public awareness of WRA's mandate

Generally, there is low public awareness of WRA in the LVN Basin. Some of the stakeholders in the basin are unaware of WRA's role in regulating the use and management of water resources. Those that are aware of WRA's mandate sometimes criticise the Authority of weak performance. Thus, there is urgent need to create awareness and understanding of WRA mandate as a Regulator through activism and engagement with other partners. This can be achieved by articulating WRA's functions well, demonstrating ways of measuring results achieved and packaging results in ways attractive to different stakeholders in the basin. Improved enforcement of offenders is also another alternative that will enable water users to realise the value addition of WRA's services for the fees they remit to the Authority.

4.6.2 Enabling environment

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, and inadequate vehicles and/or fuel.

Inadequate office space and equipment

The WRA does not own any office buildings and office structures. The current buildings and office structures are owned by the Ministry of Water and Irrigation. Inadequate ownership of immovable assets by the WRA attest to the fledgling phase the WRA is currently in, in addition inadequate ownership may present challenges with the WRA identifying itself as an independent body.

The estimated value of the building and office structures in the LVN catchment is Ksh 78 000 000. This figure is not disaggregated in terms of regional offices and sub regional offices as a result one cannot determine whether more office space is required per sub office.

Data collection tools/equipment and infrastructure at gauging stations are often in need of maintenance, repair or upgrade, e.g. survey equipment, meter readers, water quality monitoring equipment and manual data collection tools. This is a major concern considering that there are internationally and locally shared rivers and aquifers which require regular monitoring to ensure that water use activities do not negatively impact on users downstream.

Inadequate vehicles and/or fuel

The basin has 6 vehicles with Kakamega with 2, Eldoret has 2 vehicles, Kitale and Siaya offices have 1 vehicle respectively. The cumulative value of the vehicles is Ksh 11 870 000. The basin does not have sufficient vehicles to undertake functions. In the Water Resources Authority Establishment Report it was recorded that each WRA Basin office requires 2 vehicles and drivers and each sub-regional office requires a minimum of 3 vehicles. The sub regional offices are significantly under capacitated.

4.6.2.2 WRA staffing capacity

As of 2018, the LVN catchment had a cumulative staff complement of 70 people of which 34 are deployed in the Kakamega RO, 17 are in the Siaya RO and 19 are in the Kita SRO. Although the current figures do not provide disaggregation of technical staff, professional staff and administrative support, there is a significant capacity gap in sub regional offices. The capacity gaps need to be addressed through increased employment and training of staff. The shortage of staff at the sub-regional offices affects the operational excellence of WRA at a localised level.

4.6.2.3 Enforcement capacity of WRA

At the end of the 2013/14 FY in June 2014 the LVN catchment recorded the lowest number of metered abstractions (surface and groundwater) indicating a weakness in the compliance and enforcement capacity of the WRA (Water Resources Management Authority, 2016). There is a need to increase water meters to improve accountability of allocated water resources as well as improve compliance & enforcement of water permit conditions on metered users.

4.6.2.4 Implementation ability/capacity

There is concern regarding the ability of the WRA to implement certain conditions of the Water Act in the catchment as well as operationalise strategic plans. The WRA has lagged in regulating water users and has been unsuccessful in performing critical water management functions due to inadequate capacity and resource constraints. By June 2013 LVN catchment had the lowest performance, in comparison to other basins, in implementing the catchment management strategy. The catchment had the lowest proportion of permitted water use, lowest number of effluent dischargers complying with EDCP, and a low proportion of operational water resource monitoring stations (Water Resources Management Authority, 2016).

4.6.2.5 Capacity in WRA to deal with drought related disasters

Drought related disasters present challenges to equitable water allocation and have the potential to increase the frequency conflict over water resources. LVN catchment has limited capacity to navigate through drought periods. Out of the water related conflicts reported the WRA was able to resolve half of those case, in addition the catchment was unable to carry out robust drought management measures (Water Resources Management Authority, 2016). The capacity of the LVN catchment regarding drought management needs to be strengthened through the establishment of appropriate structures that develop drought response strategies. The WRA and the district Disaster Operations Centre (DOC) under the Ministry of Special Programs need to coordinate to ensure the harmonisation of drought response measures of the LVN catchment with that of the district office.

4.6.2.6 Capacity in WRA with regards to flood mitigation

Flooding events are a serious issue in the basin, concerningly is the relatively limited capacity of the WRA to effectively manage flood events. The WRA only mainstreamed flood management in their operations in June 2011. Since then several achievements have been made such as the mapping of flood prone areas. Only three areas were identified in the LVN catchment namely Budalangi, Lower Yala and Namanjalala. There is inadequate clarity regarding whether structural measures such as building of evacuation centres and installation of flood warning systems have been developed around the areas. Moreover, there is inadequate indication whether non-structural measures have been implemented such as the inclusion of flood management in the catchment plan and sub catchment plans of WRUAs. In 2013, the World Bank completed a study through the Water Partnership Programme which identified the construction of large and medium sized reservoirs upstream the upstream the catchment for flood management and water supply. There is no indication regarding the uptake of the research recommendations by the Ministry of Water and Irrigation

4.6.2.7 Capacity to enforce reserve flows

In 2014 the LVN catchment had not developed a water allocation plan indicating constraints in determining reserve flows. Subsequently the WRA is yet to enforce reserve flows adequately (Water Resources Management Authority, 2016). There are capacity gaps in integrating the reserve and planning for the reserve in the catchment. To overcome these challenges training of existing technical staff is required in order to build technical competency in reserve determination. Furthermore, adequate equipment to support reserve determination is required.

4.6.2.8 Capacity of WRA with regards to climate change adaptation strategies

Climate proofing the LVN basin is critical for the continued social and economic development of the catchment. The current catchment management plans and sub-catchment plans do not explicitly address climate change and do not elucidate on climate adaptation strategies. Revising the plans to include specific actions for addressing climate risks in the basin is required. In addition, the institutional capacity of the WRA in terms of appointing climate technical support and the allocation of resources (finances) needs to be strengthened. The existing WRA staff complement does not constitute climate experts. The capacity of the WRA in LVN to develop and implement climate change adaptation strategies is relatively low in comparison to other basins where IFMP has been implemented. As a result, greater support and increased allocation of resources (human and financial) is required in order to improve the climate resiliency of the basin.

4.6.3 Transboundary and trans-county issues

LVN catchment has four transboundary rivers presenting a greater potential for multiple conflicts due to the overly complex environment for managing water resources.

4.6.3.1 Inter-basin transfers

The LVN basin does not receive additional water supply from inter basin transfers nor does it augment the supply of other basins through transfers.

4.6.3.2 Internationally shared water resources

The LVN basin's major rivers flow into Lake Victoria and flow across borders. The Nzoia and Yala Rivers flow into Lake Victoria which straddles Kenya, Uganda and Tanzania (Water Resources Management Authority, 2013). The Sio, Lwakhakha, Malakisi and Malaba rivers flow across the border to Uganda and ultimately flow into Lake Victoria. There are sporadic water use and water pollution related conflicts between the Kenya-Uganda border, specifically Busia-Malaba border, and other Nile treaty countries. Uganda has complained that there is water pollution from the Kenyan side on the Sio, Lwakhakha, Malakisi and Malaba rivers.

The management of water in the LVN catchment is complex because all the catchment's major rivers discharge downstream to Lake Victoria. As a result, infrastructural development (i.e. dams) and activities on the major rivers of the basin need to be carefully considered as they might negatively affect the runoff to the Lake. This could potentially lead to conflict between the riparian states due to the decreased discharge from the rivers into the lake.

To minimise water related conflicts and move towards the long-term sustainable water management of Lake Victoria waters, the Lake Victoria Basin Commission (LVBC) was established in 1999 and operationalised in 2004. Despite the presence of this institution conflicts in Lake Victoria persist. According to Okumu (2010) over the past five years, there has been a serious dispute between Uganda and her neighbours over the cause of a drop in the water level of the lake by 1.5 metres between 2004 and 2006 (Okumu, 2010). While Tanzania and Kenya have blamed Uganda for causing the decline by over-draining the lake for hydroelectric production, Uganda has attributed the drop to climate change.

Uganda was also in July 2008 accused of entering into a secret agreement with Egypt to release more water into the Nile to meet Egypt's increasing needs (Okumu, 2010).

4.6.3.3 Trans-county conflict

There are reported cases of water related conflicts between West Pokot, Nandi Hills, Kiminini, and Tindinyo areas. These cases are prominent during dry seasons when the resource is scarce. There have been water pollution related conflicts between communities in Busia town in addition to riparian land misuse. For Malaba town, there have been cases of illegal use of wetland and areas for agricultural and commercial use contrary to the set-out regulations for conserving wetlands.

The Lake Basin Development Authority plans to build a dam inside the South Nandi Forest that will lead to the clearing of 1 185 ha of closed canopy rainforest, including 10 million indigenous trees (Temper et al., 2015). The dam will significantly drain the Yala Swamp, a wetland of international importance by diverting 9% of waters of the Yala river to the adjacent Nyando river (Temper et al., 2015). The dam is will support irrigation of 17 000 ha in the Nyanza sugar belt, the supply of drinking water to the Vihiga/Sabatia, Hamisi, Nandi Central, Kisumu and Nyando districts (in the region of Lake Basin District), flood control downstream of the dam, the development of fisheries in the area of the reservoir and the tourist development of the region (Temper et al., 2015).

The Nandi county local communities are strongly opposed to the project because the proposed benefits are not attractive enough; and for political reasons, where they feel they will bear the cost of the dam, with benefits being reaped by the downstream community members and counties (Temper et al., 2015). The Nandi county council has threatened to move to court to challenge the proposed project. Street protest have been held by the affected community groups and interest groups (Temper et al., 2015). The continuation of the project has potential to escalate levels of intra county tensions as well as inter county tensions.

Land conflicts in Nandi county exist in Tindiret and Mosop where adjudication and issuing of title deeds still needs to be done. Squatters were evicted by the government from Kipkurere forest, Nandi South forest, Cengalo forest and other public land, resulting in Internally Displaced persons without land. There is tension over land held by multinational companies who took over land previously annexed by colonialists. Tensions across ethnic communities resulted in conflict in 1992, 1997 and 2007, and still needs to be resolved (County Government of Nandi, 2018).

4.6.3.4 Land and resource conflict

The acquisition of land in the Yala swamps by the Dominion Group for the agricultural projects led to turmoil and conflict with the community resulting in the Group's exit 12 years earlier than the lease period of 25 years (Kamadi, 2019). A set of events contributed to the conflict for one the community was not consulted prior the land acquisition deal, secondly revenue generated from the initiatives were not ploughed back to the community and lastly land grabs from the community member. However, the Dominion Group would drive communities soon after the land grab (Kamadi, 2019).

05

Image source: Street Trader 2019 'Omufunje'. Available online at https://www.standardmedia.co.ke/article/2001310556/uasin-gishu-county-given-two-weeks-to-open-eldoret-market

Vision and Scenario Evaluation

5 Vision and Scenario Evaluation

5.1 Introduction

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

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

Becoming a model basin in collaborative catchment management, protection, conservation and control; equitably allocating good quality water for sustainable socio-economic development and preservation of ecosystems 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 typical six step conceptual approach towards the evaluation of water management interventions.

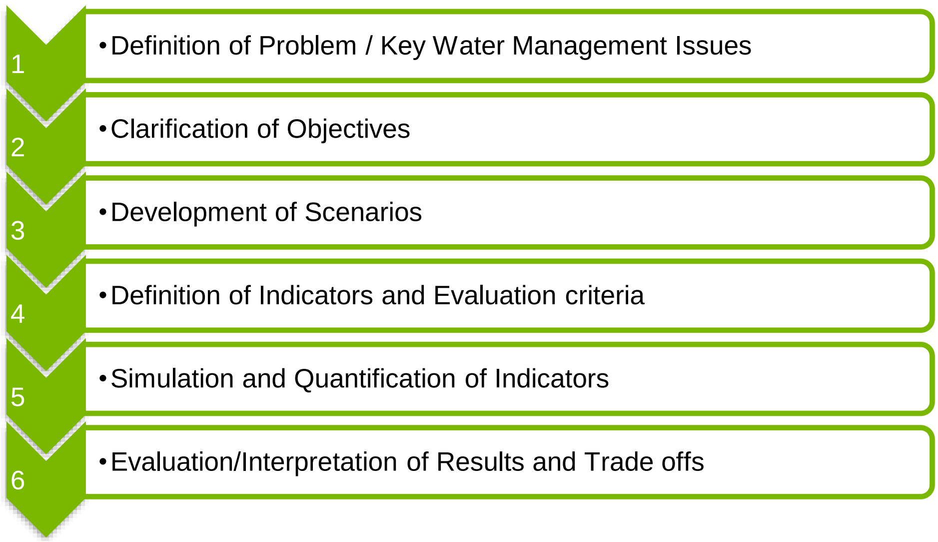


Figure 5-1: Scenario Evaluation (adapted from Kusek & Rist, 2004 and World Bank, 2008)

The key aim of the LVN 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.**

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 under different scenarios.

5.4.1.2 Climate change impacts

The impacts of climate change on future precipitation and temperature within the LVN 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.

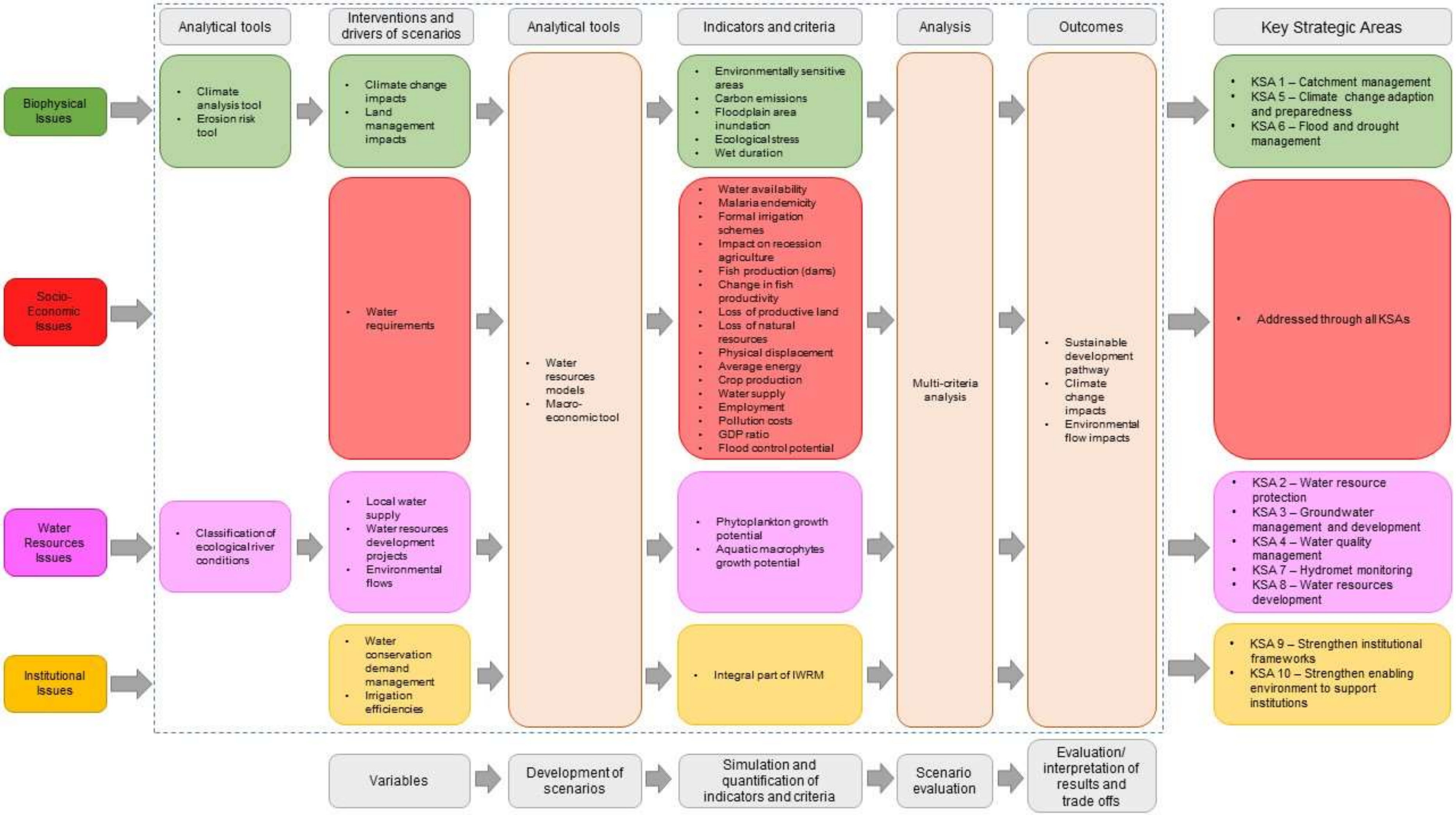


Figure 5-2: Approach to scenario development and evaluation

5.4.2 Socio-economic

5.4.2.1 Future water requirements

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

Irrigation water requirements

To estimate future (2040) small-scale irrigation areas in the LVN 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 LVN 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 LVN 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 LVN 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 LVN 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 LVN 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 LVN 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**
Kocholia	1AD	Busia	67	Water supply; Irrigation (Amoni – Amagoro Villages); Mini-hydropower (<1MW)
Siyoi	1BC	Trans Nzoia, West Pokot	4	Water Supply (Kapenguira)
Moi's bridge	1BE	Trans Nzoia	214	Water supply (Moi's bridge, Matunda); Large scale irrigation (New)
Upper Nzoia	1BG	Bungoma	204	Large scale irrigation (New), Hydropower (16MW); flood control
Kibolo	1CE	Uasin Gishu	40	Water supply (Lumakanda); Large scale irrigation (New)
Teremi	1DB	Bungoma	3	Water Supply (Kimilili, Bungoma, Chwele)
Lower Nzoia	1EE	Siaya	395	Large scale irrigation (New), Hydropower (25MW); flood control
Nandi Forest	1FD	Nandi	220	Water supply (Yala, and Kisumu in LVS Basin); Large scale irrigation (New), Hydropower (50MW); flood control

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

Transfers			
Scheme	**Counties**	**Proposed capacity (MCM/a)**	**Purpose**
Moiben (Chebara)	Uasin Gishu	5 MCM/a	Water supply (Eldoret)
Moiben (Chebara)	Uasin Gishu		Water supply (Iten)

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

Large scale irrigation				
Scheme	**County**	**Proposed Area (ha)**	**Crop type**	**Source**
Lower Sio	Busia	5 280	Rice	Run of river abstraction
Moi's bridge	Trans Nzoia	15 840	Horticulture, maize	Moi's Bridge Dam
Upper Nzoia	Bungoma	24 000	Horticulture, maize	Upper Nzoia Dam
Kibolo	Uasin Gishu	9 200	Horticulture, maize	Kibolo Dam
Lower Nzoia	Siaya	10 470	Horticulture	Lower Nzoia Dam
Yala	Siaya	4 800	Horticulture	Run of river abstraction

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 LVN Basin, towards identifying a sustainable development pathway, various scenarios representing a possible 2040 future were defined and analysed using the 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. In addition, the erosion risk and sediment yield tool was used to estimate potential sediment yield and cumulative sediment loads under each scenario.

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 LVN 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 also 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 with irrigation development

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, except Upper and Lower Nzoia irrigation schemes which were assumed to be limited to the areas currently under implementation. Yet, 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). Similar to Scenario 0, non-compliance with the Q95 Reserve due to inadequate monitoring and enforcement is assumed. Climate change impacts are incorporated in the water resources model.

5.5.3 Scenario 2: Limited development

The limited development scenario is the same as Scenario 1, except that limited funds are now available to implement some of the dams and planned transfer schemes as identified in various studies and plans and by stakeholders, for supplying future urban demands. The large-scale irrigation schemes are the same as Scenario 1. As some funds are now available, compliance with Q95 as the ecological reserve is assumed. However, similar to Scenario 1, vegetation loss at 10% across the catchment is still assumed due to the focus on large scale development in the basin.

Two sub-scenarios were defined under Scenario 2:

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

5.5.4 Scenario 3: Full development

The full development scenario is the same as Scenario 2, except that more funds are now available to implement all of the major irrigation schemes at maximum planned areas, i.e. Upper and Lower Nzoia schemes are also implemented at full areal extent. This scenario is evaluated with limited storage and full storage respectively, i.e. the potential benefits of implementing Moi’s Bridge, Upper and Lower Nzoia dams are assessed. In essence this scenario evaluates the availability of water and the need for identified storage and transfer schemes to supply future demands, specifically the significant large-scale irrigation (including Upper and Lower Nzoia irrigation schemes) and the projected urban demands. It evaluates the trade-off between potential socio-economic benefits due to the water resources developments, and negative environmental and social impacts. Similar to Scenarios 1 and 2, vegetation loss at 10% across the catchment is still assumed due to the focus on large scale development in the basin.

Three sub-scenarios were defined under Scenario 3:

- Scenario 3A: Limited storage and Q95 as environmental flow requirement
- Scenario 3Bi: Full storage and Q95 as environmental flow requirement
- Scenario 3Bii: Full storage and EFlow holding flows as environmental flow requirement

5.5.5 Scenario 4: Sustainable development

This scenario represents a progressive approach towards a sustainable development future, i.e. balanced water resources development which limits environmental and social impacts yet provides meaningful socio-economic benefits linked to the development of water resources with a reliable supply of water. This scenario avoids any development in environmentally sensitive areas, assumes 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. 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. Compliance with Q95 as the ecological reserve is assumed.

The criteria which were adopted for the sustainable development of water resources in the LVN 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.Urban centres were modelled to abstract from rivers in addition to the stored water withdrawals
- 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 4:

- Scenario 4A: No reduction in large-scale irrigation areas
- Scenario 4Bi: A reduction in the areal extent of some of the large-scale irrigation schemes as well as a further reduction in future urban demands based on less conservative projections

Scenario 4Bii: Relocating some of the proposed dams further downstream, to increase upstream catchment areas and runoff into the dams (Teremi and Siyoi dams) and assigning some of the water in the proposed Kibolo Dam towards meeting Eldoret's future water demands. As well as a further reduction in the areal extent of some of the large-scale irrigation schemes

5.5.6 Additional scenario

The LVN has an additional scenario 4, in comparison to the other basin plans. This is because several large-scale irrigation projects are either in construction or planned for implementation in the Nzoia River Basin. Feasibility and hydrological studies for these schemes were undertaken independently and at different times. If implemented together, the planned schemes will have a significant impact on the overall water balance of the basin. Large-scale schemes that are in construction or that have progressed to feasibility stage include:

a) Lower Nzoia Irrigation Project Phase 1 (LNIP-1): 4000 ha

b) Lower Nzoia Irrigation Project Phase 2 (LNIP-2): 3800 ha

c) The NIB has plans for several irrigation projects in the Upper Nzoia Basin, the largest of which is the Upper Nzoia Irrigation Development Project. The project is located in the Middle and Upper Nzoia River Basin. According to the project feasibility study (NIB, Gedo Associates 2015), the project will develop four clusters totalling 7000 ha in Bungoma County.

These developments were modelled under an additional scenario, Scenario 2: Limited Development; which was not modelled in the other Kenya basins. The imminent developments (a to c) are based on run-of-river abstractions, thus Moi's Bridge and Upper and Lower Nzoia dams were not modelled, which would alter water balances and water availability significantly. A Limited development scenario with and without climate change were developed.

In addition to these projects, the National Water Master Plan (NWMP, JICA, 2010) envisages further growth in small scale irrigation throughout the basin and the following configuration of large schemes:

- Lower Nzoia Irrigation Project (10,470 ha). This scheme is now effectively replaced by (a) and (b) above.

- Upper Nzoia Irrigation Project (24,000 ha). This is a variation of (c) above, but with a larger area.
- Moi's Bridge Dam Irrigation Project (19,800 ha)
- Kibolo Dam Irrigation Project (11,500 ha).

While the NWMP envisaged large scale irrigation development in the Nzoia Basin, the need for storage to supply future demands in the dry season was recognized. Therefore, Scenario 3: Full development had an additional scenario for limited storage i.e. without Moi's Bridge and Upper and Lower Nzoia dams; which differed from the other basin. And two scenarios with the proposed NWMP storage with Q95 applied and with EFlow holding flows as opposed to Q95; similarly to the other basins.

Lastly, based on the supply shortages still evident in the sustainable development scenario 4Bi; and additional sustainable development scenario was developed which allowed for increased catchment areas for the proposed dams- namely Termei and Siyoi- and aligned all population growth rates to that of the largest urban centre i.e. Eldoret.

Table 5-4: Scenario definition

Category	Type	Scenario 0	1	2A	2B	3A	3Bi	3Bii	4A	4Bi	4Bii
Water resources development	Large dams	Chebara (18 MCM)	Chebara (18 MCM)	Chebara (18 MCM)	Chebara (18 MCM)	Chebara (18 MCM)	Chebara (18 MCM)	Chebara (18 MCM)	Chebara (18 MCM)	Chebara (18 MCM)	Chebara (18 MCM)
		Ellegirini (2 MCM)	Ellegirini (2 MCM)	Ellegirini (2 MCM)	Ellegirini (2 MCM)	Ellegirini (2 MCM)	Ellegirini (2 MCM)	Ellegirini (2 MCM)	Ellegirini (2 MCM)	Ellegirini (2 MCM)	Ellegirini (2 MCM)
		Kipkarren (3 MCM)	Kipkarren (3 MCM)	Kipkarren (3 MCM)	Kipkarren (3 MCM)	Kipkarren (3 MCM)	Kipkarren (3 MCM)	Kipkarren (3 MCM)	Kipkarren (3 MCM)	Kipkarren (3 MCM)	Kipkarren (3 MCM)
				Siyoi (4 MCM)	Siyoi (4 MCM)	Siyoi (4 MCM)	Siyoi (4 MCM)	Siyoi (4 MCM)	Siyoi (4 MCM)	Siyoi (4 MCM)	Siyoi (4 MCM)
				Kibolo (40 MCM)	Kibolo (40 MCM)	Kibolo (40 MCM)	Kibolo (40 MCM)	Kibolo (40 MCM)	Kibolo (40 MCM)	Kibolo (40 MCM)	Kibolo (40 MCM)
				Teremi (3 MCM)	Teremi (3 MCM)	Teremi (3 MCM)	Teremi (3 MCM)	Teremi (3 MCM)	Teremi (3 MCM)	Teremi (3 MCM)	Teremi (3 MCM)
				Nandi Forest (220 MCM)	Nandi Forest (220 MCM)	Nandi Forest (220 MCM)	Nandi Forest (220 MCM)	Nandi Forest (220 MCM)	Nandi Forest (220 MCM)	Nandi Forest (220 MCM)	Nandi Forest (220 MCM)
							Moi's Bridge (214 MCM)	Moi's Bridge (214 MCM)	Moi's Bridge (214 MCM)	Moi's Bridge (214 MCM)	Moi's Bridge (214 MCM)
							Upper Nzoia 34B (204 MCM)	Upper Nzoia 34B (204 MCM)	Upper Nzoia 34B (204 MCM)	Upper Nzoia 34B (204 MCM)	Upper Nzoia 34B (204 MCM)
							Lower Nzoia 42A (395 MCM)	Lower Nzoia 42A (395 MCM)	Lower Nzoia 42A (395 MCM)	Lower Nzoia 42A (395 MCM)	Lower Nzoia 42A (395 MCM)
	Hydropower			Nandi Forest (50 MW)	Nandi Forest (50MW)	Nandi Forest (50 MW)	Nandi Forest (50 MW)	Nandi Forest (50 MW)	Nandi Forest (50 MW)	Nandi Forest (50 MW)	Nandi Forest (50 MW)
							Upper Nzoia (16 MW)	Upper Nzoia (16 MW)	Upper Nzoia (16 MW)	Upper Nzoia (16 MW)	Upper Nzoia (16 MW)
							Lower Nzoia (25 MW)	Lower Nzoia (25 MW)	Lower Nzoia (25 MW)	Lower Nzoia (25 MW)	Lower Nzoia (25 MW)
	Intra-basin transfers	Moiben - Eldoret	Moiben - Eldoret	Moiben - Eldoret	Moiben - Eldoret	Moiben - Eldoret	Moiben - Eldoret	Moiben - Eldoret	Moiben - Eldoret	Moiben - Eldoret	Moiben - Eldoret
		Moiben - Iten	Moiben - Iten	Moiben - Iten	Moiben - Iten	Moiben - Iten	Moiben - Iten	Moiben - Iten	Moiben - Iten	Moiben - Iten	Moiben - Iten
				Moiben - Eldoret (additional capacity)	Moiben - Eldoret (additional capacity)	Moiben - Eldoret (additional capacity)	Moiben - Eldoret (additional capacity)	Moiben - Eldoret (additional capacity)	Moiben - Eldoret (additional capacity)	Moiben - Eldoret (additional capacity)	Moiben - Eldoret (additional capacity)
				Moiben – Iten (additional capacity)	Moiben – Iten (additional capacity)	Moiben – Iten (additional capacity)	Moiben – Iten (additional capacity)	Moiben – Iten (additional capacity)	Moiben – Iten (additional capacity)	Moiben – Iten (additional capacity)	Moiben – Iten (additional capacity)
											Kipkarren - Eldoret
	Inter-basin transfers			Nandi Forest - LVS	Nandi Forest – LVS	Nandi Forest - LVS	Nandi Forest - LVS	Nandi Forest - LVS	Nandi Forest - LVS	Nandi Forest - LVS	Nandi Forest - LVS

Category	Type	Scenario									
		0	1	2A	2B	3A	3Bi	3Bii	4A	4Bi	4Bii
Water resources development	Small-scale irrigation	1,499 ha	67,889 ha	67,889 ha	67,889 ha	67,889 ha	67,889 ha	67,889 ha	67,889 ha	67,889 ha	67,889 ha
	Large-scale irrigation	2,180 ha	59,480 ha	59,480 ha	59,480 ha	79,150 ha	79,150 ha	79,150 ha	79,150 ha	74,800 ha	70,650 ha
	Small dams and pans	8	8	8	8	8	8	8	125	125	125
	Groundwater use	47	47	47	47	47	47	47	175	175	175
Environment	Ecological reserve	No	No	Q95	Q95	Q95	Q95	Eflows	Q95	Q95	Q95
Catchment	Forests	Curremt	10% reduction	10% reduction	10% reduction	10% reduction	10% reduction	10% reduction	10% improvement	10% improvement	10% improvement
	Erosion risk -sediment (million t/a)	7.31	7.31	7.17	7.17	7.17	7.09	7.09	6.74	6.74	6.74
Climate	Climate change	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Water demand (MCM/a)	Irrigation	40	1678	1845	1722	2321	2012	2012	1733	1322	1100
	Domestic/Industrial	205	1080	1080	1080	1080	1080	1080	673	673	673
	Other	41	111	111	111	111	111	111	111	111	111
	Export	0	0	189	189	189	189	189	189	189	189
	Total	286	2869	3225	3102	3701	3392	3392	2706	2295	2073

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 LVN 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	SC3Bi	SC3Bii	SC4A	SC4Bi	SC4Bii
ENVIRONMENT	Footprint areas	Environmentally sensitive areas	Area (km^2)	n/a	46.9	51	51	94	97	97	97	92	92
		Carbon emissions dams	tons	n/a	0	24788	24788	24788	65539	65539	65539	65539	65539
		Carbon emissions LIR	tons	n/a	852065	852065	852065	1170543	1170543	1170543	1170543	1026357	1026357
	Downstream areas	Floodplain area inundated	% change from baseline	n/a	-36.7	-35.9	-29.6	-36.3	-34.3	-27.5	-33.5	-32.8	-33.1
		Ecological stress	Index (-5 to 0)	n/a	-4.1	-3.8	-3.7	-3.8	-3.7	-3.4	-3.7	-3.6	-3.8
		Wet duration	% change from baseline	n/a	-46.0	-44.4	-35.0	-44.7	-47.7	-47.0	-45.7	-42.1	-44.7
	Water quality	Phytoplankton growth potential	Average growth potential %	80.5	62.6	70.4	69.7	70.4	65.4	62.0	67.5	70.3	69.0
		Aquatic macrophytes growth potential	Index (-5 to 0)	0.0	-0.5	-1.1	-1.1	-1.2	-1.3	-0.6	-1.3	-1.0	-1.0
SOCIAL	Water availability	Water availability riparian users	% change from baseline	n/a	-72.3	-49.4	-44.9	-49.4	-50.6	-20.1	-51.8	-51.4	-53.9
	Community health and safet	Malaria endemicity	Malaria endemicity (km^2)	5	102	103	103	136	148	135	135	120	133
	Food security and livelihoods	Formal irrigation schemes	Area (km^2)	22	601	601	601	806	806	806	806	715	715
		Impact on recession agriculture	% change from baseline	n/a	-36.7	-35.9	-29.6	-36.3	-34.3	-27.5	-33.5	-32.8	-33.1
		Fish production (dams/lakes)	tons/annum	17	11	63	64	63	415	412	407	452	461
		Change in fish productivity	% change from baseline	n/a	-46.0	-44.4	-35.0	-44.7	-47.7	-47.0	-45.7	-42.1	-44.7
		Loss of productive land	Area (km^2)	n/a	313	318	318	417	448	448	448	399	399
		Loss of natural resources	Area (km^2)	n/a	46.9	51	51	94	97	97	97	92	92
	Displacement	Physical displacement	Number people	n/a	173363	176151	176151	231580	247963	247963	247963	221029	221029
ECONOMIC	Energy	Avg energy	GWh/annum	n/a	0	0	0	0	412	444	438	445	438
	Food production	Crop production (formal irrigation)	Million ton/annum	0.01	0.64	0.86	0.92	1.18	1.80	1.72	2.01	1.93	1.89
		Fish production (dams/lakes)	tons/annum	17	11	63	64	63	415	412	407	452	461
	Water supply	Urban water supply	Ratio	0.94	0.55	0.49	0.51	0.49	0.58	0.45	0.68	0.75	0.96
		Domestic water supply	Ratio	0.98	0.93	0.87	0.89	0.87	0.86	0.67	0.87	0.87	0.87
		Formal irrigation water supply	Ratio	1.00	0.50	0.61	0.63	0.57	0.70	0.65	0.76	0.79	0.77
		Small-scale irrigation water supply	Ratio	0.95	0.69	0.60	0.62	0.60	0.60	0.44	0.80	0.80	0.80
	Employment	Employment formal irrigation	Jobs/annum	4360	120160	120160	120160	201375	201375	201375	201375	178675	178675
		Employment hydropower	Jobs/annum	n/a	0	0	0	0	412	444	440	445	438
	Pollution costs	Pollution cost index - dams / irrigation	Ratio of baseline	1.0	1.0	1.2	1.2	1.3	1.2	1.0	1.2	1.2	1.2
	Sediment	Sediment potential index	Ratio of baseline	1.00	1.00	0.98	0.98	0.98	0.97	0.97	0.92	0.92	0.92
	Primary GDP	GDP index	Ratio of baseline	1.0	4.2	5.3	5.4	5.3	10.0	9.5	11.0	10.9	11.0
	Flood control	Flood control potential	Ratio	0.004	0.004	1.05	1.05	1.05	1.30	1.30	1.30	1.30	1.24

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 Water resources infrastructure development analysis

The objective of this evaluation was to compare the benefits and impacts under four development scenarios:

- Scenario 1, where there is an increase in basin-wide water demand without investment in water storage infrastructure;
- Scenario 2A, which involves the construction of some dams and limited irrigation development;
- Scenarios 3A, which involves full large-scale irrigation development compared to 2A, but with limited storage provided for irrigation;
- Scenario 3Bi which involves the same large-scale irrigation development as in 3A, but with new dams constructed including Moi's Bridge, Upper Nzoia and Lower Nzoia dams.

The results of the analysis are summarised in Table 5-10 and shows that:

- Scenarios 3A and 3Bi rank above Scenarios 1 and 2A from an Economic and Social perspective. This highlights the benefits of increasing the supply reliability through the construction of dams, the benefits of large-scale irrigation schemes with storage provided, more hydropower and increasing fish production in dams.
- Scenario 3Bi ranks the lowest from an Environmental perspective mainly due to the full environmental and social impacts associated with the dam footprint areas.

- 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, 3A, and 3Bi should lead to a slight improvement to the aquatic environment, it is not enough to outscore Scenario 1 Environmentally – also because application of Q95 as a constant minimum flow does not significantly improve the aquatic environment.
- The business as usual scenario (Scenario 1) scores lowest under Economic and Social indicators, 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, limited development, and full development scenarios

	ECON	ENV	SOC
SC1	0.378	0.540	0.381
SC2A	0.397	0.525	0.406
SC3A	0.407	0.497	0.423
SC3Bi	0.605	0.496	0.653
SC1	4	1	4
SC2A	3	2	3
SC3A	2	3	2
SC3Bi	1	4	1

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

- Supply deficits for current urban and rural domestic demands as well as small scale irrigation demands currently occur mainly due to shortfalls during the dry season.
- The expected growth in urban centre water demands by 2040 will result in a significant reduction in supply reliability to the urban centres. A key priority for the development of water resources in the Lake Victoria North Basin should therefore concern improved water supply to the main urban centres including Eldoret and Kakamega, through the provision of storage and/or intra-basin transfers.
- Interventions towards improving water availability and assurance of supply to urban users should include a combination of new storage dams, new and/or upgrades to existing inter- and intra-basin transfers, water demand management measures, conjunctive use 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.
- The full extent of planned large-scale irrigation development in the Nzoia sub-basin (as per the NWMP) appear to be feasible but will require the construction of the Upper and Lower Nzoia dams to ensure a high reliability of supply.
- The areal extent of the irrigation scheme linked to the proposed Kibolo Dam should potentially be reduced, as some of the water in Moi's Bridge Dam need to be reserved for supplying Eldoret.
- To ensure a reliable supply of water, the areal extent of the proposed large-scale irrigation schemes in the Yala and Sio sub-basins should be reduced, if these schemes are to operate as run-of-river schemes.
- Climate change is expected to result in increased rainfall and temperatures; however, the net impact will be less water availability and increased irrigation demands. This highlights the importance of providing storage and the need for water demand management.

- It is imperative that water demand management is implemented in all urban areas, while irrigation efficiencies should also be improved.
- The availability of water for use within the basin will be severely impacted by the introduction of variable minimum environmental flows as opposed to the current Q95 minimum constant flow. Careful consideration should be given to resource classification and how this will impact water resources availability.

5.7.2 Full and sustainable development analysis

The objective of this evaluation was to compare Scenario 3Bi, which involves full irrigation and water resources infrastructure development as per existing plans vs Scenarios 4A and 4Bi, both of which represent sustainable development scenarios, i.e. reduced future urban demands through the successful implementation of water demand management measures, improved irrigation efficiencies, localised storage and groundwater development and reduced large-scale irrigation areas.

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

- The sustainable scenarios (Scenarios 4A and 4Bi) perform well from an Economic, Environmental and Social perspective, highlighting the importance of sustainable water resources development and management in the LVN Basin.
- Scenarios 4Bi has reduced large-scale irrigation areas, which results in improved supply reliability compared to both Scenarios 3Bi and 4A. This highlights the importance of reducing the large-scale irrigation areas to areas that can be sustainable supplied by the available water in the LVN Basin.
- Similarly, Scenario 4Bi has superior urban supply reliabilities due to the relocation of some of the dams supplying urban areas and allowing Eldoret to make use of water being stored in the proposed Kibolo Dam.

Table 5-11: Scenario scores and ranking for the sustainable development comparison

	ECON	ENV	SOC
SC3Bi	0.489	0.442	0.511
SC4A	0.517	0.483	0.539
SC4Bi	0.532	0.512	0.557
SC3Bi	3	3	3
SC4A	2	2	2
SC4Bi	1	1	1

Evidently, Scenario 4Bi ranks highest in this comparison; however, the supply reliability to urban users is still too low, which called for an additional sustainable comparison.

5.7.3 Urban demand and infrastructure locality analysis

The objective of this evaluation was to compare the benefits and impacts under two sustainable development scenarios: Scenario 4Bi, which involves sustainable development interventions with further reduced urban and large-scale irrigation demands vs Scenario 4Bii, which has a further reduction in urban demands and improved, additional interventions to improve the supply to urban users, while the location of some of the proposed infrastructure is reconsidered.

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

- Scenario 4Bii ranks above Scenario 4Bi from an Economic, and Social perspective, which confirms Scenario 4Bii as the more sustainable development pathway, with the maximum economic benefit, without unsustainable social footprints. Both Scenarios 4Bi and 4Bii include reduced water demands, which highlights the importance of improved water demand management in the LVN Basin.

- The supply reliability to urban users is greatly improved in Scenario 4Bii due to the additional abstractions from Kibolo Dam to supply Eldoret as well as the relocation of Teremi and Siyoi dams further downstream to increase their catchment areas.
- Scenario 4Bii scores lower than 4Bi from an Environmental Perspective, due to the dam footprints having a more severe impact after relocation down the rivers.

Table 5-12: Scenario scores and ranking for the sustainable pathway comparison

	ECON	ENV	SOC
SC4Bi	0.542	0.411	0.561
SC4Bii	0.559	0.411	0.568
SC4Bi	2	1	2
SC4Bii	1	2	1

5.7.4 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 5-13.

- Scenario 2B (without climate change), ranks above Scenario 2A (with climate change) from an Economic, Social and Environmental perspective. This is expected due to the anticipated decrease in runoff in the Basin under Scenario 2A – even though the rainfall in the basin is expected to increase, the increased evapotranspiration due to increased temperatures results in a net reduction in water availability and a net increase in crop water requirements.

Table 5-13: Scenario scores and ranking for the climate change comparison

	ECON	ENV	SOC
SC2A	0.475	0.379	0.478
SC2B	0.498	0.417	0.508
SC2A	2	2	2
SC2B	1	1	1

5.7.5 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 3Bi with Q95 as minimum environmental flow vs. Scenario 3Bii with EFlow holding flows.

The results of the analysis are summarised in Table 5-14.

- The impacts of the EFlows from an Economic perspective are evident and Scenario 3Bii scores lower than Scenario 3Bi for this category. Under Scenario 3Bii, 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, hydropower generation and assurance of supply to urban users suffer.
- Scenario 3Bi scores lower than Scenario 3Bii from an Environmental and a Social 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. The Q95 also has more of a negative impact on recession agriculture and the availability of water for riparian users.

Table 5-14: Scenario scores and ranking for the environmental flow comparison

	ECON	ENV	SOC
SC3Bi	0.553	0.371	0.556
SC3Bii	0.552	0.465	0.579
SC3Bi	1	2	2
SC3Bii	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.

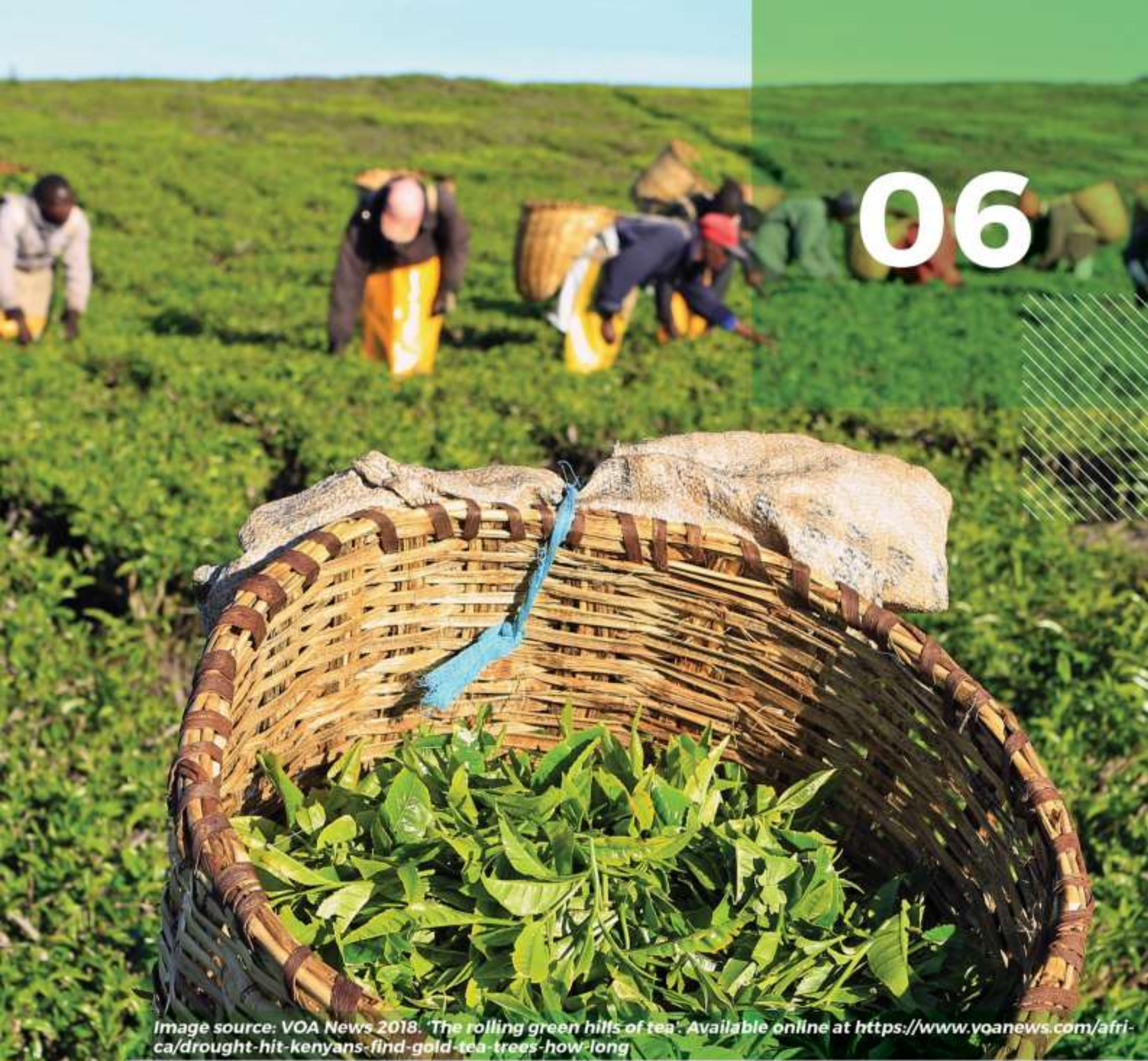


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Image source: VOA News 2018. 'The rolling green hills of tea'. Available online at https://www.voanews.com/africa/drought-hit-kenyans-find-gold-tea-trees-how-long

Key Strategies and Themes

6 Key Strategies and Themes

6.1 Introduction

The key aim of the LVN Basin Plan is to provide a clear way forward for the integrated management and development of the water resources of the LVN 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 LVN Basin and to unlock the value of water as it relates to socio-economic development, ten Key Strategic Areas (KSAs) were formulated for the LVN Basin as presented in Table 6-1.

Table 6-1: Key Strategic Areas and Objectives

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

The 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. The utilisation and management of land and water resources should thus be done in an integrated manner in order to ensure the sustainability of both.

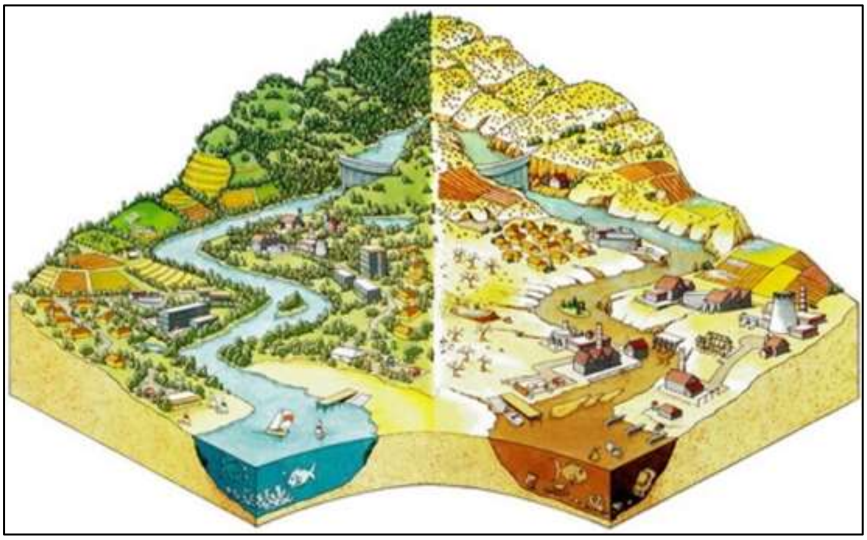


Figure 6-1: Illustration of good (left) and poor (right) state of both land and water resources in a catchment

Land degradation is not just the physical degradation of the soil, but the disturbance of the biophysical environment through human activity. This occurs through activities such as overgrazing, deforestation, alien invasive infestation, poor solid waste management and other similar disruptive actions, and leads to a disturbance of the natural system, which in some cases pushes a system beyond a critical threshold. The impacts of land degradation are long-term and damaging to not only the biophysical environment, but also the socio-economic environment of communities. A loss of soil fertility will lead to low crop yields, which in turn lead to food shortages and reduced income generation, whilst increased runoff due to exposed soil and soil erosion leads to gully erosion and sedimentation of water bodies, leading to biodiversity threats and water resources depletion and degradation, and a reduced capacity to use the water resource e.g. for irrigation or hydropower. In general, the impact that is readily felt in rural communities is a reduced standard of living, which leads to chronic poverty.

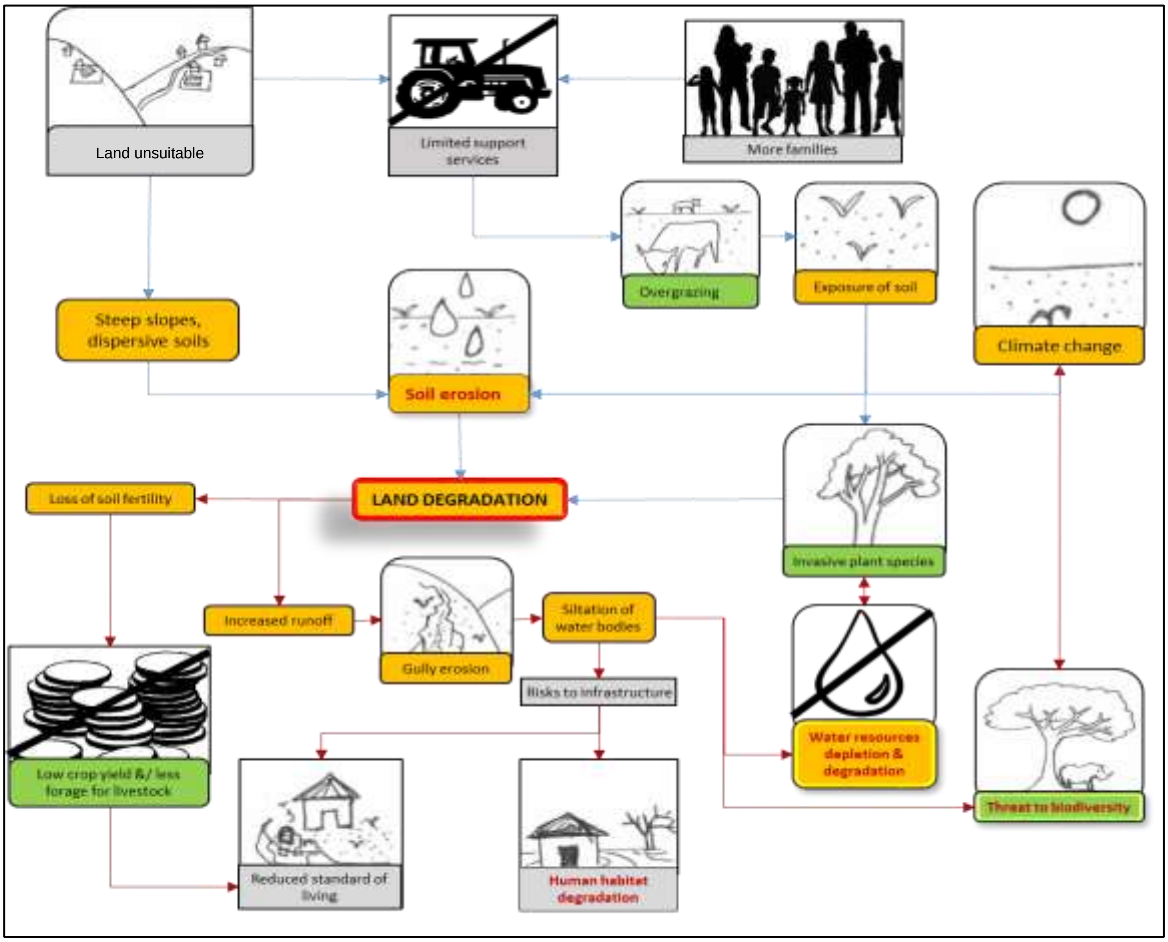


Figure 6-2: An example of the interconnected links of land degradation

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.

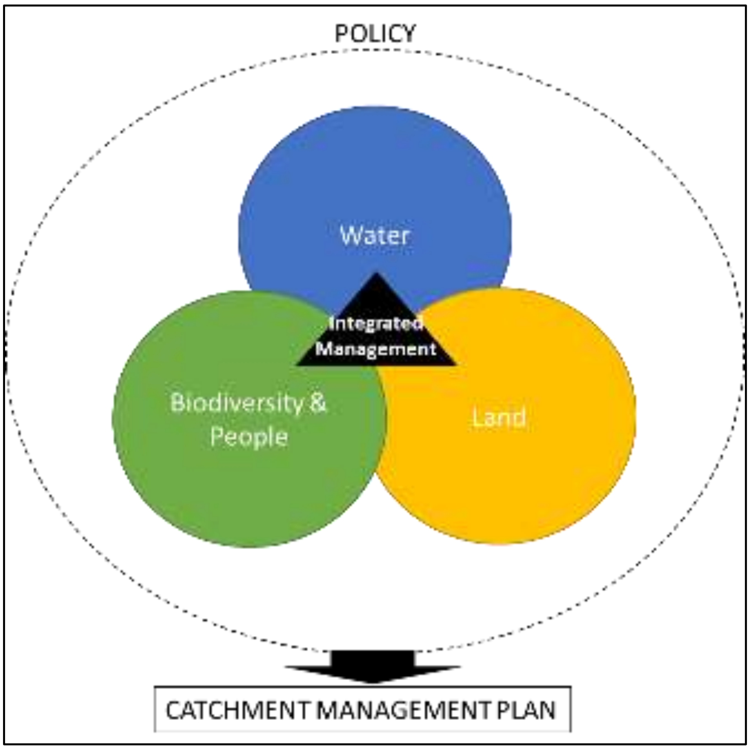


Figure 6-3: The interaction of different management strategies for Catchment Management

In its widest possible sense, Integrated Catchment Management recognises the need to integrate all environmental, economic and social issues within a catchment (at any scale) into an overall management philosophy, process and strategy or plan. It is thus aimed at deriving the greatest possible outcome of sustainable benefits for future generations and the communities in the area of concern whilst protecting the natural resources upon which these communities rely. Often, water resource management paradigms have assumed that sustainability of water resources can be achieved merely through focused efforts to control water use and protect the integrity of water resources within a catchment context. However, in more recent times it has been acknowledged that this approach ignores the complex issues of land use patterns and the varied roles played by stakeholders, which impact on the water use and water resources. In order to achieve integrated catchment management and derive the best outcome of benefits while protecting resources, requires careful planning, the physical implementation of activities in day to day practices and livelihoods, and a strong legislative, regulatory and institutional framework to support the planning process and implementation.

There are several concepts and principles that are important to integrated catchment management. These are discussed below:

6.2.2.1 Catchment and River Basin Scale

A water resource at a particular location is the product of runoff or groundwater recharge that originates in, and reflects conditions and events throughout, a geographically defined drainage area known as a catchment ("local scale") or basin (large scale, multiple catchments). The way humans use and abuse land inside the catchment has a decisive impact on the quantity and quality of the water resource and on the health of the aquatic ecosystems reliant on that resource. In this way the hydrological cycle, land-use and aquatic ecosystem functioning form a continuum bounded by the extremities of the catchment. This calls for recognition that naturally occurring water can usually be effectively and efficiently management only within river basin (regional scale management) or catchment (local scale management) boundaries, because of the need to technically account for all aspects of the hydrological cycle, including the way humans change aspects of the cycle by land use. Figure 6-4 illustrates how water and land use activities overlap in an example catchment.

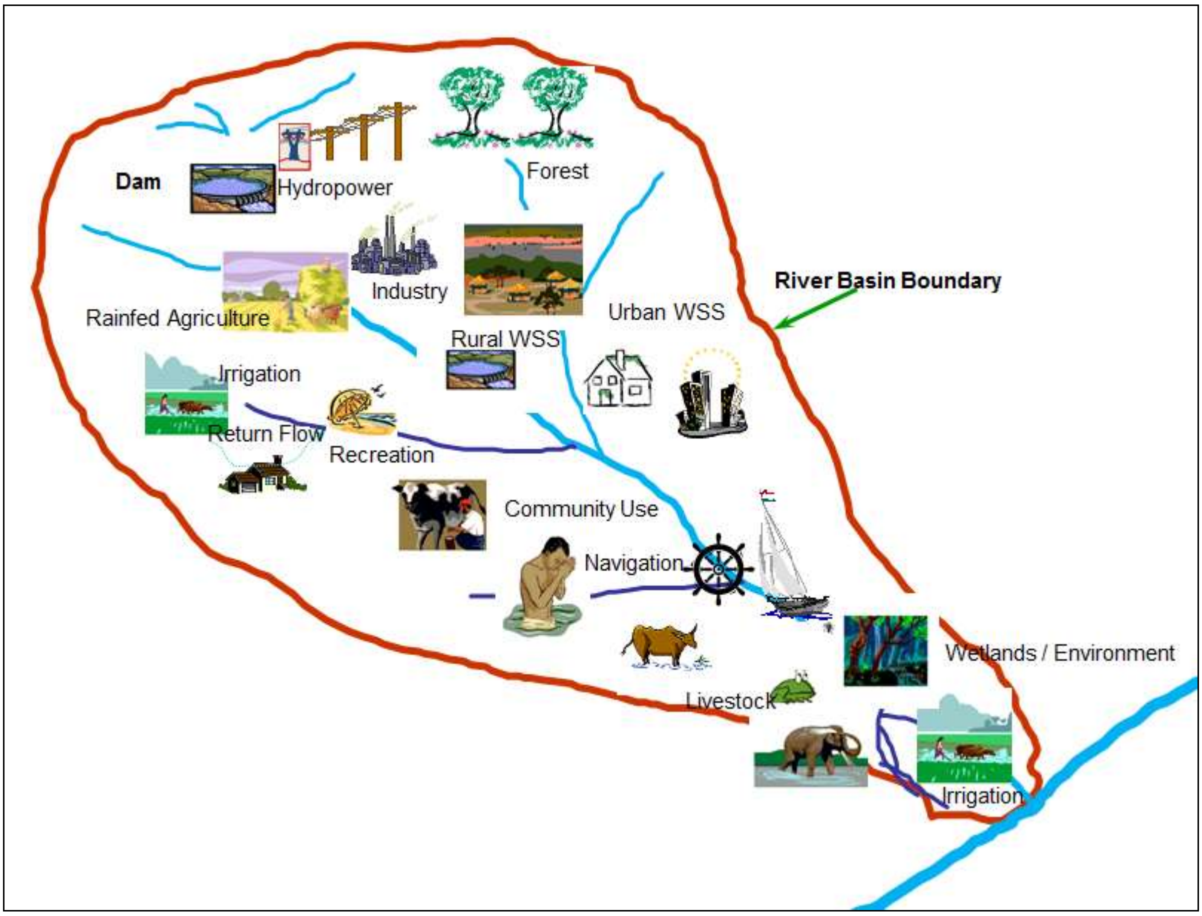


Figure 6-4: Illustration of water and land use activities within a catchment

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 LVN Basin

There are always rules, formal/informal, which determine how people access resources and opportunities (Levine & Pavanello, 2012). These rules, and the ways in which they are enforced, constitute 'institutions'. Institutions could relate to the institutions of the state or organised committees following written constitutions, to informal rules of culture and locally accepted figures of authority. Local-level catchment management strategies address issues that are locally relevant, but depending on the mandate, also legislatively relevant.

Who is responsible for catchment management?

Integrated catchment management requires management of both land and water resources, inclusive of different role players and institutions. Some of the institutions involved are as follows:

- Water resource-based: WRA/BWRC/WRUA
- Land/Agricultural based: AFFA/Extension officers/Pastoralists
- Environmental/Biodiversity based: NEMA/KWTA/KFS/KWS
- Governance based: County government

It is critical that these institutions are aware of each other to achieve sustainable management of the Basin.

6.2.3.1 Water resource-based issues

The LVN Basin is managed by three WRA Sub-regional offices, which manage eight Catchment Management Units (CMUs) based on hydrological, water resources and land use considerations. Some of the WRA offices in the LVN 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 Catchment Management Strategy was developed for the LVN Basin for the period 2015-2022 (Water Resources Management Authority, 2015a). Chapter 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 or other sources of funding. The SCMP is an IWRM tool for water resource management to support sub-catchment management. The LVN Basin has 94 existing WRUAs out of a potential 106 WRUAs needed to cover the whole basin. The gap of 12 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 LVN Basin and relevant issues

Upper and Lower LVN		
	WRA SR / SRO / CMUs	Kipkaren - Upper Yala, Elgon – Cherangani, Lower Nzoia - Yala / Eldoret, Kitale, Siaya / Kipkaren, Upper Yala, Upper Nzoia, Middle Nzoia, Sio-Malaba-Malakisi, Mount Elgon, Lower Nzoia, Lower Yala
	Issues	- Catchment degradation especially in Mount Elgon, Maragoli, Moiben, Chepkaitit, Timboroa - Flooding in areas such as Budalangi, Namanjalala, Malaba, Bumula - Encroachment and cultivation on wetlands and riparian zones - Climate change and variability which results in high magnitudes of floods and droughts - Pollution, mainly from major towns in the form of industrial discharges, agrochemicals, sewage and solid waste disposal.

6.2.3.2 Land/Agriculture-based issues

Various Directorates under the Agriculture, Fisheries and Food Authority (AFFA) provide technical input and advice to County Governments. The Authority also conducts farmers' training programs aimed at increasing their knowledge on production technologies and prospects for various types of crops, through farmer training institutions. Extension officers are involved in on the ground catchment management activities, particularly for smallholder farmers. These smallholder farmers are most at risk to the impacts of climate change and infertile soils. Conservation agriculture has been promoted as a sustainable alternative for farmers to address the problem of declining soil fertility and provide the dual benefit of enhanced food production and adaptation/resilience to changing climatic conditions (Agriculture and Food Authority, 2017).

Agricultural extension services in Kenya date back to the early 1900s. Agricultural extension services refer to a systematic process of working with producers or communities to help them acquire relevant and useful agriculture or related knowledge and skills to increase farm productivity, competitiveness and sustainability (Agriculture and Food Authority, 2017). Catchment management approaches are promoted through various methods, with a focus on soil and water conservation and conservation agriculture.

Land and water is also important to pastoralists, although the importance of the resource is linked to treating it as common property freely available for all with livestock (Levine & Pavanello, 2012). The management of natural resources is thus inseparable from the management of relationships between the pastoralist clans and ethnic groups. Pastoralists move their herds in seasonal patterns, according to the conditions of each year. This movement is managed to maintain the right balance of species in the best possible condition over the long term through careful control of grazing (Levine & Pavanello, 2012). Management requires a set of rules and requires the right institutional framework. This is mainly set by groups of elders, who constitute customary authorities.

The Agricultural Sector Development Strategy (ASDS) intends to provide a guide for overcoming challenges facing the agricultural sector in Kenya. The ASDS 2010-2020 (2010) proposes integrated development and management of rangeland due to the climatic changes, coupled with overstocking and degraded environment, having devastating effect on pasture regeneration and pastoralists livelihoods. Rangelands are chronically short of pasture and water (Government of Kenya, 2010a), restoring this will require reseeding and range pitting, bush control, soil conservation and water rehabilitation and development. The ASDS 2010-2020 (2010) also emphasises the need to rehabilitate and protect water catchments due to issues such as increased runoff, flash floods, reduced infiltration, erosion and siltation, and limited water resource base.

Table 6-3: Land/agricultural institutions operating at local level in the LVN Basin and relevant issues

Upper LVN		
	AFFA/extension services	West Pokot, Trans Nzoia, Elgeyo Marakwet, Uasin Gishu, Nandi, Kakamega, Bungoma
	Issues	- Farmers on Mount Elgon and Cherangany Hill slopes encouraged to adopt better farming practices and increase tree cover on their farms - In Trans Nzoia county unsuitable farming practices (i.e. farming along riverbanks) are leading to environmental degradation - In Nandi county farmers practice forestry to increase percentage of cover on their land and for commercial purposes
Lower LVN		
	AFFA/extension services	Bungoma, Kakamega, Vihiga, Siaya, Busia
	Issues	- In Bungoma county water pollution caused by fertilizers and industrial effluents discharged directly into rivers. - In Bugoma county grazing stock in rivers and along riparian land leads to water quality issues - Reduced farm productivity in Kakamega county due to rainfall variability - Farmers encroaching into Yala Swamp

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 LVN Basin the gazetted water towers include Mount Elgon.

The Forest Management and Conservation division under the Kenya Forest Service (KFS) is charged with the management and conservation of the natural forests in Kenya, of which most form water towers. Strategic outputs involve increasing percentage cover through tree planting and gazetting new forests; as well as improving livelihoods. The Division includes forest biodiversity conservation, participatory forest management and fire management, natural forest management, licencing and eco-tourism.

The KFS Forest Farm and Dryland Forestry program provides technical support to the counties, advisory services for forest management, promoting biomass energy development and utilization, promote dryland forest conservation and promote participatory forest extension methodologies including farmer field schools. Issues in the Forestry sector are weak institutions arising from weak governance structures and inadequate capacity for law enforcement and weak stakeholder participation in forest management and governance. This is exacerbated by inadequate funding of the forestry sector from the exchequer, civil and public sectors. Since the enactment of the new Constitution in 2010, nationally and within the basin, the level of public support to the conservation of forests has increased significantly but has not been matched by an equal measure of resource allocation in all sectors. For example, the Forest Management and Conservation Fund (FMCF) established in the Forests Act 2005 and the Forest Management and Conservation Act No.34 2016 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 LVN 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 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 LVN Basin and relevant issues

Upper LVN		
	Water Towers (KWTA)	Mount Elgon, Cherangany Hills
	Gazetted forests (KFS)	Excision, Kapanyar, Kapolet, Kiptaberr, Kaisungor, Kipkunurr, Totopket, Chemurokoi, Cheboit, Kapchemutwa, Kaptagat, Kipkabus, Kapchorua Block I, Nabkoi, Northern Tinderet, Eldoret_A, Eldoret_B, Turbo_A, Turbo_B, Lugari, Sekhendu, Mount Elgon_A, Mount Elgon_B, Katalale, Kitale Township A, Kitale Township B, Kitale Township C, Taressia, North Nandi, Kaptaroi, Ururu, South Nandi
	National Parks (KWS)	Chepkitale, Mount Elgon, Saiwa swamp
	Mount Elgon Ecosystem Conservation Programme	Mount Elgon
	Issues	- Priority to increase tree cover in Mount Elgon and Cherangany Hills for conservation of water catchments of Lake Victoria and Lake Turkana - In Trans Nzoia there is a high demand for wood fuel from increasing population and tea factories causes forest degradation, although this could be offset by agroforestry - Sangalo and Kipkurere forest in Uasin Gishu county under threat from population pressure. - Rampant logging in Uasin Gishu county - Nandi county has commercial and illegal logging and forest encroachment
Lower LVN		
	Water Towers (KWTA)	Mount Elgon
	Gazetted forests (KFS)	Mumbaka, Nanyungu, Namuluku, Wanga, Bunyala, Mlaba, Kakamega, Buyangu, Got Abiero, Ramogi
	National Parks (KWS)	Kakamega
	Issues	- In Bungoma county wetlands are being encroached by communities for crop land - Mount Elgon forest in Bungoma county has suffered from overexploitation and depletion of resources - Encroachment into Kakamega forest - Yala swamp in Siaya county has had a major loss due to drainage since the 1960s.

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.

Trans Nzoia county is generally flat with Mount Elgon rising in the northwest (County Government of Trans Nzoia, 2018). Nzoia River extends through the county, with the Nzoia River and its tributaries flowing into Lake Victoria. Most natural forest cover occurs in Mount Elgon and Cherangany Hills. Uasin Gishu county is a highland plateau with its main rivers (Sosiani, Kipkaren, Kerita, Nderugut, Daragwa and Sambu) draining into Lake Victoria (County Government of Uasin Gishu, 2018). Nandi county comprises rolling hills, a plateau, swamp and escarpment. The main rivers are Kimondi and Mokong Rivers, which converge to form Yala River. Kipkarren River also extends across the county and eventually converges with Nzoia River in Kakamega county. The largest forest in the county is the South Nandi tropical rain forest.

Bungoma county rises from Mount Elgon in the north and extends down towards Lake Victoria (County Government of Bungoma, 2018). Nzoia, Sosio, Kibisi, Kuywa, Lwakhakha, Malakisi, Sio and Khalaba Rivers extend across the county, draining to Lake Victoria. Seasonal wetlands occur on the main stem of Lwakhakha, Malakisi and Khalaba Rivers and permanent wetlands occur on lower Sio River. Kakamega county has several hills, with the Nandi escarpment forming a prominent feature in the east (County Government of Kakamega, 2017). Nzoia, Yala, Lusumu, Isiukhu, Sasala, Viratsi and Sivilie Rivers extend across the county. Aside from the gazetted forest various natural forests have been integrated with farms therefore there is a need for communities to engage in agroforestry activities. Vihiga county Nzoia and Yala Rivers traverse Siaya county and enters Lake Victoria through Yala Swamp (County Government of Siaya, 2018). High altitude areas are more suitable for agriculture and livestock, whilst the low-lying areas receive less rainfall therefore are more suited to cotton growing and drought resistant crops. There are both fish landing sites and aquaculture ponds in the county to meet the demand. Agroforestry is practiced limiting impact on natural forests and improving agriculture productivity. Yala Swamp is fed by Nzoia River in Busia county (County Government of Busia, 2018).

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

Upper LVN		
	Counties	West Pokot, Trans Nzoia, Elgeyo Marakwet, Uasin Gishu, Nandi, Kakamega, Bungoma
	Issues	Trans Nzoia - Water pollution - Informal settlements in the forests - Unsustainable livelihoods (i.e. charcoal burning and wetland farming) - High cost of water harvesting Uasin Gishu - Population pressure on forests - Forest fires - Introduction of alien invasives by communities - Annual wetland burning by local communities Nandi - Sand mining is Aldai and Tinderet Sub-counties is often done in wetlands and major rivers and is a major contributor to water pollution - Deforestation and encroachment - Overgrazing contributed to soil erosion in rainy season. - Landslides experienced along the escarpment and Cherondo and Uson in Tinderet sub-county

Upper LVN		
Lower LVN		
	Counties	Bungoma, Kakamega, Vihiga, Siaya, Busia
	Issues	Bungoma - Reduction in river volume and water pollution related to reduced fish stocks, reduced domestic water, irrigation, drying up of wetlands, springs, boreholes, dams and pans - Increased water borne illnesses - Poor water quality from human, industrial and agricultural sources - Inadequate road drainage causes erosion Kakamega - Encroachment to forests - Soil erosion from flash floods during rainy season - Limited waste disposal and management - Quarrying, particularly gold mines, not using sustainable methods. Brick making is also on the increase, which requires wood fuel and creates gullies. - Springs and streams drying up - Reduced farm productivity due to rainfall patterns changing - Frequent flash floods and rise in temperature - Increase in vector diseases Siaya - Farming encroachment to Yala Swamp - Gold mining and sand mining (Nzoia River) - Deforestation - Water pollution Busia - Unsustainable use of vegetation and forest cover - Increasing population causes pressure on forests due to need for wood fuel - Poor waste disposal

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).

In order to comprehensively and systematically address the range of catchment management issues identified in the LVN 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.

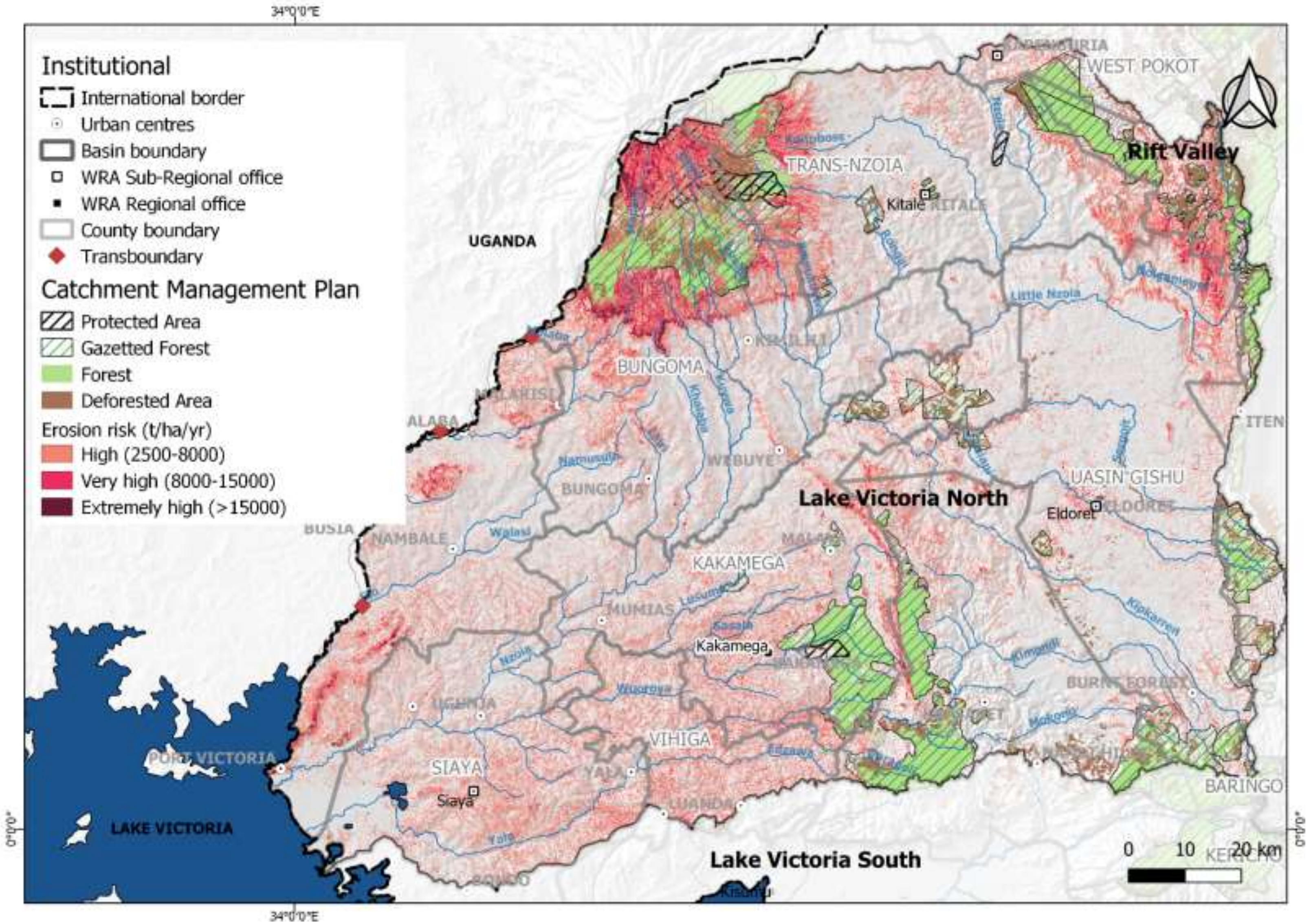


Figure 6-5: Catchment management considerations in LVN Basin

Table 6-6: Strategic Framework - Catchment Management

1	**Key Strategic Area:**	**Catchment Management**
1.1	**Theme:**	**Promote improved and sustainable catchment management**
1.1.1	Promote sustainable land development and planning	

NEMA Environmental Sustainability Guidelines for Ministries, Departments and Agencies (MDAs) defines sustainability as meaning “meeting the needs of the present without compromising the ability of future generations to meet their own needs”. Sustainability is defined as not being an end goal, but rather a journey that MDAs should take to improve the social equity, environmental, and economic conditions in their jurisdiction.

In order to reduce the degradation of land and water resources, a sustainable management approach must be implemented in the LVN 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 village, 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 at catchment level	

Water conservation and management is considered a priority in the LVN Basin due to high water use. Water is important in the Basin both for urban use as well as for agricultural use therefore water management and access to water are important. Access can be improved through community or household storage of water and through resource protection. Access to water is also improved through water efficiency and through recycling water. The timeframe of access to water is also important as the seasonality of water resources increases human/wildlife conflict.

Water resource management has been identified as a strategic objective in most CIDPs, with strategies involving water harvesting, storage and treatment. Catchment management activities that can be also be implemented to promote water conservation and management are as follows (Braid & Lodenkemper, 2019):

1. **Water use efficiency and recycling**

   By improving water efficiency through suitable crop selection, proper irrigation scheduling, effective irrigation techniques, and using alternative sources of water for irrigation, it will be possible to increase water availability and make the water last longer. These also address point source protection of water collection points. These activities should be implemented by smallholder farmers.

   - Water use efficiency, i.e. through installation of drip irrigation systems.
   - Wastewater recycling, i.e. treating wastewater to remove solids and impurities, greywater can be separated from blackwater.
   - Excess water reuse, i.e. channel water spills at hand pumps to a ‘fertility pit’.

1	Key Strategic Area:	Catchment Management

2. Water harvesting and storage

By providing access to additional water by harvesting water (collecting runoff) and storing water. By harvesting water, farmers can increase the area they irrigate, grow crops in the dry season, and support livestock. Water storage at the household or village level improves access to water, and reduces the labour burden, by reducing the number of trips to boreholes. These activities should be implemented in the semi-arid regions of the LVN 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 LVN 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 the LVN Basin which do not have a dense vegetation cover are more prone to high levels of erosion than the lower plains. Land use in these areas is becoming increasingly more degraded and stormwater management is becoming an issue during frequent floods. Improved erosion and runoff control measures and sediment trapping will improve resilience to floods and erosion. In the lower plains of the LVN 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 (2010) emphasizes the need to restore rangelands through reseeding and range pitting, bush

1	Key Strategic Area:	Catchment Management

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 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.

1	Key Strategic Area:	Catchment Management

- Gabion baskets, bank collapse along rivers and gullies contribute to catchment degradation. Gabion baskets are rock filled structures to protect banks, reduce erosion and prevent bank collapse.

1.2.3	Promote conservation agriculture and improved farm management

One of the most important natural resources is the soil. Healthy and fertile soils produce good yields of crops; whereas poor or degraded soils produce low and unreliable yields. Soil health is a function of rooting depth, nutrient fertility, structure, organic matter content, below-ground biodiversity and water holding capacity – all of which are related. Ensuring soils remain healthy and fertile requires a variety of management techniques including climate-smart farming practices and nutrient management.

Most of the CIDPs promote soil fertility improvement and agroforestry but a more holistic approach would to consider conservation agriculture and improved farm management as follows (Braid & Lodenkemper, 2019):

1. Climate-smart agriculture

Climate-smart agriculture practices contribute to improving the health of the soil by enhancing its physical, chemical and biological properties. Good soil health will produce higher and more stable yields. These techniques contribute to avoiding erosion and controlling rainfall runoff, by increasing infiltration of rainwater and water holding properties and thereby improving soil moisture. Climate-smart agriculture covers the principles and practices of conservation agriculture and Permaculture (natural farming). Nutrient management focuses on soil fertility, which is of fundamental importance for agricultural production. These include compost techniques and natural fertilizers.

- Conservation agriculture: Conservation agriculture combines profitable agricultural production with environmental concerns and sustainability by conserving, improving, and using natural resources more efficiently through integrated management of soil, water and biological resources. Conservation agriculture contributes to food security and increases tolerance to changes in temperature and rainfall including incidences of drought and flooding. Conservation agriculture combines three basic principles or 'pillars': (i) minimum tillage, (ii) crop rotation and (iii) maintaining soil cover by crops or crop residues.
  - **Conservation tillage:** Minimum tillage is superficial loosening of the soil (5 cm), ripping of planting rows with a ripper tine (chisel plough), or making permanent planting basins by hand, without disturbing the soil between. Zero or no-tell is direct planting through a mulch layer using a special planter or hand tool. Conservation tillage is any form of reduced tillage technique.
  - **Crop rotation and intercropping:** Mixing crops by either planting a different crop in each field every season, or by planting a mixture of crops which complement each other can be beneficial. Rotating crops regularly reduces the ability of each crop's pests to become established in the soil through minimising the available food and habitat for each pest. The variety of crops also increases opportunities for a mixture of pest predators to survive.
  - **Soil cover (mulching):** Soil cover and mulches protect the soil from the heating and drying effects of direct sunlight and the physical damage caused by heavy rain. They also reduce evaporation, and moderate soil surface temperatures. Soil covers also slow surface runoff during rainstorms, reducing erosion and increasing infiltration.
- Natural farming (small scale): Energy can be saved by laying out the farm and household cultivation/ farming beds and plots more efficiently.

2. Nutrient management

Soil fertility is of fundamental importance for agricultural production. Certain techniques maximize the efficiency of nutrients and water use for better agricultural productivity. This improves and sustains soil quality for the future. These include compost techniques and natural fertilizers.

- Compost: Compost helps return nutrients to the soil, reduces reliance on chemical fertilizers, increases soil organic matter, maintains moisture and provides soil cover. Compost can be made household level for cost-effective soil fertility improvement.
- Natural fertilizer: A balance of all essential soil nutrients is necessary for healthy plant growth. The application of any one nutrient in a soil with multiple nutrient deficiencies will have limited impact on crop growth.
- Micro dosing: Low-technology precision agriculture technique initially developed by ICRISAT. Small doses of fertilizer applied in the right place has been found to lead to large benefits in yields for the smallholder farmer.
- Weeding: A move from conventional farming (i.e. tilling the soil) to conservation farming can result in increased number of weeds. An appropriate weeding strategy is required for successful conservation farming. Weeds lower crops yields due to competition for water, nutrients, light and space.
- Agroforestry: Agroforestry is the intentional integration of trees within a cropping system for multiple benefits. It is increasingly recognised as one way of dealing with the lack of space and infertile soils.

1	Key Strategic Area:	Catchment Management
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 LVN Basin Catchment Management Strategy (2015) wetlands are under pressure from human encroachment for settlement, expansion of crop production, urbanization, property development and livestock grazing. These wetlands need protection from degradation and restoration of their functional capacities.

Although significant wetlands are protected from use (refer to KSA 2), in certain cases seasonal wetlands are utilized by surrounding communities. It is important to not only conserve what is existing, but also improve the farming practices and grazing in wetlands for more sustainable utilisation and reduced impacts (Braid & Lodenkemper, 2019).

1. **Wetland conservation**

   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. 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. Programmes that require management are as follows:

- Alien vegetation woodlots for personal and commercial use
- Promotion of alien vegetation for agroforestry use
- Agroforestry tree nurseries
- Beekeeping
- Inland aquaculture

1.3.3 Improved solid waste management

To ensure that catchment management activities and resource protection activities can be implemented, it is important that activities around the household, farm and village are also sustainable and of a high standard. These include activities such as waste management. Waste management involves the generation, collection, transportation, and disposal of garbage, sewage and other waste products. Responsible waste management is the process of treating solid wastes and offers a variety of solutions for waste with the ultimate aim of changing mind-sets to regard waste as a valuable resource rather than something that must be thrown away. The government is constitutionally bound to provide sanitation services to all of its citizens, this includes the removal and proper treatment of solid waste. In reality this is not being done in many parts of the country, particularly in remote rural areas. Water resources nearby urban areas are particularly at risk, as evident in the CIDPs. It is important to ensure that the mind-set of waste management extend to individuals and communities as it is important for a clean and safe environment.

1	Key Strategic Area:	Catchment Management

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 through the use of alien trees (i.e. eucalyptus). Consideration needs to be made to the objective of these programmes as there could be significant long-term challenges associated with planting trees with high water requirements in counties with limited water supply.

1.3.5 Removal of alien invasive species

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.

1	Key Strategic Area:	Catchment Management

- Removal of larger hardwood invading alien vegetation:
  - Ring barking
  - Strip barking
  - Hand pull

2. Utilising and controlling blue gum (eucalyptus) trees

Blue Gum trees, if left unmanaged, will invade and replace indigenous vegetation by monopolising the water resources. Application of invasive species management should be done throughout the catchment, but a particular focus should be given to areas closer to settlements, areas near smaller non-perennial rivers and areas known to have an elevated fire risk

3. Utilising and controlling pine trees

Invasive plants such as pine trees use much more water than indigenous species. As such they prevent rainwater from reaching rivers and deprive people and ecosystems of much needed water. Invasive alien plants can displace indigenous species and thereby reduce biodiversity. Invading alien plants also increase fuel loads enhancing the potential intensity of fires that destroy infrastructure and damage soils. However, as they are fast growing trees, they are useful for afforestation projects, they must however be carefully managed in order to prevent uncontrollable spread through the catchment.

4. Utilising and controlling Bamboo

There are many types of bamboo but in general they can be divided into either clumpers or runners. The clumping species are non-invasive and can be used for building materials or stabilising soil erosion. Running bamboo species can be become very invasive and must be controlled.

5. Utilising and controlling Prosopis species

Prosopis spp. also known as mesquite, is a dominant groundwater dependent invasive alien species found in the arid and semi-arid areas. Hybridization between the dominant species, *Prosopis velutina* and *Prosopis glandulosa var. torreyana* are very invasive.

6. Utilising and controlling water weed/hyacinth

Water hyacinth, *Eichhornia crassipes* (Mart.) *Solms-Laubach* (Pontederiaceae) is a perennial, herbaceous, free-floating aquatic plant that is widely recognized as one of the world's worst invasive weeds. Anyone undertaking biological or chemical control methods should have proper training in the use of the chemical/biological agents. Additionally, they must have a strategic plan in place over several years to ensure that the process in successful and the system doesn't relapse into an infestation state.

1.3.6	Improved fisheries management

Promote the sustainable development and management of fisheries in lakes, dams, wetlands and rivers.

1.3.7	Improved energy management

To ensure that catchment management activities and resource protection activities can be implemented, it is important that activities around the household, farm and village are also sustainable and of a high standard. These include activities such as energy management. Renewable sources of energy should be promoted to generate electric power for use in the household, or community, as a replacement for the burning of wood or charcoal.

Most CIDPs promote "green energy" as an alternative fuel to wood and charcoal.

The following renewable sources could also be promoted for energy supply instead of burning wood or charcoal:

- Solar cooker
- Solar electrification
- Solar borehole pump
- Wind pump
- Micro hydropower
- Biogas digester
- Energy efficient stoves and ovens
- Heat retention cooker
- Solar turtle

1.3.8	Improved sand mine management

Develop policies for sand harvesting. Consider alternative sources of sand.

1.4	Theme:	Rehabilitation of degraded environments

1.4.1	Rehabilitation and Restoration Plan

Develop a restoration and rehabilitation programme. Refer to 1.2.2.

1	Key Strategic Area:	Catchment Management
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.		
1.4.6	Mining area rehabilitation	
Mining removes the protective covering from the land and exposes soils to soil erosion as well as pollution impacts. During mining activities exposed soils must be revegetated and soil conservation techniques implemented.		

6.3 Water Resources Protection

6.3.1 Introduction

Water is critical to social and economic development but also supports key ecological systems which underpin human wellbeing and provides essential ecosystem goods and services. According to the Water Act 2016, a water resource is defined as *"any lake, pond, swamp, marsh, stream, watercourse, estuary, aquifer, artesian basin or other body of flowing or standing water, whether above or below the ground, and includes sea water and transboundary waters within the territorial jurisdiction of Kenya*". It is important to differentiate between surface and groundwater resources as these are treated differently within the context of water resources protection: surface water resources include rivers (i.e. stream, watercourse), wetlands (i.e. lakes, ponds, swamp, marsh, spring) and estuaries, while groundwater resources refer to aquifers and artesian basins.

> *"In Kenya, wetlands are defined as areas of land that are permanently or occasionally water logged with fresh, saline, brackish, or marine waters, including both natural and man-made areas that support characteristic plants and animals. These include swamps, marshes, bogs, shallow lakes, ox-bow lakes, dams, riverbanks, floodplains, fishponds, lakeshores and seashores. They also include coastal and marine wetlands such as deltas, estuaries, mud flats, mangroves, salt marshes, seagrass beds and shallow reefs all of which at low tide should not exceed 6 meters."*
>
> \- Ministry of Environment Water and Natural Resources, 2013

The 2016 Water Act also outlines the designation of Basin areas, with functions of Basin Water Resource Committees (BWRCs) within each Basin clearly stated. Furthermore, the Act defines the establishment and functions of Water Resource Users Associations (WRUAs) i.e. associations of water resource users at the sub-basin level in accordance with Regulations prescribed by the 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: The different levels of water resources protection in Kenya

6.3.2 Classification of water resources and resource quality objectives

To date, Kenya has not classified its water resources. Protection of water resources requires defining the Class, the Resource Quality Objectives and the Reserve of the resource. The Water Act 2016 states that the WRA shall classify each water resource, specify the resource quality objectives, and specify the requirements for achieving the objectives. The Act also prescribes criteria for classifying water resources for the purpose of determining water resources quality objectives for each class of water resource. These criteria include trans-boundary considerations, strategic functions, ecological functions and vulnerability and may be considered as Resource Directed Measures, which provide the descriptive and quantitative goals for the state of the resource. This is different to the local scale management of resources, which is directed through Source Directed Controls (i.e. specifying the criteria for controlling impacts such as waste discharge or abstraction).

Classifying water resources is a stepwise process. The classification and resource quality objectives approach forms part of the Water Resource Management cycle which is an adaptive management approach focused on goal-setting (Figure 6-7). The first step in the cycle is to determine a vision for the desired future state of water resources. Water resources are then categorised according to specific Water Resource Classes which represent a management vision of a particular catchment, take into account the current state of the water resource and defines the ecological, social and economic aspects that are dependent on the resource (Department of Water Affairs, 2007). The vision for the desired future state of water resources are typically expressed as a range of Ecological Categories e.g. from A to F, in order of decreasing levels of protection for, or increasing levels of risk to aquatic species and habitats (Department of Water Affairs, 2011). The resulting Ecological Categories and ultimately the determined Class of a resource will then dictate the Resource Quality Objectives (RQOs)and the associated Reserve that is set to achieve it. The RQOs 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 RQOs is to establish clear goals relating to the relevant water resources that can be monitored and thereby give effect to the desired water resource classes in the catchment.

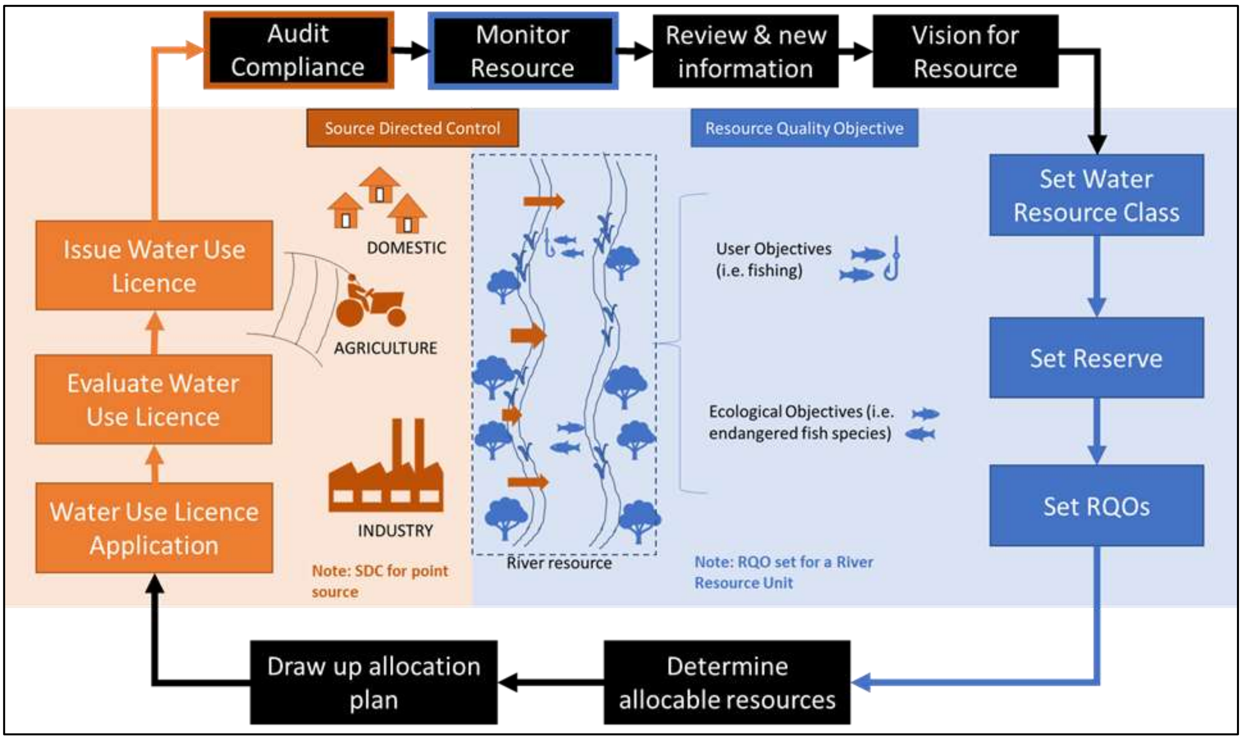


Figure 6-7: Water resources management cycle

Classifying water resources and determining Resource Quality Objectives follow aligned steps as shown in Figure 6-8. These involve delineating the water resources, establishing a vision for the Basin, linking the value and condition of water resources, quantifying the environmental water requirements (i.e. the EFlows), determining future scenarios and associated water resource classes, then prioritising and selecting resource units to take forward for development of Resource Quality Objectives.

The Reserve (in terms of quantity and quality) refers to the volume of water needed to satisfy the basic human needs of people who are or may be supplied from the water resource (i.e. Basic Human Needs) and the volume of water needed to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the water resource (i.e. ecological Reserve). The Reserve must therefore be met before any allocation may be made.

The Kenya Guidelines for Water Allocation (Water Resources Management Authority, 2010) defines the Reserve quantity for streams and rivers as "*the flow value that is exceeded 95% of the time as measured by a naturalised flow duration curve"*. Although this minimum flow value, which classifies as a rapid hydrological index method, allows the Reserve to be quantified, no consideration is given to the specific nature of rivers or its biota, the timing and duration of flows or the broader aquatic ecosystem.

*based on Department of Water Affairs, 2007, 2011

Figure 6-8: The seven steps to determine water resource classes and resource quality objectives

The Reserve constitutes one of the four demand categories when allocating water resources in Kenya as shown in Figure 6-9. The total water resource is made up of what is available for allocation or use and the Reserve.

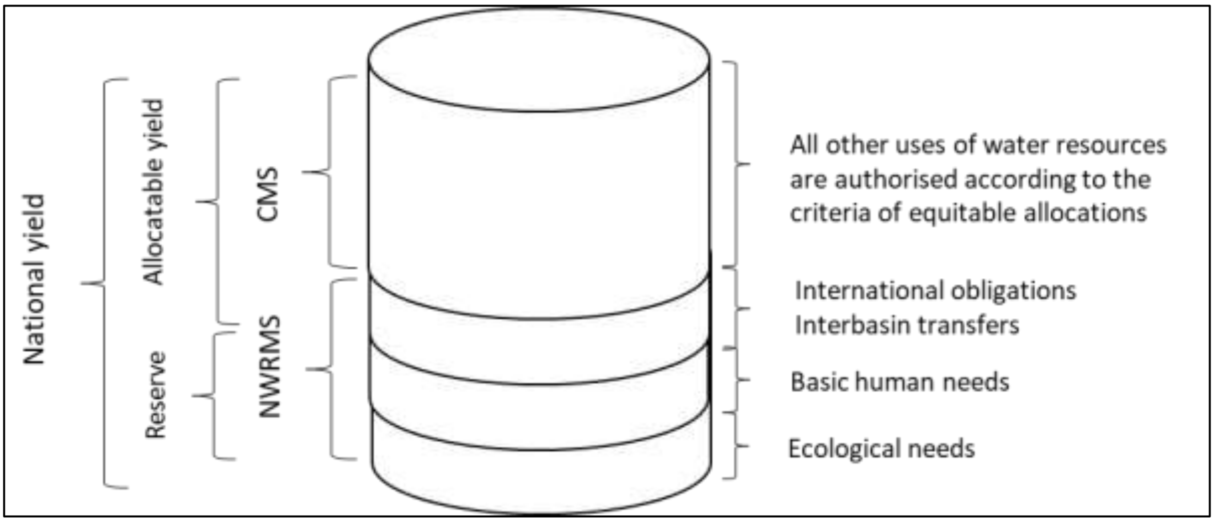


Figure 6-9: The total water resource, comprised of the Reserve and allocable resource (Water Resources Management Authority, 2010)

6.3.3 Water resources protection in the LVN Basin

In accordance with the Water Act 2016, at the basin-level, BWRCs must 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 RQOs. 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 LVN Basin has 94 existing WRUAs out of a potential 106 WRUAs needed to cover the whole basin. The gap of 12 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 LVN basin as well as water towers are summarised in Table 6-7. The table also lists water towers in these respective parts of the basin.

Table 6-7: Counties, WRA offices and Water Towers in the LVN Basin

Basin	Counties	WRA Sub-Region	WRA SRO	CMU	Water Towers (KWTA)
Upper LVN	West Pokot, Trans Nzoia, Elgeyo Marakwet, Uasin Gishu, Nandi, Kakamega, Bungoma	Kipkaren - Upper Yala Elgon – Cherangani	Kitale Eldoret	Kipkaren Upper Yala Upper Nzoia Middle Nzoia Sio-Malaba-Malakisi, Mount Elgon	Mount Elgon, Cherangany Hills
Lower LVN	Bungoma, Kakamega, Vihiga, Siaya, Busia	Lower Nzoia - Yala	Siaya	Lower Nzoia Lower Yala	Mount Elgon

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).

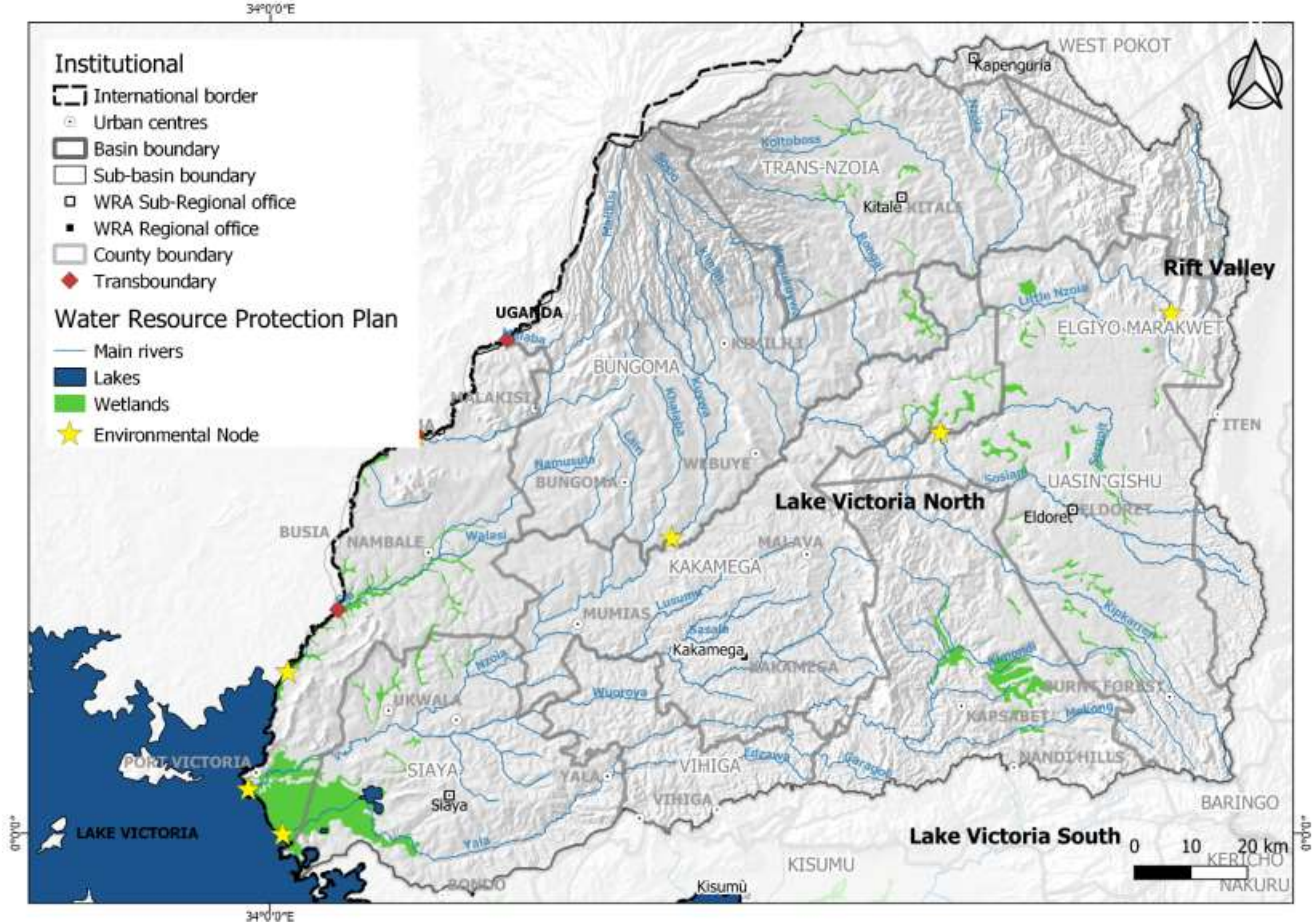


Figure 6-10: Water resources protection considerations in LVN Basin

In order to comprehensively and systematically address the hydrometeorological monitoring issues and challenges in the LVN 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.

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 to set a baseline for Resource Directed Measures. This baseline will inform classification and resource quality objectives for the significant water resources in the Basin.		
2.1.2	Determine Class of water resources	
Determining the Class of a water resource is the first step in the Water Resource Management cycle. A vision for the desired future state of water resources results in Ecological Categories for water resources based on the level of protection or increasing levels of risk. Ultimately the determined Class of a resource will determine the Reserve and associated resource quality objectives that are set to achieve it.		
2.2	**Theme:**	**Ecological Reserve**
2.2.1	Reserve determination	
In order to protect the water resources of the LVN Basin the ecological Reserve needs to be determined. The total water resource (surface and groundwater) is made up of what is available for allocation or use and the Reserve. The Reserve (in terms of quantity and quality) is made up of what is needed to satisfy the basic human needs of people who are or may be supplied from the water resource (i.e. Basic Human Needs) and what is needed to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the water resource (i.e. ecological Reserve). The water requirements of the ecosystem must therefore be met before any allocation may be made. This forms part of the Water Resource Management cycle which is an adaptive management approach focused on goal setting. Once the 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 environmental reserve has been set then the flows required to maintain the reserve need to be managed. Implementing the operating rules to ensure that the releases from infrastructure required by users and the ecology are met in time and at Eflow site. This may consist of the operation of dams, abstractions and other infrastructure as well as management through licensing and implementation of restrictions. Compliance hydrological monitoring is required, based largely on the continuous monitoring at a network of flow and water level gauges. Compliance monitoring is also required, based on monitoring low flows and water levels at gauging weirs and boreholes.		
2.3	**Theme:**	**Determine Resource Quality Objectives**
2.3.1	Set Resource Quality Objectives	
Determine the resource quality objectives for prioritised water resources in the LVN Basin.		
2.4	**Theme:**	**Conservation and protection of ecological infrastructure**
2.4.1	Integrate environmental considerations into basin development and planning	
Water is critical to social and economic development but is also a critical component in supporting key ecological systems which underpin human wellbeing as well as providing essential ecosystem goods and services. A strategic social and environmental assessment is therefore an important component of the Classification of LVN 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	Key Strategic Area:	Water Resources Protection
2.4.4	Ecosystem services protection	
Water is critical to social and economic development but is also a critical component in supporting key ecological systems which underpin human wellbeing as well as providing essential ecosystem goods and services. In particular, certain environmentally sensitive areas are reliant on the protection of water resources. Although environmentally sensitive areas are defined by NEMA, this information should be provided to WRA during the Classification of water resources in order for WRA to classify and protect according to the Water Act 2016.		

6.4 Groundwater Management

6.4.1 Introduction

Many LVN Towns rely on groundwater to a certain degree, as described in the Office of the Auditor-General's report on the LVNWWDA (Office of the Auditor-General, 2016). While volumetric data is sparse, reliance on groundwater is clearly of significance. Given the above, groundwater resources are clearly very important in the LVN Basin, and particularly so for rural water supplies. The very nature of these sources (particularly shallow wells and springs) mean that other than as part of county or NGO development or rehabilitation programmes, they are seldom counted; abstraction from them is even more rarely quantified. Few of them are likely to have Water Permits (the PDB captures the geology of the groundwater source, but does not differentiate between boreholes, shallow wells or springs); furthermore, groundwater sources other than boreholes exploited by motorised pumps are also rarely captured by the PDB.

Spring flow and baseflow contribute significantly to maintaining streamflow, particularly during dry seasons. Protecting springs is a simple, sensible and relatively cheap measure with potentially significant health benefits (Kremer et al., 2011).

A groundwater management plan (GMP) is therefore necessary for the integrated and rational management and development of groundwater resources. A GMP should capture and integrate basic groundwater understanding, describe sustainable management measures and present an action plan in a single document. The GMP must present both clear objectives and desired outcomes. The GMP should describe the financial requirements needed to implement it, the time frame for its implementation and the monitoring network necessary to monitor the resource across the plan's lifetime. A GMP is not a static instrument; as resources monitoring and data analysis takes place across the plan period, improvements and even whole new aspects may need to be incorporated, as development occurs across the resource. Finally, the plan must include a regular, planned stakeholder consultation mechanism which provides feedback and an avenue for information dissemination by the WRA and stakeholders.

Ultimately, a GMP must:

- Conserve the overall groundwater resource base and protect its quality; and
- Recognise and resolve local conflicts over resource allocation (abstraction or pollution) (Foster et al., 2015).

Groundwater in Kenya is not currently managed in a coherent fashion (Mumma et al., 2011). A final draft National Policy on Groundwater Resources Development and Management was published in 2013 (MoWI, 2013), but despite the best of intentions, groundwater remains poorly understood and poorly managed. The policy document highlights several specific issues:

- The availability and vulnerability of groundwater resources in Kenya are poorly understood;
- The institutional arrangements for groundwater management in Kenya, including groundwater management capacity and financing are weak;
- There is very limited integrated water resources management in Kenya, with groundwater and surface water typically being treated as separate water resources; and
- There is very limited groundwater quality management in Kenya.

A groundwater management strategy is influenced by hydrogeological, socio-economic and political factors, therefore both policy and strategy together inform a GMP. The GMP needs to be differentiated from an Aquifer Management Plan as the GMP considers groundwater management from the Basin perspective, while an Aquifer Management Plan is applied to a single aquifer unit.

6.4.2 Groundwater use

Because of the high and generally reliable rainfall in LVN Basin, much of the water used to meet formal water supply demand comes from surface water sources. However, across the Basin groundwater has long been used for urban and rural water supplies, particularly to meet private water demands (DHV Consultants, 1988; Ministry of Foreign Affairs of Finland, 2009). While no towns or other major centres rely heavily on groundwater, groundwater use is widespread across the Basin. According to the Kenya National Water Master Plan (NWMP) 2030, there are 1 776 boreholes in the Basin; however, only 1 383 separate groundwater permit applicants are captured in the PDB.

In Busia County, groundwater makes up 68% of the drinking water (46% from boreholes and 22% from springs) (County Government of Busia, 2018). In Trans Nzoia, the CIDP states that 52% of all the households use springs, wells or boreholes. In every other category, groundwater constitutes a small (sometimes vanishingly small) proportion of total water use. The preponderance of total surface water use over groundwater use is striking; groundwater use constitutes just over 2% of total water use. Navakholo (Kakamega County) relies exclusively on two high-capacity boreholes for water supply, yielding 58 m3/hr (C-9232) and 29 m3/hr (C-9243); these are unusually high yields for the LVN Basin (Lake Victoria North Water Services Board, 2011).

Limited conjunctive use is in place at present, other than in the following public water supply systems: Butere, Nambale, Shitole, Mumias and Bungoma.

Kakamega uses four boreholes to supplement surface water resources; Busia uses eight boreholes, Butere five (yielding three to eight m^3/hr, for a total of 420 m^3/d in 2011: Lake Victoria North Water Services Board, 2011, Nambale (Busia County) five, Shitole (Bungoma County) uses three and Mumias two. While volumetric data are sparse, reliance on groundwater is clearly of significance. In Bungoma Town surface water from the Kuywa River (about 8 500 m^3/d) is supplemented by six boreholes in the Town, between them supplying about 500 m^3/d (County Government of Bungoma, 2018; Ministry of Lands and Physical Planning, 2017).

In 2016/17, Busia Town was supplied with an average of 2 770 m^3/d (Water Services Regulatory Board, 2018). Busia water supply relies on the Sio river (design capacity 2 900 m^3/d) and eight boreholes for water supply; the latter can supply 1 080 m^3/d, with yields ranging from three to 14 m^3/hr (WSTF, ND).

In the Vihiga County In addition to surface water, the Sosiani and Vihiga schemes are served by protected springs, providing 400 and 150 m3/d respectively; the Sosiani Scheme cannot be expanded further, though there is some scope for expanding the Vihiga Scheme (Kanda et al., 2018).

In the commercial irrigated agricultural zone in the humid uplands of the LVN Basin, private sector farmers may practice limited conjunctive use (particularly horticultural enterprises in the Eldoret area). These users combine surface water abstraction, limited groundwater use and extensive rainwater harvesting to maintain water supplies. This is likely to intensify as more and more pressure is placed on limited land and water resources.

6.4.3 Groundwater resource potential

The annual groundwater recharge for the LVN Basin was estimated at 1,508 MCM/a, with a sustainable annual groundwater yield of 216 MCM/a. This is significantly higher than the NWMP 2030 sustainable groundwater yield estimate of 116 MCM/a for the LVN Basin. However, whereas the NWMP 2030 assumed sustainable yield as a percentage of recharge (10%), the groundwater assessment which was conducted as part of this Consultancy estimated sustainable yield based on regional and secondary permeability and topography. **Annexure B** lists the groundwater potential per sub-basin.

Projected sub-basin precipitation and temperature changes under climate change scenario RCP 4.5 (refer to **Annexure A**) were superimposed on the groundwater model of the LVN Basin to assess the potential impacts on recharge and groundwater potential. It was found that the recharge in the basin will increase marginally by 0.3% to 1 530 MCM/a, while the potential groundwater yield is expected to marginally increase by 0.5% to 217 MCM/a under RCP 4.5.

6.4.4 Proposed aquifer classification

The current classification system of aquifers in the LVN 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 Figure 6-11 and Table 6-9.

It is acknowledged that this approach does not specifically capture those aquifer units or parts of aquifer units that are of key importance as water supply sources. However, these should ultimately be captured by Aquifer Management Plans and numerical models developed for them. They would be designated Priority Aquifers.

Note: Proposed classification, aquifer use management and aquifer health management are included in “ISC Report D2-2: Groundwater Monitoring and Management Guideline”.

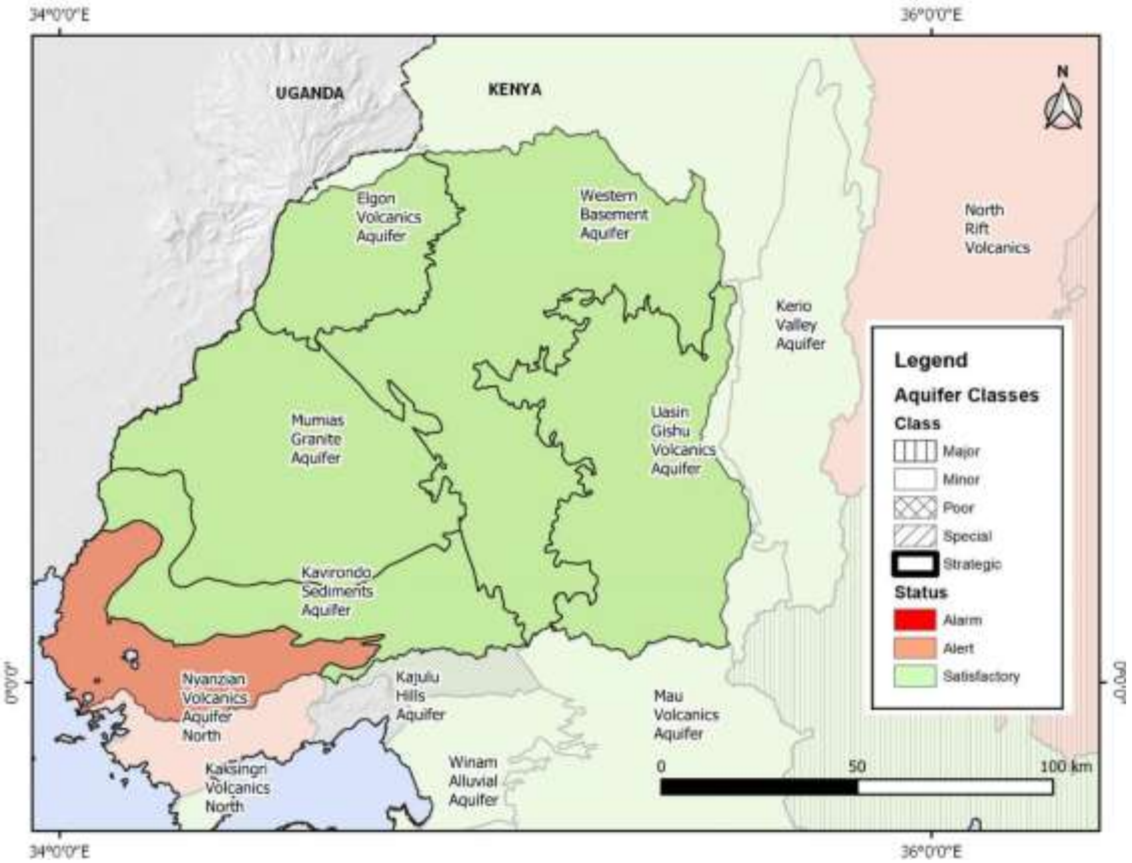


Figure 6-11: Proposed aquifer classification of the LVN Basin

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

Name	Geology/lithology	Area (km^2)	Depth range (m)	Yield potential (m^3/day)	Dominant flow type(s)	Typical water quality	Status
MINOR AQUIFERS							
Mount Elgon Volcanics	This aquifer consists almost entirely of agglomerate and breccia of which the main constituent is a mela-nephelinite lava. They have a phonolitic appearance due to the dark colour and the nepheline laths. Minor fine-grained tuffaceous bands occur. The agglomerate is largely uniform in appearance, containing boulders of various size. The rocks are horizontally bedded, perhaps reflecting the depositional nature of the volcanics, rather than lava flows	1,744	<100	<86	Fracture and intergranular	EC<1500 µS/cm	Satisfactory
Western Basement	The Basement System rocks here do not show the diversity of high-grade regional metamorphic types, which characterize other areas of Basement System rocks in Kenya. They consist of schists, gneisses and migmatites derived from an original sedimentary succession, which has been transformed by regional metamorphism and recrystallization. Originally pure quartzose sandstones occur as granular quartzites, with small amounts of muscovite, and originally less pure sandstones are now represented by quartz-mica schists. Granitic sheet and vein intrusions and pegmatite veins are common. Some degree of granitization has affected all the Basement System rocks of the area, with the exception of the quartzites and related rocks.	5,190	<60	<86	Intergranular and fracture	Ec<1,500 µS/cm	Satisfactory
Mumias Granite	The granite is an intrusive body into the rocks of the Kavirondian System and appears to be one large batholith. There are two types – a finer-grained leucocratic type and the normal coarse-grained type. It lacks the strong vertical jointing of the Maragoli Granite	3,863	<30	<86	Fracture and intergranular	Ec<1500 µs/cm	Satisfactory
Kavirondo sediments	The sediments consist of an Upper Division rich in feldspathic grits (arkose) with pebble bands containing slate at its base. The Middle Division has slates, mudstones, and phyllites, with intercalated finer grits and siltstones. Its Lower Division is made up of conglomerates, breccias, siltstones, and feldspathic grits (arkose) containing pebble bands. The grits are highly angular being residuals from granite and other rocks rich in feldspar. The rocks suggest the rapid deposition in a large continental basin. The Lower Division has interstitial pyrite.	2,169	<30	<240	Intergranular	Ec<1500 µs/cm	Satisfactory
Uasin Gishu Volcanics	The volcanic suite has a basal tuffaceous member comprising tuffs, tuffaceous grit and agglomeratic tuffs, overlaid by Lower and Upper Uasin Gishu Phonolites. These phonolites are somewhat similar to the Kapiti type. They are dense, black and heavy, with platy white felspar phenocrysts and yellowish rounded, resinous, nepheline phenocrysts. The lower of the two phonolites is distinguished by its sparsely porphyritic lava while upper contain abundant large nepheline and glassy feldspar phenocrysts.	4,249	50-100	<240	Intergranular and fracture	Varied; EC<1000 to EC>1500 µS/cm	Satisfactory

6.4.5 Key groundwater issues and challenges in the LVN 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 risk of pollution to deep groundwaters across Kenya is discussed in general terms in the National Groundwater Quality Report (Water Resources Authority, 2019c).

The vulnerability of LVN Basin aquifers is largely unknown, as few studies have been carried out at the appropriate level of detail; shallow groundwater pollution in Eldoret is discussed below.

The GMP must therefore address vulnerability and include measures to:

- 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

Surface waters in the LVN Basin are quite frequently polluted, due to both industrial and municipal wastewater discharge; this is described elsewhere in this report. Natural groundwater contaminants include high TDS (total dissolved solids), fluoride, chloride, iron and manganese. These are distributed in groundwaters across the LVN Basin, but basement groundwaters often contain groundwater with elevated TDS.

Both the KEFINCO (Ministry of Foreign Affairs of Finland, 2009) and RWSS programmes (DHV Consultants, 1988) relied heavily on boreholes fitted with handpumps; it soon became clear that iron was a sufficiently serious contaminant that it led to the abandonment of a "*relatively high percentage (10-12%) of boreholes and wells not used for drinking because of the bitter taste of the water (probably caused by a high manganese and/or iron concentration)*" (*verbatim*, DHV Consultants, 1988). The problem was serious enough that KEFINCO constructed iron removal plants (IRPs) and trained communities to use them. KEFINCO also funded a University of Nairobi research project into iron removal from groundwater (Muruiki, 1994).

An aspect of iron in groundwater relates to pH and the use of galvanised iron (GI) rising main and pump parts. Groundwaters of pH <6.5 corrode GI pipe and fittings (Langenegger, 1994). This is particularly a problem in parts of LVN. KEFINCO responded by constructing boreholes with uPVC rather than mild steel (Ruotsalainen & Turunen, 1994). Similar problems were noted in the RUWASA Project in Uganda, where Danida and the Uganda Government switched from using GI to stainless steel downhole materials in pumps in response to corrosion and problem iron (Baumann, 1998).

Generally, the extent and significance of groundwater pollution in the LVN Basin is relatively unknown. However, given high LVN Basin population densities and reported experiences in other Basins, shallow groundwater pollution is likely to be more widespread than currently reported. Research conducted as part of this consultancy indicate that the following localities have associated groundwater quality issues.

- A number of studies show that shallow groundwaters beneath informal settlements in Eldoret contain measurable and significant concentrations of *E. coli* bacteria (the Kenya Standard is nil colony counts in 250 mL of sample: Kenya Bureau of Standards, 2007). A study in Langas (Kiptum & Nbambuki, 2012) found nitrate concentrations exceeding the Standard in 28 out of 60 dry and wet season well samples (the Kenya Standard for nitrate is 50 mg/L). The highest nitrate concentration was 157.5 mg/L (minimum 2.2, mean 50.9 mg/L). Phosphates were present at significant concentrations, but not reaching the Standard (2 mg/L). Every sample reported measurable concentrations of faecal coliforms (lowest reported 25 counts, volume unit not given; highest – 'too numerous to count'). This paper presented the results of a PMWIN groundwater particle-tracking model which indicates that the minimum safe separation distance between a latrine and a shallow well should be 48 m; in one plot, latrine and well were only 5.5 m apart. The conclusion of this Study was that groundwater pollution is due to human waste leachate from pit latrines. If reported nitrate values are anything to judge by, it is likely that other anthropogenic contaminants are present – sodium and chloride, for example (AGROSS, 2001). Other studies have confirmed these patterns (Muruka et al., 2012; Muyoma et al., 2017).
- Adika et al. (2018) reported excessive trace metals in Kakmega groundwaters (it is unclear whether the sources were shallow wells or boreholes, as the terms are used interchangeably in this paper); reported mercury concentrations ranged from 0.0025 to 0.061 mg/L (the Kenya Standard is 0.001 mg/L); arsenic ranged from 0.012 to 0.019 mg/L (the Standard is 0.01 mg/L). Cadmium was present in two samples at 0.003 mg/L (which is equal to the Standard) and lead ranged from 0.001 to 0.006 mg/L (< Standard, which is 0.01 mg/L). Mercury concentrations are alarmingly high, arsenic concentrations rather less so. The paper does not discuss possible sources in any but a generalised fashion.
- Wambu et al. (2016) reported copper^{2+} and zinc^{2+} concentrations in a range of waters in the Siaya County lakeside zone. In five boreholes, copper^{2+} concentrations ranged from 0.72 to 2.63 mg/L and zinc^{2+} from 0.06 to 0.603 mg/L (Kenya Standards are 1 and 5 mg/L respectively). In four springs copper ranged from 0.42 to 2.44 mg/L and zinc from 0.12 to 0.59 mg/L. The zinc standard was not exceeded, but copper concentrations did exceed the Standard in one borehole and one spring sample. The paper does not discuss possible sources of soluble copper.
- A research thesis by a student at Kenyatta University (Wekesa, 2015), describes significant heavy metal contamination of shallow well waters in the Kuywa river basin (Bungoma County); excessive concentrations of lead, copper and cadmium were reported.
- K'oreje et al. (2016) found pharmaceutical compounds in wastewaters, surface waters and groundwaters in Kisumu (2016); and in wastewaters and surface waters in Nairobi (2012, 2016), albeit at low concentrations. Similar GW pollution in the LVN Basin is likely, particularly in aquifers beneath high density informal settlements. These are the only studies of their type carried out in Kenya that we have reviewed; 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 (see Lapworth et al. (2012) for examples and EPA Ireland (2015) for a broad review).

6.4.5.3 Other issues and challenges

Regulatory

Poor planning and water allocation when it comes to considering SW and groundwater allocation; the two remain divided, and effectively treated as different water resources. The recent Water Allocation Plan Guideline (Water Resources Authority, 2019a) should help to resolve this, as it treats both resources in a given area in its approach to WAPs.

Unclear NEMA and WRA mandates with regards to wastewater management and licensing (both bodies seek 'polluter payments' from water users/polluters). 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).

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 leading to poor technical quality (installing mild steel casing/screen in low pH groundwater environments, for example). Further potential conflict between national and county governments is likely, regarding the sharing of natural resources benefits (cf. *the Natural Resources (Benefit Sharing) Bill*, 2014 and *the Natural Resources (Benefit Sharing) Bill*, 2018). Both Bills specifically include water resources.

Inadequate monitoring

The LVN Basin has 19 groundwater monitoring points (0 Strategic, 6 Major, 7 Minor and 6 Special), all of which are operational (Water Resources Authority, 2018d); in the 2014 reporting period (Water Resources Management Authority, 2016) there were 13 operational monitoring boreholes. Broadly however, the monitoring network needs to be expanded as a matter of some urgency. Data quality is patchy, with most groundwater level data being collected from boreholes that are used as production boreholes and too often show dynamic as well as static water levels. This restricts the use of water level data to determine long-term trends.

Field water quality data collection is also improving, with a broader range of measurements planned in order that resource-quality objectives (RQOs) can be determined. Parameters planned to be included are temperature, electrical conductivity, total suspended solids, dissolved oxygen and pH (Water Resources Management Authority, 2015a).

Abstraction monitoring is done on an *ad hoc* basis at best. Groundwater users are required to submit abstraction data monthly or quarterly as evidence to support their water charge payments, but these are rarely checked in the field by the WRA. The capacity to improve abstraction monitoring will be boosted by the adoption of formal guidelines for groundwater abstraction surveys, using electromagnetic flow meters (Water Resources Authority, 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 several separate systems:

- The 1992 NWMP (Water Resources Management Authority, 1992) initiated the National Water Resources Database (NAWARD), which remains a source of data - although it has not been updated since 2005. In the period 2005-2010, the data collection role was taken up by the WRA, and during the handover period, there was a measure of confusion as to which agency drilling contractors should submit drilling data to (Ministry of Water and Irrigation, 2012).
- The WRA currently collects and stores borehole data in a combination of paper and digital formats, with the long-term intention of digitising all records. The first attempt at digitising borehole data was made in 2010 as part of the Nairobi Borehole Census. All borehole records that could be found across a wide range of sources were digitised and established in a Microsoft Access database system, protected by password access.

Completion of the digitisation exercise is essential. This should be digitally linked to/interfaced with the PDB.

Over-abstraction in the LVN Basin

The presence of over-abstraction across the LVN Basin is not really known, although there are some concerns (e.g. the Webuye aquifer).

Insufficient information on GW recharge and GW potential

There is a need to select Priority Aquifers for modelling (see Table 7-12 above), then prioritise these and develop models. This inevitably requires the establishment of a water resources monitoring network in advance of generating a model, which would involve climate, surface water flows, groundwater levels, groundwater abstraction and water quality (both surface and groundwater). 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 is one transboundary aquifer in the LVN Basin:

- Mount Elgon aquifer. Area in Kenya covers 4 900 km^2, shared with Uganda. Comprises a combination of trachytes and metamorphic Basement (ILEC et al., 2015).

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 6-10: 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

That climate change will affect Kenya is largely unquestioned. Numerous global climate models forecast increasing temperatures, deeper dry seasons and more intense rainfall. The effects of both floods and drought have been significant, adversely affecting gross domestic product (GDP). Adverse effects on the water sector are well documented (Mogaka et al., 2005; Mwangi & Mutua, 2015).

Kenya has developed a climate change adaptation plan (Government of Kenya, 2016), which "recognizes that climate change is a cross-cutting sustainable development issue with economic, social and environmental impacts". The Plan is underpinned by the Climate Change Act.

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 the LVN Basin aquifers are uncertain, though as adduced above, an increase in mean annual recharge is likely.

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 LVN Basin, Table 6-11 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 6-11: 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 LVN Basin. In parallel, more detailed estimates of sustainable groundwater yield in priority areas / aquifers should be undertaken.

3.1.2 Groundwater assessment – assess 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 LVN 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 (old WAB 28; current WRMA 009A or B).

3.1.4 Groundwater allocation

National resource quality objectives should be developed. In relation to a groundwater resource, the resource quality objectives means the quality of all aspects of the resource and could include any or all the following (Colvin et al., 2004):

- Water levels, GW gradients; storage volumes; a proportion of the sustainable yield of an aquifer and the quality parameters required to sustain the groundwater component of the Reserve for basic human needs and baseflow to springs, wetlands, rivers, lakes, and estuaries.
- Groundwater gradients and levels required to maintain the aquifer's broader functions.
- The presence or absence of dissolved and suspended substances (naturally occurring hydrogeochemicals and contaminants).
- 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.
- 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.
- 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.
- Any other groundwater characteristic.

It is clear that resource quality objectives can include any requirements or conditions that may need to be met to ensure that that the water resource is maintained in a desired and sustainable state or condition.

The Guidelines for the Development of Water Allocation Plans in Kenya (Water Resources Authority, 2019a) discusses the determination of water balances and accommodates both surface water and groundwater. Current groundwater potential by sub-basin in the LVN Basin should be determined from the assessment of available groundwater and the current use (from the abstraction survey). Groundwater allocation plans should be developed. Groundwater allocation varies according to the importance of, and knowledge base for, a given aquifer:

- Poor and Minor aquifers: 25% of test discharge in an individual borehole is the safe allocable volume. Where an aquifer is reasonably well described (i.e. representative transmissivity values are available, as is the width, length and hydraulic gradient across the aquifer), then Darcy's Law (Darcy, 1856) may be used to determine mean through-flow (Q = -k.i.A). In this case, total allocable water should be 25% of average through-flow.
- For Major aquifers, the approach proposed in the NWMP 2030 is proposed. The NWMP 2030 adopts a cautious approach to determining sustainable groundwater abstraction; this is defined as 10% of recharge, but specifically excludes the riparian zone, which it determines as total river length x 1km. Recharge was defined as annual renewable resource minus annual surface water runoff, with 'annual renewable resource' defined as precipitation minus evapotranspiration.
- For Strategic and Special aquifers that are not (or not yet) designated Priority Aquifers and subjected to modelling, the NWMP 2030 approach should be used.

3	Key Strategic Area:	Groundwater management

- For Priority Aquifers that have been modelled, allocable GW is 10% of mean annual recharge. Mean annual recharge should, wherever possible, consider both wet and dry years in order to recognise natural recharge variability.
- The allocation of GW from aquifers that experience episodic recharge or are fossil aquifers remains unresolved (e.g. the Merti aquifer; Blandenier, 2015). How they should be treated in Kenya requires further debate and ultimately, a policy decision.

All of the above require the completion of the aquifer classification exercise.

3.2	**Theme:**	**Groundwater development**
3.2.1	Aquifer recharge	

Estimates of recharge per sub-basin in the LVN 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, apart from the Miocene Uasin Gishu phonolites east of Eldoret described the recharge zone (The Nature Conservancy, 2019). This makes it difficult to protect such areas, and recharge areas for Priority Aquifers should therefore be defined.
- **Protection of natural recharge:** Land use planning and groundwater management are regarded as separate functions of different arms of Government. This is a fundamental disconnect, meaning that land use plans disregard how different land uses may affect both recharge and abstraction. The National Land Use Policy (2017) provides an entry point to begin discussions between the water sector and other players. This requires a high-level policy discussion to align land use planning and WRM actions that favour (or do not conflict with), sensible groundwater resources management. Numerous legal instruments exist across numerous state and county actors.
- **Managed aquifer recharge:** First mentioned in the 1999 Policy document (Government of Kenya, 1999) and the Water Design Manual (Ministry of Water and Irrigation, 2005), Managed Aquifer Recharge is covered in the 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, 2015; 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 LVN Basin but has yet to be described.
- **Managed Aquifer Recharge potential in the LVN Basin:** Aquifers in the LVN Basin have not been assessed for MAR potential. There is almost certainly scope for MAR across the LVN Basin, given the humid nature of the Basin.

3.2.2	Local groundwater development: Reconciliation of water demands and groundwater availability and implementation of groundwater schemes

Local groundwater development is largely ad hoc at present, and heavily under-written at the WWDA and County level for rural water supply (boreholes, shallow wells and protected springs) to meet the water demands of small rural centres, schools and other institutions. 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.

3.2.3	Large scale groundwater development: Reconciliation of water demands and groundwater availability and implementation of groundwater schemes

Assess allocable groundwater potential close to major demand centers and determine if groundwater resources could meet demands.

3.2.4	Conjunctive use: Reconciliation of water demands and groundwater availability

The existing extent of conjunctive use in the LVN Basin should be determined using the PDB and existing reports and studies. Areas of unexploited groundwater resources should also 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	

3	Key Strategic Area:	Groundwater management

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 0.01 mg/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.)

1. **An Asset Inventory database system should be developed:**

- Each asset should be tagged with a unique number
- Each item and its tag number should be entered into the inventory database, together with all relevant details (year purchased/acquired, office allocated to, office lent to, last service or maintenance period, next recommended service/maintenance etc.). The database system must allow that major components (such as a multi-parameter water quality probe), are linked to related spare parts (such as individual parameter probes or calibration reagents).
- Where an item is available for rent to the public (such as geophysics equipment), the relevant details should be included in the inventory database; this will include, but not necessarily limited to, the following:
    - Rental cost (per day or per week, as relevant)
    - Rental requirements (items rented must be insured by the renter and proof of insurance provided to the WRA)
    - Any other condition of rental
    - Name, address and relevant details of the renter, and the anticipated duration of the rental period

3.3.2	Develop asset management plan

Asset management is necessary to ensure that assets are used for the correct purpose and contribute to meeting the objectives of the WRA at National, basin and sub-basin levels. The asset management plan should ensure that the location and status of all assets are known to relevant staff. An asset management plan should be developed which must list all equipment and facilities that require refurbishing, along with a corresponding programme and budget. This should involve appropriate consultation with basin and sub-basin offices:

- For each item, determine what refurbishment is required
- Draw up a priority list of the items to be refurbished, together with a deadline for its refurbishment
- Determine the cost and duration of the refurbishment process
- Draw up a Refurbishment Plan, containing the deadlines, costs and duration of refurbishment, and feed this into the annual procurement planning process
- When refurbishment commences, ensure that the process is monitored, and funds spent on it are tracked
- After refurbishment, update the Asset Inventory to reflect change of status
- Amend Asset Management Plan as necessary

The asset management plan will ensure that all equipment is 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

3	Key Strategic Area:	Groundwater management
- 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, follow Guidelines for Vulnerability Assessments and assess LVN Basin Groundwater Vulnerability Groundwater conservation areas (GCAs): As above for GCAs; assess which LVN 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 LVN 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 LVN Basin's polluted aquifers:** Use the Guidelines for Groundwater Quality Surveys in Kenya (WRA, 2019) to define the extent of polluted aquifers, and determine what pollutants are present. Follow guidance presented in the NWQMS (MoWI, 2012). **For each polluted aquifer, determine the optimum and most cost-effective way to rehabilitate it. T**he approach to be adopted will depend on the following: - Whether the aquifer is confined or unconfined; - The nature of the pollutant; e.g. dense non-aqueous phase liquids (DNAPLs) require a different treatment approach – pump, treat, return - compared with an aquifer polluted with human wastewater – eliminate the pollution source(s) followed by natural attenuation and remediation; - Whether the source of the pollution is diffuse or from a point source; - The affected aquifer area. - Prioritise aquifers for rehabilitation and implement rehabilitation programmes.		

6.5 Water Quality Management

6.5.1 Introduction

Water quality is the physical, chemical, biological and aesthetic properties of water that determine its fitness for its intended use, and that are necessary for protecting the health of aquatic ecosystems.

Water quality management is the maintenance of the fitness for use of surface and groundwater resources, on a sustainable basis, by achieving a balance between socio-economic development and water resources protection. Fitness for use is an evaluation of how suitable water is for its intended purpose (e.g. domestic, agricultural or industrial water supply) or for protecting the health of aquatic ecosystems. The fitness for use evaluation is based on scientific evidence in the form of water quality guidelines or standards for different water uses (e.g. drinking water standards). The business of water quality management is the ongoing process of planning, development, implementation and administration of Kenyan water quality management policies, the authorisation of water uses that impact on water quality, and monitoring and auditing all these activities.

This section provides an introduction of the key water pollutants responsible for the deterioration of water quality in the basin, the point and non-point sources associated with the pollutants, and overview of the water quality status and threats in the basin, and a strategic framework for water quality management in the basin.

6.5.2 Water Quality Standards and Guidelines

Kenya has standards for drinking water quality (Table 6-12) and for effluent discharge limits for discharges into sewers and water bodies (Table 6-13) 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 6-12: 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 6-13: Kenya Effluent Discharge Standards into water bodies and sewers

Parameters	Unit	WHO 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	-	-

Parameters	Unit	WHO Standards	
		Discharge into environment	Discharge into public sewer
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

Water quality in the LVN Basin, especially downstream of urban centres, is highly impacted by pollution from industries, informal settlements, indiscriminate disposal of wastes, etc.

In order to develop and successfully implement a Water Quality Management Plan for the LVN 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 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 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 (NO2, NO3, NH4, PO4). 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 of 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 napthalenes. 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.

Cyanide Poisoning in Cassava Local cases of cassava poisoning have been reported in Siaya in the Lake Victoria North Basin. Cassava is a hardy plant that thrives during drought and is used as a staple source of carbohydrates, especially during famine. Cassava is the third-most important food source in tropical countries, but it has one major problem: The roots and leaves of poorly processed cassava plants contain Linamarin, a cyanogen - a substance that, can trigger the production of cyanide. Cyanide occurs naturally in many plants. Many edible plants contain cyanogenic glycosides. Other plants that contain high levels of cyanogens are

Sorghum (whole immature plant), bamboo shoots and Lima seeds (Nartey (1980); Honig et al. (1983). Cassava roots however contain less linamarin level s than that found in leaves. Linamarin is converted to cyanide when cassava is eaten raw or when poorly cooked or processed. Long-term exposure of low doses of cyanide over time can lead to health problems, hence the danger posed by cyanide poisoning for those who use cassava as a staple carbohydrate source. Levels of cyanide in water sources are generally low but depend on releases from upstream sources and discharges. Cyanide is highly acute and toxic and should not be present in drinking water. The East African Standard for Discharges of Effluent into water bodies gives the maximum permissible level for cyanide as 0.05 mg/l. To avoid cassava poisoning, cassava roots, peels and leaves should not be eaten raw as they contain two cyanogenic glucosides, linamarin and lotaustralin. These are decomposed by linamarase, a naturally occurring enzyme in cassava, liberating hydrogen cyanide (HCN), which is toxic. An effective way of removing cyanogens from cassava leaves is by pounding or crushing and then boiling them in water. Most of the cyanogenic glucosides are removed and cyanohydrins and free cyanide are completely removed in this way. (Nambisan 1994).

Other proven methods of cyanide removal but with varying degrees of success include:

Drying in the sun; Drying in an oven; Steaming, baking and frying; Fermentation of crushed cassava roots; Steam distillation of cassava pulp.

Sources of pollution are generally divided into two categories, namely point sources and nonpoint sources.

- **Point sources** of pollution is one whose initial impact on a water resource is at a well-defined local point (such as a pipe or canal). The US EPA describes point sources of pollution as any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. Typical point sources of pollution are listed below

Industrial point sources	Effluent discharges from industries can have a significant impact on receiving water bodies. These can include high concentrations of BOD/COD, nutrients, heavy metals, acids, dyes, suspended solids, oils and grease, bacterial pathogens, chemicals, phenols, etc.
Wastewater treatment works (WWTWs)	Wastewater treatment works (WWTWs) that discharge treated effluent into surface water streams are important point sources of pollution if they do not meet effluent standards. Domestic WWTWs are regarded as important sources of nutrients, organic matter (BOD/COD), suspended solids, human pathogens, and depending on the demographics, a source of partially metabolised pharmaceuticals and endocrine disrupting chemicals.
Mining and quarrying operations	Mines can be significant source of pollution and pollutants such as heavy metals, suspended solids, salinity, sulphates, and acidification are associated with mining activities. High suspended sediment loads, and increased turbidity are associated with sand mining and washing operations.
Agricultural processing plants	Agricultural processing plants such as coffee washing stations contribute significantly to the organic loads in receiving rivers and streams. The same applied to dairies and milking operations. Tea factories also produce wastewater that are rich in organic material. Fish farms can also have a major impact on water quality as the outflow from ponds can be high in BOD/COD, ammonium and nitrates from fish wastes and food residues.
Solid waste dumps and landfills	Solid waste dumps and landfills can also be regarded as point sources of pollution. Pollutants in seepage/leachate from landfills include organic wastes from decomposing organic wastes, heavy metals from corroding metallic objects and old batteries, waterborne pathogens from discarded diapers and sewage sludge, acidic waters, hydro-carbons and oils from used motor and cooking oils, etc.

– **Mitigation measures:** the following are some remedial measures to forestall pollution from point sources:

  - Treatment of industrial waste discharges at source, before discharge into receiving water bodies

- Ensuring that industrial waste discharges meet the stipulated Effluent Discharge Standards before being discharged
- Regularly reviewing the performance and waste removal efficiency of WWT plants as well as carrying out effective operation and maintenance procedures
- Preparing and implementing safe and sound mining and quarrying operation guidelines
- Ensuring that solid waste is sorted at source and safely transported to the dumpsites for final sorting out and safe disposal
- Ensuring that the dumping site is selected after an EIA has been carried out on the site, and that all urban centres have a dumping site for solid wastes
- Enhancing capacity to carry out timely water quality monitoring to identify polluters and take legal action against them.

- **Nonpoint sources** (also called diffuse sources) of pollution whose initial impact on a water resource occurs over a wide area or long river reach (such as un-channelled surface runoff from agricultural land or stormwater and dry-weather runoff from a dense settlement). The US EPA describes nonpoint source pollution resulting from land runoff, precipitation, atmospheric deposition, drainage, seepage or hydrologic modification. Nonpoint source (NPS) pollution, unlike pollution from industrial and sewage treatment plants, comes from many diffuse sources. NPS pollution is caused by rainfall moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, and ground waters.

Agricultural nonpoint sources

Agriculture is a major nonpoint source of pollution. The following generic land use categories can contribute to nonpoint source pollution, particularly sediments, nutrients, and agrochemicals:

Livestock grazing can contribute to sediment yield through removal of the natural vegetative cover (overgrazing), while nutrients and pathogens are associated with livestock faecal matter. These impacts are aggravated and significant bank destabilisation (habitat destruction) can occur where livestock are allowed direct access to wetlands and rivers.

Croplands, vegetable gardens and flower growing tunnels are often a major rural source of sediment, particularly if good land management practices are not adhered to. Wash-off of nutrients from fertilizers and of agrochemicals (pesticides and herbicides) can also have a significant impact, where these are applied. Croplands are particularly vulnerable during the preparation of plots for planting and harvesting when the soil is disturbed.

Irrigation of crops can be a further source of nutrient (inorganic fertilizer), pesticides, and pathogens if manure is used as fertilizer.

Confined animal facilities, such as livestock enclosures (zero grazing), piggeries, and chicken farms, can contribute significant nutrient, organic matter (BOD) and pathogen loads from faecal waste, especially during storm runoff directly to a stream or river. This is the main concentrated agricultural source and may include dairies and piggeries.

Urban nonpoint sources

High levels of non-point sources of contamination, particularly organic material (BOD/COD), hydrocarbons, pathogens, and sediments are associated with formal urban areas and industrial activities with the urban boundaries. Their general character and impacts in Kenya are like 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 causes 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 operations such gold and gemstone mining provides employment to some 146 000 people compared to the large scale mining that employs about 9 000 workers (PACT and Alliance for Responsible Mining (ARM), 2018). A significant impact of artisanal and small-scale 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.

6.5.3.2 Measures to undertake for accidental oil product spillages (pipeline leakages, trucks, petrol stations) and other pollutants to the Lake Victoria Basin waters

Under the LVEMP 1 – (1997-2003) a "Study on Toxic Chemicals and Oil Products Spill Contingency Plan for Lake Victoria" was undertaken. Before that there was no such a plan. The plan was to be adopted and implemented by the three EA countries that share Lake Victoria. The main purpose of such a plan was to ensure that countries prepared a timely response in case there was any oil spillage or any toxic pollutant spilled into the lake. The response could involve, local, national and regional actions including industry, and other agencies in order to minimize the impact and damage that would be caused by such a spillage. It appears that the provisions and recommendations of such a plan were never fully adopted or implemented and there are now plans to prepare a new plan under the coordination of the LVBC.

Although a draft Oil Spills Contingency Plan *(The National Contingency Plan for Marine Spills from Shipping and Offshore Installations, 2014)* has been prepared for the port of Mombasa by the Kenya Maritime Authority, it does not cover Lake Victoria waters.

In the event of an accidental oil spillage, the following is a summary of the measures to undertaken in sequence, if such an oil spillage and other pollutants occurs in the Lake Victoria basin waters:

- Notification/Reporting of spillage (where, when, size)
- Assessing/Establishing nature and type of spillage (chemical/oil; properties)
- Establishing level of response required (availability and location of equipment such as booms, pumps, boats and personnel)
- Setting up national response units/teams
- Activating national and regional response units
- Responses (local, national, regional, international)
- Sampling and analysis of samples (Environmental monitoring)
- Clean up of spillage
- Salvage/Termination of clean-up
- Protection of sensitive ecosystems
- Restoration of ecosystems
- Legal and economic aspects (Liability and compensation for pollution damages)

- Prosecution and reparation

It should be recalled that the sinking of the ship, MV Nyerere, off the Tanzania coast near Mwanza in 2018, was a wake-up call to the EA countries to put in place, locate and rescue plans and oil spill contingency plans to deal with such emergencies. However, it is noted that the LVBC also has one container of Oil Spill response equipment to handle small to medium oil and chemical spills that can be safely handled by local oil terminal personnel - equipment stationed at Kisumu Port which can be used in the event of oil pollution in the Lake. A major component in dealing with all the stages of reporting spillage and the responses is effective communication, which should be coordinated preferably from a central emergency response centre.

A toxic chemicals and oil spill contingency plan will need to be reviewed and revised preferably every two years.

6.5.4 Water Quality Status in the LVN Basin

Water resources in the LVN 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 typical point and non-point sources of pollution in the LVN Basin are as follows:

- Point Sources:
  - Domestic and industrial effluents from: Kitale, Eldoret, Kakamega, Busia, Bungoma, Webuye, Siaya
  - Oils and Grease: from garages in these towns
  - Human wastes: from markets and urban centre and fish landing villages
  - Sugar Mills: Nzoia, Mumias, Kibos, Butali,

- Non-Point sources:
  - Environmental degradation especially catchment and wetlands destruction.
  - Release of high nitrate and phosphate quantities into the environment due to poor application of agricultural chemicals on tea, coffee, maize and sugarcane farms.
  - Use of herbicides and acaricides on farms.
  - Sedimentation from murram, feeder and animal truck roads.
  - Soil erosion due to poor agricultural practices resulting in soil cover destruction or overgrazing.

Table 6-14 below identifies the actual sources of pollution within the LVN Basin:

Table 6-14: Major sources of pollution in LVN Basin

Basin	Type of Pollution	Sources of Pollution
Upper Yala	Municipal wastes and untreated sewage, including hospital and	Towns of Kakamega, Khayega and Mbale

Basin	Type of Pollution	Sources of Pollution
	laboratory wastes	
	Agro chemicals	Coffee, Tea and sugar cane farms along the Yala sub-catchments.
	Mining wastes	Gold mining along the mid-Yala river
	Industrial waste discharges including dyes and detergents	Towns of Kakamega, Khayega and Mbale, Kipkaren
	Soil erosion and sediment	Evident on riparian reserves, and hill slopes and unpaved roads in the smaller towns and rural areas
	Oil drilling wastes	None
	UPOPs, including air pollution	Towns of Kakamega, Khayega and Mbale
	Solid wastes	Towns of Kakamega, Khayega and Mbale and small urban centres
	Salinity	None
Upper & Middle Nzoia/Sio Malaba Malakisi	Municipal wastes and untreated sewage, including hospital and laboratory wastes	Towns of Eldoret, Kitale, Kapsabet.
	Agro chemicals	Tea, coffee and sugar cane farms along the Nzoia, Sio and Malaba Malakisi sub-catchments
	Mining wastes	Quarrying and Sand harvesting along the water courses of Malakisi, Sirisia, Kundos, Kipkaren and Mokong
	Industrial waste discharges, including dyes and detergents	Towns of Eldoret, Kitale, Kapenguria.
	Soil erosion and sediment	Evident on riparian reserves, and hill slopes and unpaved roads in the smaller towns and rural areas
	UPOPs, including air pollution	Open burning of pesticides and other organic compounds in solid wastes in the major towns of Eldoret, Kitale and Kapenguria
	Solid wastes	Towns of Eldoret, Kitale, Kapenguria. and other small urban centres
	Salinity	None
Lower Nzoia and Lower Yala	Municipal wastes and untreated sewage, including hospital and laboratory wastes	Towns of Siaya, Mumias
	Agro chemicals	Tea, coffee and sugar cane farms along the Nzoia and Yala rivers
	Mining wastes	Gold mining in Siaya, Kakamega and Nandi Counties and sand mining along the river Yala
	Industrial waste discharges, including dyes and detergents	From towns of Siaya and Mumias
	Soil erosion and sediment	Encroachment on riparian reserves, and hill slopes and unpaved roads in the smaller towns and rural areas
	Solid wastes	From towns of Siaya and Mumias and other urban centres
	UPOPs including air pollution	Open burning of pesticides and other organic compounds in solid wastes in the towns of Siaya and Mumias
	Salinity	Some Ground waters have slightly high salinity and TDS along the shores of L. Victoria.

6.5.4.1 Surface water

Surface Waters in the LVN Basin have been divided into Upper Yala, Upper &Middle Nzoia / Sio Malaba Malakisi and Lower Nzoiaand / Lower Yala.

Figure 6-12 shows the water quality characteristics of water bodies within the LVN Basin.

Upper Yala River System

Some of the rivers that drain and form the Upper Yala are the Kimondi, Kesses and Kipkaren. 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 sugarcane and horticulture. Industrial effluents from towns also contribute to the pollution of these rivers.

These rivers are 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 these rivers forming Upper Yala, which in the past few decades were suitable for domestic purposes, are now unsuitable in their raw state.

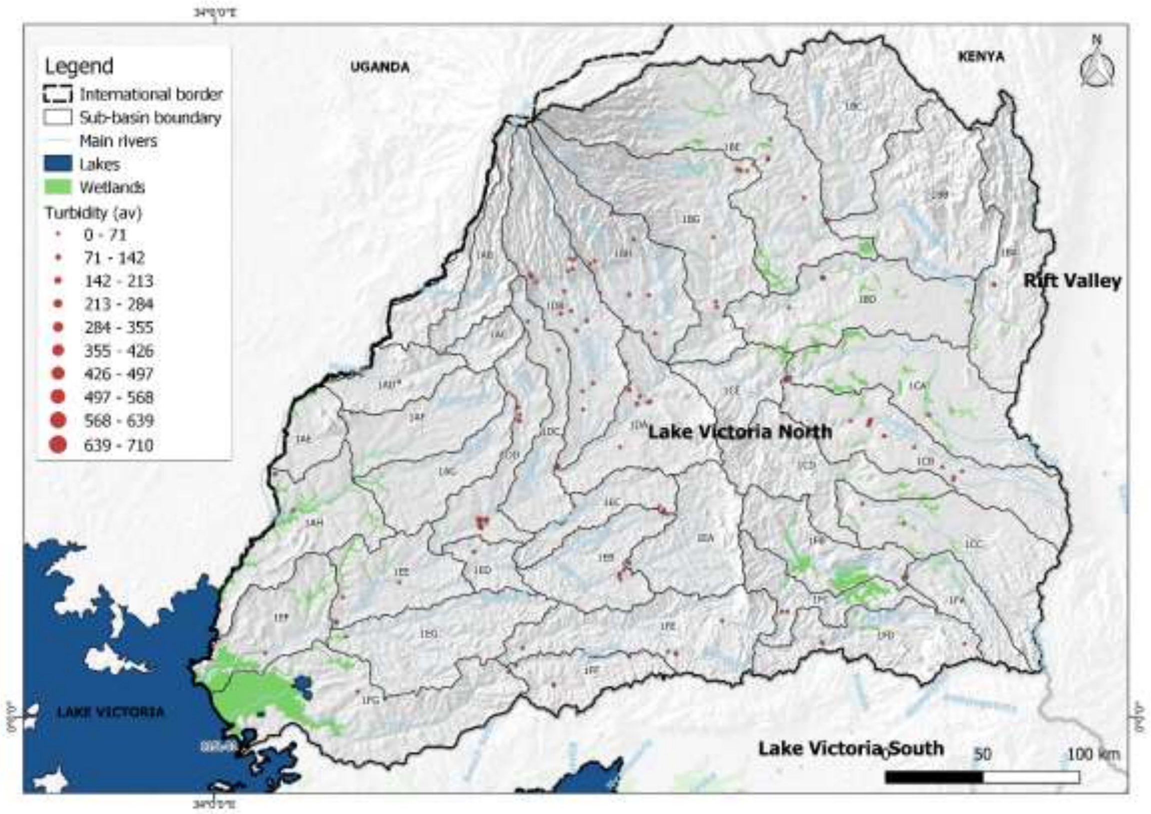
Table 6-15: Major Sources of Point Pollution into Yala River

Item No.	Name of Source	Type of waste	Receiving River System
1.	Moi University Sewage treatment works	Domestic sewage	Kesses
2.	Kapsabet Municipal sewage works	Domestic sewage	Mokong’
3.	KCC- Kapsabet	Milk processing	Kesses
4.	Bondo T. T. C. Sewage Works	Domestic sewage	Yala

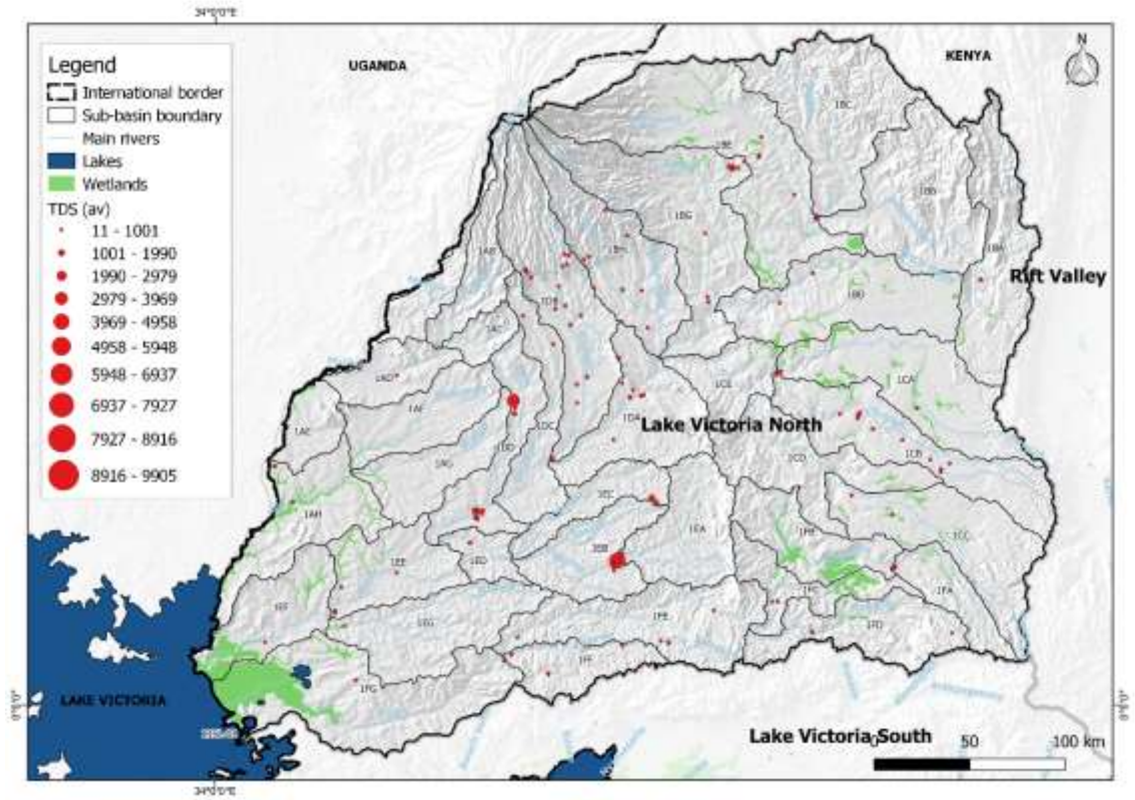
Upper/Middle Nzoia and Sio and Malaba-Malakisi Rivers

Over 15 rivers drain and form the Upper and Middle Nzoia. The main tributaries include: Kuywa, Koitobus, Ellegrin, Endoroto, Safu, Kimilili, Terem, Chwele, Isiukhu and Sosiani. To these we add the Sio, and Malaba, Malakisi. Like in the case of the Upper Yala System, these rivers are also polluted by anthropogenic activities. Severe land degradation and pollution of the rivers by domestic and industrial effluent from urban settlements and effluent from agro-based industries such as tea, coffee, sugarcane, and horticulture make these rivers appear turbid and coloured brown.

All these rivers show high levels of colour and turbidity, bacterial contamination, diminished dissolved oxygen levels and moderately high concentrations of BOD and COD. In their current state these rivers forming Upper and middle Nzoia and the Sio, Malaba- Malakisi, cannot be used directly for domestic purposes without treatment to remove suspended material and disinfect the water.



a.



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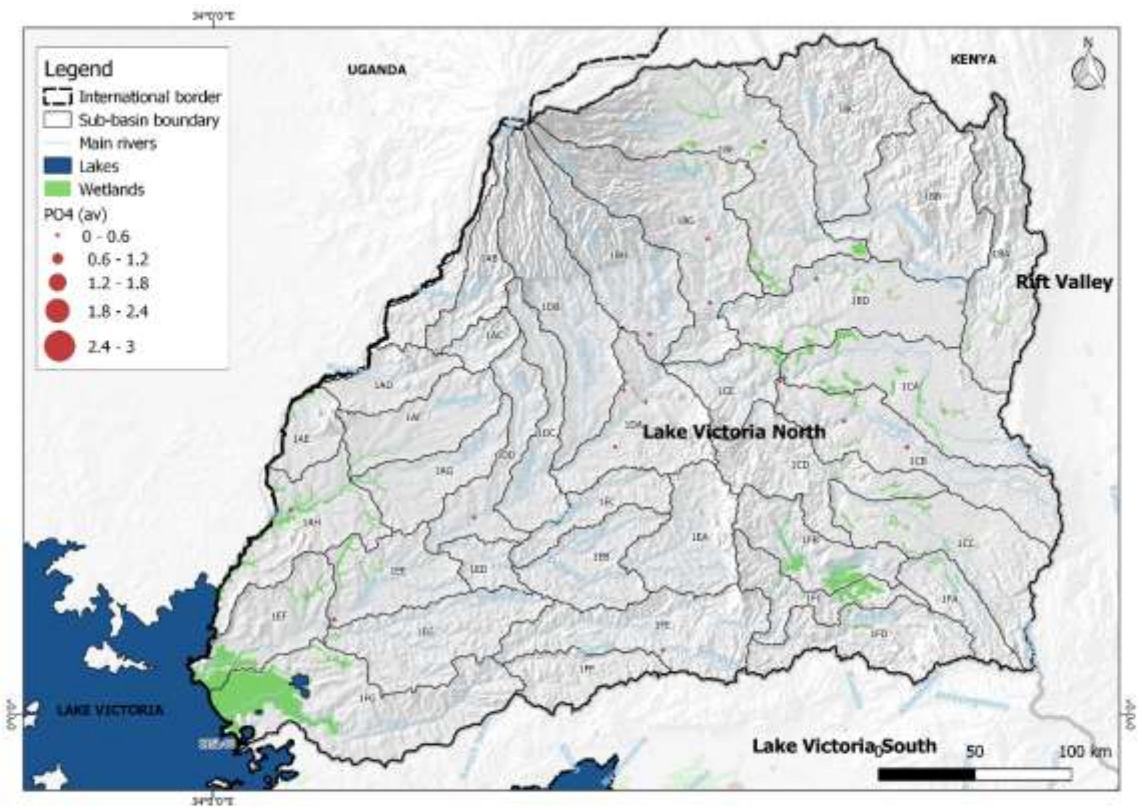

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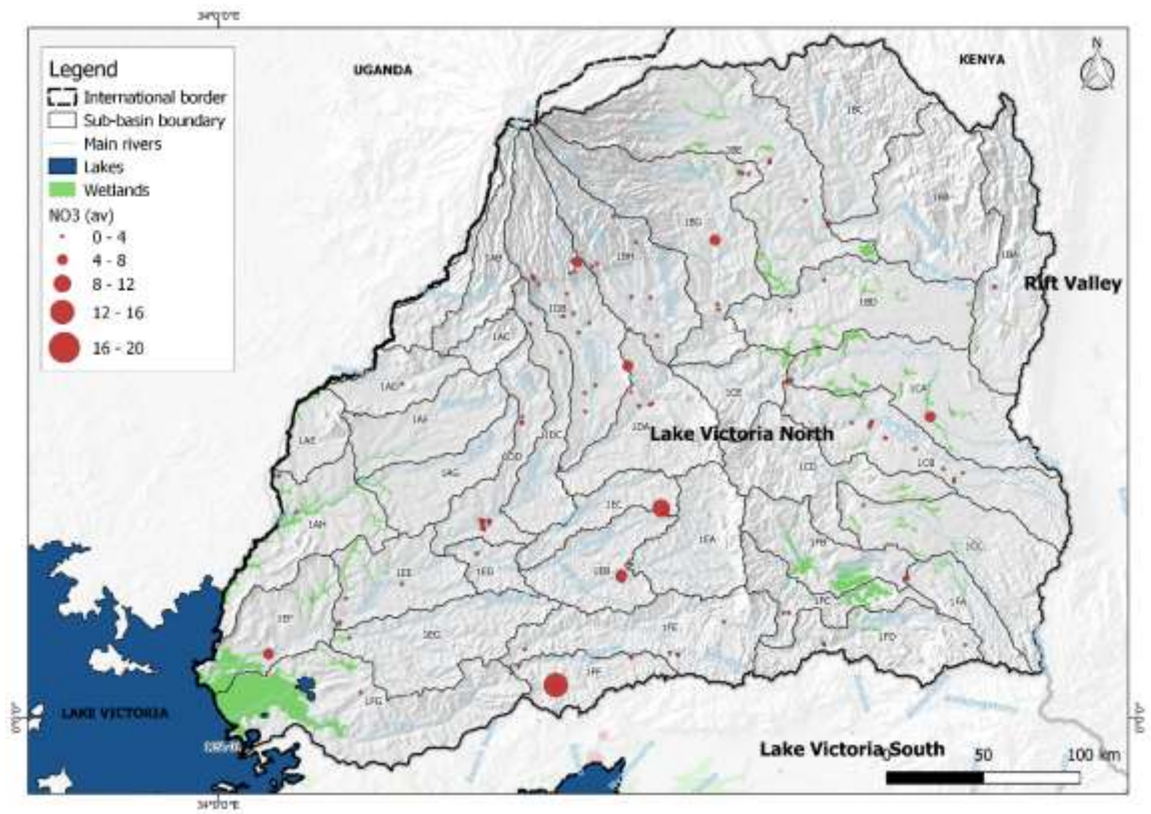

d.

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

Figure 6-12: The water quality monitoring stations in LVN Basin with turbidity (a), TDS (b), PO4 (c) and NO3 (d) *

Table 6-16: Major Point sources of Pollution in the Nzoia River Catchment

Item	Point Source	Activity/Nature of waste	Receiving River/System
1.	Kitale Municipal Council - Conventional sewage plant - Sewage Oxidation Ponds	 Domestic Sewage Domestic sewage	 Kiminini Koitobos
2.	KCC - Kitale	Milk processing	Koitibos
3.	Eldoret Municipal Council - Oxidation ponds - Conventional sewage plant	 Domestic sewage Domestic sewage	 Sosiani Sosiani
4.	Webuye Municipal Sewage Ponds	Domestic sewage	Nzoia
5.	Panafrican Paper Mills (E.A.) Ltd, Webuye Sewage Ponds	Paper manufacture	Nzoia
6.	Bungoma Municipal sewage ponds	Domestic sewage	Khalaba
7.	Nzoia Sugar Company effluent ponds	White sugar processing	Kuywa
8.	Mumias Sugar Company - Factory effluent ponds - Domestic sewage ponds	 White sugar processing Domestic sewage	 Nzoia Nzoia
9.	Mumias Municipal sewage works	Domestic sewage	Nzoia
10.	Kakamega Municipal sewage ponds (2No.)	Domestic sewage	Isiukhu & Lusumu
11.	West Kenya Sugar Co.	Sugar production	Lusumu
12.	Mukangu Sugar Co. Ltd	White Sugar processing	Isiukhu
13.	Moi University Chepkoilel Campus	Domestic sewage	Sergoit
14.	Siaya District Hospital sewage	Hospital & domestic wastewater	Huludhi

Lower Yala and Nzoia Rivers

The rivers that form Lower Yala and Nzoia are: Lusumu, Wuoroya and Edzawa. The most critical water quality issue in these rivers is high sediment loads and associated turbidity, giving the water a dark brown colour. The water also has high bacteria counts emanating from the urban and rural settlements upstream along the river.

6.5.4.2 Groundwater

A comprehensive overview of groundwater quality is provided in Section 2.

6.5.5 Strategy

In addition to the main objective of this Water Quality Management Plan, other objectives include:

- That the need for socio-economic development is balanced appropriately with the need to protect water quality for clean and safe water, and to enhance the quality of life of citizens and aquatic ecosystems,
- That a coherent approach to managing water quality are followed by government ministries and local authorities to ensure good governance of water quality,
- That there is an effective monitoring chain of data acquisition, information generation, and knowledge application so that water quality managers can make informed decisions about the management of water quality in the basin, and
- That water resource management institutions have the capacity and systems in place to efficiently manage water quality.

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

In order to comprehensively and systematically address the water quality issues and challenges in the LVN Basin, Table 6-17 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 6-17: 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 LVN catchment. This entails implementation of routine water quality monitoring of rivers and lakes, reservoirs, effluent discharges, urban rivers, and dams/lakes. It also refers to initiation of limited duration water quality surveys to investigate specific problems in collaboration with, for example, academic institutions and selected specialists. It includes the upgrading central and regional laboratories. Lastly, it is essential that all the data gathered by means of routine programs and surveys, be stored and managed in Mike Info to maintain the integrity of the data, and to generate information and routine reports that meet the needs of water resource managers. 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 LVN Basin by ensuring that capacitated technical staff have the resources to collect water samples and conduct in-field measurements on schedule, the water testing laboratories can analyse the water samples accurately and on-time, submit the analysis results to the Mike Info water quality database, and the data are reviewed, analysed, reported on, and acted on by catchment staff.		
4.1.2	Biological Water Quality Monitoring	
Develop the required capacity to undertake biomonitoring in Kenya to assess aquatic ecosystem health. Identify streams in the LVN 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 LVN 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 LVN 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 LVN Basin should be enforced. This database should also serve as the approved database for all reporting and assessment of water quality data in the LVN 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 LVN 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 LVN Basin**
With so many institutions involved in different aspects of water quality management in the LVN 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 LVN 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 LVN Basin. WRA should advocate alignment of strategies to serve a common purpose of rehabilitating urban rivers and streams in the LVN 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 LVN Basin. Participate in river clean-up campaigns of rivers. This can be achieved by using the inter-agency taskforce 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 LVN 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 LVN 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, several 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.		

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

The management of stormwater in urban areas is important because it is the conduit for transporting pollutants into urban streams, and eventually nearby rivers and lakes. This requires promoting the use of structural stormwater control and treatment facilities (e.g. instream detention ponds) in urban areas, as well as reducing stormwater runoff by improved rainfall infiltration systems, efficient drainage network, and improved rainwater harvesting by households, complexes, and commercial buildings. Riparian buffer strips 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 have impacts on nutrient enrichment and pollution from the use of agrochemical to control pests. To deal with these impacts, authorities should promote climate smart agriculture, encourage farmers to use a combination of organic and inorganic fertilisers on their fields, and promote integrated pest management and the use of biodegradable pesticides where possible. Roads, particularly unpaved roads have a large impact on erosion and sediment production. It is recommended that gravel road drainage infrastructure be maintained to reduce erosion, and to implement dust suppression measures on unpaved urban roads to manage wash-off of fine sediments into the stormwater drainage system during rainfall events.

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 LVN 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 un-sewered 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 County Integrated Development Plans (CIDPs) and to develop relevant county legislation.

The National Climate Change Action Plan 2013 to 2017 (Government of Kenya, 2013b) sets out a vision for a low carbon development pathway for Kenya and lists specific adaptation and mitigation actions for each national planning sector to support this vision. One of the “big wins” identified in the draft National Climate Change Action Plan 2018-2022 relates to “improved water resources management”.

The draft National Climate Change Action Plan 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 National Climate Change Action Plan 2018-2022 guides the climate actions of the national and county governments, the private sector, civil society and other actors as Kenya transitions to a low carbon climate resilient development pathway. It identifies strategic areas where climate action over the next five years is linked to Kenya’s Big Four Agenda, recognising that climate change is likely to limit the achievement of these pillars. One of the “big wins” identified in the draft National Climate Change Action Plan 2018-2022 relates to “improved water resources management”. Of 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 National Climate Change Action Plan 2018-2022 also prioritises seven climate change actions (Table 6-18), three of which (nos. 1 to 3) align very strongly with the planning and management of water resources.

Table 6-18: Priority climate change actions (Draft National Climate Change Action Plan, (GoK, 2018))

Disaster Risk (Floods and Drought) Management	Reduce risks to communities and infrastructure resulting from climate-related disasters such as droughts and floods.
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.
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.
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.
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.
Manufacturing	Improve energy and resource efficiency in the manufacturing sector.
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 LVN 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 LVN Basin Plan, the objective of this component of the Plan is to understand the degree to which climate change will compromise the water resources sector and how those impacts will in turn alter the exposure to food security and to flood and drought risk. This component will also explore opportunities presented by climate change such as climate financing.

6.6.2 The changing climate in Kenya

Kenya's climate is already changing. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) presents strong evidence that surface temperatures across Africa have increased by 0.5-2°C over the past 100 years, and from 1950 onward climate change has changed the magnitude and frequency of extreme weather events.

The frequency of cold days, cold nights and frost has decreased; while the frequency of hot days, hot nights and heat waves has increased. Temperature increase has been observed across all seasons 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 increases vulnerability. The increasing intensity and magnitude of weather-related disasters in Kenya aggravates conflicts, mostly over natural resources, and contributes to security threats. Expected social, environmental and economic impacts associated with climate change in Kenya are summarized in Table 6-19. Aspects which relate to water resources management and planning are highlighted.

Table 6-19: Potential climate change impacts in Kenya

Social impacts	
Flooding	**Fluvial flooding** leads to the greatest loss of human lives in Kenya. In the aftermath of floods, there are often cholera outbreaks while people also experience an upsurge of mosquito-borne diseases e.g. malaria and dengue fever. The impacts of coastal flooding can also be severe due to sea level rise. The coastal area in Kenya has the largest seaport in East Africa, tourism and fishing industries.
Droughts	**Droughts** in Kenya destroy livelihoods, trigger local conflicts over scarce resources and erode the ability of communities to cope. Drought can cause changes in the migratory patterns of animals and increase conflicts between people and animals. Kenya's ASALs are particularly vulnerable to the impacts of climate change: The highest incidence of poverty is found in these areas and women and men experience greater competition over resources, growing populations and lower access to infrastructure. The ASAL economy is also typically highly dependent on climate sensitive activities e.g. livestock and wildlife tourism.
Human conflict	**Cross-border and cross-county conflict** is often exacerbated by climate change. As temperatures rise and rainfall patterns change, some areas become less conducive for livestock, particularly cattle, leading to a reduction in herd numbers. Counties with more favourable conditions often enter into resource use conflicts as pastoralists from other counties move their animals to water and better pasture conditions.24 Cross border conflicts could also increase with neighbouring countries as pastoralists compete for food, water and grazing.
Migration	Migration linked to climate change does occur in Kenya - mainly as vulnerable groups are reliant on **resource-based livelihoods**. Reduced agricultural productivity and resource scarcity along with increased floods and droughts also contribute to movement of people.
Vulnerable groups	Vulnerable groups include remote and pastoralist communities, hunters and gatherers, fisher communities and people who live in urban slums. All of these are affected by climate change because of environmental degradation and **growing competition for land and water.**

Social impacts	
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 / more frequent 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 soil properties.
Loss of biodiversity	Climate change is contributing to a loss of Kenya's biodiversity including plant species, some animal species, and a decline in the productivity of fisheries in inland waters Climate change also has the potential to alter migratory routes and timings of species that use seasonal wetlands (such as migratory birds) and track seasonal changes in vegetation (such as herbivores). Furthermore, climate change also significantly affects marine ecosystems.
Deforestation and forest degradation	**Deforestation and forest degradation** in Kenya 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.

Economic impacts	
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

Source: (adapted from Government of Kenya, 2018)

6.6.4 Strategy

The climate change strategy for the LVN 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 LVN Basin, Table 6-20 sets out 3 Strategic Themes with specific Strategies under each Theme. The Themes address an Improved understanding of the impacts of climate change on water resources at appropriate scales, as well as Mitigation and Adaptation.

Table 6-20: Strategic Framework - Climate Change Mitigation, Adaptation and Preparedness

5.	**Key Strategic Area**	**Climate Change Adaption 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 LVN 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 LVN 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		

5.	Key Strategic Area	Climate Change Adaption and Preparedness
be analysis of rainfall onset and cessation, particularly in rainfed agricultural areas and areas highly reliant on surface water rather than reticulation. Engage local private sector, NGOs and knowledgeable individuals to facilitate wider experience transfer of adaptation practices. Engage local private sector, NGOs and knowledgeable individuals to facilitate wider experience transfer of adaptation practices		
5.2	**Theme:**	**Climate change mitigation**
5.2.1	Promote the generation and use of clean energy	
Propagate the usage of renewable energy source just as hydropower, wind power and solar geysers		
5.3	**Theme:**	**Climate change adaptation**
5.3.1	Promote climate resilient infrastructure	
Promote the development in low risk areas and increase setback from rivers and ocean interfaces. Build to increased threshold specifications to address future climate impacts for both road and stormwater infrastructure		
5.3.2	Climate-related disaster risk management	
Reduce the risk of disasters linked to climate change e.g. floods, droughts, health-related risks, crop production etc. by understanding the potential threats and risks and by implementing structural and non-structural mitigation measures.		
5.3.3	Promote agroforestry	
Enhance the CO_2 sink by promoting varied land usage to increase biodiversity and minimise soil erosion and increase soil nutrients retention. Actively plant, living fences, medicinal and fruit trees.		
5.3.4	Mainstream climate change adaptation in water resources strategy, planning and management at basin and catchment level	
Implementation and enforcement of practical mainstreaming practices and enhance the awareness of potential climate impacts on communities to promote uptake of adaptation.		
5.3.5	Enhance resilience of agriculture sector through climate smart agriculture	
Employ likely increased stress impact principles promoting soil quality, better drainage and weed/disease control in agricultural practices		

6.7 Flood and Drought Management

6.7.1 Introduction

Floods and droughts are caused by extreme climatic events and can have devastating consequences for the socio-economic welfare of rural and urban communities and regions.

Flooding of land surfaces occurs when heavy rainfall leads to runoff volumes that exceed the carrying and storage capacities of stream channels and urban drainage systems. In the process, crop and grazing lands, villages and urban neighbourhoods become inundated, transport infrastructure destroyed, and powerlines flattened. Floods can cause displacement of people, loss of life (human and livestock), increases in water related-diseases, severe soil erosion, landslides, 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 LVN Basin

6.7.2.1 Frequency and extent of floods

The frequency and extent of significant floods in Kenya have increased during the past six decades from about one flood period every four years, on average, to a near-annual event, as is illustrated by the following details:

- Between 1961 and 1997/98, Kenya experienced eight 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, 2 000 human deaths, 2.3 million livestock lost and 100 000 km roads and 13 major bridges destroyed (Gathura, 2015). The *Siaya, Busia, Uasin Gishu and Trans Nzoia* counties were particularly severely impacted.
- 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 *Kitale and all the eastern counties* in the LVN Basin were impacted to varying degrees (Huho et al., 2016). In November 2006, in Budalangi, the collapse of dykes led to flooding which displaced more than 10 000 people. In late 2008, the Nzoia River burst its banks at various locations and caused wide-spread displacements.
- Widespread flooding and occasional landslides during March–May 2013 displaced 140 000 people and led to 96 deaths. *Siaya and Vihiga counties* in the LVN Basin were impacted (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. LVN Basin counties that were impacted were *Busia, Siaya and Nandi* (International Federation of Red Cross, 2016a).
- Widespread flooding and occasional landslides during April and May 2016 displaced 48 000 people and caused 100 deaths. LVN Basin counties that were severely impacted were *Busia and Kakamega* (International Federation of Red Cross, 2016b).
- During 2017, two different periods of significant flooding occurred in separate parts of Kenya - during May in south-eastern Kenya and during November in northern Kenya. The LVN Basin was not severely impacted (Davies, 2017).
- Widespread flooding and various landslides during March-May 2018 impacted more than 800 000 people across Kenya, including in LVN Basin counties, *Siaya and Busia*. About 300 000 people were displaced and 186 people lost their lives across the country. More than 8 500 hectares of crops were destroyed and some 20 000 livestock lost, while about 100 schools were flooded (OCHA, 2018).

6.7.2.2 Flood-prone areas in LVN Basin

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

- Long-duration flooding (up to a month) in the Lower Nzoia River at Budalangi in Busia county
- Long-duration flooding (up to a month) in the Lower Nyala River and, particularly, Yala Swamp in Siaya county
- Short-duration flooding (1 – 2 days) in the Lower Sio and Lower Malikisi Rivers, in Busia county
- Short-duration (1 – 2 hours) flash floods in the foothills of Mount Elgon in Bungoma county.

6.7.2.3 Frequency and extent of droughts

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. The counties of the LVN Basin which were impacted by some of these droughts were Trans Nzoia and Uasin Gishu.

Table 6-21: Widespread Kenyan droughts during the past two decades (Huho et al, 2016; Reliefweb, 2018)

Years	Impacts
2016-17	3.4 million people severely food insecure, of which 1.1 million are children. About 0.5 million people without access to clean water.
2011-12	3.75–4.3 million people in dire need of food.
2008-09	4.4 million people affected; 2.6 million people at risk of starvation, 70% loss of pastoral livestock.
2004-06	3.5 million people affected; 2.5 million close to starvation; 40 human lives lost; 40% cattle, 27% sheep and 17% goats lost.
1999-2001	4.4 million people affected.

6.7.2.4 Drought-prone areas in LVN Basin

The climate of LVN Basin can be categorised as moderate to humid, with relatively high mean annual rainfall (1 200 – 1 800 mm/a). Under these favourable climate conditions, it follows that, should consecutive rainfall seasons produce below-average rainfall, emergency drought conditions would not generally develop in the LVN Basin, but two vulnerable counties might be Trans Nzoia and Uasin Gishu.

6.7.3 Existing flood and drought management measures and response plans

The following sections outline the various flood and drought management strategies/plans, relevant to LVN Basin, that have been compiled during the recent past.

6.7.3.1 National Water Master Plan 2030, Volume II Part B – LVN Catchment Area

The Water Master Plan for the LVN Basin consists of eight component plans, one of which is a flood and drought disaster management plan.

Flood disaster management plan

The proposed components of a flood disaster management plan for the LVN Basin distinguished between “structural” and “non-structural” measures, as follows:

- Implementation of Flood Control Measures planned in the Western Kenya Community Driven Development and Flood Mitigation Project (WKCDD&FMP). This includes various structural flood control measures such construction of new multi-purpose dams, construction of new and rehabilitation of dykes and river improvement works.
- Operation of a Flood Early Warning System (FEWS) in the Nzoia River Basin. Flood forecasting analysis was to be performed by WRMA regional offices, in cooperation with KMD. Warning information would also be provided by WRMA regional offices.
- Preparation of a Flood Fighting Plan for the Nzoia and Yala Rivers for the existing dykes along the lower reaches of Nzoia and Yala Rivers prepared by the WRMA LVN Regional Office. The target section for the flood fighting plan was to be 18.4 km on the left bank and 16.2 km on the right bank of the Nzoia River, and 9 km on the right bank of the Yala River. The flood fighting plan was aimed at preventing an expansion of inundation areas caused by dyke breaching and/or overtopping.

Drought disaster management plan

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

- Preparation of drought operating rules for five existing and seven proposed reservoirs as well as of restrictions placed on water supplies to the different water-user sectors.
- Establishment of a Basin Drought Conciliation Council for each of the Nzoia and Yala River systems, respectively, with legal status to avoid water conflict during droughts. Each Council's membership would comprise WRMA regional staff, county staff and representatives of WRUAs.
- Establishment of a drought early warning system based on existing KMD seasonal rainfall forecasts and utilised to commence with timely water restrictions.

6.7.3.2 LVN Catchment Area Catchment Management Strategy 2015 – 2022 (Water Resources Management Authority, 2015a)

In the LVN 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 LVN Basin

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.

Source: (Water Resources Management Authority, 2015a)

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

Goal: Effectively manage floods and droughts in collaboration with stakeholders.

Objectives:

- To develop and implement a framework for collaboration with County Governments and other Stakeholders on Integrated Flood and Drought Management.
- To enhance capacity on Integrated Flood and Drought Management, including monitoring skills, use of information systems and flood control centres.
- To mainstream Flood and Drought Management in Sub-Catchment Management Plans.

In pursuit of these objectives, the CMS proposes 17 individual Strategic Actions, some of which to be completed between 2015 and 2020, while the rest are continuous and ongoing.

6.7.4 Key achievements, challenges and constraints

In the documents discussed in Section 7.9.3 above, as well as in various relevant documents available on the GoK website, a range of achievements, challenges and constraints regarding flood and drought disaster management are identified. Although many 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.

6.7.4.1 Achievements

- Detailed dyke studies on the Lower Nzoia River which involved detailed assessment of the existing structures, including geotechnical, geomorphology, hydraulic modelling, historical hydrological and rainfall data etc., were successfully completed as part of the WKCDD&FMP (The World Bank, 2016). Important rehabilitation of some 20 km of the existing structures, as well as some 1.3 km of river training to increase discharge capacity, have also been completed.
- The Flood Early Warning System for the Nzoia River as part of the WKCDD&FMP is innovative and highly impactful, complete with real time flood prediction equipment, production and dissemination of daily flood watch bulletins, and radio broadcasts in the local dialect (The World Bank, 2016).
- Under the WKCDD&FMP, sediment loads in the Nzoia decreased from 180 tons/day in 2008 to 139 tons/day in 2016 as the results of micro-catchment protection activities by WRUAs and soil and water conservation activities and establishment of soil conservation structures (The World Bank, 2016).
- The National Hydrometeorological Network Design Project for the Republic of Kenya, currently underway, has designed a provisional network of 28 meteorological and 53 surface water stations (telemetric or automatic or manual) for LVN 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].
- During drought periods, the WRA LVN Regional Office institutes water use restrictions at the catchment level, applied at the major dams for domestic water supply purposes, namely, Moiben, Twin Rivers, Ellegirini, Kipkarren, Lessos.
- 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.

6.7.4.2 Challenges

- Sourcing financing for the completion of the rehabilitation of flood protection dykes along the Lower Nzoia and Lower Yala Rivers. The cost of this work was estimated at USD 54 million by the World Bank (2016).
- Ongoing urbanisation leading to increased urban populations.
- Ongoing encroachment of communities in flood-prone zones for crop and livestock farming.
- 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 hydrometeorological data collection and subsequent analysis necessary for setting up early warning systems.
- Adaptation required in the face of climate change impacts in the form of increased frequency of floods and droughts.

6.7.4.3 Constraints

- *Institutional complexity*: In terms of the Water Act of 2016, a Basin Water Resources Committee (BWRC) for the LVN 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 LVN 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 Development Initiatives (2017) found that coordination between national and local actors in humanitarian resource mobilisation was generally incoherent. Hence, this review concluded that international relief aid organisations and local NGOs have had to establish personal working relationships with institutional actors in each of the counties in which they operate to streamline collaboration by the county governments and other government agencies.
- *Institutional overlaps:* There is considerable overlap between the roles and functions of the National Disaster Operations Centre (NDOC) and National Disaster Management Unit (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 Disaster Risk Management Bill, currently under consideration by Parliament, is aimed at bringing NDMA, NDOC and NDMU together as a new "Disaster Risk Management Authority."
- *Monitoring shortcomings*: WRA's surface water monitoring network is well-developed, but data quality is often poor due to inadequate operational and maintenance funding, vandalism of stations and, in some areas, flood damage of river gauging stations.

  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 1 200 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.

6.7.5 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).

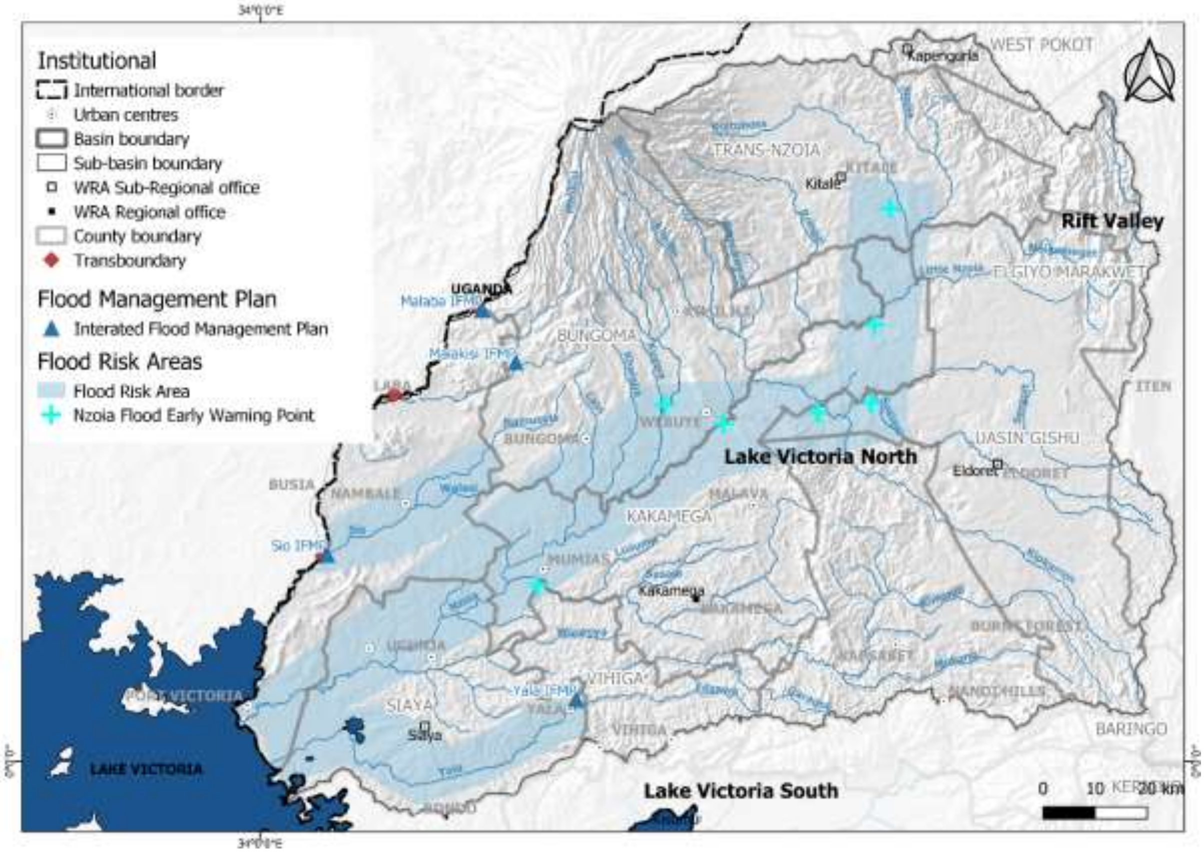

Figure 6-13: Flood management plan for LVN Basin

In order to comprehensively and systematically address the flood and drought issues and challenges in the LVN Basin, Table 6-23 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

6.	**Key Strategic Area 6**	**Flood and drought management**
6.1	**Theme:**	**Flood management**
6.1.1	Undertake flood risk assessment	
The most flood-prone counties in the LVN Basin are Siaya, Busia and Vihiga. Under the WKCDD&FM Project, detailed flood risk assessments were conducted for the Lower Nzoia River portion of the Siaya county. For the Lower Yala River and the rest of the above county areas, high-level assessments will be made of the flood exposure of each village and town 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. 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 LVN Basin, which will provide a starting point for the Integrated Flood Management Plans discussed below.		
6.1.2	Formalise institutional roles and partnership collaborations.	
The government institutions and agencies and other stakeholders with partnership roles in flood management are		

6.	Key Strategic Area 6	Flood and drought management

as follows[6]:

- 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 the *LVN Basin Flood Response Forum (FRF)* be established that integrates all flood-relevant resource mobilisations and related interventions in the LVN Basin by the various collaboration partnerships listed above. The *LVN 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 *LVN Basin FRF* must be systematised through the development of appropriate standard operating procedures (SOPs)[7].

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 plan is that it is better to protect more people from the frequent smaller floods, than fewer people from the rarer larger floods. Flood early warning systems should be used to warn communities when larger floods may occur.
- SOPs that comprise sequential response actions: monitoring ⇨ early warning alerts ⇨ severity trigger alerts ⇨ pro-active resource mobilisations ⇨ emergency interventions ⇨ post-flood recovery interventions.

Objectives of the flood response protocol:

- Minimise the impacts of flooding on the safety and quality of life of affected communities.
- Minimise environmental impacts.
- Accelerate recovery of prior homestead environments, livelihoods and transport routes of affected communities.

6.1.4	Develop Integrated Flood Management Plans

An Integrated Flood Management Plan (IFMP) will be developed for each of the individual catchments in the Lake Victoria North Basin, namely the Nzoia, Yala, Malaba, Malakisi, and Sio River catchments. The IFMPs will be

[6] There are currently three bills seeking to establish a National Disaster Management Authority and a National Disaster Management Fund. However, the three bills differ in content and structure e.g. proposed governance structure, membership and functions among other things. The mandates of NDMA, NDOC and NDMU overlap in various ways. The Disaster Risk Management Bill, currently under consideration by parliament, is aimed at bringing NDMA, NDOC and NDMU together as a new "Disaster Risk Management Authority." The sponsors of the bills will have to sit and agree on how to collapse the three bills into one or alternatively, the first bill to pass through all the stages of development will be adopted and the rest will be nullified.

[7] SOPs aim at: (1) Providing a list of major executive actions involved in responding to disasters and necessary measures needed for preparedness, response and relief. (2). Indicating various actions that should be taken and by which actors within their sphere of responsibilities – linking up with their contingency plans. (3) Ensuring that all concerned actors and agencies know the precise actions required of them at each stage of the response and that all actions are closely and continuously coordinated (Development Initiatives, 2017).

6.	Key Strategic Area 6	Flood and drought management

structured around the following topics:

- Overview of the natural conditions (topography, climate, soils, land-use, land-cover, hydrology) and the socio-economic make-up of each catchment.
- Overview of the statutory, institutional and civil society stakeholder context of each catchment.
- Characteristics of floods and flooding in each catchment, namely identifying all flood-prone locations, flash floods, long-duration overbank inundations, sediment dumping floods, etc.
- Overview of existing flood management/counter measures – both structural and non-structural.
- Analysis and costing of required flood management/counter measures at all flood-prone locations, categorised as follows: *prevention measures; protection measures; preparedness measures; flood early warning systems; emergency response measures*.
- Stakeholder participation in prioritising required flood management/counter measures at all flood-prone locations.
- Proposed Implementation Schedules of flood management/counter measures at all flood-prone locations.
- Funding sources for the proposed flood management/counter measures.

6.1.5 Implement flood management measures

The above proposed Implementation Schedules for the five catchment IFMPs that cover the Lake Victoria North Basin, will be reviewed by the *Lake Victoria North 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 Lake Victoria North Basin at all flood-prone locations.

The above re-prioritised non-structural and structural flood management/counter measures will encompass the following: *prevention measures; protection measures; preparedness measures; flood early warning systems; emergency response measures*. These measures will be focused on flood-prone river reaches and floodplains in each of the six catchments in the Lake Victoria North River Basin. Wherever feasible, *community-based* flood early warning and flood preparedness approaches will be followed.

The *Lake Victoria North 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 Lake Victoria North 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 Lake Victoria North 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 *Lake Victoria North Basin Flood Response Forum (FRF)* to be introduced in Theme 6.2.1.

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 Lake Victoria North Basin FRF. The resources and experience of the NDMU/NDOC (or their successor institution) can make valuable contributions to developing community self-help awareness in terms of flood management.

6.2	Theme:	Drought management

6.2.1 Formalise institutional roles and partnership collaborations.

The government institutions and agencies and other stakeholders with partnership roles in drought management

6.	Key Strategic Area 6	Flood and drought management

are as follows[8]:

- 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.

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 LVN 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 LVN Basin must be reviewed and deliberated by the collaboration partnership participants in the LVN Basin Drought Response. In the case of an adverse severity assessment, the LVN 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 LVN Basin.

6.2.4	Strengthen existing drought early warning systems

[8] 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.

6.	Key Strategic Area 6	Flood and drought management
The NDMA currently issues regular Drought Early Warning Bulletins for ASAL counties. Bulletins must in future also be issued for LVN counties that are more drought-prone than the rest, namely Trans Nzoia and Uasin Gishu. SOP responses based on the Bulletins' early warning findings and alerts must be an integrating force in the above *LVN Basin Drought Response*. The sub-county scale of the Bulletins' reporting ensures that such responses can be spatially accurately focused. Furthermore, such informed responses will secure appropriate and timeous resource mobilisations and humanitarian interventions across all the collaborating partnerships at county, sub-county and local community scales across the above two drought-prone counties in the LVN 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 *LVN Basin Drought Response*.		
6.2.4	Capacity development	
Capacity for drought management in the LVN 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 LVN Basin's two 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 LVN 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 *LVN Basin Drought Response* introduced in Sub-Section 7.2.1. *Institutional technical skills*: The strategy is to strategically expand institutional technical skills relevant to drought response activities across three different sets of competencies, namely, (i) competence at translating Drought Early Warning Bulletin information to support prioritisation of resource mobilisations for humanitarian interventions; (ii) competence at logistical planning of required interventions followed by subsequent operationalisation; (iii) competence at communicating technical and logistical information in multi-stakeholder environments.		

6.8 Hydrometeorological Monitoring

6.8.1 Introduction

An operational and well-maintained hydrometeorological network is critical to support the WRA with its key functions related to water resources planning, regulation and management in the LVN 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 LVN Basin

A brief overview of the existing hydrometeorological monitoring network in the LVN Basin is provided in Section 2.4.8. The current network is inadequate, and the network is not being effectively operated. Data management and sharing platforms are not well established, and there is inadequate technical capacity for data processing, analysis and reporting. There is also inadequate maintenance of the monitoring stations. Although the WRA continuously rehabilitates and expands the hydromet monitoring network, issues such as ageing, vandalism and flood damage limit progress.

The majority of the operational river gauging stations in the LVN Basin are rated sections. Most are read manually by gauge readers. It has been reported that manual measurements are often difficult during high flow and flood events due to access challenges. Although procedures are in place to collect discharge data, compliance is often hampered due to logistical, financial and capacity constraints. Rating curves are updated yearly at the National office and distributed to the regional and subregional offices for use. Flow measurement for checking and updating rating curves are typically done manually with flow meters. However, local offices often lack 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.

LVN Basin has the highest population density out of all the basins, and the threat of anthropogenic pollution is particularly high, particularly in the urban centres. 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 Regional Water Testing Laboratory at Kakamega. It is well equipped with basic laboratory equipment, and it is manned by three WQ&PCOs instead of an optimal number of five. Currently it can analyse both physicochemical parameters but no pesticide residues and heavy metals in samples. The Laboratory is also in a poor state and the floor, water sinks and reagent cabinets need to be fixed. There is an urgent need for the upgrade of this laboratory. Furthermore, the mandates and roles and responsibilities of the different institutions involved in water quality management in the LVN 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 LVN Basin, there is currently a total of 21 groundwater monitoring points: 8 Major, 9 Minor and 4 Poor. 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 LVN 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 LVN Basin entailed an assessment of the existing and historical network in the LVN Basin against specific criteria. The result is a surface water network design for the LVN Basin consisting of 47 stations. In addition to the refurbishment of some of the manual stations, 14 stations will be upgraded from manual to automatic. Only 1 new station (automatic) will be constructed. Telemetric and automatic stations will remain the same. An additional 7 stations are being upgraded as part of the Nzoia FEWS project. All 7 stations are currently operational.

Table 6-24: Proposed surface water monitoring network for the LVN Basin

Sub-Regional Office	Total Number of SW Stations					
	Telemetric	Automatic	Manual	TOTAL (excl. Nzoia FEWS)	Nzoia FEWS	TOTAL (incl. Nzoia FEWS)
Eldoret	0	3	15	**18**	3	**21**
Kitale	0	9	7	**16**	3	**19**
Siaya	4	6	3	**13**	1	**14**
TOTAL	**4**	**18**	**25**	**47**	**7**	**54**

The maps below display the locations of the streamflow gauging stations per SRO area.

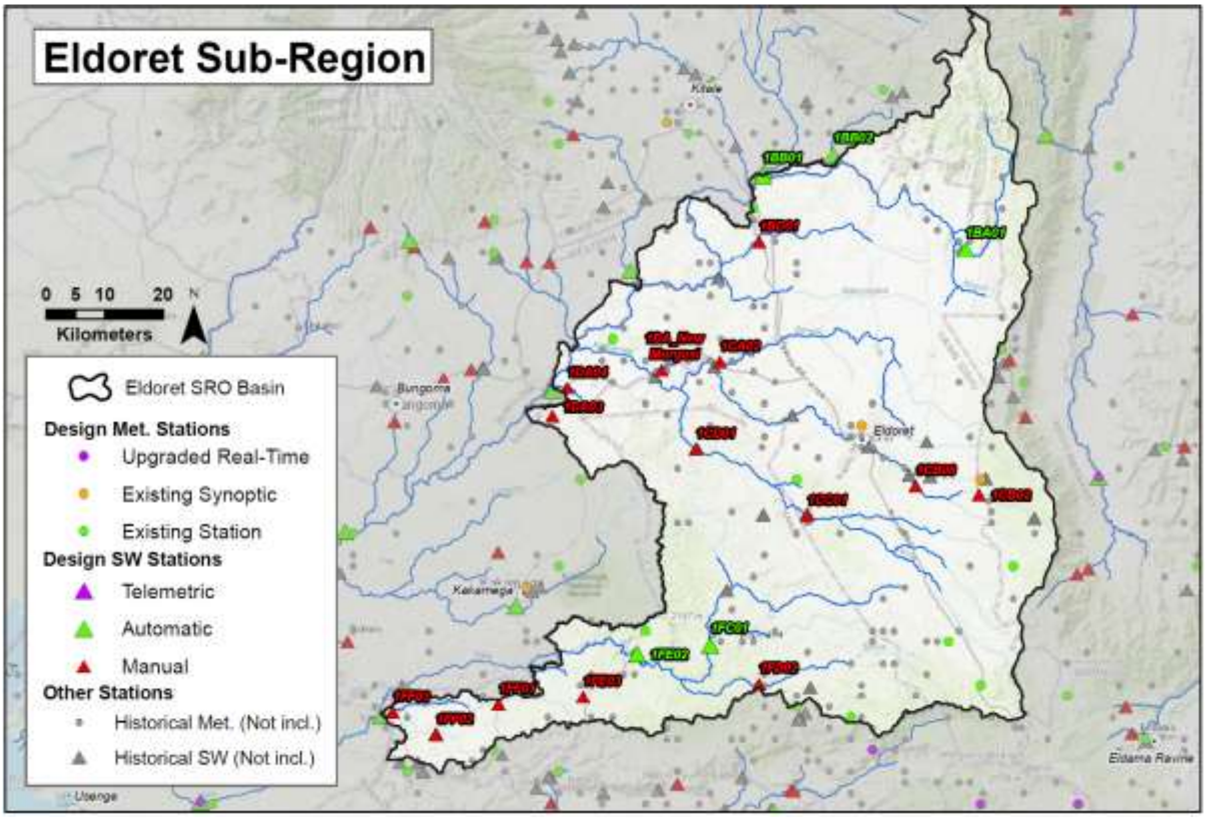

Figure 6-14: Eldoret sub-region: Proposed flow and met monitoring network

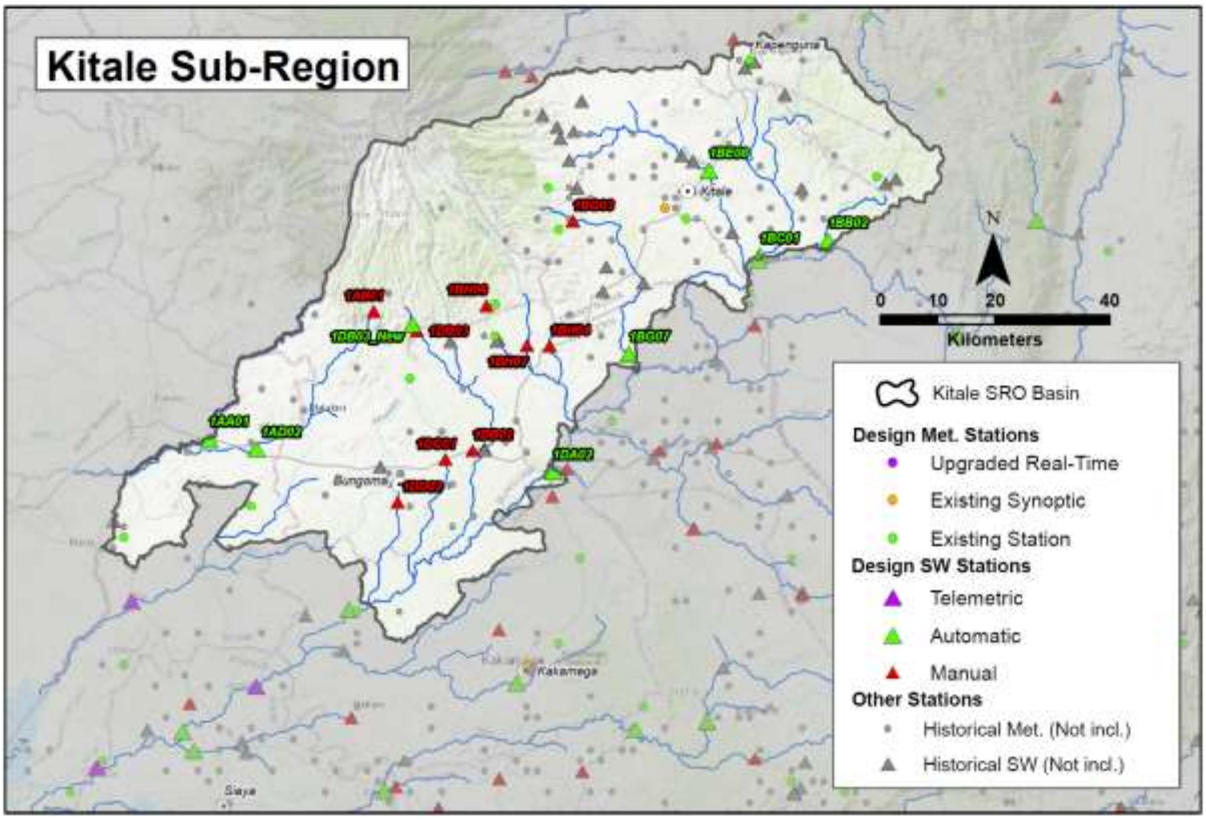

Figure 6-15: Kitale sub-region: Proposed flow and met monitoring network

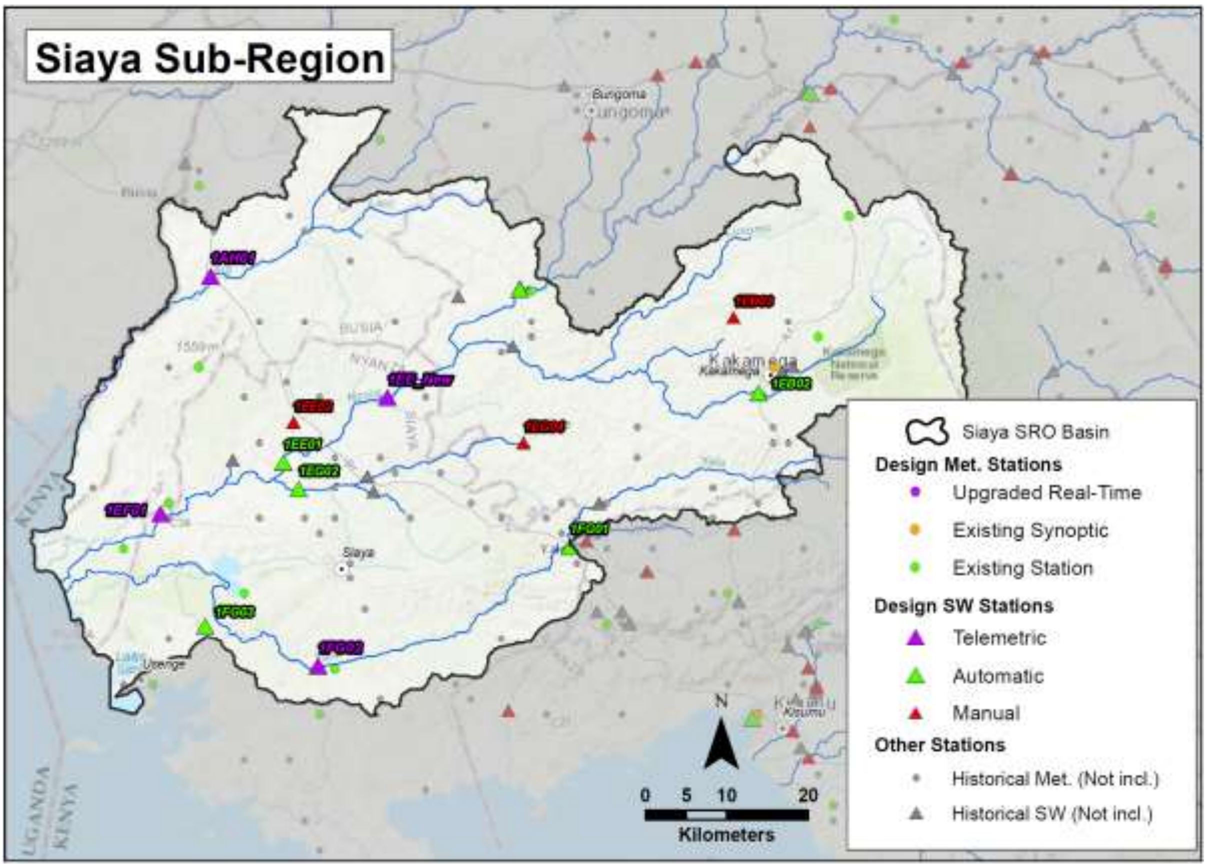

Figure 6-16: Siaya sub-region: Proposed flow and met monitoring network

6.8.3.2 Monitoring of dam and lake levels

No dam and lake surface water monitoring stations are proposed for LVN basin.

6.8.3.3 Meteorological monitoring

The approach towards the design of a meteorological network for the LVN Basin entailed an assessment of the historical meteorological network in the LVN Basin against specific criteria. The network design took into consideration the overlap of the Kenya Water Security and Climate Resiliency Project (KWSCRP) and the Nzoia Basin Forecasting project. The LVN meteorological network design for the LVN Basin consists of 28 stations: 7 in Eldoret Subregion (Figure 6-14), 13 in Kitale Subregion (Figure 6-15), and 8 in Siaya Subregion (Figure 6-16). All of these stations already exist and need to be upgraded or repaired.

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 LVN 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 LVN Basin

LVN Basin	Current stations (2018)	Proposed stations to be retained	Proposed stations to be discontinued	Proposed new stations	Total
Surface water	37	37	0	7	**44**
Effluent stations	25	25	0	11	**36**
Ground water	13	13	0	5	**18**
Total	**75**	**75**	**0**	**23**	**98**

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 LVN basin

LVN Basin	Proposed baseline monitoring stations	Proposed first priority stations
Surface water	6	8
Effluent stations	-	10
Ground water	-	6
Total	**6**	**24**

Surface Water

The proposed surface water station water quality network for the LVN 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)
- Agrochemical 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 Multi parameter 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 LVN Basin should have Portable Water Testing Kits to ensure regular water quality testing at these stations. 1st Priority stations comprise of all National stations, Special Stations, Global stations (In-lake stations, Lake Shore stations), River mouth stations, Pollution Hotspots, Upstream of Dams, intakes for Water supplies and Transboundary stations. Samples drawn from these stations as a priority will be able to give a fair description of the surface water quality in the basin. 2nd Priority Stations constitute the remainder of the water quality monitoring network stations, from which samples will be taken and tested in accredited laboratories as is the current practice. The maps below display the locations of the proposed surface water quality stations per WRA sub-region.

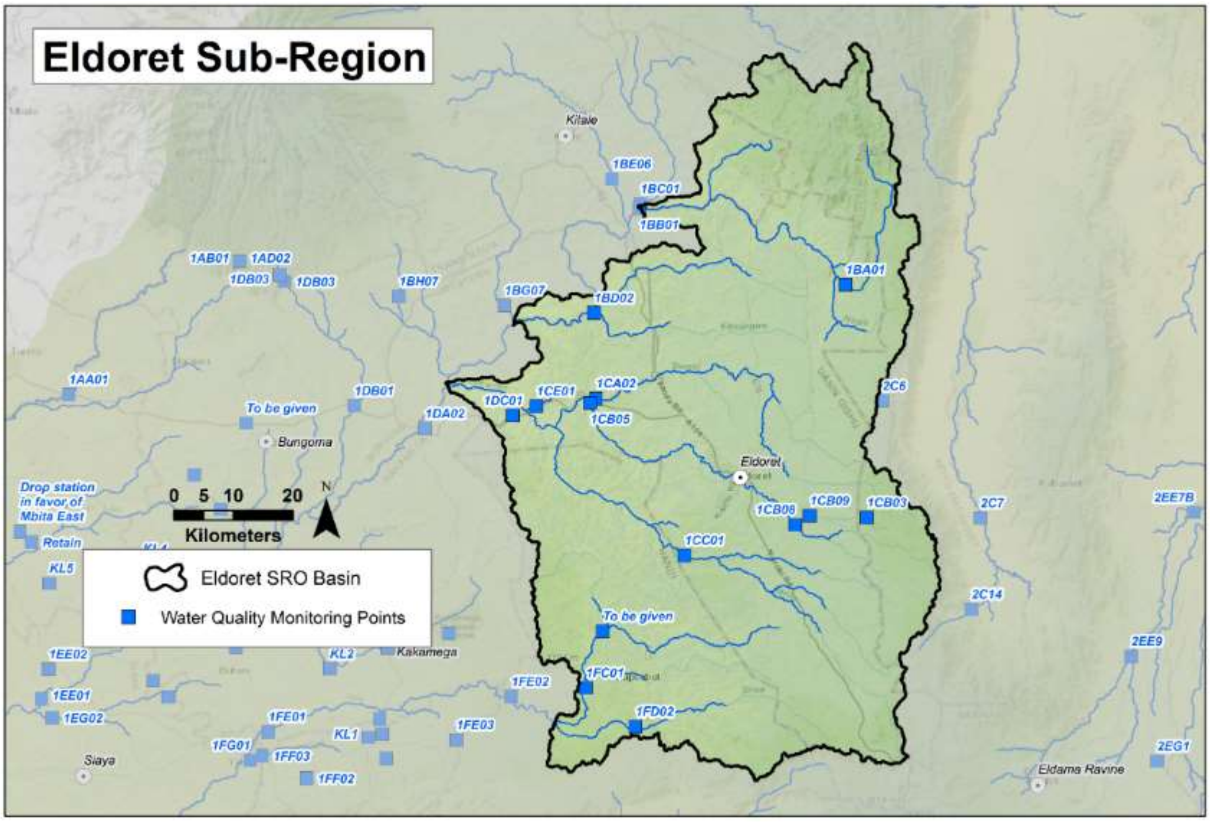

Figure 6-17:Eldoret sub-region: Proposed surface water quality monitoring points

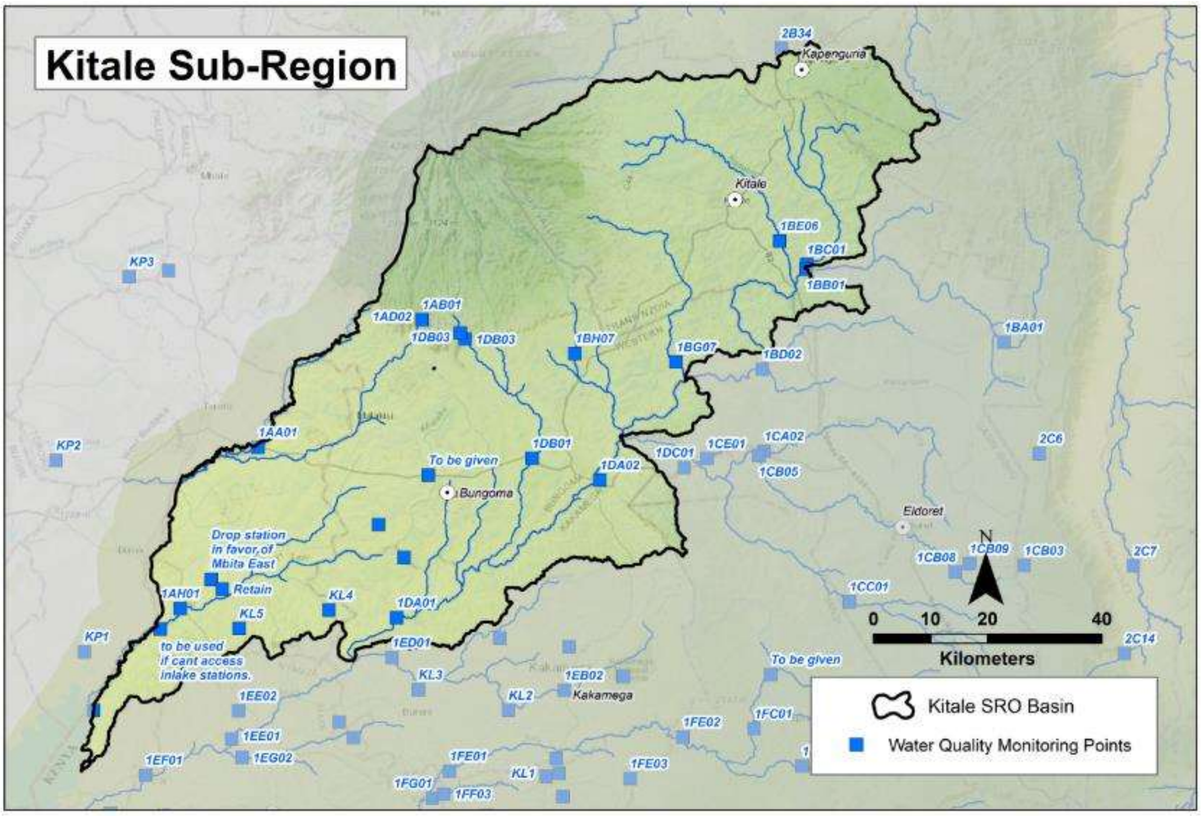

Figure 6-18: Kitale sub-region: Proposed surface water quality monitoring points

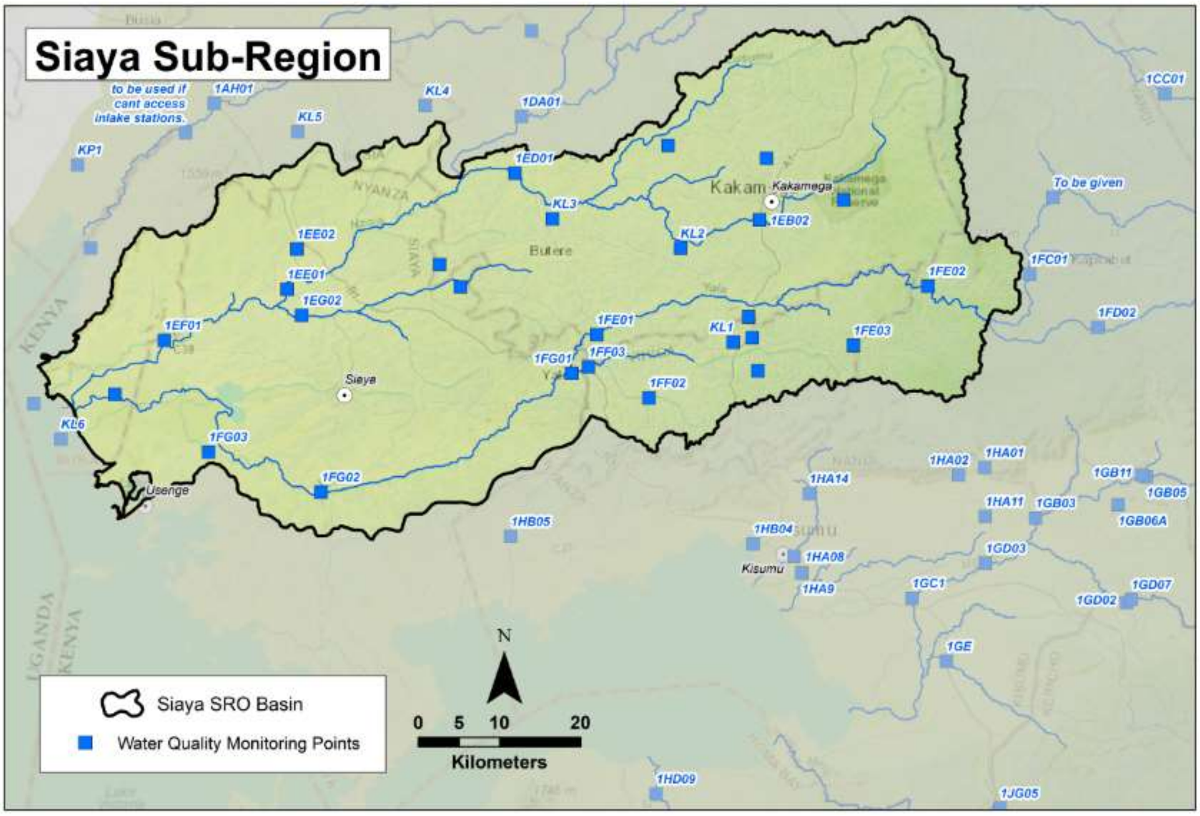

Figure 6-19: Siaya sub-region: Proposed surface water quality monitoring points

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 based on past polluting history of the source. Most of the sources within the LVN 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 Slaughterhouses
- 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 numbers These were later changed, after the establishment of WRA, and each region kept its own borehole records. It is also a requirement that each borehole shall have a Borehole 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 boreholes being monitored do not have borehole IDs and neither are the borehole completion reports available. It is recommended that this information be looked for and documented for all boreholes. For boreholes that do not have Borehole Completion Report or WQ Baseline Reports, it is proposed that the oldest WQ report on record be used as the borehole WQ Baseline Report. If the boreholes do not have any WQ test report, then a sample should be taken and analysed, and its report preserved as the borehole Baseline WQ report against which other subsequent future analyses can be compared. Most borehole 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. No major WQ changes are expected unless there is accidental pollution. Ideally monitoring should be bi-annual instead of the recommended quarterly.

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 borehole. Most of the boreholes proposed for WQ monitoring lack a complete set of coordinates. The few that had coordinates could also not be validated. It is suggested that during the launch of the revised WQM Network, with the aim of collecting the first set of samples for testing, the correct coordinates could be established as well as the validation of any other information.

Sampling/Monitoring frequency

The frequency of sampling or monitoring will be dependent on the nature and type of sampling stations. Generally, for groundwater sources, lakes and dams, which are not expected to undergo drastic WQ changes over time, the sampling frequency can be bi-annual. For river stations and effluent stations, whose water quality is constantly changing at short intervals, the recommended frequency of monitoring can vary from daily to quarterly. In general, and for most stations a sampling frequency of quarterly has been recommended, but this can be varied depending on the type of station and the circumstances prevailing.

Water Quality Design Parameters

The parameters to be tested for at each monitoring station have been identified and may be described as either Basic or Special parameters. Basic Parameters include pH, Colour, Turbidity, TSS, Conductivity, TDS, Chloride, Temperature, Coliforms, DO, Fluoride, Ammonia, Total Nitrogen, Nitrates, Nitrite, Total Phosphorus, Phosphates, Sulphates, Sodium, Potassium, Calcium, Manganese, Iron, Magnesium. Special Parameters refer to pesticide residues, heavy metals, hydrocarbons, oil and grease, sediment load, BOD and COD, and emerging special parameters such as organic micro-pollutants e.g. pharmaceuticals, hormones and chemical substances used in products and households.

At some stations, critical or important parameters have been identified, which should be given priority when testing. Such parameters would include Chromium downstream of a tannery; heavy metals downstream of a metallurgical industry; pesticide residues and nutrients downstream of an intensive farming area and BOD and COD downstream of a coffee de-pulping factory for example.

The selection of test parameters will typically be dictated by the data needs and issues in the river basin. Because of inadequate equipment currently, laboratories in Kenya are only able to carry out tests for a handful of parameters.

As a minimum requirement, all Regional Labs should be capable of analysing for all the basic parameters and where not possible, special parameters can be tested for at the CWTL. The CWTL in Nairobi should be elevated to a reference Laboratory to carry out advanced water quality analysis, and should be manned by qualified, trained and experienced staff.

Water Quality Design Equipment

Once the design parameters have been identified, equipment for the analysis of the parameters need to be selected for each station. These have been generally described as either basic or advanced equipment. Basic equipment is used for routine water quality testing. Such equipment would include a pH meter, conductivity meter and UV-Vis spectrophotometer among others. Advanced equipment would include atomic absorption spectrophotometer and gas liquid chromatography and high-pressure liquid chromatography 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, dissolved oxygen meter, water still, water bath, hot plate, refrigerator, flame photometer, turbidimeter, desiccators, computers, printers, fuming hood, titrators, ovens, water bath, centrifuges, incubators, rotary kilns, muffles, comparators, multi-probes and many assorted items.

- Advanced water testing equipment: atomic absorption spectrophotometer, gas liquid chromatography, high pressure liquid chromatography, and inductively coupled plasma mass spectrophotometer.

6.8.3.5 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). 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. 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	
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		

No FEWS design has been proposed in the LVN basin as part of this consultancy. As part of the separate Nzoia FEWS project, 32 currently operational meteorological stations and an additional 7 surface water stations in Lake Victoria North will be upgraded.

6.8.4 Strategy

In order to comprehensively and systematically address the hydrometeorological monitoring issues and challenges in the LVN Basin, Table 6-28 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 6-28: 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 LVN Basin was assessed in terms of operational status, challenges, maintenance and equipment needs and data quality. Stations were prioritised for rehabilitation, for improvements and upgrades and for re-calibration. New station locations were identified based on pre-defined criteria and should be implemented according to the recommendations made in the Monitoring Network Design Report. A maintenance plan with budgets, timeframes and structured responsibilities should be prepared. The type of flow gauging stations to be installed should take into account that changes in river channel form due to floods often lead to changes in the rating curve, which requires re-calibration. Consideration should therefore also be given to fixed weirs (concrete structures) as opposed to rated sections.		
7.1.2	Monitoring: Dams and lakes	
The current instrumentation and level gauging network in dams and lakes in the LVN 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 LVN 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 LVN 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 LVN Basin was assessed in terms of operational status, challenges, maintenance and equipment needs and data quality. WRA stations were prioritised for rehabilitation where required, for improvements and for upgrades. New station locations were identified based on pre-defined criteria and should be implemented according to the recommendations made in the Monitoring Network Design Report. A maintenance plan with budgets, timeframes and structured responsibilities should be prepared. WRA's requirements as far as meteorological data needs in relation to water resources planning and management are concerned should be discussed with KMD and roles and responsibilities with regard to the design, upgrade and maintenance of the meteorological monitoring network should be clearly defined.		
7.1.6	Flood early warning monitoring network	
Under this Consultancy, the current flood early warning network in the LVN Basin was assessed in terms of operational status, challenges, maintenance and equipment needs and data quality. Stations were prioritised for rehabilitation where required, for improvements and for upgrades. New station locations were identified based on pre-defined criteria and should be implemented according to the recommendations made in the Monitoring Network Design Report. A maintenance plan with budgets, timeframes and structured responsibilities should be prepared. WRA's requirements as far as meteorological data needs in relation to flood management are concerned should be discussed with KMD and roles and responsibilities with regard to the design, upgrade and maintenance of the meteorological monitoring network should be clearly defined.		
7.1.7	Metering of bulk 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		

7	Key Strategic Area:	Hydrometeorological Monitoring
purposes.		
7.2	**Theme:**	**Improved data and information management**
7.2.1	Enhanced data management	
Data protocols and procedures with regard to data collection, transfer, capture, storage, quality control and dissemination should be evaluated, standardised and improved where necessary in accordance with international best practice. Technical and computing capacity for processing, analysis and reporting of data should be addressed and enhanced. The MIKE Info database application which was developed for the WRA under this Consultancy should be employed by WRA SRO, RO and HQ staff to capture, store, quality control and manage hydromet data in accordance with training provided.		
7.2.2	Improved water resources information management systems	
The knowledge base tools which were developed under this Consultancy should be employed by WRA SRO, RO and HQ staff to manage and disseminate information related to water resources planning and management taking into consideration the specific needs and challenges across different organisations and institutions as stakeholders.		
7.2.3	Improved forecasting systems	
The real-time system developed under this Consultancy for accessing, visualizing and analysing hydromet observations in near real-time should be employed to inform decision making with regard to flood forecasting and water resources management. Shared mandates and responsibilities should be discussed and agreed with KMD.		

6.9 Water Resources Development

6.9.1 Introduction

The purpose of this Water Resources Development Plan relates to the planning and development of large-scale water resources and related infrastructure which will support socio-economic development in the LVN Basin, while improving water availability and assurance of supply to current and projected future water users in the basin, and 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 meet the expected growth in water requirements with 2040 as the planning horizon. This included 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 project in Kenya. Proposed development interventions up to 2040 were therefore limited to what was considered reasonable from a financial and practical perspective and 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 facilitate an adaptive development strategy towards improving climate resilience.

6.9.2 Current water demands, resources development and supply reliability

Existing large water resources development in the LVN Basin mainly concern the supply of water to Eldoret, which involves three dams and an intra-basin transfer. These dams include Kipkarren Dam on the Kipkarren River, Ellegirini dam on the Sosiani River as well as Moiben (Chabara) Dam on the Moiben River. From Moiben Dam, there is a 60 km pipeline supplying Eldoret, and Iten Town along the way. Kesses Dam on the upper Mokong River supplies water to Kesses and Lessos urban centres. Several smaller dams and pans supply localised domestic, livestock and irrigation demand in the basin. There is an existing large-scale irrigation scheme (Dominion Farms) along the lower Yala River and another scheme (Bunyala) along the lower Nzoia River. Both of these schemes grow rice and are supplied via run-of-river abstractions. There are currently no large hydropower installations in the LVN Basin.

Ongoing water resources development projects in the basin include the Lower Nzoia Irrigation Scheme and the Upper Nzoia irrigation scheme. The Lower Nzoia scheme involves developing 4 000 ha on the left bank of the lower Nzoia River (Phase 1) and a further 3 800 ha (Phase 2) on the right (northern) bank of the Lower Nzoia River. The Upper Nzoia scheme involves the development of 7 000 ha on the banks of the Upper Nzoia River, upstream of the confluence with the Kipkarren river. Water for these schemes will be abstracted directly from the Nzoia River.

The WWDAs in the basin also have various ongoing local and regional water supply projects which typically involve abstraction works, treatment, storage and distribution. Examples supplying Kakamega, Eldoret and other towns include the Kakamega-Bungoma Bulk Water Supply Project, the Kipkarren Dam Water Supply Project, Kongoni, Sango and Lumino Dam projects, and Mwamba and Mukhuyu water projects.

Currently, the main demand for water in the LVN Basin is constituted by domestic and industrial water requirements, followed by irrigation and livestock. The total current water requirement (2018) in the LVN Basin equates to 286 MCM/a.

Table 6-29: Current (2018) water demands in the LVN Basin per main sector

Sector	Volume (MCM/a)
Irrigation	40
Domestic and Industrial	205
Livestock	29
Other	12
Total	286

6.9.3 Water resources development potential

The current (2018) total water demand in the LVN Basin (286 MCM/a) constitutes approximately 5% of the total water resources available for use (5 046 MCM/a).

The results of the surface water resources analysis which was undertaken for this Consultancy, estimated the total natural surface runoff in the LVN Basin as 5 622 MCM/a, equivalent to an average runoff coefficient of about 20%. The current surface water demand in the LVN Basin was estimated at 239 MCM/a, which is about 5% of the surface water available - taking into consideration the ecological reserve (Q95), calculated as 792 MCM/a.

The current groundwater use in the LVN Basin was estimated at 47 MCM/a, which is about 20% of the estimated sustainable groundwater yield (216 MCM/a).

It is important to realise that although the water balances might indicate that the total annual demand is less than the water resources available, supply deficits often occur during dry years and/or the dry season, when the demand exceeds availability of water in the rivers.

6.9.4 Future water requirements

The scenario analyses undertaken as part of this Consultancy, highlighted the imperative that water demand management be implemented in all urban areas, while irrigation efficiencies should also be improved throughout the LVN Basin. The future water requirements as presented below therefore incorporate a 20% reduction in major urban water requirements through water demand management, as well as improved irrigation efficiencies and reduced large-scale irrigation areas. Under this scenario, the total future (2040) water requirement in the LVN Basin was calculated at 1 884 MCM/a as detailed below. This represents a significant increase compared to the 2018 water demand in the basin.

Table 6-30: Projected future (2040) water demands in the LVN Basin per main sector

Sector	MCM/a
Irrigation	**1 100**
- Small scale / Private	542
- Large-scale	559
Domestic and Industrial	**673**
- Urban centres	124
- Basin-wide	549
Livestock	**95**
Other	**16**
Total	**1 884**

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 LVN Basin, up to 2040, is to address the expected growth in urban water demands, to ensure a reliable water availability for the proposed large-scale irrigation development as well as the significant expansion of small-scale irrigation in the basin, to improve existing and future water resources availability for smaller towns and basin-wide domestic and livestock water demands and to unlock the significant potential for socio-economic development through the construction of large, multi-purpose water resources development projects in the basin. This will necessitate the construction of small-scale and large-scale storage and regulation infrastructure, the expansion of existing and the development of new intra- and inter-basin transfers, and increased groundwater abstraction. In addition; water demand management will be required for both small and large-scale irrigation and for urban centres.

To meet the above objectives will require the following interventions:

- The existing transfer from Moiben Dam to Eldoret and Iten needs to be expanded, while a new dam would have to be constructed on the Sosiani River or the Kipkarren River to supply Eldoret.
- To meet the future domestic and industrial demands of other urban areas (e.g. Kakamega, Kapenguria, Moi's bridge, Matunda, Lumakanda, Kimilili, Bungoma, Chwele, Yala, Siyaya, Mbale), towns and rural areas as well as livestock and small-scale irrigation water demands within the remainder of the LVN Basin, additional storage should be provided through the implementation of already identified dams, the construction of additional dams and pans, and through the construction of more boreholes, while more intra-basin transfers might also be required.
- The proposed Nandi Forest Multipurpose Dam Project needs to be implemented to make use of the abundant water resources in the upper Yala River - to augment the future urban water supply to Kisumu, to generate hydropower and to enable large-scale irrigation development along the lower Oroba River in Lake Victoria South Basin. The dam would also be able to provide for the expected increase in domestic and small-scale irrigation water demands in the middle and lower Yala sub-basin, and possibly to augment the supply to Kakamega through an intra-basin transfer.
- The Lower and Upper Nzoia Dam projects, as well as Moi's Bridge and Kibolo Dam should be implemented to increase supply reliability to future large-scale irrigation development. An added benefit of these projects relates to the generation of hydropower and flood control.

Implementation and enforcement of the Q95 flow downstream of proposed dams and large-scale irrigation schemes to maintain the ecological health of the rivers. Table 6-31 summarises the proposed water resources developments and interventions in the LVN Basin with a planning horizon of 2040, while Figure 6-20 displays the locations of the existing and proposed large-scale water resources developments

Table 6-31: Water resources development plan for the LVN Basin

Item	2018	2040	Comment
Storage: Large dams (MCM)	24	1 104	2 new dams to supply growing urban centres 5 new multi-purpose dams to be used for large-scale irrigation supply, domestic supply, flood control and/or hydropower generation.
Storage: Small dams / pans (MCM)	8	125	To supply towns and local domestic and livestock demands and improve assurance of supply for small-scale and private irrigation
Groundwater use (MCM/a)	47	175	As conjunctive use with surface water storage
Irrigation area (ha)	3 629	138 000	The increase in irrigation area is due to new small-scale and large-scale schemes
Hydropower (MW)	0	91	As secondary benefit of three of the multi-purpose dams
Inter-basin transfer	0	189	Transfer from Nandi Forest Dam to LVS
Intra-basin transfer	10	17.5	Transfer from Moiben Dam to Eldoret

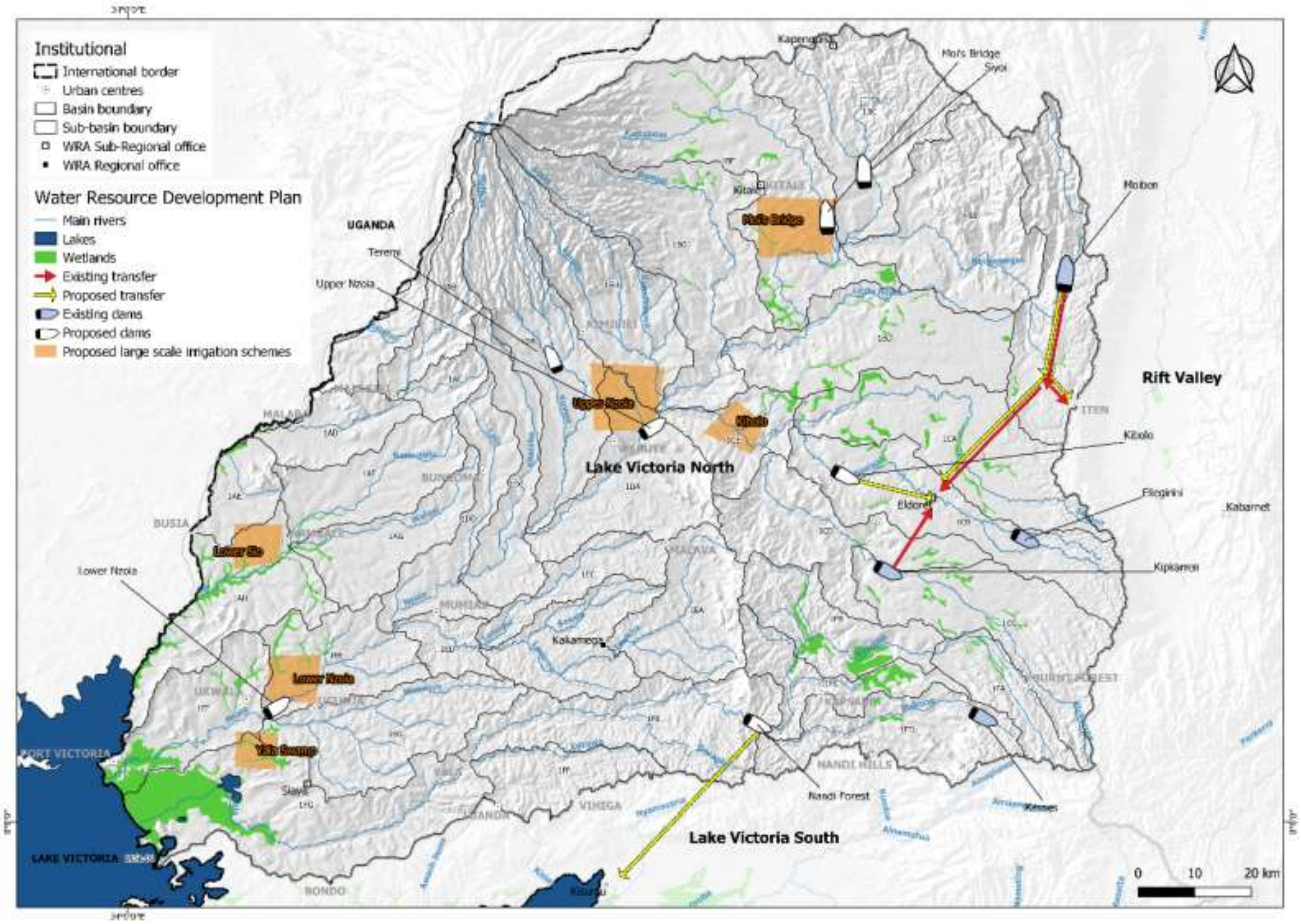

Figure 6-20: Proposed developments, dams and transfer schemes in the LVN Basin

6.9.5.2 Urban and town water supply

The current (2018) water demand of Eldoret (22 MCM/a) already exceeds the capacity of the existing water supply system and the analysis undertaken as part of this Consultancy has confirmed that the current annual assurance of supply is very low. This is not acceptable and is expected to deteriorate even further in future as the demand increases - even with water demand management. The existing schemes supplying water to Eldoret include Kipkarren, Ellegirini and Twin Rivers dams as well as a transfer from Moiben (Chabara) Dam. The expected future water demand in Eldoret, based on expected population growth, results in an estimated 2040 demand of 70 MCM/a (191 355 m^3/day) under full supply conditions. To achieve an acceptable reliability of supply to Eldoret in future, the transfer from Moiben Dam needs to be expanded to 17.5 MCM/a, while an additional dam needs to be constructed on either the Sosiani River or the Kipkarren River to further augment the supply to Eldoret by at least 20 MCM/a. Water could be transferred to Eldoret from the proposed Kibolo Dam on the lower Sosiani River. In addition, it is imperative that water demand management measures to reduce demand in Eldoret (aiming for a 20% reduction) are implemented as soon as possible.

In order to improve the existing assurance of supply and to meet the expected growth in water requirements of some of the other major towns in the LVN Basin, additional dams and regional water supply schemes will be required. These include Siyoi Dam (4 MCM) to supply Kapenguria and Teremi Dam (3 MCM) to supply surrounding towns such as Kimilili. The proposed Moi's Bridge Dam (214 MCM) on the upper Nzoia River will be primarily used for irrigation. However, it will also be able to supply surrounding towns e.g. Moi's Bridge, Matunda and even Kitale with water. Similarly, the proposed Nandi Forest Multipurpose Dam in the upper Yala Catchment will be able to augment the water supply to towns such as Kapsabet, Vihiga and Yala. It could also serve as a potential source of water supply to Kakamega in the adjacent Nzoia catchment.

6.9.5.3 Multipurpose Dam Projects

The proposed Nandi Forest Multipurpose Dam Project is a key project in the basin and entails a number of components, viz. a 220 MCM storage dam at the confluence of the Remonde (Kimondi) and Sirua (Mokong) Rivers in the Nandi Forest at an elevation of 1 800 masl, a 17.5 km tunnel which will divert about 6.6 m^3/s to Lake Victoria South Basin and a powerhouse at the foot of the Nayndo escarpment with an installed hydropower capacity of 50 MW. The flow will eventually be discharged into the Oroba River, from where the water will be abstracted for proposed irrigation of up to 16 500 ha in Miwani and Chemelil. Other potential benefits include water supply to Kapsabet, towns along the middle and lower Yala River e.g. Yala and Siaya and potentially to Kakamega in the adjacent Nzoia catchment as well as to Kisumu and other towns in the Lake Victoria South Basin.

Similarly, the proposed Lower and Upper Nzoia dam projects are key to the development in the basin. The Upper Nzoia Dam project is proposed on the Nzoia River upstream of the confluence with the Kipkarren River. The dam has been proposed with a capacity of 204 MCM. The purpose of the dam is primarily to irrigate the proposed Upper Nzoia irrigation scheme (24 000 ha); but owing to its large storage volume will also be able to offer flood control measures for the sub-basins downstream as well as generation of hydropower with a proposed installed capacity of 16 MW. The Lower Nzoia dam project is proposed upstream of the Wuoroya River confluence. The dam has a proposed storage volume of 395 MCM. The purpose of the dam is primarily to irrigate the proposed Lower Nzoia irrigation scheme (10 470 ha); but will also be able to offer flood control measures, especially given the proximity of flood prone areas along the lower Nzoia River; as well as generation of hydropower with a proposed installed capacity of 25 MW.

Under the sustainable scenario; both the Upper and Lower Nzoia Dam projects can supply the demand for irrigation with an assurance of supply above 90%, as well as generation of hydropower to capacity. Opportunities also exist to potentially develop transfer routes from these dams to supply towns in the Nzoia catchment and even in neighbouring catchments.

6.9.5.4 Hydropower development

Proposed hydropower development in the LVN Basin includes 16 MW to be installed at the Upper Nzoia Dam, 25 MW at Lower Nzoia Dam and 50 MW at the Nandi Forest Dam.

Preliminary analyses have shown that the generation of hydropower at these dams will be good given the large dam capacities, even if the dams are operated to meet irrigation and/or domestic demands as first priorities. On average, in the order of 300 GWh/a could be generated in total.

Although the development of a hydropower scheme at Webuye Falls in the middle Nzoia River catchment has been promoted for a number of years (10 MW), the construction of Upper Nzoia Dam with its associated 16 MW of installed hydropower is more feasible and will serve to stabilise local electricity supply in the basin.

6.9.5.5 Large-scale Irrigation development

It is evident that there is significant irrigation potential in the LVN Basin due to the abundance of water and the relatively limited water use at present. Within the Nzoia Basin, the total large-scale irrigation development which is proposed equals about 68 000 ha. Four storage dams would be required to ensure a high assurance of supply to some of the schemes, including Moi's Bridge Dam, Upper and Lower Nzoia Dams and Kibolo Dam. Some of the proposed storage dams also include opportunities for water supply to urban centres, hydropower generation and flood control. Run-of river schemes which are proposed include the Lower Sio Scheme (5 280 ha) along the lower Sio River and the Lower Yala River Scheme (3 680 ha) along the lower Yala River. Cost-benefit analyses have shown that careful consideration needs to be given to the types of crops cultivated in the proposed large-scale irrigation areas to ensure the financial viability of these schemes, especially those schemes which abstract directly from the rivers.

Table 6-32: Proposed large scale irrigation areas

Scheme name	Sustainably irrigated area (ha)
Lower Sio	5 280
Moi's bridge	15 840
Upper Nzoia	24 000
Kibolo	9 200
Lower Nzoia	10 470
Yala	3 680

6.9.6 Water to supply basin-wide domestic, irrigation and livestock demands

In order to meet future domestic and industrial demands in towns and rural settlements outside of the major urban centres, and to improve reliability of supply to existing and future small-scale irrigation, new or additional storage dams as well as local groundwater development should be implemented to provide carry-over storage and to meet supply deficits during dry years and/or the dry season when the demand exceeds availability of water in the rivers.

The water resources model, in conjunction with the groundwater availability assessment model, was used to determine surface water storage requirements and groundwater development per-sub-basin. The total additional storage volume (as local dams and pans) in the LVN Basin, which will be required to meet 2040 demands, amount to 117 MCM, while the total volume of additional groundwater development which will be required was estimated at 128 MCM/a. Table 6-33 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 6-33: Additional storage requirements and groundwater development to meet 2040 demands

Sub-basin	Groundwater (MCM/a)	Surface water storage (MCM)	Dams already identified for supplying domestic and livestock demands
1AA	0.0	0.8	
1AB	2.5	0.0	
1AC	0.4	0.0	
1AD	1.8	0.0	
1AE	1.5	0.0	
1AF	3.7	0.4	
1AG	2.6	0.9	
1AH	4.3	0.0	
1BB	4.7	0.0	
1BC	4.2	4.4	Siyoi Dam (4MCM)
1BD	4.1	0.0	
1BE	5.4	0.0	
1BG	4.1	19.1	
1BH	7.2	0.2	
1CA	2.1	0.0	
1CB	7.1	7.0	
1CC	3.0	0.0	
1CD	3.0	0.2	
1CE	1.5	0.0	
1DA	6.6	12.3	
1DB	8.7	5.4	Teremi Dam (3 MCM) could supply urban demands in 1DA, 1DB, 1DC and 1DD
1DC	1.6	3.4	
1EA	6.2	0.1	
1EB	3.9	31.0	
1EC	3.3	1.1	
1ED	0.2	0.0	
1EE	5.3	24.8	
1EF	0.0	0.0	
1EG	6.6	1.6	
1FA	1.2	0.0	
1FB	2.9	0.0	
1FC	1.5	3.4	
1FD	2.7	0.0	
1FE	7.2	0.5	
1FF	0.0	0.0	Shortfall in domestic/small scale irrigation to be supplied from Nandi Forest Dam
1FG	7.0	0.0	Shortfall in domestic/small scale irrigation to be supplied from Nandi Forest Dam
Total	**127.9**	**116.5**	

6.9.7 Project investment programme

The proposed water resources developments were grouped into schemes for implementation. 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). 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.

Note: The Nandi Forest Scheme, most of whose benefits are realised in the LVS Basin, was evaluated as part of the LVS Scheme Analysis.

Table 6-34 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 6-34: Scheme multi-criteria analysis - Decision matrix

			Lower Sio Irrigation (5,280ha)	Moi's Bridge Dam (214MCM) Moi's Bridge & Matunda Supply Moi's Bridge Irrigation (15,840ha)	Upper Nzoia Dam (204MCM) Hydropower (16MW) Upper Nzoia Irrigation (24,000ha) Flood control	Kibolo Dam (40MCM) Eldoret & Kibolo Supply Kibolo Irrigation (9,200ha)	Lower Nzoia Dam (395MCM) Hydropower (25MW) Lower Nzoia Irrigation (10,470ha) Flood control	Siyoi Dam (4MCM) Rural supply	Teremi Dam (3MCM) Rural Supply	Yala Irrigation (4,800ha)	Moiben-Eldoret Transfer (5MCM)
Footprint areas	Environmentally sensitive a	Area (km2)	0	0	65	23	0	0	0	0	0
	Carbon emissions dams	tons	0	20575	20176	2606	0	115	1140	0	0
	Carbon emissions LIR	tons	0	310390	449615	266352	0	0	0	0	0
Downstream areas	Floodplain area inundated	% change from baseline	-6.6	-34.1	-40.9	-97.1	-33.3	-11.5	-20.1	-33.3	0.0
	Ecological stress	Index (-5 to 0)	-5.0	-3.0	-5.0	-5.0	-5.0	-2.0	-2.0	-5.0	0.0
	Wet duration	% change from baseline	-22.0	-51.5	-49.3	-61.2	-52.6	-18.3	-34.2	-58.8	0.0
Water quality	Phytoplankton growth pote	Average growth potential %	0.00	96.25	70.03	69.26	62.81	6.17	0.00	0.00	0.00
	Aquatic macrophytes growt	Index (-5 to 0)	-1.00	-1.00	-2.00	-5.00	-4.00	0.00	0.00	0.00	0.00
'ater availabili	Riparian users	% change from baseline	-79.8	-42.7	-79.3	-71.0	-98.4	-21.2	-24.5	-97.0	0.0
nity health an	Malaria endemicity	Malaria endemicity (km2)	10.6	24.7	33.7	13.1	35.4	0.6	5.7	9.8	0.0
Food security and livelihoods	Formal irrigation schemes	Area (km2)	52.8	158.4	240.0	92.0	104.7	0.0	0.0	48.0	0.0
	Impact on recession agricul	% change from baseline	-6.6	-34.1	-40.9	-97.1	-33.3	-11.5	-20.1	-33.3	0.0
	Fish production (dams/lake	Tons/annum	0.0	21.2	94.5	9.0	257.2	1.1	5.2	0.0	0.0
	Change in fish productivity	% change from baseline	-22.0	-51.5	-49.3	-61.2	-52.6	-18.3	-34.2	-58.8	0.0
	Loss of productive land	Area (km2)	27.1	96.3	119.3	55.8	75.1	0.0	0.2	21.3	0.00
	Loss of natural resources	Area (km2)	0.0	0.0	64.8	23.3	0.0	0.0	0.1	0.0	0.00
Displacement	Physical displacement	Number people	15621	52621	67183	35608	40050	11	119	7502	0.00
Energy	Avg energy	GWh/annum	0.00	0.00	61.38	0.00	113.77	0.00	0.00	0.00	0.00
ood productio	Crop production (formal irr	Ton/annum	25721	147259	124328	69314	75850	0	0	22410	0.00
	Fish production (dams/lake	Ton/annum	0.00	21.15	94.54	8.97	257.16	1.09	5.23	0.00	0.00
Employment	Employment formal irrigati	Number people	13200	39600	60000	23000	26175	0	0	12000	0.00
	Employment hydropower	Number people	0	0	153	0	284	0	0	0	0.00
Sediment	Volume of dam silted	Index (-5 to 0)	0.00	-3.00	-4.00	-5.00	-4.00	-5.00	-5.00	0.00	0.00
Financial	BCR	Ratio	0.74	1.36	1.04	2.09	1.07	2.39	5.55	0.21	1.33
Flood control	Flood control potential	Ratio (Dam capacity/MAR)	0.00	1.95	0.17	0.36	0.12	0.03	0.02	0.00	0.00
ater productiv	Water productivity formal i	Million USD/MCM	0.29	2.18	1.92	2.86	2.96	0.00	0.00	1.98	0.00
	Water productivity hydropc	Million USD/MCM	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00
Preparedness for implementation		5 Ready for implementation, 0	0.00	0.00	4.00	0.00	4.00	0.00	3.00	1.00	4.00
Public perception/buy-in		5 Full public support, -5 Very cc	2.00	1.00	1.00	1.00	1.00	1.00	1.00	-3.00	3.00
Scale of impact		5 Basin wide and beyond, 1 Ver	2.00	2.00	4.00	1.00	4.00	1.00	1.00	2.00	2.00
Transboundary and trans-county implicati		5 Beneficial, -5 Detrimental	-1.00	-1.00	3.00	-1.00	3.00	-1.00	-1.00	-1.00	-1.00
Potential downstream environmental imp		5 Beneficial, -5 Detrimental	0.00	-2.00	-3.00	-1.00	-2.00	-1.00	1.00	-1.00	-1.00
Fatal flaw		0 None, -5 Flawed	0.00	0.00	-1.00	0.00	-1.00	0.00	0.00	-1.00	0.00

The outcome of the multi-criteria analysis provided a ranking of future schemes as shown in Table 6-35

Table 6-35: Ranked water resources development schemes

1	Lower Nzoia Scheme	Lower Nzoia Dam (395 MCM)
		Hydropower (25 MW)
		Lower Nzoia Irrigation (10 470 ha)
		Flood control
2	Moiben-Eldoret Scheme	Moiben-Eldoret transfer (5 MCM/a
3	Moi's Bridge Scheme	Moi's Bridge Dam (214 MCM)
		Water supply
		Moi's Bridge Irrigation (15 840 ha)
4	Teremi Scheme	Teremi Dam (3 MCM)
		Water supply
5	Upper Nzoia Scheme	Upper Nzoia Dam (204 MCM)
		Hydropower (16 MW)
		Upper Nzoia Irrigation (24 000 ha)
		Flood control
6	Lower Sio Scheme	Lower Sio Irrigation (5 280 ha)
7	Siyoi Scheme	Siyoi Dam (4 MCM)
		Water supply
8	Yala Scheme	Yala Irrigation (3 680 ha)
9	Kibolo Scheme	Kibolo Dam (40 MCM)
		Water supply
		Kibolo Irrigation (9 200 ha)

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 6-36) was developed which provides information on the timing / phasing of schemes and associated capital, operations and maintenance expenditure from 2020 to 2040.

Table 6-36: LVN 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				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
Intra-basin Transfers	**Capacity**		**Water Supply**	**Hydropower**	**Flood Control**	**LS Irrigation**	**7**	**45**																					
Moiben Dam to Eldoret Transfer Expansion	7.5 MCM	6.1	💧				7	45	3	3	23	23																	
Inter-basin Transfers							**84**	**560**																					
Nandi Forest Multipurpose Dam, Transfer to LVS and HP	220 MCM, 189 MCM/a, 50 MW	94	💧	💧		💧	84	560	Cost included in Lake Victoria South Basin Plan																				
Other Water Resources Developments							**201**	**1343**																					
Siyoi Dam	4 MCM	16	💧				5	36					5	18	18														
Kibolo Dam	40 MCM	27	💧			💧	21	140							11	11	47	47	47										
Teremi Dam	3 MCM	17	💧				5	30				5	15	15															
Moi's Bridge Dam	214 MCM	49	💧			💧	38	253	19	19	84	84	84																
Upper Nzoia Dam (Site 34B)	204 MCM; 16 MW	194		💧		💧	36	241						18	18	121	121												
Lower Nzoia Dam (Site 42A)	395 MCM; 25 MW	540		💧		💧	50	335																		50	168	168	
Dams and pans	117 MCM	-	💧				37	247	19	19	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
Groundwater development (Boreholes)	128 MCM/a	-	💧				9	61	5	5	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Large Scale Irrigation Schemes (excl. dams)							**216**	**1438**																					
Lower Sio	5 280 ha	-				💧	20	130									20	43	43	43									
Yala Swamp	3 680 ha	-				💧	14	91													7	7	30	30	30				
Upper Nzoia	24 000 ha	-				💧	71	473					35	35	118	118	118	118											
Lower Nzoia	10 470 ha	-				💧	31	206	31	34	34	34														34	34	34	
Moi's Bridge	15 840 ha	-				💧	47	312					23	23	104	104	104												
Kibolo	9 200 ha	-				💧	34	227																	17	17	76	76	76
								O&M Cost	0.0	0.0	3.9	7.9	10.8	12.0	18.4	27.4	37.5	43.1	45.8	47.3	47.7	48.1	49.2	50.4	51.6	52.8	60.2	67.5	69.8
								Total Annual Cost (USD Million)	**76**	**80**	**161**	**170**	**191**	**138**	**303**	**397**	**463**	**268**	**152**	**107**	**71**	**71**	**96**	**97**	**115**	**171**	**354**	**361**	**162**

6.9.8 Strategy

In order to comprehensively and systematically address the water resources development challenges in the LVN Basin, Table 6-37 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 6-37: 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 take into account the reserve and RQOs.		
8.2	**Theme:**	**Water Resources Planning**
8.2.1	Updated planning for bulk water resources development	
The existing large-scale, integrated bulk water supply systems (storage, conveyance, treatment) which supply Eldoret as well as regional water supply schemes should be optimised and expanded in line with water demand projections. Enough lead time should be allowed for the implementation of the future phases. The conjunctive use of surface and groundwater to meet urban and rural demands should be investigated. The existing inter- and intra-basin transfers within the LVN Basin should be assessed i.t.o. water resource sustainability and/or infrastructure capacity constraints. Enough lead time should be allowed for the implementation of the future phases.		
8.3	**Theme:**	**Water storage and conveyance**
8.3.1	Implement large dams: complete relevant feasibility and impact studies and plans; design and construct	
To utilise the available water resources in the basin and to improve the reliability of supply will require significant storage of water during the wet seasons – specifically as part of the water supply systems to Eldoret and for the large-scale irrigation schemes being planned. The proposed dams should be investigated in more detail and implemented in line with the investment plan.		
8.3.2	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.		
8.3.2	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		

8.	Key Strategic Area	Water resources development
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		
8.3.3	Provide other types of storage	
Sand dams, artificial recharge and water harvesting should be investigated and implemented where feasible to provide storage of water during the wet season for use during the dry season, especially in areas without reliable river flows.		
8.3.4	Upgrade existing / Construct new water transfers	
The LVN Basin has limited inter and intra-basin transfers. Proposed expansion of these transfers should be implemented timeously to ensure reliability of supply in line with future water demands.		
8.4	**Theme:**	**Groundwater development**
8.4.1	Develop groundwater resources	
Implement under Strategic Theme 3.2		
8.5	**Theme:**	**Hydropower development**
8.5.1	Large scale hydropower development	
Whereas the primary purpose of the proposed large dams in the LVN Basin, due to the high water demands in the basin, will be urban supply and/or irrigation, the dams can also be used for hydropower generation. The possibility of retrofitting existing large dams with hydroelectric power generation capabilities should also be investigated.		
8.5.2	Small scale hydropower development	
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.		
8.6	**Theme:**	**Water for agriculture**
8.6.1	Large scale irrigation development: Develop new / expand existing irrigation schemes. Limit to max sustainable areas	
Although some large-scale irrigation development can be accommodated in the LVN Basin, the extent of the originally proposed developments should be scaled down in light of constraints associated with water availability and assurance of supply.		
8.6.2	Promote water conservation in irrigation	
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.		
8.6.5	Improved water supply reliability at local scale through construction of small dams / pans and/or development of local groundwater resources to provide carry-over storage during the dry season	
Implement under Strategies 8.3.2 and 3.2.2		
8.7	**Theme:**	**Water based tourism and recreation**
8.7.1	Promote water-based tourism and recreation	
Adventure tourism, leisure activities, recreational activities and resorts should be promoted in the vicinity of large dams, especially at dams situated close to major cities.		
8.8	**Theme:**	**Non-conventional water resources**
8.8.1	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	
The feasibility of re-use as an alternative and/or integrated supply option to Eldoret should be evaluated as part of a detailed feasibility study.		
8.8.4	Water Conservation and Demand Management	
WCDM should be implemented as an immediate option to reduce water demand in Eldoret.		
8.9	**Theme:**	**Water resources systems operation**
8.9.1	Optimise system operating rules	
The operation of the bulk water systems supplying Eldoret should be integrated and optimised, taking into consideration new dams and transfers.		
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 LVN Basin to inform decision with regard to curtailment of water use and the need for/phasing of new augmentation schemes.		

6.10 Institutional Strengthening and Enabling Environment

6.10.1 Introduction

In effect, the key aspect of any institutional reform process is to find an appropriate balance between operational functionality and the need for effective oversight and governance. Despite the various efforts that have been targeted at improving the institutional framework in the LVN Basin, there remains 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 significant, 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, given the high population density of the LVN Basin, its importance 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 LVN Basin, the need to ensure that this takes place in a sustainable manner will become increasingly imperative. The shifts towards strengthening the regulatory role of the Water Resources Authority (WRA), aligned to the Water Act 2016, are important and will have an impact on the institutional roles and responsibilities within the LVN 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 LVN 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 LVN 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 LVN Basin, there is a dire need to put in place dynamic measures to prevent the BWRCs from running into similar challenges as the CAACs and to ensure that the guidance provided by the BWRCs is considered and translated into implementable actions wherever possible. WRA is currently exploring options that will ensure better operational functionality of the BWRCs given the current setting.

Additionally, the Constitution of Kenya 2010 introduced the County Governments (CGs) into the water resources management space with a mandate on catchment conservation in their respective jurisdictions. There are teething challenges on how to better coordinate water resource management efforts cohesively between WRA and the Counties. These challenges include inadequate awareness of the CGs roles in catchment conservation and what this means for WRA in the overall regulation of management and use of the resource. It is anticipated that the BWRCs will provide a platform to ensure better coordination between WRA and the CGs, especially as the CGs are members of the BWRCs.

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 LVN Basin, but predominantly there are challenges with capacity of the WRUAs along with financing gaps for the WRUAs that affect their sustainability.

Lastly, noting the importance of inter-sectoral approaches to support improved water resources management and development, there is currently insufficient partnerships and stakeholder engagement to foster these integrated approaches.

6.10.3 Strategies

The Institutional Strengthening Plan for the LVN Basin is aligned with the overall vision for the Basin and focusses on becoming a model basin in collaborative catchment management, protection, conservation and control; equitably allocating good quality water for sustainable socio-economic development and preservation of ecosystems 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 LVN 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 Key Strategic Areas and Strategic Themes to achieve this objective and provides specific strategies under each theme.

Table 6-38: Strategic Framework – Institutional Strengthening

9	**Key Strategic Area:**	**Strengthen the Institutional Frameworks**
9.1	**Theme:**	**Promote improved and sustainable catchment management**
9.1.1	Strengthen WRA's regulatory role	
The Water Act 2016, aligned to the Constitution of Kenya (2010), provides for the strengthening of the regulatory functioning of the WRA. Towards this end there is a need to separate out the regulatory and management functions of the Authority and provide different reporting lines for these differing functions. This will enable WRA to focus on its regulatory functions and in the longer-term work towards the delegation of management and operational functions to the BWRCs when they are established, the County Governments and WRUAs. Acknowledging that the process of establishing the BWRCs may be lengthy, and the need to strengthen the institutional capacity of the Counties and WRUAs will require time, there is need for WRA to establish interim modalities to bridge this gap and to ensure a smooth transition. This will require an optimisation of the ROs and the SROs supported by a capacity building drive. 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 several 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.		
9.1.2	Strengthen BWRCs	
The BWRCs have more representation from different stakeholders in the basin and will thus enable improved engagement across a wider range of stakeholders as well as inter-sectoral issues. There are lessons to be learned from the former 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 resource management, but also a range of skills to enable sound governance.		
9.1.3	Strengthen county governments engagements in WRM in the basin	
The introduction of county governments into the management frameworks provides an opportunity for improved management at local levels. The key role of county governments to support localised socio-economic development is crucial and therefore there is a very important need to align planning instruments to ensure that the sustainable development of water resources does underpin this developmental agenda. To date, engagements with the county governments are unstructured, partly borne from a lack of clarity as to institutional mandates, roles and responsibilities. WRA needs to clarify these roles and responsibilities and to introduce more structured strategic planning and operational engagement. The BWRCs will provide a platform for structured engagements with the county governments, at a governance and strategic level, however, there is need to explore more ways of engaging with the counties at the basin and sub-basin level for day to day issues that may arise. Training and capacity building 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.		
9.1.4	Strengthen WRUAs	

9	Key Strategic Area:	Strengthen the Institutional Frameworks
WRUAs play an important role in sub-catchment management, but there are a range of institutional and capacity challenges that require resolution to enable WRUAs to be more effective. The institutional linkages between county governments and the WRUAs are important and ways to improve and strengthen these will be an important part of improving localised operational water resource management and development. WRUAs have had sustainability issues and exploring approaches that enhance their livelihoods while promoting catchment management will be an added advantage. More importantly, a more sustainable financing approach for WRUAs' activities is most needed to ensure financial sustainability of WRUAs. There is a need to provide training and capacity building to the members periodically on matters relating to WRM. Equally, improvements in information dissemination are needed to ensure community members can understand the message being passed across.		
9.2	**Theme: Guidelines, codes 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 6-39: 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 resource 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	Enhancement 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 resource management and development has increasingly been recognised. This will support the development of more aligned planning approaches to both management and development, as well as provide additional capacity support when and where appropriate. This could also introduce efficiencies that adjust institutional capacity requirements. To this end, there is a need for the development of a partnership framework that provides the basis for the approach towards partnerships. This will then be implemented through the ongoing development of partnership arrangements over time.		
10.1.4	Strengthen stakeholder engagement	
The importance of stakeholder engagement cannot be over emphasised. The improvement in the development of		

10	Key Strategic Area:	Strengthen the enabling environment to support institutions
water resource management and development solutions, the improvement in alignment of operational activities and the development of a sense of ownership of the management regime all provide the basis for more robust and sustainable management. There is a clear understanding that there is a need to improve upon the levels of stakeholder engagement and this cuts across the various institutions that play a role in water resource management and development. In this regard, the development of an agreed upon basin-wide framework for engagement is a key first step, supported then by the implementation of this framework. A key element of this, will include improving the functionality of the existing forum.		
10.1.5	Improved research	
Noting the impacts that climate variability and climate change will have upon the water resources of the LVN basin, together with the need to support ongoing development, there will be an ongoing need to develop innovative solutions to the ongoing challenges of water resource management and development. Research towards finding these innovative approaches and technologies will become increasingly important. Developing the network of supporting research institutions will be an important step together with providing the appropriate communication and engagement channels that enables exchange of information. A key challenge has always been ensuring that the research agenda is supportive of the challenges that the sector is experiencing, and so the need to ensure ongoing exchange is critical.		
10.1.6	Innovative financing	
Ensuring adequate financial resources to support integrated water resources management at the basin level is a significant challenge evidenced by the financial hurdles for catchment-based institutions such as the WRA ROs and SROs, the former CAACs and forums. Embracing innovative internal and external resource mobilisation strategies is needed. This needs to factor in new entities in the sector such as the County Governments and other water sector institutions. The private sector provides opportunities for innovative financing for water resources management and should therefore be explored to complement the budget allocated for water resources management from the national fiscus. Internal and external resource mobilisation strategies will be implemented concurrently because of the very crucial role financing plays as a key enabler for IWRM implementation.		

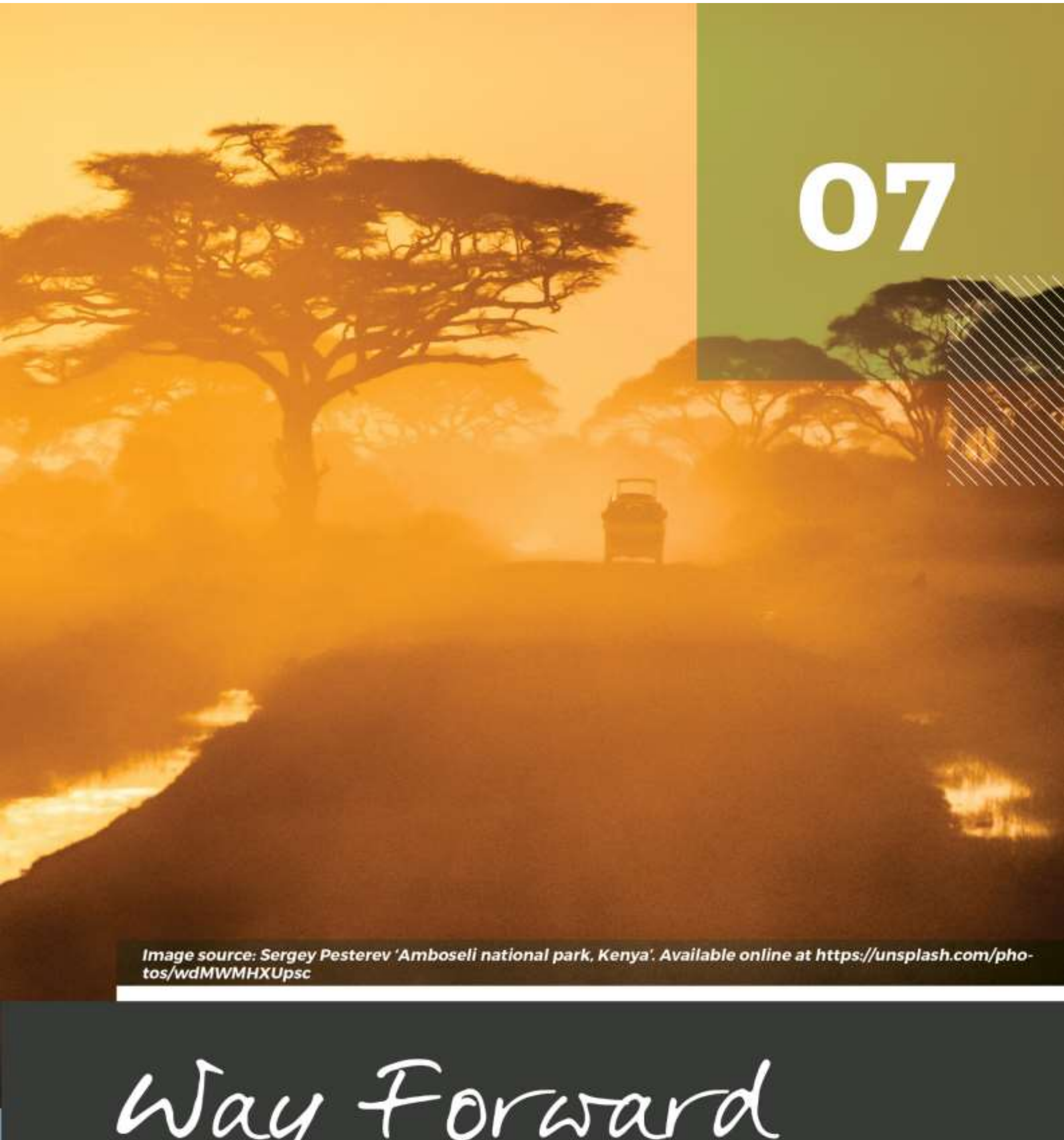

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Image source: Sergey Pesterev 'Amboseli national park, Kenya'. Available online at https://unsplash.com/photos/wdMWMHXUpsc

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 need 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 LVN Basin relate to the assurance of supply for the planned developments and growth in the basin, and water quality issues in some areas, which are exacerbated by various management and institutional challenges. The rationale for the development of this Basin Plan was to assess whether the basin’s water resources are sufficient to meet the expected growth in water requirements with 2040 as the planning horizon. These water requirements refer not only to those in the LVN Basin but include the volume of water to be transferred from the LVN Basin to the LVS Basin.

The essence of the proposed water resources development plan for the LVN Basin, up to 2040, is to address the expected growth in urban water demands, to ensure a reliable water availability for the proposed large-scale irrigation development in the 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 the significant potential for socio-economic development through the construction of large, multi-purpose water resources development projects in the basin. This will necessitate the construction of small-scale and large-scale storage and regulation infrastructure, the expansion of existing and the development of new intra- and inter-basin transfers, and increased groundwater abstraction. In addition, water demand management will be required for both small and large-scale irrigation and for urban centres.

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

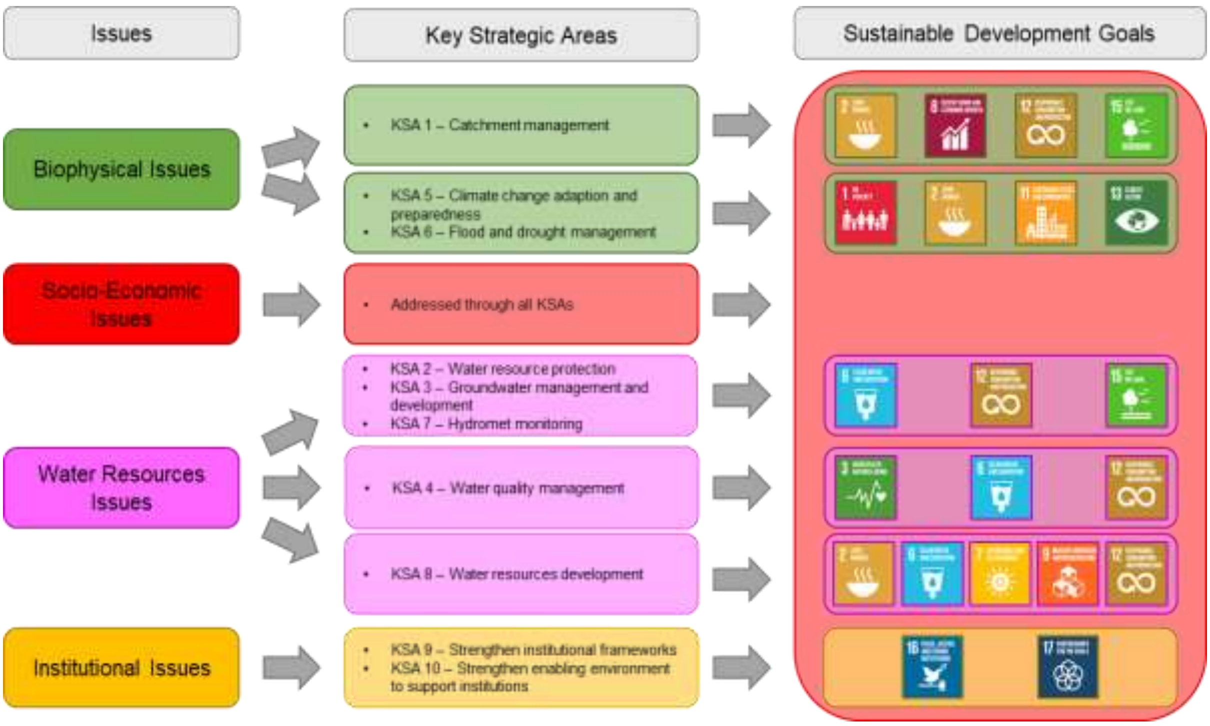

Figure 7-1: Integration of the SDGs into the LVN Basin Plan

7.3.2 Linkages with other plans

This LVN Basin Plan provides a vision and framework for the development and management of the water and related land resources of the LVN Basin. Essentially it reinforces the LVN 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 (Kerio Valley Development Authority and Lake Basin Development Authority) as well as the Water Works Development Agencies (LVN 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 LVN 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 sections deal with each of these steps.

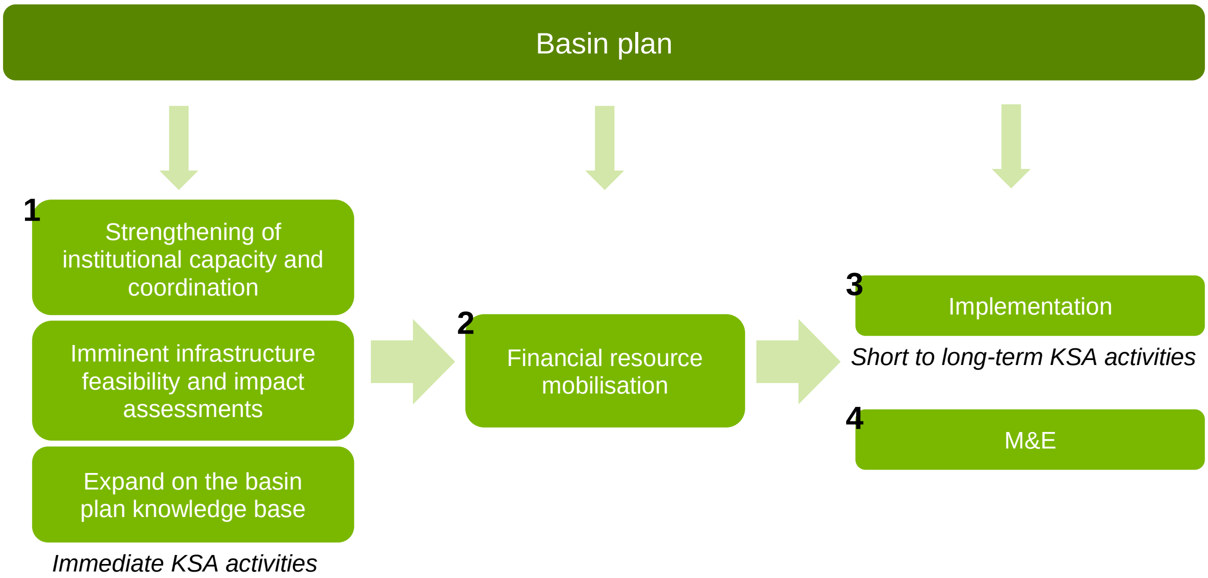

Figure 7-2: Roadmap for implementation of the Basin Plan

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 LVN Basin, feasibility studies should begin immediately for the Moiben Dam to Eldoret Transfer Scheme and Moi's Bridge Dam, while the Upper Nzoia Dam should be investigated in more detail. In addition, relevant studies and designs should start as soon as possible for the development of groundwater and smaller dams and pans to address the needs of water users at a local scale. 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' timeframe 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 inexpensive 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		**6 %**
	- 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 LVN Basin (conducted prior to Reserve and RQO determination) - Determine the Reserve for prioritised water resources in the LVN Basin (note Reserve required for RQOs) - Determine the Resource Quality Objectives for prioritised water resources in the LVN Basin	

KSA	Priority activities (immediate)	% of total KSA budget
KSA 3 Groundwater management		**12 %**
-	Implement aquifer mapping and groundwater modelling across the LVN basin	
-	Complete aquifer classification	
-	Improve estimates of sustainable groundwater yield in priority areas using advanced techniques	
-	Prepare groundwater abstraction plan and undertake groundwater abstraction and water quality survey	
-	Undertake groundwater balance to determine sustainable yield available	
-	For each aquifer in the basin, develop Allocation Plan and disaggregate to sub-basins	
KSA 4 Water quality management		**2 %**
-	Implement national water quality monitoring programme in the LVN 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 LVN Basin for piloting biomonitoring and undertake pilot studies	
-	Compile an inventory of surface water pollution sources	
-	Upgrade central laboratories in the Basin to support the national water quality monitoring programme. These include, inter alia, the recruitment of more technical staff, equipping the laboratory and stocking it with reagents, procuring Field Testing Kits, and operationalising the LIMS in the central laboratory.	
-	All historical and new water quality data collected by WRA in the LVN basin stored in Mike Info	
-	Advocate for alignment of strategies to serve a common purpose of rehabilitating urban rivers and streams in the LVN Basin	
-	Establish a coordination and cooperation mechanism to ensure there is alignment of actions to address water pollution management in the LVN Basin.	
-	Embed water quality management activities related to domestic water use, crop and livestock production in SCMPs	
KSA 5 Climate change adaptation and preparedness		**13 %**
-	Use climate change databases, historical data and analytical tools (ISC and other) to identify trends and quantify climate change impacts on surface water and groundwater availability at relevant temporal and spatial scales: rainfall intensity; frequency of extreme rainfall events; rainfall seasonality; inter-and intra-annual rainfall variability; rainfall-runoff relationships; stream flow; groundwater recharge; irrigation demands	
-	Assess potential social impacts: flooding; droughts; human conflict; migration; vulnerable groups; ocean acidification; agriculture; food production	
-	Assess potential social impacts: flooding; droughts; human conflict; migration; vulnerable groups; ocean acidification; agriculture; food production	
-	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		**14 %**
-	Government institutions/agencies and other stakeholders with partnership roles in flood management will form the LVN Basin Flood Response Forum (FRF) under the auspices of the KMD to integrate all flood-relevant resource mobilisations and related interventions in the LVN Basin.	
-	Establish a Secretariat for the LVN Basin FRF with accommodation in the WRA Regional Office.	
-	Develop appropriate SOPs for the LVN Basin FRF.	
-	Organisational alignment/ collaboration: The LVN Basin Flood Response Forum (FRF) will expand organisational capacity in the LVN 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 LVN Basin Drought Response Forum with accommodation in the Offices of one of the drought-prone counties.	
-	The NDMA issues regular Drought Early Warning Bulletins for ASAL counties. The LVN Basin does not have any ASAL counties, but sub-county Bulletins will be arranged for drought-vulnerable areas in the Trans Nzoia and Uasin Gishu counties.	
-	Organisational alignment/ collaboration: LVN Basin Drought Response Forum will expand organisational capacity in the Basin by aligning the drought response roles and responsibilities of the government institutions/ agencies, International Relief Aid Agencies, Kenya Red Cross, NGOs and other stakeholders with partnership roles in drought management.	

KSA	Priority activities (immediate)	% of total KSA budget
KSA 7 Hydrometeorological Monitoring		**7 %**
- 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.		
KSA 8 Water Resources Development		**4 %**
- Implement 1 large dam (Moi's Bridge Dam): 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 - Phased design and construction of identified small dams / pans: 117 MCM total storage - Moiben Dam to Eldoret Transfer Expansion (7.5 MCM/a) - Investigate possibility of retrofitting existing dams with hydroelectric power generation capabilities. - Assess potential for the development of small-scale hydropower plants, especially in the upper LVN Basin - Implement 1 large-scale irrigation scheme (Lower Nzoia)		
KSA 9 Strengthen the Institutional Frameworks		**41 %**
- Separate out regulatory and management functions of the Authority and provide different reporting lines for these. Parallel improvement and strengthening of the regulatory approaches utilised by the WRA. - Updating WRA's standards, policies and regulations in line with the WA2016 - 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 for county governments. - Undertake training and capacity building for the new legislative instruments - 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 - Complete the development of a National Policy for the Protection of Groundwater with all key stakeholders involved. - Complete the development of a National Policy for the Protection of Groundwater with all key stakeholders involved. - Develop / Update Guidelines for surface and groundwater - Relevant Codes of Practice for Water Resources Planning and Management - Develop / Update National Manuals relevant to WRPM		

KSA	Priority activities (immediate)	% of total KSA budget
KSA 10 Strengthen the enabling environment to support institutions		21 %
- Develop a partnerships framework - Identify potential partners - Undertake stakeholder consultations - Undertake awareness creation and information dissemination activities - Strengthen existing partnerships, particularly on a local level - Develop a basin-wide stakeholder engagement framework - Undertake stakeholder analysis - 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 LVN 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 monitoring and evaluation (M&E) include the selection of M&E indicators and ensuring feedback of the results into the decision-making and implementation processes. In simple terms, M&E is necessary to ensure that implementation of the Basin Plan takes place with the intended results and impacts. 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 the plan implementation. It is essential that there is full consistency between the goals, objectives, strategies, activities and the chosen indicators. The M&E should focus on the implementation issues (are activities implemented according to planning) and the results (e.g. is water used more efficiently?). M&E will aid the successful implementation of the Basin Plan by ensuring that targets and goals set out in the Basin Plan are achieved and that problems regarding implementation are detected early and addressed. Good targets and indicators, stakeholder participation in monitoring process as well as good feedback mechanisms are essential for effective M&E.

7.4.4.2 Targets and indicators

Monitoring of the LVN Basin Plan and achievements should be done based on the Implementation Plan (**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 stepwise 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**	5.1	34.3	29.7	22.1	**91**
	– 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**	10.0	29.3	18.7	28.0	**86**
	– Groundwater resource assessment, allocation and regulation					
	– Groundwater development					
	– Groundwater asset management					
	– Conservation and protection of groundwater					
KSA 4	**Water quality management**	3.8	27.7	80.9	107.7	**220**
	– 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**	4.4	11.4	11.1	7.9	**35**
	– 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** – Flood management – Drought management	6.9	32.8	4.0	6.8	**51**
KSA 7	**Hydromet monitoring** – Improved monitoring network – Improved information management	2.0	12.1	8.5	5.0	**28**
KSA 8	**Water resources development** – Surface water resource assessment, allocation and regulation – Water resources planning – Water storage and conveyance – Groundwater development – Hydropower development – Water for agriculture – Water based tourism and recreation – Non-conventional water resources – Water resources systems operation	130	681	1 841	928	**3 580**
KSA 9	**Strengthen Institutional frameworks** – Promote improved and sustainable catchment management – Guidelines, codes of practice and manuals	5.0	2.6	2.7	2.0	**12**
KSA 10	**Strengthen enabling environment to support institutions** – Develop institutional capacities to support improved IWRM&D	5.3	9.0	4.4	6.0	**25**
Total		**173**	**841**	**2 003**	**1 115**	**4 132**

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 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, 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	Improved understanding of water conservation and management; Reduction in water use; Increased water storage and water availability in the sub-	Immediate	WRA MoWSI KWTA MOALF	BWRC WWDA	WRUA CG	CBO

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
		protection and infiltration	catchment; Increased groundwater recharge					
		Promote catchment-based water conservation and management principles with relevant MDAs through training, forums and conferences.	Level of awareness regarding water conservation and management; Number trainings/forums/conferences held	Short-term	WRA MoWSI MoALF KWTA	BWRC WWDA	CG WRUA	CBO KALRO

An example associated M&E sheet is shown in **Table 7-5**.

Table 7-5: Monitoring and Evaluation example sheet

Key Strategic Area 1:		Catchment Management				
Strategic Objective:		To ensure integrated and sustainable water, land and natural resources management practices				
Strategic Theme 1.1:		Rehabilitation of degraded environments				
Theme priority:		Important				
Strategy		Activities	Indicators (M&E)	Scoring	Notes/Progress	Date
1.2.1	Promote water conservation and management at catchment level.	Embed catchment-based water conservation and management activities related to crop and livestock production in SCMPs: E.g. improved water use efficiency; water harvesting and storage; groundwater protection and infiltration	Improved understanding of water conservation and management	No. of programs	Note on the improved understanding	Capture date
			Reduction in water use	Water use	Note on the water use reductions related to individual activities	Capture date
			Increased water storage and water availability in the sub-catchment	Water availability	Note on activities related to increased water storage and water availability	Capture date
			Increased groundwater recharge	Groundwater use	Notes on activities related to groundwater recharge	Capture date
		Promote catchment-based water conservation and management principles with relevant MDAs through training, forums and conferences.	Level of awareness regarding water conservation and management;	No. of programs	Note on the improved awareness	Capture date
			Number trainings/forums/conferences held	No. of training/forum /conference	Notes on improved awareness	Capture date

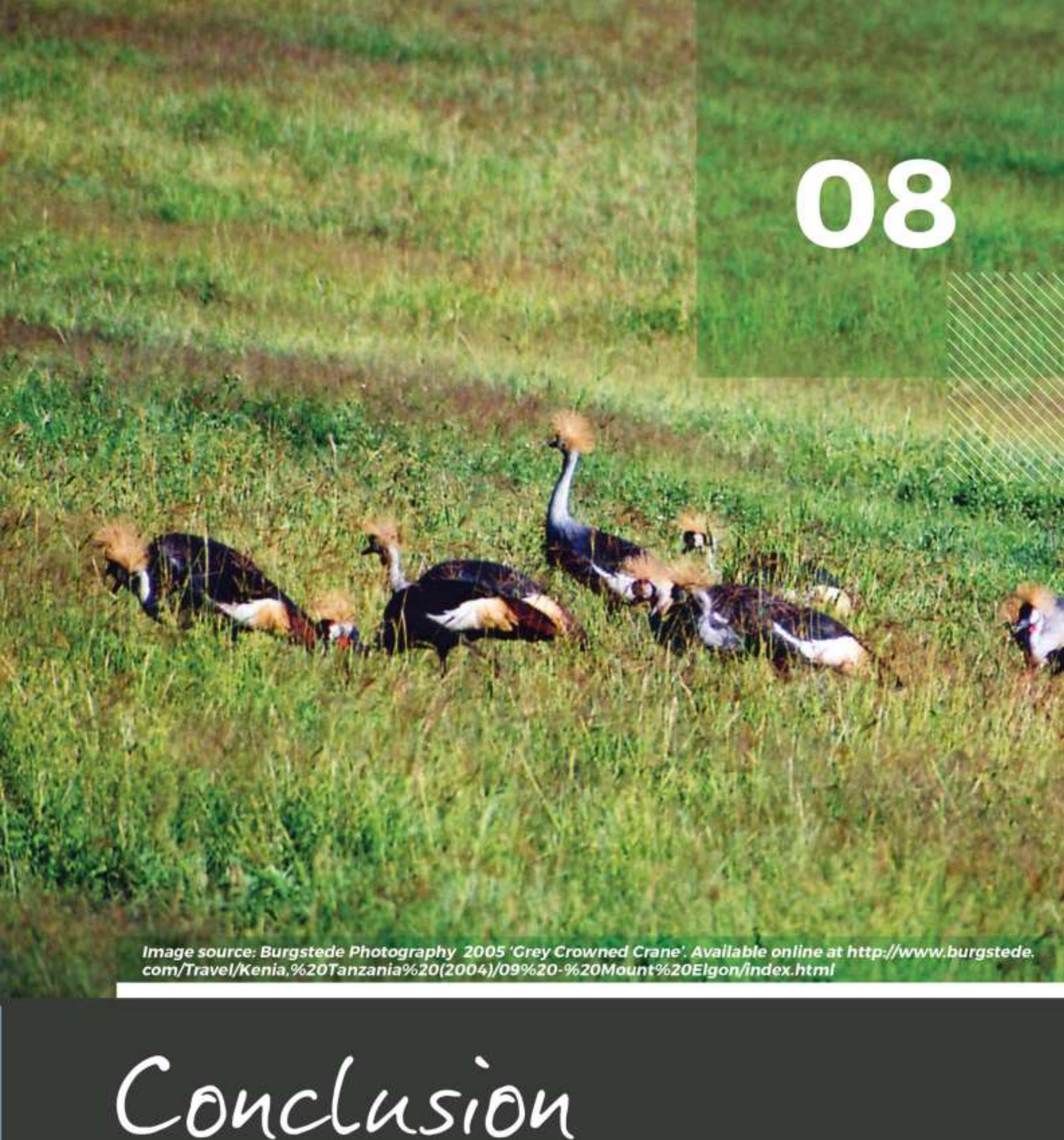

Image source: Burgstede Photography 2005 'Grey Crowned Crane'. Available online at http://www.burgstede.com/Travel/Kenia,%20Tanzania%20(2004)/09%20-%20Mount%20Elgon/index.html

08

Conclusion

8 Conclusion

Integrated Water Resources Management is based on the equitable and efficient management and sustainable use of water. It recognises that water is an integral part of the ecosystem, a natural resource, and a social and economic good, whose quantity and quality determine the nature of its utilisation (Global Water Partnership, 2006)(Global Water Partnership, 2006). This emphasises the importance of an integrated approach towards water resources planning, development and management – focusing on an enabling environment, institutional framework and setting up the management instruments required by institutions to understand mandates, roles and responsibilities to effectively and seamlessly do their job.

The LVN 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 LVN 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 LVN 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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A1: Erosion risk and land use capability

Erosion risk in the LVN Basin was determined by using the Revised Universal Soil Loss Equation (RUSLE) model (Renard, Foster, Weesies, & Porter, 1991). The RUSLE model is used widely to predict long-term rates of inter-rill and rill erosion from field or farm size units subject to different management practices. RUSLE is a lumped model which assumes spatially homogeneous hillslopes. A raster-based GIS soil erosion risk assessment tool for the LVN Basin was developed, which calculates the mean annual gross soil erosion at a cell level as the product of six factors:

$$A = R_i \times K_i \times L_i \times S_i \times C_i \times P_i \quad (1)$$

where:

subscript $i = i^{th}$ cell

A_i = the average annual soil loss per unit area within the cell ($t{\cdot}ha^{-1}{\cdot}a^{-1}$)

R_i = rainfall-runoff erosivity factor ($MJ{\cdot}mm{\cdot}ha^{-1}{\cdot}h^{-1}{\cdot}a^{-1}$)

K_i = the soil erodibility factor ($t{\cdot}h{\cdot}MJ^{-1}{\cdot}mm^{-1}$)

L_i = the slope length factor

S_i = the slope steepness factor

C_i = the cover management factor

P_i = the conservation support practice factor

Input data for each erosion factor in the RUSLE model were collected from various sources as presented in Table A1-1.

Modelling the sediment production potential is based on the relatively constant factors associated with topography and soils. These factors are unlikely to change significantly over the short-term as they relate to the geomorphology of the Basin. Rainfall is dependent on climatic factors, therefore is inherently variable. The management factors (i.e. crop and practice) are more variable, as they are dependent on the conservation management measures and seasonal rainfall. A wider study in Kenya (Dunne, 1979) indicated that land use was a dominant control of sediment yield, although runoff and topography were also recognised as important. It was also determined that yield from agricultural land and grazed land was significantly greater than from forested basins, with variability in cultivated land.

Rainfall erosivity

One of the key drivers of erosion is rainfall erosivity. Although rainfall itself will not necessarily result in high levels of erosion, intense prolonged rainfall will act to increase soil erosion rates. Rainfall erosivity has a high impact on soil erosion as it provides the energy required to detach soil particles. As shown in Figure A1-1, rainfall erosivity is very high in the middle LVN Basin, with lower values in the upper Basin and at the basin outlet into Lake Victoria. Most wetlands occur in these lower rainfall erosivity zones. This is indicative of a zone of deposition, where wetlands provide important flood attenuation services.

Table A1-1: Identified sources of input data for GIS based RUSLE model

	Factor	Input / Reference Data	Data type (Extent)	Resolution (arc-seconds)	Parameters used / derived
Output	**A**	-	Grid	1	-
Input	**R**	a) Global Rainfall Erosivity coverage based on the Global Rainfall Erosivity Database (GloREDa) b) CHIRPS precipitation dataset	a) Grid (Global) b) Grid (Global)	a) 30 b) 180	a) R Factor b) Mean Annual Precipitation (MAP)
	K	a) Soil and terrain database for Kenya (ver. 2.0) (KENSOTER) b) SOTER-based soil parameter estimates (SOTWIS) for Kenya c) ISRIC SoilGrids	a) Microsoft Access Database / Vector geometry (Kenya) b) Microsoft Access Database / Vector geometry (Kenya) c) Grid (Global)	a) n/a b) n/a c) 8	a) , b), c) sand, clay, silt and organic carbon fractions. Soil structure, soil permeability, surface stoniness
	LS	SRTM Digital Elevation Data 1-arc second	Grid (Global)	1	Derived surface slope, flow direction, flow accumulation, specific contributing area
	C	Cloud filtered Landsat Imagery	Grid (Global)	1	Normalized Difference Vegetation Index (NDVI)
	P	a) RCMRD Kenya Crop Mask 2015 b) RCMRD Kenya Sentinel2 LULC 2016 land cover c) Google Earth d) Limited field visits	a) Grid and Vector (Kenya) b) Grid (Kenya) c) Satellite imagery (Global) d) Local	a) 1 b) 1 c) n/a d) n/a	• Main Crop type • Crop extent • Visual inspection of practice type • Visual confirmation of practice type

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Soil erodibility

A second key driver of erosion relates to soil characteristics. The mountain, hillslope and footslope landforms in the LVN Basin has high soil erodibility. The soils in the upper parts of the LVN Basin are mainly Ferralsols, which are strongly weathered soils with low nutrient levels. These are interspersed with Nitisols which are deep red soils with some organic matter.

The lower parts of the LVN Basin are mainly Acrisols which are acidic soils with clay-rich subsoils. The Basin is also scattered with Gleysols, which are soils saturated by groundwater for long periods.

Vegetation cover

Vegetation cover is important when it comes to soil erosion, as dense vegetation cover will act to protect the land from erosion, whilst overgrazed land is more exposed. The density of vegetation cover reflects the influence of cropping practices, vegetation canopy and general ground cover. Maintaining a dense and diverse vegetation cover is important for catchment management as it reduces erosion. Water availability has an important control over vegetation growth. The protected forests in the Basin indicate a low cover factor (i.e. high vegetation cover), with areas in the upper and lower Basin that have a higher cover factor (i.e. low vegetation cover).

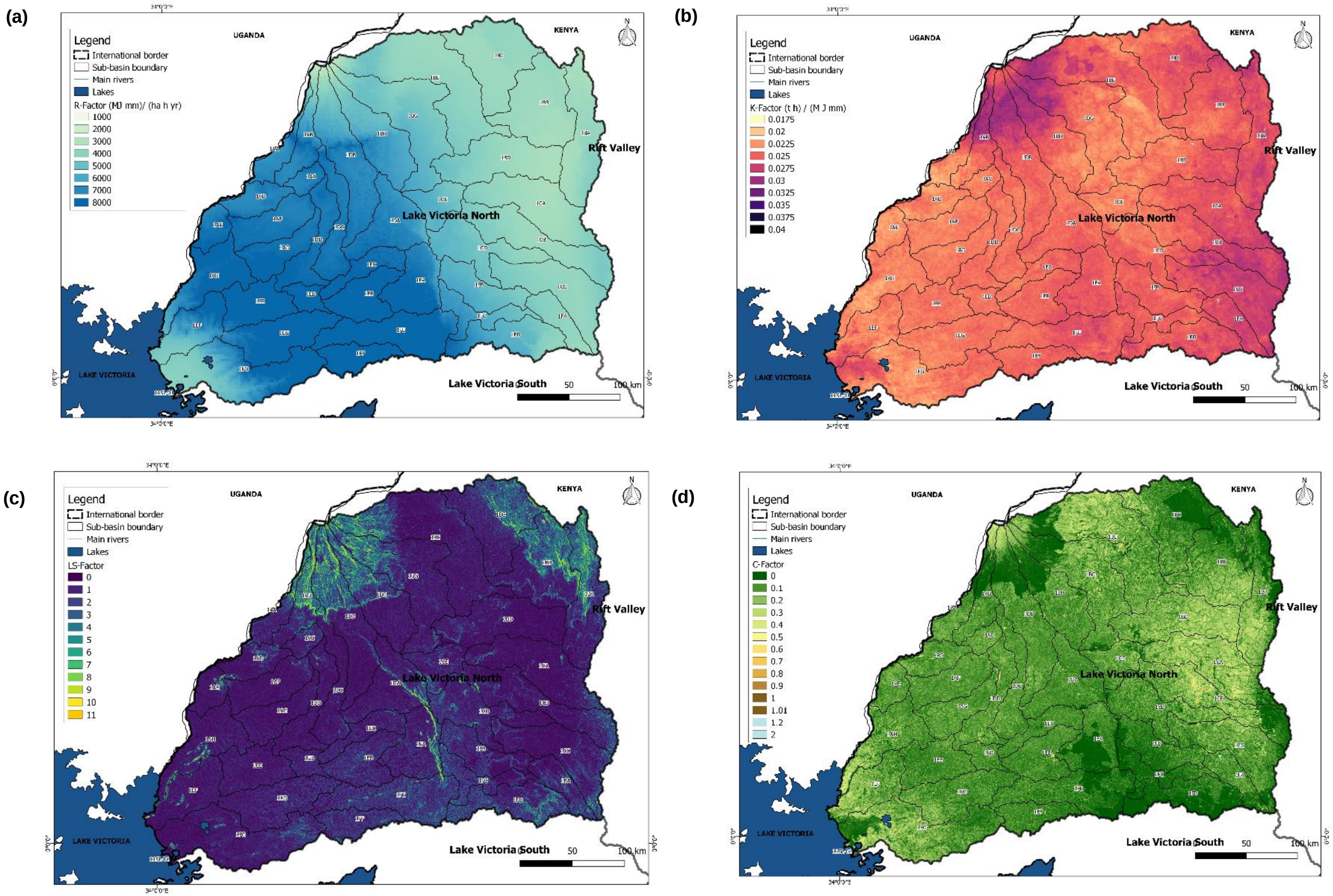


Figure A1-1: RUSLE factor maps for LVN Basin (a) rainfall-runoff erosivity, (b) soil erodibility, (c) slope length and slope steepness, (d) cover management factor

Estimated soil loss

Applying the RUSLE-based soil erosion risk assessment tool to the LVN Basin, using the flow chart as shown in Figure A1-2, resulted in estimates of soil erosion risk (expressed as long term average soil loss per unit area) as displayed in Figures A1-3 and A1-4. It should be noted that Figure A1-4 is based on an assumed conservative conservation support practice (P) factor value of 1.

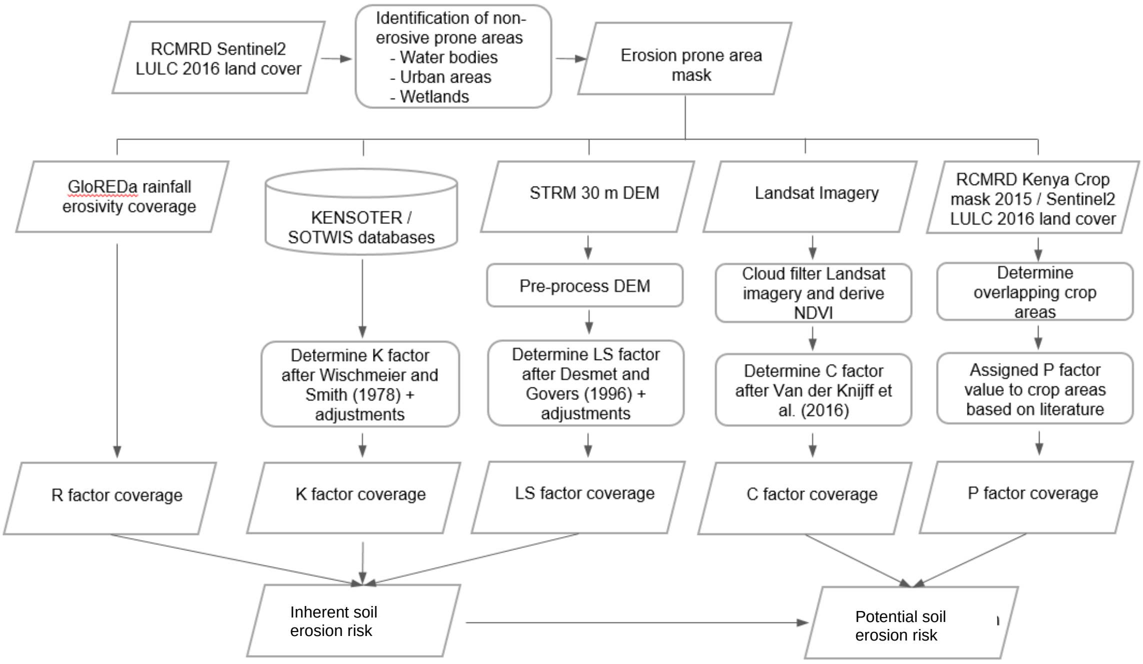


Figure A1-2: Modelling flow chart for soil erosion risk in Kenya

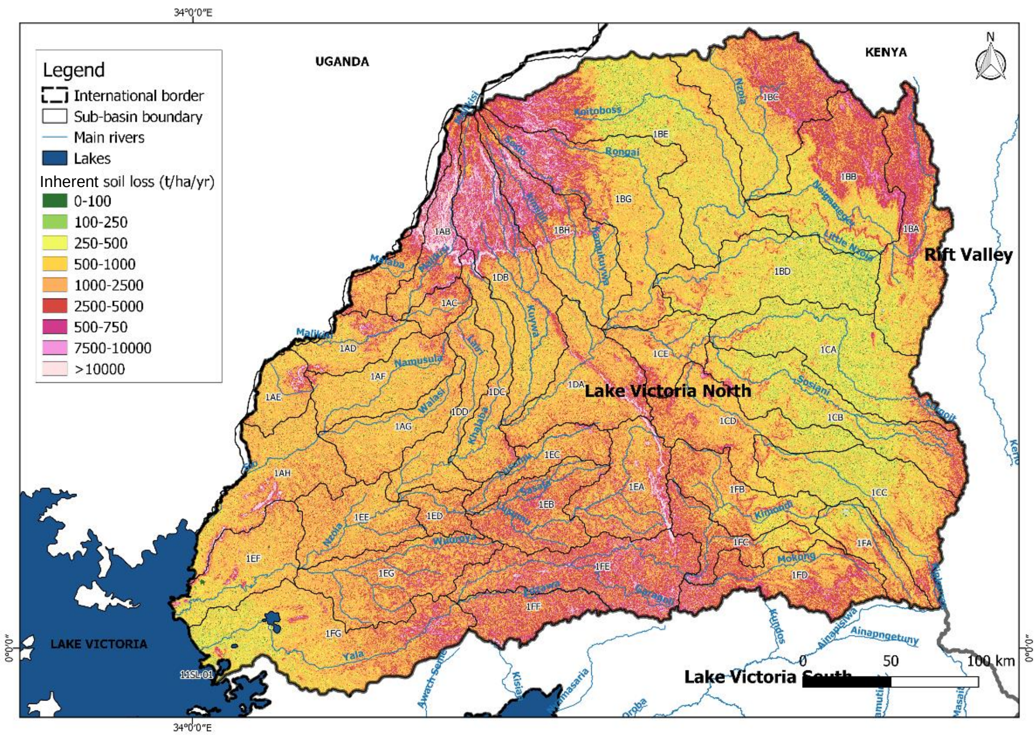


Figure A1-3: Lake Victoria North Basin Inherent Soil Erosion Risk

When comparing the inherent soil erosion risk to the potential soil erosion risk in Figure A1-4, 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 the footslopes of Mt Elgon below the forest has less vegetation cover which influences the higher erosion rates. The gazetted forests in the headwaters of Nzoia and Yala Rivers have very low rates of erosion**.**

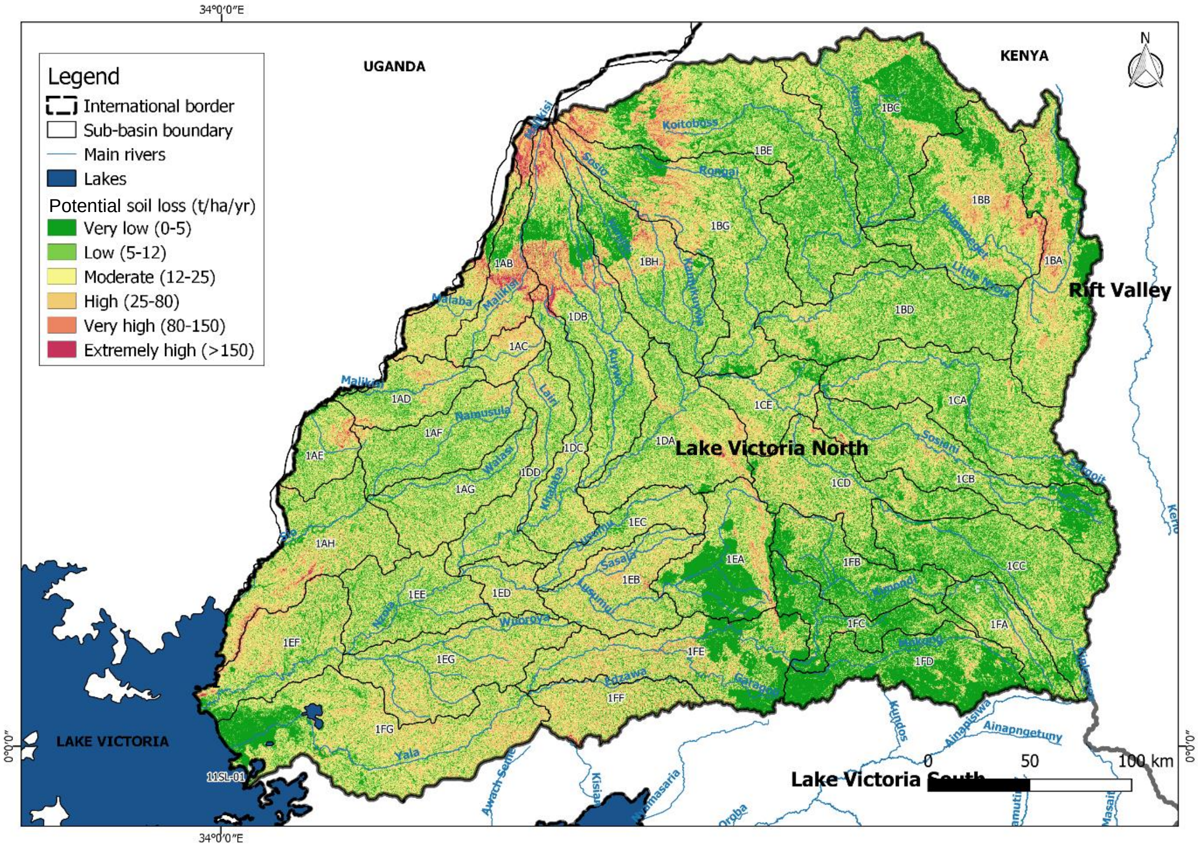


Figure A1-4: Lake Victoria North Basin Potential Soil Erosion Risk

Table A1-2: LVN Basin mean factors, potential soil loss and estimated soil loss

Sub-basin	Mean R	Mean K	Mean LS	Mean potential soil loss (t/ha/yr)	Mean C	Mean estimated soil loss (t/ha/yr)	Erosion risk
1AA	6715.99	6715.99	6715.99	342.30	0.12	31.90	High
1AB	6358.75	6358.75	6358.75	541.76	0.11	47.50	High
1AC	7287.11	7287.11	7287.11	211.67	0.14	28.79	High
1AD	7142.94	7142.94	7142.94	166.18	0.13	19.35	Moderate
1AE	7653.27	7653.27	7653.27	169.00	0.13	20.57	Moderate
1AF	7484.38	7484.38	7484.38	122.83	0.12	14.51	Moderate
1AG	7822.61	7822.61	7822.61	125.80	0.12	15.39	Moderate
1AH	7857.92	7857.92	7857.92	176.37	0.15	23.84	Moderate
1BA	3575.10	3575.10	3575.10	233.43	0.13	22.77	Moderate
1BB	3497.95	3497.95	3497.95	213.99	0.13	22.18	Moderate
1BC	3643.43	3643.43	3643.43	196.89	0.09	12.09	Moderate
1BD	3800.66	3800.66	3800.66	68.62	0.21	12.42	Moderate
1BE	3923.67	3923.67	3923.67	145.39	0.17	18.61	Moderate

Sub-basin	Mean R	Mean K	Mean LS	Mean potential soil loss (t/ha/yr)	Mean C	Mean estimated soil loss (t/ha/yr)	Erosion risk
1BG	4757.30	4757.30	4757.30	203.76	0.14	20.04	Moderate
1BH	5746.65	5746.65	5746.65	282.15	0.10	21.75	Moderate
1CA	3587.87	3587.87	3587.87	73.56	0.21	12.53	Moderate
1CB	3959.80	3959.80	3959.80	113.16	0.17	13.45	Moderate
1CC	3976.15	3976.15	3976.15	112.56	0.13	11.40	Low
1CD	4754.73	4754.73	4754.73	145.32	0.12	15.63	Moderate
1CE	5298.76	5298.76	5298.76	151.78	0.13	18.62	Moderate
1DA	6997.91	6997.91	6997.91	192.88	0.11	18.54	Moderate
1DB	6437.56	6437.56	6437.56	334.26	0.11	29.47	High
1DC	7513.88	7513.88	7513.88	168.70	0.12	19.78	Moderate
1DD	7708.58	7708.58	7708.58	136.50	0.13	17.80	Moderate
1EA	7709.48	7709.48	7709.48	289.78	0.06	14.99	Moderate
1EB	8300.13	8300.13	8300.13	268.85	0.10	25.94	High
1EC	7831.93	7831.93	7831.93	196.78	0.10	19.49	Moderate
1ED	8099.89	8099.89	8099.89	200.75	0.11	21.67	Moderate
1EE	8383.02	8383.02	8383.02	158.25	0.10	16.08	Moderate
1EF	6445.05	6445.05	6445.05	142.34	0.18	21.80	Moderate
1EG	8386.38	8386.38	8386.38	209.08	0.12	22.76	Moderate
1FA	3961.95	3961.95	3961.95	142.93	0.11	12.78	Moderate
1FB	5346.02	5346.02	5346.02	161.48	0.07	9.61	Low
1FC	6034.31	6034.31	6034.31	241.68	0.04	7.04	Low
1FD	5479.56	5479.56	5479.56	271.51	0.03	6.20	Low
1FE	8624.05	8624.05	8624.05	381.38	0.06	20.20	Moderate
1FF	9285.54	9285.54	9285.54	354.04	0.09	28.92	High
1FG	6384.68	6384.68	6384.68	155.07	0.17	19.38	Moderate

Sediment yield

Soil erosion involves the detachment, transport and eventual deposition of soil particles (Lal, 2001). Energy for these processes is provided for by physical (wind/water), gravity (landslides), chemical (weathering) or tillage sources. Sediment particles, once picked up by water, actually spend a relatively short time being transported and in fact more time in storage (Meade, 1982). This means that an understanding of the source (i.e. sediment potential areas) and sink (i.e. depositional areas) zones are needed in order to understand the impact of sedimentation. Erosion acts as the source of sediment, which travels downstream and has indirect impacts. These impacts can be seen when sediment travels in suspension, i.e. turbidity impacts to biodiversity, and when sediment stops moving and is deposited, i.e. sedimentation impacts to biodiversity and infrastructure. On the one hand deposited sediment renews soil fertility and lines channels of canal beds against seepage, but on the other hand it reduces capacity of reservoirs, inlet channel and irrigation canals (Ali, 2014). High sediment loads transported by the river during flood seasons has major influences on operation of reservoirs and in general reduces storage capacity. When in suspension sediment becomes a pollutant in its own right, as it limits light penetration and healthy plant growth. When sediment settles on the river bed it may smother aquatic habitats and impact fish spawning grounds. Nutrient rich sediments (especially sediments linked to agricultural lands) create turbid conditions which may result in eutrophication where fish species may be unable to survive.

Tracing the pathway of sediment from the upper LVN Basin, to Lake Victoria indicates that there are landforms which are linked to deposition zones, acting as sediment “traps” or buffer zones. These landforms such as alluvial plains, wetlands and delta plains are areas where sediment will likely be deposited. Infrastructure such as dams will also trap sediments, the scale of this relating to the dam storage capacity as well as location within a catchment.

Based on the characteristics in Table A1-3, sediment delivery ratios were estimated for each sub-basin and sediment yield values calculated as shown in Figure A1-5.

Table A1-3: Physiographic catchment characteristics contributing to sediment dynamics of LVN Basin

Factor	Basin
Basin area (m^2)	18,374
Annual Rainfall (mm)	1000 – 1900
Elevation (masl)	1,130 – 4,320
Topography	The upper Basin comprises three major water towers, while the middle Basin is covered by hilly topography extending into the flood plains up to Lake Victoria.
Vegetation	The vegetation cover is mainly a mosaic of forest and evergreen vegetation, with mountain forest vegetation in the highlands.
Land-use	Land use in the Basin is dominated by agricultural use, with small urban and industrial areas.
Connectivity (upper)	Within the Upper LVN catchments the landforms change from steep slopes to plateaux. There are 3 existing dams and there are scattered wetlands within the plateaux. These wetlands and dams have a limited sediment trapping capacity as they are located in the upper Basin.
Connectivity (middle)	Within the Middle LVN catchments the landforms move from plateaux to plain before reaching Lake Victoria. The Yala Swamp occurs as the Yala River discharges into Lake Victoria. This is indicative of a depositional feature.

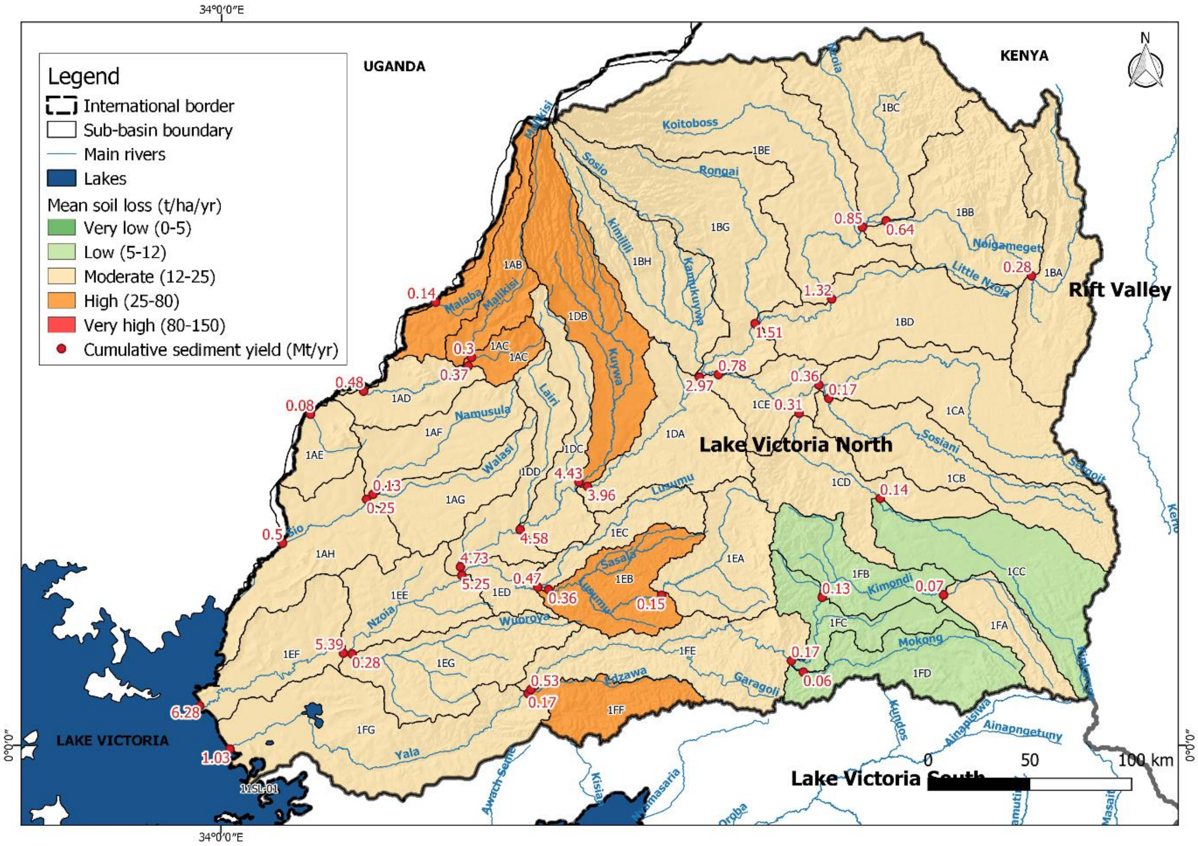


Figure A1-5: LVN Basin - Cumulative sediment loads

Table A1-4 summarises the erosion potential and sediment yield in the LVN Basin.

Table A1-4: Long term average soil loss estimates per sub-basin in the LVN Basin

Sub-Basin	Area (km²)	Potential soil loss (t/km2/yr)	Incremental sediment yield (t/km2/yr)	Cumulative sediment load (Mt/yr)
1AA	202.61	3422	318	0.14
1AB	287.41	5417	474	0.30
1AC	112.14	2116	287	0.37
1AD	253.93	1661	193	0.48
1AE	184.33	1690	205	0.08
1AF	402.93	1228	145	0.13
1AG	347.21	1257	153	0.25
1AH	506.57	1763	238	0.50
1BA	636.65	2334	227	0.28
1BB	754.61	2139	221	0.64
1BC	770.60	1968	120	0.85
1BD	686.65	686	124	1.51
1BE	1153.08	1453	186	1.32
1BG	913.81	2037	200	2.97
1BH	581.03	2821	217	0.28
1CA	718.32	735	125	0.36
1CB	657.17	1131	134	0.17
1CC	663.78	1125	114	0.14
1CD	516.87	1453	156	0.31
1CE	258.06	1517	186	0.78
1DA	527.79	1928	185	3.96
1DB	727.91	3342	294	4.43
1DC	351.38	1687	197	4.58
1DD	368.33	1364	177	4.73
1EA	440.69	289	149	0.15
1EB	382.33	2688	259	0.36
1EC	236.80	1967	194	0.47
1ED	131.06	2007	216	5.25
1EE	395.22	1582	160	5.39
1EF	419.99	1423	218	6.28
1EG	554.09	2090	227	0.28
1FA	238.12	1429	127	0.07
1FB	369.66	1614	961	0.13
1FC	271.71	2416	703	0.17
1FD	476.06	2715	619	0.06
1FE	661.05	3813	201	0.53
1FF	272.72	3540	289	0.17
1FG	951.68	1550	193	1.03

Land use capability

To assist with the assessment of land capability and sustainable land use in the Basin, a GIS-based land capability tool was developed based on the USDA Land Capability Classification System as defined in Table A1-5. The USDA Land Capability Classification relies on the following principles (Klingebiel & Montgomery, 1961):

- Areas of land are put into classes ranging from best (Class I) to worst (Class VIII),
- Land allocated to a particular capability class has the potential for the use specified for that class and for all classes below it.

Placing soils in these classes allows for an understanding of the crop and management constraints. The suitability of soils is as follows:

- Order A: Arable land – high potential land with few limitations (Class I and II)
- Order B: Arable land – moderate to severe limitations (Class III and IV)
- Order C: Grazing and forestry land (Class V, VI and VII)
- Order D: Land not suitable for agriculture (Class VIII)

Table A1-5: Relationship between USDA soil capability classification classes and intensity with which each class can be used safely (Davidson, 1992)

Soil Capability			WILDLIFE	FORESTRY	GRAZING			CULTIVATION				Description	Soil/Terrain parameter			Soil/terrain parameter mix summary
Orders		Classes			Limited	Moderate	Intense	Limited	Moderate	Intense	Very Intense		Slope	Erosion	Soil Depth	
Arable	A	I	x	x	x	x	x	x	x	x	x	Soils have slight limitations that restrict their use.	S1	E1	D1	Gentle slope, very low erosion, deep soils
		II	x	x	x	x	x	x	x	x		Soils have moderate limitations that reduce the choice of plants or require moderate conservation practices.	S2	E1, E2	D1	Gentle to moderate slope, very low to low erosion, deep soils
	B	III	x	x	x	x	x	x	x			Soils have severe limitations that reduce the choice of plants or require special conservation practices.	S3	E1-E3	D1 - D2	Moderate slope, very low to moderate erosion, deep to medium deep soils
		IV	x	x	x	x	x	x				Soils have very severe limitations that reduce the choice of plants or require very careful management, or both.	S4	E1-E4	D1 - D2	Moderate slope, very low to high erosion, deep to medium deep soils
Non- arable	C	V	x	x	x	x	x					Soils have little or no hazard of erosion but have other limitations, impractical to remove, that limit their use mainly to pasture, range, forestland, or wildlife food and cover.	S4	E1-E5	D1 - D2	Moderate slope, very low to very high erosion, deep to medium deep soils
		VI	x	x	x	x						Soils have severe limitations that make them generally unsuited to cultivation and that limit their use mainly to pasture, range, forestland, or wildlife food and cover.	S5	E1-E5	D1 - D2	Steep slope, very low to high erosion, deep to medium deep soils
		VII	x	x	x							Soils have very severe limitations that make them unsuited to cultivation and that restrict limit their use mainly to grazing, forestland, or wildlife.	S5	E1-E5	D2 - D3	Steep slope, very low to high erosion, medium to shallow soils
	D	VIII	x									Soils and miscellaneous areas have limitations that preclude their use for commercial plant production and limit their use to recreation, wildlife, or water supply or for aesthetic purposes.	S6	E1-E6	D2 - D3	Very steep slope, very low to high erosion, medium to shallow soils

Davidson (1992) categorised the USDA Classes in terms of the intensity of soil disturbance that is "safe" and introduced soil and terrain as useful physical parameters to define Classes, i.e. Slope Class (Table A1-6), Erosion Hazard Class (Table A1-7) and Soil Depth Class (Table A1-8**Error! Reference source not found.**).

Table A1-6: Slope Class for input to the Soil capability classification

Slope Class	Slope (%)
S1	0-5
S2	5-8
S3	8-12
S4	12-20
S5	20-40
S6	40-100

Table A1-7: Erosion Hazard Class for input to the Soil capability classification

Erosion Hazard Class	Erosion Hazard	Erosion (t/ha.yr)
E1	Very Low	0-5
E2	Low	5-12
E3	Medium	12-25
E4	High	25-80
E5	Very High	80-150
E6	Extremely High	>150

Table A1-8: Slope Depth Class for input to the Soil capability classification

Soil Depth Class	Soil Depth (mm)
D1	>300
D2	200
D3	<100

Using the USDA Land Capability Classification System in conjunction with Davidsons's land usability criteria, the LVN Basin was assessed in terms of land capability (excluding meteorological conditions). The resultant Land Capability map is shown in Figure A1-6 **Error! Reference source not found.** for the Basin. It is evident that the tops of hills and mountains have a soil capability of 8 and steep slopes have a soil capability of 5-7 (i.e. non-arable land). Most of the Basin has a soil capability of 1-3 (i.e. arable land).

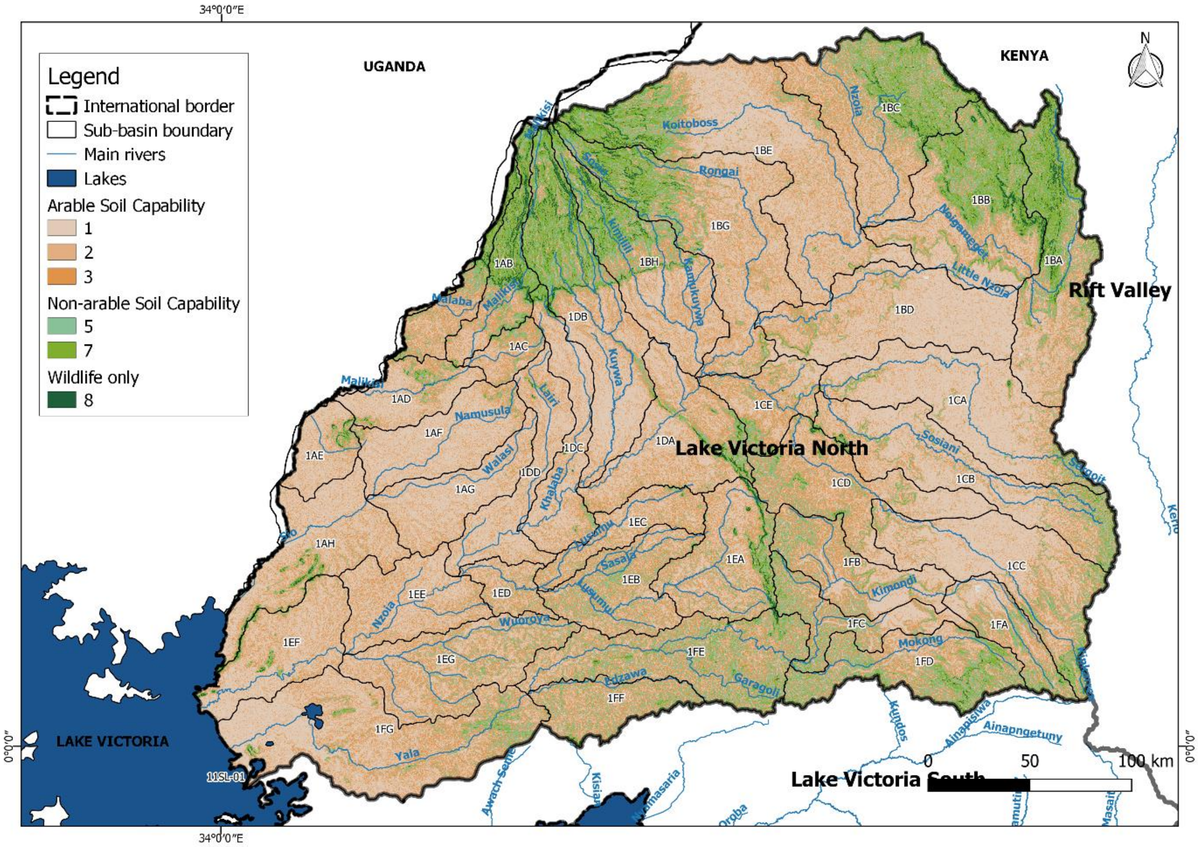


Figure A1-6: LVN Basin Soil Capability Map

Overlaying the Land Capability map with the current land use in the Basin, provides an indication of the level of sustainable land use in the basin under current conditions. From Figure A1-7, it is evident that the mountainous regions have unsustainable land uses, particularly around the lower slopes of Mt Elgon and on the boundary of the upper Basin.

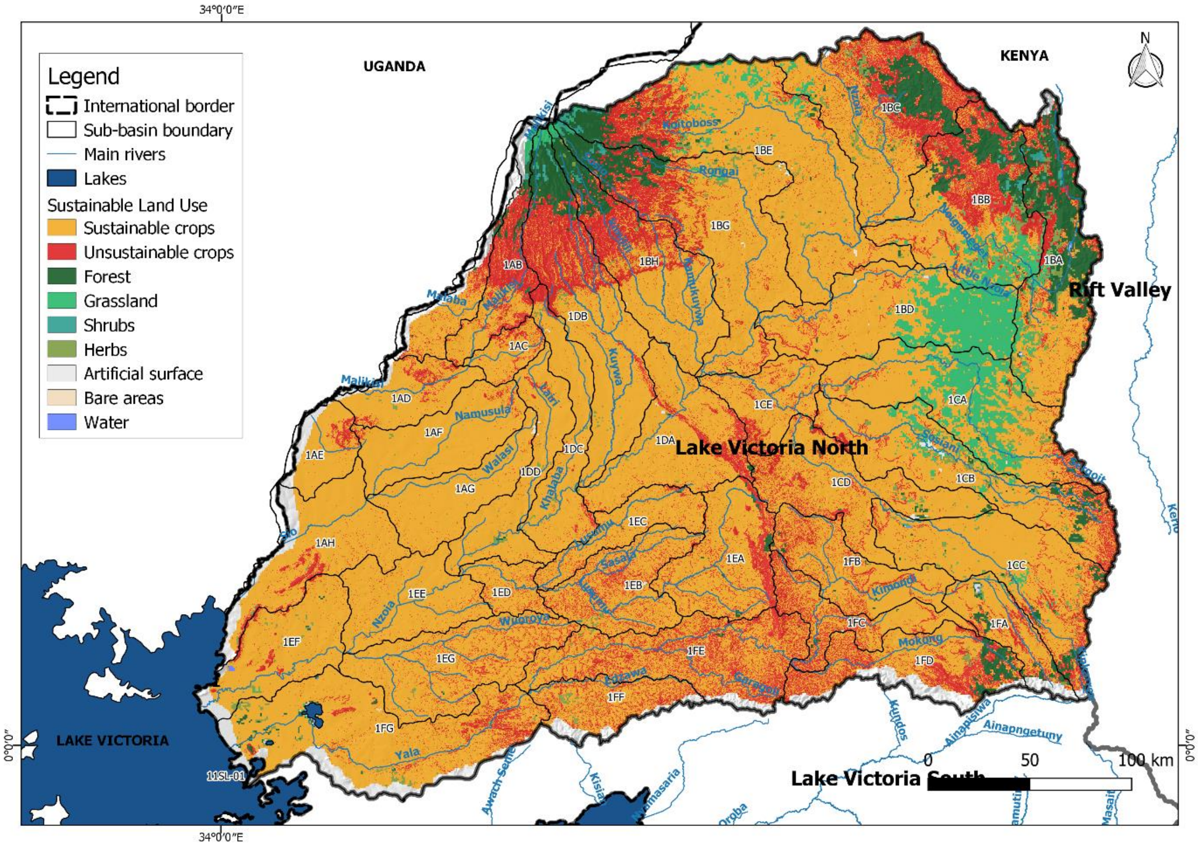


Figure A1-7: Sustainability of current land use in the LVN Basin

A2: Climate analysis

The scale of future climate impacts varies based on the anthropogenic mitigation of factors responsible for currently experienced changes. The mitigation scenarios account for several variances of potential global economic and environmental development and are quantified as the Representative Concentration Pathways (RCP).

In line with industry standards, the scenarios considered for this analysis were the RCP4.5 (likely) and RCP8.5 (worst case) scenarios. These RCPs show the change from pre-industrial insolation watts per m^2 resulting from the emissions. RCP 4.5 – likely best case – emissions stabilise from 2040 and decrease thereafter. RCP 8.5 represents the very high greenhouse gas emission scenario – emissions don't stabilise, worst case scenario with a focus on economic advancement at the expense of environmental sustainability. These emission scenarios give light to the varying potential climatic futures based on human development goals in the present and near future.

For these RCPs, Table A2-1 shows estimated concentrations of greenhouse gases viz. CO2, CH4 and N2O based on a combination of assessment models (MESSAGE (Riahi, Gruebler, & Nakicenovic , 2007), AIM (Hijioka , Matsuoka, Nishimoto, & Masui, 2008)), GCAM (Wise, et al., 2009), IMAGE (van Vuuren, et al., 2007)), global carbon cycle, and atmospheric chemistry and climate models. They also integrate assumed land use changes and sector-based emissions of greenhouse gasses from present day levels. The present greenhouse gasses include the sectoral assessment of energy supply, industry, transport, and buildings with contributions of 47%, 30%, 11% and 3% respectively (IPCC, Summary for Policymakers, 2014).

Table A2-1: Representative Concentration Pathways

	CO_2 (ppm)	CH_4 and N_2O (ppm)	Resulting radiative forcing ($W.m^{-2}$)	Scenario
RCP 4.5	538	92	4.5	Best case - Medium scenario
RCP 8.5	936	377	8.5	Worst case

The greenhouse gas concentrations under different RCPs are used as input for the coupled model ensembles of the IPCC Assessment Report Five (IPCC, Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects, 2014) (AR).

Using climate projection data requires the acknowledgement of various uncertainties. The IPCC projections rely on forty different GCMs with different accuracies forecasting to the varying RCP scenarios. These RCPs are themselves estimates of potential future thermal forcings, as informed by adherence to emission policies and potential future technologies. The downscaling of the IPCC data required robust constraining parameters to present a more accurate local projection. In areas where observational data is limited, these constraining parameters have increased uncertainty. Results obtained, and recommendations made based on these data should be used as a guideline to adapt/mitigate to a potential future climate rather than a definitive one. This is particularly prevalent when noting the significant disparity even in the current variability of rainfall regimes. This is influenced by things like topography, wind, vegetation and even ocean currents. Beyond that, a further layer of complexity is added with looking at rainfall intensity, diurnal and seasonal onsets before accounting for short and long-term influences such as the diurnal, seasonal, inter annual cycles, the ENSO cycles as well as decadal changes. When projecting precipitation changes into a semi unknown future these uncertainties are further exacerbated. The projection parameters are therefore presented in terms of a probability of changes highlighting the most likely range of precipitation experienced in the future. The probabilities also allow for the possibility of more extreme anomalous occurrence of events in both directions i.e. probability of more extreme rainfall days as well as less extreme rainfall days.

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

Data to be used in climate analysis need to be of sufficient duration and resolution to account for the cycles of natural meteorological variability as well as any climate change signal embedded in the data. While there is currently a dearth of climate change data of sufficient length and integrity for trend analysis available, SIMCLIM (CLIMSystems, 2005) and CORDEX (Gutowski et al, 2016) data were used to inform the analysis of climate change impacts as part of the development of this Basin Plan.

SimCLIM data is downscaled to 5km resolution from the IPCC AR5 climate models. It presents the monthly projection from 1996 to 2100 through selected models or a model ensemble, with different environmental sensitivities. SimCLIM is native to ESRI ArcGIS 10.3 and provides the basis for all spatial climate analysis and long-term trends.

CORDEX (A Coordinated Regional Climate Downscaling Experiment) data is downscaled to 45km resolution and has a daily temporal scale to 2100. The high temporal resolution of this data gives an indication of intra-seasonal meteorological characteristics. High resolution data has several advantages over the large scale GCMs, chief among them the increased spatial and temporal resolution. Having spatial higher resolution provides greater local context between areas of interest, while daily scale temporal scales allow for analysis such as extreme events or accumulation anomalies that is not possible in monthly data. The CORDEX experiments seeks to downscale the GCMs utilised in the IPCC AR5 analysis.

The GCM models listed in Table A2-2 were utilised for downscaling in this analysis.

Table A2-2: GCM model input

Model	Institute
CCCma-CanESM2	Canadian Centre for Climate Modelling and Analysis
CNRM-CERFACS-CNRM-CM5	Météo-France / Centre National de Recherches Météorologiques
CSIRO-QCCCE-CSIRO-Mk3-6-0	Commonwealth Scientific and Industrial Research Organization& Queensland Climate Change Centre of Excellence
ICHEC-EC-EARTH	Irish Centre for High-End Computing & -Earth consortium
IPSL-IPSL-CM5A-MR	Institut Pierre Simon Laplace
IROC-MIROC5	Model for Interdisciplinary Research on Climate
MOHC-HadGEM2-ES	Met Office Hadley Centre
MPI-M-MPI-ESM-LR	Max-Planck-Institut für Meteorologie
NCC-NorESM1-M	Norwegian Climate Centre & Norwegian Earth System Model 1
NOAA-GFDL-GFDL-ESM2M	National Oceanic and Atmospheric Administration & Earth System Model - Geophysical Fluid Dynamics Laboratory

Precipitation and Temperature

The climate analysis showed a general increase (between 0% and 6%) in mean annual precipitation (MAP) across the LVN Basin by 2050, with the average MAP across the basin increasing from 1536 mm to 1606 mm by 2050 under RCP 4.5.

Day and night temperatures in the basin are expected to increase by up to 1.2°C and 1.4°C respectively by 2050 (RCP 4.5).

To assess the expected impacts on more localised precipitation in the LVN Basin as result of climate change, four sub-basins were selected for detailed analyses namely: 1BC, 1CB, 1EF and 1FF. The sub-basins and river nodes are illustrated in Figure A2-1.

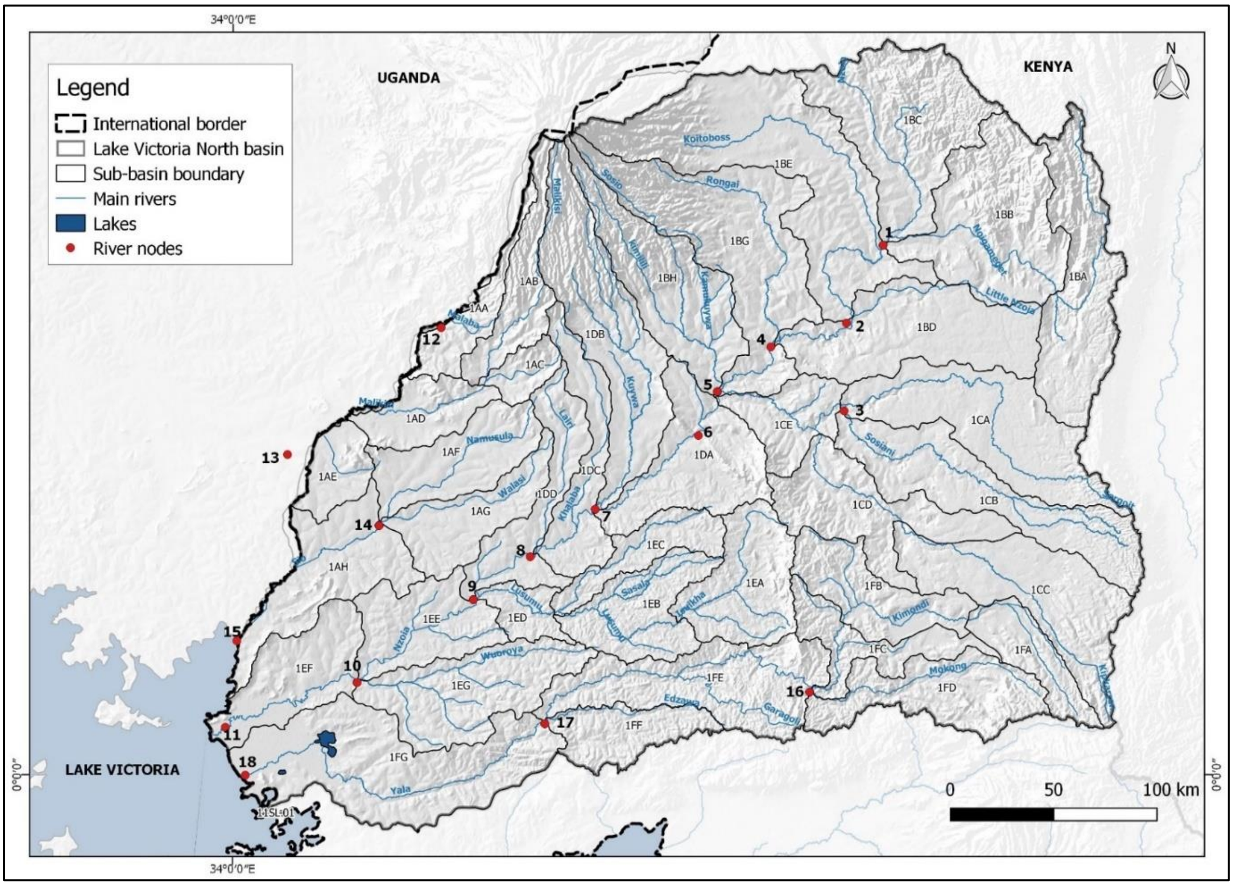


Figure A2-1: LVN Basin with sub-basins and river nodes

75th percentile precipitation values for the RCP4.5 scenario were used in the analysis. Figure A2-2 illustrates the anticipated changes in precipitation in the selected sub-basins. Changes were expressed as monthly percentage change from the average monthly historical precipitation (period between 1980-2000) to the average monthly future precipitation (period between 2040-2060).

The LVN Basin precipitation is follows the precipitation trends of Uganda with heavy rains from March to May and from September to November. Figure A2-2 indicates a consistent percentage increase in future precipitation in all four sub-basins during the ‘short’ rainy season from September to November, with a smaller relative increase in precipitation during the drier months of December to February. October and November experience a greater percentage increase relative to that of December, suggesting that the precipitation during the short rainy season will increase in intensity. During the ‘long’ rainy season from March to May the increase in precipitation occurs during March and April, however decreases in May, also suggesting increased precipitation intensity. It is important to note that although the percentage change in precipitation is quite high during the dry months of Jan and Feb, actual rainfall depths are very low (Figure A2-3 to Figure A2-6). During the dry season from June to October, an overall decreasing precipitation trend is observed, especially in May and June, suggesting that the dry season will shift earlier.

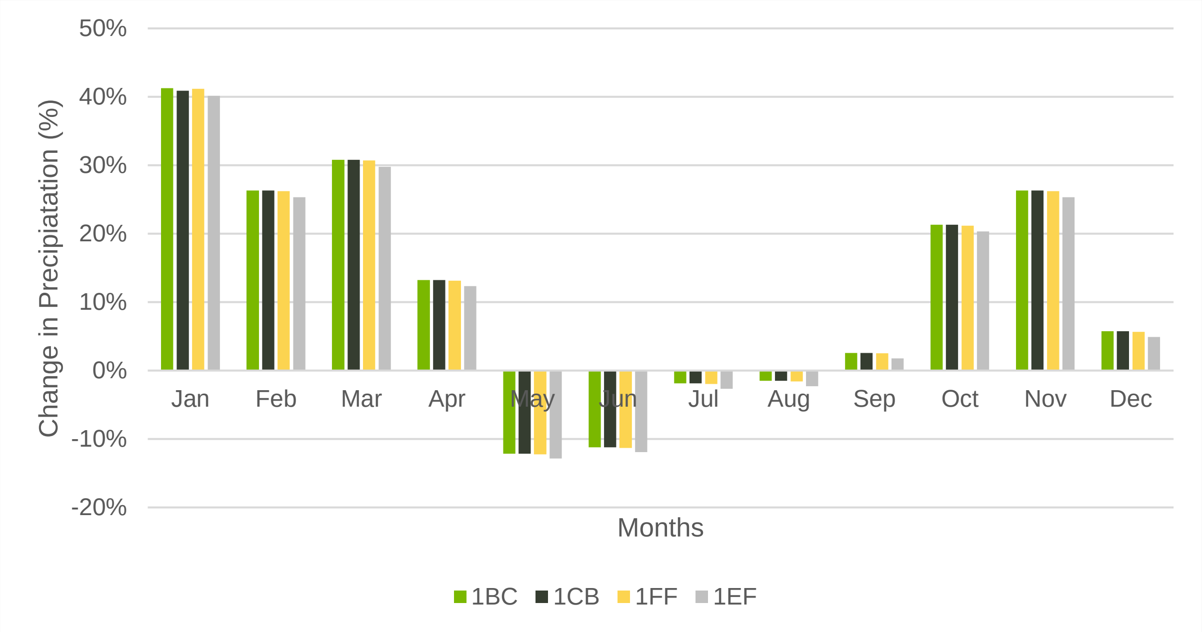


Figure A2-2: Percentage change in monthly precipitation for the period 2040 to 2060 compared to 1980 to 2000 in four sub-basins

Figure A2-3 to Figure A2-6 illustrate the historical monthly average precipitation (1980 to 2000), the monthly average future precipitation (2040 to 2060), as well as the associated percentage change in each of the four sub-basins. Evident from the figures is the significant increase in precipitation depth for September to November. The significant percentage increase in precipitation during the dry months of January to March, as illustrated in Figure A2-1, is also evident from Figure A2-2 to Figure A2-5. However, the precipitation depths remain relatively low. The rainy seasons also appear to shift slightly earlier. The precipitation during the dry season (June to October) decreases.

Figure A2-7 to Figure A2-10 present the range of monthly precipitation as box and whisker plots for both historical (1980 to 2000) precipitation as well as future (2040 to 2060) expected precipitation.

The figures show a significant increase under climate change in mean precipitation for April accompanied by a significant increase in the range of precipitation depths, suggesting that April precipitation will become more variable (see Figure A2-6a) as an example). Similarly, the figures show an increase in mean precipitation for Oct, Nov and Dec under climate change. However, during these months, the future range (variability) of precipitation depths will increase. This suggests higher precipitation variability during the short rainy season, as well as more intense precipitation events.

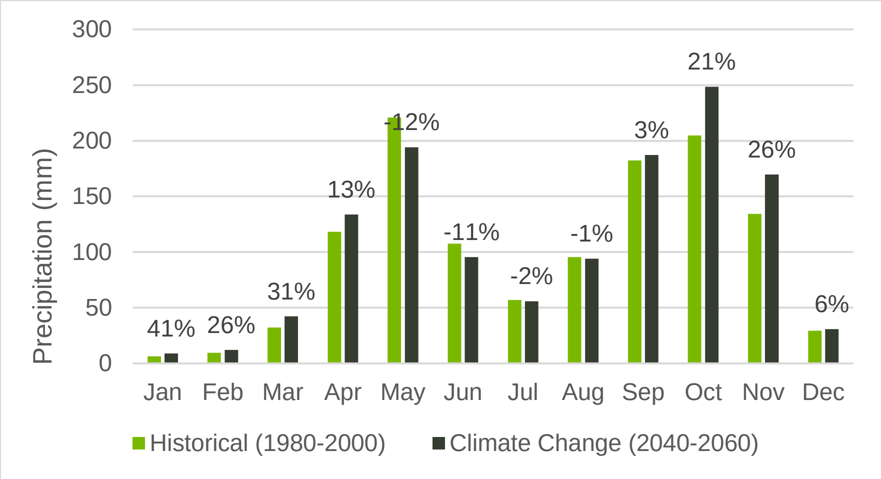


Figure A2-3: Percentage change - monthly avg. precipitation sub-basin 1BC

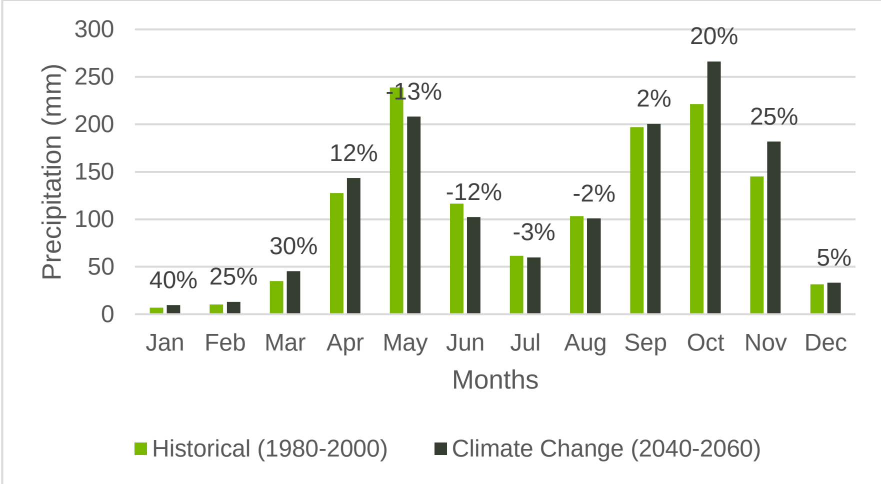


Figure A2-4: Percentage change - monthly avg. precipitation sub-basin 1CB

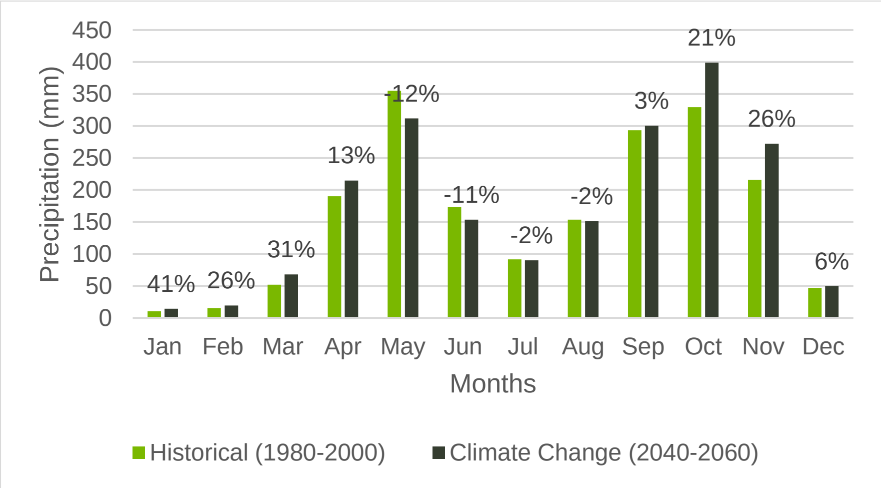


Figure A2-5: Percentage change - monthly avg. precipitation sub-basin 1FF

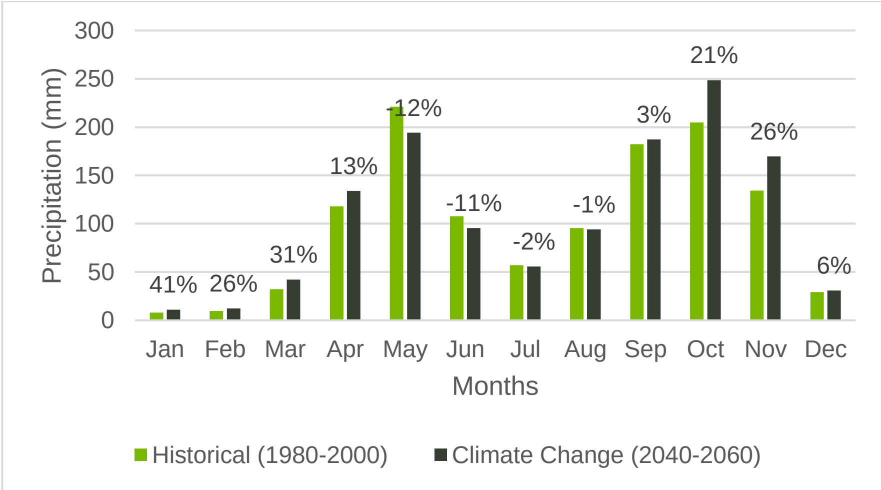


Figure A2-6: Percentage change - monthly avg. precipitation sub-basin 41EF

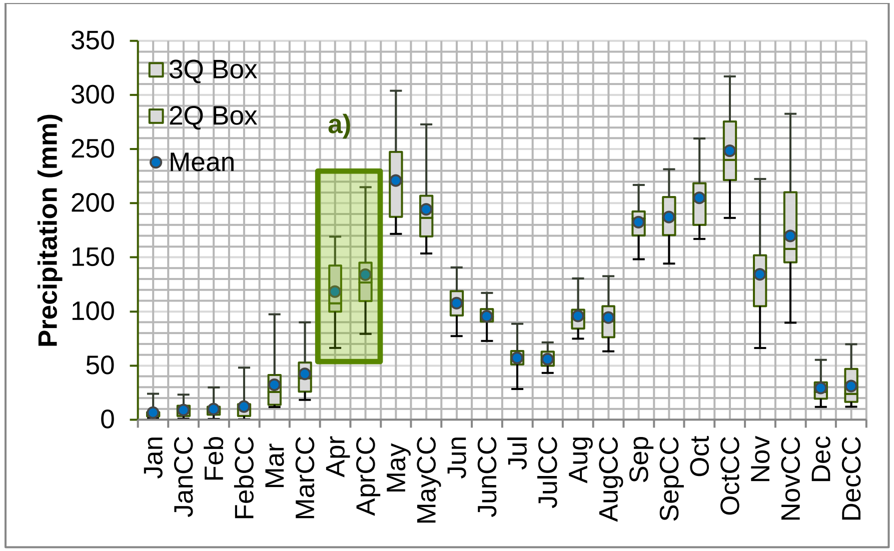


Figure A2-7: Precipitation box-plots for sub-basin 1BC

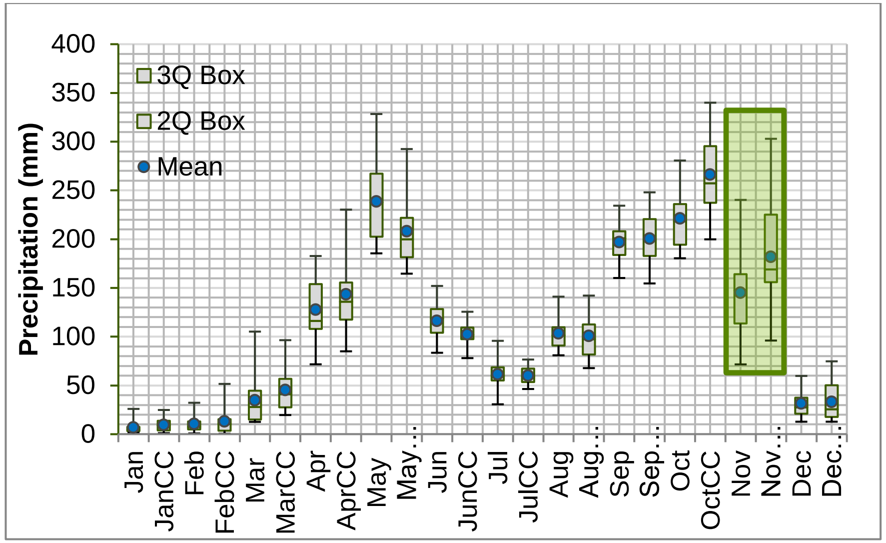


Figure A2-8: Precipitation box-plots for sub-basin 1CB

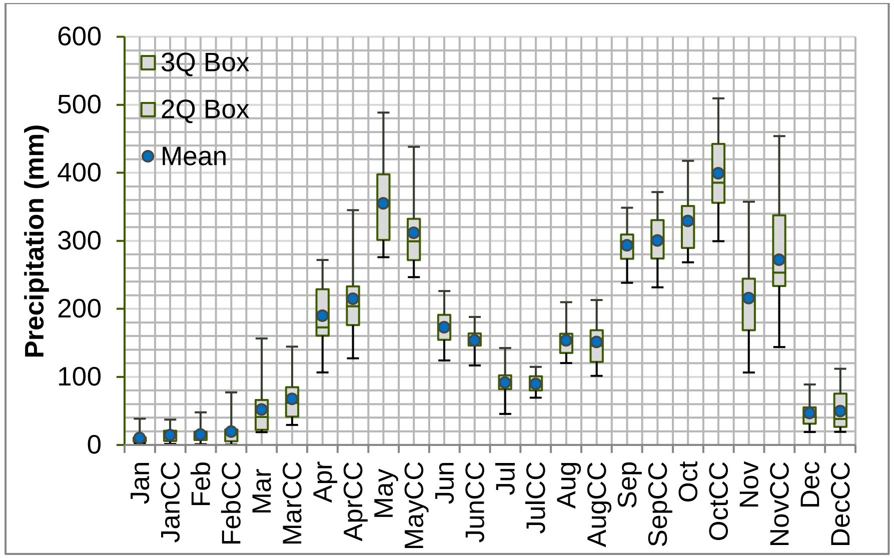


Figure A2-9: Precipitation box-plots for sub-basin 1FF

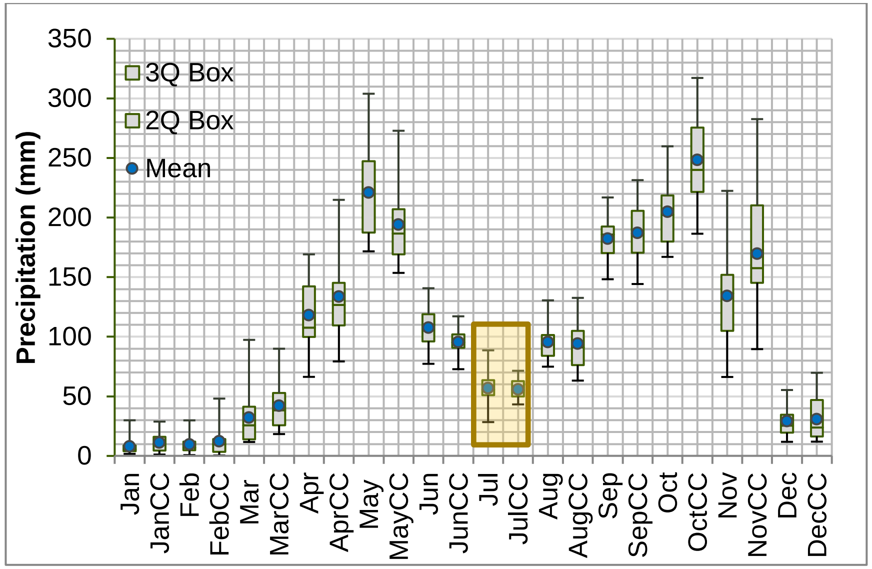


Figure A2-10: Precipitation box-plots for sub-basin 1EF

Stream Flow

Projected sub-basin precipitation and temperature changes under climate change scenario RCP 4.5 were superimposed on the hydrological model of the LVN Basin to assess the potential impacts on runoff. A simulation period of 1960 to 2017 was used. The analysis showed that natural runoff in the basin is expected to decrease in most sub-basins by between 6% and 15%. The total surface water runoff from the LVN Basin is projected to decrease with 7% by 2050 under RCP 4.5.

To assess the expected impacts on stream flow in the LVN Basin as result of climate change, four river nodes were selected: Node 1 and Node 3 in the upper catchment; and Node 11 and Node 17 in the lower catchment. The river nodes within the LVN Basin are indicated by red dots in Figure A2-1.

Figure A2-11 shows the percentage change in monthly average natural flow under climate change at each river node. The flow is expected to decrease over all the months in all sub-basins. Although rainfall is expected to increase, the temperature increase causes greater evapotranspiration and evaporation losses within the LVN basin causing an overall decrease in flow. The flow decreases both during the rainy seasons as well as in the dry season.

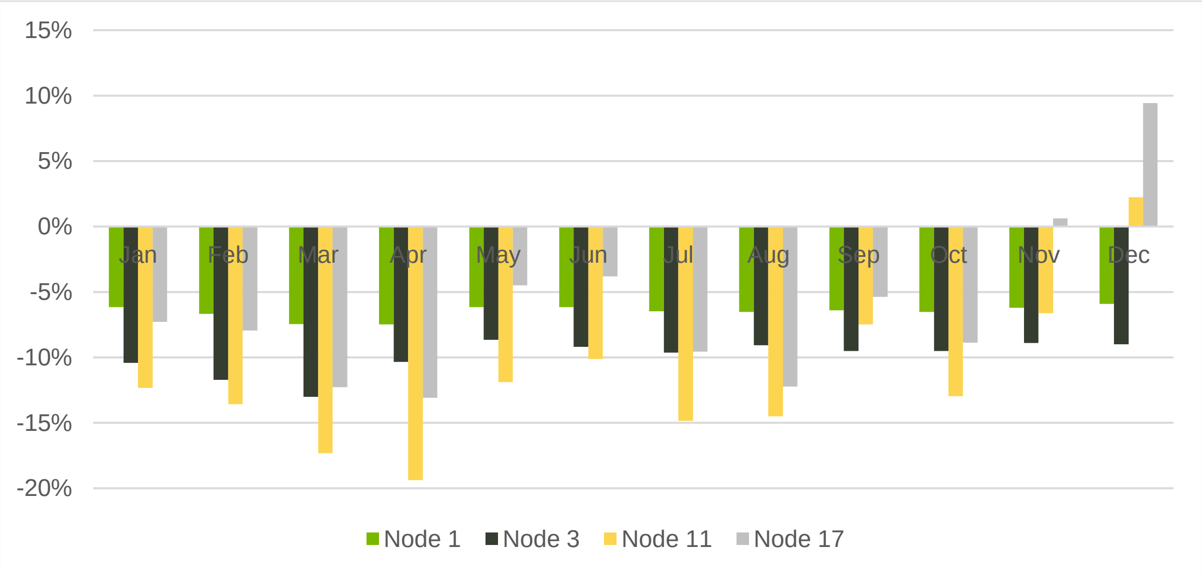


Figure A2-11: Percentage change between historical naturalised flow and naturalised flow with climate change

Figure A2-16 to Figure A2-19 illustrate the historical and future (climate change) monthly average flow, as well as the associated percentage change pertaining to each node, while Figure A2-12 to Figure A2-15 present flow duration curves for each node as well as the associated percentage change for different exceedance probabilities under climate change.

With respect to Node 1 (Figure A2-16), high flows with a low exceedance probability (less than 20%) are expected to experience a smaller relative decrease compared to lower flows associated with high exceedance probabilities (greater than 80%); suggesting that the rivers will have significantly decreased flows especially in the dry season. Furthermore, the decrease in average monthly flow results in a decrease in magnitude of all instantaneous flows. Node 3, node 11 and node 17 portray general decreased magnitudes in flow peaks in both the high flows and low flows, suggesting that there are transfer, evaporation and infiltration losses within the sub-basins.

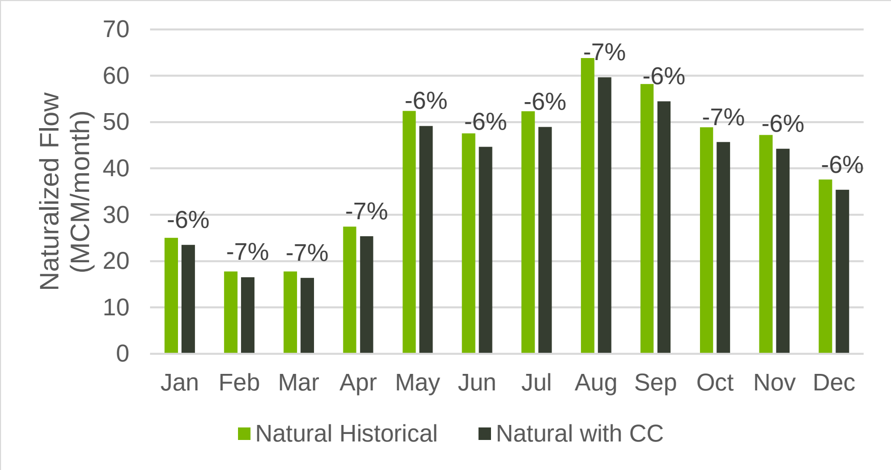


Figure A2-12: Monthly average flows and percentage change under current and future climate conditions – LVN Node 1

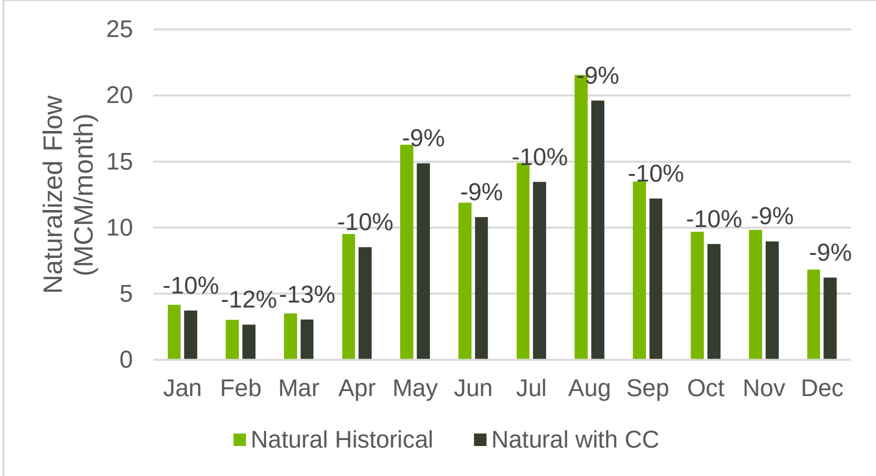


Figure A2-13: Monthly average flows and percentage change under current and future climate conditions – LVN Node 3

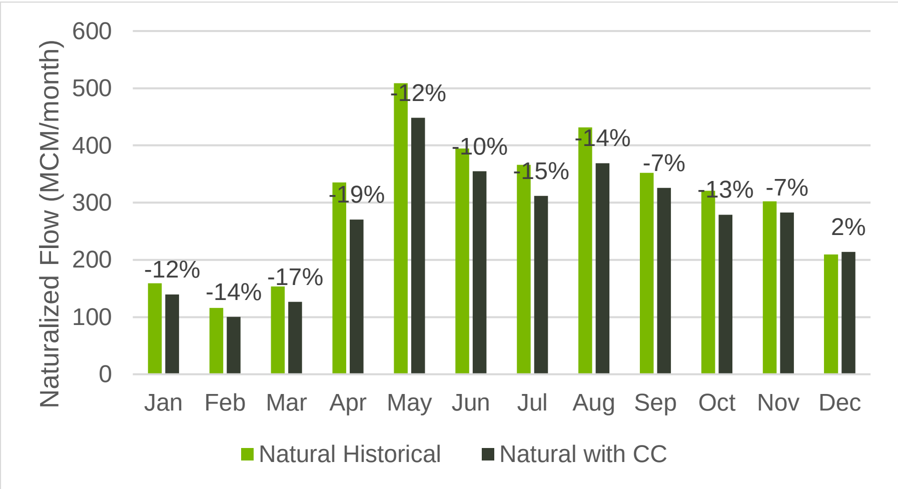


Figure A2-14: Monthly average flows and percentage change under current and future climate conditions – LVN Node 11

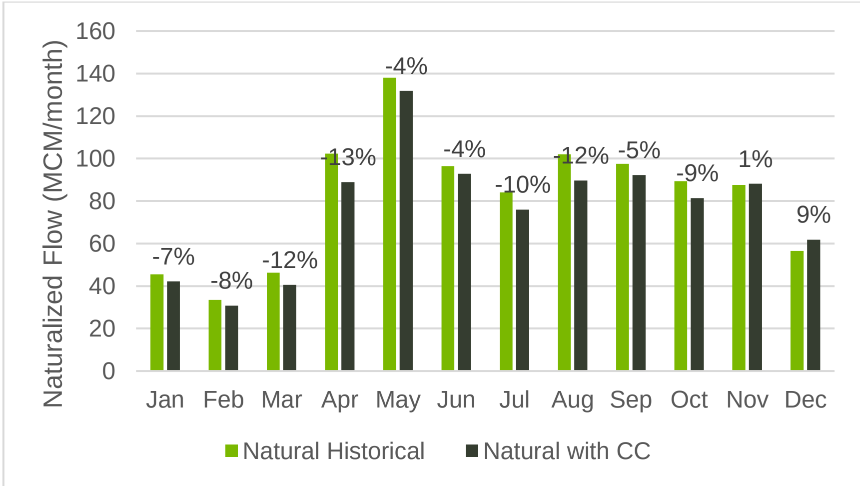


Figure A2-15: Monthly average flows and percentage change under current and future climate conditions – LVN Node 17

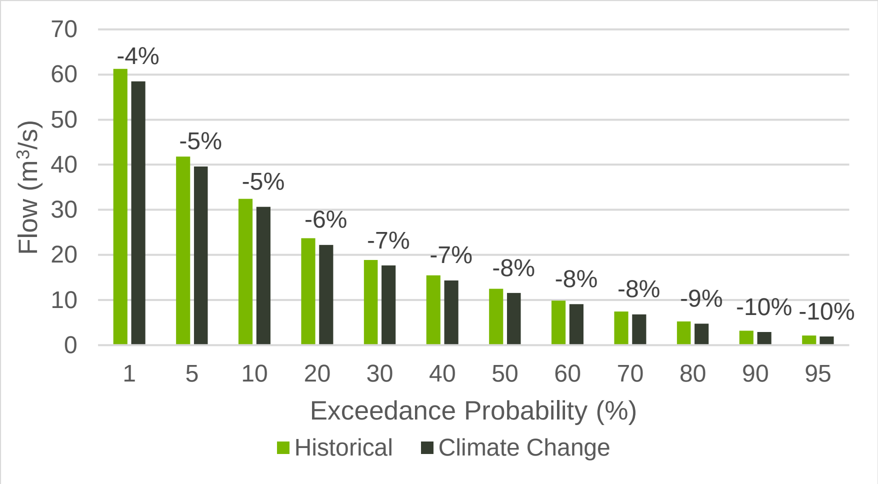


Figure A2-16: Monthly flow exceedance and percentage change under current and future climate conditions – LVN Node 1

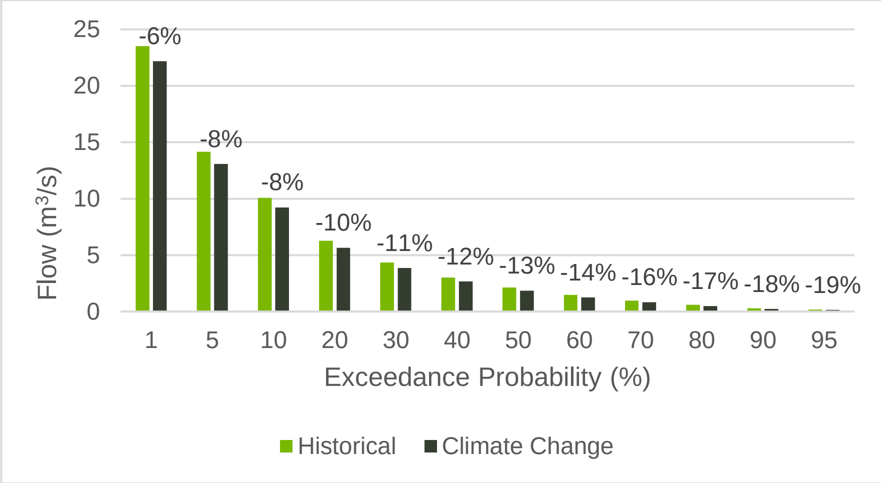


Figure A2-17: Monthly flow exceedance and percentage change under current and future climate conditions – LVN Node 3

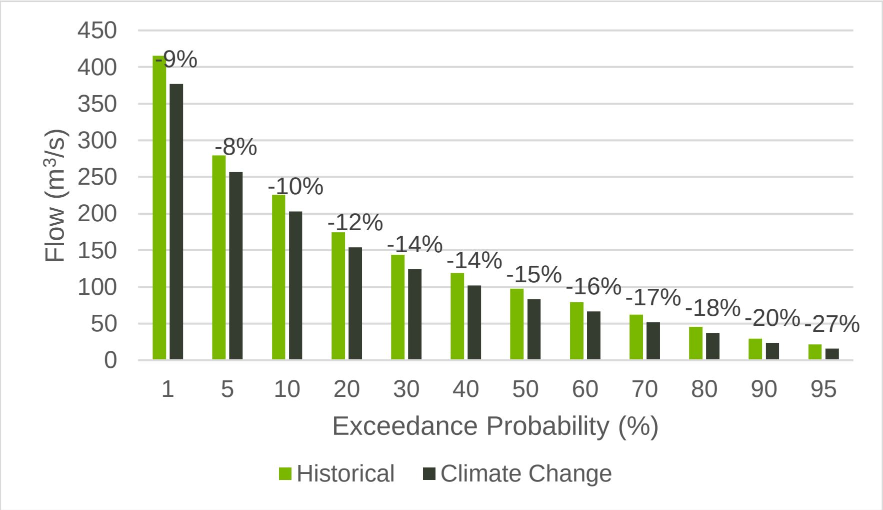


Figure A2-18: Monthly flow exceedance and percentage change under current and future climate conditions – LVN Node 11

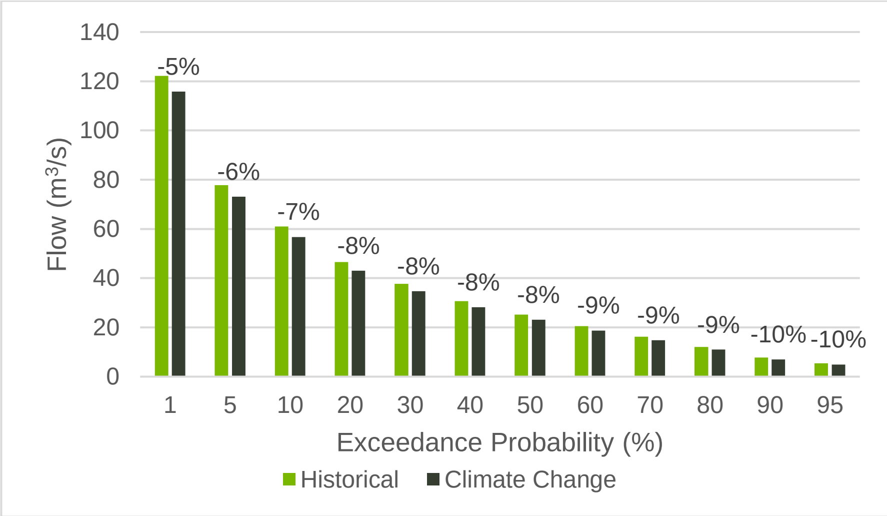


Figure A2-19: Monthly flow exceedance and percentage change under current and future climate conditions – LVN Node 17

A3: Surface water resources modelling

The main objectives of the surface water resources analysis for the Lake Victoria North Basin are to quantify the available surface water within the basin under natural conditions in both space and time, as well as to assess the present-day (baseline) surface water availability. This has been achieved through the development of a water resources systems model of the basin, which simulates the hydrological network, water demands and water resources infrastructure. MIKE HYDRO Basin, which incorporates the NAM rainfall-runoff model, was used as the water resources system model.

Hydrometeorological data collection and review

The Water Resources Authority (WRA) rainfall database contains historical daily data at 130 rainfall stations in the Lake Victoria North Basin, with data availability ranging from 1926 up to 2000. Of these, 33 stations with good quality records were selected. Raw data availability at each station is displayed in Figure A3-1, while the locations of the stations are shown in Figure A3-2.

Using monthly gap-filling tools, the station records were patched. The monthly gap filled data were disaggregated to daily data using nearby station daily rainfall patterns.

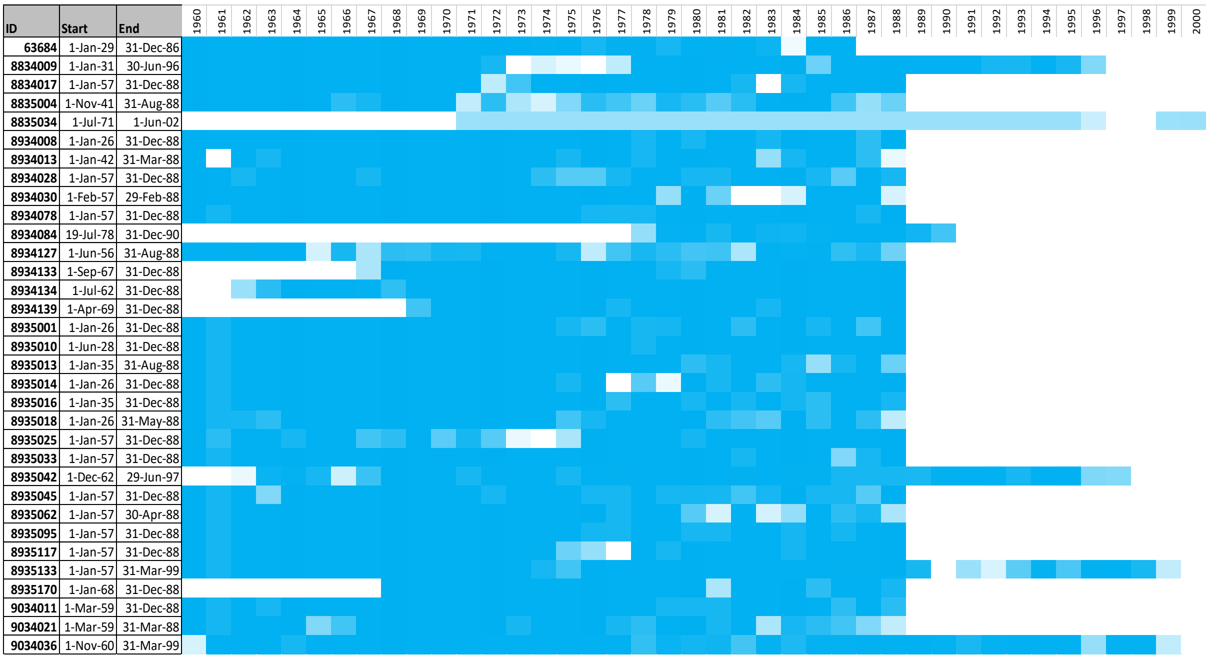


Figure A3-1: Data availability at selected rainfall stations

As the majority of the WRA data only extended up to Dec 1989, the Climate Hazards Group InfraRed Precipitation with Stations data (CHIRPS) dataset (Funk et al, 2015) was used to extend the rainfall datasets at the selected stations from 1989 to 2010. The CHIRPS dataset was identified for potential use, due to its relatively high resolution compared to other blended station data and satellite blended precipitation datasets.

CHIRPS is a 30+ year quasi-global rainfall dataset, spanning 50°S - 50°N (and all longitudes). CHIRPS incorporates 0.05° resolution satellite imagery with in-situ station data to create gridded rainfall time series starting in 1981 to near-present. CHIRPS was developed to support the United States Agency for International Development Famine Early Warning Systems Network (FEWS NET) and is freely available. CHIRPS data been used in studies to quantify the hydrologic impacts of decreasing precipitation and rising air temperatures in the Greater Horn of Africa, as well as support effective hydrologic forecasts and trend analyses in south-eastern Ethiopia (Funk, et al., 2015). CHIRPS daily precipitation data (Jan 1989 - Jan 2017) were extracted for multiple 0.05° grid cells corresponding to selected rainfall stations locations. The extracted CHIRPS records were used to extend the gap-filled observed rainfall records providing point rainfall time series for the period from Jan 1960 to Jan 2017.

Due to the relatively few rainfall stations in the Lake Victoria North Basin, as well as the limited availability of high elevation and near recent observed precipitation data, a Mean Annual Precipitation (MAP) surface for the basin was generated using the CHIRPS rainfall dataset (see Figure A3-3).

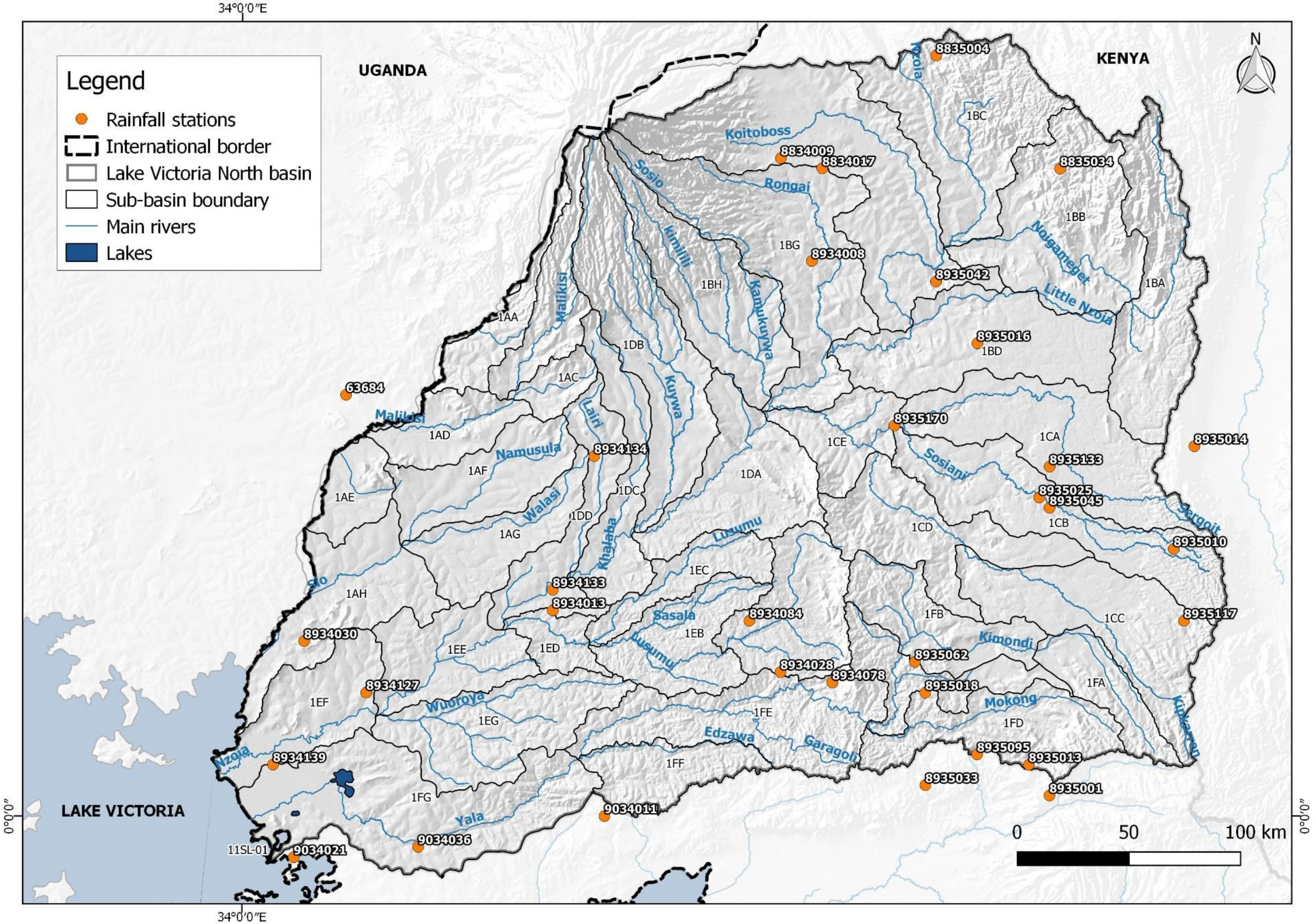


Figure A3-2: Location of selected rainfall stations

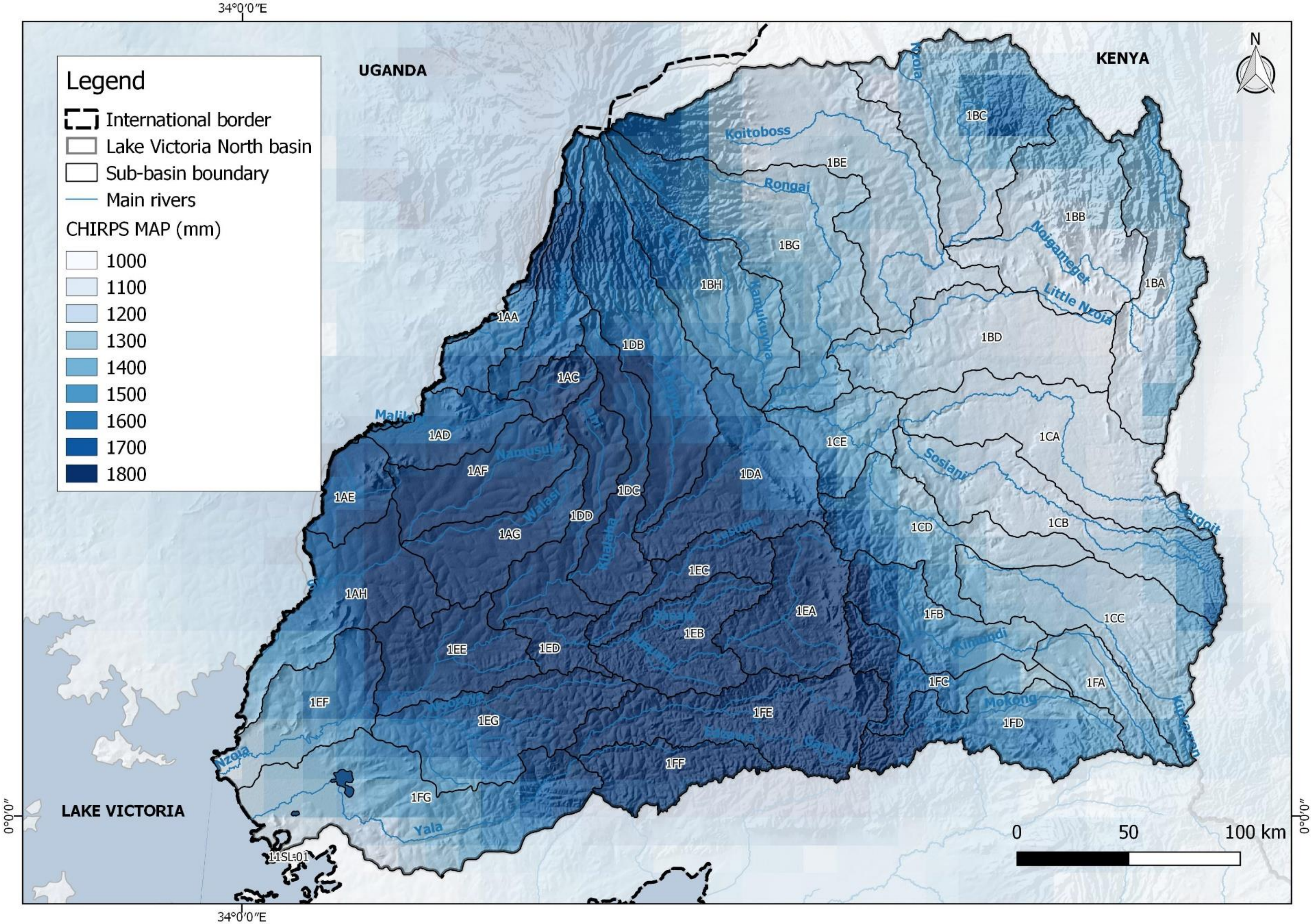


Figure A3-3: Mean Annual Precipitation

Streamflow data

In total, the Lake Victoria North Basin has historical daily water level records of varying quality and completeness for approximately 200 streamflow stations. Historical spot flow measurements of water level and discharge are available at 70 stations, with converted discharge records only available at 27 stations. A review of the available discharge records based on station location, records length, and data quality, resulted in an initial selection of 23 stations which are representative of the upper, middle and lower sections of the basin. Data availability at these stations, as sourced from WRA, is shown in Figure A3-4. Record periods at these stations vary between 2 and 50 years, however some stations are characterised by significant periods of missing data.

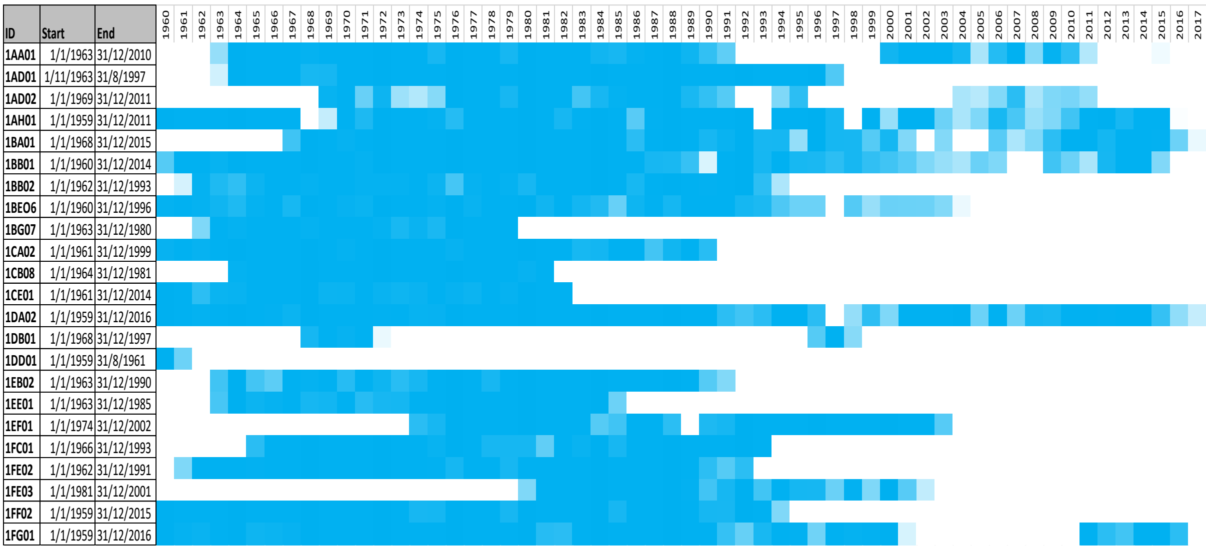


Figure A3-4: Data availability at selected river gauging stations

After quality control, which involved graphical analysis, mass plots and statistical analyses, anomalies and inconsistencies in some of the station records were identified. Eventually, only 22 stations were selected as listed in Table A3-1. These stations were used for calibration and validation of the rainfall-runoff model. Their locations within the basin are indicated in Figure A3-5.

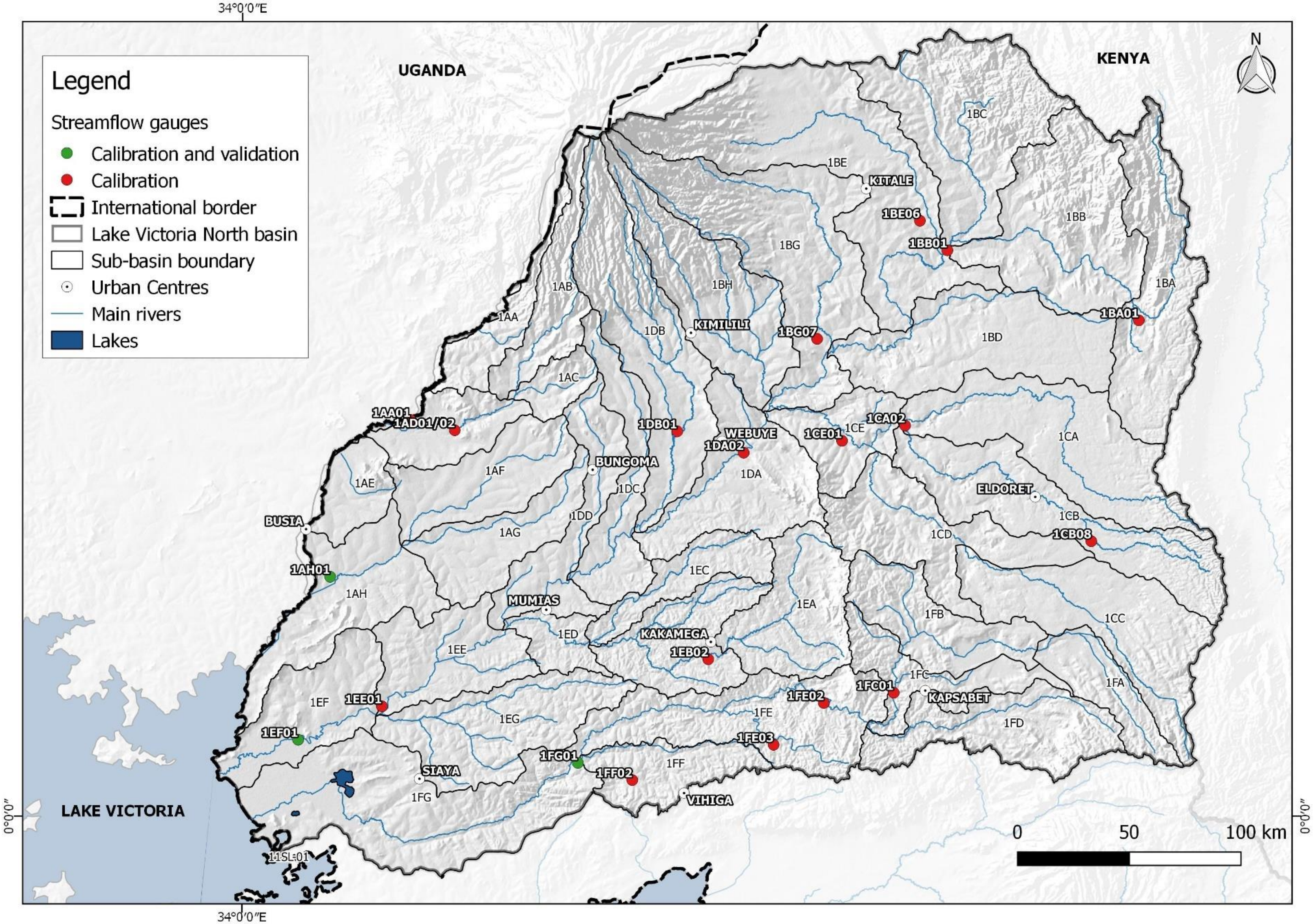


Figure A3-5: Locations of selected streamflow gauging stations

Table A3-1: Selected streamflow gauges for model calibration and validation

Station ID	Name	Longitude (°)	Latitude (°)	Catchment Area (km^2)
1AA01	MALABA	34.2708	0.6417	577
1AD01/02	MALAKISI	34.3389	0.6236	461
1AH01	SIO RIVER	34.1417	0.3875	1016
1BA01	MOIBEN	35.4431	0.8042	262
1BB01	NZOIA	35.1333	0.9208	1387
1BD02	LARGE NZOIA	35.0611	0.7611	563
1BE06	KOITOBOS	35.0903	0.9653	832
1BG07	RONGAI	34.9250	0.7736	740
1CA02	SERGOIT	35.0667	0.6333	692
1CB08	ENDOROTO	35.3667	0.4458	196
1CE01	KIPKARREN	34.9653	0.6083	2667
1DA02	NZOIA	34.8069	0.5889	8415
1DB01	KUYWA	34.7000	0.6236	533
1EB02	ISIUKHU	34.7500	0.2542	476
1EE01	NZOIA	34.2250	0.1778	11860
1EF01	NZOIA AT RUAMBWA FERRY	34.0903	0.1236	12684
1FC01	KIMONDI	35.0486	0.2000	852
1FD02	MOKONG RIVER	35.1244	0.1378	360
1FE02	YALA	34.9361	0.1833	1458
1FE03	GARAGOLI	34.8553	0.1156	64
1FF02	ZAABA	34.6278	0.0583	47
1FG01	YALA	34.5403	0.0861	2306

Evaporation data

Potential or reference evapotranspiration (ETo) data is one of the key inputs for rainfall runoff modelling. An analysis of evaporation data in the WRA repository was undertaken to assess data availability. The WRA database contains seven evaporation stations in the Lake Victoria North Basin. However, stations are plagued with data availability issues.

Observed evaporation data were thus considered insufficient for water resources modelling and gridded temperature data from the US National Oceanic and Atmospheric Administration (NOAA) was rather used to derive potential evaporation estimates in the basin. The NOAA dataset was derived from observed temperature data and consists of gridded average temperature data with a spatial resolution of 0.5° (approximately 50km over the equator) and a temporal resolution of one month for the period 1948-2017. The temperature based Blaney-Criddle method was used to convert the temperature data to monthly gridded reference ETo.

Water Resources Model

MIKE HYDRO Basin is a commercially-available, multipurpose, map-based decision support tool developed by the Danish Hydraulics Institute (DHI) for integrated river basin analysis, planning and management (DHI, 2017). It is designed for analysing water sharing issues at international, national and local river basin level and includes the lumped and conceptual NAM rainfall-runoff model.

In essence, the purpose of the water resources simulation modelling as part of this study, was to provide a tool to determine the natural, current and future surface water balance of the Lake Victoria North Basin and to assess the impacts of future development opportunities in an integrated manner to support future water allocations and planning. The model was used, firstly, to evaluate the historic (natural) and present-day (baseline) water balance of the Basin and will be used to simulate the water balance under alternative future development, land-use and climate-change scenarios during the next model development phase.

Based on the availability of historical rainfall data (see Section **Error! Reference source not found.**), a simulation period from 1 Jan 1960 to 1 Jan 2017 was determined for the model simulations, which were conducted at a daily time-step.

The water resources modelling task involved the sequential steps listed below, each of which is discussed in more detail in the following sections:

1. Model sub-catchment delineation
2. Assignment of hydro-meteorological time series data to model sub-catchments
3. Model calibration and validation
4. Configuration of natural and present-day models

Catchment delineation

River network generation and catchment delineation of model sub-catchment areas within the Lake Victoria North Basin were based on the HydroSHED hydrologically conditioned 90 m SRTM DEM (NASA, 2009), processed within MIKE HYDRO Basin's catchment delineation tool. Sub-catchment areas were delineated upstream of points of interest such as WRA sub-basin outlets (i.e. 1AA, 1AB…), streamflow gauging stations, existing and proposed dams, tributary confluences, river diversion or abstraction points and proposed water resources development schemes. Figure A3-6 presents an overview of the Lake Victoria North Basin containing the final delineated model sub-catchments. In total, 76 sub-catchments were delineated.

Assignment of hydro-meteorological data

The NAM rainfall-runoff model, which is incorporated in the MIKE HYDRO Basin model, requires rainfall and evaporation time series data to be assigned to each model sub-catchment.

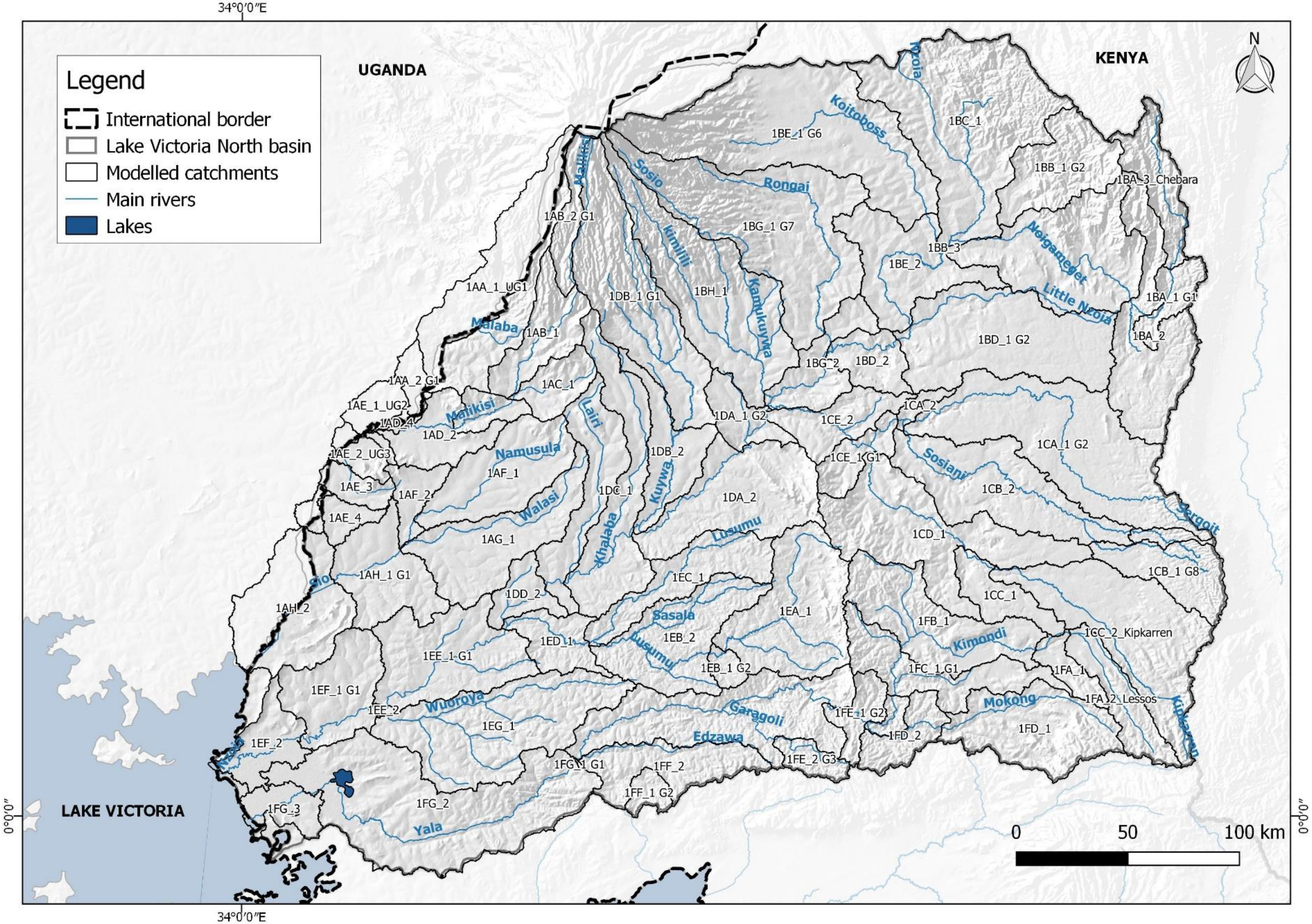
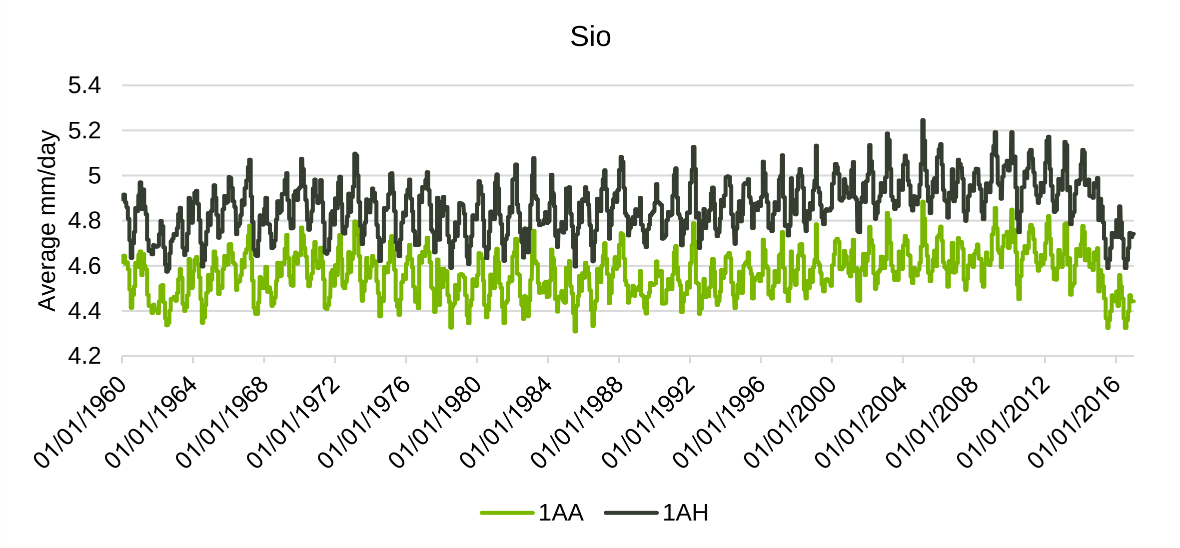
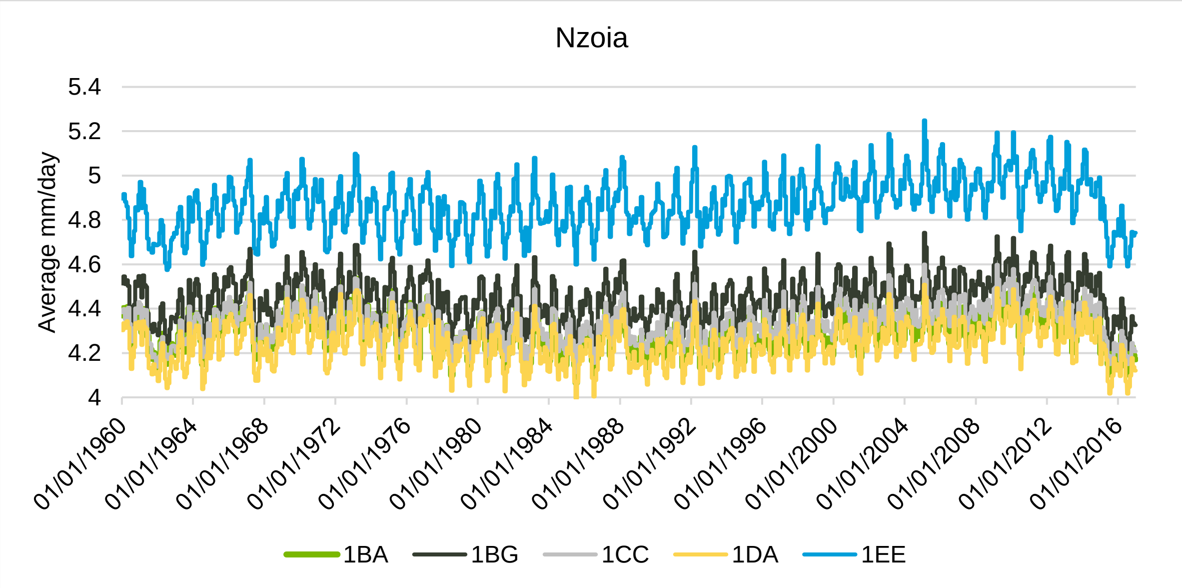


Figure A3-6: Delineated model sub-catchments in the Lake Victoria North Basin

The point rainfall data at the 33 rainfall stations across the Basin (see Section 2.1) were converted from units of millimetres per day to % MAP per day for the simulation period (1960 – 2017). Point rainfall time series were then converted to catchment (areal) rainfall time series with the use of Thiessen Polygons, resulting in a single, daily % MAP file for each modelled sub-catchment. The conversion of rainfall units from % MAP back to mm, was achieved though multiplication with the sub-catchment MAPs extracted from the CHIRPS-based MAP coverage.

Based on the constructed ETo surface for the Lake Victoria North Basin as discussed in Section 0, areal averaged monthly ETo values for each model sub-catchment were calculated and assigned. An example of calculated daily ETo values at locations in the upper, middle and lower regions of each of the main rivers of are shown below shown in Figure A3-7.





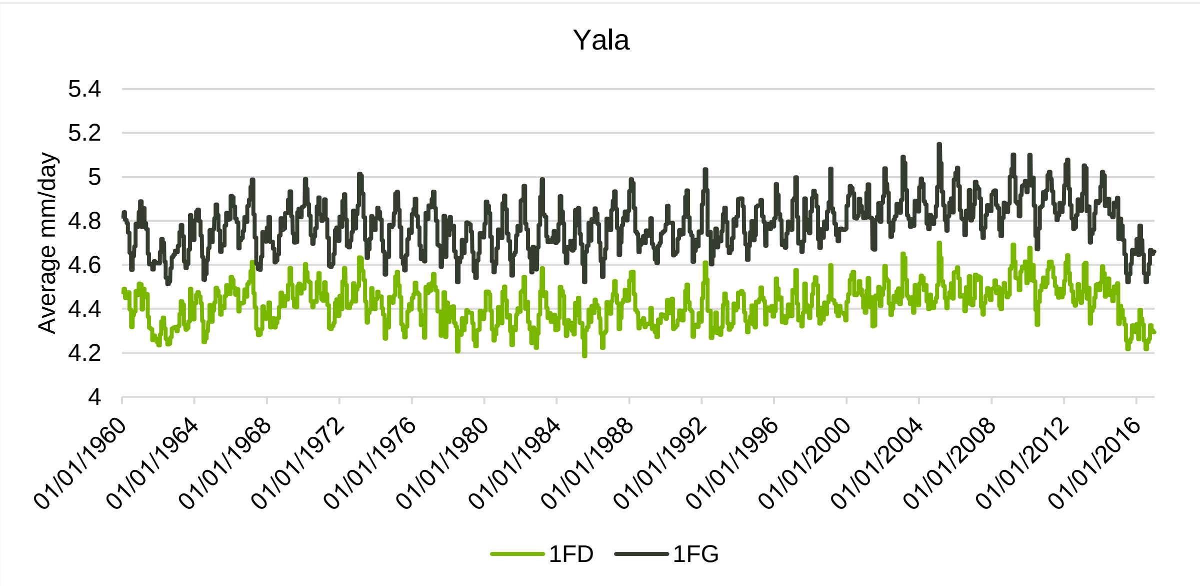


Figure A3-7: Typical reference ETo values of the three main rivers in the Lake Victoria North Basin

Model Calibration

The calibration of the NAM rainfall-runoff model in the Lake Victoria North Basin was dependent on the availability of concurrent and good quality historical precipitation and streamflow data, as discussed in Section **Error! Reference source not found.** and Section 0. On this basis, 21 selected flow gauging stations were chosen as calibration locations. The majority of potential calibration periods at these stations occurred between 1960 and 1980 - due to better observed data availability and apparent superior data quality compared to more recent time periods. Although the relatively undeveloped state of the identified calibration catchments during this time period meant that the catchments could be considered close to their 'natural' state, historical water demand data for calibration periods, from the WRA database, were added to downstream observed streamflow records at the calibration sites in order to 'naturalise' the observed flow records before calibration. A description of the NAM rainfall-runoff model calibration parameters is provided in Table A3-2.

Table A3-2: NAM rainfall-runoff calibration parameters

Category	Parameter Name	Parameter Abbreviation	Description	Typical Values
Surface-rootzone:	Maximum water content in surface storage	UMax	Represents the cumulative total water content of the interception storage (on vegetation), surface depression storage and storage in the uppermost layers (a few cm) of the soil.	10 mm-20 mm
Surface-rootzone:	Maximum water content in root zone storage	LMax	Represents the maximum soil moisture content in the root zone, which is available for transpiration by vegetation.	50 mm-300 m
Surface-rootzone:	Overland flow runoff coefficient	CQOF	Determines the division of excess rainfall between overland flow and infiltration.	0-1
Surface-rootzone:	Time constants for routing interflow	CKIF	Determines the amount of interflow, which decreases with larger time constants.	500 hrs - 1000 hrs
Surface-rootzone:	Time constants for routing overland flow	CK1	Determine the shape of Hydrograph peaks. The routing takes place through two linear reservoirs (serially connected) with different time constants, expressed in hours. High, sharp peaks are simulated with small time constants, whereas low peaks, at a later time, are simulated with large values of these parameters.	3 hrs - 48 hrs
Surface-rootzone:	Time constants for routing overland flow	CK2		
Surface-rootzone:	Root zone threshold value for overland flow	TOF	Determines the relative value of the moisture content in the root zone (L/Lmax) above which overland flow is generated. The main impact of TOF is seen at the beginning of a wet season, where an increase of the parameter value will delay the start of runoff as overland flow.	0% - 70% of Lmax. Max value 0.99
Surface-rootzone:	Root zone threshold value for interflow	TIF	Determines the relative value of the moisture content in the root zone (L/Lmax) above which interflow is generated.	-
Groundwater	Root zone threshold value for GW recharge	TG	Determines the relative value of the moisture content in the root zone (L/Lmax) above which groundwater (GW) recharge is generated. The main impact of increasing TG is less recharge to the groundwater storage.	0% - 70% of Lmax. Max value 0.99
Groundwater	Time constants for routing base flow	CKBF	Can be determined from the Hydrograph recession in dry periods. In rare cases, the shape of the measured recession changes to a slower recession after some time.	-

Category	Parameter Name	Parameter Abbreviation	Description	Typical Values
Groundwater	Lower base flow/recharge to lower reservoir	CQLow	Percentage recharge to the lower groundwater reservoir as percentage of the total recharge.	0% - 100%
Groundwater	Time constant for routing lower base flow	CKLow	Specified for CQLow > 0 as a baseflow time constant, which is usually larger than the CKBF.	-

Simulated streamflow sequences were calibrated against naturalised observed flow records through the iterative adjustment of the NAM model parameters until the ‘goodness of fit’ between the simulated and observed flow records was within acceptable standards. ‘Goodness of fit’ was assessed based on graphical comparison of time series and scatterplots, while various metrics and statistical indices such as average annual flow, standard deviation of annual flow, seasonality index, coefficient of determination and the Nash-Sutcliffe coefficient of efficiency were considered.

The Nash-Sutcliffe Efficiency (NSE) is a normalised statistic used to assess the predictive power of hydrological models by determining the relative magnitude of the residual variance compared to the measured data variance (Nash and Sutcliffe, 1970). NSE indicates how well the plot of observed versus simulated data fits the 1:1 line. NSE ranges between $-\infty$ and 1, with NSE equal to 1 being the optimal value. Values between 0 and 1 are generally viewed as acceptable levels of performance, whereas values smaller than 0 indicates that the mean observed value is a better predictor than the simulated value, which indicates unacceptable performance (Moriasi et al., 2007).

Calibrated NAM parameters at the calibration gauges are presented in Table A3-3 with calibration performance metrics per gauge summarised in Table A3-4. Calibration plots are presented in Figure A3-8 to Figure A3-27.

Table A3-3: Calibrated NAM model parameters

Gauge		Surface-rootzone							
Parameter Set	Gauge	Umax	Lmax	CQOF	CKIF	CK1	CK2	TOF	TIF
no.	ID	mm	mm	-	h	h	h	-	-
1	1AA01	15	350	0.3	1000	24	24	0.1	0.1
2	1AD01	20	350	0.1	1000	24	24	0.1	0.1
3	1AH01	10	200	0.3	1000	24	24	0.1	0.1
4	1BA01	20	300	0.1	800	24	24	0.1	0.1
5	1BB01	10	400	0.2	1000	24	24	0.1	0.1
6	1BD02	10	400	0.2	1000	24	24	0.1	0.1
7	1BE06	20	300	0.05	1000	24	24	0.1	0.1
8	1BG07/ 1DA02	10	350	0.3	1000	24	24	0.1	0.1
9	1CA02/ 1CB08/ 1CE01	10	400	0.3	1000	24	24	0.2	0.1
10	1DB01	10	300	0.3	1000	24	24	0.1	0.1
11	1EB02	10	200	0.3	1000	24	24	0.1	0.1
12	1EE01/ 1EF01	10	200	0.3	800	24	24	0.2	0.2
13	1FC01	15	200	0.4	1000	24	24	0.3	0.1
14	1FE02/ 1FE03/ 1FF02/ 1FG01	10	200	0.3	800	24	24	0.2	0.1

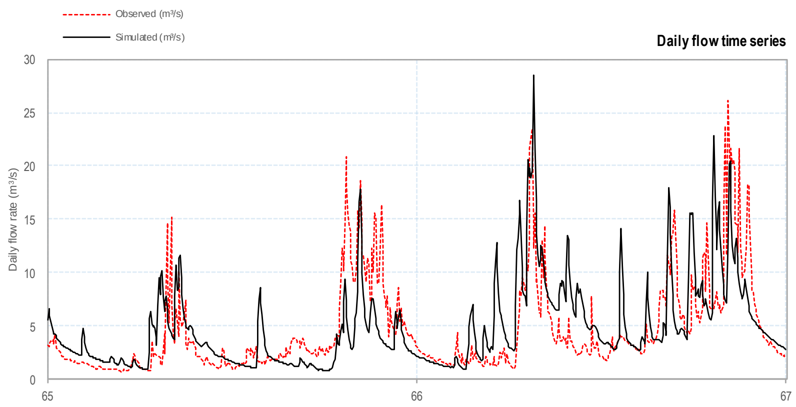
Gauge		Groundwater			
Parameter Set	Gauge	TG	CKBF	CQLow	CKLow
no.	ID	-	h	%	h
1	1AA01	0.1	1000	20	4500
2	1AD01	0.3	1000	20	4500
3	1AH01	0.1	1000	20	4500
4	1BA01	0.01	1500	20	4500
5	1BB01	0.1	1000	20	4500
6	1BD02	0.1	1000	20	4500
7	1BE06	0.01	1500	40	4500
8	1BG07/ 1DA02	0.01	1000	40	4500
9	1CA02/ 1CB08/ 1CE01	0.3	700	20	4500
10	1DB01	0.01	1000	40	4500
11	1EB02	0.3	700	20	4500
12	1EE01/ 1EF01	0.3	700	20	4000
13	1FC01	0.01	600	20	4500
14	1FE02/ 1FE03/ 1FF02/ 1FG01	0.3	800	30	4000

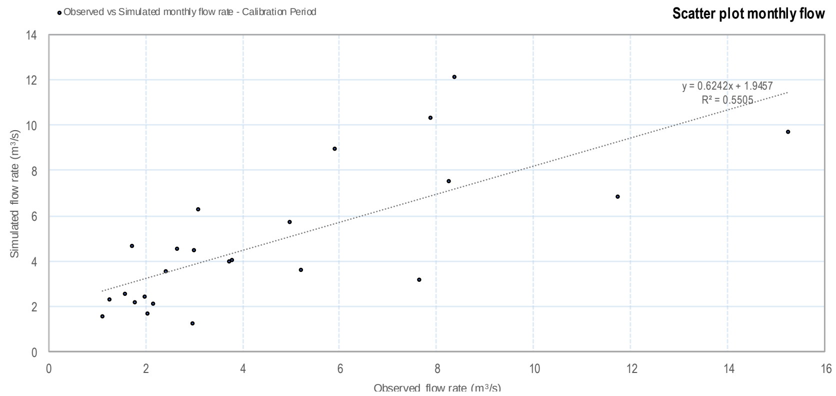
Table A3-4: Calibration performance metrics

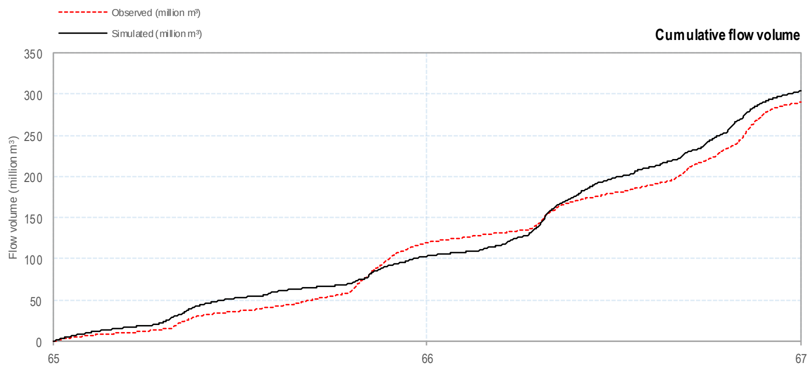
Station number	Catchment Area (km^2)	Calibration Period	Observed MAR (Mm^3)	Simulated MAR (Mm^3)	Coefficient of Determination (r^2)	Water Balance Error (WBL)	Nash-Sutcliffe efficiency (NSE)
1AA01	577	1965-1967	145.1	152.0	0.551	4.6	0.275
1AD01/02	461	1964-1967	119.1	132.1	0.695	9.9	0.395
1AH01	1016	1977-1984	423.3	430.8	0.773	1.8	0.528
1BA01	256.9	2009-2014	76.6	94.2	0.663	18.6	0.378
1BB01	1387	1984-1986	139.4	149.5	0.822	6.6	0.500
1BD02	3869	1990-1995	538.8	594.3	0.524	9.4	0.211
1BE06	832	1981-1990	73.8	72.8	0.673	-1.3	0.553
1BG07	740	1963-1980	155.4	124.3	0.718	-25.0	0.512
1CA02	692	1961-1990	72.6	77.1	0.706	5.8	0.490
1CB08	196	1971-1973	49.4	48.7	0.823	-1.3	0.439
1CE01	2666	1962-1983	540.7	445.9	0.747	-21.3	0.509
1DA02	8414	1961-1963	520.4	950.8	0.907	45.3	0.108

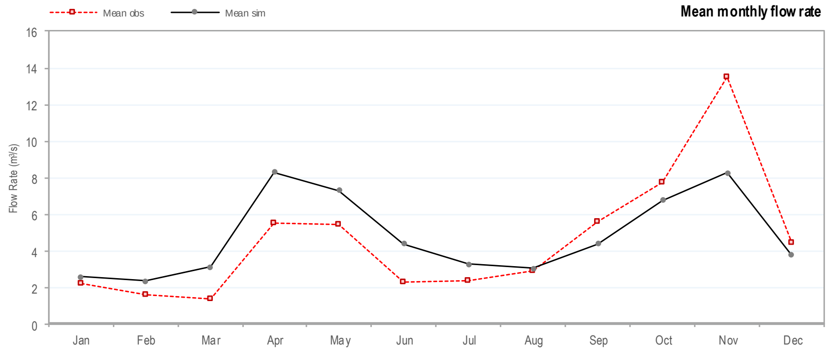
Station number	Catchment Area (km^2)	Calibration Period	Observed MAR (Mm^3)	Simulated MAR (Mm^3)	Coefficient of Determination (r^2)	Water Balance Error (WBL)	Nash-Sutcliffe efficiency (NSE)
1DB01	533	1968-1970	97.1	108.9	0.763	10.9	-0.35
1EB02	476	1980-1990	254.2	261.6	0.630	2.8	0.251
1EE01	11860	1963-1983	2682.4	3091.9	0.835	13.2	0.619
1EF01	12684	1974-1988	3541.0	3153.4	0.800	-12.3	0.662
1FC01	852	1984-1988	120.5	125.4	0.626	3.9	0.311
1FE02	1458	1983-1987	180.6	274.6	0.553	34.3	0.226
1FE03	64	1981-2002	38.8	36.6	0.425	-5.9	-0.318
1FF02	47	1960-1975	23	27.7	0.684	17.1	0.257
1FG01	2306	1960-1990	932.4	974.1	0.708	4.3	0.389

Calibration Results: 1AA01-   Catchment Area: 577.27 km³   10/26/2018 8:36 AM









Performance Metrics   Node no. N394|Net flow to node   Node no. N394|Net flow to node

Coeff. of Determination (r^2) 0.551

Nash-Sutcliffe Coeff. of Efficiency 0.275

	Observed	Simulated	%Difference	Target %		Observed
Mean Annual Runoff (MAR) Jan- Dec [M m³]	145.1	152.0	4.5%	± 4%	Unit runoff [mm]	251.4
Annual Standard Deviation [M m³]	35.8	68.4	47.6%	± 6%	MAP [mm]	1668
Seasonal Index	23.40	12.78	-83.1%	± 8%	Runoff %	15%

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	2.2	1.6	1.4	5.5	5.4	2.3	2.4	3.0	5.6	7.8	13.5	4.5	4.6
Simulated	2.6	2.4	3.1	8.3	7.3	4.4	3.3	3.1	4.4	6.8	8.3	3.8	4.8
%difference	14.7%	31.7%	54.4%	33.9%	25.8%	47.2%	27.6%	3.5%	-27.3%	-14.5%	-62.5%	-17.9%	4.6%

MHB results file: C:\DHI\113699 Kenya ISC\1.1-LVN\01-MIKE_HYDRO_Basin\01-MHB_Projects\Natural\LVN-Natural_demands.mhydro - Result Files\RiverBasin_LVN Natural_demands.dfs0

Document: C:\DHI\113699 Kenya ISC\1.1-LVN\01-MIKE_HYDRO_Basin\01-MHB_Projects\Calibration\Nzoia\[MHB_Calibration_1AA01.xlsm]Sheet1

Figure A3-8: Calibration plot for streamflow gauge 1AA01

Calibration Results: 1AD01-

Catchment Area: 465.196 km³

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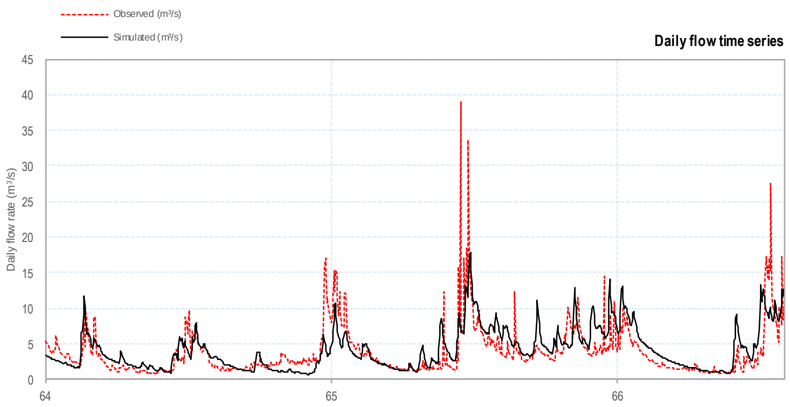

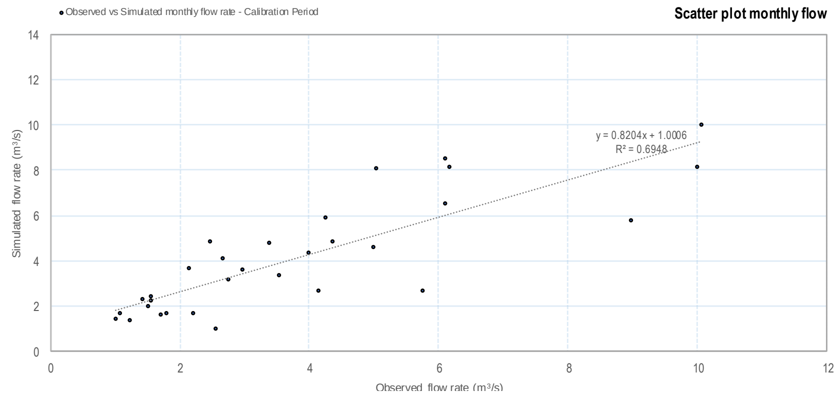

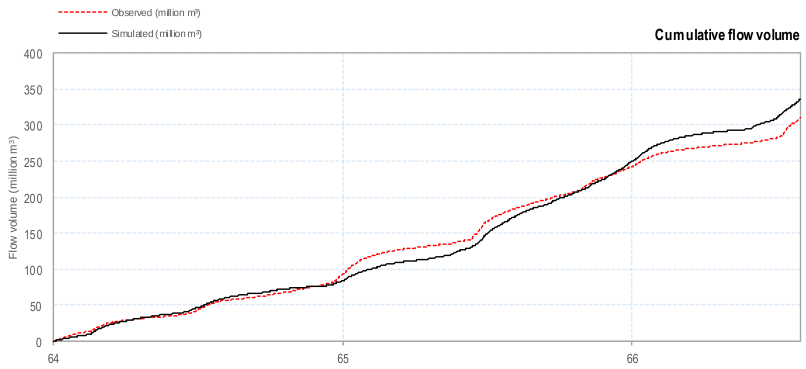

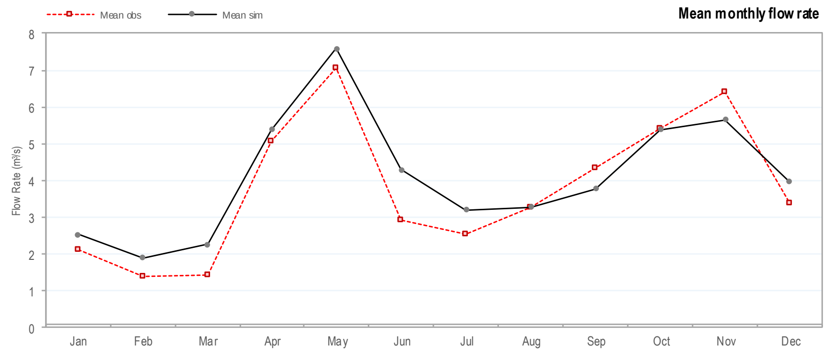

Performance Metrics

Node no. N397|Net flow to node

Coeff. of Determination (r^2) 0.695

Nash-Sutcliffe Coeff. of Efficiency 0.395

	Observed	Simulated	%Difference	Target %		Observed
Mean Annual Runoff (MAR) Jan- Dec [Mm³]	119.1	132.1	9.8%	± 4%	Unit runoff [mm]	256.1
Annual Standard Deviation [Mm³]	25.8	60.8	57.5%	± 6%	MAP [mm]	1712
Seasonal Index	14.89	11.98	-24.3%	± 8%	Runoff %	15%

Node no. N397|Net flow to node

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	2.1	14	14	5.1	7.1	2.9	2.5	3.3	4.3	5.4	6.4	3.4	3.8
Simulated	2.5	19	2.3	5.4	7.6	4.3	3.2	3.3	3.8	5.4	5.7	4.0	4.2
%difference	16.7%	26.2%	37.7%	5.8%	6.8%	32.1%	20.5%	-0.5%	-14.3%	-0.2%	-13.3%	14.2%	9.9%

MHB results file: C:\DHI\113699 Kenya ISC\1.1-LVN\01-MIKE_HYDRO_Basin\01-MHB_Projects\Natural\LVN-Natural_demands.mhydro - Result Files\River Basin_LVN Natural_demands.dfs0

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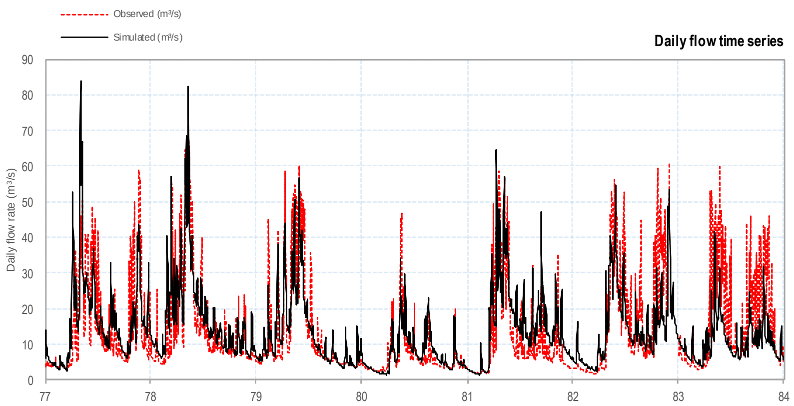
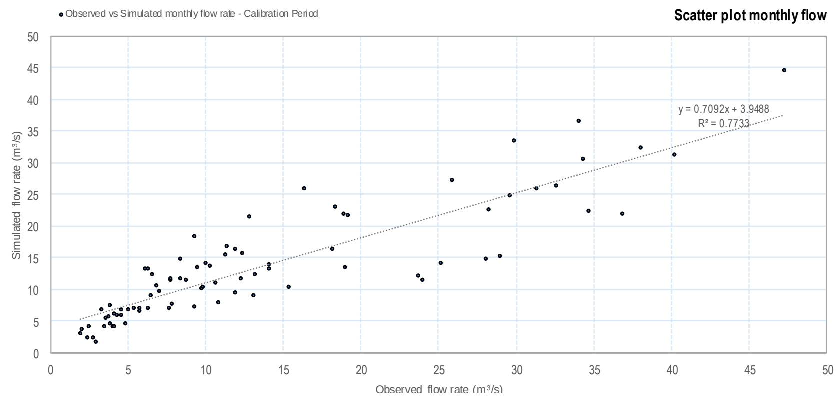
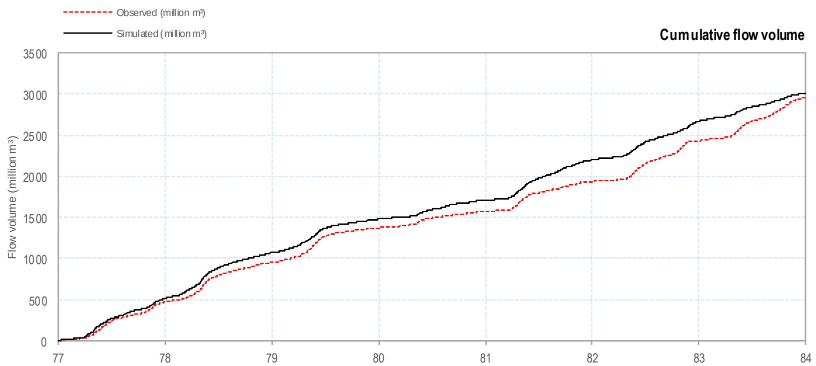
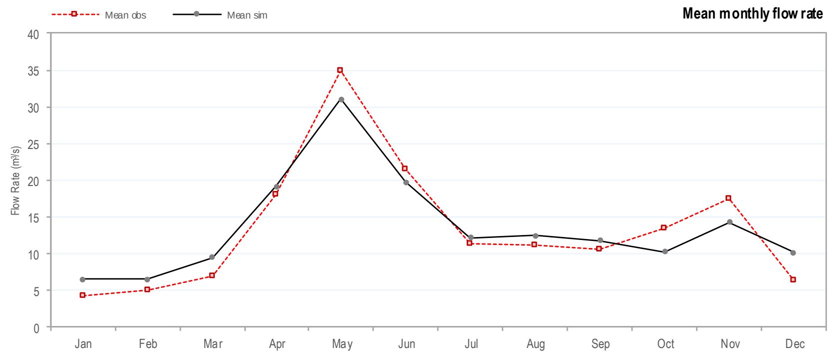
Figure A3-9: Calibration plot for streamflow gauge 1AD01

Calibration Results: 1AH01- Catchment Area: 1016.192 km³ 10/26/2018 8:38 AM









Performance Metrics

Node no. N400|Net flow to node

Coeff. of Determination (r^2) 0.773

Nash-Sutcliffe Coeff. of Efficiency 0.528

	Observed	Simulated	%Difference	Target %		Observed
Mean Annual Runoff (MAR) Jan- Dec [M m³]	423.3	430.8	1.7%	± 4%	Unit runoff [mm]	416.6
Annual Standard Deviation [M m³]	114.6	112.1	-2.3%	± 6%	MAP [mm]	1723
Seasonal Index	25.50	17.71	-44.0%	± 8%	Runoff %	24%

Node no. N400|Net flow to node

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	4.3	4.9	6.9	18.1	34.9	21.5	11.3	11.1	10.6	13.4	17.4	6.3	13.4
Simulated	6.5	6.5	9.4	19.1	31.1	19.8	12.2	12.5	11.8	10.3	14.2	10.2	13.7
%difference	34.3%	24.3%	26.5%	5.2%	-12.4%	-9.0%	7.2%	10.8%	9.9%	-31.1%	-22.5%	38.1%	1.8%

MHB results file: C:\DHI\113699 Kenya ISC\1.1-LVN\01-MIKE_HYDRO_Basin\01-MHB_Projects\Natural\LVN-Natural_demands.mhydro - Result Files\River Basin_LVN Natural_demands.dfs0

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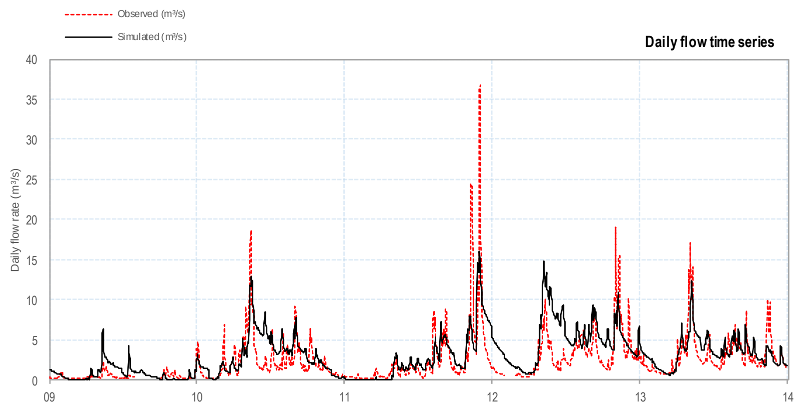
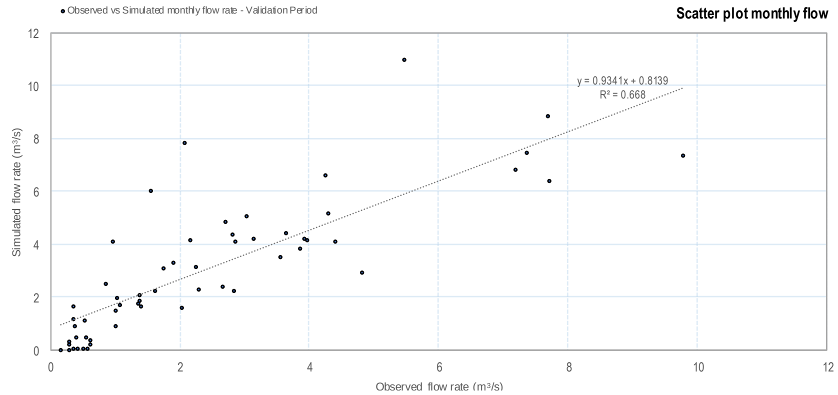
Figure A3-10: Calibration plot for streamflow gauge 1AH01

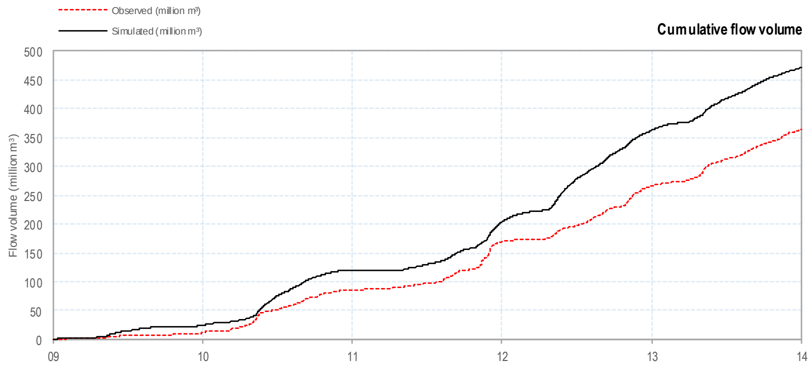
Calibration Results: 1BA01-

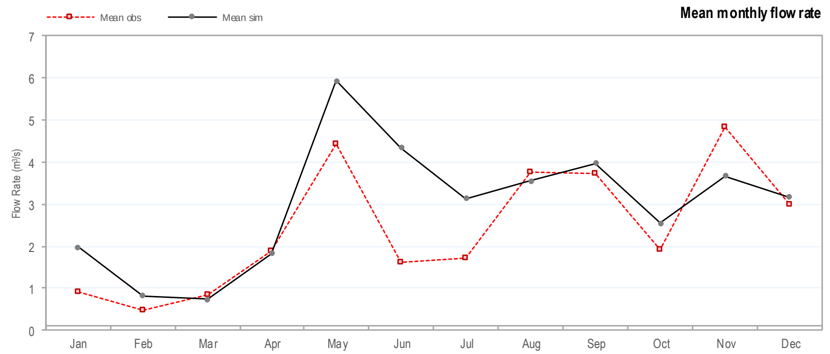
Catchment Area: 256.9 km³

10/27/2018 4:52 PM









Performance Metrics

Node no. N402|Net flow to node

Coeff. of Determination (r^2) 0.668

Nash-Sutcliffe Coeff. of Efficiency 0.378

	Observed	Simulated	%Difference	Target %		Observed
Mean Annual Runoff (MAR) Jan- Dec [Mm³]	76.6	94.2	18.6%	± 4%	Unit runoff [mm]	298.3
Annual Standard Deviation [Mm³]	11.8	48.6	75.7%	± 6%	MAP [mm]	1301
Seasonal Index	17.31	18.46	6.2%	± 8%	Runoff %	23%

Node no. N402|Net flow to node

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	0.9	0.5	0.8	19	4.4	16	17	3.8	3.7	19	4.8	3.0	2.4
Simulated	2.0	0.8	0.7	18	5.9	4.3	3.1	3.6	4.0	2.5	3.7	3.2	3.0
%difference	54.2%	43.2%	-15.6%	-2.3%	25.0%	62.4%	45.7%	-6.1%	5.8%	24.5%	-31.2%	5.3%	18.6%

MHB results file: C:\DHI\113699 Kenya ISC\1.1-LVN\01-MIKE_HYDRO_Basin\01-MHB_Projects\Natural\LVN-Natural_with demands.mhydro - Result Files\River Basin_LVN Natural_demands.dfs0

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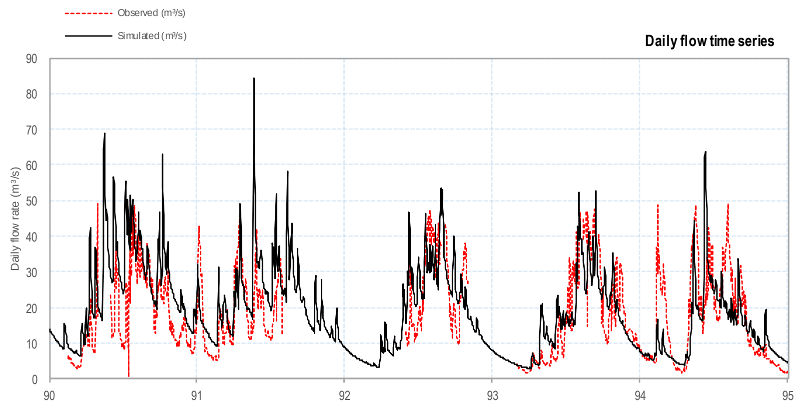
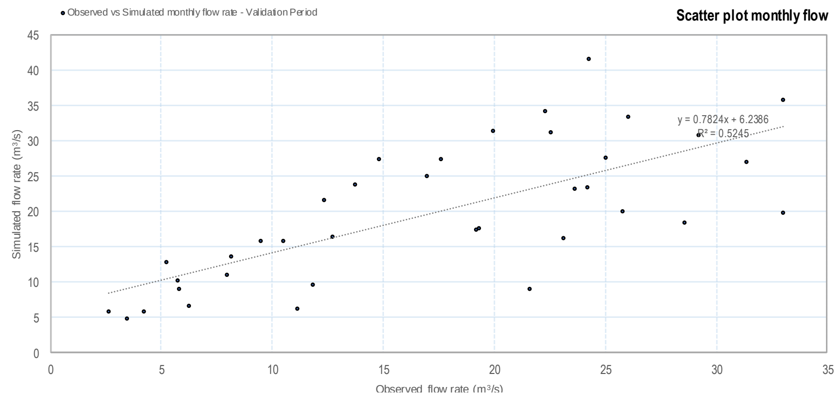
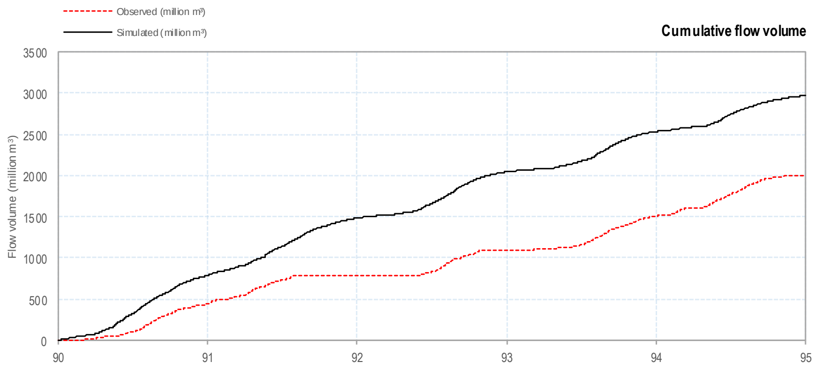
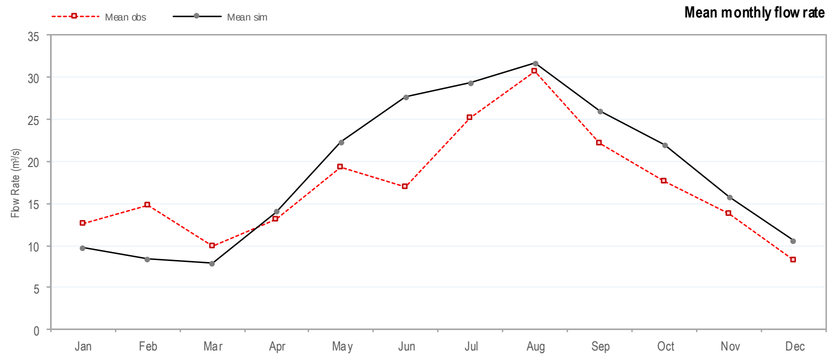
Figure A3-11: Calibration plot for streamflow gauge 1BA01

Calibration Results: 1BD02 - Catchment Area: 3869 km³ 10/27/2018 5:28 PM









Performance Metrics

Node no. N405|Net flow to node

Coeff. of Determination (r^2) 0.524

Nash-Sutcliffe Coeff. of Efficiency 0.211

	Observed	Simulated	%Difference	Target %		Observed
Mean Annual Runoff (MAR) Jan- Dec [M m³]	538.8	594.3	9.3%	± 4%	Unit runoff [mm]	139.3
Annual Standard Deviation [M m³]	Insufficient	146.3	Insufficient	± 6%	MAP [mm]	1159
Seasonal Index	28.04	20.87	-34.3%	± 8%	Runoff %	12%

Node no. N405|Net flow to node

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	12.7	14.9	9.9	13.2	19.4	17.0	25.2	30.8	22.2	17.7	13.7	8.3	17.1
Simulated	9.7	8.4	7.9	14.0	22.3	27.7	29.4	31.7	26.0	22.0	15.7	10.6	18.8
%difference	-30.1%	-77.1%	-25.2%	6.0%	13.0%	38.7%	14.2%	2.8%	14.6%	19.4%	12.7%	21.2%	9.4%

MHB results file: C:\DHI\113699 Kenya ISC\1.1-LVN\01-MIKE_HYDRO_Basin\01-MHB_Projects\Natural\LVN-Natural_with demands.mhydro - Result Files\River Basin_LVN Natural_demands.dfs0

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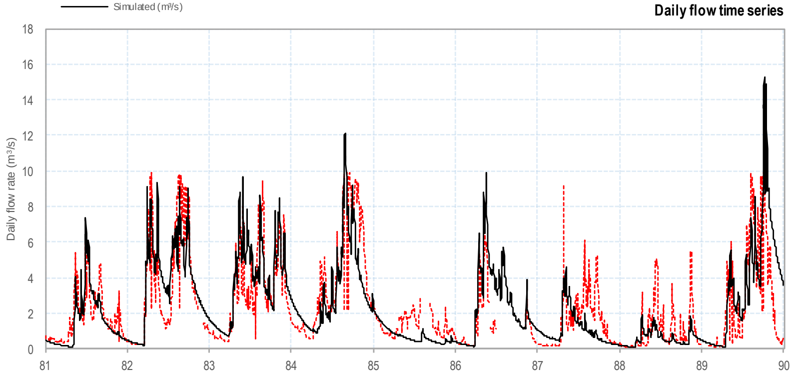
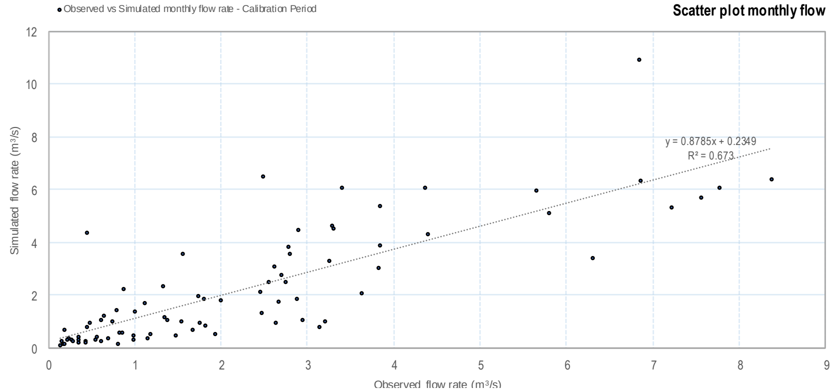
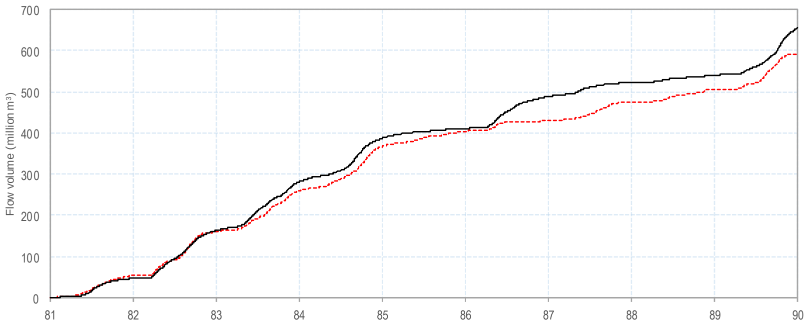
Figure A3-12: Calibration plot for streamflow gauge 1BD02

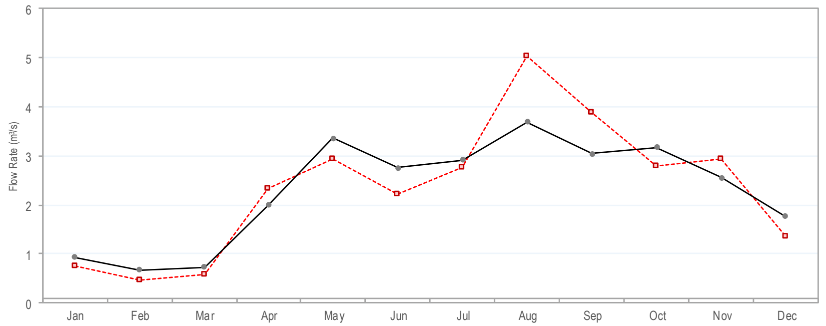
Calibration Results: 1BE06 - Catchment Area: 8317 km²

10/26/2018 8:41AM









Performance Metrics

Node no. N407|Net flow to node

Coeff. of Determination (r^2) 0.673

Nash-Sutcliffe Coeff. of Efficiency 0.553

	Observed	Simulated	%Difference	Target %		Observed
Mean Annual Runoff (MAR) Jan- Dec [Mm³]	73.8	72.8	-1.3%	± 4%	Unit runoff [mm]	88.8
Annual Standard Deviation [Mm³]	32.6	42.5	23.4%	± 6%	MAP [mm]	1245
Seasonal Index	24.16	19.76	-22.3%	± 8%	Runoff %	7%

Node no. N407|Net flow to node

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	0.8	0.5	0.6	2.3	2.9	2.2	2.8	5.0	3.9	2.8	2.9	1.3	2.3
Simulated	0.9	0.7	0.7	2.0	3.4	2.8	2.9	3.7	3.1	3.2	2.6	1.8	2.3
%difference	17.7%	28.9%	21.5%	-16.9%	12.8%	19.3%	4.8%	-36.2%	-27.4%	12.4%	-15.1%	23.7%	-1.3%

MHB results file: C:\DHI\113699 Kenya ISC\1.1-LVN\01-MIKE_HYDRO_Basin\01-MHB_Projects\Natural\LVN-Natural_demands.mhydro - Result Files\River Basin_LVN Natural_demands.dfs0

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Figure A3-13: Calibration plot for streamflow gauge 1BE06

Calibration Results: 1BG07 -

Catchment Area: 740 km³

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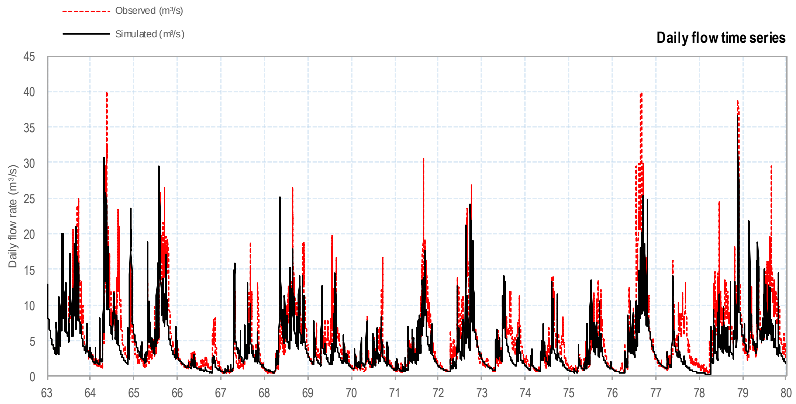

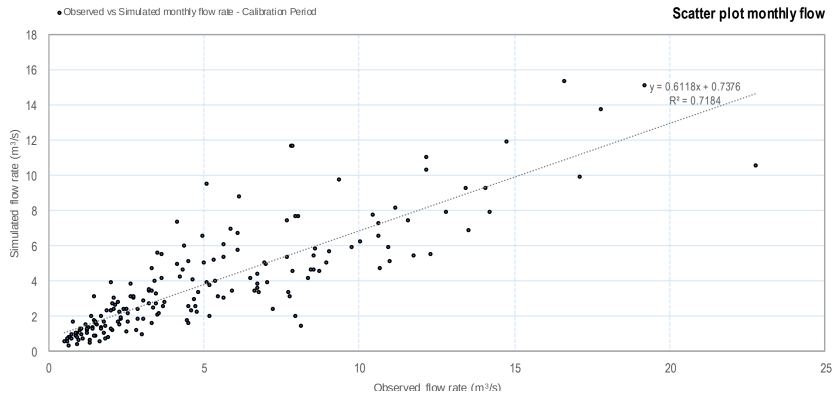

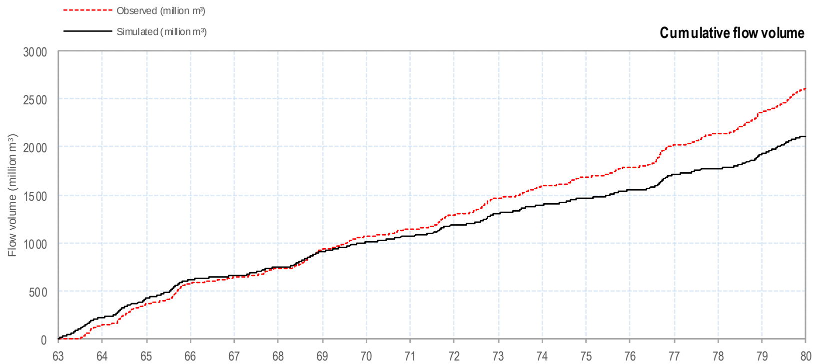

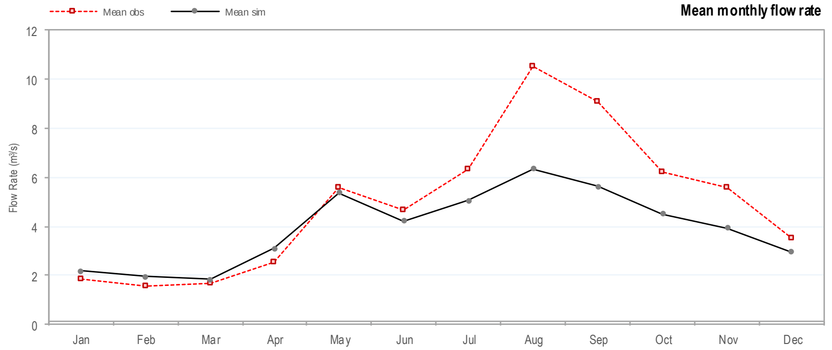

Node no. N409|Net flow to node

Node no. N409|Net flow to node

Performance Metrics

Coeff. of Determination (r^2) 0.718

Nash-Sutcliffe Coeff. of Efficiency 0.512

	Observed	Simulated	%Difference	Target %		Observed
Mean Annual Runoff (MAR) Jan- Dec [Mm³]	155.4	124.3	-25.0%	± 4%	Unit runoff [mm]	210.0
Annual Standard Deviation [Mm³]	65.6	55.5	-18.2%	± 6%	MAP [mm]	1345
Seasonal Index	22.47	16.45	-36.6%	± 8%	Runoff %	16%

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	1.9	1.6	1.7	2.5	5.6	4.6	6.3	10.5	9.1	6.2	5.6	3.5	4.9
Simulated	2.2	2.0	1.8	3.1	5.4	4.2	5.1	6.3	5.6	4.5	3.9	3.0	3.9
%difference	15.2%	20.5%	8.3%	18.5%	-3.7%	-9.9%	-24.6%	-65.9%	-61.3%	-37.9%	-41.8%	-18.9%	-25.0%

MHB results file: C:\DHI\113699 Kenya ISC\1.1-LVN\01-MIKE_HYDRO_Basin\01-MHB_Projects\Natural\LVN-Natural_demands.mhydro - Result Files\River Basin_LVN Natural_demands.dfs0

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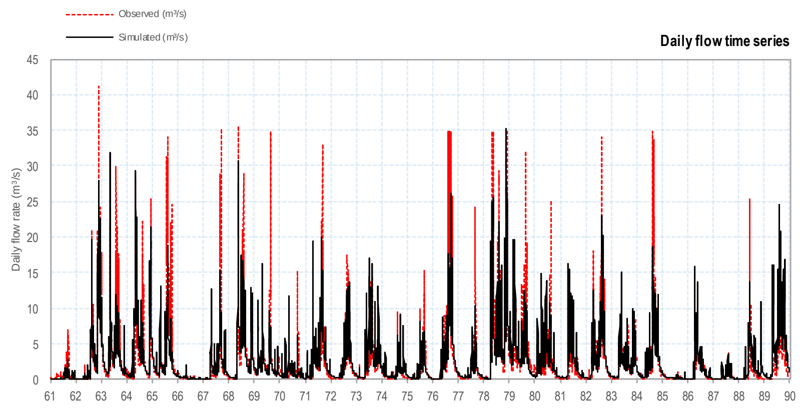
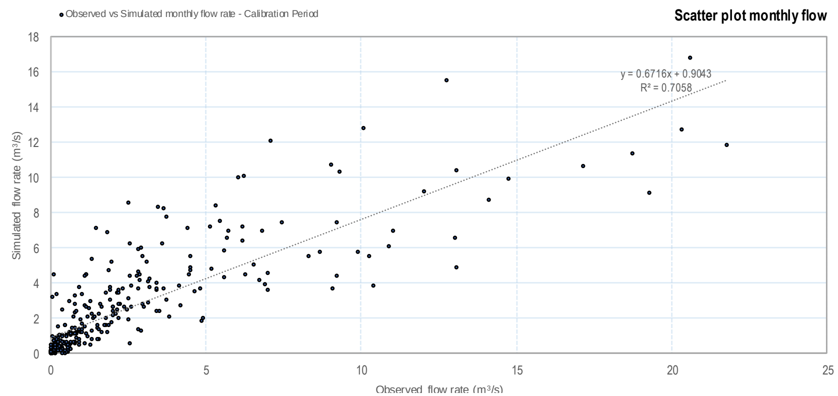
Figure A3-14: Calibration plot for streamflow gauge 1BG07

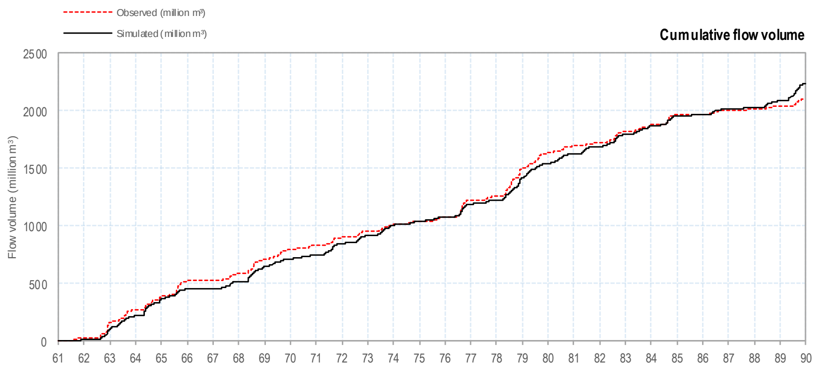
Calibration Results: 1CA02 -

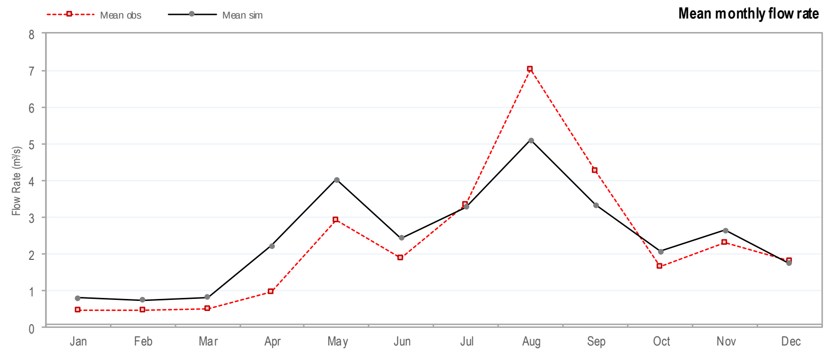
Catchment Area: 692.24 km³

10/26/2018 7:58 AM









Performance Metrics

Node no. N412|Net flow to node

Coeff. of Determination (r^2) 0.706

Nash-Sutcliffe Coeff. of Efficiency 0.490

	Observed	Simulated	%Difference	Target %		Observed
Mean Annual Runoff (MAR) Jan- Dec [Mm³]	72.6	77.1	5.8%	± 4%	Unit runoff [mm]	104.9
Annual Standard Deviation [Mm³]	60.1	46.8	-28.4%	± 6%	MAP [mm]	1159
Seasonal Index	26.98	20.74	-30.1%	± 8%	Runoff %	9%

Node no. N412|Net flow to node

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	0.5	0.5	0.5	10	2.9	19	3.4	7.0	4.2	17	2.3	18	2.3
Simulated	0.8	0.7	0.8	2.2	4.0	2.4	3.3	5.1	3.3	2.1	2.6	17	2.4
%difference	42.6%	38.0%	37.4%	56.8%	27.9%	23.0%	-2.5%	-37.8%	-27.7%	19.2%	11.8%	-5.1%	5.8%

MHB results file: C:\DHI\113699 Kenya ISC\1.1-LVN\01-MIKE_HYDRO_Basin\01-MHB_Projects\Natural\LVN-Natural_demands.mhydro - Result Files\River Basin_LVN Natural_demands.dfs0

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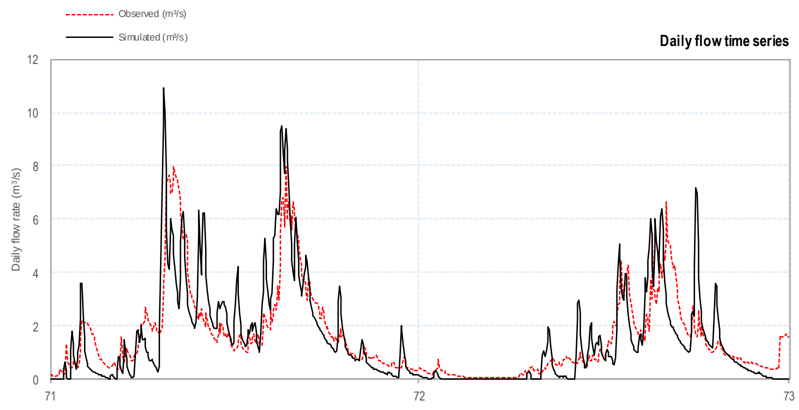
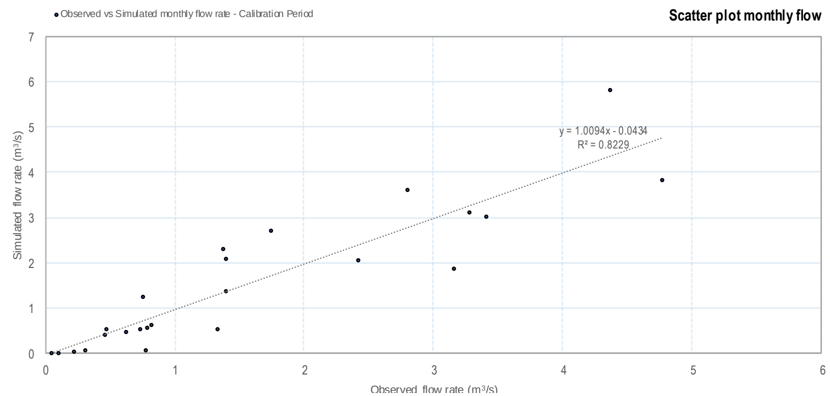
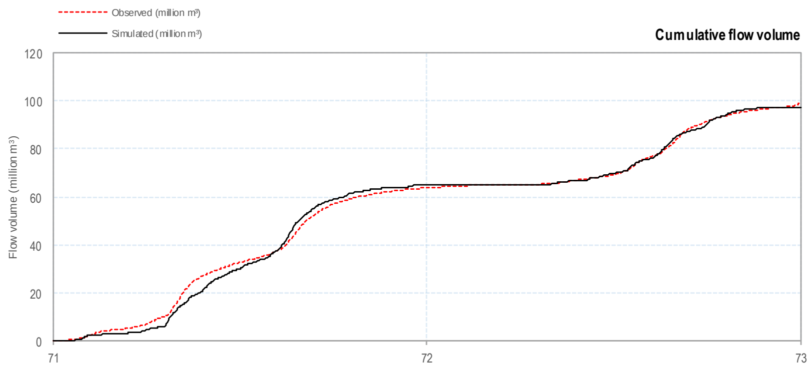
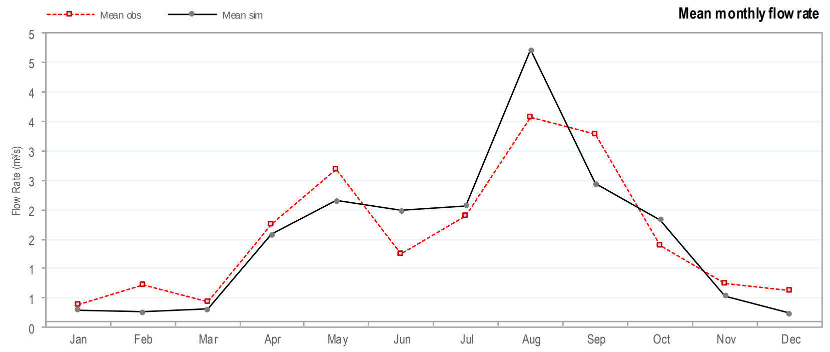
Figure A3-15: Calibration plot for streamflow gauge 1CA02

Calibration Results: 1CB08 -   Catchment Area: 196.3 km²   10/26/2018 8:23 AM









Node no. N413|Net flow to node

Node no. N413|Net flow to node

Performance Metrics

Coeff. of Determination (r^2) 0.823

Nash-Sutcliffe Coeff. of Efficiency 0.439

	Observed	Simulated	%Difference	Target %		Observed
Mean Annual Runoff (MAR) Jan- Dec [M m³]	49.4	48.7	-1.3%	± 4%	Unit runoff [mm]	251.5
Annual Standard Deviation [M m³]	20.2	23.0	12.2%	± 6%	MAP [mm]	1278
Seasonal Index	27.19	32.85	17.2%	± 8%	Runoff %	20%

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	0.4	0.7	0.4	1.7	2.7	1.3	1.9	3.6	3.3	1.4	0.8	0.6	1.6
Simulated	0.3	0.3	0.3	1.6	2.2	2.0	2.1	4.7	2.4	1.8	0.5	0.2	1.5
%difference	-30.5%	-178.5%	-43.1%	-10.9%	-24.9%	37.0%	7.6%	24.1%	-34.4%	24.6%	-41.2%	-159.2%	-1.3%

MHB results file: C:\DHI\113699 Kenya ISC\1.1-LVN\01-MIKE_HYDRO_Basin\01-MHB_Projects\Natural\LVN-Natural_demands.mhydro - Result Files\River Basin_LVN Natural_demands.dfs0

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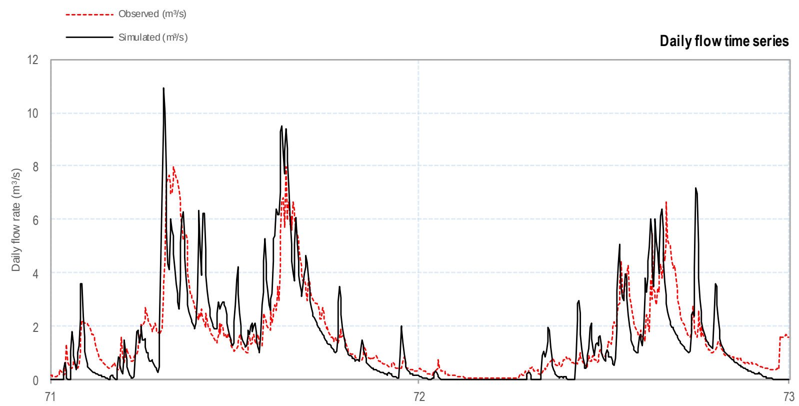
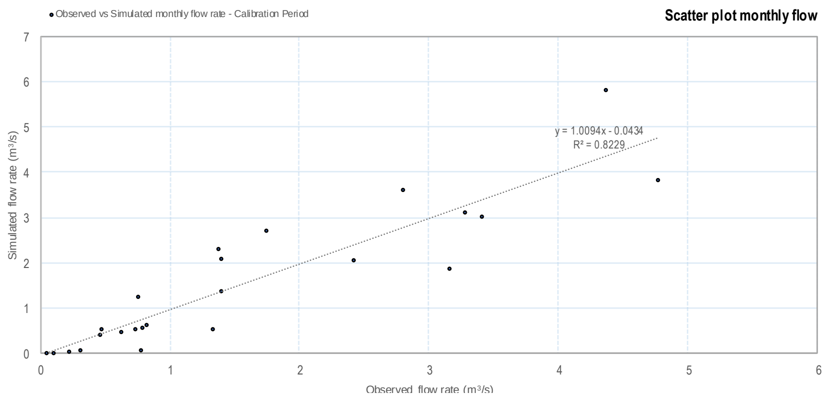
Figure A3-16: Calibration plot for streamflow gauge 1CB08

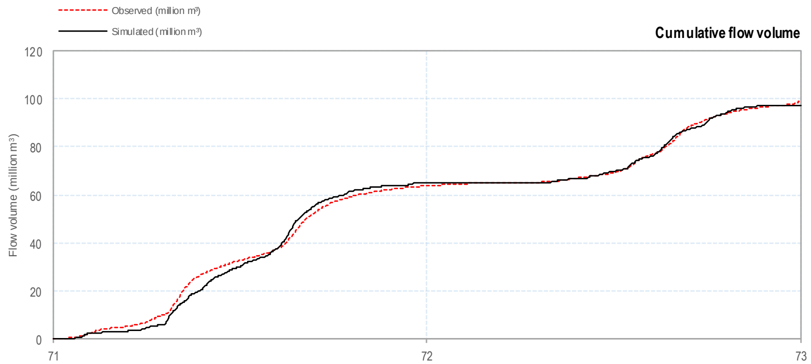
Calibration Results: 1CB08 -

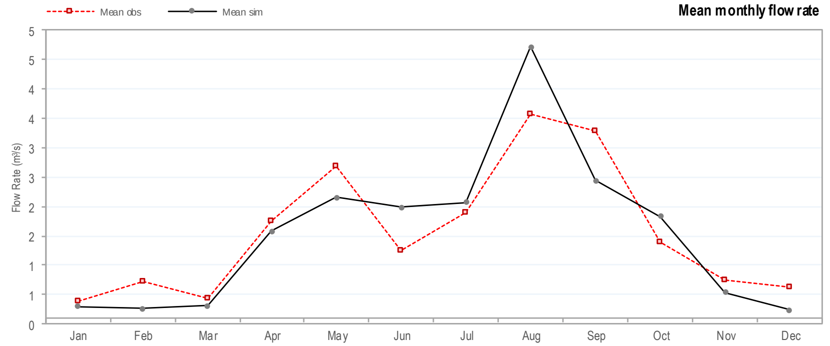
Catchment Area: 196.3 km²

10/26/2018 8:23 AM









Performance Metrics

Node no. N413|Net flow to node

Coeff. of Determination (r^2) 0.823

Nash-Sutcliffe Coeff. of Efficiency 0.439

	Observed	Simulated	%Difference	Target %		Observed
Mean Annual Runoff (MAR) Jan- Dec [M m³]	49.4	48.7	-13%	± 4%	Unit runoff [mm]	251.5
Annual Standard Deviation [M m³]	20.2	23.0	12.2%	± 6%	MAP [mm]	1278
Seasonal Index	27.19	32.85	17.2%	± 8%	Runoff %	20%

Node no. N413|Net flow to node

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	0.4	0.7	0.4	1.7	2.7	1.3	1.9	3.6	3.3	1.4	0.8	0.6	1.6
Simulated	0.3	0.3	0.3	1.6	2.2	2.0	2.1	4.7	2.4	1.8	0.5	0.2	1.5
%difference	-30.5%	-178.5%	-43.1%	-10.9%	-24.9%	37.0%	7.6%	24.1%	-34.4%	24.6%	-41.2%	-159.2%	-13%

MHB results file: C:\DHI\113699 Kenya ISC\1.1-LVN\01-MIKE_HYDRO_Basin\01-MHB_Projects\Natural\LVN-Natural_demands.mhydro - Result Files\River Basin_LVN Natural_demands.dfs0

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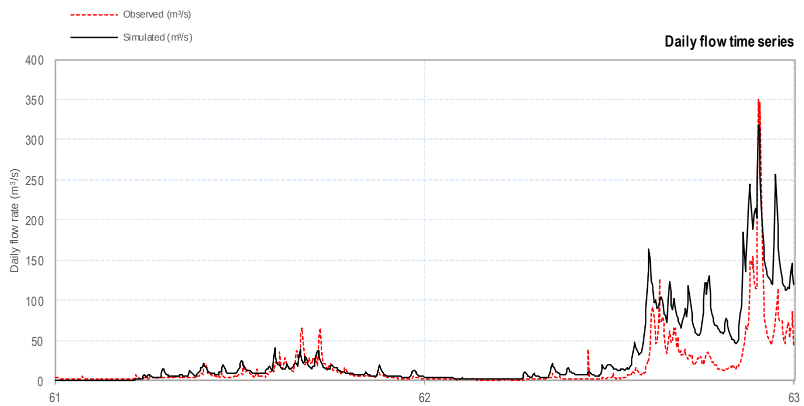
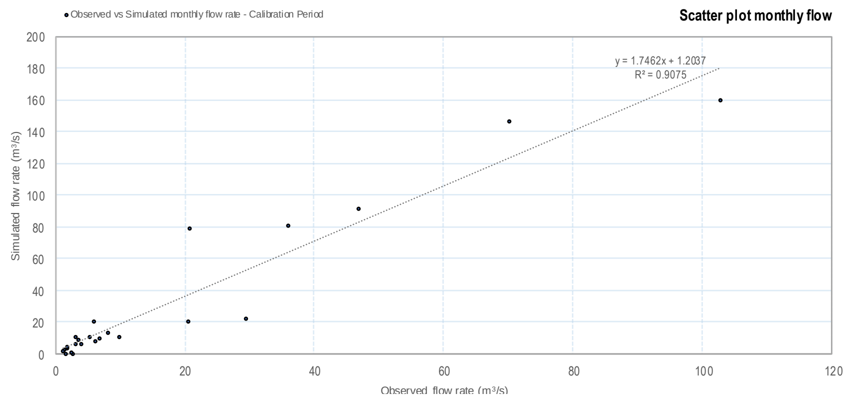
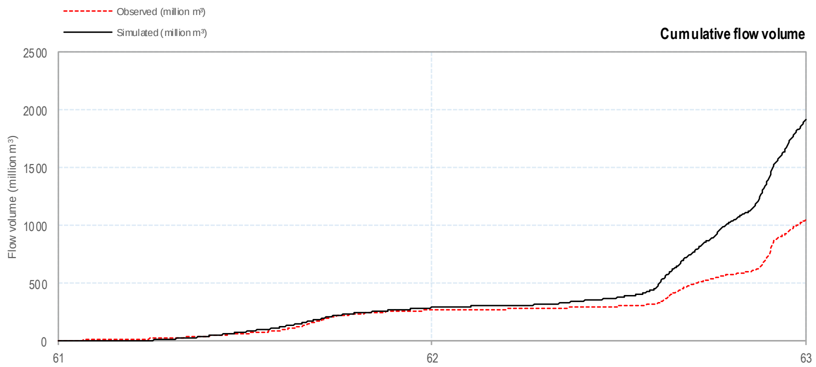
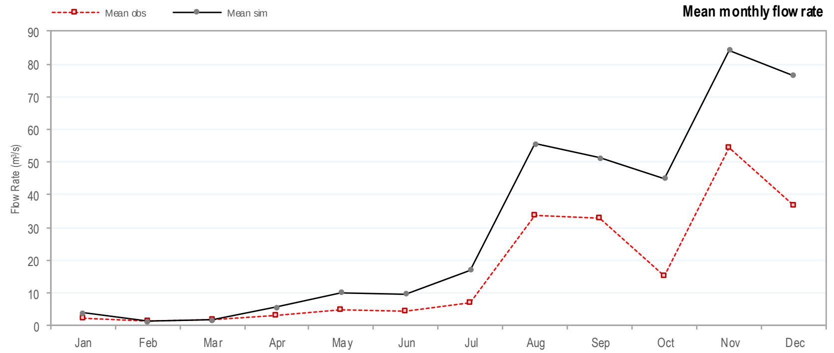
Figure A3-17: Calibration plot for streamflow gauge 1CE01

Calibration Results: 1DA02 - Catchment Area: 841.4 km² 10/27/2018 8:08 PM









Performance Metrics

Node no. N420|Net flow to node

Coeff. of Determination (r^2) 0.907

Nash-Sutcliffe Coeff. of Efficiency 0.108

	Observed	Simulated	%Difference	Target %		Observed
Mean Annual Runoff (MAR) Jan- Dec [Mm³]	520.4	950.8	45.3%	± 4%	Unit runoff [mm]	619
Annual Standard Deviation [Mm³]	364.0	940.2	61.3%	± 6%	MAP [mm]	1702
Seasonal Index	45.67	45.23	-1.0%	± 8%	Runoff %	4%

Node no. N420|Net flow to node

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	2.3	1.5	1.9	2.9	5.0	4.4	7.0	33.7	32.8	15.3	54.4	36.6	16.5
Simulated	3.8	1.3	1.6	5.6	10.1	9.7	16.9	55.6	51.4	45.0	84.3	76.5	30.2
%difference	39.7%	-17.1%	-13.4%	47.1%	50.4%	54.6%	58.4%	39.4%	36.3%	66.0%	35.4%	52.1%	45.3%

MHB results file: C:\DHI\113699 Kenya ISC\1.1-LVN\01-MIKE_HYDRO_Basin\01-MHB_Projects\Natural\LVN-Natural_with demands.mhydro - Result Files\River Basin_LVN Natural_demands.dfs0

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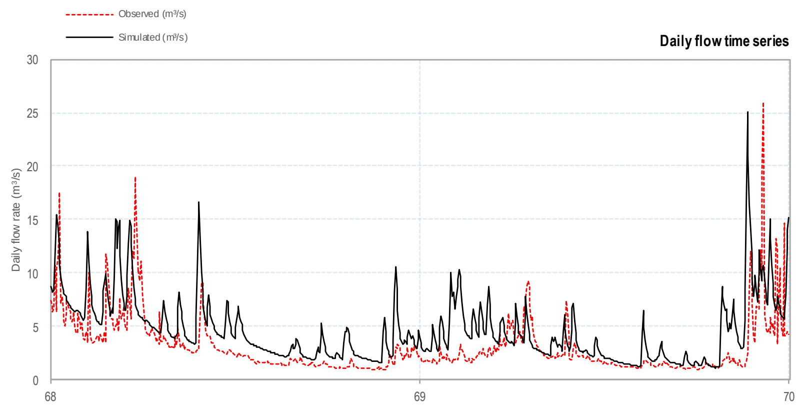
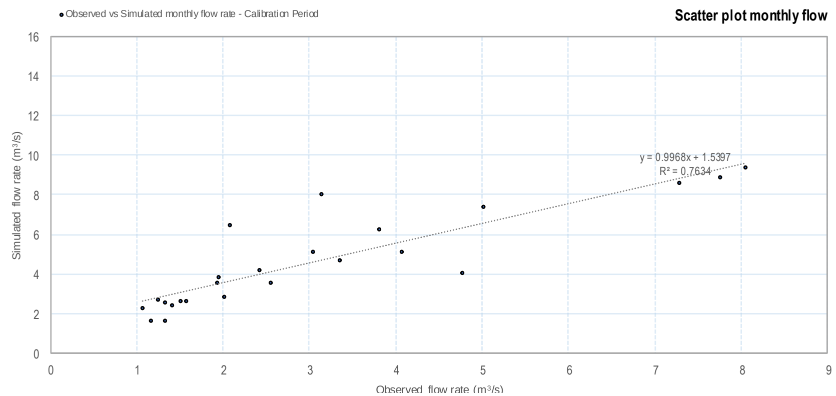
Figure A3-18: Calibration plot for streamflow gauge 1DA02

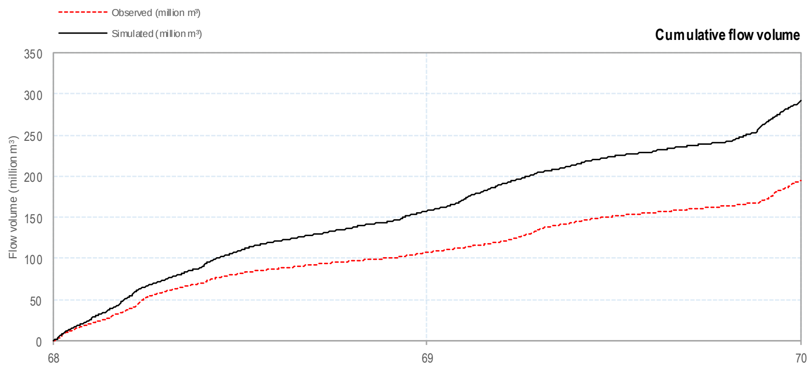
Calibration Results: 1DB01-

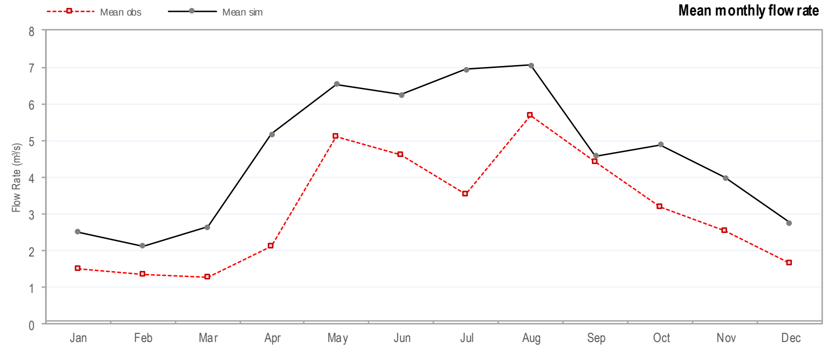
Catchment Area: 533 km³

10/26/2018 9:05 AM









Performance Metrics

Node no. N134|Net flow to node

Coeff. of Determination (r^2)	0.763
Nash-Sutcliffe Coeff. of Efficiency	-0.350

	Observed	Simulated	%Difference	Target %		Observed
Mean Annual Runoff (MAR) Jan- Dec [M m³]	97.1	108.9	10.9%	± 4%	Unit runoff [mm]	182.1
Annual Standard Deviation [M m³]	Insufficient	# DIV/0!	Insufficient	± 6%	MAP [mm]	1669
Seasonal Index	16.56	27.10	38.9%	± 8%	Runoff %	11%

Node no. N134|Net flow to node

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	1.5	1.3	1.3	2.1	5.1	4.6	3.5	5.7	4.4	3.2	2.5	1.6	3.1
Simulated	2.5	2.1	2.6	5.2	6.5	6.2	6.9	7.1	4.6	4.9	4.0	2.8	3.5
%difference	40.7%	37.2%	51.2%	59.2%	22.1%	26.3%	48.9%	19.2%	3.5%	34.9%	36.7%	40.7%	10.9%

MHB results file: C:\DHI\113699 Kenya ISC\1.1-LVN\01-MIKE_HYDRO_Basin\01-MHB_Projects\Natural\LVN-Natural_demands.mhydro - Result Files\River Basin_LVN Natural_demands.dfs0

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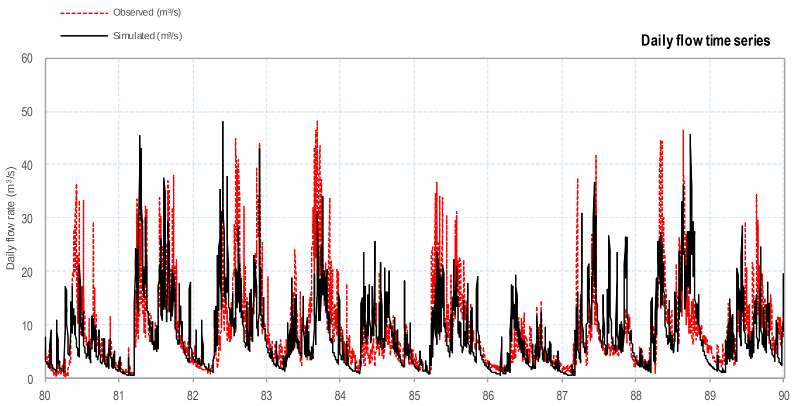
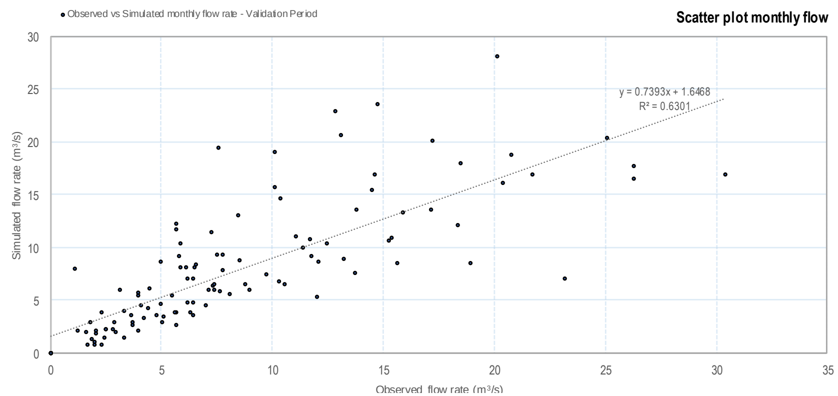
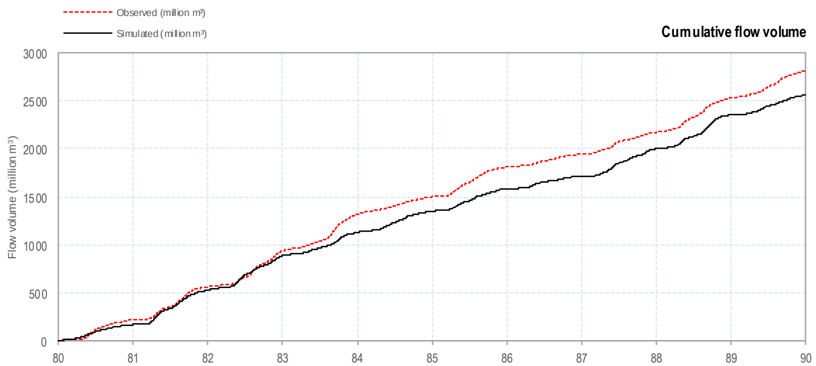
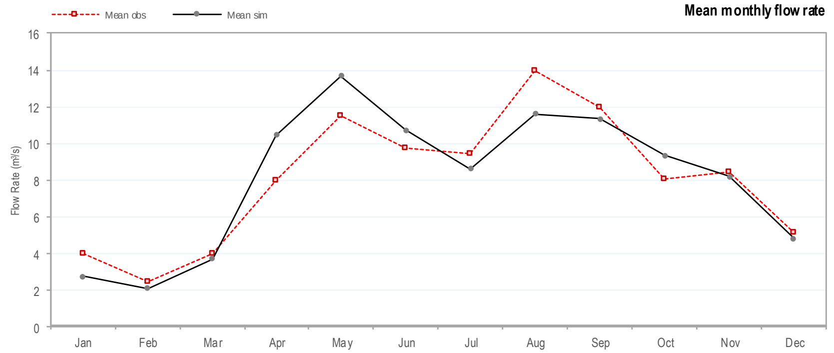
Figure A3-19: Calibration plot for streamflow gauge 1DB01

Calibration Results: 1EB02 - Catchment Area: 475.9 km³ 10/26/2018 9:09 AM









Performance Metrics

Node no. N427|Net flow to node

Coeff. of Determination (r^2) 0.630

Nash-Sutcliffe Coeff. of Efficiency 0.251

	Observed	Simulated	%Difference	Target %		Observed
Mean Annual Runoff (MAR) Jan- Dec [M m³]	254.2	2616	2.8%	± 4%	Unit runoff [mm]	534.2
Annual Standard Deviation [M m³]	123.7	83.9	-47.4%	± 6%	MAP [mm]	2005
Seasonal Index	18.00	19.71	8.6%	± 8%	Runoff %	27%

Node no. N427|Net flow to node

Average monthly flow rate [m³/s]

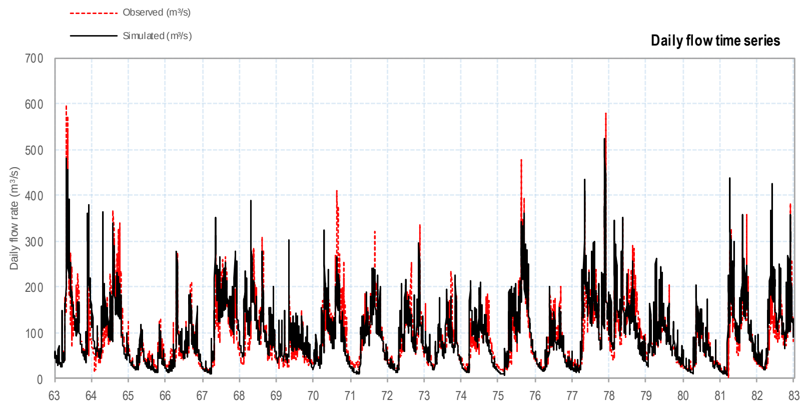
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	4.0	2.5	4.0	8.0	11.5	9.7	9.4	13.9	12.0	8.1	8.4	5.1	8.1
Simulated	2.7	2.1	3.7	10.5	13.7	10.7	8.6	11.6	11.3	9.3	8.2	4.8	8.3
%difference	-45.7%	-17.8%	-6.4%	23.6%	16.0%	9.1%	-9.2%	-20.0%	-5.8%	13.5%	-2.7%	-6.5%	2.8%

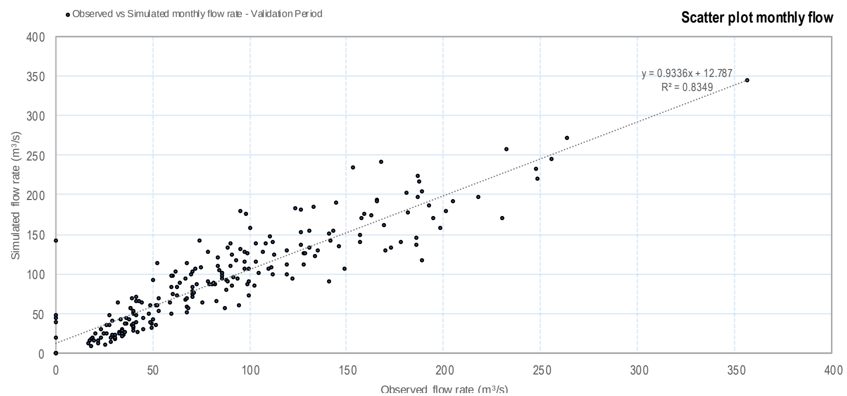
MHB results file: C:\DHI\113699 Kenya ISC\1.1-LVN\01-MIKE_HYDRO_Basin\01-MHB_Projects\Natural\LVN-Natural_demands.mhydro - Result Files\River Basin_LVN Natural_demands.dfs0

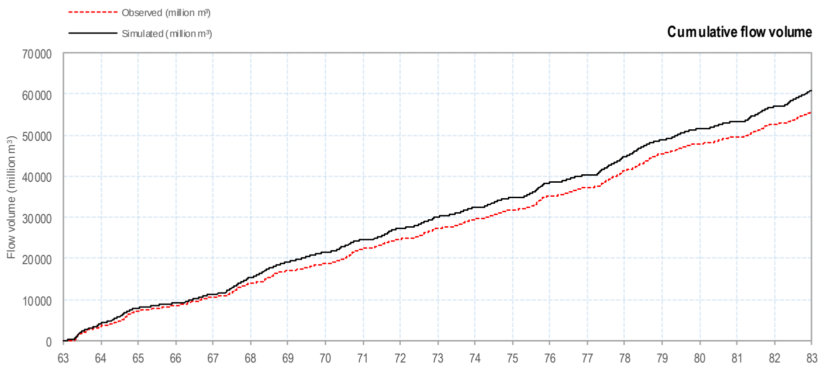
Document: C:\DHI\113699 Kenya ISC\1.1-LVN\01-MIKE_HYDRO_Basin\01-MHB_Projects\Calibration\Nzoia\[MHB_Calibration_1EB02.xlsm]Validation

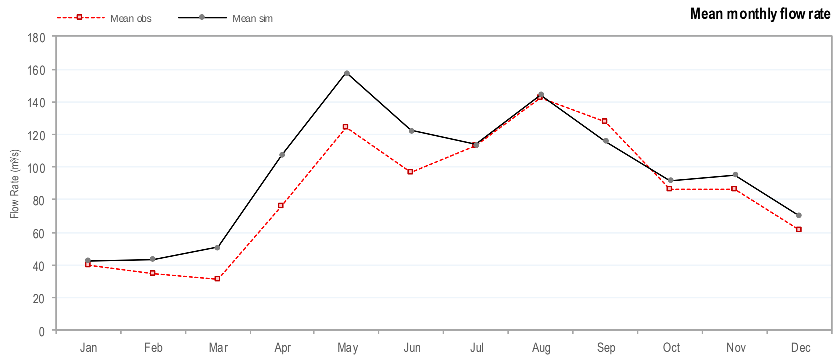
Figure A3-20: Calibration plot for streamflow gauge 1EB02

Calibration Results: 1EE01- Catchment Area: 11859 km³ 10/29/2018 9:45 AM









Performance Metrics

Node no. N430|Net flow to node

Coeff. of Determination (r^2) 0.835

Nash-Sutcliffe Coeff. of Efficiency 0.619

	Observed	Simulated	%Difference	Target %		Observed
Mean Annual Runoff (MAR) Jan- Dec [Mm³]	2682.4	3091.9	13.2%	± 4%	Unit runoff [mm]	226.2
Annual Standard Deviation [Mm³]	852.6	955.1	10.7%	± 6%	MAP [mm]	1880
Seasonal Index	18.58	15.87	-17.1%	± 8%	Runoff %	12%

Node no. N430|Net flow to node

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	39.4	34.9	31.2	75.8	124.5	96.4	113.5	142.3	127.4	86.3	86.7	61.6	85.0
Simulated	42.6	43.5	50.7	107.1	157.5	122.4	113.6	144.6	116.1	91.8	95.3	70.4	98.0
%difference	7.4%	19.8%	38.5%	29.2%	21.0%	21.2%	0.1%	1.6%	-9.8%	5.9%	9.0%	12.6%	13.2%

MHB results file: C:\DHI\113699 Kenya ISC\1.1-LVN\01-MIKE_HYDRO_Basin\01-MHB_Projects\Natural\LVN-Natural_with demands.mhydro - Result Files\River Basin_LVN Natural_demands.dfs0

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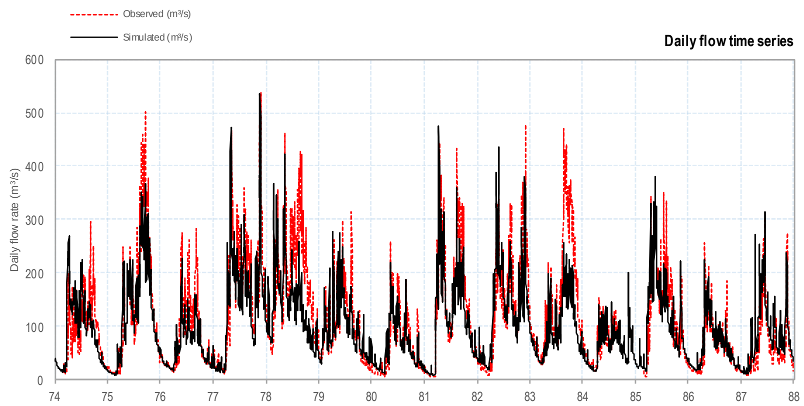
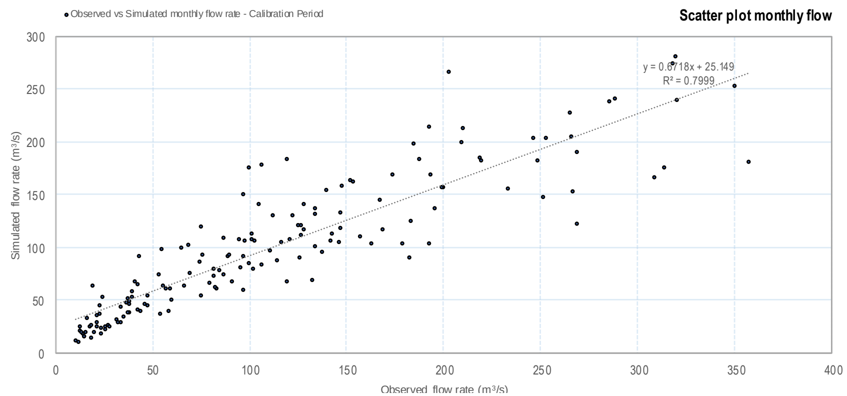
Figure A3-21: Calibration plot for streamflow gauge 1EE01

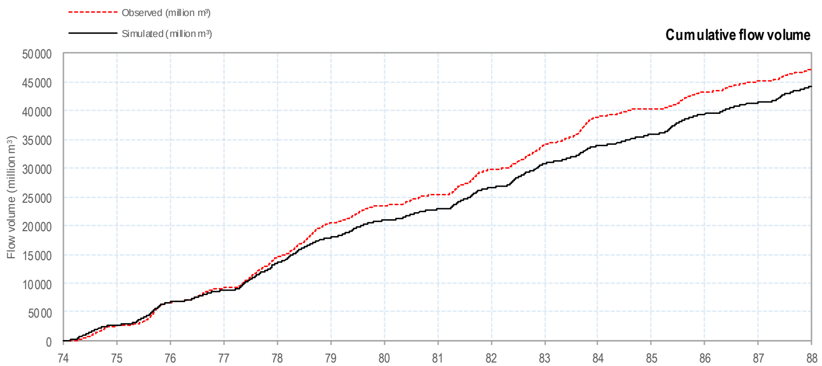
Calibration Results: 1EF01-

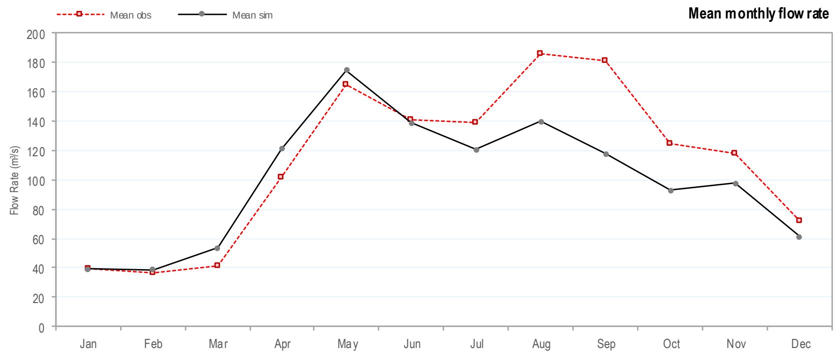
Catchment Area: 12683.9 km³

10/29/2018 10:53 AM









Performance Metrics

Node no. N431|Net flow to node

Coeff. of Determination (r^2) 0.800

Nash-Sutcliffe Coeff. of Efficiency 0.662

	Observed	Simulated	%Difference	Target %		Observed
Mean Annual Runoff (MAR) Jan- Dec [M m³]	3541.0	3153.4	-12.3%	± 4%	Unit runoff [mm]	279.2
Annual Standard Deviation [M m³]	1524.6	975.4	-56.3%	± 6%	MAP [mm]	1561
Seasonal Index	19.38	17.97	-7.8%	± 8%	Runoff %	18%

Node no. N431|Net flow to node

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	39.8	36.4	41.5	102.2	165.2	141.2	139.5	185.9	181.2	124.5	117.6	71.6	112.2
Simulated	39.3	39.0	53.6	120.9	174.8	138.9	120.5	139.7	117.6	93.1	97.8	61.0	100.0
%difference	-1.4%	6.6%	22.6%	15.5%	5.5%	-1.7%	-15.8%	-33.1%	-54.1%	-33.7%	-20.3%	-17.3%	-12.3%

MHB results file: C:\DHI\113699 Kenya ISC\1.1-LVN\01-MIKE_HYDRO_Basin\01-MHB_Projects\Natural\LVN-Natural_with demands.mhydro - Result Files\River Basin_LVN Natural_demands.dfs0

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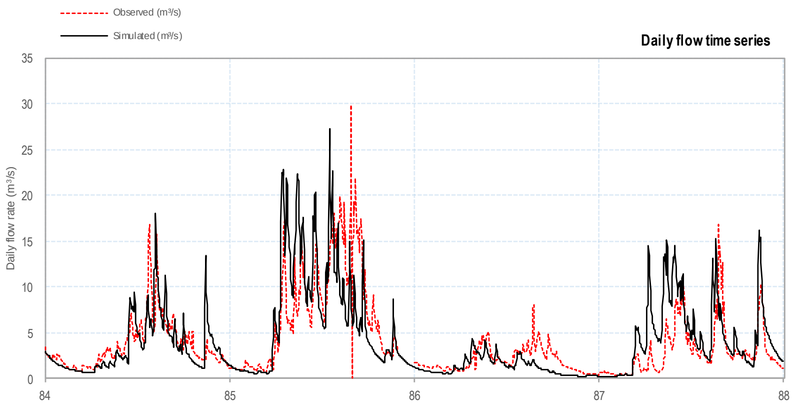
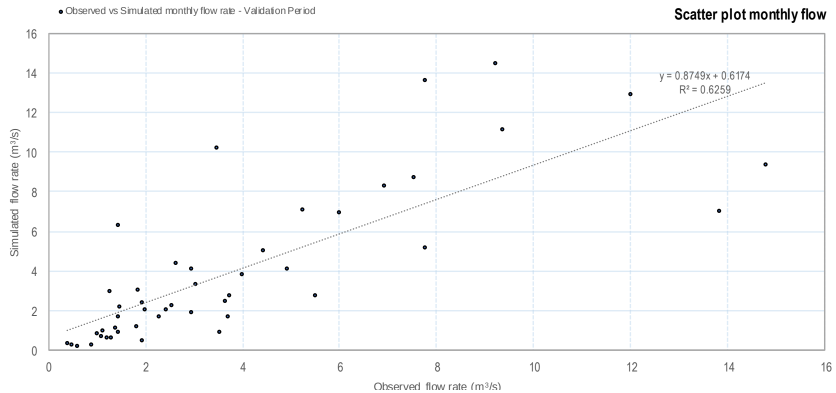
Figure A3-22: Calibration plot for streamflow gauge 1EF01

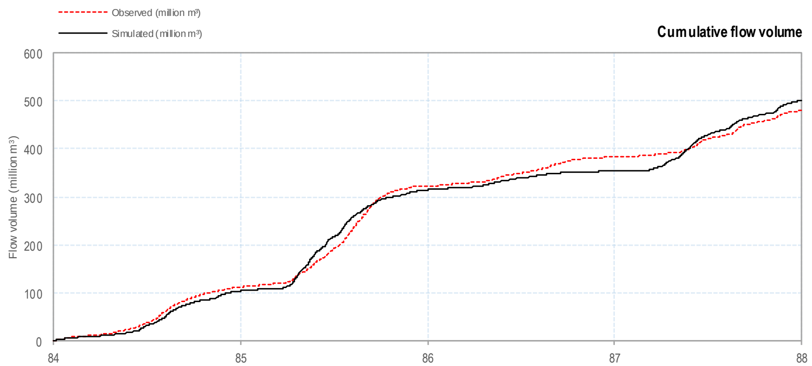
Calibration Results: 1FC01-

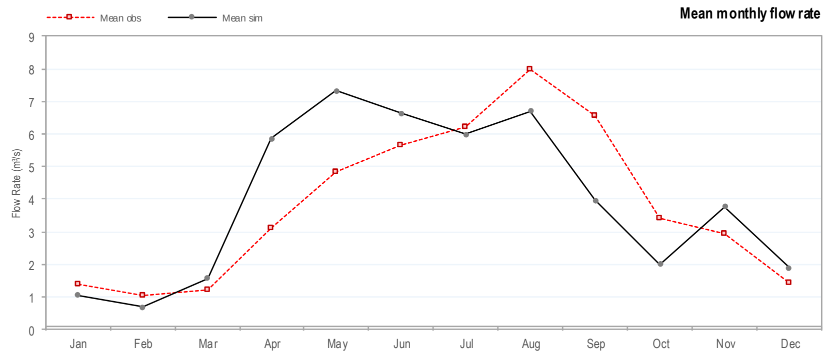
Catchment Area: 852 km³

10/29/2018 11:13 AM









Performance Metrics

Node no. N436|Net flow to node

Coeff. of Determination (r^2) 0.626

Nash-Sutcliffe Coeff. of Efficiency 0.311

	Observed	Simulated	%Difference	Target %		Observed
Mean Annual Runoff (MAR) Jan- Dec [M m³]	120.5	125.3	3.8%	± 4%	Unit runoff [mm]	1414
Annual Standard Deviation [M m³]	25.6	72.2	64.5%	± 6%	MAP [mm]	1606
Seasonal Index	22.83	27.03	15.5%	± 8%	Runoff %	9%

Node no. N436|Net flow to node

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	14	11	12	3.1	4.8	5.7	6.2	8.0	6.6	3.4	2.9	14	3.8
Simulated	11	0.7	16	5.9	7.3	6.6	6.0	6.7	4.0	2.0	3.8	19	4.0
%difference	-310%	-52.2%	23.5%	46.7%	34.1%	14.7%	-4.2%	-19.1%	-65.1%	-69.7%	219%	25.2%	3.8%

MHB results file: C:\DHI\113699 Kenya ISC\1.1-LVN\01-MIKE_HYDRO_Basin\01-MHB_Projects\Natural\LVN-Natural_with demands.mhydro - Result Files\River Basin_LVN Natural_demands.dfs0

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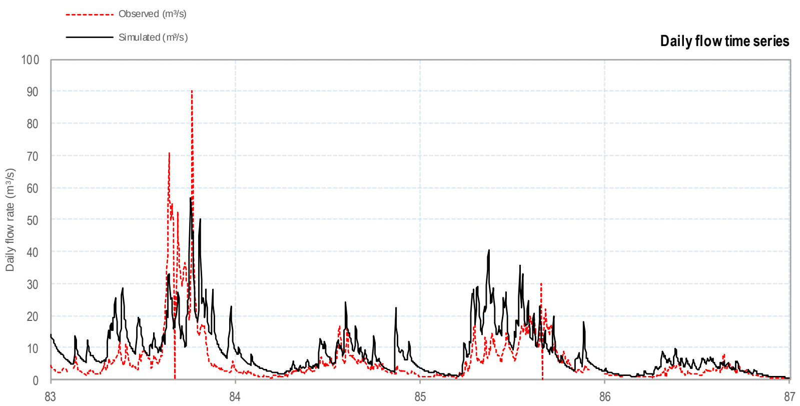
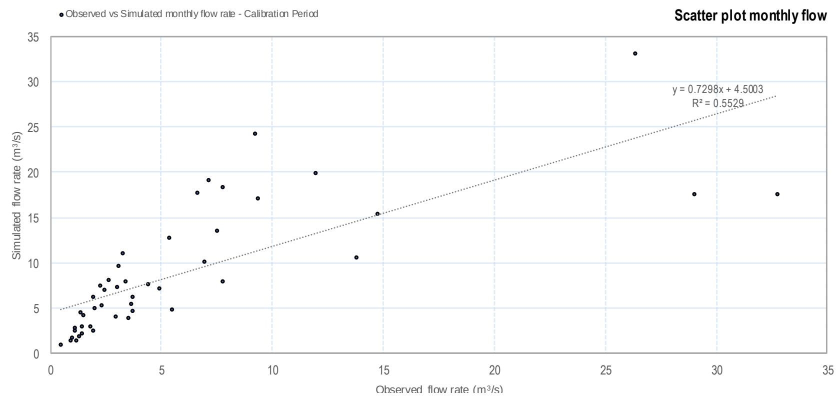
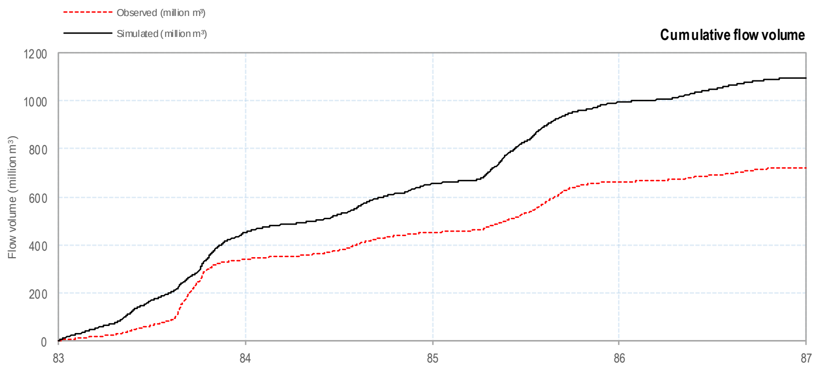
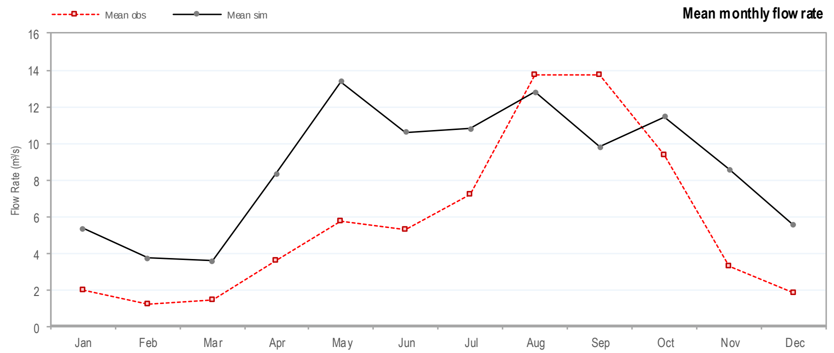
Figure A3-23: Calibration plot for streamflow gauge 1FC01

Calibration Results: 1FE02 - Catchment Area: 1457 km³ 10/29/2018 1:47 PM









Performance Metrics

Node no. N160|Net flow to node

Coeff. of Determination (r^2) 0.553

Nash-Sutcliffe Coeff. of Efficiency 0.226

	Observed	Simulated	%Difference	Target %		Observed
Mean Annual Runoff (MAR) Jan- Dec [M m³]	180.6	274.6	34.3%	± 4%	Unit runoff [mm]	123.9
Annual Standard Deviation [M m³]	35.4	153.3	76.9%	± 6%	MAP [mm]	1965
Seasonal Index	23.48	16.48	-42.4%	± 8%	Runoff %	6%

Node no. N160|Net flow to node

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	2.0	1.3	1.4	3.6	5.8	5.3	7.2	13.7	13.8	9.4	3.3	1.9	5.7
Simulated	5.4	3.7	3.6	8.4	13.4	10.6	10.8	12.8	9.8	11.5	8.6	5.5	8.7
%difference	62.4%	65.9%	59.8%	57.0%	57.0%	50.2%	33.0%	-7.4%	-40.4%	18.3%	61.6%	66.0%	34.3%

MHB results file: C:\DHI\113699 Kenya ISC\1.1-LVN\01-MIKE_HYDRO_Basin\01-MHB_Projects\Natural\LVN-Natural_with demands.mhydro - Result Files\River Basin_LVN Natural_demands.dfs0

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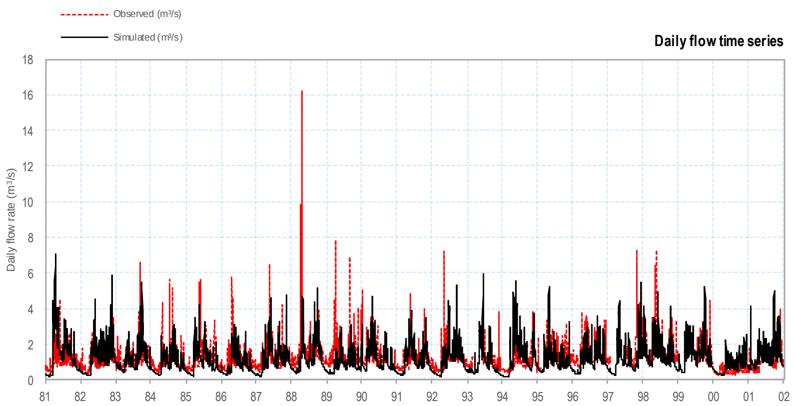
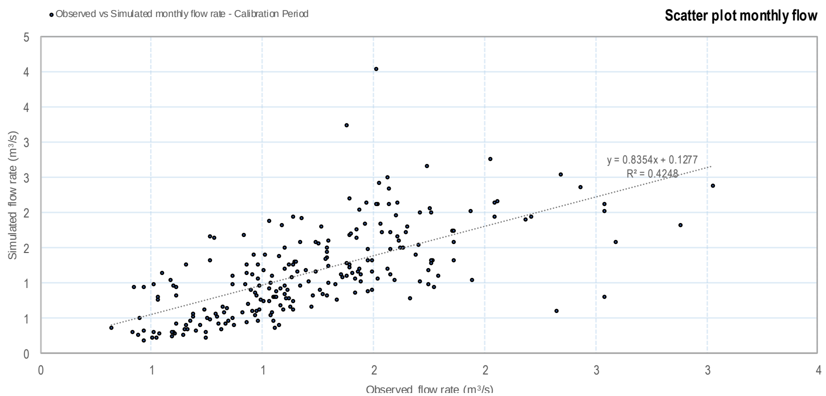
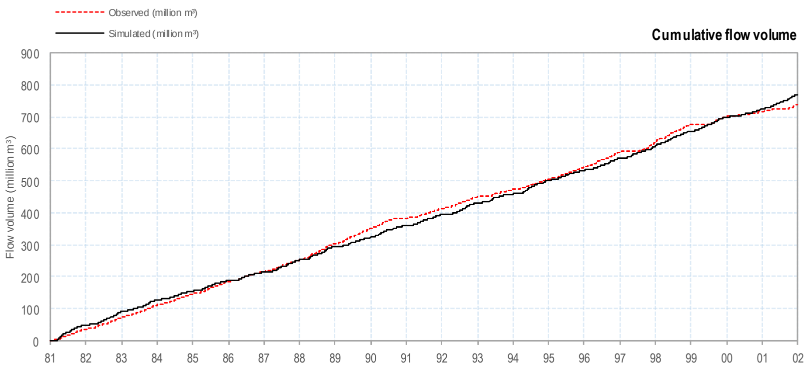
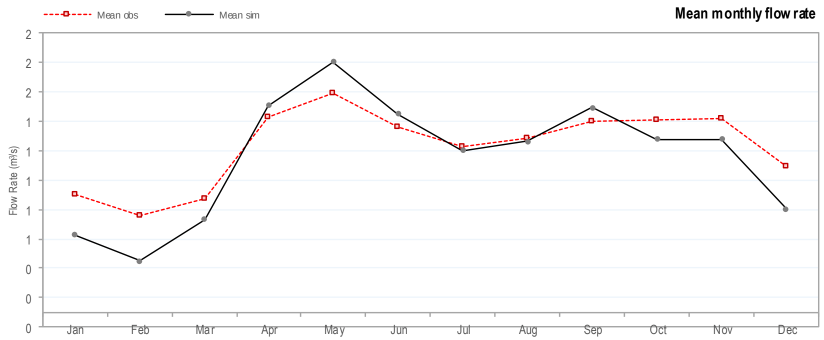
Figure A3-24: Calibration plot for streamflow gauge 1FE02

Calibration Results: 1FE3 - Catchment Area: 64 km³ 10/26/2018 9:46 AM









Performance Metrics

Node no. N161|Net flow to node

Coeff. of Determination (r^2) 0.425

Nash-Sutcliffe Coeff. of Efficiency -0.318

	Observed	Simulated	%Difference	Target %		Observed
Mean Annual Runoff (MAR) Jan- Dec [M m³]	38.8	36.6	-6.0%	± 4%	Unit runoff [mm]	606.2
Annual Standard Deviation [M m³]	8.0	6.8	-16.3%	± 6%	MAP [mm]	1965
Seasonal Index	10.74	14.49	25.9%	± 8%	Runoff %	31%

Node no. N161|Net flow to node

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	0.9	0.8	0.9	14	16	14	12	13	14	14	14	11	12
Simulated	0.6	0.5	0.7	15	18	15	12	13	15	13	13	0.8	12
%difference	-44.2%	-68.2%	-19.0%	5.1%	11.7%	6.1%	-1.9%	-1.6%	6.1%	-10.0%	-11.1%	-35.8%	-5.9%

MHB results file: C:\DHI\113699 Kenya ISC\1.1-LVN\01-MIKE_HYDRO_Basin\01-MHB_Projects\Natural\LVN-Natural_demands.mhydro - Result Files\River Basin_LVN Natural_demands.dfs0

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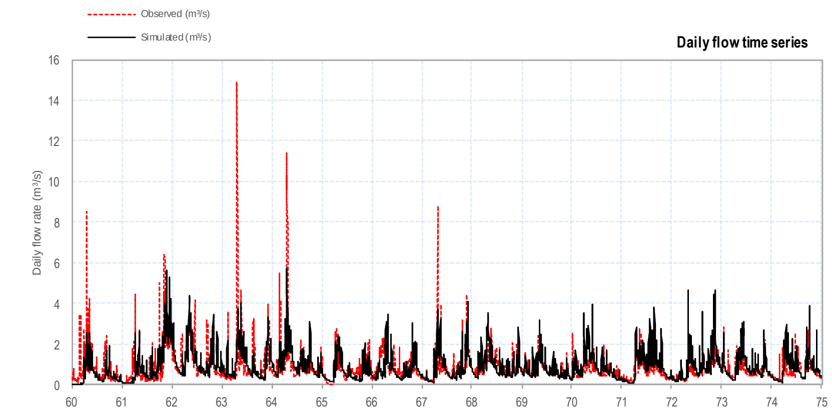
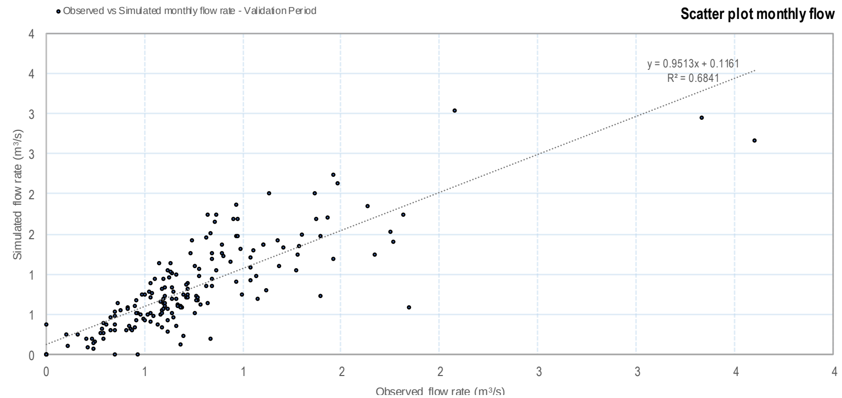
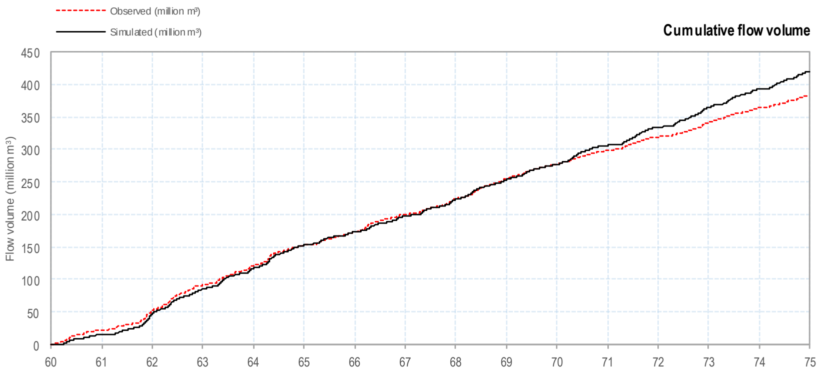
Figure A3-25: Calibration plot for streamflow gauge 1FE03

Calibration Results: 1FF02 - Catchment Area: 47 km³ 10/26/2018 9:50 AM







Performance Metrics

Node no. N164|Net flow to node

Coeff. of Determination (r^2) 0.684

Nash-Sutcliffe Coeff. of Efficiency 0.257

	Observed	Simulated	%Difference	Target %		Observed
Mean Annual Runoff (MAR) Jan- Dec [M m³]	23.0	27.7	17.1%	± 4%	Unit runoff [mm]	488.4
Annual Standard Deviation [M m³]	7.6	6.0	-27.3%	± 6%	MAP [mm]	1866
Seasonal Index	10.45	14.26	26.7%	± 8%	Runoff %	26%

Node no. N164|Net flow to node

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	0.5	0.4	0.6	1.2	1.0	0.7	0.6	0.6	0.6	0.7	0.9	0.8	0.7
Simulated	0.6	0.4	0.5	1.3	1.7	1.0	0.7	0.7	0.8	0.9	1.1	0.9	0.9
%difference	14.9%	2.4%	-15.2%	8.0%	38.0%	32.1%	14.2%	11.1%	15.3%	23.4%	14.4%	15.9%	17.1%

MHB results file: C:\DHI\113699 Kenya ISC\1.1-LVN\01-MIKE_HYDRO_Basin\01-MHB_Projects\Natural\LVN-Natural_demands.mhydro - Result Files\River Basin_LVN Natural_demands.dfs0

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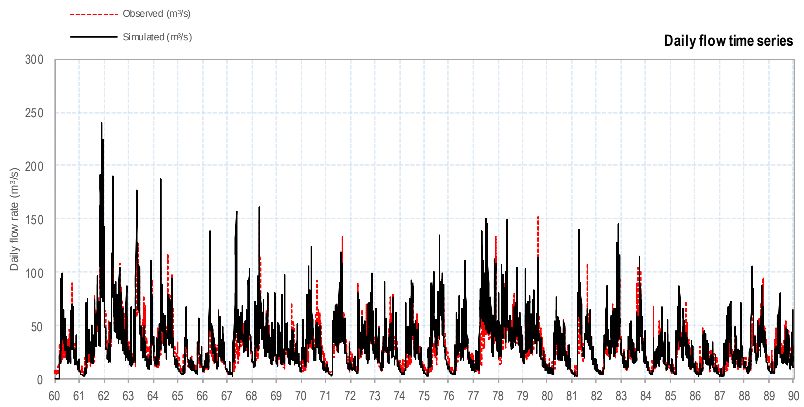
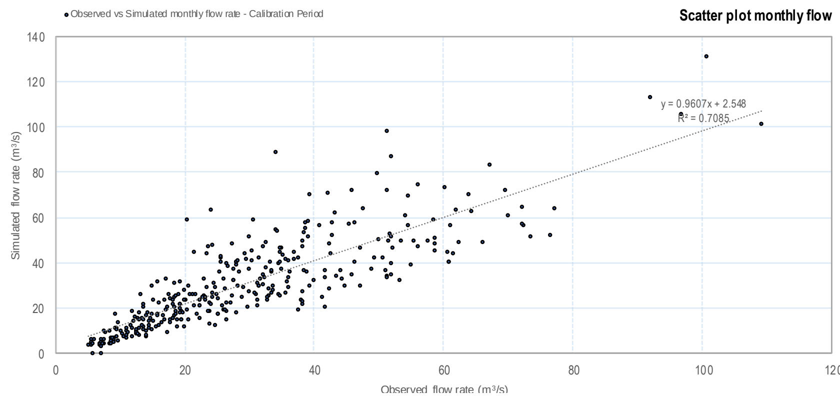
Figure A3-26: Calibration plot for streamflow gauge 1FF02

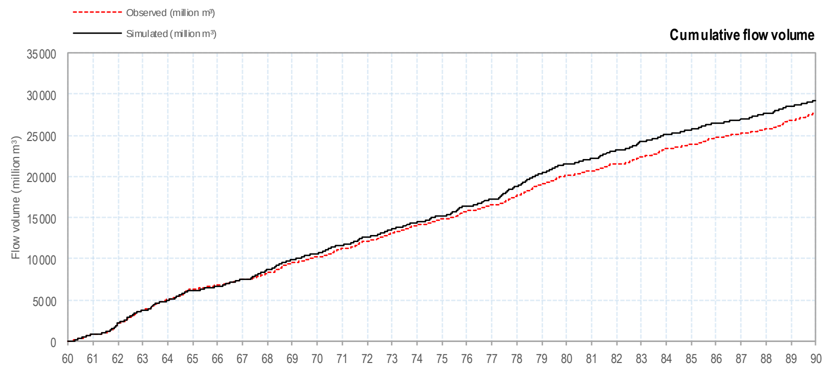
Calibration Results: 1FG01-

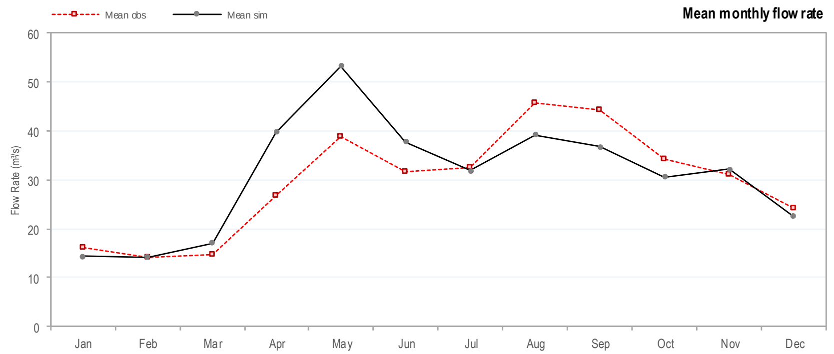
Catchment Area: 2305 km³

10/29/2018 1:29 PM









Performance Metrics

Coeff. of Determination (r^2) 0.708

Nash-Sutcliffe Coeff. of Efficiency 0.389

Node no. N165|Net flow to node

	Observed	Simulated	%Difference	Target %		Observed
Mean Annual Runoff (MAR) Jan- Dec [M m³]	932.4	974.1	4.3%	± 4%	Unit runoff [mm]	404.5
Annual Standard Deviation [M m³]	255.8	306.2	16.4%	± 6%	MAP [mm]	1467
Seasonal Index	16.32	14.92	-9.4%	± 8%	Runoff %	28%

Node no. N165|Net flow to node

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	16.1	14.1	14.8	26.9	39.0	31.6	32.5	45.9	44.2	34.2	31.1	24.1	29.5
Simulated	14.4	14.2	17.1	39.8	53.2	37.8	31.9	39.2	36.8	30.6	32.2	22.6	30.9
%difference	-12.1%	0.5%	13.4%	32.4%	26.8%	16.4%	-1.9%	-17.0%	-20.2%	-12.0%	3.4%	-6.9%	4.3%

MHB results file: C:\DHI\113699 Kenya ISC\1.1-LVN\01-MIKE_HYDRO_Basin\01-MHB_Projects\Natural\LVN-Natural_with demands.mhydro - Result Files\River Basin_LVN Natural_demands.dfs0

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Figure A3-27: Calibration plot for streamflow gauge 1FG01

Model Validation

The calibrated NAM rainfall-runoff model was validated by comparing observed and simulated flows at three flow gauging stations representative of the three main rivers (Sio, Nzoia and Yala) of the basin. Validation performance metrics are presented below while a comparison of daily simulated and observed flows is shown in in Table A3-5 and Figures A3-28 to A3-30. The validation was deemed to be acceptable.

Table A3-5: Validation at selected gauges

Station number	Catchment Area (km^2)	Calibration Period	Observed MAR (Mm^3)	Simulated MAR (Mm^3)	Coefficient of Determination (R^2)	Water Balance Error (WBL)	Nash-Sutcliffe efficiency (NSE)
1AH01	1016	1984-2014	358.2	364.3	0.581	1.7	0.442
1EF01	12684	1995-1998	3740.5	3716.9	0.670	-0.7	0.270
1FG01	2306	2013-2017	932.4	974.1	0.708	4.3	0.389

A visual comparison of observed vs. simulated flows confirmed a reasonable fit between simulated and observed flows, with particular emphasis on flow recession curves and low flows during the dry seasons as shown in Figure A3-18 and Figure A3-19 below.

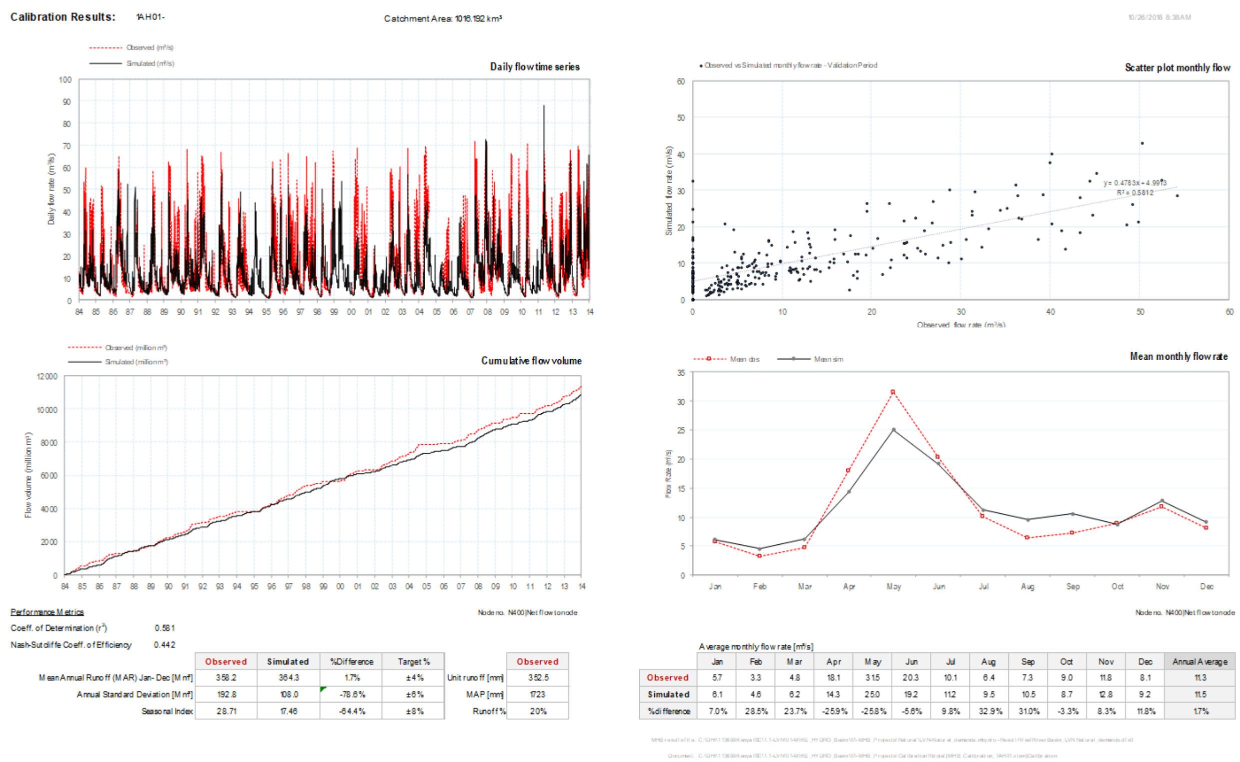
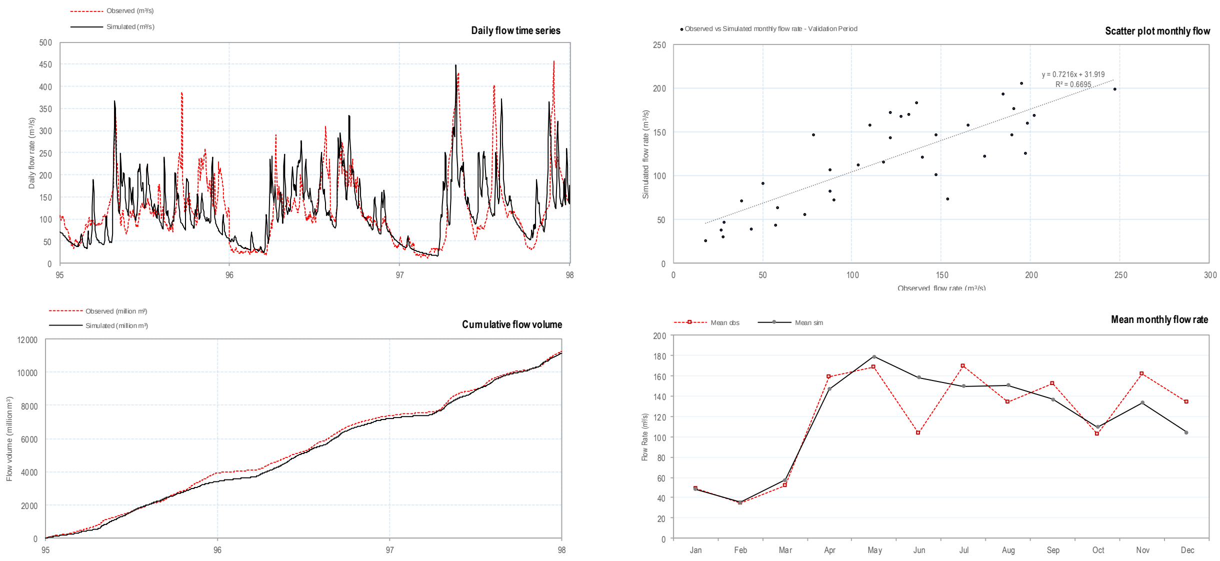


Figure A3-28: Gauge 1HA01 validation (1984-2014)

Calibration Results: 1EF01- Catchment Area: 12683.9 km³ 10/29/2018 10:53 AM



Performance Metrics

Coeff. of Determination (r^2) 0.670

Nash-Sutcliffe Coeff. of Efficiency 0.270

Node no. N431|Net flow to node

	Observed	Simulated	%Difference	Target %		Observed
Mean Annual Runoff (MAR) Jan- Dec [Mm³]	3740.5	3716.9	-0.6%	± 4%	Unit runoff [mm]	294.9
Annual Standard Deviation [Mm³]	263.5	269.6	2.3%	± 6%	MAP [mm]	1561
Seasonal Index	15.57	15.97	2.6%	± 8%	Runoff %	19%

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	48.6	34.2	52.3	159.6	168.6	103.2	169.7	134.7	152.3	102.3	162.4	134.2	118.5
Simulated	48.5	35.4	57.3	146.9	178.9	158.7	150.0	151.1	136.9	109.6	133.4	104.2	117.8
%difference	-0.3%	3.1%	8.7%	-8.7%	5.7%	34.9%	-13.1%	10.8%	-11.3%	6.7%	-21.7%	-28.8%	-0.7%

MHB results file: C:\DHI\113699 Kenya ISC\1.1-LVN\01-MIKE_HYDRO_Basin\01-MHB_Projects\Natural\LVN-Natural_with demands.mhydro - Result Files\River Basin_LVN Natural_demands.dfs0

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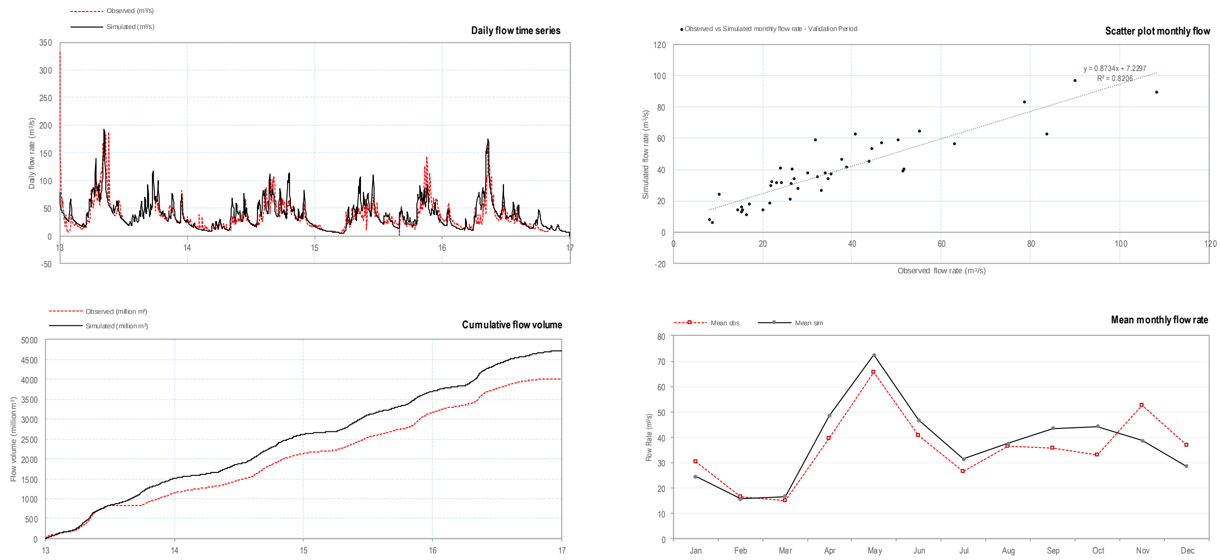
Figure A3-29: Gauge 1EF01 validation (1995-1998)

Calibration Results: 1FG01- Catchment Area: 2305 km³ 10/29/2018 1:29 PM



Performance Metrics

Coeff. of Determination (r^2) 0.821

Nash-Sutcliffe Coeff. of Efficiency 0.501

Node no. N165|Net flow to node

	Observed	Simulated	%Difference	Target %		Observed
Mean Annual Runoff (MAR) Jan- Dec [Mm³]	1128.2	1182.2	4.6%	± 4%	Unit runoff [mm]	489.4
Annual Standard Deviation [Mm³]	29.7	223.9	86.7%	± 6%	MAP [mm]	1467
Seasonal Index	16.39	14.26	-14.9%	± 8%	Runoff %	33%

Average monthly flow rate [m³/s]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Observed	30.5	16.6	15.2	39.5	65.7	40.5	26.6	36.5	35.7	32.9	52.6	36.8	35.7
Simulated	24.5	15.7	16.7	48.5	72.4	46.8	31.3	37.5	43.5	44.2	38.8	28.5	37.5
%difference	-24.5%	-5.3%	9.0%	18.6%	9.3%	13.3%	15.1%	2.9%	17.8%	25.5%	-35.6%	-29.2%	4.6%

MHB results file: C:\DHI\113699 Kenya ISC\1.1-LVN\01-MIKE_HYDRO_Basin\01-MHB_Projects\Natural\LVN-Natural_with demands.mhydro - Result Files\River Basin_LVN Natural_demands.dfs0

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Figure A3-30: Gauge 1FG01 validation (2013-2017)

Model configuration

Assignment of calibrated NAM parameters to uncalibrated sub-catchments was based on a number of hydrological and physiographical criteria including proximity to the calibrated catchments, similarity in vegetation cover, soil depth and catchment MAP. For uncalibrated model sub-catchments situated between multiple calibrated catchments, transition parameter sets based on average parameter values were assigned (see Table A3-6). Table A3-7 presents the parameters assigned to each model sub-catchment.

Table A3-6: Transition NAM model parameters

Parameters		Surface-rootzone							
Para meter Set	Calibration Gauge	Umax	Lmax	CQOF	CKIF	CK1	CK2	TOF	TIF
no.	ID	mm	mm	-	h	h	h	-	-
15	1BB01/ 1BE06	20	400	0.01	1000	24	24	0.1	0.1
16	1FC01/ 1FE02	10	200	0.4	1000	24	24	0.3	0.1

Parameters		Groundwater			
Parameter Set	Calibration Gauge	TG	CKBF	CQLow	CKLow
no.	ID	-	h	%	h
15	1BB01/ 1BE06	0.01	700	20	4500
16	1FC01/ 1FE02	0.01	1500	40	4500

Table A3-7: NAM model parameters assigned to model sub-catchments

General		Gauge	Surface-rootzone								Groundwater			
Catchment Name	Area	Calibration Gauge	Umax	Lmax	CQOF	CKIF	CK1	CK2	TOF	TIF	TG	CKBF	CQLow	CKLow
-	km^2	ID	mm	mm	( )	h	h	h	( )	( )	( )	h	%	h
1AA_1_UG1	525.6	1AA01	15	350	0.3	1000	24	24	0.1	0.1	0.1	1000	20	4500
1AA_2 G1	51.7	1AA01	15	350	0.3	1000	24	24	0.1	0.1	0.1	1000	20	4500
1AB_1	192.6	1AD01	20	350	0.1	1000	24	24	0.1	0.1	0.3	1000	20	4500
1AB_2 G1	93.4	1AD01	20	350	0.1	1000	24	24	0.1	0.1	0.3	1000	20	4500
1AC_1	110.8	1AD01	20	350	0.1	1000	24	24	0.1	0.1	0.3	1000	20	4500
1AD_1 G2	68.5	1AD01	20	350	0.1	1000	24	24	0.1	0.1	0.3	1000	20	4500
1AD_2	157.2	1AD01	20	350	0.1	1000	24	24	0.1	0.1	0.3	1000	20	4500
1AD_3	11.6	1AD01	20	350	0.1	1000	24	24	0.1	0.1	0.3	1000	20	4500
1AD_4	13.9	1AD01	20	350	0.1	1000	24	24	0.1	0.1	0.3	1000	20	4500
1AE_1_UG2	73.3	1AH01	10	200	0.3	1000	24	24	0.1	0.1	0.1	1000	20	4500
1AE_2_UG3	67.1	1AH01	10	200	0.3	1000	24	24	0.1	0.1	0.1	1000	20	4500
1AE_3	69.8	1AH01	10	200	0.3	1000	24	24	0.1	0.1	0.1	1000	20	4500
1AE_4	58.0	1AH01	10	200	0.3	1000	24	24	0.1	0.1	0.1	1000	20	4500
1AE_5_UG4	28.5	1AH01	10	200	0.3	1000	24	24	0.1	0.1	0.1	1000	20	4500
1AF_1	317.4	1AH01	10	200	0.3	1000	24	24	0.1	0.1	0.1	1000	20	4500
1AF_2	85.6	1AH01	10	200	0.3	1000	24	24	0.1	0.1	0.1	1000	20	4500
1AG_1	351.5	1AH01	10	200	0.3	1000	24	24	0.1	0.1	0.1	1000	20	4500
1AH_1 G1	261.7	1AH01	10	200	0.3	1000	24	24	0.1	0.1	0.1	1000	20	4500
1AH_2	395.5	1AH01	10	200	0.3	1000	24	24	0.1	0.1	0.1	1000	20	4500
1BA_1 G1	89.3	1BA01	20	300	0.1	800	24	24	0.1	0.1	0.01	1500	20	4500
1BA_2	378.3	1BA01	20	300	0.1	800	24	24	0.1	0.1	0.01	1500	20	4500
1BA_3_Chebara	167.6	1BA01	20	300	0.1	800	24	24	0.1	0.1	0.01	1500	20	4500
1BB_1 G2	265.3	1BB01	10	400	0.2	1000	24	24	0.1	0.1	0.1	1000	20	4500
1BB_2 G1	486.8	1BB01	10	400	0.2	1000	24	24	0.1	0.1	0.1	1000	20	4500
1BB_3	0.2	1BB01	10	400	0.2	1000	24	24	0.1	0.1	0.1	1000	20	4500
1BC_1	771.0	1BB01/ 1BE06	20	400	0.01	1000	24	24	0.1	0.1	0.01	1500	40	4500
1BD_1 G2	563.2	1BD02	10	400	0.2	1000	24	24	0.1	0.1	0.1	1000	20	4500
1BD_2	121.9	1BD02	10	400	0.2	1000	24	24	0.1	0.1	0.1	1000	20	4500
1BE_1 G6	831.7	1BE06	20	300	0.05	1000	24	24	0.1	0.1	0.01	1500	40	4500
1BE_2	315.7	1BE06	20	300	0.05	1000	24	24	0.1	0.1	0.01	1500	40	4500
1BG_1 G7	740.1	1BG07	10	350	0.3	1000	24	24	0.1	0.1	0.01	1000	40	4500
1BG_2	170.4	1BG07	10	350	0.3	1000	24	24	0.1	0.1	0.01	1000	40	4500
1BG_3	2.2	1BG07	10	350	0.3	1000	24	24	0.1	0.1	0.01	1000	40	4500

General		Gauge	Surface-rootzone								Groundwater			
Catchment Name	Area	Calibration Gauge	Umax	Lmax	CQOF	CKIF	CK1	CK2	TOF	TIF	TG	CKBF	CQLow	CKLow
-	km^2	ID	mm	mm	( )	h	h	h	( )	( )	( )	h	%	h
1BH_1	578.5	1BG07	10	350	0.3	1000	24	24	0.1	0.1	0.01	1000	40	4500
1CA_1 G2	692.2	1CA02	10	400	0.3	1000	24	24	0.2	0.1	0.3	700	20	4500
1CA_2	27.8	1CA02	10	400	0.3	1000	24	24	0.2	0.1	0.3	700	20	4500
1CB_1 G8	196.3	1CB08	10	400	0.3	1000	24	24	0.2	0.1	0.3	700	20	4500
1CB_2	435.7	1CB08	10	400	0.3	1000	24	24	0.2	0.1	0.3	700	20	4500
1CB_3_Ellegirini	31.4	1CB08	10	400	0.3	1000	24	24	0.2	0.1	0.3	700	20	4500
1CC_1	125.8	1CE01	10	400	0.3	1000	24	24	0.2	0.1	0.3	700	20	4500
1CC_2_Kipkarren	535.7	1CE01	10	400	0.3	1000	24	24	0.2	0.1	0.3	700	20	4500
1CD_1	521.5	1CE01	10	400	0.3	1000	24	24	0.2	0.1	0.3	700	20	4500
1CE_1 G1	100.2	1CE01	10	400	0.3	1000	24	24	0.2	0.1	0.3	700	20	4500
1CE_2	159.8	1CE01	10	400	0.3	1000	24	24	0.2	0.1	0.3	700	20	4500
1DA_1 G2	106.2	1DA02	10	350	0.3	1000	24	24	0.1	0.1	0.01	1000	40	4500
1DA_2	418.3	1DA02	10	350	0.3	1000	24	24	0.1	0.1	0.01	1000	40	4500
1DB_1 G1	533.5	1DB01	10	300	0.3	1000	24	24	0.1	0.1	0.01	1000	40	4500
1DB_2	195.0	1DB01	10	300	0.3	1000	24	24	0.1	0.1	0.01	1000	40	4500
1DC_1	372.4	1DA02	10	350	0.3	1000	24	24	0.1	0.1	0.01	1000	40	4500
1DD_1 G1	253.0	1DA02	10	350	0.3	1000	24	24	0.1	0.1	0.01	1000	40	4500
1DD_2	93.5	1DA02	10	350	0.3	1000	24	24	0.1	0.1	0.01	1000	40	4500
1EA_1	438.0	1EB02	10	200	0.3	1000	24	24	0.1	0.1	0.3	700	20	4500
1EB_1 G2	37.9	1EB02	10	200	0.3	1000	24	24	0.1	0.1	0.3	700	20	4500
1EB_2	344.7	1EB02	10	200	0.3	1000	24	24	0.1	0.1	0.3	700	20	4500
1EC_1	239.8	1EB02	10	200	0.3	1000	24	24	0.1	0.1	0.3	700	20	4500
1ED_1	131.0	1EB02	10	200	0.3	1000	24	24	0.1	0.1	0.3	700	20	4500
1EE_1 G1	387.9	1EE01	10	200	0.3	800	24	24	0.2	0.2	0.3	700	20	4000
1EE_2	6.2	1EE01	10	200	0.3	800	24	24	0.2	0.2	0.3	700	20	4000
1EF_1 G1	265.6	1EF01	10	200	0.3	800	24	24	0.2	0.2	0.3	700	20	4000
1EF_2	149.7	1EF01	10	200	0.3	800	24	24	0.2	0.2	0.3	700	20	4000
1EG_1	552.5	1EF01	10	200	0.3	800	24	24	0.2	0.2	0.3	700	20	4000
1FA_1	74.0	1FC01	15	200	0.4	1000	24	24	0.3	0.1	0.01	600	20	4500
1FA_2_Lessos	164.7	1FC01	15	200	0.4	1000	24	24	0.3	0.1	0.01	600	20	4500
1FB_1	371.8	1FC01	15	200	0.4	1000	24	24	0.3	0.1	0.01	600	20	4500
1FC_1 G1	241.5	1FC01	15	200	0.4	1000	24	24	0.3	0.1	0.01	600	20	4500
1FC_2	33.9	1FC01	15	200	0.4	1000	24	24	0.3	0.1	0.01	600	20	4500
1FD_1	360.1	1FC01/ 1FE02	10	200	0.4	1000	24	24	0.3	0.1	0.01	700	20	4500
1FD_2	118.5	1FC01/ 1FE02	10	200	0.4	1000	24	24	0.3	0.1	0.01	700	20	4500
1FE_1 G2	89.5	1FE02	10	200	0.3	800	24	24	0.2	0.1	0.3	800	30	4000
1FE_2 G3	64.4	1FE03	10	200	0.3	800	24	24	0.2	0.1	0.3	800	30	4000
1FE_3	508.9	1FE03	10	200	0.3	800	24	24	0.2	0.1	0.3	800	30	4000

General		Gauge	Surface-rootzone								Groundwater			
Catchment Name	Area	Calibration Gauge	Umax	Lmax	CQOF	CKIF	CK1	CK2	TOF	TIF	TG	CKBF	CQLow	CKLow
-	km^2	ID	mm	mm	( )	h	h	h	( )	( )	( )	h	%	h
1FF_1 G2	47.1	1FF02	10	200	0.3	800	24	24	0.2	0.1	0.3	800	30	4000
1FF_2	226.7	1FF02	10	200	0.3	800	24	24	0.2	0.1	0.3	800	30	4000
1FG_1 G1	1.3	1FG01	10	200	0.3	800	24	24	0.2	0.1	0.3	800	30	4000
1FG_2	817.7	1FG01	10	200	0.3	800	24	24	0.2	0.1	0.3	800	30	4000
1FG_3	100.5	1FG01	10	200	0.3	800	24	24	0.2	0.1	0.3	800	30	4000

A Natural MIKE HYDRO Basin model of the Lake Victoria North Basin was configured. The Natural model represents the pristine state of the basin before any man-made influences, i.e. no water use and no water related infrastructure. Figure A3-31 displays the Natural model configuration for the Lake Victoria North Basin. The relatively high spatial resolution that was adopted for model construction, in terms of number of model sub-catchments, is evident.

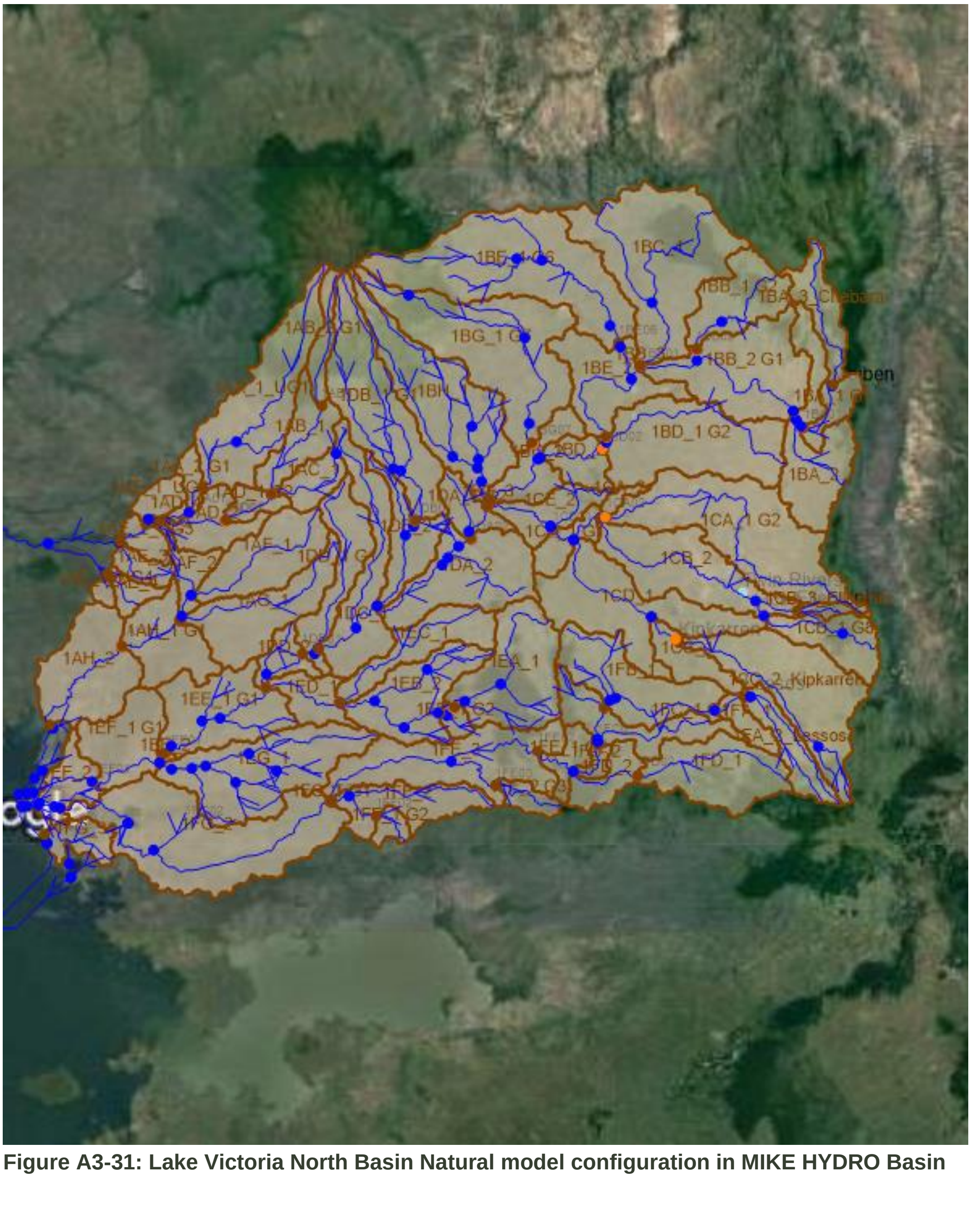

Figure A3-31: Lake Victoria North Basin Natural model configuration in MIKE HYDRO Basin

A4: Groundwater

The process used to quantify the groundwater potential followed four steps:

- **i.** Develop a weighting system for the four groundwater yield-related criteria that takes the five groupings (from very high to very low) into account. The weightings provide numerical values to the groups whereby a favourable groundwater area is afforded a higher value than a poor groundwater area. These values are referred to as Group Weights in Table A4-1.
- ii. Assign weightings to each of the four groundwater yield-related criteria (termed Layer Weight in Table A4-1). This step caters for placing greater value on Regional Permeability and Recharge than Secondary Permeability and Landforms as the former two criteria were considered to have a greater impact on groundwater availability than the latter two criteria.
- iii. For each of the four groundwater yield-related criteria obtain a score by multiplying the Weights by the Layer Weights, and then summing the scores for the four groundwater yield-related criteria to give the percentage of groundwater recharge that could potentially be available for use.
- iv. Multiply the percentage obtained in (iii) above by the groundwater recharge values obtained in Section 3.4 to obtain the rate at which groundwater is potentially available for use (Figure A4-1).

Table A4-1: The Weights and Layer Weights for the four groundwater yield-related criteria

Layer	Criteria	Layer weight	Groups and Group Weights					
			1	**2**	**3**	**4**	**5**	**Total**
1	Regional permeability	0.3	Very High 40	High 25	Medium 20	Low 10	Very Low 5	100
2	Secondary permeability	0.2	Very High 35	High 30	Medium 20	Low 10	Very Low 5	100
3	Landforms	0.2	Very High 40	High 30	Medium 15	Low 10	Very Low 5	100
4	Recharge	0.3	Very High 35	High 30	Medium 20	Low 10	Very Low 5	100

Using this GIS-based approach to estimate the abstractable proportion of recharge gives the following extreme values:

- An area rated as Very High for all four groundwater yield-related criteria gives an abstractable proportion of recharge value of 37.5%.
- An area rated as Very Low for all four groundwater yield-related criteria gives an abstractable proportion of recharge value of 5%.

This range is similar to the ~5 % to ~50 % that were obtained in neighbouring Ethiopia and South Sudan (ENTRO, 2016).

Note: For a detailed description of the approach which was followed for the assessment of groundwater resources, refer to “ISC Report C2-1: National Groundwater Potential Assessment”.

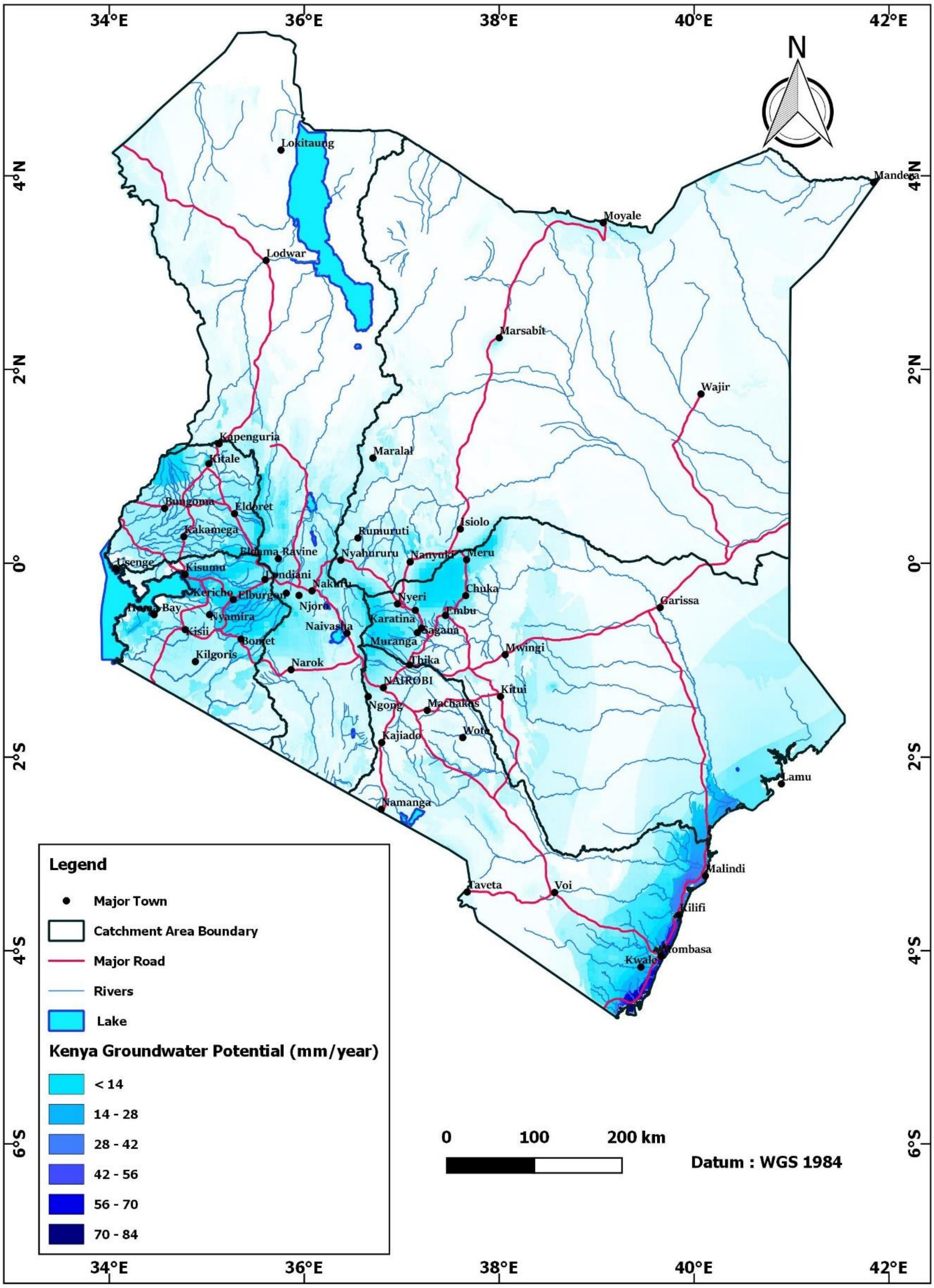

Figure A4 -1: Groundwater Potential in mm/year

A5: Environmental flows

In order to provide a scientific, high level approach towards the determination of provisional environmental flows to be used at basin-level water resource planning, so-called "Holding EFlows" were determined as ecological water requirements for sensitivity analysis purposes. These flows are coarse and provisional and their purpose is to provide interim numbers for insertion into basin-level water resource plans. They should not be used in detailed design, planning and operation of developments. Information for these latter purposes should come from higher confidence, more comprehensive EFlow assessments.

Note: *A detailed description of the methodogy which was used to derive the EFlows is presented in a stand-alone report: "KWSCRP: Holding environmental flows requirements for selected Kenyan rivers, Southern Waters, 2018".*

In essence the approach involved 5 key steps:

- Delineate the rivers into homogeneous biophysical river zones and social areas and assign representative nodes.
- Calculate the Hydrological Index (HI) for the rivers and use these to access EFlows recommendations for rivers with similar HI from the South African Desktop Model (Hughes & Münster, 2000).
- Review EFlows assessments done in similar southern and eastern African rivers to provide guidance on Holding EFlows allocations.
- Obtain naturalised and 'current day' (c. 2017) hydrological records for the study rivers for use in cross-checking the Holding EFlows against reality.
- Use Steps 2, 3 and 4 to estimate Holding EFlows to maintain the study rivers in a range of ecological conditions.

The approach also provided for the determination of the present ecological condition of representative reaches based on a "Habitat Integrity Method". Table A5-1 defines the ecological categories as used in the assessment of current ecological condition.

Table A5-1: Ecological condition and scores (Kleynhans, 1996)

CATEGORY	DESCRIPTION	SCORE (%)
A	Unmodified, natural	90-100
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.	80-90
C	Moderately modified. A loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.	60-79
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.	40-59
E	The loss of natural habitat, biota and basic ecosystem functions is extensive.	20-39
F	Modifications have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.	0

The EFlows assessment for the LVN Basin delineated the Basin into 38 sub-basins with three main components; the Nzoia River and tributaries, the Yala River and the transboundary rivers. Nodes were assigned to represent each of the river types. The nodes were positioned at the downstream end of the reaches they represent. The current ecological condition of the rivers at the node locations were assessed at desktop level using a habitat integrity scoring method with limited field visits. Figure A5-1 indicates the locations of the representative nodes as well as the ecological condition of 7 representation reaches in the basin, while Table A5-2 summarises the hydro-geomorphological characteristics and the present ecological condition of the representative nodes in the LVN Basin.

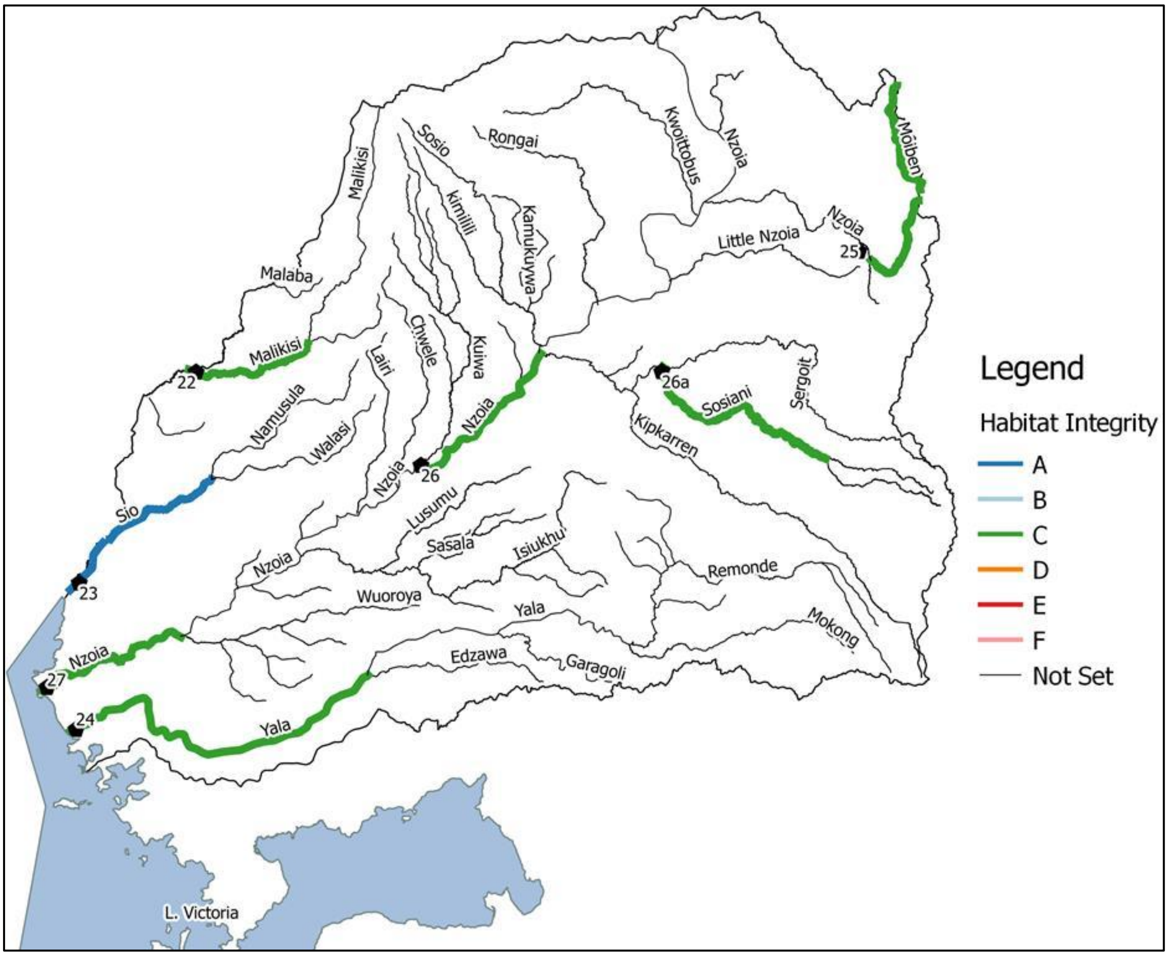

Figure A5-1: Ecological condition of 7 representative reaches in the LVN Basin

Table A5-2: Main hydro-geomorphological characteristics and 2018 ecological condition of representative nodes in the LVN Basin

Node		River	Description	Ecological condition	Zone	Rosgen (1994)	Coordinates	
#	Code						X	Y
28	22	Malikisi	d/s end before Ugandan border	C (76.6%)	-	E	34.2417	0.6324
29	23	Sio	d/s confluence Namsula and Walasi Rivers	A (94.4%)	-	F	34.0353	0.2600
30	24	Yala	d/s confluence Remonde River	C (69.2%)	-	F	34.5225	0.0682
31	25	Nzoia / Moiben	Transitional zone and d/s Moiben HPP	C (68.4%)	Transitional	C	34.4127	0.8456
32	26	Nzoia	d/s planned Nzoia 34B and Moi's Bridge HPP	C (62.8%)	Upper Foothills	F	34.8670	0.6867
33	26a	Sosiani	d/s Twin Rivers HPPs and planned Kibolo HPPs	C (61.3%)		F	34.9922	0.5926
34	27	Nzoia	d/s planned Nzoia 42A HPP	C (67.2%)	Lower Foothills	F	34.2349	0.1898

The Holding EFlows, as a percentage of natural flows, for all sub-basins in the LVN Basin are summarised in Table A5-3. It is important to note that further assessments would be required for all surface and groundwater resources in order to define the Resource Directed Measures for the Water Resource Management cycle.

Table A5-3: Holding EFlows as percentage of natural monthly flows in the LVN Basin

Longitudinal zone	Sub-basins	HI		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Lake Margin	1AB, 1AF, 1AG, 1AH, 1FA, 1FB, 1FC, 1FD, 1FE, 1FF, 1FG	1-6	A	73.0	100.0	100.0	73.0	73.0	73.0	100.0	100.0	73.0	73.0	73.0	73.0
			B	60.0	90.0	90.0	60.0	60.0	60.0	90.0	90.0	60.0	60.0	60.0	60.0
			C	40.0	60.0	60.0	40.0	40.0	40.0	60.0	60.0	40.0	40.0	40.0	40.0
			D	25.5	39.5	39.5	25.5	25.5	25.5	39.5	39.5	25.5	25.5	25.5	25.5
	1AA, 1AC, 1AE,	n/a													
Transitional	1BA	1-6	A	73.0	100.0	100.0	73.0	73.0	73.0	100.0	100.0	73.0	73.0	73.0	73.0
			B	60.0	90.0	90.0	60.0	60.0	60.0	90.0	90.0	60.0	60.0	60.0	60.0
			C	40.0	60.0	60.0	40.0	40.0	40.0	60.0	60.0	40.0	40.0	40.0	40.0
			D	25.5	39.5	39.5	25.5	25.5	25.5	39.5	39.5	25.5	25.5	25.5	25.5
Upper Foothills	1BB, 1BC, 1BD, 1BE, 1BG, 1BH, 1CA, 1CB, 1CC, 1CD, 1CE, 1DA, 1DB, 1DC	1-6	A	73.0	100.0	100.0	73.0	73.0	73.0	100.0	100.0	73.0	73.0	73.0	73.0
			B	60.0	90.0	90.0	60.0	60.0	60.0	90.0	90.0	60.0	60.0	60.0	60.0
			C	40.0	60.0	60.0	40.0	40.0	40.0	60.0	60.0	40.0	40.0	40.0	40.0
			D	25.5	39.5	39.5	25.5	25.5	25.5	39.5	39.5	25.5	25.5	25.5	25.5
Lower Foothills	1DD, 1EA, 1EB, 1EC, 1ED, 1EE	1-6	A	73.0	100.0	100.0	73.0	73.0	73.0	100.0	100.0	73.0	73.0	73.0	73.0
			B	60.0	90.0	90.0	60.0	60.0	60.0	90.0	90.0	60.0	60.0	60.0	60.0
			C	40.0	60.0	60.0	40.0	40.0	40.0	60.0	60.0	40.0	40.0	40.0	40.0
			D	25.5	39.5	39.5	25.5	25.5	25.5	39.5	39.5	25.5	25.5	25.5	25.5
Lowland	1EG, 1EF	1-6	A	73.0	100.0	100.0	73.0	73.0	73.0	100.0	100.0	73.0	73.0	73.0	73.0
			B	60.0	90.0	90.0	60.0	60.0	60.0	90.0	90.0	60.0	60.0	60.0	60.0
			C	40.0	60.0	60.0	40.0	40.0	40.0	60.0	60.0	40.0	40.0	40.0	40.0
			D	25.5	39.5	39.5	25.5	25.5	25.5	39.5	39.5	25.5	25.5	25.5	25.5

A6: Multi-criteria analysis – indicators

Name	**Environmentally sensitive area (EN1.1)**
Type	Environment (EN)
Category	Footprint (1)
Motivation	Protection of ecologically sensitive areas will serve to protect the biodiversity and ecosystem services associated with such areas.
Description	Extent of ecologically sensitive area within dam / irrigation scheme footprint
Units	km^2

Source Data

Ecologically Sensitive Areas refer to those areas located within the primary impact zones that have been, or could potentially be, classified into one of the IUCN protected area management categories (www.iucn.org). The IUCN categories provide a global standard for defining and recording protected areas and are increasingly being incorporated into government legislation (**www.iucn.org**). The IUCN Protected Areas Categories System are as follows:

- Category Ia – Strict Nature Reserve
- Category Ib – Wilderness Area
- Category II – National Park
- Category III – Natural Monument or Feature
- Category IV – Habitat / Species Management Area
- Category V – Protected Landscape e.g. Water Towers
- Category VI – Protected area with Sustainable Use of Natural Resources

Typical areas in Kenya that could potentially be classified using the IUCN system include:

- Wetlands. Points identified as wetlands of international importance (www.ramsar.org).
- Birds. Points identified as Important Bird Areas (www.birdlife.org)
- National parks and reserves
- Gazetted water towers

Method of calculation: Interrogation of spatial data (GIS)

Intersect dam full supply / irrigation scheme clearing area with environmentally sensitive area(s)

References

African Development Bank (ADB) 2004. Group Policy on the Environment. February 20094.

Birdlife International. Important Bird Areas Programme. (www.birdlife.org).

International Finance Corporation (IFC). 2012. Performance Standard 6. Biodiversity Conservation and Sustainable Management of Living Natural Resources.

NEPAD 2003. Action plan for the environment initiative of the New Partnership for Africa's Development.

Ramsar (www.ramsar.org).

BirdLife International and NatureServe (2011) Bird species distribution maps of the world. BirdLife International, Cambridge, UK and NatureServe, Arlington, USA.

Name	**Carbon emissions (EN1.2)**
Type	Environment (EN)
Category	Footprint (1)
Motivation	Woody vegetation located within the area of inundation or irrigation area to be cleared could lead to generation of greenhouse gases.
Description	Potential carbon emission within dam footprint due to flooding and decomposition of woody biomass inundated; Potential carbon emission within irrigation scheme footprint due to clearing and burning of natural vegetation.
Units	million ton

Source Data

Woody biomass (Mg/ha) Carbon Dioxide Information Centre: Geographical Distribution of Woody Biomass Carbon in Tropical Africa: An Updated Database for 2000 (**https://cdiac.ess-dive.lbl.gov/**)

Method of calculation: Interrogation of spatial data (GIS)

Intersect dam full supply / irrigation scheme clearing area with woody biomass spatial data in Mg/ha.

References

African Development Bank (ADB) undated draft. Energy Sector Policy of the African Development Bank Group.

EDF 2007. Prefeasibility study of Mandaya Hydropower Project, Ethiopia. Eastern Nile Power Trade Programme Study. Module M5. Report prepared by EDF and Scott Wilson for the Eastern Nile technical Regional Office.

Gibbs, H.K. and S. Brown. 2007. Geographical Distribution of Woody Biomass Carbon in Tropical Africa: An Updated Database for 2000, NDP-055b. Available at [http://cdiac.ornl.gov/epubs/ndp/ndp055/ndp055b.html] from the Carbon Dioxide Information Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee. doi: 10.3334/CDIAC/lue.ndp055.2007.

Global Land Cover 2000 Database. European Commission, Joint Research Centre, 2003. http://www-gen.jrc.it/glc2000.

Scanlon, A., Kile, R., and Blumstein, B. 2004. Sustainable hydropower - guidelines, compliance standards and certification. United Nations Symposium on Hydropower and Sustainable Development, Beijing 27-29 October 2004. Hydro Tasmania, Australia.

World Commission of Dams. 2000. Dams and development a new framework for decision-making. The Report of the Word Commission on Dams. London: Earthscan Publications, Thanet Press

Name	**Floodplain inundation (EN2.1)**
Type	Environment (EN)
Category	Downstream areas (2)
Motivation	Floodplains provide significant ecosystem services including biodiversity support, nursery areas for fish, and production of various natural resources, including timber, thatching grass and medicinal plants.
Description	Extent of floodplain inundation in river reach downstream of dam during wet season

Units	% Change from baseline

Source Data Water resources simulation model output: Timeseries of flow in river reach downstream of proposed dam

Method of calculation: Timeseries analysis Identify wettest month from Natural time series Extract annual wettest month timeseries from Baseline and Scenario simulation results Calculate median wettest month flow rates for Baseline and Scenario Calculate change in wettest month median flow rate: Scenario compared to Baseline % change

References

Opperman, J.J., Moyle, P.B., Larsen, E.W., Florsheim, J.L., Manfree, A.D. Floodplains: Processes and Management for Ecosystem Services. University of California Press, 2017. Available at **https://www.jstor.org/stable/10.1525/j.ctv1xxt6n**

Name	**Ecological stress (EN2.2)**
Type	Environment (EN)
Category	Downstream areas (2)
Motivation	Wet and dry season low flows and within year flow variability are important drivers of instream ecological processes and associated river health. Aquatic biota have evolved life history strategies to cope with the natural stress regime, and any changes to the natural stress regime (increase or decrease) tend to reduce biodiversity because these changes produce conditions suitable to a few taxa only.
Description	Ecological stress rating in river reach downstream of proposed dam or large abstraction due to anticipated changes in key flow components
Units	Index (-5 to 0)

Source Data Water resources simulation model output: Timeseries of flow in river reach downstream of proposed dam / abstraction point

Method of calculation: Timeseries analysis Dry season low flow Identify driest month from Natural time series Extract annual dry season timeseries for three consecutive dry months (driest month and adjacent months) from Baseline and Scenario simulation results

Calculate median dry season flow rate for Baseline and Scenario

Calculate change in dry season median flow rate: Scenario compared to Baseline % change

Wet season base flow

Identify wettest month from Natural time series

Extract annual wet season baseflow timeseries as average of months immediately before and after wettest month from Baseline and Scenario simulation results

Calculate median wet season base flow rate for Baseline and Scenario

Calculate change in wet season base flow median flow rate: Scenario compared to Baseline % change

Within year flow variability

Extract annual flow amplitudes - difference between max and min monthly flow rate - from Baseline and Scenario simulation results

Calculate median of annual flow amplitudes for Baseline and Scenario

Calculate change in median flow amplitude: Scenario compared to Baseline % change

Rating

		Dry / Wet Season Low Flows	Annual Flow variation
0	Zero	0	0
-1	Negligible	<20% gain <17% drop	6 - 10% gain 5 - 9% drop
-2	Low	20 - 49% gain 17 - 34% drop	11 - 24% gain 10 - 19% drop
-3	Moderate	50 - 99% gain 35 - 49% drop	25 - 99% gain 20 - 49% drop
-4	High	100 - 149% gain 50 - 59% drop	100 - 399% gain 50 - 79% drop
-5	Very High	>150% gain >60% drop	400>% gain <80% drop

References

Hijri, R., and Panella, T. 2003. Evolving policy reforms and experiences for addressing downstream impacts in World Bank Water Resources Projects. Rivers Research & Applications 19: 667-681.

World Bank. 2001. Making Sustainable Commitments: An Environment Strategy for the World Bank. World Bank: Washington, DC.

World Commission on Dams. 2000. Dams and Development: A New Framework for Decision Making. Earthscan Publications: London.

Name	**Wet season duration (EN2.3)**
Type	Environment (EN)
Category	Downstream area (2)
Motivation	The length of the wet season is important for biological production, flushing of fine sediments, channel maintenance and floodplain inundation.
Description	Duration of wet season (high flows) in river reach downstream of dam

Units	% Change from baseline

Source Data Water resources simulation model output: Timeseries of flow in river reach downstream of proposed dam

Method of calculation: Timeseries analysis Identify 20th percentile exceedance flow rate from Natural time series Calculate number of days during which the Natural 20th percentile flow rate is exceeded in Baseline and Scenario simulations Calculate change in number of exceedance days: Scenario compared to Baseline % change

References

Opperman, J.J., Moyle, P.B., Larsen, E.W., Florsheim, J.L., Manfree, A.D. Floodplains: Processes and Management for Ecosystem Services. University of California Press, 2017. Available at https://www.jstor.org/stable/10.1525/j.ctv1xxt6n

Name	**Phytoplankton growth potential (EN3.1)**
Type	Environment (EN)
Category	Water quality (3)
Motivation	Retention time in dams is easy to measure and is directly related to the potential for phytoplankton biomass and algal blooms, such as potentially toxic blue-green algae (cyanobacteria), Microcystis. Rivers usually do not support large populations of plankton, except in their lower reaches, where current speeds are slow. The development of plankton populations is generally associated with standing water. Impoundments provide ideal conditions for the development of plankton, which respond rapidly to changes in flow conditions on account of their rapid life histories, which are typically measures in days or weeks. The availability of nutrients decreases as retention time increases, so small impoundments with short retention times can cause water quality to deteriorate for downstream users, whereas impoundments with long retention time can serve to improve water quality for downstream users.
Description	Potential for phytoplankton growth
Units	Phytoplankton growth risk (%)

Source Data Water resources simulation model output Timeseries of inflow into proposed dam Timeseries of proposed dam storage volume

Method of calculation: Timeseries analysis $y = x^{1.59} (0.13) (0.99^{x})$

where y = phytoplankton growth potential (%); x = retention time (days), calculated from the median annual storage divided by mean annual inflow into reservoir

References

Coveney, M. F., J. C. Hendrickson, E. R. Marzolf, R. S. Fulton, J. Di, C. P. Neubauer, D. R. Dobberfuhl, G. B. Hall, H. W. Paerl, and E. J. Phlips. 2011. Chapter 8. Plankton. In: St. Johns River water Supply Impact Study. St. Johns River Water Management District, Palatka, FL, USA. St. Johns River Water Management District, Palatka, Florida.

Wagner-Lotkowska, K. Izydorczyk, T. Jurczak & M. Tarczynska, P. Frankiewicz 2004. Ecohydrological methods of algal bloom control. In: Zalewski, M & Wagner-Lotkowska (Eds). Chapter 12: Reservoir & lake management: Improvement of Water Quality. Integrated watershed management – Ecohydrology 7 Phytotechnology Manual. United Nations Environmental Programme.

Name	**Aquatic macrophytes growth potential (EN3.2)**
Type	Environment (EN)
Category	Water quality (3)
Motivation	Floating macrophytes reduce the availability of light and oxygen in the water, with detrimental implications for biodiversity. The plants provide ideal habitat for bilharzia snails, and also increase evapotranspiration losses.
Description	Potential for macrophyte growth
Units	Aquatic macrophyte growth risk (%)

Source Data

Water resources simulation model output

Timeseries of flow in river reach downstream of proposed irrigation scheme return flow

Timeseries of irrigation scheme return flows

Nitrogen export coefficient

Method of calculation: Timeseries analysis

$$y = 108 / (1+((x/2.29)^{-0.83}))$$

where y = aquatic macrophyte growth potential (%); x = total nitrate concentration (mg/l) in receiving river immediately downstream of irrigation discharge point

References

Coetzee, J. A and Hill, M. P. 2012. The role of eutrophication in the biological control of water hyacinth, Eichhornia crassipes, in South Africa. Biocontrol 57: 247-261.

Byrne, M., Hill, M., Robertson, M., King, A. J., Katembo, N., Wilson, J. Brudwig, R., Fisher, J. 2010. Integrated management of Water Hyacinth in South Africa. Development of an integrated management plan for water hyacinth control, combining biological control, herbicidal control and nutrient control, tailored to the climatic regions of South Africa. Water Research Commission Report No TT 454/10. Pretoria.

National Agricultural Research Organization (NARO) 2008. The national invasive species strategy, action plan and policy guidelines for Uganda. Report submitted to CABI, under the UNEP/GEF Project: Removing barriers to invasive plant management in Africa (UNEP/GEF Project No GFL 2328-2711-4890.

Name	**Water availability for riparian users (SL1.1)**
Type	Social (SL)
Category	Water availability (1)
Motivation	Upstream storage and flow regulation as well as large river abstractions may negatively impact dry season water availability in the river downstream and could impact riparian users
Description	Change in water availability during dry season
Units	% Change from baseline

Source Data

Water resources simulation model output

Timeseries of flow in river reach downstream of proposed dam / abstraction point

Method of calculation: Timeseries analysis

Identify driest month from Natural time series

Extract annual dry season timeseries for three consecutive dry months (driest month and adjacent months) from Baseline and Scenario simulation results

Calculate median dry season flow rate for Baseline and Scenario

Calculate change in dry season median flow rate: Scenario compared to Baseline % change

References

Matunda, J.M. Sustainable management of riparian areas in Kenya:a critique of the inadequacy of the legislative framework governing the protection of sustainable management of riparian zones in Kenya. University of Nairobi, 2015.

Name	**Malaria susceptibility (SL2.1)**
Type	Social (SL)
Category	Community health and safety (2)
Motivation	The increased availability of open water (dams) and wetted areas (irrigation schemes) could potentially increase the risk of malaria
Description	Susceptibility of areas where new irrigation schemes and/or dams are proposed to malaria based on the WHO malaria incidence map for Africa
Units	Malaria endemicity (%)

Source Data

WHO Malaria incidence map of Africa (https://www.who.int/gho/map_gallery/en/)

Method of calculation: Interrogation of spatial data (GIS)

Intersect dam full supply / irrigation scheme clearing area with WHO Malaria prevalence map and calculate average % malaria endemicity in footprint area(s)

References

Kibret, S., Lautze, J., McCartney, M., Nhamo, L., Yan, G. 2019. Malaria around large dams in Africa: effect of environmental and transmission endemicity factors. Malaria Journal 18, Article number 303 (2019)

World Health Organisation: Global Health Observatory Data. Available at **https://www.who.int/data/gho**

Name	**Commercial irrigation (SL3.1)**
Type	Social (SL)
Category	Food security and livelihoods (3)
Motivation	Development of large-scale, commercial irrigation stimulates the economy, creates jobs, improves food security and improves socio-economic conditions
Description	Extent of proposed large-scale irrigation schemes
Units	km^2

Source Data

Planned large scale irrigation (km^2)

Method of calculation: Interrogation of spatial data (GIS)

Sum all proposed large-scale irrigation scheme areas in study area

References

Gwiyani-Nkhomo, B. Irrigation development and its socioeconomic impact on rural communities in Malawi. Development Southern Africa, Vol 28, 2011 – Issue 2

Name	**Recession agriculture (SL3.2)**
Proxy	*Floodplain inundation (EN2.1)*
Type	Social (SL)
Category	Food security and livelihoods (3)
Motivation	Recessional agriculture is a form of agricultural cultivation that takes place on a floodplain. Farmers practice recessional agriculture by successively planting in the flooded areas after the waters recede. A reduction in annual flood levels could impact recession agriculture.
Description	Extent of floodplain inundation in river reach downstream of dam during wet season
Units	% Change from baseline

Source Data

Water resources simulation model output:

Timeseries of flow in river reach downstream of proposed dam

Method of calculation: Timeseries analysis

Identify wettest month from Natural time series

Extract annual wettest month timeseries from Baseline and Scenario simulation results

Calculate median wettest month flow rates for Baseline and Scenario

Calculate change in wettest month median flow rate: Scenario compared to Baseline % change

References

Opperman, J.J., Moyle, P.B., Larsen, E.W., Florsheim, J.L., Manfree, A.D. Floodplains: Processes and Management for Ecosystem Services. University of California Press, 2017. Available at https://www.jstor.org/stable/10.1525/j.ctv1xxt6n

Name	**Fish production - dams (SL3.3)**
Type	Social (SL)
Category	Food security and livelihoods (3)
Motivation	This indicator is linked to areas that will become inundated through impoundment, and therefore represents the additional fish habitat created by impoundments.
Description	Potential fisheries production
Units	ton per annum

Source Data
Water resources simulation model output: Timeseries of surface area in proposed impoundment

Method of calculation: Timeseries analysis
$y = 13.143\ x^{0.8305}$ where y = fish production (t/a); x = median area of inundation over simulation period (km^2)

References

Bassa, G. K. 1986. Fishery resources of Southern Sudan. In A.B. Zahlan (ed.): The Agricultural sector of Sudan: Policy and systems studies, 291-299. London (UK), Ithaca Press.

Food and Agricultural Organisation of the United Nations (FAO) 2007. African water resource database. GIS-based tools for inland aquatic resource management. 2 Technical manual and workbook. CIFA Technical Paper 33/2.

Halls, A. S 1999. Spatial Models for the Evaluation and Management of Inland Fisheries. Final Report. FIR Plansys 23220 01 20, MRAG Ltd. London.

Welcomme, R. L. 2011. An overview of global catch statistics for inland fisheries. ICES Journal of Marine Science 68(8): 1751-1756.

Witte, F., de Graaf, M., Mkumbo, O. C., El-Moghraby, A. I. and Sibbing, F. A. 2009. Fisheries production in the Nile System. Dumont, H. J. (ed.). The Nile: origin, Environments, Limnology and Human Use. Springer. Monographiae Biologicae 89: P 723-747.

Name	**Fish production - river (SL3.4)**
Proxy	*Wet season duration (EN2.3)*
Type	Social (SL)
Category	Food security and livelihoods (3)

Motivation	The length of the wet season is important for biological production, flushing of fine sediments, channel maintenance and floodplain inundation.
Description	Duration of wet season (high flows) in river reach downstream of dam
Units	% Change from baseline

Source Data

Water resources simulation model output:

Timeseries of flow in river reach downstream of proposed dam

Method of calculation: Timeseries analysis

Identify 20th percentile exceedance flow rate from Natural time series

Calculate number of days during which the Natural 20th percentile flow rate is exceeded in Baseline and Scenario simulations

Calculate change in number of exceedance days: Scenario compared to Baseline % change

References

Opperman, J.J., Moyle, P.B., Larsen, E.W., Florsheim, J.L., Manfree, A.D. Floodplains: Processes and Management for Ecosystem Services. University of California Press, 2017. Available at https://www.jstor.org/stable/10.1525/j.ctv1xxt6n

Whitehead, P.J.P. Ministry of Forest Development, Game and Fisheries. The river fisheries of Kenya. The East African Agricultural Journal , April, 1960

Name	**Productive land use (SL3.5)**
Type	Social (SL)
Category	Food security and livelihoods (3)
Motivation	Protection of land that is currently productive will maintain livelihoods and social structures
Description	Extent of productive land area within dam / irrigation scheme footprint
Units	km^2

Source Data

World Bank Global Land Cover (Globcover): The GlobCover project has developed a service capable of delivering global composites and land cover maps using as input observations from the 300m MERIS sensor on board the ENVISAT satellite mission. The GlobCover 2009 land cover map is derived by an automatic and regionally-tuned classification of a time series of global MERIS (MEdium Resolution Imaging Spectrometer) FR mosaics for the year 2009. The global land cover map counts 22 land cover classes defined with the United Nations (UN) Land Cover Classification System (LCCS). (https://datacatalog.worldbank.org/dataset/global-land-cover-2009)

Method of calculation: Interrogation of spatial data (GIS)

Intersect dam full supply / irrigation scheme clearing area with GlobCover dataset
GlobCover productive land-use categories:

Post-flooding or irrigated shrub or tree crops

Post-flooding or irrigated herbaceous crops

Rainfed croplands Rainfed herbaceous crops Rainfed shrub or tree crops (cash crops, vineyards, olive tree, orchards…) Mosaic cropland (50-70%) / vegetation (grassland/shrubland/forest) (20-50%) Mosaic cropland (50-70%) / grassland or shrubland (20-50%) Mosaic vegetation (grassland/shrubland/forest) (50-70%) / cropland (20-50%) Mosaic grassland or shrubland (50-70%) / cropland (20-50%) Mosaic forest (50-70%) / cropland (20-50%)

References

Perez-Hoyos, A., Rembold, F., Kerdiles, H., Gallego, J. Comparison of global land cover datasets for cropland monitoring. Remote sensing, Nov 2017. Available at https://www.mdpi.com/journal/remotesensing

Name	**Access to natural resources (SL3.6)**
Proxy	*Environmentally sensitive area (EN1.1)*
Type	Social (SL)
Category	Food security and livelihoods (3)
Motivation	Protection of ecologically sensitive areas will serve to protect natural resources.
Description	Extent of ecologically sensitive area within dam / irrigation scheme footprint
Units	km^2

Source Data

Ecologically Sensitive Areas refer to those areas located within the primary impact zones that have been, or could potentially be, classified into one of the IUCN protected area management categories (www.iucn.org). The IUCN categories provide a global standard for defining and recording protected areas and are increasingly being incorporated into government legislation (**www.iucn.org**). The IUCN Protected Areas Categories System are as follows:

- Category Ia – Strict Nature Reserve
- Category Ib – Wilderness Area
- Category II – National Park
- Category III – Natural Monument or Feature
- Category IV – Habitat / Species Management Area
- Category V – Protected Landscape e.g. Water Towers
- Category VI – Protected area with Sustainable Use of Natural Resources

Typical areas in Kenya that could potentially be classified using the IUCN system include:

- Wetlands. Points identified as wetlands of international importance (www.ramsar.org).
- Birds. Points identified as Important Bird Areas (www.birdlife.org)
- National parks and reserves
- Gazetted water towers

Method of calculation: Interrogation of spatial data (GIS)

Intersect dam full supply / irrigation scheme clearing area with environmentally sensitive area(s)

References

African Development Bank (ADB) 2004. Group Policy on the Environment. February 20094.

Birdlife International. Important Bird Areas Programme. (www.birdlife.org).

International Finance Corporation (IFC). 2012. Performance Standard 6. Biodiversity Conservation and Sustainable Management of Living Natural Resources.

NEPAD 2003. Action plan for the environment initiative of the New Partnership for Africa's Development.

Ramsar (www.ramsar.org).

BirdLife International and NatureServe (2011) Bird species distribution maps of the world. BirdLife International, Cambridge, UK and NatureServe, Arlington, USA.

Name	**Physical displacement (SL4.1)**
Type	Social (SL)
Category	Displacement (4)
Motivation	Displacement impacts are classified as physical and economic displacement. Physical displacement is associated with the displacement of local communities due to dam inundation, and or area taken up by irrigation schemes and canals.
Description	Physical displacement of people due to inundation by proposed dam / establishment of planned irrigation scheme
Units	number of people

Source Data

Africa High Resolution Population Density Maps (www.un-spider.org/links-and-resources/data-sources/africa-high-resolution-population-density-maps)

WorldPop database (https://www.worldpop.org/)

Method of calculation: Interrogation of spatial data (GIS)

Intersect dam full supply / irrigation scheme clearing area with population density spatial data

References

Facebook Connectivity Lab and Center for International Earth Science Information Network - CIESIN - Columbia University. 2016. High Resolution Settlement Layer (HRSL). Source imagery for HRSL © 2016 DigitalGlobe. Accessed DAY MONTH YEAR.

Lloyd, C. T., Sorichetta, A., Tatem A. High resolution global gridded data for use in population studies. Scientific Data 4, Article number 170001 (2017)

Name	**Energy generated (EC1.1)**
Type	Economic (EC)
Category	Energy (1)
Motivation	Hydropower generation is a key benefit linked to water resources development and stimulates socio-economic development at local, national and regional levels

Description	Average hydropower generated
Units	GWh/a

Source Data

Water resources simulation model output:

Timeseries of hydropower output at HP node

Method of calculation: Timeseries analysis

Calculate average energy (GWh/a) generated over simulation period

References

Degefu, D. M., He, W., Zhao, J.H. Hydropower for sustainable water and energy development in Ethiopia. Sustainable Water Resources Management 1, 305-314 (2015)

Name	**Crop production (EC2.1)**
Type	Economic (EC)
Category	Food production (2)
Motivation	Increased food production through irrigation is a key benefit linked to water resources development. It creates food security and stimulates socio-economic development.
Description	Crop yield
Units	million ton/a

Source Data

Water resources simulation model output:

Timeseries of crop water requirements

Timeseries of crop water deficit

Typical crop yields as provided by Food and Agricultural Organisation FAOSTAT (http://www.fao.org/faostat/en/#home)

Method of calculation: Timeseries analysis

Calculate maximum crop yield (t) based on irrigation scheme area (km2) and FAO crop yield (t/ha)

$y = 1.4493x^2 + 3.0897x - 0.6197$

where y = actual crop yield as proportion of maximum crop yield (%); x = water applied ratio (%)

References

Stone, L.R., Sclegel, A.J., Khan, A.H., Klocke, N.L., Aiken, R.M. Water supply/yield relationships developed for study of water management. Journal of natural resources and life sciences education. Vol 35 (2006)

Name	**Fish production - dams (EC2.2)**
Proxy	*Fish production - dams (SL3.3)*
Type	Economic (EC)
Category	Food production (2)
Motivation	This indicator is linked to areas that will become inundated through impoundment, and therefore represents the additional fish habitat created by impoundments.
Description	Potential fisheries production
Units	ton per annum

Source Data

Water resources simulation model output:

Timeseries of surface area in proposed impoundment

Method of calculation: Timeseries analysis

$y = 13.143\ x^{0.8305}$

where y = fish production (t/a); x = median area of inundation over simulation period (km^2)

References

Bassa, G. K. 1986. Fishery resources of Southern Sudan. In A.B. Zahlan (ed.): The Agricultural sector of Sudan: Policy and systems studies, 291-299. London (UK), Ithaca Press.

Food and Agricultural Organisation of the United Nations (FAO) 2007. African water resource database. GIS-based tools for inland aquatic resource management. 2 Technical manual and workbook. CIFA Technical Paper 33/2.

Halls, A. S 1999. Spatial Models for the Evaluation and Management of Inland Fisheries. Final Report. FIR Plansys 23220 01 20, MRAG Ltd. London.

Welcomme, R. L. 2011. An overview of global catch statistics for inland fisheries. ICES Journal of Marine Science 68(8): 1751-1756.

Witte, F., de Graaf, M., Mkumbo, O. C., El-Moghraby, A. I. and Sibbing, F. A. 2009. Fisheries production in the Nile System. Dumont, H. J. (ed.). The Nile: origin, Environments, Limnology and Human Use. Springer. Monographiae Biologicae 89: P 723-747.

Name	**Urban supply (EC3.1)**
Type	Economic (EC)
Category	Water supply (3)
Motivation	Reliable supply of water to urban areas is imperative for economic growth and investment
Description	Water supplied to urban areas
Units	% of demand supplied

Source Data

Water resources simulation model output:

Timeseries of urban demand Timeseries of urban water user deficit

Method of calculation: Timeseries analysis
Urban supply ratio (%) = mean annual supply (MCM) / mean annual demand (MCM)

References

Stéphanie dos Santos, E. Adams, G. Neville, Y. Wada, A. de Sherbinin, et al.. Urban growth and water access in sub-Saharan Africa: Progress, challenges, and emerging research directions. Science of the Total Environment, Elsevier, 2017, 607-608, pp.497 – 508.

Name	**Rural supply (EC3.2)**
Type	Economic (EC)
Category	Water supply (3)
Motivation	Reliable supply of water to rural areas is imperative for health and social welfare
Description	Water supplied to rural users
Units	% of demand supplied

Source Data
Water resources simulation model output: Timeseries of rural demand Timeseries of rural water user deficit

Method of calculation: Timeseries analysis
Rural supply ratio (%) = mean annual supply (MCM) / mean annual demand (MCM)

References

Cook, J., Kimuyu, P., Wittington, D. The costs of coping with poor water supply in rural Kenya. Water resources research. Vol 52 (2). Jan 2016. Available at https://doi.org/10.1002/2015WR017468

Name	**Irrigation supply (EC3.3 & EC3.4)**
Type	Economic (EC)
Category	Water supply (3)
Motivation	Reliable supply of water to irrigation areas is imperative for good crop yields
Description	Water supplied to irrigation users
Units	% of demand supplied

Source Data
Water resources simulation model output: Timeseries of irrigation demand Timeseries of irrigation water user deficit
Method of calculation: Timeseries analysis
Irrigation supply ratio (%) = mean annual supply (MCM) / mean annual demand (MCM)

References

Stone, L.R., Sclegel, A.J., Khan, A.H., Klocke, N.L., Aiken, R.M. Water supply/yield relationships developed for study of water management. Journal of natural resources and life sciences education. Vol 35 (2006)

Name	**Flood reduction (EC4.1)**
Type	Economic (EC)
Category	Flood damage (4)
Motivation	Large dams provide flood attenuation with potential flood risk reduction downstream
Description	Storage provided by dam as proportion of total natural runoff
Units	Ratio

Source Data
Water resources simulation model output: Timeseries of inflow sequence into proposed dam Full storage volume of proposed dam

Method of calculation: Timeseries Analysis
Flood reduction benefit = Dam volume (MCM) / Natural Mean Annual Runoff at dam location (MCM)

References

Volpi, E., Di Lazzaro, M., Bertola, M., Viglione, A. Fiori, A. Reservoir Effects on Flood Peak Discharge at the Catchment Scale. Water Resources Research, Vol 54 (11)

Name	**Employment – Commercial irrigation (EC5.1)**
Type	Economic (EC)
Category	Macro-economic (5)
Motivation	Development of large-scale, commercial irrigation creates jobs
Description	Extent of proposed large-scale irrigation schemes and potential income
Units	number of jobs

Source Data
Planned large scale irrigation (km^2) Water resources simulation model output: Timeseries of crop water requirements Timeseries of crop water deficit Typical crop yields - Food and Agricultural Organisation FAOSTAT (http://www.fao.org/faostat/en/#home) Potential crop income - Food and Agricultural Organisation FAOSTAT (http://www.fao.org/faostat/en/#home) Primary and secondary economic indicators

Method of calculation: Macro-economic analysis
Use macro-economic model **(Annexure A6)** to analyse the impacts of commercial irrigation on regional economic activity and job creation

References

Neubert, S. Poverty oriented irrigation policy in Kenya: Empirical results and suggestions for reform. German Development Institute, Discussion Paper. Dec 2007

Name	**Employment – Hydropower generation (EC5.2)**
Type	Economic (EC)
Category	Macro-economic (5)
Motivation	Development of hydropower creates direct and indirect employment
Description	Energy generated through hydropower
Units	number of jobs

Source Data
Water resources simulation model output: Timeseries of hydropower output at HP node Primary and secondary economic indicators

Method of calculation: Macro-economic analysis
Use macro-economic model **(Annexure A6)** to analyse the impacts of energy generation on regional economic activity and job creation

References

Renner, M., García-Baños, C., Khalid, A. The International Renewable Energy Agency. Renewable Energy and Jobs Annual Review 2019. International Renewable Energy Agency

Name	**Health cost related to water quality (EC5.3)**
Type	Economic (EC)
Category	Macro-economic (5)
Motivation	Poor water quality leads to direct and indirect costs associated with health issues
Description	Health costs related to poor water quality
Units	Relative to baseline

Source Data

Refer to Indicators EN3.1 and EN3.2

Primary and secondary economic indicators

Method of calculation: Macro-economic analysis

Use macro-economic model (Annexure A6) to analyse the potential impacts of poor water quality on health cost.

References

Clough, J. Africa's Water Quality A Chemical Science Perspective A report by the Pan Africa Chemistry Network. March 2010

Name	**Water resources development's contribution to GDP growth (EC5.4)**
Type	Economic (EC)
Category	Macro-economic (5)
Motivation	Water resources development and efficient management increases GDP
Description	GDP growth as a function of water resources development
Units	Relative to baseline

Source Data

Refer to Annexure A6

Primary and secondary economic indicators

Method of calculation: Macro-economic analysis

Use macro-economic model **(Annexure A6)** to analyse the potential impacts of water resources development on GDP.

References

Blignaut, J, Van Heerden, J. The impact of water scarcity on economic development initiatives. Water SA vol.35 n.4 Pretoria Jul. 2009

Name	**Sediment load (EC6.1)**
Type	Economic (EC)
Category	Sediment (6)
Motivation	Land use cover and management affect erosion risk and potential sediment yield
Description	Potential soil loss and sediment loads in rivers
Units	Ratio (Potential sediment load / Baseline sediment load)

Source Data

Refer to Annexure A1

Method of calculation: Spatial Analysis

Refer to Annexure A1

References

Lahlou, A. Environmental and socio-economic impacts of erosion and sedimentation in north Africa. Erosion and Sediment Yield: Global and Regional Perspectives (Proceedings of the Exeter Symposium, July 1996). IAHS Publ. no. 236, 1996. 491

A7: Macro-economic analysis

Background

To understand the role of water resources to the current economy and the potential for future development in Kenya, a set of macro-economic indicators were developed which relate to economic policy assessments, GDP, employment and government expenses. The purpose of this was to assess how alternative water resources development scenarios in individual river basins compare in terms of macro-economic impacts through water resources system components (irrigation, hydropower, etc. and macro-economic sectors (e.g. agriculture, manufacturing, etc.). Furthermore, it allows comparison of economic impacts linked to investments in water resources system components among the six river basins in Kenya and provide insight into the sectoral and total economic value of water resources development priorities and policies for Kenya.

Methodology

Both Primary and Secondary economic indicators were used in the macro-economic analysis.

Primary Economic Indicators

To analyse the impacts of regional water resources development on regional economic activity, Gross Value Added (GVA) was used for measuring gross regional domestic product as a measure of the output of entities smaller than the national economy. GVA is defined as GDP + subsidies - (direct, sales) taxes. The Kenya National Bureau of Statistics reports regional economic activity, as GVA, by 17 economic sectors. This was determined as overly detailed for the scope of this analysis and consequently the 17 sectors were aggregated to 4 economic sectors that better link to outputs of water resources analyses. The aggregation is presented in Figure A7-1.

Figure A7-1: Aggregation of Macro-Economic Sectors for the Hydro-Economic Analysis

1	Agriculture, forestry and fishing	
2	Mining and quarrying	
3	Manufacturing	
4	Electricity supply	
5	Water supply; waste collection	
6	Construction	
7	Wholesale and retail trade; repair of motor vehicles	
8	Transport and storage	
9	Accommodation and food service activities	
10	Information and communication	
11	Financial and insurance activities	
12	Real estate activities	
13	Professional, technical and support services	
14	Public administration and defence	
15	Education	
16	Human health and social work activities	
17	Other service activities	

1		Agriculture
2		Industry, Commerical, & Services
3		Electric Geneartion
4		Transport

Secondary Economic Indicators

Secondary indicators which were utilised and related to water resources analysis outputs include Employment and Government spending in the Health Sector.

Table A7-1 displays the relationship between the Economic Indicators and the water resources model outputs as incorporated into the Macro-Economic analysis.

Table A7-1: Linkages between the Economic Indicators and Hydro-Model Indicators

Economic Sector	Water Sector	Water resources model output	Units
Agriculture	Irrigation Supply	Irrigation supply	MCM/a
Industry, Commercial, Services	Urban Water Supply	Urban water supply	MCM/a
Energy	Hydropower Generation	Hydropower generated	GWh/a
Transport	Flood Control	Storage in large dams	Flood Control Index
Employment – Agriculture	Irrigation Area	Irrigation area	Hectare Irrigated
Employment -Industry	Energy Generation	Hydropower generated	GWh/a
Health Cost	Water Quality	Water quality index	Water Pollution Index

Data

The Kenya National Bureau of Statistics spatially disaggregated the Gross Domestic Product of Kenya to County level. The estimation for 17 economic sectors and 47 counties revealed that there are significant differences in the size of economy across counties. The average contribution per county to GVA over the period 2013-2017 is approximately 2.1 percent with a standard deviation of 3.2. As may be expected, this indicates large disparities in the size of GDP across the counties. Nairobi County takes the lead, contributing approximately 21.7 percent of GDP over the period, followed by Nakuru (6.1%), Kiambu (5.5%) and Mombasa counties (4.7%) (KNBS, 2019).

Table A7-2 shows estimates of GVA at current prices by County and by industry (sector). The breakdown indicates how much each county contributed to each economic activity. For instance Samburu Counry contributed KSh 10,847 million to the Agriculture, Forestry and Fishing sector in 2017.

Table A7-2: Gross Value Added (GVA) at current prices by county and by industry (sector).

		SECTORAL GVA (KSH Millions)					
ID	**County**	**Agriculture**	**Industrial**	**Energy**	**Transport**	**Services**	**Total**
30	BARINGO	53633	357	413	4737	33726	92866
36	BOMET	114076	5314	205	2512	37462	159569
39	BUNGOMA	107829	2024	433	10388	62835	183509
40	BUSIA	50020	453	246	3253	32740	86712
28	ELGEYO	127967	527	209	3579	27249	159531
14	EMBU	39794	2644	6503	10599	44194	103734
7	GARISSA	16845	1712	318	1410	19109	39394
43	HOMA	68247	958	486	5708	38799	114198
11	ISIOLO	3325	52	162	1030	11281	15850
34	KAJIADO	15954	7897	2789	7899	73266	107805
37	KAKAMEGA	95193	9451	975	7504	69440	182563
35	KERICHO	62765	13867	853	5787	53527	136799
22	KIAMBU	132421	54081	9533	29094	196789	421918
3	KILIFI	38319	11790	1471	11411	56304	119295
20	KIRINYAGA	41208	8110	826	9763	40929	100836
45	KISII	85550	3338	1149	9578	63931	163546
42	KISUMU	51445	24721	4106	19636	94581	194489
15	KITUI	41799	755	960	7147	50899	101560
2	KWALE	39610	1747	730	4198	39993	86278
31	LAIKIPIA	35489	823	723	5904	38156	81095
5	LAMU	18699	174	340	4171	9002	32386
16	MACHAKOS	56112	48155	9019	12736	106838	232860
17	MAKUENI	47606	1050	373	5276	46619	100924
9	MANDERA	14169	206	581	1155	18990	35101
10	MARSABIT	16078	85	259	337	17314	34073
12	MERU	124381	8401	1025	19072	76767	229646
44	MIGORI	40861	8726	352	6648	39750	96337
1	MOMBASA	1459	48506	20546	88308	173303	332122
21	MURANGA	89003	9679	1675	7005	65656	173018
47	NAIROBI	4102	375282	26878	184845	901216	1492323
32	NAKURU	301349	15408	36932	30640	133133	517462
29	NANDI	71213	4709	489	3300	39980	119691
33	NAROK	120355	2322	653	4601	51295	179226
46	NYAMIRA	56634	6728	489	3268	36120	103239
18	NYANDARUA	209519	1815	400	4269	29200	245203
19	NYERI	92859	5996	1703	12263	62140	174961
25	SAMBURU	10847	76	123	1234	14223	26503
41	SIAYA	50685	1282	390	3858	39050	95265
6	TAITA	19858	828	567	3109	27019	51381
4	TANA	18333	68	73	924	14100	33498
13	THARAKA	38740	317	210	2381	26044	67692
26	TRANS	50628	1058	810	7958	56229	116683
23	TURKANA	41493	153	2066	7750	26839	78301
27	UASIN-GISHU	63017	8628	1042	17552	72034	162273
38	VIHIGA	20160	2017	547	2292	34034	59050
8	WAJIR	20032	465	22	258	16382	37159
24	WEST	19311	2862	69	3904	20639	46785

Figure A7-2 presents total GVA by county with the six Kenya River Basins overlaid, while Figure A7-3 presents Agricultural GVA per county. These figures show how spatially varied the GVA values are- both within river basins and between river basins.

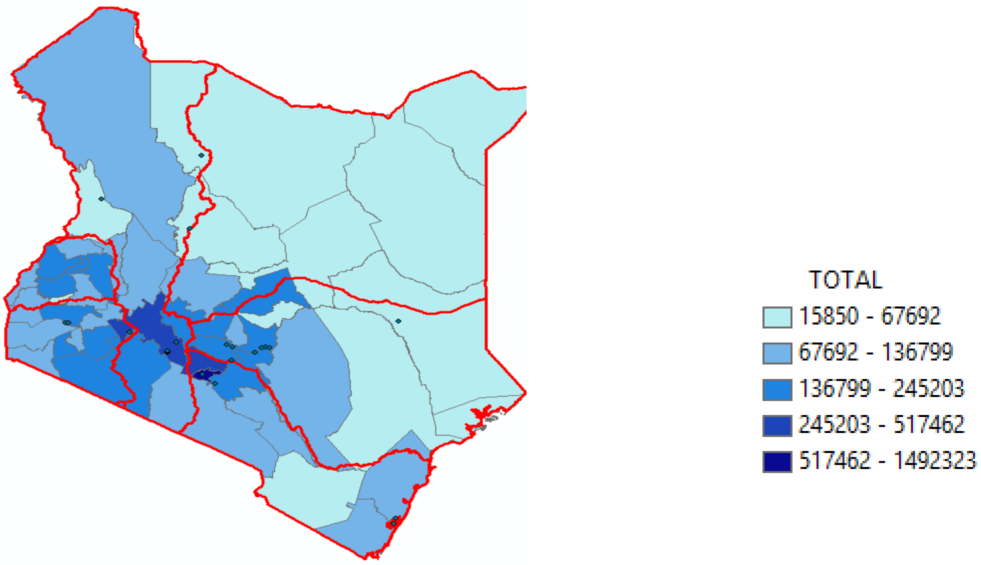

Figure A7-2: TOTAL GVA by County (KSH Millions)

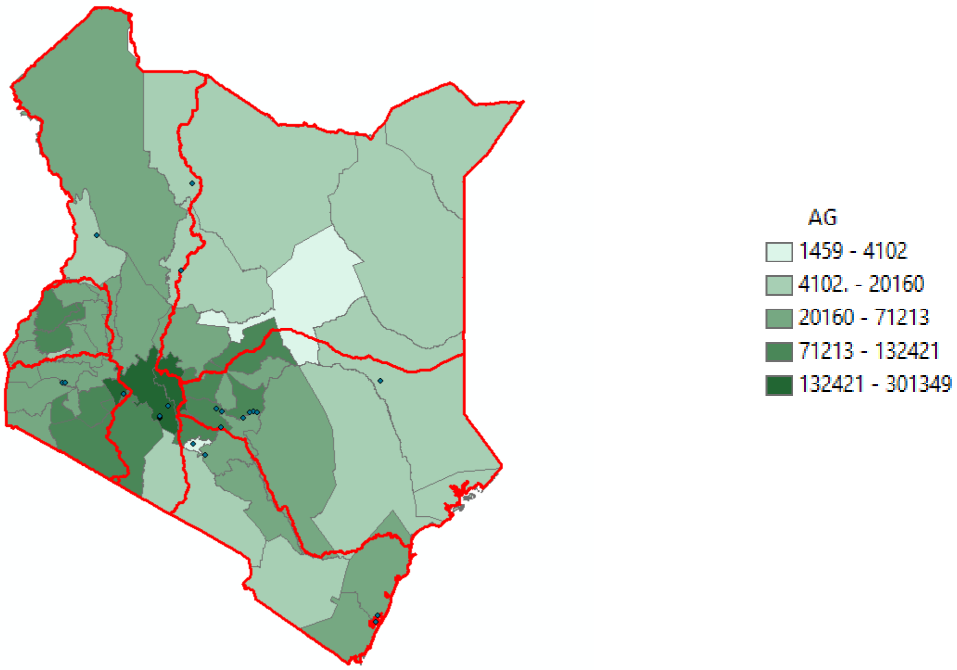

Figure A7-3: Agricultural GVA by County (KSH Millions)

Since the Hydro-Model Indicators are provided at River Basin level, the economic indicators needed to be calculated likewise. Using GIS tools, the area of each County in each river basin was estimated (Table A7-3) and a matrix of weights from Country to River basin was developed. With this matrix the GVA per river basin could be estimated. Figures A7-4 and A7-5 show River Basin GVAs for Total GVA and Agricultural GVA respectively.

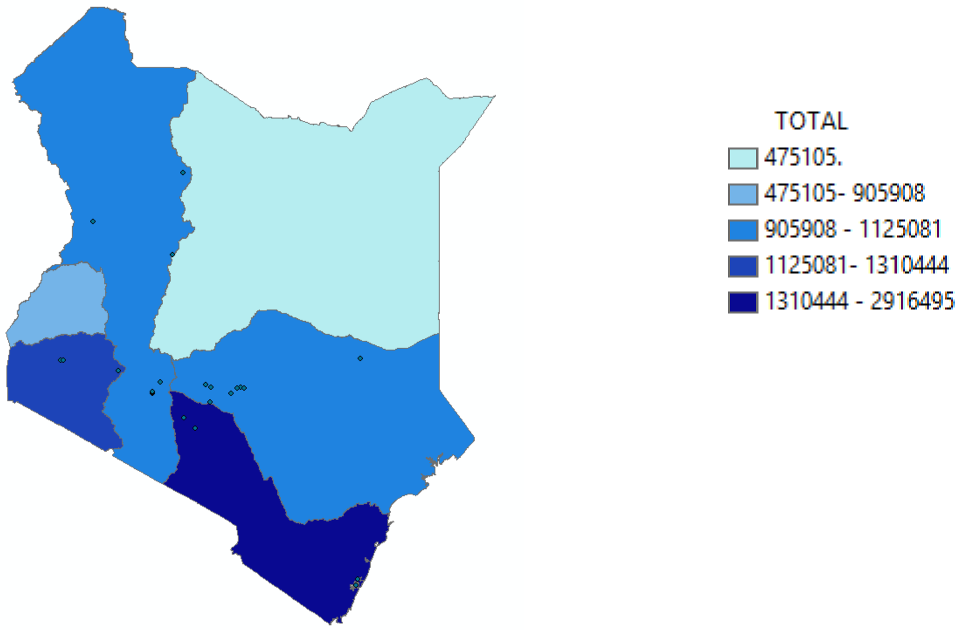

Figure A7-4: TOTAL GVA by River Basin'

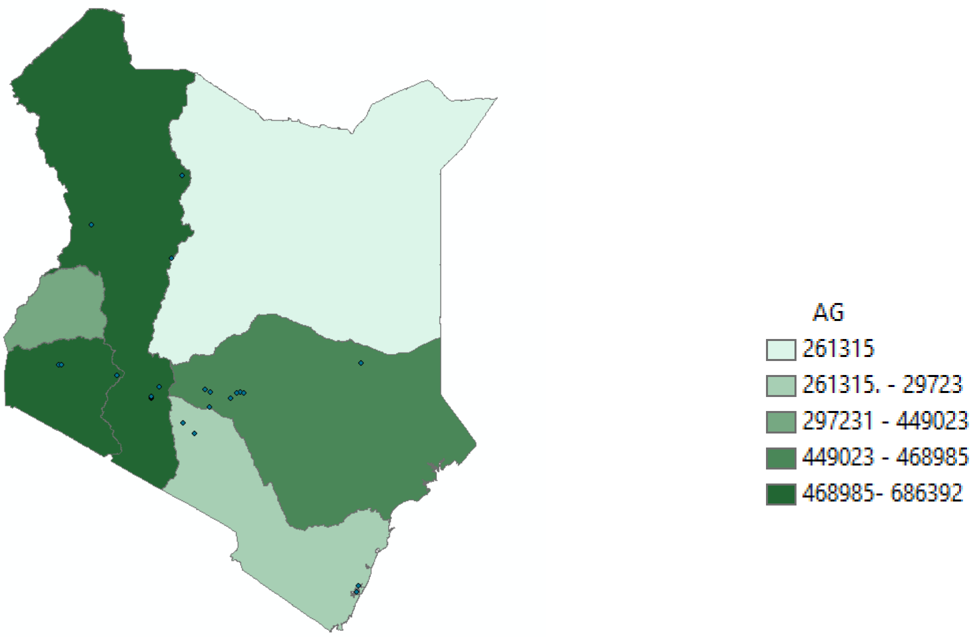

Figure A7-5: Agricultural GVA by River Basin

Table A7-3. TOTAL GVA by County

		BASIN					
ID	County	ACA	ENNCA	LVNCA	LVSCA	RVCA	TCA
30	BARINGO					100%	
36	BOMET				100%		
39	BUNGOMA			100%			
40	BUSIA			100%			
28	ELGEYO				35%	65%	
14	EMBU						100%
7	GARISSA		32%				68%
43	HOMA				100%		
11	ISIOLO		89%				11%
34	KAJIADO	64%				36%	
37	KAKAMEGA			100%			
35	KERICHO				100%		
22	KIAMBU	78%				11%	12%
3	KILIFI	85%					15%
20	KIRINYAGA						100%
45	KISII				100%		
42	KISUMU				100%		
15	KITUI	4%					96%
2	KWALE	100%					
31	LAIKIPIA		88%			12%	
5	LAMU						100%
16	MACHAKOS	66%					34%
17	MAKUENI	100%					
9	MANDERA		100%				
10	MARSABIT		79%			21%	
12	MERU		47%				53%
44	MIGORI				100%		
1	MOMBASA	100%					
21	MURANGA						100%
47	NAIROBI	100%					
32	NAKURU				16%	84%	
29	NANDI			64%	36%		
33	NAROK				50%	50%	
46	NYAMIRA				100%		
18	NYANDARUA		38%			62%	
19	NYERI		30%				70%
25	SAMBURU		77%			23%	
41	SIAYA			52%	48%		
6	TAITA	100%					
4	TANA						100%
13	THARAKA						100%
26	TRANS			91%		9%	
23	TURKANA					100%	
27	UASIN-GISHU			100%			
38	VIHIGA			76%	24%		
8	WAJIR		100%				
24	WEST					100%	

Figure A7-6 displays the locations of existing electrical power generation stations across Kenya, whjch were used, along with the locations of proposed hydropower stations, to assess energy benefits.

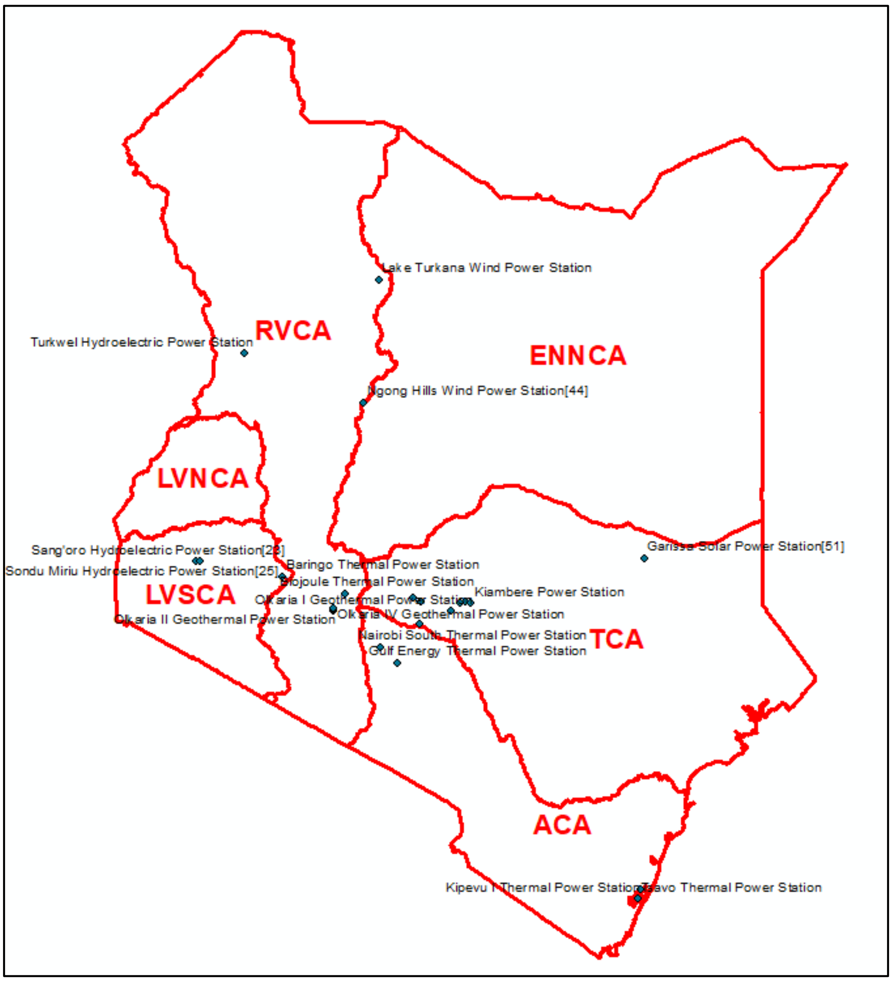

Figure A7-6: Electric Generation Stations in relation to river basins

Estimation of macro-economic indicators

Using the 2017 GVA data aggregated to the six river basins and the outputs from the water resources Baseline (current day) model, data coefficients were determined for each river basin, which were then used to generate primary and secondary economic indicators based on the water resources model outputs for each river basin and each scenario.

References

Power Africa, 2015 Development of Kenya's Power Sector 2015-2020

Trading Economics, 2019, Kenya - Total electricity output, https://tradingeconomics.com/kenya/total-electricity-output-gwh-wb-data.html

KNBS, 2019, Gross County Product. Kenya National Bureau of Statistics.

B1: Water availability, current water demands (2018) and water balance per sub-basin

Subbasin	Area (km2)	MAP (mm)	Water resources potential (MCM/a)			Q95 (MCM/a)						Water balance	
			Natural Surface Runoff	Groundwater sustainable yield	Total		Irrigation	Livestock	Domestic / Industrial	Wildlife & Fisheries	Total	(MCM/a)	%
1AA	565	1700	161.6	1.0	163	22	0.2	0.3	5.3	0.3	6.1	135	83%
1AB	280	1699	84.7	5.2	90	11	0.0	0.3	1.0	0.3	1.7	77	86%
1AC	108	1841	46.8	1.7	49	8	0.0	0.3	0.0	0.3	0.7	40	83%
1AD	246	1744	64.1	2.2	66	7	0.4	0.3	1.5	0.3	2.5	57	86%
1AE	191	1781	27.0	2.7	30	0	0.6	0.3	0.0	0.3	1.2	28	96%
1AF	395	1828	168.6	3.9	173	29	0.6	0.6	0.1	0.3	1.6	142	82%
1AG	344	1877	159.4	2.8	162	27	0.5	0.6	0.0	0.3	1.5	134	83%
1AH	644	1756	194.3	9.1	203	33	2.1	0.6	3.8	0.3	6.8	163	80%
1BA	622	1332	157.0	6.2	163	17	1.1	0.6	0.6	0.3	2.6	143	88%
1BB	737	1253	170.9	5.3	176	12	0.7	0.9	1.3	0.3	3.3	161	91%
1BC	755	1390	177.0	4.7	182	24	0.8	0.6	1.4	0.3	3.2	155	85%
1BD	671	1181	112.8	7.4	120	10	0.3	0.9	9.1	0.3	10.6	99	83%
1BE	1124	1270	154.1	8.9	163	17	0.4	0.9	2.3	0.3	4.0	142	87%
1BG	894	1370	210.3	9.5	220	30	0.3	1.3	22.2	0.3	24.0	165	75%
1BH	567	1517	204.9	8.0	213	37	0.1	0.6	2.8	0.3	3.9	172	81%
1CA	705	1180	96.3	8.7	105	4	0.4	0.9	0.6	0.3	2.2	99	95%
1CB	650	1303	126.9	8.8	136	6	0.7	0.6	33.0	0.3	34.6	95	70%
1CC	648	1340	142.3	9.9	152	7	0.5	0.6	0.5	0.3	1.9	143	94%
1CD	511	1380	111.3	3.2	115	6	0.5	0.6	0.4	0.3	1.9	106	93%
1CE	255	1437	79.4	3.0	82	4	0.1	0.3	0.7	0.3	1.4	77	93%
1DA	514	1593	188.0	6.9	195	11	0.1	0.9	0.8	0.3	2.2	182	93%
1DB	713	1701	287.5	10.9	298	66	0.1	0.9	8.4	0.3	9.8	223	75%
1DC	365	1843	188.1	1.7	190	51	0.1	0.6	0.0	0.3	1.0	138	72%
1DD	339	1874	172.7	7.3	180	46	0.1	0.6	70.1	0.3	71.1	63	35%
1EA	429	1643	187.1	6.4	194	36	0.1	0.6	0.5	0.3	1.6	156	81%
1EB	375	1551	186.3	5.1	191	40	0.1	0.6	4.8	0.3	5.9	146	76%
1EC	235	1525	110.6	3.4	114	23	0.1	0.3	0.1	0.3	0.8	90	79%
1ED	128	1948	79.6	1.8	81	9	0.0	0.3	0.0	0.3	0.6	71	88%
1EE	386	1914	169.3	5.6	175	15	0.9	0.6	0.5	0.3	2.3	158	90%
1EF	407	1602	63.4	3.3	67	3	8.3	0.6	0.1	0.3	9.3	55	82%
1EG	541	1807	200.8	6.9	208	18	0.8	0.9	0.1	0.3	2.2	187	90%
1FA	234	1355	62.0	2.9	65	4	0.1	0.3	0.1	0.3	0.8	60	92%
1FB	364	1527	107.5	7.9	115	10	0.4	0.6	0.2	0.3	1.6	104	90%
1FC	273	1636	96.7	1.8	99	9	0.2	0.3	1.1	0.3	1.9	88	89%
1FD	469	1569	158.3	8.4	167	19	0.4	0.6	1.6	0.3	2.9	144	87%
1FE	649	1976	429.9	9.5	439	81	0.2	1.3	8.8	0.3	10.6	347	79%
1FF	268	1900	154.2	3.8	158	30	0.0	0.9	20.0	0.3	21.3	107	67%
1FG	901	1496	130.6	7.5	138	9	18.0	1.3	1.4	0.3	21.0	108	78%
Total	**18500**	**-**	**5622**	**216**	**5838**	**792**	**40.3**	**29.0**	**205.3**	**12.0**	**286.0**	**-**	**-**

B2: Future (2040) water demands per sub-basin

Subbasin	Future water demand (MCM/a)				
	Irrigation	Livestock	Domestic / Industrial	Wildlife & Fisheries	Total
1AA	5.1	0.9	2.0	0.5	8.5
1AB	4.0	0.9	4.7	0.5	10.1
1AC	1.8	0.3	0.0	0.5	2.6
1AD	4.9	1.6	1.8	0.5	8.9
1AE	5.3	0.9	0.0	0.5	6.7
1AF	13.4	2.5	0.0	0.5	16.5
1AG	11.7	1.8	0.0	0.5	14.0
1AH	53.7	2.5	6.4	0.5	63.1
1BA	0.7	2.5	7.0	0.5	10.7
1BB	15.4	3.4	0.5	0.5	19.8
1BC	15.6	3.3	12.0	0.5	31.4
1BD	14.9	3.4	4.8	0.5	23.6
1BE	103.1	4.1	4.5	0.5	112.2
1BG	130.6	4.3	75.1	0.5	210.5
1BH	4.5	2.5	19.3	0.5	26.8
1CA	6.8	2.7	0.1	0.5	10.1
1CB	4.7	3.3	99.9	0.5	108.3
1CC	9.1	3.3	0.1	0.5	13.0
1CD	10.4	2.5	0.2	0.5	13.7
1CE	43.2	1.6	1.7	0.5	47.1
1DA	61.3	3.4	1.2	0.5	66.4
1DB	17.7	3.4	31.3	0.5	52.8
1DC	16.1	2.5	0.0	0.5	19.1
1DD	32.6	2.5	148.4	0.5	184.0
1EA	20.2	2.5	0.3	0.5	23.5
1EB	41.2	3.3	68.3	0.5	113.2
1EC	14.1	1.6	0.0	0.5	16.2
1ED	0.5	0.9	0.0	0.5	1.9
1EE	141.5	1.8	0.1	0.5	143.9
1EF	6.1	1.8	0.2	0.5	8.6
1EG	27.0	3.4	0.2	0.5	31.1
1FA	4.0	0.9	0.1	0.5	5.5
1FB	9.7	1.8	0.1	0.5	12.0
1FC	4.1	1.6	11.2	0.5	17.5
1FD	30.9	1.8	2.2	0.5	35.4
1FE	26.9	5.8	3.4	0.5	36.6
1FF	0.0	3.4	162.0	0.5	165.9
1FG	187.3	5.0	3.7	0.5	196.5
Total	**1100.0**	**95.3**	**672.8**	**16.4**	**1883.8**

C1. Environmental management

Framework

To ensure quality of attention to environmental and social factors that affect the sustainable utilisation of water and allied resources in the LVN Basin, the legislative, policy and institutional framework for environmental management should govern the development, and implementation of the strategies, sub-plans and actions emanating from this LVN Basin Plan. This framework needs to be understood if the LVN Basin Plan is to attain the goals of social acceptability, economic viability and technical sustainability in line with internationally accepted standards for good practice.

- ***The Constitution of Kenya, 2010:*** is the supreme law in the Country providing the broad framework regulating all existence and development aspects of interest to the people of Kenya, and along which all national and sectoral legislative documents are drawn. Chapter V is entirely dedicated to land and environment, and a number of environmental principles feature in various parts. The Constitution embodies social and economic rights of an environmental character, such as the right to water, food and shelter, the right of every person to a clean and healthy environment, and the right to have the environment protected for the benefit of present and future generations through legislative measures.

- ***The National Environment Policy, 2012:*** provides a holistic framework to guide the management of the environment and natural resources in Kenya. It further ensures that the linkage between the environment and poverty reduction is integrated in all government processes and institutions to facilitate and realize sustainable development at all levels in the context of green economy enhancing social inclusion, improving human welfare and creating opportunities for employment and maintaining the healthy functioning of ecosystem.

- ***The Environmental Management and Coordination Act, 1999 (as amended 2015) Cap 387 (EMCA):*** is the framework law on the environment in Kenya. The EMCA was enacted to provide an appropriate legal and institutional framework for the management of the environment in Kenya. The Act was amended in May 2015 and took effect on 17 June 2015.

  The Act aims to improve the legal and administrative coordination of the diverse sectoral initiatives in the field of environment in order to enhance the national capacity for its effective management. In addition, the Act seeks to align the 77 sector specific legislations pertaining to the environment in a manner designed to ensure greater protection of the environment. This is in line with national objectives and sustainable development goals enunciated in the Agenda 21 of the Earth Summit held in Rio de Janeiro in 1992. The ultimate objective is to provide a framework for integrating environmental considerations into the country's overall economic and social development. In terms of environmental management, the EMCA provides a comprehensive legal and institutional framework for the handling of all environmental issues in Kenya and covers all sectoral laws.

  EMCA does not repeal the sectoral legislation but seeks to coordinate the activities of the various institutions tasked to regulate the various sectors. These institutions are referred to as Lead Agencies in EMCA.

The EMCA is supported by several subsidiary Regulations such as Solid Waste Management Regulations (2006), Environmental Management and Coordination (Water Quality) Regulations (2006) and Emissions Regulations (2007), as well as other pertinent International Environmental Regulations.

National institutions

National institutions in Kenya who are involved with biodiversity and ecosystems management are listed below.

Table C1-1: Institutions and Ministries with mandates for biodiversity and ecosystems management

Ministry/ institution	Main roles and responsibilities	Legislative framework
Water Resources Authority (WRA)	Regulation of the management and use of water resources. This is done through permitting, b) support preparation of the Government's plans and programs for the protection, conservation, control and management of water resources through formulation of National Management strategy, c) formulation and enforcement of standards, procedures and Regulations for the management and use of water resources and flood mitigation. Protection of catchment areas, conservation of ground water, power to require permit applications or re-applications, agreements as to protection of sources of water, etc.,regulation of abstraction of ground water.	Water Act (2016).
Water Resource User Associations (WRUAs)	Ensure cooperative management of water resources at the sub-basin and community level.	Water Act (2016).
Ministry of Forestry and Wildlife	Formulate forestry and wildlife policies, initiate and oversee drafting of relevant legislation, sector coordination and guidance, monitoring and evaluation.	Forests Act (No. 7 of 2005) Wildlife (Conservation and Management) Act (Cap 376)
Kenya Wildlife Service (KWS)	Conserve wildlife and their ecosystems; National Ramsar administrative authority.	Wildlife (Conservation and Management) Act (Cap 376).
Kenya Forestry Service (KFS)	Conserve, develop and sustainably manage Kenya's forest resources for the country's social-economic development.	Forests Act (No. 7 of 2005).
Ministry of Environment and Mineral Resources	Formulate environmental laws and policies, monitor, protect, conserve and manage the environment and natural resources by ensuring sustainable utilisation.	Environmental Management and Coordination (Amendment) Act, 2015
National Environment Management Authority (NEMA)	Coordinate environmental management; provide guidance on the development of wetland management plans; ensure compliance of environmental laws.	Environmental Management and Coordination Act (No. 8 of 1999).
Ministry of Fisheries Development	Formulate policies, oversee drafting of relevant legislation, policy formulation, sector coordination and guidance, monitoring and evaluation.	Fisheries Act (Cap 378).
National Museums of Kenya (NMK)	Promote Kenya's heritage by collecting and preserving artefacts and research.	National Museums and Heritage Act (No. 6 of 2006).

Ministry/ institution	Main roles and responsibilities	Legislative framework
District Environmental Committees (DECs)	Provide technical support for environmental management including all ecosystems and integrate wetland protection into district development plans.	Environmental Management and Coordination Act (No. 8 of 1999).

The institutional framework for the implementation of EMCA and its Regulations include:

- The National Environment Council (The Council): is responsible for policy formulation and directions for the purposes of the EMCA. The Council also sets national goals and objectives and determines policies and priorities for the protection of the environment.
- The National Environmental Management Authority (NEMA): is the body charged with overall responsibility of exercising general supervision and co-ordination over all matters relating to the environment and to be the principal instrument of government in the implementation of all policies relating to the environment. Activities of NEMA are handled by three core directorates: Enforcement, Education and Policy.
- Lead Agencies: Lead Agencies are defined in Section 2 of EMCA as any Government ministry, department, parastatal, and State Corporation or local authority in which any law vests functions of control or management of any element of the environment or natural resource.
- County Environmental Committees (CEC): are the District level bodies chaired by respective County Commissioners and bringing together representatives from all the ministries; representatives from local authorities within the province/district; two farmers/pastoral representatives; two representatives from NGOs involved in environmental management in the province/district; and a representative of each regional development authority in the province/district. To each CEC in the country is attached a County Environmental Coordinator who serves as the secretary to the CEC, and as the NEMA Officer on the ground, is charged with responsibility of overseeing environmental coordination among diverse sectors.

Strategic Environmental Assessment (SEA)

Role of SEA

Strategic Environmental Assessment (SEA) in the context of the Kenyan Environmental legislation refers to a range of analytical and participatory approaches that aim to systematically integrate environmental consideration into ***policies, plans and programmes*** and evaluate the interlinkages with economic and social considerations.

In the SEA process, likely significant effects of a policy, plan, or program on the environment, which may include secondary, cumulative, synergistic, short, medium and long term, permanent and temporary impacts are identified, described and evaluated in an environmental report.

This process extends the aims and principles of Environmental Impact Assessment (EIA) upstream in the decision-making process, beyond the project level and when major alternatives are still open (NEMA, 2011). SEA represents a proactive approach to integrating environmental considerations into the higher levels of decision making, consistent with the principles outlined in Agenda 21 (UNEP, 2007).

SEA can play an advocacy role, where its primary purpose is to raise the profile of the environment, and typically this would occur when the SEA is applied to a plan, policy or programme that has already been developed. In the context of the LVN Basin Plan however, SEA might be a better used in an integrative role, where the focus is on combining environmental, social and economic considerations into the planning process. In this way the SEA can promote an integrated system of planning that incorporates sustainability objectives at a policy, plan or programme level (DEAT, 2004).

There are a number of strategic decisions that are typically taken at the policy, plan and programme level that have an influence on downstream projects and developments. The role of SEA is to allow for the decision-maker to proactively determine the most suitable development type for a particular area, before development proposals are formulated and subjected to EIA (DEAT, 2004). In this way SEA can strengthen future EIAs by considering a broader range of alternatives, addressing cumulative effects, and facilitating the enhancement of a chosen level of environmental quality at a strategic level, thereby providing better context for EIA processes. The role of SEA and the role of EIA are complimentary, and SEA has the potential to make the EIA process more powerful. These tools can be utilised by WRA, BWRCs and WRUAs to vet the environmental integrity of developments in the LVN basin that are linked to water resources management. Developments that are most likely to have negative impacts on the resources can be prevented trough public consultation phases or public commenting phases.

Table C1-2: Comparison between the different roles offered through SEA and EIA (adapted from DEAT, 2004)

SEA: Policy, Plan and Programme Level	EIA: Project Level
Is pro-active and can inform future development proposals	Is reactive to a development proposal decision already taken
Is used to assess the effect of the existing environmental and socio-economic conditions on development opportunities and constraints	Is used to assess the effect of a proposed development on the environment and socio-economic conditions
Relates to areas, regions or sectors of development	Relates to a specific project
Enables the development of a framework against which positive and negative impacts can be measured	Enables the identification of project-specific impacts
Is a process aimed at the development of a sustainability framework to inform continuous decision-making over a period of time	Has a well-defined beginning and end and focuses on informing a specific decision
Is focussed on maintaining a chosen level of environmental quality and socio-economic conditions	Is focused on the mitigation of negative impacts and the enhancement of positive impacts
Has a wide perspective and includes a low level of detail to provide a vision and framework	Has a narrow perspective and includes intricate detail

Key aspects typically addressed under a SEA include developing baseline information, determining compatibility of proposed project interventions with the basin environment conditions, identifying and evaluating the significant environmental impacts of the proposed interventions in the basin plan, assessing the environmental costs and benefits of the proposed projects to the local and national economy, and evaluating and selecting the best project alternatives from the various options.

Issues to be considered are broad and generally relate to destruction of the physical environment through deforestation and degradation, loss of biodiversity-destruction of flora and flora, increased human-wildlife conflict, increased demand for forest products, environmental pollution and catchment degradation, contamination of rivers, wetlands and ground water resources, climate change and related disasters like floods, drought, pests and diseases, overgrazing, increased urbanization, poor governance and weak institutions, and consumer rights and access to information.

The SEA provides every stakeholder a *locus standi* to address environmental degradation and undertaking specific EIA's for interventions proposed in the basin plan.

Specifically, the SEA will offer various opportunities among them:

- Improved processes of environmental administration and governance, so that the purpose and expectations of the various policies and legislation are fully attained.
- Enhanced engagement of communities and wider stakeholders in the basin in environmental issues and governance.
- Capacity building of all stakeholders to allow the processes of environmental administration and governance in the basin to be conducted with best practices and underlying goals as provided in the various statutes and policies.

SEA Challenges

Some of the expected challenges in implementing the SEA process include:

- Inadequate participation of the key stakeholders in the SEA process and conflicting mandates in the governance framework of the key natural resources in the basin.
- Lack of effective coordination among implementing agencies and institutions in the basin
- Lack of effective political will during the implementation of the SEA recommendations
- Lack of a benefit sharing framework of the key natural resources in the basin within the framework of an agreed public private partnership
- Lack of adequate resources to implement the recommendations in the SEA

Legislative Framework for SEA

The legislative framework for SEA in the Kenyan context includes:

- ***The Environmental Management and Coordination Act, 1999 (as amended 2015) Cap 387 (EMCA):*** Prior to amendment in 2015, EMCA addressed itself primarily to Environmental Impact Assessment (Section 58). However, the EMCA (as amended 2015) now also addresses Strategic Environmental Assessment. EMCA (as amended) Article 57 (A) (1) states that "*all Policies, Plans and Programmes for implementation shall be subject to Strategic Environmental Assessment*". It describes plans, programmes and policies as those that are-
    - Subject to preparation or adoption by an authority at regional, national, county or local level, or which are prepared by an authority for adoption through a legislative procedure by Parliament, Government or if regional, by agreements between the governments or regional authorities, as the case may be;
    - Determined by the Authority as likely to have significant effects on the environment.
- ***The Environmental (Impact Assessment and Audit) Regulations, 2003:*** Recognizes SEAs as a measure of environmental impact assessment at a strategic level for policy, plans and programmes. The Regulation's Part VI Sections 42 and 43 address Strategic Environment Assessments:
    - Section 42(1) requires Lead Agencies in consultation with NEMA to subject all policy, plans and programmes for implementation to a Strategic Environment Assessments.
    - Section 42(3) commits the Government and all Lead Agencies to incorporate principles of SEA in the development of sector or national policy.
    - Section 43(1) provides the requisite content for a Strategic Environmental Impact Report.

- Section 43(2) requests certain information within the policy, plan or programme.
- Section 43(3) commits the Government and all Lead Agencies to incorporate principles of SEA in the development of sector or national or regional policy.

- ***National Guidelines for Strategic Environmental Assessment in Kenya, (NEMA, Revised 2011):*** Increasingly, NEMA was faced with the challenges of the inadequacy of EIA to deal with cumulative, synergistic, secondary and long-term impacts. These impacts are better addressed if policies, plans and programmes are subjected to an SEA process. Consequently, NEMA formulated the National SEA guideline to give an understanding on the of the general principles, basic steps of SEA application, the tools and techniques to be adopted, the final output of the SEA process and enhance the practice of SEA in Kenya.
- ***Draft Environmental (Strategic Assessment, Integrated Impact Assessment and Audit) Regulations, 2018:*** NEMA has recently prepared draft Regulations, and as these are intended to repeal the Environmental (Impact Assessment and Audit) Regulations, 2003, their content will likely be of consequence to the LVN Basin Plan and its sub-plans. The overall objective of the Draft Environmental Regulations (2018) is to align processes with the EMCA following its amendment in 2015. The regulations also seek to address emerging issues such as environmental and social safeguard procedures; and Climate Change. Part VI 41(1) to 50(3) details the requirements for SEA.

Process of SEA

The SEA process described follows those set out in the **Draft** Environmental Regulations (2018). These regulations have undergone public consultation: stakeholder forums were held in March 2018, and a national validation workshop was held in Nairobi on 4th April 2018. It is therefore anticipated that these regulations will be enacted imminently.

The Draft Environmental Regulations (2018) (Section 41(1)) require that NEMA in consultation with county governments, Lead Agencies, institutions and private entities subject all proposals for policies, plans or programmes to an SEA, and describe the objectives of such a study in Section 42(2). The following legislated steps required for an SEA are described in Sections 42(1) to 50(3):

- **Step 1 - Screening:**
  - Step 1.1 – Programme Brief: The policy, plan or programme brief is to be submitted to NEMA for screening.
  - Step 1.2 – NEMA Review: NEMA will undertake a screening process and determine the need for an SEA. If an SEA is required, then NEMA will request a scoping study with the objective of defining the geographical and thematic scope of the assessment, and Step 2 is then applicable.
- **Step 2 – Scoping:**
  - Step 2.1 – Scoping Study: A licensed lead environmental expert/firm is to be appointed to undertake the scoping study.
  - Step 2.2 – Public Consultation: Consultation with the relevant government authorities, agencies and public is to be undertaken to obtain comment. The first of two mandatory public meetings is to be held in the Scoping stage.
  - Step 2.3 - Scoping Report: The licensed lead environmental expert/firm is to prepare and submit a Scoping Report to NEMA. The mandatory content of the Scoping Report is provided in Section 41(4).
- **Step 3 – Scoping Report Review:**

    - Step 3.1 – NEMA Review: NEMA are to review the adequacy of the Scoping Report, and either approve it (thereby instructing the commencement of the SEA); or request additional information. Once the Scoping report is approved, then Step 4 is applicable.

- **Step 4 – SEA:**

    - Step 4.1 – SEA Study: The team of experts will undertake the SEA, and the mandatory process of conducting an SEA is described in Section 44(3)

    - Step 4.2 – Public Consultation: Consultation with the relevant government authorities, agencies and public is to continue to be undertaken to obtain comment. The second of two mandatory public meetings is to be held in the SEA stage.

    - Step 4.3 – SEA Report: A draft SEA Report is to be prepared and submitted to NEMA. The mandatory content of the SEA Report is provided in Section 44(2).

- **Step 5 – Draft SEA Report Review:**

    - Step 5.1 – NEMA Review: NEMA are to review the adequacy of the Draft SEA Report, once approved, Step 5.2 is applicable.

    - Step 5.2 – Organs of State: NEMA is to dispatch copies of the Draft SEA Report to the relevant County Government, Lead Agencies and stakeholders for comment within a stipulated timeframe.

    - Step 5.3 – General Public: NEMA are to provide notice of the availability of the draft report for comment and make it available for comment to the general public (as per specific public consultation steps described in Sections 46(2)(3)(4) and (5)) for a stipulated timeframe.

    - Step 5.4 – NEMA Review: Upon closure of the comment period, NEMA are to review the draft SEA Report and make comments on their review that are to be sent to the SEA team for inclusion in the draft SEA Report (a Technical Advisory Committee may be appointed by NEMA to undertake a detailed review, in which case their comments are also to be included in the draft SEA Report)

- **Step 6 – Revised SEA Report:**

    - Step 6.1 – Update Draft SEA: The draft SEA is to be revised to incorporate all comments and a Revised SEA Report is to be submitted to NEMA.

    - Step 6.2 – Validation Workshop: Upon verification of the revised report, the SEA team in consultation with NEMA is to hold a validation workshop with the public and stakeholders, and the report is to be updated accordingly as the "Final" version.

- **Step 7 – Final SEA Report:**

    - Step 7.1 – Final Submission: The Final SEA Report is to be submitted to NEMA together with the requisite forms as per Section 48.

    - Step 7.2 – Record of Decision: NEMA are to determine a Record of Decision within the requisite timeframes, and if this is an approval then NEMA are to include written conditions which are to be accepted by the proponent before implementing the plan or programme. If this is a rejection, then NEMA are to provide reasons for this.

- **Step 8 – Monitoring & Evaluation:**

    - Step 8.1 – Annual Reports: The proponent is to undertake monitoring and evaluation of the policy, plan or programme, and submit annual report to NEMA.

    - Step 8.2 – NEMA Evaluation: NEMA is to undertake a formal evaluation of the monitoring results within three years.

SEA in the context of the LVN Basin Plan

The SEA for the LVN Basin will in general conduct a detailed project life cycle analysis to identify known and/or foreseeable impacts, which can be positive or negative, and to develop mitigation and management measures to ensure sustainability of the projects identified under the Basin Plan.

The main recommendations for the LVN Basin Plan in terms of the legislated requirements for SEA are:

1. In the context of the LVN Basin Plan and its sub-plans, SEAs should be instituted as a set of core assessment activities that are integrated into all phases of the planning processes, rather than as separate procedures. This integrated assessment approach should evolve gradually and retain flexibility, initially through simple technical assessments and moving towards more sophisticated, open processes as the plans become more focused and concrete. The SEAs should be a continuous process that also addresses institutional and governance considerations at different tiers of decision-making.
2. A Programme Brief (as per Step 1 of the SEA Process described above) for the LVN Basin Plan should be prepared and submitted to NEMA, who can determine whether an SEA is required for the entire plan, or whether SEA's might be better applied to sub-plans and their resulting plans and programmes when more information is available, and when a defined stakeholder group can be determined.
3. The World Bank (2005) suggests that to better influence policies, plans or programmes, the SEA process should move towards a continuous process that also addresses institutional and governance considerations. It is recommended that the SEA activities that are immediately applied to the LVN Basin planning process include a detailed stakeholder analysis:

- There is a need to carry out a mapping and analysis of key institutions in the National and County Governments, civil and private sectors and their overlapping mandates while identifying opportunities for synergy. A detailed stakeholder analysis that is undertaken early on can offer great value to the LVN Basin planning process and can include a governance and institutional assessment to determine how these currently operate and are envisaged to change in the basin. Specifically, integrating SEA activities early on into the basin planning can offer various opportunities:
    - Improved processes of environmental administration and governance, so that the purpose and expectations of the various policies and legislation are fully attained.
    - Enhanced engagement of communities and wider stakeholders in the basin in environmental issues and governance.
    - Capacity building of all stakeholders to allow the processes of environmental administration and governance in the basin to be conducted with best practices and underlying goals as provided in the various statutes and policies.

4. Environmental problems are typically complex, uncertain, and occur at various scales affecting multiple people at different levels. In many cases, the problems are also caused by people. This therefore demands transparent decision-making and buy-in that considers the views of people interested in or affected by a given project. Stakeholder engagement is therefore increasingly embedded into environmental management.

   According to the SEA guidelines, the Kenyan government asks three relatively simple questions of a proposed plan:

    - Has there been effective co-operation between the SEA team and those responsible for developing the PPP?
    - Was there effective public involvement?
    - Was there effort to involve less powerful stakeholders in the consultation?

As detailed in the Inception and Interim Reports for the LVN Basin Plan, stakeholder consultation is deeply embedded into this process across Tasks 2 (Basin Planning) and 4 (Stakeholder Consultation). The focus of the stakeholder engagement included in these phases is to learn from the local ecological knowledge with existing catchment management practices; and to provide an enabling environment for implementation of the plans.

It is important to note that should the relevant plans go through an SEA and/or EIA process, the relevant stakeholder engagement guidelines must be followed, unless otherwise agreed upon with the NEMA. Such requirements would include making the SEA and/ or EIA reports available to the public for comment and provide opportunity to engage through public meetings. As has already been considered in Tasks 2 and 4, efforts to engage with vulnerable stakeholders must be specifically considered, considering alternative approaches where necessary.

As part of the decision-making process, the NEMA uses the submitted copies of the SEAs/ EIAs to distribute to the necessary commenting authorities. This provides another opportunity for the public to review and comment on the proposal before the NEMA provides an authorisation. During this time, it is important to consider the SEA and EIA regulations, and appoint a specific SEA expert to undertake this exercise.

Environmental Impact Assessment (EIA)

Role of EIA

An EIA in the context of the Kenyan Environmental Legislation refers to a systematic examination that is conducted to determine whether a **programme, activity or project** will have any adverse impacts on the environment.

The main purpose of an EIA is to determine and evaluate the environmental implications of development and to inform decision-making at a project level. An EIA process focuses on the positive and negative environmental and social impacts of a specific development project once it has been designed, and proposes measures to mitigate the negative impacts, while maximising the positive ones (DEAT, 2004). The EIA process is seen as a tool to facilitate informed decision-making on sustainable development in Kenya.

The EIA process integrates environmental considerations into all stages of the planning and development process of a project and requires post-impact monitoring and management. Principles for good environmental assessment practice, includes (DEAT, 2002):

- Focus on the main issues.
- Involve the appropriate persons and groups.
- Link information to decisions about the project.
- Present clear options for mitigation for impacts and for sound environmental management.
- Provide information to decision-makers in a useful form.

Legislative Framework for EIA

The legislative framework for EIA in Kenya is set out below:

- ***The Environmental Management and Coordination Act, 1999 (as amended 2015) (EMCA):*** The Act provides a number of mechanisms to protect the environment one of which is environmental impact assessment. Project activities that are subject to an EIA process are set out in the Second Schedule of the EMCA. Sections 58 – 67, deal with the EIA process. All EIA’s need to be undertaken by a NEMA registered and licensed EIA/EA expert.

- ***The Environmental (Impact Assessment and Audit) Regulations, 2003:*** Recognises EIA as a means to determine whether a programme, activity or project will have an adverse impact on the environment.
  - Part I Section 4(1) prohibits anyone from implementing a project that is likely to have a negative environmental impact, or for which an EIA is required under the Act or Regulations, unless an EIA has been concluded and approved.
  - Part II Sections 7 – 10 set out the requirements and process for Project Report; and NEMA will either issue a license if satisfied that the project will not have significant environmental impact or that the report discloses sufficient mitigation measures OR will request an EIA if the project will have a significant environmental impact or that the report discloses insufficient mitigation measures.
  - Part III Sections 11 - 17 set out the requirements and process for Environmental Impact Assessment Study.
- ***Draft Environmental (Strategic Assessment, Integrated Impact Assessment and Audit) Regulations, 2018:*** Refers to Integrated EIA rather than EIA, although by definition this is deemed to be the same thing. The Regulation's requirements for an Integrated EIA differ from the previous 2003 Regulations in that the anticipated potential risks of a project or activity will dictate whether a simpler process termed a Project Report is necessary, or whether a full Integrated EIA is necessary.
  - Part I Section 4(1) prohibits anyone from implementing a project that is likely to have a negative environmental impact, or for which an EIA is required under the Act or Regulations, unless an Integrated EIA has been concluded and approved.
  - Part III sets out the requirements for a Project Report.
  - Part IV sets out the requirements for an Integrated EIA.

Process of EIA

The EIA processes described below follows those set out in the Draft Environmental Regulations (2018). Depending on the potential risk (low, medium or high) of a project activity, the proponent will either submit a Project Report or an EIA Study Report to the Authority:

- Part III 10 (1) require anyone undertaking a project listed as low or medium risk of the Second Schedule of the Act, to prepare a Project Report (low to medium risk projects and activities).
- Part IV 15(1) requires that an Integrated EIA study be undertaken for all high-risk projects tabulated in the Second Schedule of the Act (high risk projects and activities).

The following legislated steps required for a Project Report are described in Sections 10(1) to 14(4):

- **Step 1 – Project Report Preparation:**
  - Step 1.1 - Describe Project: The Project Report is to include content as required in Section 10(1)(a) to (o), which in summary includes project information, location and activities proposed, potential environmental; economic and socio-cultural impacts and possible mitigation options, accident and health and safety action plans, public participation issues, a climate change vulnerability assessment and an environmental management plan.
  - Step 1.2 – Public Consultation: Consultation with the public including at least one public meeting. The aim of the meeting would be to explain the project and it's social, economic and environmental impacts, and collate all oral or written comments on the proposed project and

attach the evidence of such public participation in the Project Report through signed attendance register, minutes and photographs.

  - Step 1.3 – Project Report Preparation: The licensed lead environmental expert/firm is to prepare a Project Report to NEMA.
  - Step 1.4 – Form 9 Application: an application for an environmental impact assessment license is to be submitted to NEMA and the appointed agent in the County.

- **Step 2 – Project Report Review:**
  - Step 2.1– Organs of State: NEMA is to dispatch copies of the Project Report to the relevant County Government, Lead Agencies and stakeholders for comment within a stipulated timeframe.
- **Step 3 – Project Report Determination:**
  - Step 3.1 – Decision: NEMA are to issue a license if the project will have no significant impact on the environment, or that the project report discloses sufficient mitigation measures. If this is a rejection then NEMA are to provide reasons for this and are to advise on suitable alternatives (in which case Step 3.2 is applicable).
  - Step 3.2 – Appeal: The proponent may appeal the decision within the stipulated timeframes.

The following legislated steps required for an Integrated EIA are described in Sections 15(1) to 31(2):

- **Step 1 – Scoping:**
  - Step 1.1 – Scoping Report: A scoping study is to be undertaken as per Section 15(3) and a Scoping Report of a content as described in Section 15(4) is to be prepared.
  - Step 1.2 - Terms of Reference: A ToR for the Integrated EIA is to be prepared.
  - Step 1.3 – Public Notification: Notification of the project intentions to the public is to be undertaken in accordance with Section 20(1).
- **Step 2 – Scoping Report Review:**
  - Step 2.1 – Submit to NEMA: The Scoping Report and ToR is to be submitted to NEMA for approval. Upon approval, Step 2.1 is applicable.
  - Step 2.1 – Appoint Team: A competent team of licensed environmental assessment experts are to be appointed to undertake the Integrated EIA.
- **Step 3 – Integrated EIA:**
  - Step 3.1 – Integrated EIA study: An Integrated EIA study is to be undertaken as per Section 19(a) to (d), and an Integrated EIA Report of a content as described in Section 21(1)(a) to (q) is to be prepared and submitted to NEMA.
- **Step 4 – Integrated EIA Review:**
  - Step 4.1 – Organs of State: NEMA is to dispatch copies of the report to the relevant Lead Agencies for comment within a stipulated timeframe.
  - Step 4.2 – General Public: NEMA are to provide notice of the availability of the report for comment and make it available for comment to the general public (as per specific public consultation steps described in Sections 24(1)(3) and (4) for a stipulated timeframe.

- Step 4.3 – Public Hearing: Upon receipt of written comment, NEMA may hold a public hearing as per Section 25 (1) to (7).

- **Step 5 – License:**

Step 5.1 – Record of Decision: NEMA are to determine a Record of Decision within the requisite timeframes, and if this is an approval then NEMA are to issue a license and include written conditions which are to be accepted by the proponent before implementing the project. If this is a rejection, then NEMA are to provide reasons for this.

C2. Catchment Management

C2.1. Legal and institutional environment

C2.1.1. National level

- At a National level natural resource use provides employment and income. Within the Lake Victoria North Basin small scale irrigation and pastoralism make up the majority of employment opportunities.
- The key ministries in Kenya responsible for enacting policies related to catchment management are the Ministry of Water and Sanitation, Ministry of Agriculture and Irrigation; and Ministry of Environment and Forestry.
- National policies and legislation feed into the local-level catchment management, where projects are implemented on the ground. It is therefore important to understand the underlying policies driving these projects as in most cases similar strategies are being implemented by different institutions.
- The National Environmental Management Agency (NEMA) is responsible for coordinating environmental management; providing guidance on the development of environmental management plans and ensure compliance of environmental laws. The Kenya Water Towers Agency (KWTA) is responsible for management of Kenya's water towers. Kenya Forest Service (KFS) has a mandate to conserve, develop and sustainably manage Kenya's forest resources for the country's socio-economic development. Kenya Wildlife Service (KWS) has a mandate to conserve and manage wildlife in Kenya, and to enforce related laws and regulations. KWS is also the RAMSAR Administrative Authority.

C2.1.2. Basin and sub-basin level

- County governments' Integrated Development Plans (IDPs) are meant to provide an overall framework for development in each county. The plans aim to coordinate the work of both levels of government in a coherent plan to improve the quality of life for all the people and contribute towards devolution. The first plans cover the period 2013 to 2017, the second plans over 2018 to 2022.
- The County governments rely on technical input and advice from the different agencies with a mandate to govern natural resources. A major issue is the mandates related to wetlands and riparian lands.

C2.1.3. National plans and policies

- The **Kenya Vision 2030 (2008)** set targets such as improved water and sanitation, increased agricultural production, a clean environment and more energy production by 2030. All of these cross-cutting targets impact catchment management.

- The **Kenya National Policy on Water Resource Management and Development (NPWRMD, 1999) p**rovides specific policy objectives including protection of water resources, supply of water while ensuring safe disposal of wastewater and environmental protection**.**
- In accordance with the Kenya Vision 2030 goal that agricultural production increase by 10% by 2019, various agriculture policies and strategies have been developed to guide this development (SEE IRR SECT ANAL). Transformation of smallholder, subsistence agriculture to modern agriculture was identified as a fundamental component, as was increased irrigation. An **Irrigation and Drainage Master Plan** was prepared in 2009 (MWI, 2009). This was followed by the **National Water Master Plan** (JICA, 2013) which evaluated irrigation potential against availability of water. Other ongoing national projects involve improving rainwater harvesting and storage for agriculture; rehabilitation and protecting water catchments; and implementing the irrigation flagship projects.
- The **National Environment Policy (NEP, 2013)** provides the goal of a better quality of life for present and future generations through sustainable management and use of natural resources. Guiding principles include an ecosystem approach to management, sustainable resource use as well as inclusion of communities in decision making.
- The **2010 Constitution in Article 69** recognises the importance of forests for sustainable development, the provides for the state to work towards increasing the country's forest cover to 10% of the land area of Kenya. The Constitution provides for two tiers of Government with the national government being responsible for policy development and regulation. The second tier of governance are 47 geographical units of devolved government, known as counties. Lake Victoria North Basin has nine counties, although some counties cross hydrological boundaries. These counties may be involved in various functions which are closely linked to catchment management.
- The **Water Act (2016)** gives the Water Resources Authority (WRA) a clear role in the regulation of water resources. However, there are some ambiguities in the Water Act that require resolution.
- The **Agriculture, Fisheries and Food Authority Act (Act No 13 of 2013)** provides for the regulation and promotion of agriculture. This is supported through the establishment of the Agriculture, Fisheries and Food Authority (AFFA) that is charged with, in consultation with County Governments, administering the **Crops Act (Act No 16 of 2013)** and the **Fisheries Act (CAP 378 of 1989)**.
- Directorates of the Agriculture, Fisheries and Food Agency (AFFA) include coffee; nuts and oil; fibre; horticultural crops; food crops; sugar; tea; pyrethrum and other industrial crops. The drive to increase agricultural development will require ongoing development in irrigation capacity. As such, a **draft Irrigation Bill** was developed in 2015 intended to repeal the Irrigation Act (CAP 347 of 2013). This amendment bill has yet to be enacted and provides for the establishment of a National Irrigation Development Service and strengthening of irrigation regulations.
- The **Environmental Management and Coordination Act (EMCA, 1999)** provided Kenya's first framework for environmental legislation. The EMCA recognises the importance of improving the legal alignment and administration across the various sectors that are engaged in the management and development of environmental resources.
- The **Forest Conservation and Management Act (2016)** mandates the Directorate of Natural Resources-Forest Conservation to formulating forest policies, initiating and overseeing drafting of relevant legislation, sector coordination and guidance, monitoring and evaluation.
- The **Wildlife Conservation and Management Act (2013)** mandates the Directorate of Natural Resources-Wildlife Conservation in formulating wildlife policies, initiating and overseeing drafting of relevant legislation, sector coordination and guidance, monitoring and evaluation.

C3. Water resources protection

C3.1. Legal and institutional environment

C3.1.1. National level

- The mandate for protecting water resources in Kenya falls on the **Water Resources Authority (WRA)** (the Authority) through Part III of the **Water Act of 2016** under the "Regulation of the Management and Use of Water Resources". A specific aspect which is addressed in the Act relates to the Authority "*prescribing criteria for classifying water resources for the purpose of determining Water Resources Quality Objectives for each Class of Water Resource*". Classifying and determining Water Resource Quality Objectives provide a series of measures to achieve protection while at the same time acknowledging the important role of water resources in supporting social and economic development. Further to the above, where the Authority considers a water resource vulnerable, special measures may be published in a Gazette to declare the catchment area a Protected Area. The Authority may then impose requirements or regulations and prohibit activities to ensure the protection of the area and water resources. The same is considered for the conservation of groundwater for public interest.
- The **National Environmental Management Authority (NEMA)** is responsible for coordination of environmental management, and the **Kenya Water Towers Agency (KWTA)** for coordination of the protection, rehabilitation, conservation, and sustainable management of Kenya's water towers, wetlands and biodiversity hotspots. Environmental Committees provide technical support for environmental management and provide input to provincial/district development plans.

C3.1.2. Basin and sub-basin level

- The 2016 Water Act outlines the designation of Basin areas, with functions of **Basin Water Resource Committees (BWRCs)** within each Basin clearly stated. Furthermore, the Act defines the establishment and functions of **Water Resource Users Associations (WRUAs)** i.e. associations of water resource users at the sub-basin level in accordance with Regulations prescribed by the Authority. These associations are community based for collaborative management of water resources and resolution of conflicts concerning the use of water resources.
- Protection of water resources in Kenya therefore starts at the National level with the WRA developing policies and legislation for protection of water resources. BWRCs then enact these measures to fulfil the water resource quality objectives for each class of water resource in a basin and need to put in place measures for sustainable management of the water resources; whilst at the sub-basin level more local level community-based management occurs through WRUAs.

C3.1.3. National plans and policies

- The **Kenya Vision 2030 (2008)** set targets such for a clean environment by 2030.
- The **Kenya National Policy on Water Resource Management and Development (NPWRMD, 1999)** provides specific policy objectives including protection of water resources.
- In the **Water Act (2016)**, the specific functions of the WRA which relate to water resources protection include:
    - formulate and enforce standards, procedures, and regulations for the management and use of water resources

- regulate the management and use of water resources
- receive water permit applications for water abstraction, water use and recharge and determine, issue and vary water permits; and enforce the conditions of those permits
- In addition, the WRA has the power to:
- collect, analyse and disseminate information on water resources
- monitor compliance by water users with the conditions of permits and the requirements of the Act
- issue permits for inter-basin water transfer
- delegate regulatory functions to the Basin Water Resource Committees

- Part V of the **Environmental Management and Coordination Act (EMCA, 1999)** focuses on the protection and conservation of the environment. According to the Act, certain activities in relation to a river, lake or wetland require an environmental impact assessment. The Minister may also declare a lake shore, wetland, coastal zone or river bank to be a protected area and impose restrictions to protect them. The Minister may issue general and specific orders, regulations or standards for the management of a lake shore, wetland, coastal zone or river bank. Although it is acknowledged that environmental issues cut across different sectors, the Act emphasises the principles and provides guidance for improved environmental management.
- Other areas of relevance to water resources protection in Kenya, which are regulated by various government departments, include: protection of traditional interests of local communities customarily resident within or around a lake shore, wetland, coastal zone or river bank or forests defined as protected; protection of hill tops, hill sides, mountain areas and forests for sustainable utilisation and protection of water catchment areas; protection of forests on private land; conservation of biological resources in situ (related to buffer zones near protected areas and alien invasive species management); protection of environmentally significant areas; and protection of the coastal zone
- Consistency across the Water Act (2016) and the EMCA (1999) in relation to water resources protection is important to allow for a coordinated approach. In the Water Act (2016), as has been defined above, water resources have a wide-ranging definition ranging from surface water to groundwater resources; whilst the EMCA (1999) focuses on the surface water resources (river, lake, wetland, coastal zone) as well as the upper catchment areas. Although this is an institutional issue, it impacts the protection and management strategies for water resources.

C4. Groundwater management

C4.1. Legal and institutional environment

C4.1.1. National plans and policies

- The **Water Act (2016)** defines protection of groundwater under Section 22/23 and groundwater use is managed through Section 47 and 104.
- The **National Land Use Policy (2017)** considers surface and underground water bodies.
- Part VIII (Conservation Orders, Easements and Incentives, Wildlife Conservation Orders and Easements), S. 65 (4) of the **Wildlife Conservation and Management Act (2013)** which states, inter alia, “a wildlife conservation order or easement may be created so as to” (d), “preserve the quality and flow of water in a dam, lake, river or aquifer”.
- The **Draft National Policy Groundwater Resources Development and Management (2013)** highlights a number of specific issues:
    - The availability and vulnerability of groundwater resources in Kenya are poorly understood;

  - The institutional arrangements for groundwater management in Kenya, including groundwater management capacity and financing are weak;
  - There is very limited integrated water resources management in Kenya, with groundwater and surface water typically being treated as separate water resources; and
  - There is very limited groundwater quality management in Kenya.
- Section 23 of the **Agriculture, Fisheries and Food Authority Act (2013)** relates to land preservation guidelines, on preservation of soil.
- Section 5.3 (Required Policy and Legal Reforms) of the **National Water Harvesting and Storage Management Policy (2010)**, recommended the formulation of a Policy on Ground Water Protection
- Section 5.1 of the **Draft National Policy on Trans-Boundary Waters (2009) relates to s**ustainable management and equitable utilization of trans-boundary water resources (para. 38: provision for “groundwater conservation areas” with respect to transboundary waters)
- Part XI of the **Water Resources Management Rules (2007)** relates to Protected Areas and Groundwater Conservation Areas.
- Section 25 of the **National Museums and Heritage Act (2006)** relates to the declaration of monuments.
- Section 2.1.2 of a **Sessional Paper No. 1 of 1999 on National Policy on Water Resources Management and Development indicates** “In addition, groundwater conservation zones need to be identified to avoid depletion of this resource”.
- Part V of the **Environmental Management and Co-ordination Act (1999)** relates to the Protection and Conservation of the Environment, inter alia.
- **Masterplan for the Conservation and Sustainable Management of Water Catchment Areas in Kenya (MEMR, 2012)**
- **Kenya Water Towers Status Report; Saving our Future & Heritage, A Call To Action (KWTA, 2015).**

C5. Climate change adaptation

C5.1. Legal and institutional environment

C5.1.1. National level

- The Kenya Agricultural and Livestock Research organisation have a **National Strategy on Genetic Resources within the context of climate change (2016-2021)**
- The Ministry of Agriculture and Irrigation, Ministry of Transport, Infrastructure, Housing and Urban Development have a **Blue Economy Strategy (2017)**
- The National Treasury Ministry of Interior and Coordination have **Kenya’s Disaster Risk Financing Strategy (2018-2022)** and **National Disaster Risk Management Policy (2017)**
- The National Drought Management Authority have a **National Drought Management Authority Act (No 4 of 2016), Ending Drought Emergencies Strategy** and **Public Finance Management (National Drought Emergency Fund) Regulations, 2018**.
- The Ministry of Energy has an **Energy Bill (2017)** – Part 3, section 43; Part 4, section 74 (i); and Part 9 address climate change-related issues.

- The Ministry of Environment and Forestry has an **Environmental Management and Coordination Act, 1999 (Cap. 387), Green Economy Strategy and Implementation Plan (GESIP 2016-2030)** and **Kenya Strategic Investment Framework on Sustainable Land Management (2017-2027).**
- The Kenya Forest Services and Ministry of Environment and Forestry have a **National Forest Programme (2017) – chapter on climate change and REDD + Readiness Plan and analysis (2013-2017)**
- The Ministry of Health has a **Health Act (No 21 of 2017)** – section on environmental health and climate change (Part VII, sections 68 and 69)
- The Ministry of Transport, Infrastructure, Housing and Urban Development has a **Kenya Building Research Centre: Strategic Plan, 2017/18-2021/22**
- The Ministry of Lands and Physical Planning has a **National Spatial Plan (2015-2045)**
- The Ministry of Transport, Infrastructure, Housing and Urban Development has an **Action Plan to reduce CO2 Emissions from Aviation (2015), Executive Order: The Nairobi Metropolitan Area Transport Authority (2017), Kenya National Aviation Action Plan for International Civil Aviation Organisation (ICAO) and Mitigation plan for International Maritime Organisation (IMO) (2017)**
- The Ministry of Water and Sanitation Water Act (No 43 of 2016) – establishes **National Water Harvesting and Storage Authority, Draft Water Harvesting and Storage Policy (2018) Basin and sub-basin level**

C5.1.2. Basin and Sub-basin level

- The Kenya Vision 2030 – the country's development blueprint – recognised climate change as a risk that could slow the country's development. Climate change actions were identified in the Second Medium Term Plan (MTP) (2013-2017). The Third Medium Term Plan (2018-2022) recognised climate change as a crosscutting thematic area and mainstreamed climate change actions in sector plans.
- The County Governments have a key delivery role in implementing the Climate Change Act, 2016, having jurisdiction, as set out in the Fourth Schedule (Part 2) of the Constitution, over sectors relevant for climate change such as agriculture, soil and water conservation, forestry, water and sanitation, and health. Article 203(2) of the Constitution requires that County governments be allocated a minimum of 15% of national revenue received annually, but the allocation often surpasses the minimum thus giving County governments considerable scope to influence climate change investments.

C5.1.3. National plans and policies

- **East African Climate Change Master Plan (EACCCMP, 2011-2031)** provide a long-term vision and a basis for Partner States to operationalise a comprehensive framework for adapting to and mitigating climate change, in line with the EAC Protocol on Environment and Natural Resources Management and with international climate change agreements.
- **East African Community Climate Change Policy and Strategy (2010)** was developed by the **East African Community (EAC)** Secretariat. This document guides partner countries with the preparation and implementation of collective measures to address climate change in the region.
- The **East African Community Climate Change Policy and Strategy (2010)** was developed by the **East African Community (EAC)** Secretariat. This document guides partner countries with the preparation and implementation of collective measures to address climate change in the region.

- The **African Union Agenda 2063** commits to climate change action to prioritise adaptation. It calls on member countries to implement the Programme on Climate Action in Africa, including climate resilience in agriculture.
- The **African Forest Landscape Restoration Initiative (AFR100)** aims to bring 100 million hectares of land in Africa into restoration by 2030.
- The **Constitution of Kenya** (2010) demands sustainable development and provides for the right to a clean and healthy environment through legislative and other measures.
- **National Climate Change Response Strategy (2010)** is Kenya's National Climate Change Response Strategy was the first national policy document on climate change. It aimed to advance the integration of climate change adaptation and mitigation into all government planning, budgeting and development objectives.
- Kenya's **National Climate Change Action Plan, 2013-2017** was a five-year plan that aimed to further Kenya's development goals in a low carbon climate resilient manner. The plan set out adaptation, mitigation and enabling actions.
- Kenya's **National Adaptation Plan 2015-2030** was submitted to the UNFCCC in 2017. The NAP provides a climate hazard and vulnerability assessment and sets out priority adaptation actions in the 21 planning sectors in MTP II.
- Kenya's **Nationally Determined Contribution (NDC) (2016)** under the Paris Agreement of the UNFCCC includes mitigation and adaptation contributions. In regard to adaptation, "Kenya will ensure enhanced resilience to climate change towards the attainment of Vision 2030 by mainstreaming climate change into the Medium Term Plans (MTPs) and implementing adaptation actions". The mitigation contribution "seeks to abate its GHG emissions by 30% by 2030 relative to the BAU scenario of 143 MtCO2-eq." Achievement of the NDS is subject to international support in the form of finance, investment, technology development and transfer and capacity development.
- The **Climate Change Act (No 11 of 2016)** is the first comprehensive legal framework for climate change governance for Kenya. The objective of the Act is to "Enhance climate change resilience and low carbon development for sustainable development of Kenya." The Act establishes the National Climate Change Council (Section 5), Climate Change Directorate (Section 0), and Climate Change Fund (Section 25).
- The objectives of the **Kenya Climate Smart Agriculture Strategy (KCSAS)** are to adapt to climate change and build resilience of agricultural systems while minimising greenhouse gas emissions. The actions will lead to enhanced food and nutritional security and improved livelihoods.
- The **Climate Risk Management Framework (2017)** for Kenya integrates disaster risk reduction, climate change adaptation, and sustainable development so that they are pursued as mutually supportive rather than stand-alone goals. It promotes an integrated climate risk management approach as a central part of policy and planning at National and County levels.
- The **National Climate Change Framework Policy (2018)** aims to ensure the integration of climate change considerations into planning, budgeting, implementation and decision-making at the National and County levels and across all sectors.
- The **National Climate Finance Policy (2018)** promotes the establishment of legal, institutional and reporting frameworks to access and manage climate finance. The goal of the policy is to further Kenya's national development goals through enhanced mobilisation of climate finance that contributes to low carbon climate resilient development goals.

- The Government of Kenya **Big Four Agenda (2018-2022)** establishes priorities areas for 2018 to 2022 of ensuring food security, affordable housing, increased manufacturing and affordable healthcare. Sector plans and budgets are to be aligned to the Big Four priorities.
- The **Climate Change Act, 2016 is** Key legislation guiding Kenya's climate change response, setting the legal basis for mainstreaming climate change considerations and actions into sector functions. The Act seeks to provide the "*framework for enhanced response to climate change and to provide for mechanisms and measures to achieve low carbon climate development*". The Act promotes a mainstreaming approach which includes integrating climate change in all sectors and at all levels. The Act applies to all sectors of the economy and at national and county levels. Specific objectives of the Act, that relate to water resources planning and development, include:
    - mainstream climate change responses into development planning, decision making and implementation;
    - build resilience and enhance adaptive capacity to the impacts of climate change;
    - formulate programmes and plans to enhance the resilience and adaptive capacity of human and ecological systems to the impacts of climate change
    - mainstream and reinforce climate change disaster risk reduction into strategies and actions of public and private entities;
    - mainstream the principle of sustainable development into the planning for and decision making on climate change response; and
    - integrate climate change into the exercise of power and functions of all levels of governance, and to enhance cooperative climate change governance between the national government and county governments.
- The Constitution of Kenya advances gender equality, stating in Chapter 4, the Bill of Rights that "women have the right to equal opportunities in political, economic and cultural spheres," and in order to achieve that equality, requires that government to put in place and implement affirmative actions that deliver equity for women. This commitment to gender equality and implementation of gender equity is taken up in section 7(6) of the Climate Change Act, 2016 that requires the President to ensure compliance with the two thirds gender principle when appointing members to the National Climate Change Council. Further, section 8(2)(c) of the Climate Change Act, 2016 obligates the Cabinet Secretary responsible for climate change affairs to formulate and implement a national gender and intergenerational responsive public education and awareness strategy.

C6. Flood and drought management

C6.1. Legislative and institutional environment

C6.1.1. National level

- The Constitution of Kenya (2010) requires the National Government to perform a wide range of water resource management functions. Relevant here is Section 24: Disaster management – The National Government will institute **integrated flood and drought management plans** to address water related disasters such as floods, droughts and landslides.
- The Water Act (No. 43 of 2016) provides a statutory foundation for flood and drought management plans. The Water Act aims "to provide for the regulation, management and development of water resources, water and sewerage services". Section 12 of the Act establishes a national Water Resources Authority (WRA) whose functions are "to formulate and enforce standards, procedures and regulations for the management and use of water resources and **flood mitigation**". The WRA must also "provide information and advice to the Cabinet Secretary for formulation of policy on national water resource management, water storage and **flood control strategies**".

- Section 32 of the Act establishes a national Water Storage Authority (WSA) whose functions and powers are "to undertake on behalf of the national government, the development of national public water works for water resources storage and **flood control**; collect and provide information for the formulation by the Cabinet Secretary of the national water resources storage and **flood control strategies**". The WSA must also "undertake on behalf of the national government **strategic water emergency interventions during drought**; and advise the Cabinet Secretary on any matter concerning national public water works for water storage and **flood control**".

- The National Drought Management Authority (NDMA) Act (No.4 of 2016) provides an important statutory foundation for drought management plans. The NDMA is an agency of the Government of Kenya under the Ministry of Planning and Devolution, mandated "to establish mechanisms **which ensure that drought does not result in emergencies** and that the impacts of climate change are sufficiently mitigated". The NDMA exercises its functions both at national level and Basin level, and in collaboration with county governments, also at county and community level. However, the NDMA's primary focus is on the 23 drought-prone counties, known as the ASAL (Arid and Semi-Arid Lands) counties.

- The National Disaster Operations Centre (NDOC) is responsible for **coordinating all disaster response operations in the country** – and was leading the country's El Niño flood response in 2015. It does this through partnering with other actors such as the police and the Kenya Red Cross. NDOC was established in 1997, following the El Niño floods, within the Ministry of Interior. Besides response, NDOC also plays a preparedness role by managing the country's disaster loss database. It has also led disaster drills for man-made disasters.

- The National Disaster Management Unit (NDMU) was established in 2013 as an effective and competent disaster management unit with an established command structure, budget and Standard Operating Procedures (SOPs) based on best practices. The NDMU, together with stakeholders, formulated the National Emergency / Disaster Plan and SOPs which were signed off in 2014. The Plan and SOPs recognizes the existence of other National and contingency plans. The National Plan and SOPs is anchored in the medium-term Phase Two of Vision 2030 in that it promotes safety, security and **protecting Kenyan assets from adverse impacts of hazards and disasters**.

- The mandates of the NDMA, NDOC and NDMU clearly overlap. The **Disaster Risk Management Bill**, currently under consideration, is aimed at bringing NDMA, NDOC and NDMU together as a new "Disaster Risk Management Authority".

- The Kenya Meteorological Department (KMD) of the Ministry of Environment and Mineral Resources issues regular short-term and seasonal rainfall forecasts for the whole country which form part of the structure of Kenya's **drought preparedness**.

C6.1.2. Basin and Sub-Basin level

- Section 27 of the Water Act specifies establishment of Basin Water Resources Committees responsible for the management of the water resources within a particular Basin area, with various powers and functions, among which is to advise the Water Resources Authority and county governments concerning **flood mitigation activities**. Each county government in a Basin has one representative on the Basin Water Resources Committee, which, in collaboration with the NDMA, must **develop drought contingency plans** for the ASAL counties and oversee their implementation as emergency response interventions. (It should be noted that at the time of writing the Basin Water Resources Committee for the Lake Victoria North Basin has not been established.)

- Section 29 of the Water Act specifies establishment of Water Resource Users Associations (WRUAs) at the sub-basin level as community-based associations for collaborative management of water resources and resolution of conflicts concerning the use of water resources. The Basin Water Resources Committees may contract WRUAs as agents **to perform certain duties** in water resource management.

- The NDMA issues regular **drought early warning bulletins** on a county basis which cover various bio-physical indicators, as well as a range of socio-economic impact indicators.

C6.1.3. National plans and policies

- The Water Resources Management Authority (WRMA) Strategic Plan for 2012 – 2017 (WRMA, 2013) specifies six strategic objectives for the WRMA covering the five financial years 2012/13 to 2016/17. Each strategic objective is served by various underlying strategies. Under strategic objective 5, "To heighten the national development agenda on water resources", two of the underlying strategies are "Develop i**ntegrated River Basin flood management plans**" and "Develop and implement programs to **strengthen communities' preparedness/adaptation** to impacts of climate change."
- Under the National Water Master Plan 2030 (known as NWMP 2030), developed as part of the above Strategic Plan, five development plans and three management plans were developed for each of six Basin areas that cover the whole of Kenya (WRMA, 2013). A **flood and drought management plan** featured among the latter three plans.
- The Ending Drought Emergencies Common Programme Framework (EDE-CPF) (NDMA, 2017) has three components: drought risk and vulnerability reduction, drought early warning and early response, and institutional capacity for drought and climate resilience and comprises six sets of interrelated action plans for ensuring **ongoing drought preparedness**. The EDE-CPF is currently being operationalised through its 3rd Medium-Term Plan 2018-2022 and is mainly focused on the ASAL counties (NDMA, 2017).

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Key Strategic Area 1:	Catchment Management														
Strategic Objective:	To ensure integrated and sustainable water, land and natural resources management practices														
Strategy		Activities	Target/Indicators (M&E)	CMS Strategic Action	Implementation horizon	Key role players				Budget (USD Million)					Funding source
						National	Basin	Local	Other	2020-2022	2022-2025	2025-2030	2030-2040	Total cost	
Strategic Theme 1.1:		Promote improved and sustainable catchment management											Strategic theme 1.1 total:	4	
Theme priority:		Very Important													
1.1.1	Promote sustainable land development and planning														
i		MDAs and private sector to incorporate NEMA Environmental Sustainability Guidelines into relevant policies	NEMA Guidelines reflected in relevant policies		Short-term	NEMA MoWSI MoALF MoEF WRA KWS KWTA AFA	BWRC WWDA	CG WRUA	WSP CFA Private sector	-	0.8	-	-	0.8	MoEF NEMA CG
ii		Increase awareness of sustainable catchment management with relevant ministries (e.g. MWSI, MoALF, MoEF), WRUAs, CGs etc. through training, brochures, social media, internet, factsheets, forums and workshops.	Level of awareness re sustainable catchment management; Number workshops, trainings.	LA08 PA43	Immediate	WRA MoWSI MoALF MoEF NEMA	BWRC	CG WRUA	Media Development partner CFA CBO	1.6	-	-	-	1.6	MoWSI MoEF
iii		Integrate County Spatial Plan into the CIDPs including construction, restoration, rehabilitation and protection.	County Spatial Plans developed		Medium-term	MoLPP MoALF		CG WRUA		-	-	0.8	-	0.8	CG
1.1.2	Strengthen participatory approaches														
i		Devolve ownership of catchment management activities to WRUAs through SCMP development.	Sustainable catchment management activities incorporated in SCMPs; Number SCMPs developed	LA07	Immediate	WRA KWS KFS KWTA	BWRC	WRUA CG	CFA CBO	0.53	-	-	-	0.53	MoWSI WSTF
Strategic Theme 1.2:		Sustainable water and land use and management practices											Strategic theme 1.2 total:	4	
Theme priority:		Critical													
1.2.1	Promote water conservation and management at catchment level														
i		Embed catchment-based water conservation and management activities related to crop and livestock production in SCMPs: E.g. improved water use efficiency; water harvesting and storage; groundwater protection and infiltration	Improved understanding of water conservation and management; Reduction in water use; Increased water storage and water availability in the sub-catchment; Increased groundwater recharge	LA10	Immediate	WRA MoWSI KWTA MOALF	BWRC WWDA	WRUA CG	CBO	0.53	-	-	-	0.53	CG
ii		Promote catchment-based water conservation and management principles with relevant MDAs through training, forums and conferences.	Level of awareness regarding water conservation and management; Number trainings/forums/conferences held	LA10 PA43 WA16 WA17	Short-term	WRA MoWSI MoALF KWTA	BWRC WWDA	CG WRUA	CBO KALRO	-	0.53	-	-	0.53	CG
1.2.2	Promote soil conservation and management at catchment level														
i		Embed catchment-based soil conservation and management activities related to crop and livestock production in SCMPs: E.g rangeland management; erosion and runoff control measures; gully management and sediment trapping; stream/river bank management.	Improved understanding of soil conservation and management; Improved soil conservation within farms and rangeland; Sustainable land management; Improved soil conservation within Water Towers; Improved soil conservation within gazetted forests; Rangeland health; Reduced sedimentation	LA10	Immediate	WRA MoALF KWTA	BWRC	CG WRUA	NGO CFA CBO	1.06	-	-	-	1.06	MoWSI MoALF CG

Key Strategic Area 1:	Catchment Management													
Strategic Objective:	**To ensure integrated and sustainable water, land and natural resources management practices**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
ii	Promote catchment-based soil conservation and management with relevant MDAs through training, forums and conferences.	Level of awareness regarding catchment-based soil conservation and management; Number trainings/forums/conferences held	LA10 PA43	Medium-term	WRA MoWSI MoALF NEMA	BWRC	CG WRUA	NGO KALRO CBO	-	-	0.53	-	0.53	MoWSI MoALF CG
1.2.3	**Promote conservation agriculture and improved farm management**													
i	Embed conservation agriculture and improved farm management activities related to crop and livestock production in SCMPs: E.g. climate smart agriculture; conservation agriculture; soil fertility management; natural farming; agroecological farming	Improved understanding of conservation agriculture; Number of times each farmer's land is tilled and total ha tilled; Concentration of soil carbon (g/km soil); Nutrients in soil; Active climate smart agriculture inclusive of conservation tillage, crop rotation/intercropping and soil cover; Active nutrient management; Number of farmers adopting climate smart agriculture and conservation agriculture	PA43	Immediate	WRA MoALF MoWSI MoEF NEMA	BWRC	WRUA CG	KALRO CFA CBO	0.53	-	-	-	0.53	MoWSI MoALF CG
ii	Promote conservation agriculture and improved farm management with relevant MDAs through training, forums and conferences.	Level of awareness re conservation agriculture and improved farm management; Number of training forums		Medium-term	WRA MoALF MoWSI MoEF KFS NEMA	BWRC	CG WRUA	KALRO CBO	-	-	0.53	-	0.53	MoWSI MoALF CG
Strategic Theme 1.3:	**Natural resources management for the protection and sustainable use of natural resources**												Strategic theme 1.3 total:	**57**
Theme priority:	**Critical**													
1.3.1	**Improved wetlands and lake management**													
i	Delineate and classify lakes and wetlands at basin scale and conduct status quo assessment for significant wetlands considered as part of Resource Directed Measures	Significant lakes and wetlands - health and services assessed, delineated and classified	LA12-14	Short-term	MoEF NEMA WRA MoWSI NLC	BWRC	CG WRUA	CBO Wetlands International	-	1.6	-	-	1.6	MoEF
ii	Establish an effective and efficient institutional and legal framework for integrated management and wise use of wetlands which will enhance and maintain functions and values derived from wetlands in order to protect biological diversity and improve livelihood of Kenyans.	Clear mandates, roles and responsibilities regarding lake and wetland management		Short to medium-term	MoWSI MoEF WRA NEMA	BWRC	CG WRUA	Wetlands International	-	1.6	1.6	-	3.2	MoEF MoWSI
iii	Promote communication, education and public awareness among stakeholders regarding the importance of sustainable lake and wetland utilisation	Level of awareness regarding sustainable lake and wetland utilization; Regulatory compliance with National Wetlands Conservation and Management Policy; Number stakeholder consultation forums held	LA17	Short-term	MoEF NEMA WRA MoEd	BWRC	CG WRUA	Media NGO CBO	-	1.6	-	-	1.6	MoEF
iv	Improve scientific information and knowledge base on Kenyan wetland ecosystems through research and specific studies.	Number of research papers published; Number of studies completed; Improved knowledge base; Knowledge management system established.		Short to medium-term	MoEF NEMA WRA		WRUA	NGOs Universities	-	1.6	1.6	-	3.2	MoEF WSTF

Key Strategic Area 1:	Catchment Management													
Strategic Objective:	**To ensure integrated and sustainable water, land and natural resources management practices**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
v	Strengthen institutional capacity on conservation and management of wetlands through training and capacity building.	Enhanced institutional capacity towards effective lake and wetland management; Number of staff trained		Medium-term	MoEF NEMA WRA MoWSI	BWRC WWDA	WRUA CG	CETRAD	-	-	1.6	-	1.6	MoEF
vii	Promote innovative planning and integrated management approaches towards wetlands conservation and management in Kenya through training, and capacity building.	Enhanced innovative planning and management for sustainable lake and wetland management; Regulatory compliance with National Wetlands Conservation and Management Policy.		Medium to long-term	MoEF NEMA WRA MoWSI	BWRC WWDA	CG WRUA	CETRAD	-	-	1.6	1.6	3.2	MoEF
viii	Promote partnership and cooperation at regional and international levels for the management of transboundary wetlands and migratory species.	Enhanced partnerships and cooperation regarding sustainable lake and wetland management and utilization; Number international treaties/agreements signed; Number joint initiatives done for wetland protection		Short to long-term	MoWSI MoEF WRA NEMA AFA MoFA MoEACRD		CG WRUA	NGO	-	0.2	0.2	0.4	0.8	MoEF
ix	Enforce wetland and lake buffers.	Wetland and lake buffers enforced	LA18-19	Short to long-term	NEMA WRA MoWSI		CG WRUA	NGO	-	1.6	1.6	3.2	6.4	MoEF
1.3.2	**Promote alternative and sustainable livelihoods**													
i	Promote alternative and sustainable livelihoods through local level initiatives.	Increase in alternative and sustainable livelihoods; Reduced encroachment and destruction of natural resources	PA26	Short to medium-term	MoALF MoEF		WRUA CG	KALRO CBO	-	1.59	1.59	-	3.18	MoALF WSTF
ii	Promote agroforestry (i.e. live fencing, medicinal trees, fodder trees, fruit trees) through local level initiatives.	Increase in Agroforestry; Increase in tree coverage; Number households supported through agroforestry		Short to long-term	KFS MoEF KWTA MoALF		WRUA CFA CG	KEFRI CBO	-	0.53	0.53	1.06	2.12	KFS MoALF
1.3.3	**Improved solid waste management**													
i	Implement improved household waste management with help of the county governments and other stakeholders.	Reduced household waste issues; Recycled waste products	LA23	Short-term	NEMA NETFUND MoEF MoH		CG	CBO NGO	-	1.6	-	-	1.6	MoEF CG
ii	Implement improved village waste management with help of the county governments and other stakeholders.	Reduced village waste issues; Reduced point source water pollution; Public Private Partnerships in waste collection	LA23	Short-term	NEMA NETFUND MoEF MoH		CG	NGO CBO Private sector	-	1.6	-	-	1.6	MoEF CG
iii	Consider developing recycling or buy-back centers as an alternative to current solid waste management.	Reduced solid waste	LA24	Medium-term	NEMA NETFUND MoEF MoH		CG	NGO CBO Private sector	-	-	1.6	-	1.6	CG
iv	Identify and map solid waste hotspots in 9 counties.	No. solid waste hotspots identified; Maps produced	LA20	Medium-term	NEMA NETFUND MoEF MoH		CG WRUA		-	-	1.6	-	1.6	CG
1.3.4	**Improved forestry management**													
i	Coordinate approach to forestry management – roles, responsibilities and mandates	Clear understanding of roles and responsibilities regarding forestry management; Reduced duplication of efforts in conservation; Increased inter-agency collaboration		Immediate	KWS KWTA KFS MoEF NEMA		CG WRUA	NGO CFA	0.8	-	-	-	0.8	MoEF CG

Key Strategic Area 1:	Catchment Management													
Strategic Objective:	**To ensure integrated and sustainable water, land and natural resources management practices**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
ii	Promote international best practice in sustainable plantation forestry through training, and capacity building.	Forest density; Selection of beneficial trees for forest reserves; Number of people trained		Medium to long-term	KFS MoEF			CFA	-	-	0.2	0.4	0.6	MoEF
iii	Enhance protection of forest reserves through community involvement and enforcement	Protected forest density; Number of community groups involved		Short to long-term	KWS KWTA KFS MoEF		CG WRUA	CFA	-	1.6	1.6	3.2	6.4	MoEF
iv	Prevent slash and burn agriculture	Ha of forest preserved		Short-term	AFA MoEF KFS KWTA		CG	CFA	-	0.8	-	-	0.8	MoEF CG
1.3.5	**Removal of alien invasive species**													
i	Develop national program for utilising and controlling identified alien invasive species	Alien invasive control Plan		Short-term	KWS KWTA KFS MoEF NEMA			KEFRI	-	0.1	-	-	0.1	MoEF
1.3.6	**Improved fisheries management**													
i	Promote sustainable development and management of fisheries for maximum social and economic benefit.	Sustainable fishing		Short to medium-term	AFA MoALF		CG	KMFRI	-	0.8	0.8	-	1.6	AFA
1.3.7	**Improved energy management**													
i	Develop and enforce sustainable charcoal strategy.	Reduction in production and use of charcoal		Short to medium-term	MoEF NEMA KFS MoEn EPRA		CG	NGO CBO	-	0.8	0.8	-	1.6	MoEF
ii	Promote renewable energy sources.	No. renewable energy schemes implemented		Medium to long-term	MoEF NEMA MoEn EPRA REREC		CG	KenGen	-	-	3.2	6.4	9.6	CG
1.3.8	**Improved sand mine management**													
i	Collaborate with county governments in developing and implementing a sand harvesting policy.	Sand harvesting policy	LA09	Short-term	NEMA		CG		-	0.8	-	-	0.8	MoEF
ii	Enforcement of Sand Conservation and Utilisation Act	Regulated sand harvesting		Medium-term	NEMA		CG WRUA		-	-	0.4	-	0.4	MoEF
iii	Initiate study to identify alternative sources of building materials other than sand.	Alternative building materials identified and used	LA11	Short-term	NEMA WRA NCA				-	0.2	-	-	0.2	MoEF
iv	Initiate cross-boundary sand management in the basin	Coordination framework to standardize sand management and regulation developed		Medium-term	NEMA WRA		CG		-	-	0.4	-	0.4	MoEF

Key Strategic Area 1:	Catchment Management														
Strategic Objective:	To ensure integrated and sustainable water, land and natural resources management practices														
Strategy		Activities	Target/Indicators (M&E)	CMS Strategic Action	Implementation horizon	Key role players				Budget (USD Million)					Funding source
						National	Basin	Local	Other	2020-2022	2022-2025	2025-2030	2030-2040	Total cost	
Strategic Theme 1.4:		Rehabilitation of degraded environments											Strategic theme 1.4 total:	27	
Theme priority:		Very Important													
1.4.1	Rehabilitation and Restoration Plan														
i		Prepare rehabilitation and restoration program for Basin: Land, Riparian areas, Forests, Mining areas in collaboration with stakeholders.	No. rehabilitation and restoration programs developed	LA15	Short to medium-term	NEMA WRA KFS KWS KWTA MoALF	BWRC	CG WRUA	CBO CFA	-	1.6	1.6	-	3.2	MoEF
1.4.2	Land restoration and rehabilitation of specific priority areas														
i		Identify, review and update catchment degradation hotspot areas.	Catchment degradation hotspots identified	LA06	Short-term	WRA NEMA KFS KWTA	BWRC	CG WRUA		-	0.8	-	-	0.8	CG
ii		Collaborate with county governments in Soil and Water conservation measures (Strategy 1.2.2).	Soil and water management improvement; Number of collaborations	LA10	Short-term	WRA	BWRC	CG WRUA	NGO CBO	-	1.6	-	-	1.6	CG
1.4.3	Site specific rehabilitation of degraded riparian areas														
i		Identify and map urban river hotspot areas for clean-up campaigns.	Urban river hotspot areas identified and mapped	LA20	Short-term	WRA NEMA		CG WRUA		-	0.8	-	-	0.8	MoEF CG
ii		Carry out river clean-up activities in identified hotspot areas in collaboration with counties and key stakeholders.	Hotspots cleaned; Number of stakeholders engaged in clean-ups	LA21	Short-term	WRA NEMA		CG WRUA	CBO	-	1.6	-	-	1.6	MoEF CG
iii		Increase/maintain natural riparian vegetation cover.	Natural riparian vegetation cover increased/maintained	LA18	Short to long-term	WRA NEMA KFS		CG WRUA	CBO	-	1.6	1.6	3.2	6.4	CG
1.4.4	Site specific rehabilitation of degraded wetlands.														
i		Identify, review and update wetland degradation hotspot areas.	Wetland degradation hotspots identified and mapped		Short-term	NEMA WRA		CG	NGO CBO	-	0.8	-	-	0.8	MoEF CG
ii		Develop rehabilitation and restoration program for degraded wetlands.	Wetland rehabilitation program		Short-term	NEMA WRA NLC	BWRC	CG WRUA	NGO CBO	-	0.8	-	-	0.8	MoEF CG
iii		Increase/maintain natural wetland vegetation cover.	Natural wetland vegetation cover increased	LA18	Short to long-term	WRA NEMA KWS		CG WRUA	NGO CBO	-	0.8	0.8	1.6	3.2	MoEF CG
1.4.5	Site specific rehabilitation of Gazetted forests or protected forests that have been degraded														
i		Recommend identified areas for gazettement.	Gazette areas identified	LA16	Short-term	KFS WRA NEMA KWTA		CG		-	0.2	-	-	0.2	KFS
ii		Increase/maintain natural vegetation cover in protected areas	Natural vegetation cover increased/maintained; Number of indigenous species planted	LA18	Short to long-term	KWS KWTA KFS			CFA	-	0.5	0.5	1	2	MoEF KFS, KWTA

Key Strategic Area 1:		Catchment Management													
Strategic Objective:		**To ensure integrated and sustainable water, land and natural resources management practices**													
Strategy		**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
						National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
iii	Undertake reforestation in prioritised degraded forest areas. Consider soil and water conservation techniques and beneficial/natural trees.		Ha forest cover increased; Number of indigenous trees planted		Short to medium-term	KWS KWTA KFS			CFA	-	1.6	1.6	-	3.2	MoEF KFS
1.4.6	**Mining area rehabilitation**														
i	Rehabilitate degraded sand mining areas.		Rehabilitated sand mining areas		Short-term	NEMA		CG WRUA		-	0.8	-	-	0.8	MoEF CG
ii	Rehabilitate prioritised abandoned mines and/or mining areas at active mines.		Revegetated mining areas and soil conservation techniques implemented		Short to medium-term	NEMA		CG WRUA		-	0.8	0.8	-	1.6	MoEF CG

Key Strategic Area 2:	Water Resource Protection													
Strategic Objective:	**To protect and restore the quality and quantity of water resources of the basin using structural and non-structural measures**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
Strategic Theme 2.1:	**Classification of water resources**												Strategic Theme 2.1 total:	**0.1**
Theme priority:	**Very critical**													
2.1.1 Determine the baseline for Resource Directed Measures: Surface and groundwater assessments at appropriate scales to inform the classification of water resources in the basin.														
i	Implement under Strategies: 8.1.1: Surface water resources assessment - surface water availability at relative scales 3.1.1: Groundwater assessment – assess groundwater availability in terms of quantity and quality													
2.1.2 Determine Class of water resources														
i	Classify all significant water resources in the Basin (conducted prior to Reserve and RQO determination)	Water resources classified; Water resources classification report	LA03-04	Immediate	WRA NEMA				0.05	-	-	-	0.05	WRA
Strategic Theme 2.2:	**Ecological Reserve**												Strategic Theme 2.2 total:	**2.5**
Theme priority:	**Very Important**													
2.2.1 Reserve determination														
i	Determine the Reserve for prioritised water resources in the Basin (note Reserve required for resource quality objectives)	Reserve determined	LA01 WA11	Immediate	WRA		CG		0.05	-	-	-	0.05	WRA
2.2.2 Reserve compliance														
i	Increase Reserve awareness through training, brochures, social media, internet, factsheets and SCMPs.	Level of awareness regarding Reserve; Number of trainings and awareness campaigns undertaken	WA17	Short to medium-term	WRA		WRUA		-	0.2	0.2	-	0.4	WRA WSTF
ii	Monitor and enforce Reserve compliance: Dam owners and operators, abstractors.	Environmental flows met	LA02 WA15	Medium to long-term	WRA	BWRC	WRUA		-	-	1	1	2	WRA WSTF
Strategic Theme 2.3:	**Resource Quality Objectives**												Strategic Theme 2.3 total:	**0.2**
Theme priority:	**Critical**													
2.3.1 Set Resource Quality Objectives														
i	Determine the resource quality objectives for prioritised water resources in the Basin	Resource Quality Objectives set	LA05 WA29	Immediate	WRA NEMA	BWRC	CG WRUA		0.2	-	-	-	0.2	WRA
Strategic Theme 2.4:	**Conservation and protection of ecological infrastructure**												Strategic Theme 2.4 total:	**2.0**
Theme priority:	**Important**													
2.4.1 Integrate environmental considerations into basin development and planning														
i	Ensure compliance with Kenyan environmental legislation in planning policies, plans and programs related to basin planning and development	SSEAs successfully completed; Categorise and protect environmentally sensitive areas; Identify and define environmentally sensitive areas		Short to long-term	WRA NEMA	BWRC	WRUA		-	0.15	0.15	0.3	0.6	WRA
2.4.2 Groundwater protection														
i	Implement under Strategy 3.4.1 Groundwater source protection													
2.4.3 Riparian areas protection														
i	Protect and conserve prioritized riparian areas	Riparian areas defined and protected	WA36	Short to medium-term	NEMA WRA		WRUA		-	0.2	0.2	-	0.4	WRA

Key Strategic Area 2:		Water Resource Protection														
Strategic Objective:		To protect and restore the quality and quantity of water resources of the basin using structural and non-structural measures														
Strategy		Activities	Target/Indicators (M&E)	CMS Strategic Action	Implementation horizon	Key role players				Budget (USD Million)					Funding source
						National	Basin	Local	Other	2020-2022	2022-2025	2025-2030	2030-2040	Total cost	
2.4.4	Ecosystem services protection														
i	Protect and conserve sensitive ecosystems which provide important ecological services.		Environmentally sensitive areas protected	WA36	Short to medium-term	NEMA		WRUA		-	0.2	0.2	-	0.4	WRA
ii	Give monetary value to ecological infrastructure and ecosystem services		Payment for ecosystem services initiated		Long-term	WRA NEMA		WRUA		-	-	-	0.6	0.6	WRA WSTF

Key Strategic Area 3:	Groundwater Management													
Strategic Objective:	**The integrated and rational management and development of groundwater resources**													
Strategy	**Activities**	**Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022 - 2025**	**2025 - 2030**	**2030 - 2040**	**Total cost**	
Strategic Theme 3.1:	**Groundwater resources assessment, allocation, regulation**											Strategic theme 3.1 total:	**14**	
Theme priority:	**Critical**													
3.1.1	**Groundwater assessment – assess groundwater availability in terms of quantity**													
i	Implement aquifer mapping and groundwater modelling across the basin	Groundwater resources mapped	LA26	Immediate to short-term	WRA				2	2	-	-	4	WRA MoWSI
ii	Complete aquifer classification.	Aquifers classified		Immediate	WRA				0.05	-	-	-	0.05	WRA
iii	Improve estimates of sustainable groundwater yield in priority areas using advanced techniques	High confidence estimates of sustainable yield	WA12	Immediate to medium-term	WRA MoWSI				0.8	0.8	0.8	-	2.4	WRA MoWSI
3.1.2	**Groundwater assessment – assess groundwater quality and use**													
i	Prepare groundwater abstraction plan and undertake groundwater abstraction and water quality survey	Groundwater abstraction survey successfully completed		Immediate to short-term	WRA MoWSI	BWRC	CG	WRUA	1.6	1.6	-	-	3.2	WRA MoWSI
3.1.3	**Update and improve permit database**													
i	Reconcile PDB with groundwater abstraction survey results	PDB reconciled with groundwater abstraction survey results		Short-term	WRA				-	0.16	-	-	0.16	WRA
ii	Revise/adapt PDB to reflect new proposed Aquifer Classification	Revised PDB		Short to medium-term	WRA				-	0.8	0.8	-	1.6	WRA
iii	Develop system for on-line updating of drilling contractor information to improve borehole data capture via an online system	Revised PDB		Short to medium-term	WRA				-	0.45	0.45	-	0.9	WRA
3.1.4	**Groundwater allocation**													
i	Set National resource quality objectives	Implement under Strategy 2.3.1: Set resource quality objectives												
ii	Undertake groundwater balance to determine sustainable yield available	Groundwater balance	WA02	Immediate to short-term	WRA				0.05	0.05	-	-	0.1	WRA
iii	For each aquifer in the Basin, develop Allocation Plan and disaggregate to sub-basins.	LVN Basin Water Allocation Plans	WA13	Immediate to short-term	WRA	BWRC	CG	WRUA	1	1	-	-	2	WRA
Strategic Theme 3.2:	**Groundwater development**											Strategic theme 3.2 total:	**62**	
Theme priority:	**Very important**													
3.2.1	**Aquifer recharge**													
i	Conduct preliminary assessment of recharge areas from existing data. Define recharge areas for Priority Aquifers.	Groundwater recharge areas defined; Recharge water quality, quantity and mechanism determined		Short-term	WRA				-	0.8	-	-	0.8	WRA
ii	Roll out Managed Aquifer Recharge studies in the Basin	Managed Aquifer Recharge studies in the LVN Basin		Medium to long-term	WRA		CG	WSP Private sector (industry, agric., mining)	-	-	0.8	1.6	2.4	WRA

Strategy	Activities	Indicators (M&E)	CMS Strategic Action	Implementation horizon	Key role players: National	Basin	Local	Other	Budget (USD Million): 2020-2022	2022 - 2025	2025 - 2030	2030 - 2040	Total cost	Funding source
Key Strategic Area 3:	**Groundwater Management**													
Strategic Objective:	**The integrated and rational management and development of groundwater resources**													
3.2.2	**Local groundwater development: Reconciliation of water demands and groundwater availability and implementation of groundwater schemes**													
i	Assess allocable groundwater potential close to local demand centers and determine if groundwater resources could meet local demands.	Implement under Strategy 8.2.1: Updated planning for bulk water resources development												
ii	Implement groundwater abstraction schemes in accordance with groundwater development planning	Successful implementation of groundwater schemes in collaboration with Water Service Providers.		Short to long-term	WRA		CG	WSP	4.5	16	14	24	58.5	MoWSI
3.2.3	**Large scale groundwater development: Reconciliation of water demands and groundwater availability and implementation of groundwater schemes**													
i	Assess allocable groundwater potential close to major demand centers and determine if groundwater resources could meet demands.	Implement under Strategy 8.2.1: Updated planning for bulk water resources development												
3.2.4	**Conjunctive use: Reconciliation of water demands and groundwater availability**													
i	Implement under Strategies 3.2.2 and 3.2.3													
Strategic Theme 3.3:	**Groundwater asset management**											Strategic theme 3.3 total:	**4**	
Theme priority:	**Important**													
3.3.1	**Develop asset inventory**													
i	Develop a needs assessment for groundwater management needs	Needs assessment completed		Short-term	MoWSI WRA			WSP	-	0.05	-	-	0.05	MoWSI
Ii	Acquire necessary equipment and accessories for groundwater management	Equipment/accessories acquired		Short-term	MoWSI WRA			WSP	-	0.8	-	-	0.8	MoWSI
Iii	Establish Asset Inventory.	Asset inventory compiled (number of boreholes, Spatial data, Mechanical and Electrical Equipment; Civil infrastructure etc)		Short-term	MoWSI WRA			WSP	-	2.4	-	-	2.4	MoWSI
iv	Commission or develop an Asset Inventory database system.	Asset inventory database in place		Short-term	MoWSI WRA			WSP	-	0.1	-	-	0.1	MoWSI
3.3.2	**Develop asset management plan**													
i	Prepare groundwater asset management plan	Groundwater asset management plan		Short to medium-term	WRA			WSP	-	0.48	0.48	-	0.96	MoWSI
Strategic Theme 3.4:	**Conservation and protection of groundwater**											Strategic theme 3.4 total:	**6**	
Theme priority:	**Important**													
3.4.1	**Groundwater source protection**													
i	Assess LVN Basin groundwater Vulnerability	Groundwater vulnerability assessed	LA25	Short-term	WRA				-	0.1	-	-	0.1	WRA
iii	Assess which LVN Basin aquifers or parts of aquifers require formal protection.	Groundwater conservation areas (GCAs) identified		Short-term	WRA				-	0.05	-	-	0.05	WRA
iv	Assess which LVN Basin aquifers contain important GDEs	Groundwater dependent ecosystems (GDEs) identified		Short-term	WRA				-	0.05	-	-	0.05	WRA
v	Develop an LVN Basin groundwater Protection Plan	LVN Basin groundwater Protection Plan	LY08	Short-term	WRA MoWSI NEMA MoICNG		CG WRUA	WSP Private sector (industry, agric.,	-	0.2	-	-	0.2	WRA

Key Strategic Area 3:		Groundwater Management														
Strategic Objective:		The integrated and rational management and development of groundwater resources														
Strategy		Activities	Indicators (M&E)	CMS Strategic Action	Implementation horizon	Key role players				Budget (USD Million)						Funding source
						National	Basin	Local	Other	2020-2022	2022 - 2025	2025 - 2030	2030 - 2040	Total cost		
									mining)							
vi	Implement groundwater protection measures		Number of protected aquifers		Short to long-term	WRA				-	1	1	2	4		WRA
3.4.2	**Rehabilitate polluted aquifers, springs and wells**															
i	Define LVN Basin's polluted aquifers.		LVN Basin polluted aquifers identified	LA27	Short-term	WRA				-	0.2	-	-	0.2		WRA
ii	For each polluted aquifer, determine the optimum and most cost-effective way to rehabilitate it.		Rehabilitation plans for polluted aquifers	LA28	Short to medium-term	WRA				-	0.2	0.2	-	0.4		WRA
iii	Prioritise aquifers for rehabilitation and implement rehabilitation programmes.		Implementation of prioritised rehabilitation plans	LA28	Medium to long-term	WRA		WRUA		-	-	0.2	0.4	0.6		WRA

Key Strategic Area 4:	Water Quality Management													
Strategic Objective:	**Efficient and effective management of water quality to ensure that water user requirements are protected in order to promote sustainable socio-economic development in the basin**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020 - 2022**	**2020 - 2022**	**2025 - 2030**	**2030 - 2040**	**Total cost**	
Strategic Theme 4.1:	**Effective water quality data collection, information generation and dissemination, and knowledge management**											Strategic theme 4.1 total:	**8**	
Theme priority:	**Critical**													
4.1.1	**Implement routine surface and groundwater quality monitoring**													
i	Implement national water quality monitoring programme in the LVN Basin by ensuring technical staff are capacitated and laboratories can analyse the samples accurately and on time.	Number of samples collected and analysed	WA38	Immediate	WRA	WWDA			1	-	-	-	1	WRA
ii	Ensure data submitted to Mike Info WQ database, and that the data is reviewed, analysed, reported on, and acted on by catchment staff.	Number Water quality reports produced		Immediate	WRA				0.2	-	-	-	0.2	WRA
4.1.2	**Biological Water Quality Monitoring**													
i	Develop capacity to undertake biomonitoring in Kenya to assess aquatic ecosystem health.	Number of scientists capacitated to undertake biomonitoring; pilot sites identified and monitoring implemented; results integrated with WQ monitoring results	WA33-35	Immediate	WRA NEMA		WRUA	Universities KEWI	0.4	-	-	-	0.4	WRA
ii	Identify streams in the LVN Basin for piloting biomonitoring and undertake pilot studies.	Number biomonitoring sites; Number reports on pilot studies	WA33-35	Immediate	WRA NEMA			Universities KEWI	0.3	-	-	-	0.3	WRA
iii	Integrate the biomonitoring results with the water quality monitoring network to assess the overall fitness for use and ecosystem health of water resources.	State of the rivers report; Number of biomonitoring indices set	WA33-35	Short to long-term	WRA NEMA				-	0.1	0.1	0.1	0.3	WRA
4.1.3	**Undertake survey of pollution sources**													
i	Compile an inventory of surface water pollution sources.	Surface water pollution inventory	WA20-21	Immediate	WRA NEMA		WRUA		0.3	-	-	-	0.3	WRA NEMA
ii	Reconcile identified pollution sources against discharge licenses at NEMA and permits at WRA.	Reconciliation report	WA22	Short-term	WRA NEMA				-	0.05	-	-	0.05	WRA NEMA
iii	Undertake waste load assessment to assess cumulative impact of pollution sources concentrated in a specific river reach or sub-catchment	Number waste load assessments completed		Short to medium-term	WRA NEMA				-	0.2	0.2	-	0.4	WRA NEMA
iv	Effluent compliance monitoring should be undertaken at regular intervals	Number operational monitoring points and frequency of monitoring; Monitoring programme in place	WA23	Short to long-term	WRA NEMA WASREB			WSP	-	0.75	0.75	1.5	3	WRA NEMA
4.1.4	**Upgrade water quality testing laboratories**													
i	Upgrade central and regional laboratories in the LVN Basin to support the national water quality monitoring programme. These include, inter alia, the recruitment of more technical staff, equipping the laboratory and stocking it with reagents, procuring Field Testing Kits, operationalising the LIMS in the central and regional laboratories and participating in proficiency tests to acquire the	Laboratory upgrade plan completed, Upgrade plan implemented, LIMS operational, Q&A implemented, data sent to Mike Info; Number adequately equipped laboratories; Number ISO accreditations; Number trained staff	WA37	Immediate for central laboratory, short-term for regional laboratories	WRA NEMA		CG	CWTL	0.5	0.5	-	-	1	WRA MoWSI

Key Strategic Area 4:	Water Quality Management														
Strategic Objective:	Efficient and effective management of water quality to ensure that water user requirements are protected in order to promote sustainable socio-economic development in the basin														
Strategy	Activities	Target/Indicators (M&E)	CMS Strategic Action	Implementation horizon	Key role players				Budget (USD Million)						Funding source
					National	Basin	Local	Other	2020 - 2022	2020 - 2022	2025 - 2030	2030 - 2040	Total cost		
	necessary accreditation and ISO certification to enhance data credibility.														
4.1.5	Institutionalise water quality data storage and management														
i	All historical and new water quality data collected by WRA in the LVN Basin stored in Mike Info.	Historical data captured & quality controlled; Data from laboratories captured on time & quality controlled		Immediate	WRA NEMA				0.15	-	-	-	0.15		WRA
4.1.6	Design and implement routine water quality status reporting														
i	Routine water quality status reports should be designed and implemented to report on the water quality status in the LVN Basin, identify key water quality concerns, their causes and consequences, and recommend management actions to mitigate negative impacts.	WQ Status Reports produced		Short to long-term	WRA NEMA				-	0.15	0.15	0.3	0.6		WRA
Strategic Theme 4.2:	Promote sound water quality management governance in the LVN Basin											Strategic theme 4.2 total:	2		
Theme priority:	Very Important														
4.2.1	Harmonise policies and strategies towards improved water quality management														
i	Advocate for alignment of strategies to serve a common purpose of rehabilitating urban rivers and streams in the LVN Basin.	Policies and strategies reviewed for discrepancies; Policies and strategies aligned		Immediate to short-term	WRA NEMA MoALF MoWSI MoEF				0.5	0.5	-	-	1		WRA NEMA
4.2.2	Coordination and cooperation mechanism on water quality issues established at a catchment level														
i	Establish a coordination and cooperation mechanism to ensure there is alignment of actions to address water pollution management in the LVN Basin.	Inter-agency coordination body established and operational	WA39 WA43	Immediate	WRA NEMA	BWRC	CG WRUA	NGO CBO	0.1	-	-	-	0.1		WRA NEMA
ii	Embed water quality management activities related to domestic water use, crop and livestock production in SCMPs	Improved understanding of pollution sources in sub-catchments; Active water quality management; Number SCMPs developed with embedded water quality management activities		Immediate	WRA	BWRC	WRUA CG		0.3	-	-	-	0.3		WRA
iii	Promote water quality management with relevant MDAs through training, forums and conferences.	Level of awareness re water quality management; Number of participants at forums/conferences; Number of people trained on water quality management		Short-term	WRA	BWRC			-	0.05	-	-	0.05		WRA NEMA
Strategic Theme 4.3:	Efficient and effective management of point and nonpoint sources of water pollution											Strategic theme 4.3 total:	211		
Theme priority:	Important														

Key Strategic Area 4:	Water Quality Management													
Strategic Objective:	Efficient and effective management of water quality to ensure that water user requirements are protected in order to promote sustainable socio-economic development in the basin													
Strategy	Activities	Target/Indicators (M&E)	CMS Strategic Action	Implementation horizon	Key role players				Budget (USD Million)					Funding source
					National	Basin	Local	Other	2020 - 2022	2020 - 2022	2025 - 2030	2030 - 2040	Total cost	
4.3.1	**Improve sewerage systems and treatment**													
i	Prepare rehabilitation plan for existing sewerage systems in urban areas incl. sewer pipes, pump stations, wastewater treatment works etc.	Number rehablitation plans		Short-term			CG	WSC	-	1.6	-	-	1.6	MoWSI
ii	Implement rehabilitation plan for sewerage system incl. rehabilitation of existing wastewater treatment	Number successful completion of rehab works; Number of treatment works operating efficiently		Medium to long-term			CG	WSC	-	-	24	24	48	MoWSI
iii	Prepare wastewater master plan for major urban centres: assess current capacity of wastewater treatment works, required and projected capacity, maintenance needs and budgets and capex budgets for expansion.	Number wastewater master plans completed		Short-term	MoWSI		CG	WSC	-	0.5	-	-	0.5	MoWSI
iv	Construct new sewerage systems in urban areas and connect to existing / new WWTWs. Increase wastewater treatment capacity in urban areas by expanding existing / constructing new wastewater treatment plants.	Number new sewerage systems completed (area); Number existing WWTWs expanded; Number new WWTWs; Increased percentage in waste water treatment coverage		Medium to long-term			CG	WSC	-	-	32	64	96	MoWSI
v	Promote wastewater treatment at source, especially at industrial sites, housing estates, hospitals, etc. With the objective of improving the quality of effluent discharges before it enters the environment or sewerage network.	Number of onsite WWT facilities; Current vs historical effluent quality; Number of Effluent Discharge Control Plans (ECDPs) in place		Short to long-term	NEMA WRA		CG	Industries Households NGO	-	1.6	1.6	3.2	6.4	MoWSI
4.3.2	**Cleaner production methods**													
i	Support initiatives by the Kenya National Cleaner Production Center (KNCPC) to promote excellence in Resource Efficient and Cleaner Production in industries in the LVN Basin in order to reduce water usage and effluents, as well as their impacts on water quality in receiving water bodies.	Water consumption vs international norms; Effluent quality vs international norms; Current vs historical river water quality; Number initiatives on cleaner production increased		Short to medium-term	NEMA WRA KNCPC			Industries	-	0.5	0.5	-	1	MoWSI
4.3.3	**Urban stormwater, sanitation, and solid waste management, and protection of upper reaches of rivers**													
i	Control sediment pollution from construction sites and unpaved urban roads in urban areas by adopting best urban stormwater management practices such as erecting sediment traps or screens, sediment detention ponds, etc.	Number urban stormwater BMPs implemented.		Short to medium-term	NEMA WRA KURA		CG	NGO	-	2.4	2.4	-	4.8	CG
ii	Compel County Governments to maintain sewerage infrastructure and fix leaks or blockages as a matter of urgency to minimise sewage leaks into stormwater drains.	Number maintenance projects completed; Number of sewage blockages repaired; Tonnage of solid waste removed	WA39 WA43	Short-term	WRA NECC	WWDA	CG	WSP	-	2	-	-	2	WRA

Key Strategic Area 4:	Water Quality Management													
Strategic Objective:	**Efficient and effective management of water quality to ensure that water user requirements are protected in order to promote sustainable socio-economic development in the basin**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020 - 2022**	**2020 - 2022**	**2025 - 2030**	**2030 - 2040**	**Total cost**	
iii	Promote solid waste removal in urban centres and disposal at solid waste disposal sites that meet best national or international design standards.	Improved solid waste collection, transportation, treatment and disposal		Short-term	WRA NEMA		CG		-	2	-	-	2	CG
iv	Refurbish existing solid waste dumps to intercept and treat poor quality drainage water and prevent it from running into water courses.	Number drainage systems constructed to intercept the leachate		Medium to long-term	WRA NEMA		CG		-	-	2	4	6	CG
4.3.4	**Sanitation management in informal settlements**													
i	Protect receiving streams from pollution, especially urban rivers such as Ngong, Ongata Rongai, Ruiru, Kiambu and Nairobi by installing sewers or septic tanks to contain domestic wastes, by managing urban solid wastes, and monitoring receiving streams for BOD and COD.	Number of sewers or septic tanks installed; Number of solid waste handling sites constructed; Number of water samples collected and analysed for BOD and COD; Reduction in number of non-designated dump sites		Short to medium-term	WRA NEMA NLC MoH			NGOs involved in urban upliftment	-	2.4	2.4	-	4.8	CG MoWSI
ii	Control of organic pollution from unplanned and un-sewered settlements/slums in all the major urban centres through installing sewers or septic tanks and promoting solid waste collection and removal from these settlements.	Length of sewers installed; No septic tanks installed; Tonnage of solid waste removed; Number solid waste service providers registered and active		Short to medium-term	WRA	WWDA	CG		-	8	8	-	16	CG MoWSI
iii	Support international aid / private sector projects that are designed to upgrade informal settlements and slums.	Number aid projects supported; Number of households supported		Medium to long-term	WRA MoTIHUDPW		CG	NGO	-	-	1.6	1.6	3.2	CG MoWSI
4.3.5	**Management of hydrocarbon pollution**													
i	Control of oil and grease pollution, spillage and leakages from petrol stations, trucks, pipelines and oil storage facilities by ensuring that all are equipped with functional oil and grease traps, and by monitoring nearby surface and groundwater for hydrocarbons.	Number of oil & grease traps installed; Number water samples collected and analysed for hydrocarbons; Reduced level of hydrocarbons in surface water and ground water		Short to long-term	NEMA WRA MoPM MoTIHUDPW		CG Local Government	Petrol stations Workshops	-	0.8	0.8	1.6	3.2	NEMA WRA
ii	Control dumping of used motor oil at informal workshops by promoting recycling of used oil, and monitoring stormwater drains for hydrocarbon pollution.	Volume of used oil recycled; Streams complying with Oil & Grease standards; Number informal workshops recycling used oil and using recycled oil		Short-term	WRA EPRA		CG		-	0.8	-	-	0.8	NEMA CG
iii	Protect groundwater against hydrocarbon contamination near petrol stations and dump sites by drilling observation wells at high risk areas and monitoring boreholes for hydrocarbons	Groundwater complying with Oil & Grease standards; Number observation wells drilled		Short-term	WRA EPRA		CG		-	0.5	-	-	0.5	WRA
4.3.6	**Sedimentation from unpaved roads**													

Key Strategic Area 4:	Water Quality Management													
Strategic Objective:	**Efficient and effective management of water quality to ensure that water user requirements are protected in order to promote sustainable socio-economic development in the basin**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020 - 2022**	**2020 - 2022**	**2025 - 2030**	**2030 - 2040**	**Total cost**	
i	Control sediment pollution from unpaved roads by erecting sediment traps or vegetated buffer strips next to dirt and paved roads. Maintain stormwater drainage to prevent erosion next to roads and rehabilitate erosion gullies near roads.	Number of sediment traps installed; Number of buffer strips established; Reduction in sediment loads in samples analysed; Length of erosion gullies rehabilitated		Medium to long-term	MoTIHUDPW WRA KURA KeRRA		CG		-	-	1.6	3.2	4.8	CG
4.3.7	**Management of agricultural impacts on sediments, nutrients, and agrochemicals**													
i	Control nutrients pollution from agricultural activities (N & P) in all farmed areas within the Basin by compiling & maintaining inventories of fertilizer use, and monitoring nutrients in receiving water bodies (rivers, reservoirs and lakes).	Inventory of fertilizer use established and maintained; Monitoring implemented; Number samples collected and analysed for nutrient content		Short to medium-term	WRA MoALF NEMA NIB		CG	Large commercial farmers	-	0.3	0.3	-	0.6	WRA
ii	Control agrochemical (pesticides and herbicides) residue pollution from farmlands by compiling an inventory of pesticide usage in the basin, and monitoring affected water bodies for residues. Promote efficient use of agrochemicals in the agricultural sector.	Inventory of pesticide use established and maintained; Monitoring implemented; Number of samples collected and analysed for agrochemical components		Short to medium-term	WRA MoALF NEMA NIB PCPB		CG	Large commercial farmers	-	0.4	0.4	-	0.8	CG
iii	Promote best irrigation management practices and encourage irrigators to retain, treat and recycle irrigation return flows before discharging it to the environment.	Compliance with nutrient objectives in rivers and lakes; Number of farmers practicing best irrigation management practices		Medium to long-term	WRA MoALF NEMA NIB		CG	Large commercial farmers	-	-	1.6	3.2	4.8	MoALF CG
iv	Training and awareness creation on nutrient pollution, agrochemical residue pollution, best irrigation management practices and good land management practices.	Number of training forums held; Number of farmer participants		Short-term	WRA MoALF NIB KALRO		CG WRUA	CBO Local farmers	-	1.6	-	-	1.6	MoALF CG
4.3.8	**Enforcement of effluent standards**													
i	Use the results of compliance monitoring of effluent discharge license or permit conditions to prosecute offenders that consistently violate their license/permit conditions and demonstrate no intention of meeting them.	Number of polluters prosecuted		Medium to long-term	NEMA WRA		CG	WWTW operators	-	-	0.5	1	1.5	WRA NEMA
4.3.9	**Control discharges from sand mining operations.**													
i	Implement under Strategy 1.3.8: Improved sand mine management													
4.3.10	**Rehabilitation of polluted aquifers, springs and wells**													
i	Implement under Strategy 3.4.2: Rehabilitate polluted aquifers, springs and wells													

Key Strategic Area 5:	Climate Change Mitigation, Adaptation and Preparedness													
Strategic Objective:	**To implement climate change mitigation measures in the water resources sector and to ensure water resource development and management are adapted and resilient to the effects of climate change**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Area**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2020 - 2025**	**2025-2030**	**2030 - 2040**	**Total cost**	
Strategic Theme 5.1:	**Improved understanding of impacts of climate change on water resources planning and management at appropriate spatial scales**									Strategic theme 5.1 total:			**1**	
Theme priority:	**Critical**													
5.1.1	**Quantify climate change impacts (rainfall & temperature) on surface water and groundwater resources and demands in the LVN Basin at appropriate scales for planning and management**													
i	Use climate change databases, historical data and analytical tools (ISC and other) to identify trends and quantify climate change impacts on surface water and groundwater availability at relevant temporal and spatial scales: rainfall intensity; frequency of extreme rainfall events; rainfall seasonality; inter-and intra-annual rainfall variability; rainfall-runoff relationships; stream flow; groundwater recharge; irrigation demands	Quantification of climate trends and change impacts on surface water and groundwater availability at sub-basin scale	PA01 PA02 PA03 PA04 PA05 PA06	Immediate to short-term	WRA KMD				0.1	0.1	-	-	0.2	WRA
5.1.2	**Assess relevance, and scale of potential social, environmental and economic climate change impacts as defined in NCCAP in LVN Basin and its relation to water resources planning and management; prioritise areas for interventions**													
i	Assess potential social impacts: flooding; droughts; human conflict; migration; vulnerable groups; ocean acidification; agriculture; food production	Prioritised list of social impacts related to climate change in basin; Map of hotspots/high risk areas		Immediate to medium-term	NDMA NDOC CETRAD				0.1	0.1	0.2	-	0.4	WRA
ii	Assess potential environmental impacts: droughts; sea temperature; rising sea levels; ocean acidification; desertification; lad degradation; loss of biodiversity; deforestation; forest degradation	Prioritised list of environmental impacts related to climate change in basin		Immediate to medium-term	MoEF NEMA KFS CETRAD				0.1	0.1	0.2	-	0.4	WRA
iii	Assess potential economic impacts: irrigation water requirements; crop type and yield; GDP; public Infrastructure; hydropower; coastal assets; livelihoods and income generation.	Prioritised list of economic impacts related to climate change in basin; Economic valuation of impacts in the basin		Immediate to medium-term	MoEF MoALF	CETRAD			0.1	0.1	0.2	-	0.4	WRA
Strategic Theme 5.2:	**Climate change mitigation**									Strategic theme 5.2 total:			**11**	
Theme priority:	**Very important**													
5.2.1	**Promote the generation and use of clean energy**													
i	Make use of efficient energy technologies and techniques at household level (e.g. energy efficient lightbulbs, Solar cooker, Solar electrification, Solar borehole pump, Wind pump, Micro hydropower, Biogas digester, Energy efficient stoves and ovens, Heat retention cooker)	Ratio of energy efficient to non-efficient technology used in households; Number of energy saving technologies adopted; Number of households trained on the use of energy saving techniques		Medium to long-term	MoEn KPLCO			Private sector Households	-	-	2.7	5.3	8	MoEn CG
ii	Improve policies regarding renewable energy	The extent to which policies address renewable energy		Short-term	MoEn				-	0.1	-	-	0.1	MoEn
iii	Increase generation of clean energy	kWh of clean energy generated		Medium to long-term	MoEn KENGEN				-	-	1	2	3	MoEn

Key Strategic Area 5:	Climate Change Mitigation, Adaptation and Preparedness													
Strategic Objective:	**To implement climate change mitigation measures in the water resources sector and to ensure water resource development and management are adapted and resilient to the effects of climate change**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Area**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2020 - 2025**	**2025-2030**	**2030 - 2040**	**Total cost**	
Strategic Theme 5.3:	**Climate change adaptation**											Strategic theme 5.3 total:	**22**	
Theme priority:	**Very important**													
5.3.1	**Promote climate resilient infrastructure**													
i	Incorporate flexible adaptation infrastructure principles in infrastructure planning and investment plans	Flexible approaches in which infrastructure is proactively designed/phased to accommodate climate uncertainty.		Immediate to short-term	MoLPP MoTIHUDPW		Local town planning CG		4	4	-	-	8	MoEF
ii	Promote improved capacity of stormwater systems and gutters	% of urban stormwater caught in stormwater systems; Number of dwellings with gutters		Short to medium-term	MoTIHUDPW NWHSA		Property owners Local town planning CG		-	4	4	-	8	MoEF CG
iii	Promote thermally resilient road and rail infrastructure using heat resistant materials	Number of infrastructure projects using heat resistant materials		Medium to long-term	MoTIHUDPW KENHA KURA		Property owners Local engineers and construction companies		-	-	0.3	0.5	0.8	MoEF
5.3.2	**Climate-related disaster risk management**													
i	Floods	Implement under Strategic Theme 6.1: Flood management												
ii	Droughts	Implement under Strategic Theme 6.2: Drought management												
iii	Increase food security through enhanced resilience of the agricultural sector	Increased food security		Short to medium-term	MoALF NDMA	Disaster management committees	CG	NGO	-	1	1	-	2	MoALF
iv	Reduce the incidence of malaria and other diseases expected to increase due to climate change	Reduced incidence of diseases		Short to medium-term	MoH		CG		-	1	1	-	2	MoH
5.3.3	**Promote agroforestry**													
i	Promote alternative and sustainable livelihoods	Implement under Strategy 1.3.2												
5.3.4	**Mainstream climate change adaptation in water resources strategy, planning and management at basin and catchment level**													
i	Implementation and enforcement of climate change regulatory frameworks in the water sector	Number of regulatory frameworks being implemented and enforced; Level of compliance		Short to medium-term	WRA MoWSI		CG WRUA		-	0.6	0.6	-	1.2	WRA
ii	Create awareness amongst communities of the upstream and downstream impacts of climate change throughout the basin	Level of awareness regarding climate change and adaptation measures at basin level	PA07 PA08 PA09	Short-term	WRA KMD		Local councilors CG WRUA		-	0.3	-	-	0.3	WRA
iii	Increase water storage	Implement under Strategic Theme 8.3: Water storage and conveyance												
5.3.5	**Enhance resilience of agricultural sector through climate smart agriculture**													
i	Promote conservation agriculture and improved farm management	Implement under Strategy 1.2.3												

Key Strategic Area 6:	Flood and Drought Management													
Strategic Objective:	**Establish and guide a structured programme of actions aimed at ensuring prevention, mitigation, timeous response and recovery from harmful impacts of floods & droughts**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Theme**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2020-2025**	**2025-2030**	**2030-2040**	**Total cost**	
Strategic Theme 6.1:	**Flood management**										Strategic theme 6.1 total:		**14**	
Theme priority:	**Critical**													
6.1.1	**Undertake flood risk mapping**													
i	Conduct high-level assessments of the flood exposure of each village and town, as well as related transport, access and escape routes and river crossings along Lower Yala River as well as all the flood-prone locations in Siaya, Busia and Vihiga counties, including updating the existing flood risk assessment of the Lower Nzoia River under the WKCDD&FM Project. 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.	Record of successful assessments.	WA45 WA46	Short-term	WRA	LVN Basin FRF; WRA RO	CG		-	0.9	-	-	0.9	MoWSI WRA
ii	Systematise the above information in a Flood Risk Register for the LVN Basin.	Flood Risk Register	WA47	Medium-term	WRA	LVN Basin FRF	CG		-	-	0.1	-	0.1	MoWSI
6.1.2	**Formalise institutional roles and partnership collaborations**													
i	Government institutions/agencies and other stakeholders with partnership roles in flood management will form the *LVN Basin Flood Response Forum (FRF)* under the auspices of the KMD to integrate all flood-relevant resource mobilisations and related interventions in the LVN Basin.	Establishment of the LVN Basin FRF; Number of stakeholder consultations held		Immediate	KMD; NDMU; NDOC	WRA RO; BWRC; MoH RO; MoTIHUDPW RO	Flood-prone county DRM Committee; WRUA; Village DRMC; CG	International Relief Aid agencies; Kenya Red Cross Society; NGO	0.2	-	-	-	0.2	KMD
ii	Establish a Secretariat for the *LVN Basin FRF* with accommodation in the WRA Regional Office.	Establishment of Secretariat; Records of meetings		Immediate	KMD; NDMU; NDOC	WRA RO	WRUA		0.5	-	-	-	0.5	KMD WRA
iii	Develop appropriate SOPs (standard operating procedures) for the *LVN Basin FRF*.	Agreement on SOPs		Immediate to short-term	WRA; KMD; NDMU; NDOC				0.02	0.03	-	-	0.05	KMD WRA
6.1.3	**Develop flood response protocol**													
i	Develop a flood response protocol through a multi-stakeholder approach with the following components: Formalised institutional roles and partnership collaborations; flood preparedness plans for flood-prone zones; key principle: better to protect more people from the frequent smaller floods, than fewer people from the rarer larger floods; flood early warning systems used to alert communities about larger floods; standard operating procedures (SOPs) that comprise sequential flood response actions.	Agreement on flood response protocol.	WA47	Short-term	KMD; NDMU; NDOC	LVN Basin FRF	WRUA		-	0.1	-	-	0.1	KMD WRA

Key Strategic Area 6:		Flood and Drought Management													
Strategic Objective:		**Establish and guide a structured programme of actions aimed at ensuring prevention, mitigation, timeous response and recovery from harmful impacts of floods & droughts**													
Strategy		**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Theme**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
						National	**Basin**	**Local**	**Other**	**2020-2022**	**2020-2025**	**2025-2030**	**2030-2040**	**Total cost**	
6.1.4	**Develop Integrated Flood Management Plans (IFMPs)**														
i		Convert the WKCDD&FM Project proposals for the Nzoia River catchment into an IFMP.	IFMP completed.	WA51	Short-term	WRA	LVN Basin FRF	CG		-	0.1	-	-	0.1	WRA
ii		Develop an IFMP for the Yala River catchment.	IFMP completed.	WA51	Short-term	WRA	LVN Basin FRF	CG		-	0.2	-	-	0.2	WRA
iii		Develop an IFMP for the Malaba River catchment.	IFMP completed.	WA51	Short to medium-term	WRA	LVN Basin FRF	CG		-	0.1	0.1	-	0.2	WRA
iv		Develop an IFMP for the Malakisi River catchment.	IFMP completed.	WA51	Short to medium-term	WRA	LVN Basin FRF	CG		-	0.1	0.1	-	0.2	WRA
v		Develop an IFMP for the Sio River catchment.	IFMP completed.	WA51	Medium-term	WRA	LVN Basin FRF	CG		-	-	0.2	-	0.2	WRA
6.1.5	**Implement flood management measures**														
i		The *LVN Basin FRF* will prioritise the Implementation Schedules of each of the above five IFMPs. These non-structural and structural flood management/ counter measures will encompass the following: prevention measures; protection measures; preparedness measures; flood early warning systems; emergency response measures. These measures will be focused on flood-prone river reaches and flood-plains in each of the above flood-prone catchments in the LVN Basin. Wherever feasible, community-based flood early warning and flood preparedness approaches will be followed. Flash-flood-/mudslide-prone zones will receive a special focus.	All items on the Flood Risk Register completed; Implementation reports		Medium to long-term	WRA	LVN Basin FRF; WRA RO; BWRC; MoH RO; MoTIHUDPW RO	Flood-prone county DRM Committees; WRUA; Village DRMC	International Relief Aid agencies; NGO	-	-	1.5	3	4.5	WRA
ii		The *LVN Basin FRF* will provide a platform for coordinating the resourcing and supervision of the funding of the above re-prioritised non-structural and structural flood management/ counter measures. In all instances, labour-intensive approaches will be followed.	All items on the Flood Risk Register completed; Number of proposals submitted		Medium to long-term	WRA	LVN Basin FRF; WRA RO; BWRC; MoH RO; MoTIHUDPW RO	Flood-prone county DRM Committees; WRUA; Village DRMC	International Relief Aid agencies; NGO	-	-	1	2	3	WRA
6.1.6	**Capacity development**														
i		*Organisational alignment/ collaboration:* The *LVN Basin Flood Response Forum (FRF)* will expand organisational capacity in the LVN Basin by aligning the flood response roles and responsibilities of the government institutions/agencies, International Relief Aid Agencies, Kenya Red Cross, NGOs and other stakeholders with partnership roles in flood management.	Well-functioning LVN Basin FRF; Partnership & Collaboration working agreement	WA52	Immediate	KMD; NDMU; NDOC	LVN Basin FRF; WRA RO; BWRC; MoH RO; MoTIHUDPW RO			0.1	-	-	-	0.1	KMD

Key Strategic Area 6:	Flood and Drought Management													
Strategic Objective:	**Establish and guide a structured programme of actions aimed at ensuring prevention, mitigation, timeous response and recovery from harmful impacts of floods & droughts**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Theme**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2020-2025**	**2025-2030**	**2030-2040**	**Total cost**	
ii	*Institutional technical skills:* Strategically expand institutional technical skills relevant to flood response activities across three different sets of competencies: (i) competence at translating Flood Early Warning Bulletin information to support prioritisation of resource mobilisations for humanitarian interventions; (ii) competence at logistical planning of required interventions followed by subsequent operationalisation; (iii) competence at communicating technical and logistical information in multi-stakeholder environments.	Increased effectiveness of the LVN Basin FRF participants at translating Flood Early Warning Bulletin information, logistical planning and communicating technical and logistical information.	WA54 WA56	Short-term	KMD; NDMU; NDOC; WRA	LVN Basin FRF; WRA RO; BWRC; MoH RO; MoTIHUDPW RO	Flood-prone county DRM Committees; WRUA; Village DRMC	Media	-	0.3	-	-	0.3	KMD
iii	*Community preparedness*: Community-based flood early warning drills as well as emergency evacuation drills will be prioritised by the Secretariat of the *LVN Basin FRF*, with the support of the NDMU/NDOC.	Communities successfully trained; Number of warning drills held	WA44	Short to long-term	KMD; NDMU; NDOC	LVN Basin FRF	Flood-prone county DRM Committees; WRUA; Village DRMC		-	0.9	0.9	1.8	3.6	KMD
Strategic Theme 6.2:	**Drought management**											Strategic theme 6.2 total:	**36**	
Theme priority:	**Very Important**													
6.2.1	**Formalise institutional roles and partnership collaborations**													
i	Establish a Secretariat for the *LVN Basin DRF* with accommodation in the Offices of one of the drought-prone counties.	Establishment of Secretariat		Immediate	NDMA; NDMU; NDOC				4	-	-	-	4	NDMA
ii	Develop appropriate SOPs for existing *LVN Basin Drought Response strategies*.	Agreement on SOPs		Short-term	NDMA; NDMU; NDOC; WRA		WRUA		-	4	-	-	4	NDMA
iii	Update existing stakeholder maps with respect to drought within the LVN basin.	Stakeholder maps generated; Number of key players identified		Short to medium-term	WRA		WRUA		-	0.08	0.08	-	0.16	WRA
6.2.2	**Develop drought response protocol**													
i	Develop a drought response protocol through a multi-stakeholder approach with the following components: Formalised institutional roles and partnership collaborations; drought preparedness plans for drought-prone zones; standard operating procedures (SOPs) that comprise sequential drought response actions; equitable allocation of water despite systematic restrictions of supply.	Agreement on drought response protocol.		Short-term	NDMA; NDMU; NDOC; MoDASAL	LVN Basin Drought Response			-	8	-	-	8	NDMA
6.2.3	**Improve drought preparedness**													
i	The *LVN Basin Drought Response strategy* must address five primary drought response needs, i.e. drought monitoring, drought early warning, drought severity assessment, mitigation interventions and recovery interventions.	Agreement on LVN Basin Drought Response mandate.		Short-term	NDMA; NDMU; NDOC; KMD	LVN Basin Drought Response	WRUA		-	4	-	-	4	NDMA

Key Strategic Area 6:		Flood and Drought Management													
Strategic Objective:		Establish and guide a structured programme of actions aimed at ensuring prevention, mitigation, timeous response and recovery from harmful impacts of floods & droughts													
Strategy		Activities	Target/Indicators (M&E)	CMS Strategic Theme	Implementation horizon	Key role players				Budget (USD Million)					Funding source
						National	Basin	Local	Other	2020-2022	2020-2025	2025-2030	2030-2040	Total cost	
ii		Drought monitoring, drought early warning and severity assessment will continue to be conducted by the NDMA, who issues regular Drought Early Warning Bulletins for ASAL counties.	Continuity of Drought Early Warning Bulletins		Short-term	NDMA; KMD; MoDASAL	LVN Basin Drought Response			-	4	-	-	4	NDMA
iii		Drought severity assessments by the national and county-level coordinating structures of the NDMA relevant to the LVN Basin must be reviewed and deliberated by the collaboration partnership participants in the *LVN Basin Drought Response strategy*. In the case of an adverse severity assessment, the *LVN Basin Drought Response* participants will have a common point of reference from which to systematically coordinate their various drought-relevant resource mobilisations and related interventions in the LVN Basin.	Successful collaboration by LVN Basin Drought Response participants in drought severity assessments and resulting mobilisations and interventions.		Short-term	NDMA	LVN Basin Drought Response	Drought-prone county DRM Committees; WRUA; Village DRMC	International Relief Aid agencies; Kenya Red Cross Society; NGO	-	1.6	-	-	1.6	NDMA
6.2.4	**Strengthen existing drought early warning systems**														
i		The NDMA issues regular Drought Early Warning Bulletins for ASAL counties. The LVN Basin does not have any ASAL counties, but sub-county Bulletins will be arranged for drought-vulnerable areas in the Trans Nzoia and Uasin Gishu counties.	Number of additional drought-prone LVN counties issuing Drought Early Warning Bulletins		Immediate	NDMA	LVN Basin Drought Response	CG		0.1	-	-	-	0.1	NDMA
ii		SOP responses based on the Bulletins' early warning findings and alerts will be an integrating force in the LVN Basin DRF. The sub-county scale of the Bulletins' reporting ensures that such responses can be spatially accurately focused. SOP responses will secure appropriate and timeous resource mobilisations and humanitarian interventions across all the collaborating partnerships at county, sub-county and local community scales for drought-vulnerable areas in the Trans Nzoia and Uasin Gishu counties.	Successful implementation of SOPs on sub-county and local community scales.		Short-term	NDMA	LVN Basin Drought Response	Drought-prone county DRM Committees; WRA SRO; WRUA; Village DRMC	International Relief Aid agencies; Kenya Red Cross Society; NGO	-	2	-	-	2	NDMA, CG
iii		The monthly reports and maps detailing current and projected food insecurity in a number of regions in the world by the Famine Early Warning Systems Network (FEWS NET) will support the deliberations by the participants in the *LVN Basin Drought Response Strategy*.	Continuity in the use of FEWS NET monthly reports and maps.		Short-term	NDMA; Kenya Food Security Steering Group	LVN Basin Drought Response	WRUA		-	0.4	-	-	0.4	NDMA
6.2.5	**Capacity development**														
i		*Funding:* Secure a standing allocation from the recently-established National Drought Emergency Fund (DEF) to the LVN Basin's ASAL counties to ensure that finance for early drought response will always be available when needed.	Success at attaining an allocation from the National DEF.		Short-term	NDMA	LVN Basin Drought Response; National Treasury		International Relief Aid agencies	-	4	-	-	4	NDMA

Key Strategic Area 6:		Flood and Drought Management														
Strategic Objective:		**Establish and guide a structured programme of actions aimed at ensuring prevention, mitigation, timeous response and recovery from harmful impacts of floods & droughts**														
Strategy		**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Theme**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**						**Funding source**
						National	**Basin**	**Local**	**Other**	**2020-2022**	**2020-2025**	**2025-2030**	**2030-2040**	**Total cost**		
ii		*Organisational alignment/ collaboration: LVN Basin Drought Response Strategy* will expand organisational capacity in the LVN Basin by aligning the drought response roles and responsibilities of the government institutions/ agencies, International Relief Aid Agencies, Kenya Red Cross, NGOs and other stakeholders with partnership roles in drought management.	Well-functioning LVN Basin Drought Response.		Immediate	NDMA	LVN Basin Drought Response; WRA RO; BWRC; MoALF RO; MoWSI RO; MoH RO	Drought-prone county DRM Committees; WRA SRO; WRUA; Village DRMC	International Relief Aid agencies; Kenya Red Cross Society; NGO	2	-	-	-	2		NDMA
iii		*Institutional technical skills:* Strategically expand institutional technical skills relevant to drought response activities across three different sets of competencies: (i) Translating Drought Early Warning Bulletin information to support prioritisation of resource mobilisations for humanitarian interventions; (ii) Logistical planning of required interventions followed by subsequent operationalisation; (iii) Communicating technical and logistical information in multi-stakeholder environments.	Increased effectiveness of LVN Basin Drought Response, participants at prioritising resource mobilisations, logistical planning and communicating technical and logistical information.	WA54 WA56	Short-term	NDMA	LVN Basin Drought Response; WRA RO; BWRC; MoALF RO; MoWSI RO; MoH RO	Drought-prone county DRM Committees; WRA SRO; WRUA; Village DRMC	International Relief Aid agencies; Kenya Red Cross Society; NGO	-	2	-	-	2		NDMA

Key Strategic Area 7:	Hydrometeorological Monitoring													
Strategic Objective:	An operational and well-maintained hydromet network supported by effective and functional data management and information management systems.													
Strategy	Activities	Target/Indicators (M&E)	CMS Strategic Action	Implementation horizon	Key role players				Budget (USD Million)					Funding source
					National	Basin	Local	Other	2020-2022	2022-2025	2025-2030	2030-2040	Total cost	
Strategic Theme 7.1:	Improved monitoring network											Strategic Theme 7.1 total:	26	
Theme priority:	Critical													
7.1.1	**Surface water monitoring: River flow**													
i	Upgrade existing river flow gauging network based on recommendations in Monitoring Network Design Report (Interim Report 2 Volume 7A)	Number of operational stream flow gauges; Number of data sets recorded	MA04	Short-term	WRA KMD		WRUA		-	2.6	-	-	2.6	WRA
7.1.2	**Monitoring: Dams and lakes**													
i	Survey bathymetry; install level gauge, upgrade existing dam and lake gauging network (based on recommendations in Monitoring Network Design Report), settlement beacons on the crest, flow measuring gauge (V-notch) at any seepage collection points along the toe of the dam for dams for water level monitoring	Number of operational dam & lake instruments and gauges; Number of bathymetric surveys completed	LA07	Short to medium-term	WRA				-	0.5	0.5	-	1	WRA
7.1.3	**Groundwater monitoring**													
i	Design groundwater monitoring programme, to include defining Priority Aquifers and incorporating spring monitoring where relevant	Groundwater monitoring programme developed		Short to medium-term	WRA			WSP	-	4	4	-	8	WRA
ii	Acquire necessary tools for groundwater monitoring (rigs, loggers, telemetry etc.)	Plant/accessories acquired		Short to long-term	WRA			WSP	-	1	1	2	4	WRA
iii	Implement groundwater monitoring programme	Number of operational groundwater monitoring stations		Medium to long-term	WRA			WSP	-	-	1	2	3	WRA
7.1.4	**Water quality monitoring: Surface water and groundwater**													
i	Upgrade existing water quality monitoring network based on recommendations in Monitoring Network Design Report (Interim Report 2 Volume 7A)	Number of operational water quality monitoring stations		Short to medium-term	WRA				-	1	1	-	2	WRA
7.1.5	**Meteorological monitoring**													
i	Upgrade existing WRA rainfall station network based on recommendations in Monitoring Network Design Report (Interim Report 2 Volume 7A)	Number of operational WRA rainfall stations, Number of complete datasets		Short-term	WRA KMD				-	1	-	-	1	WRA
7.1.6	**Metering of bulk water use and abstractions**													
i	Develop implementation programme and implement metering of bulk water use and abstractions (surface and groundwater)	No. operational bulk water use and abstraction meters		Immediate to long-term	WRA WASREB		WWDA	WSP Private sector	1	1	1	1	4	WRA

Key Strategic Area 7:	Hydrometeorological Monitoring														
Strategic Objective:	**An operational and well-maintained hydromet network supported by effective and functional data management and information management systems.**														
Strategy		**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
						National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
Strategic Theme 7.2:		**Improved data and information management**											Strategic Theme 7.2 total:	**2**	
Theme priority:		**Critical**													
7.2.1	**Enhanced data management**														
i		Use MIKE Info database developed under ISC for capturing, storing and managing all hydromet data. Data protocols and procedures with regard to data collection, transfer, capture, storage, quality control and dissemination should be evaluated, standardised and improved where necessary in accordance with international best practice. Technical and computing capacity for processing, analysis and reporting of data should be addressed and enhanced.	Readily available, up-to-date and quality controlled hydromet data	MA09	Immediate to short-term	WRA				0.5	0.5	-	-	1	WRA
7.2.2	**Improved water resources information management systems**														
i		Use Knowledge base tools developed under ISC for dissemination of information products related to water resources management.	Knowledge products disseminated	MA12	Immediate to short-term	WRA				0.25	0.25	-	-	0.5	WRA
7.2.3	**Improved forecasting systems**														
i		Use real-time system developed under ISC for accessing, visualizing and analysing hydromet observations in near real-time to inform decision making with regard to flood forecasting and water resources management. Refer to Interim Report 1 Volume 7: Real-time System Report.	Operational forecasting system	MA11	Immediate to short-term	WRA				0.25	0.25	-	-	0.5	WRA

Key Strategic Area 8:	Water Resources Development and Management													
Strategic Objective:	**To develop water resources as a key driver for sustainable economic and social development**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
Strategic Theme 8.1:	**Water Resource assessment, allocation and regulation**											Strategic theme 8.1 total:	**10**	
Theme priority:	**Critical**													
8.1.1	**Surface water resources assessment – surface water availability at relevant scales**													
i	Refine existing water resources models to improve estimates of surface water availability at relevant spatial scales for planning, management and allocation	Surface water resources availability and quantity mapped	WA02	Short-term	WRA				-	0.5	-	-	0.5	WRA
8.1.2	**Groundwater resources assessment – groundwater availability**													
i	Implement under Strategy 3.1.1: Groundwater assessment – assess groundwater availability in terms of quantity													
8.1.3	**Assess water use and fitness for use**													
i	Undertake surface water abstraction survey	Number of abstraction surveys completed	WA05	Short to medium-term	WRA			WRUA	-	3	3	-	6	WRA
ii	Undertake groundwater abstraction survey	Implement under Strategy 3.1.2: Groundwater assessment – assess groundwater quality and use												
8.1.4	**Update and improve permit database**													
i	Reconcile PDB with surface water and groundwater abstraction survey results	Updated PDB	WA14	Short to medium-term	WRA				-	0.75	0.75	-	1.5	WRA
8.1.5	**Water allocation**													
i	Set Resource Quality Objectives (RQOs) for surface water and groundwater in the LVN Basin	Implement under Strategy 2.3.1: Set Resource Quality Objectives												
ii	Conduct surface water balance at relevant spatial scale; Determine allocation status	Water balances; Allocation status report	WA07	Short-term	WRA				-	0.3	-	-	0.3	WRA
iii	Conduct groundwater balance at relevant spatial scale; Determine allocation status	Implement under Strategy 3.1.4: Groundwater allocation												
iv	Develop surface water allocation plans at sub-basin level	Water Allocation Plans		Short-term	WRA				-	1.5	-	-	1.5	WRA
v	Develop groundwater allocation plans at sub-basin level	Implement under Strategy 3.1.4: Groundwater allocation												
Strategic Theme 8.2:	**Water resources planning**											Strategic theme 8.2 total:	**4**	
Theme priority:	**Critical**													
8.2.1	**Updated planning for bulk water resources development**													
i	Update Eldoret Master Planning: Optimise large-scale, integrated bulk water supply system supplying Eldoret: Sources, Transfers, Dams, Treatment Works, Bulk distribution network, Conjunctive use	Up to date integrated master plan indicating detailed timelines, phasing and budgets	WA74	Short-term	WRA MoWSI NWHSA	WWDA	CG	WSC WSP	-	0.3	-	-	0.3	WSC MoWSI
iii	Prefeasibility/Feasibility of regional water supply schemes to meet major towns, rural domestic and/or small-scale irrigation demands: Sources, Transfers, Dams, Treatment, Bulk distribution network, Conjunctive use	Up to date master plan for rural water supply in LVN Basin indicating detailed timelines, phasing and budgets	WA74	Short-term	WRA MoWSI NWHSA	WWDA	CG		-	4	-	-	4	WWDA MoWSI

Key Strategic Area 8:	Water Resources Development and Management														
Strategic Objective:	To develop water resources as a key driver for sustainable economic and social development														
Strategy	Activities	Target/Indicators (M&E)	CMS Strategic Action	Implementation horizon	Key role players				Budget (USD Million)						Funding source
					National	Basin	Local	Other	2020-2022	2022-2025	2025-2030	2030-2040	Total cost		
Strategic Theme 8.3:	Water storage and conveyance										Strategic theme 8.3 total:		1 532		
Theme priority:	Very important														
8.3.1	**Implement large dams: complete relevant feasibility and impact studies and plans; design and construct**														
i	Siyoi Dam (4 MCM)	Dam construction completed and successful commissioning	WA74	Short to medium-term	NWHSA MoWSI	WWDA	CG		-	23	18	-	41		MoWSI
ii	Teremi Dam (3 MCM)			Short-term	NWHSA MoWSI	WWDA	CG		-	35	-	-	35		MoWSI
iii	Kibolo Dam (40 MCM)			Medium-term	NWHSA MoWSI	WWDA	CG		-	-	161	-	161		MoWSI
iv	Moi's Bridge Dam (214 MCM)			Immediate to short-term	NWHSA MoWSI	WWDA	CG		38	252	-	-	291		MoWSI
v	Upper Nzoia Dam (Site 34B) (204 MCM)			Short to medium-term	NWHSA MoWSI	WWDA	CG		-	18	260	-	277		MoWSI
vi	Lower Nzoia Dam (Site 42A) (395 MCM)			Long-term	NWHSA MoWSI	WWDA	CG		-	-	-	385	385		MoWSI
8.3.2	**Maintenance of existing dams**														
i	Dredging of existing dams	Number of dams dredged		Medium to long-term	NWHSA MoWSI	WWDA	CG		-	-	1	1	2		MoWSI
8.3.3	**Infrastructure development - small dams and pans**														
i	Develop programme for implementation of small dams & pans. Undertake relevant studies. Identify locations and types of dams to improve assurance of supply to local urban, domestic, small scale irrigation and livestock water users	Dam construction programme and investment plan – town and rural supply; Relevant feasibility studies and reports	WA74	Immediate to short-term	NWHSA MoWSI	WWDA	CG WRUA		1	1	-	-	2		MoWSI
ii	Phased design and construction of identified small dams / pans: 117 MCM total storage	Number new dams constructed in accordance with international best practice	WA74	Immediate to long-term	NWHSA MoWSI	WWDA	CG WURA		18	70	65	130	283		MoWSI
8.3.4	**Provide other types of storage**														
i	Sand dams	Number of sand dams	WA74	Short to medium-term	NWHSA MoWSI	WWDA	CG		-	1	1	1	3		MoWSI
8.3.5	**Upgrade existing / Construct new water transfers**														
i	Moiben Dam to Eldoret Transfer Expansion (7.5 MCM/a)	Transfer volume (supply volume)	WA74	Immediate to short-term	MoWSI	WWDA	CG		6	46	-	-	52		MoWSI
Strategic Theme 8.4:	Groundwater development														
Theme priority:	Important														
8.4.1	**Develop groundwater resources**														
i	Implement under Strategic Theme 3.2: Groundwater development														

Key Strategic Area 8:	Water Resources Development and Management													
Strategic Objective:	**To develop water resources as a key driver for sustainable economic and social development**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
Strategic Theme 8.5:	**Hydropower development**											Strategic theme 8.5 total:	**350**	
Theme priority:	**Important**													
8.5.1	**Large-scale hydropower development**													
i	Nandi Forest Multipurpose Dam Project Tunnel and Hydropower (50 MW)	Large scale hydropower generation and integration with grid	WA74	Short to medium-term	KENGEN MoEn				-	23	323	-	346	KENGEN, MoEn
8.5.2	**Small-scale hydropower development**													
i	Investigate possibility of retrofitting existing dams with hydroelectric power generation capabilities.	Number of retrofitted dams	WA74	Immediate to short-term	KENGEN MoE				1	1	-	-	2	KENGEN, MoEn
ii	Assess potential for the development of small-scale hydropower plants, especially in the upper LVN Basin.	Small-scale hydropower generation and supply		Immediate to medium-term	KENGEN MoE				1	1	-	-	2	KENGEN, MoEn
Strategic Theme 8.6:	**Water for agriculture**											Strategic theme 8.6 total:	**1 660**	
Theme priority:	**Critical**													
8.6.1	**Large scale irrigation development: Develop new / expand existing irrigation schemes. Limit to max sustainable areas**													
i	Lower Sio (5280 ha)	Irrigation area		Medium to long-term	WRA MoWSI MoALF NIB	WWDA	CG		-	-	106	43	149	MoWSI
ii	Yala Swamp (4 800 ha)	Irrigation area		Long-term	WRA MoWSI MoALF NIB	WWDA	CG		-	-	-	104	104	MoWSI
iii	Upper Nzoia (24 000 ha)	Irrigation area		Short to medium-term	WRA MoWSI MoALF NIB	WWDA	CG		-	71	474	-	545	MoWSI
iv	Lower Nzoia (10 470 ha)	Irrigation area		Immediate to medium-term	WRA MoWSI MoALF NIB	WWDA	CG		65	68	102	-	235	MoWSI
v	Moi's Bridge (15 840 ha)	Irrigation area		Short to medium-term	WRA MoWSI MoALF NIB	WWDA	CG		-	46	312	-	358	MoWSI
vi	Kibolo (9 200 ha)	Irrigation area		Long-term	WRA MoWSI MoALF NIB	WWDA	CG		-	-	-	261	261	MoWSI
8.6.2	**Promote water conservation in irrigation**													
i	Increase water use efficiency through the rehabilitation or improvement of irrigation technologies and techniques, and through the use of smart metering	Water efficiency in irrigation		Short to long-term	WRA MoWSI MoALF NIB	WWDA	CG		-	1	1	1	3	MoWSI

Strategy	Activities	Target/Indicators (M&E)	CMS Strategic Action	Implementation horizon	Key role players				Budget (USD Million)					Funding source
					National	Basin	Local	Other	2020-2022	2022-2025	2025-2030	2030-2040	Total cost	
Key Strategic Area 8:	**Water Resources Development and Management**													
Strategic Objective:	**To develop water resources as a key driver for sustainable economic and social development**													
8.6.3	**Compile infrastructure development program for small scale irrigation. Develop new / expand existing irrigation schemes**													
i	Develop new small-scale irrigation schemes	Number of new small-scale irrigation schemes		Short to long-term	WRA MoALF NIB MoWSI	BWRC	CG WRUA		-	0.6	0.6	0.8	2	MoALF
ii	Provide farmers with appropriate technologies to abstract water from rivers and shallow boreholes: Treadle pumps, small motorised pumps, construct small weirs	Number of small-scale farmers using technology. Food security.		Short-term	WRA MoALF NIB MoWSI		CG WRUA		-	0.8	-	-	0.8	MoALF
iii	Refurbish existing small-scale irrigation schemes	Number of refurbished small-scale irrigation schemes		Short to long-term	WRA MoALF NIB MoWSI		CG WRUA		-	0.4	0.4	0.8	1.6	MoALF
8.6.4	**Aquaculture development**													
i	Promote aquaculture opportunities in basin - linked to new dams and improved flow regulation	Increased awareness of aquaculture		Short to medium-term	MoALF KMFRI	WWDA	CG		-	0.2	0.2	-	0.4	MoALF
ii	Develop aquaculture manual	Aqua culture manual		Medium-term	MoALF KMFRI	WWDA	CG		-	-	0.05	-	0.05	MoALF
iii	Rehabilitate aquaculture ponds and construct new ponds	Aquaculture development		Medium to long-term	MoALF KMFRI	WWDA	CG		-	-	0.1	0.1	0.2	MoALF
8.6.5	**Improved water supply reliability at local scale through construction of small dams / pans and/or development of local groundwater resources to provide carry-over storage during the dry season**													
i	Implement Under Strategies 8.3.2 and Strategy 3.2.2													
Strategic Theme 8.7:	**Water based tourism and recreation**											Strategic theme 8.7 total:	**0.2**	
Theme priority:	**Important**													
8.7.1	**Promote water-based tourism and recreation**													
i	Promote adventure tourism, leisure activities, recreational activities and resorts linked to large dams, especially at dams situated close to major cities.	Increase in water-based tourism		Short to long-term	KTF MoTW		CG	Tour operators	-	0.05	0.05	0.07	0.17	Private
Strategic Theme 8.8:	**Non-conventional water resources**											Strategic theme 8.8 total:	**22**	
Theme priority:	**Very important**													
8.8.1	**Rainwater harvesting**													
i	Rainwater harvesting should be promoted - especially in rural areas.	Increased awareness of rainwater harvesting		Short-term	WRA MoWSI NWHSA		WRUA	NGO	-	0.1	-	-	0.1	WRA
ii	Supply and install tanks for rainwater harvesting.	Number of rainwater tanks installed		Short to medium-term	WRA MoWSI NWHSA	WWDA	WRUA	NGO	-	10	10	-	20	WRA
8.8.2	**Reuse**													
ii	Not considered as an option in LVN at this stage													

Key Strategic Area 8:	Water Resources Development and Management													
Strategic Objective:	**To develop water resources as a key driver for sustainable economic and social development**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
8.8.2	**Water Conservation and Demand Management**													
i	Evaluate WCDM as an integrated option to reduce water demand in urban centres	WCDM Measures; improved water efficiency and supply		Short-term	WRA, MoWSI WASREB		CG	WSP	-	0.15	-	-	0.15	WRA
ii	Implement WCDM measures	Adoption of water saving techniques		Short to medium-term	WRA MoWSI WASREB		CG	WSP	-	1	1	-	2	CG
Strategic Theme 8.9:	**Water resources systems operation**										Strategic theme 8.9 total:		**2**	
Theme priority:	**Important**													
8.9.1	**Optimise system operating rules**													
i	Evaluate and improve operation of existing and future integrated bulk water supply systems to Eldoret to maximise yield. Develop curtailment rules.	Optimised system operating rules - multipurpose dams, user priority classification, curtailment rules		Medium-term	WRA MoWSI	WWDA	WRUA		-	-	0.85	-	0.85	MoWSI
iii	Develop and implement operating rules for proposed multipurpose dams e.g. Upper Nzoia, Lower Nzoia, Kibolo, Moi's Bridge, Nandi Forest etc.			Short to medium-term	WRA MoWSI	WWDA	WRUA		-	0.15	0.1	-	0.25	MoWSI
iv	Evaluate and improve operation of existing stand-alone dams supplying individual towns and/or small-scale irrigation. Develop curtailment rules. Consider conjunctive use.	Optimised system operating rules - multipurpose dams, user priority classification, conjunctive use, curtailment rules; Number of operating rules registered with NEMA		Short to medium-term	WRA NEMA WASREB	WWDA	WRUA		-	0.15	0.15	-	0.3	MoWSI
8.9.2	**Conduct Annual Operating Analyses (AOA) to decide need for and severity of restrictions for the coming year based on current storage levels and anticipated demands**													
i	Configure planning models and undertake annual operating analysis	AOA Reports		Short to long-term	WRA MoWSI WASREB	WWDA	WRUA		-	0.2	0.2	0.3	0.7	MoWSI

Key Strategic Area 9:	Institutional Strengthening													
Strategic Objective:	**To achieve an appropriate balance between operational functionality and the need for effective oversight and governance.**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
Strategic Theme 9.1:	**Promote improved and sustainable catchment management**											Strategic Theme 9.1 total:	**7**	
Theme priority:	**Critical**													
9.1.1	**Strengthen WRAs regulatory role**													
i	Separate out regulatory and management functions of the Authority and provide different reporting lines for these. Parallel improvement and strengthening of the regulatory approaches utilised by the WRA.	Regulatory and Management functions separated out.		Immediate	WRA, MoWSI				0.52	-	-	-	0.52	WRA GoK Donors
ii	Updating WRA's standards, policies and regulations in line with the WA2016	Guidelines, regulations		Immediate	WRA, MoWSI				0.5	-	-	-	0.5	WRA GoK Donors
iii	Undertake training and capacity building for the new legislative instruments	Training manuals, guidelines, regulations, workshops		Immediate to short-term	WRA	BWRC			0.3	0.3	-	-	0.6	WRA GoK Donors
iv	Hold stakeholder consultations for developing legislative instruments and implementation tools	Stakeholder engagement strategy; Stakeholder meetings held		Short-term	WRA, MoWSI			Private sector	-	0.15	-	-	0.15	WRA GoK Donors
v	Develop tools and systems to support implementation of the new legislative instruments	Guidelines, regulations, systems		Medium-term	WRA, MoWSI	BWRC			-	-	0.59	-	0.59	WRA GoK Donors
vi	Improve awareness creation of new legislative instruments and implementation tools	Brochures, media dissemination packages, information dissemination platforms	PA33	Medium-term	WRA, MoWSI	BWRC	CG		-	-	0.45	-	0.45	WRA GoK Donors
9.1.2	**Strengthen BWRCs**													
i	Translate lessons learnt from CAACs into improved operational modalities.	Improved channels of operation.		Immediate	WRA	CAAC			0.25	-	-	-	0.25	WRA GoK Donors
ii	Provision of secretariat services through ROs and SROs.	Secretariat services through ROs and SROs		Immediate to long-term	WRA				0.2	0.1	0.1	0.1	0.5	WRA GoK Donors
iii	Appropriate channels formed for recommendations from BWRCs to be taken on board by WRA.	Improved channels of communication.		Immediate	WRA	BWRC			0.07	-	-	-	0.07	WRA GoK Donors
iv	On-going training and capacity building.	Continued education on WRM		Short to long-term	WRA, MoWSI			Development partners	-	0.07	0.07	0.14	0.28	WRA GoK Donors
9.1.3	**Strengthen county governments engagements in WRM in the Basin**													
i	Clarify roles and responsibilities for county governments.	Clear roles and responsibilities for county governments		Immediate	MoWSI, WRA		CG		0.16	-	-	-	0.16	WRA GoK Donors
ii	Introduce more structured strategic planning and operational engagement.	Improved planning and operations		Immediate	MoWSI, WRA		CG		0.35	-	-	-	0.35	WRA GoK Donors
iii	Develop a basin or sub-basin level platform for engagement with county government.	Improved engagement	PA42	Immediate to medium-term	WRA	BWRC	CG, WRUA		0.4	0.3	0.3	-	1	WRA GoK Donors

Key Strategic Area 9:	Institutional Strengthening													
Strategic Objective:	**To achieve an appropriate balance between operational functionality and the need for effective oversight and governance.**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
9.1.4	**Strengthen WRUAs**													
i	Strengthen linkages between county governments and WRUAs.	WRUAs linked with county governments	PA42	Immediate to long-term	WRA		CG, WRUA		0.3	0.3	0.3	0.6	1.5	WRA GoK Donors
ii	Ongoing training and capacity building.	Improved capacity	PA43 PA45	Short to long-term	WRA				-	0.1	0.1	0.2	0.4	WRA GoK Donors
Strategic Theme 2.2:	**Guidelines, codes of practice and manuals**											Strategic Theme 9.2 total:	**5**	
Theme priority:	**Very important**													
9.2.1	**Develop policies**													
i	Develop a Policy on Transboundary Waters incorporating relevant elements of Treaty obligations	Transboundary Waters Policy signed by all relevant governments		Immediate to short-term	EAC Govts of South Sudan, Ethiopia and Somalia, Ministry of Foreign Affairs, MoWSI, WRA				0.3	0.3	-	-	0.6	WRA GoK Donors
ii	Complete the development of a National Policy for the Protection of Groundwater with all key stakeholders involved.	National Policy for the Protection of Groundwater		Immediate to short-term	WRA, MoWSI				0.1	0.15	-	-	0.25	WRA GoK Donors
iii	Revise the National Water Quality Management Policy	Implement under Strategy 4.2.1: Harmonise policies and strategies towards improved water quality management												
iv	Review cross-sector policies, legislation and regulations relating to wastewater; streamline/clarify the roles of the Line Ministries, WRA, NEMA, the Counties and WSPs in relation to wastewater, to eliminate the dual mandates that the WRA and NEMA currently operate under in relation to 'polluter pays' and these agencies' revenue	Reviewed policies, legislation and regulation relating to wastewater		Immediate	WRA, MoWSI, NEMA, KFS		CG	WSP	0.5	-	-	-	0.5	WRA GoK Donors
9.2.2	**Develop guidelines to support specific water resources management activities**													
i	Develop / Update Guidelines on: - the allocation of GW from fossil aquifer or aquifers that experience episodic recharge - GW vulnerability assessments - preventing/containing saltwater intrusion - defining and protecting groundwater-dependent ecosystems (GDEs) - definition and selection of Priority Aquifers, including guidance on the development of monitoring networks, the selection of appropriate instrumentation and the installation of monitoring networks - dam safety - water allocation and water quality	Guidelines and thresholds for groundwater and surface water		Immediate	MoWSI, WRA, NEMA				0.7	-	-	-	0.7	WRA GoK Donors

Key Strategic Area 9:		Institutional Strengthening														
Strategic Objective:		**To achieve an appropriate balance between operational functionality and the need for effective oversight and governance.**														
Strategy		**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
						National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
9.2.3 Develop Codes of Practice															
i	Relevant Codes of Practice for Water Resources Planning and Management		Codes of Practice completed		Immediate	MoWSI, WRA				0.35	-	-	-	0.35	WRA GoK Donors
ii	Enforce new and existing Codes of Practice in relation to WRPM		Codes of Practice compliance		Short to long-term	MoWSI, WRA		CG		-	0.5	0.5	1	2	WRA GoK Donors
9.2.4 Develop manuals															
i	Develop / Update National Manuals relevant to WRPM		National Manuals updated/ completed		Immediate to medium-term	MoWSI, WRA		CG	WSP, private sector (industry, agriculture, mining)	0.25	0.25	0.25	-	0.75	WRA GoK Donors

Key Strategic Area 10:	Enabling environment to support effective water resources planning and management													
Strategic Objective:	**To enhance human and institutional capacities for sustainable management of the water, land, ecosystems and related resources**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
Strategic Theme 10.1:	**Development of institutional capacities to support improved water resource management and development**											Strategic Theme 10.1 total:	**25**	
Theme priority:	**Very Important**													
10.1.1 Strengthen policies and regulatory instruments														
Implement under Strategy 9.1.1: Strengthen WRAs regulatory role														
10.1.2 Enhancement of technical and management capacity														
i	Development and enhancement of technical and management capacity through focused training, continuous professional development, bursary schemes, audits, incentive schemes	Improved capacity of personnel and institutions		Short to long-term	WRA				-	0.78	0.78	1.56	3.12	WRA
10.1.3 Strengthen partnerships														
i	Develop a partnerships framework	Partnerships framework developed		Immediate	WRA, MoWSI			Private sector	0.35	-	-	-	0.35	WRA
ii	Identify potential partners	Inventory of potential partners		Immediate	WRA, MoWSI		CG	Private sector, Development partners	0.5	-	-	-	0.5	WRA
iii	Undertake stakeholder consultations	Stakeholder engagement strategy		Immediate to short-term	WRA, MoWSI			Development partners	0.12	0.13	-	-	0.25	WRA, private sector
iv	Undertake awareness creation and information dissemination activities	Brochures, information dissemination packages		Immediate to short-term	WRA		CG	Development partners	0.12	0.13	-	-	0.25	WRA
v	Develop and strengthen guidelines for MOU drafting and development	Partnerships framework, improved guidelines for MOU development		Short-term	WRA				-	1.5	-	-	1.5	WRA
vi	Strengthen existing partnerships, particularly on a local level	Existing partnerships strengthened		Immediate	WRA		WRUA	CG, NGO, Development partners	0.35	-	-	-	0.35	WRA
10.1.4 Strengthen stakeholder engagement														
i	Develop a basin-wide stakeholder engagement framework	Stakeholder engagement strategy developed		Immediate	WRA				0.09	-	-	-	0.09	WRA
ii	Undertake stakeholder analysis	Identified stakeholders		Immediate	WRA	BWRC	CG, WRUA		0.15	-	-	-	0.15	WRA
iii	Implement the stakeholder engagement framework	Stakeholder engagement, workshops, forums, expos held; Level of participation		Short to long-term	WRA	BWRC	CG, WRUA	NGO	-	0.2	0.2	0.4	0.8	WRA
iv	Strengthen stakeholder engagement platforms i.e. forums	Improved guidelines for forums; Improved stakeholder participation		Immediate to short-term	WRA	BWRC	WRUA		0.45	0.45	-	-	0.9	WRA
v	Undertake awareness creation and information dissemination activities	Brochures, media dissemination packages		Short-term	WRA	BWRC	CG	Media	-	0.45	-	-	0.45	WRA

Key Strategic Area 10:	Enabling environment to support effective water resources planning and management													
Strategic Objective:	**To enhance human and institutional capacities for sustainable management of the water, land, ecosystems and related resources**													
Strategy	**Activities**	**Target/Indicators (M&E)**	**CMS Strategic Action**	**Implementation horizon**	**Key role players**				**Budget (USD Million)**					**Funding source**
					National	**Basin**	**Local**	**Other**	**2020-2022**	**2022-2025**	**2025-2030**	**2030-2040**	**Total cost**	
10.1.5	**Improved research**													
i	Strengthen links with tertiary education / research institutions	Number of tertiary institutions linked		Immediate to medium-term	WRA, Research institutions				1.2	1.2	1.2	-	3.6	WRA
ii	Incorporate R&D into WRM planning and decision making	R&D plan incorporated		Immediate to short-term	WRA, Research institutions				0.15	0.1	-	-	0.25	WRA
iii	Invest in R&D to strengthen WRM	Financing for R&D		Short to long-term	WRA, Research institutions		CG	Private sector	-	2	2	4	8	WRA, Research institutions
iv	Establish a network of supporting research institutions	Network of research institutions		Immediate to medium-term	WRA, Research institutions				0.1	0.1	0.1	-	0.3	WRA, Research institutions
v	Manage data and knowledge generation and collation	Data generated, information generated, knowledge generated		Short-term	WRA, Research institutions				-	1.05	-	-	1.05	WRA, Research institutions
vi	Disseminate data, information and knowledge	Brochures, media dissemination packages, information dissemination platforms		Short-term	WRA, Research institutions			Media	-	0.45	-	-	0.45	WRA, Research institutions
vii	Develop strategic partnerships for R&D	Strategic partnerships for R&D; MoUs signed by institutions		Immediate to medium-term	WRA, Research institutions				0.1	0.1	0.1	-	0.3	WRA, research institutions
10.1.6	**Innovative financing**													
i	Promote innovative financing for basin level institutions (BWRCs, WRUAs, forums)	Secured financing		Immediate	WRA, WSTF	BWRC	WRUA, Forums	Development partners	0.25	-	-	-	0.25	WRA
ii	Develop internal resource mobilization strategies	Income generated		Immediate	WRA, MoWSI, WSTF	BWRC			0.5	-	-	-	0.5	WRA
iii	Develop external resource mobilization strategies	Income generated; Grants secured	PA58 PA59	Immediate	WRA, MoWSI, WSTF	BWRC		Development partners	0.45	-	-	-	0.45	WRA
iv	Exploring private sector financing channels	Private sector financing secured	PA62 PA63 PA64	Immediate to short-term	WRA	BWRC		Private sector	0.15	0.15	-	-	0.3	WRA, private sector
v	Strategic partnerships for resource mobilization	Financing secured, strategic partnerships framework		Immediate to short-term	WRA, MoWSI			Development partners, Private sector	0.23	0.23	-	-	0.46	WRA, sector institutions

F1: Development costs

Major projects

Estimated project costs for specific, proposed major projects were extracted from relevant planning and design study reports where available, and from prices reported on relevant agency and government department websites, escalated to 2020 prices. Key information sources and institutions which were consulted include NWMP 2030, JICA, 2013; IDA Funding Agency Project Appraisal Reports; Kenya Vision 2030 Flagship Projects *(**http://www.vision2030.go.ke/publication/vision-2030-flagship-projects-progress-report-nov-2014/**)**;*** Blue Economy Bankable Projects *(Kenya conference on sustainable blue economy. Nairobi, Nov 2018, Ondimu et al.);* Kenya National Investment Profile *(Water for agriculture and Energy. 2015. FAO, AgWA);* Kenya National Water Harvesting and Storage Authority *(**http://www.waterauthority.go.ke/**);* Kenya National Irrigation Board; Regional Development Authorities; Water Works Development Agencies

Dams

For major dams, the approach described above for Major projects was followed. The unit cost for major dams amounts to approximately USD 1 Million per MCM of storage provided.

For minor dams (typically between 1 MCM and 30 MCM storage), where no specific cost information was readily available, a cost curve was developed based on cost estimates done as part of the NWMP (JICA, 2013), extrapolated to 2020 prices as shown below.

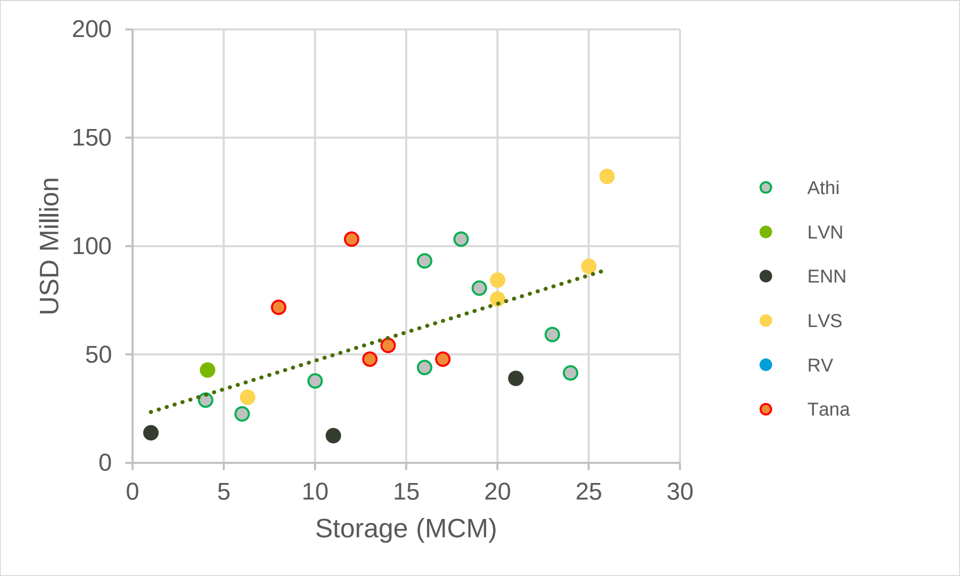

Figure F-1: Cost curve for dams smaller than 30 MCM

For small dams and pans, cost estimates obtained from Water Works Development Agencies project budgets were analysed and used to derive the following unit costs:

- 20 000 m^3 pan: USD 100 000
- 50 000 m^3 pan: USD 150 000
- 50 000 m^3 small dam: USD 175 000
- 100 000 m^3 small dam: USD 300 000

Irrigation

For large irrigation projects, the approach described above for Major projects was followed.

For schemes where no specific cost information was readily available, the following unit costs (complete) for large-scale and small-scale irrigation were derived:

- Large-scale irrigation: USD 19 700 /ha
- Small-scale irrigation: USD 9 500 /ha

The unit costs were based on information provided in the following sources: NWMP 2030 (JICA, 2013); FAO Investment Centre Technical Paper 5, Irrigation: Africa South of Sahara. Rome 1986; Kenya National Irrigation Board; IWMI Research Report 109. Costs and performance of irrigation projects: A comparison of Sub-Saharan Africa and other developing regions. (Inocencio et al, 2007)

Hydropower

For many of the planned major hydropower projects, the cost of the hydropower installation was included with the development cost of the dam.

Otherwise, a unit installation cost of USD 200 000 per MW installed was used based on international rates *(https://www.hydro.org/)*

Boreholes

For large groundwater development projects, the approach described above for Major projects was followed.

For individual boreholes, a cost of USD 20 000 per borehole was used based on typical costs in Kenya. This includes drilling and equipping of borehole with independent power supply. An average yield of 4.4 m3/h per borehole was assumed *(https://constructionreviewonline.com/2018/03/water-borehole-services-kenya/)*

Bulk Water Transfers

For bulk water transfer projects, the approach described above for Major projects was followed. Where no specific information was available, tunnels were costed at a unit cost of USD 50 million/km.

Hydromet network

Costs associated with the procurement, installation and commissioning of monitoring stations and hydromet equipment were based on information and typical unit costs provided by WRA offices and/or suppliers.

Cost Benefit Analysis (2020)

- Electricity price: 0.15 USD million/GWh. *(https://www.globalpetrolprices.com/Kenya/electricity_prices/)*
- Water supply price - urban: 2.9 USD/m3; Water supply price - rural: 1.65 USD/m3. (Gulyani, S et al. Water for the urban poor: Water markets, Household demand and Service preferences in Kenya. Water supply and sanitation sector board discussion paper series. Paper No. 5. Jan 2005)
- Irrigation: Unit crop yields and producer prices *(http://www.fao.org/countryprofiles/index/en/?iso3=KEN);* *Kenya Horticulture Validated Report 2015 – 2016. AFA – Horticultural Crops Directorate* (Avg. County values)
- Operation and Maintenance: Dams and hydropower - 2.5% of capital cost per annum; Irrigation- 0.5% of capital cost per annum.
- Discount rate: 10%

F2: Management costs

A stepwise approach for estimating costs associated with the implementation of management actions was followed:

i. Decide on the appropriate implementing agency at national, basin, county or local scale, based on defined mandates in relation to specific KSA activities. Implementing agencies include national government, sub-regional offices, county governments and WRUAs.
ii. The type of implementing agency defines the number of offices/units per Basin in the budget estimation calculation. In the case of a site- specific activity, such as the development of IFMPs, the number of sites was used to estimate the budget.
iii. Allocate budget over four time frames based on personal experience, professional consultation fees, management cost estimates as per NWMP 2030 and reference to local information. Timeframes are 2020-2022 (2 years), 2022-2025 (3 years), 2025-2030 (5 years) and 2030-2040 (10 years).
iv. Timeframes indicate which activities should be completed immediately (2022) or in the short (2025), medium (2030) or long-term (2040), as well as the duration of this implementation.

F3: General

- Upfront costs - Planning/Feasibility, Environmental Assessment, Design: 15% of capital cost
- Infrastructure replacement costs were not considered
- Annual inflation rate: 5%
- Exchange rate: 1 USD = 100 KES
- Desalination and water re-use plants were not costed as part of this Plan. Rather, the Plan recommended that the construction of such plants as alternatives to conventional surface water and groundwater resources development projects, be investigated in more detail for possible implementation in the next planning horizon.